Annex B2.2: Water Quality Assessment 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.

LONDON EFFLUENT REUSE SRO

Annex B.2.2. Water Quality Assessment Report

Report for: Thames Water Utilities Ltd

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1. INTRODUCTION

This report is part of the series of Environmental Assessment Reports which catalogue the set of environmental assessments of the London Effluent Reuse Strategic Resource Option (SRO) through RAPID Gate 2: *Detailed feasibility, concept design and multi-solution decision making* and onward to RAPID Gate 3: *Developed design, finalised feasibility, pre-planning investigations and planning applications*. The reports set out the environmental assessments, which will in turn support regulatory assessment requirements proportionate to RAPID Gate 2 and onward to RAPID Gate 3. The scope and approach to the environmental evidence provided in these reports was set out in the Gate 2 Scoping Report and consulted on with the National Appraisal Unit (NAU) in November 2021.

1.1 LONDON EFFLUENT REUSE STRATEGIC RESOURCE OPTIONS

For Gate 2, the London Effluent Reuse SRO is set out as four source options and a range of sizes. One option is in east London, utilising final effluent from Beckton sewage treatment works (STW). The other three options are in west London, utilising crude sewage or final effluent from Mogden STW to a maximum total reduction of 200 Ml/d, with differing London Effluent Reuse scheme discharge locations in the freshwater River Thames.

Full details of the conceptual design of the four schemes are provided in the Conceptual Design Reports[1] (CDR). For assessment purposes no specific mitigation is allowed for unless included as part of option design as set out in CDR (other than the Annex B.3. Habitats Regulations Assessment (HRA) Stage 2 and Annex B.5. Initial Environmental Appraisal (IEA)) which has regard for additional mitigation as per the ACWG methodology). A DRA intake would include appropriate fish screening and all new outfalls would include appropriate eel management measures.

High level summaries of each option are provided below. A full summary for the indicative operating pattern of a London Effluent Reuse SRO is presented in Section 1.2 of the Annex B.2.1. Physical Environment Assessment Report[2].

1.1.1 Beckton water recycling Scheme

Final effluent from Beckton STW would be treated at a new advanced water recycling plant (AWRP) within Beckton STW for advanced treatment. Recycled water would be conveyed via a new tunnel from the Beckton AWRP to Lockwood Pumping Station and then a Thames-Lee Tunnel (TLT) extension from Lockwood Pumping Station to a proposed new outfall located on a side channel of the freshwater Lee Diversion Channel, known as the Enfield Island Loop, upstream of the existing Thames Water Enfield intake to the King George V Reservoir. It is noted that a TLT extension could feasibly enable the conveyance of water abstracted from the River Thames at Hampton and conveyed in the Thames Lee Tunnel (TLT) to be discharged into the freshwater Lee Diversion at the Enfield Island Loop, where currently this discharges into Lockwood Reservoir and does not enter channels of the Lee. However, for Gate 2 neither the Teddington DRA nor Beckton water recycling scheme operate to transfer River Thames water in to the Enfield Island Loop, so discharge of River Thames water into the Enfield Island Loop has not been assessed.

Additional abstraction for public water supply on a put/take basis would be through existing intakes in the lower Lee, to supplement the raw water supply to the Lee Valley reservoirs. The option reduces the final effluent at the extant Beckton STW outfall to the estuarine Thames Tideway.

The Beckton water recycling scheme has been assessed for Gate 2 independently at 100 Ml/d, 200 Ml/d, and 300 Ml/d. Outside the normal operating pattern the Gate 2 engineering design includes a 15 Ml/d tunnel maintenance flow, with the recycled water being discharged to the Enfield Island Loop.

1.1.2 Mogden water recycling Scheme

Final effluent from Mogden STW would be pumped in a new pipeline to a new reuse water recycling plant located at a site near Kempton water treatment works (WTW)) for advanced treatment via a new AWRP. Recycled water would be transferred in a new pipeline for discharge into the freshwater River Thames at a new outfall upstream of the existing Thames Water Walton intake. Additional abstraction for public water supply

[1] Jacobs (2022) London Reuse Strategic Resource Option, Gate 2 Conceptual Design Reports.

[2] Ricardo (2022) London Effluent Strategic Resource Option, Gate 2 Physical Environment Assessment Report.

on a put-take basis would be through existing downstream intakes on the River Thames. AWRP wastewater and reverse osmosis (RO) concentrate would be conveyed back to Mogden STW inlet works via a return pipeline(s). There is an option that the AWRP wastewater could be discharged to the South Sewer for return to Mogden STW, but it is not possible to return the RO concentrate by this means. The scheme reduces the final effluent at the extant Mogden STW outfall to the estuarine Thames Tideway.

The Mogden water recycling scheme has been assessed for Gate 2 independently at 50 Ml/d, 100 Ml/d, 150 Ml/d and 200 Ml/d. Outside the normal operating pattern the Gate 2 engineering design includes a 25% plant maintenance flow, with the recycled water being discharged to the River Thames at Walton Bridge but not re-abstracted.

1.1.3 Mogden South Sewer Scheme

Crude sewage would be diverted from the South Sewer of the sewerage catchment of Mogden STW. The South Sewer runs close to Kempton Park WTW and the diverted sewage would be pumped to a new AWRP located at a site near Kempton WTW for advanced treatment. Recycled water would be transferred in a new pipeline for discharge into the freshwater River Thames at an outfall upstream of the existing Thames Water Walton intake. Additional abstraction for public water supply on a put-take basis would be through existing downstream intakes on the River Thames. Waste streams from the AWRP would be conveyed by a new pipeline and treated at Mogden STW. The scheme reduces the final effluent at the extant Mogden STW outfall to the estuarine Thames Tideway.

The Mogden South Sewer scheme has been assessed for Gate 2 at 50 Ml/d.

During Gate 2, Thames Water took the decision to pause development of the Mogden South Sewer scheme due to limitations on available flow within the sewer, cost of the scheme and regional modelling not selecting the scheme under any water resources planning horizon scenario. The Gate 1 concept design is therefore used in Gate 2, with the exception where scheme elements are shared with the Mogden water recycling scheme (certain conveyance routes, AWRP and discharge location) which have been further developed through Gate 2.

The Mogden South Sewer scheme has not been progressed through Gate 2 environmental assessments, and so a dedicated assessment section is not included within this report. However, due to the similarities with the 50 Ml/d Mogden water recycling scheme (AWRP, discharge location and volume), the outcomes of that assessment can be considered representative of a water quality assessment of a 50 Ml/d Mogden South Sewer scheme.

1.1.4 Teddington DRA Scheme

Final effluent from Mogden STW would be subject to further treatment at a new tertiary treatment plant (TTP) at Mogden STW. The treated water would be transferred in a new pipe-jacked tunnel for discharge into the freshwater River Thames at a new outfall upstream of the tidal limit at Teddington Weir. Additional abstraction for public water supply on a take-put basis would be through a new intake from the freshwater River Thames, upstream of the new outfall. Abstracted water would be pumped into the nearby TLT for transfer to Lockwood pumping station, part of Thames Water's Lee Valley reservoirs in North London. The scheme reduces the final effluent at the extant Mogden STW outfall to the estuarine Thames Tideway.

The Teddington DRA scheme has been assessed for Gate 2 independently at 50 Ml/d, 75 Ml/d, 100 Ml/d and 150 Ml/d. Outside the normal operating pattern the Gate 2 engineering design includes a 25% plant maintenance flow, with the treated water being discharged to the River Thames at Teddington but not re-abstracted.

1.2 THE PURPOSE OF THIS REPORT

The purpose of this series of Assessment Reports (Annex B.2) is to set out the environmental baseline for each reach of the full study area to identify the source of greatest potential magnitude of change that a London Effluent Reuse SRO might cause within that reach, and then assess the potential for change to environmental pathways (physical environment and water quality) and receptors (aquatic ecology). The report identifies where additional data and/or more detailed analysis is required in Gate 3 as the London Effluent Reuse SRO designs are developed and operating regimes refined. The findings of these reports provide the evidence base to inform the HRA, Water Framework Directive (WFD) and IEA assessments.

This report provides the assessment for the Gate 2 environmental water quality topic. Drinking water safety considerations are assessed in Annex C[3] of the London Effluent Reuse SRO submission. As per the Gate 2 Water Quality Evidence Report, Table 1-1Table 1-1 outlines the task and approach to assessment for the water quality assessment for Gate 2 of the London Reuse SRO. It also outlines the evidence base that has been used to undertake the assessment for each of the tasks.

The study area for the London Reuse SRO has been divided into the following water courses (Figure 1-1, Table Figure 1-1Table 1-2):

- The freshwater River Thames from Shepperton Weir to the tidal limit at Teddington, noting the 1D river water quality model boundary is Cricklade in the upper catchment of the River Thames
- Channels of the freshwater Lee Diversion Channel: from Newman's Weir to Flanders Weir, and the Enfield Island Loop branch channel.
- The estuarine Thames Tideway from the tidal limit at Teddington to 3km seawards of Beckton STW outfall, noting the estuarine model boundary is at Southend-on-Sea.

Section 2 of this report sets out reference conditions for the zone of influence of the London Effluent Reuse SRO sub-options. Sections 3-5 outlines the environmental assessment for each SRO sub-option included in the Gate 2 submission. Section 6 provides summary of current knowledge gaps and future investigations.

[3] Jacobs (2022) Strategic Water Quality Risk Assessment (SWQRA) for London Effluent Reuse.

Table 1-1 Tasks and assessment approach to the water quality assessment for London Effluent Reuse SRO

Task item	Scope of assessment	Approach to assessment	WQ Evidence Base for Task

a. Reuse plant/DRA treatment unit discharge quality	• Collaborative working with Engineering Consultant on changes to concentrations of chemicals discharged in final effluent from inclusion of process water	• Use Engineering Consultant's review of environmental fate (to solid wastes, liquid wastes or conversion) of chemicals to identify:
		  • Recycled water/treated effluent quality (temperature, general physico-chemical, Water Framework Directive (WFD) chemicals, olfactory inhibitors) at reuse/DRA outfall locations
		  • Environmental fate of chemicals reduced during reuse treatment and changes in final effluent concentration at Mogden/Beckton STW outfall locations
			• Spot sample data from TWUL WFD, EQSD and olfaction analytical suites

b. Water temperature change	• Assessment of water temperature effects throughout the study area (both locally at outfalls, downstream in river and in estuary) for the range of reference conditions and scenarios with reuse option	• Interrogate 3D river modelling outputs for freshwater River Thames study reaches. • Interrogate TELEMAC model outputs for tidal study reaches. • Fixed (single) point deterministic modelling for Enfield Island Loop study reach • Information on temperature change from treatment processes and conveyance routes will be included in the assessment	• EA Meteor sonde data • Thames Water sonde data
c. General physico-chemical change	• Assessment of modelled WFD water quality parameters throughout the study area (both river and estuary) for the range of reference conditions and scenarios with reuse option	• Interrogate 1D river modelling outputs for freshwater River Thames study reaches • Interrogate TELEMAC model for tidal study reaches • Fixed (single) point deterministic modelling for Enfield Island Loop study reach • Freshwater pH and alkalinity assessment as fixed-point stochastic modelling at outfall locations	• EA Meteor sonde data • Thames Water sonde data • EA WIMS spot data • Thames Water spot data
d. WFD chemicals	• Assessment of WFD and Environmental Quality Standards Directive (EQSD) chemical quality throughout the study area (both river and estuary) for the range of reference conditions and scenarios with reuse option	• Interrogate conservative tracer results from 1D river modelling fluvial model for freshwater River Thames study reaches with receiving watercourse data from the pan-SRO water quality monitoring programme to inform discharge quality information for the Engineering Consultant. • Interrogate conservative tracer results from TELEMAC model for tidal study reaches with final effluent quality data from the pan-SRO water quality monitoring programme. • Fixed (single) point stochastic modelling for Enfield Island Loop study reach	• Spot sample data from TWUL WFD, EQSD and olfaction analytical suites
e. Olfactory water quality assessment	• Assessment of specific olfactory cues and inhibitors throughout the study area (both river and estuary) for the range of reference conditions and scenarios with reuse option	• Interrogate conservative tracer results from 1D river modelling fluvial model for River Thames freshwater study reaches with data from the pan-SRO water quality monitoring programme to inform concentrations of olfactory cues and inhibitors in freshwater reaches • Interrogate conservative tracer results from TELEMAC model outputs for tidal study reaches with data from the pan-SRO water quality monitoring programme to inform concentrations of olfactory cues and inhibitors in freshwater reaches	• Spot sample data from TWUL WFD, EQSD and olfaction analytical suites
f. Richmond Pound drawdown water quality assessment	• Asses the specific effects of planned annual maintenance drawdown on water quality within Richmond Pound	• Interrogate estuarine TELEMAC modelling outputs to describe changes in general physico-chemical water quality and temperatures during those periods (baseline) and with reuse option	• EA Meteor sonde data • Thames Water sonde data

Figure 1-1 Locations of London Effluent Reuse Strategic Resource Option schemes and water quality sampling sites

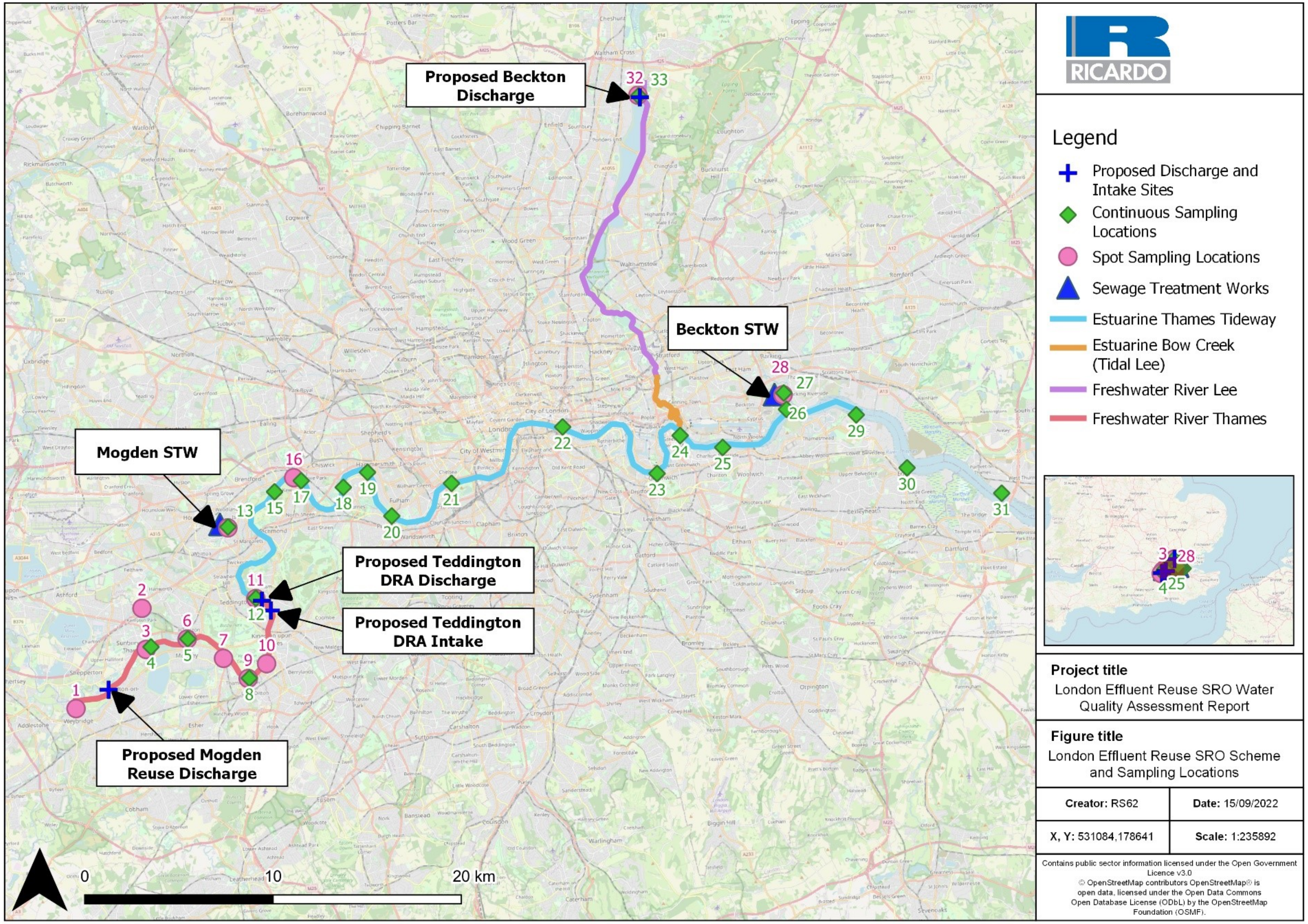

Table 1-2 Sampling sites for London Effluent Reuse Strategic Resource Option schemes

Site No.	Spot/ cont.	Site Name	Site No.	Spot/ cont.	Site Name
1	Spot	River Wey above Thames	**18**	Cont.	Chiswick Pier
2	Spot	Mogden South Sewer	**19**	Cont.	Hammersmith
3	Spot	River Thames at Walton	**20**	Cont.	Putney
4	Cont.	River Thames at Walton	**21**	Cont.	Cadogan Pier
5	Cont.	River Thames at Hampton	**22**	Cont.	Tower Pier
6	Spot	River Thames at Hampton	**23**	Cont.	Greenwich Pier
7	Spot	River Mole above Thames	**24**	Cont.	North Greenwich Pier
8	Cont.	River Thames Upstream of Hogsmill River	**25**	Cont.	Barrier Gardens Pier
9	Spot	River Thames Upstream of Hogsmill River	**26**	Cont.	Pier at Beckton STW
10	Spot	River Thames at Ravens Ait, Surbiton	**27**	Cont.	Beckton STW Final Effluent
11	Spot	River Thames at Teddington Weir	**28**	Spot	TWUL Beckton STW Final Effluent
12	Cont.	River Thames at Teddington Weir	**29**	Cont.	Pier at Crossness STW
13	Cont.	Mogden STW Final Effluent	**30**	Cont.	Erith Bath Weir
14	Spot	TWUL Mogden STW Final Effluent	**31**	Cont.	Purfleet
15	Cont.	Brentford Barge	**32**	Spot	Lee at Enfield Island Loop
16	Spot	Thames Tideway at Kew Bridge	**33**	Cont.	Lee at Enfield Island Loop
17	Cont.	Kew Barge			

2. REFERENCE CONDITIONS

2.1 INTRODUCTION

To inform the assessment for each of the tasks set out in Table 1-1, this section establishes the reference conditions for each task as per the relevant study area. The study area for each task has been set out per task as it is not consistent across tasks. The reference conditions for each of the following tasks has been set out in the following sections:

- Source water: Beckton STW or Mogden STW final effluent – Section 2.2
- Water temperature – Section 2.3
- General physico-chemical – Section 2.4
- WFD chemicals – Section 2.5
- Olfactory water quality – Section 2.6
- Richmond Pound water quality during the period without tidal management, annually in November (referred to as the drawdown period) – Section 2.7

The data used for establishing the reference conditions has been outlined in the Gate 2 Water Quality Evidence Report and in Table 1-1Table 1-1.

This reference conditions assessment has been undertaken for the following for each task:

- Source water of Mogden STW or Beckton STW final effluent including effluent temperature, general physico-chemical parameters, and effluent chemicals, including olfactory inhibitors at Mogden STW.
- Water temperature across the freshwater Thames, estuarine Thames Tideway and freshwater Lee Diversion Channel.
- WFD physico-chemical supporting elements to ecological status, including dissolved oxygen saturation, total ammonia, reactive phosphorus, water temperature, pH and BOD[4] across the freshwater Thames, estuarine Thames Tideway and freshwater Lee Diversion Channel.
- WFD chemical suite across the freshwater Thames, estuarine Thames Tideway and freshwater Lee Diversion Channel.
- Olfactory water quality, including those determinands which were added for the assessment at Gate 2 and for which data was available, such as Oxamyl[5].
- Richmond Pound drawdown water quality, including water temperature, conductivity, and dissolved oxygen for the reach between Teddington Weir and Richmond Half-tide Sluice.
- Available spot river water quality datasets were reviewed to determine the extent of variability with site or seasonality with the data appropriately subsetted. This provided the range and variability of water qualities across the range of monitored sites.

Where this report makes reference to A82 and M96 flow series, respectively these refer to 1 in 5 year and 1 in 20-year flow events. Full details of the scenarios selected is provided in Section 1.2 of the Annex B.2.1. Physical Environment Assessment Report[6].

Water Framework Directive (WFD) status bands are referred to in text, this is employed as an indication of water quality and not as a full assessment. WFD water body status is assigned by the Environment Agency.

2.2 SOURCE WATER: BECKTON STW OR MOGDEN STW FINAL EFFLUENT

2.2.1 Overview

This section sets out the reference conditions for the source water (effluent) parameters for Beckton STW and Mogden STW:

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[4] Schedule 3 Part 1 Section 1 of: Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

[5] See the Olfaction Technical Note

[6] Ricardo (2022) London Effluent Strategic Resource Option, Gate 2 Physical Environment Assessment Report.

- Effluent temperature - Section 2.2.2
- Effluent general physico-chemical - Section 2.2.3
- Effluent chemicals - Section 2.2.4

The evidence available, the general patterns observed in the data and any notable pressures are outlined for each of these reaches in the following sections.

2.2.2 Effluent temperature

The following data sources have been used to establish the effluent temperature reference conditions for the Beckton STW final effluent:

- Thames Water EQUIS water quality data – Spot sample data (2010 - 2021)
- Environment Agency Meteor Data Cloud – continuous monitoring (15-minute intervals) including as part of the Pan-SRO monitoring programme

The following data sources have been used to establish the effluent temperature reference conditions for the Mogden STW:

- Thames Water's EQuIS water quality data database – Spot sample data (2013 – 2017)
- Environment Agency Meteor Data Cloud – continuous monitoring (15-minute intervals) including as part of the Pan-SRO monitoring programme

For Beckton STW final effluent the minimum effluent temperatures recorded were 11.7^{o}C with a maximum of 25.6^{o}C. Mean temperatures measured 19.0^{o}C. Temperatures were higher in the summer and lower in the winter.

For Mogden STW final effluent the minimum effluent temperatures recorded were 7.2^{o}C with a maximum of 25.5^{o}C. Mean temperatures measured 17.3^{o}C. Temperatures were higher in the summer and lower in the winter.

Mogden STW final effluent data were parameterised using the combined TWUL and EA datasets to inform the inputs for the HRW Tideway model. A daily profile was established from the 2010-2020 dataset with an R^2 of 93%.

2.2.3 STW final effluent general physico-chemicals water quality

The following data sources have been used to establish the effluent physio-chemical reference conditions for the Beckton and Mogden STWs.

For the Beckton STW final effluent:

- Thames Water EQUIS water quality data – Spot sample data (2010 - 2021)
- Environment Agency Meteor Data Cloud – continuous monitoring (15-minute intervals) (2020-2022)
- Pan-SRO monitoring programme spot sample data (2020-2022)

For the Mogden STW final effluent:

- Thames Water EQUIS water quality data – Spot sample data (2013 – 2017)
- Pan-SRO monitoring programme spot sample data (2020-2022)

Environmental Permit consented discharge conditions for sanitary and nutrient parameters and the statistical compliance rate of the London effluent reuse schemes would need to be agreed between the Environment Agency and Thames Water. Environmental permitting is not a requirement of Gate 2 SRO assessments.

Beckton STW final effluent

Prior to treatment through the advanced water recycling plant (AWRP) for a Beckton water recycling scheme, source water quality in final effluent is reported as follows. Data sets span from 2010 to 2020.

<u>Dissolved Oxygen Saturation</u>

From a dataset that spans 7th Jan 2022 to 7th July 2022 the average dissolved oxygen percentage of 58% and a max value of 96.36% in and a minimum value of 29.22%. The DO generally stays between 50%-65% with a few outlying data points.

<u>Ammonia</u>

Through the dataset there are spikes in ammonia concentrations during the periods of 2010 and 2012 – 2013. The mean value is 0.5 mg/l, and the median value is 0.1 mg/l. The minimum value is <0.002 mg/l and the maximum value is 7.5 mg/l.

Suspended Solids

Within the dataset there is a reduction in variability from 2013 onwards. The mean value is 19 mg/l, and the median value is 10 mg/l. The minimum value is 1.9 mg/l, and the maximum value is 193.3 mg/l.

Biochemical Oxygen Demand

Within the dataset there are two spikes in BOD concentration during 2010 and 2013. Following this, the variability decreases for the rest of the sampling period. The mean value is 5.5 mg/l, and the median value is 3.6 mg/l. The minimum value is 1.0 mg/l, and the maximum value is 45.6 mg/l.

Dissolved inorganic nitrogen and phosphorus

Reference condition data for dissolved inorganic nitrogen (DIN) and phosphorus is detailed below in the accompanying assessment for the Beckton water recycling scheme.

Mogden STW final effluent

Prior to treatment through the AWRP for a Mogden water recycling scheme or Teddington DRA scheme, source water quality in final effluent is reported as follows. Data sets span from 2013 to 2017.

Dissolved Oxygen Saturation

The mean value from the dataset is 5.5 mg/l and the median is 5.4 mg/l. The lowest value is 3.0 mg/l, and the highest is 8.3 mg/l. Dissolved Oxygen Saturation exhibited a seasonal trend, with lows in the summer months (June – July) and highs in the winter (January – March).

Ammonia

The mean value is 3.2 mg/l, and the median is 1.9 mg/l. The minimum value within the dataset is 0.1 mg/l and the maximum value is 23.2 mg/l. There is no trend associated with this dataset.

Suspended Solids

The mean value is 13.6 mg/l, and the median value is 12 mg/l. The minimum value is 2 mg/l, and the maximum value is 77 mg/l. Suspended Solids showed a slight trend towards the end of the dataset, with more variability in 2013 – 2015 compared to 2016 – 2017.

Biochemical Oxygen Demand

The mean value is 5.6 mg/l, and the median value is 5.1 mg/l. The minimum value is 1.9 mg/l, and the maximum value is 20.9 mg/l. The biochemical oxygen demand showed no trend other than a spike in values in 2015.

Dissolved inorganic nitrogen and phosphorus

The mean ammonia (NH_3) concentrations are below average with values of 0.06 mg/l. Nitrite (NO_3), however, is amongst the highest values, averaging at 32.4 mg/l, over 7 mg/l greater than the average.

Most determinands had the highest values in the summer with all nitrogen based determinands showing a steep decrease in values in September, with concentrations slowly recovering towards the end of the year. After the decrease, ammonium and nitrite values remained low.

Phosphorus

The soluble reactive phosphorus (SRP) and total phosphorus (TP)[7] values at Mogden STW Final Effluent, show mean values of 2.89 and 3.43 mg/l respectively. SRP and TP are most elevated in the summer, then display a steep decrease in values in September, with concentrations slowly recovering towards the end of the year. After the decrease both TP and SRP recovered quickly reaching values close to the averages by the next monitoring period.

Hardness

[7] Total phosphorus (TP) is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. Soluble reactive phosphorus (SRP) is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells

The hardness of the freshwater River Thames has been calculated at 313 mg/l (very hard water), whilst the hardness calculated within the Mogden STW effluent is 361 mg/l, an increase of 48 mg/l, from the river due to elevated calcium and magnesium concentrations within the effluent.

2.2.4 Effluent chemicals

This section uses the consistent spot sampling dataset of the Pan-SRO monitoring programme which was established in Gate 1 at appropriate locations for the London Effluent Reuse SRO for a full suite of WFD and EQSD chemicals with best available commercial limits of detection. That monitoring programme has provided typically 15 results over a full annual cycle and is considered good data for the Gate 2 risk characterisation[8]. The monitoring programme is continuing throughout Gate 2 collecting more data that have been used in this assessment. A suite of monitoring for potential inhibitors of fish olfaction was added, with review by EA, during Gate 2.

It is noted that there are other chemical monitoring datasets for Beckton STW and Mogden STW final effluents. As these are not consistent in the chemical analysed or the limits of detection used, they have not been included in the Gate 2 analysis.

Environmental Permit consented discharge conditions for named chemicals and the statistical compliance rate of the London effluent reuse schemes would need to be agreed between the Environment Agency and Thames Water. This may also include for chemicals added as part of treatment processes. Environmental permitting is not a requirement of Gate 2 SRO assessments.

WFD Chemicals in Beckton STW final effluent

The WFD suite of chemical determinands for Beckton STW was assessed for exceedance of their limit of detection (LOD) during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 81 determinands in the chemical suite, 36 were found to be consistently below the LOD in final effluent, leaving 45 determinands for analysis. This is prior to treatment through the AWRP for a Beckton water recycling scheme. Table 2-1 shows a summary of those 45 chemicals.

The 45 determinands which were above the LOD were then assessed against the WFD standard for rivers.

Table 2-1 Summary of WFD chemicals in the Beckton STW final effluent (2020-2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
2,4-dichlorophenoxyacetic acid (2,4-D)	15	0.02	0.03	0.07	4.2	July 2021	2
Total arsenic	15	2.23	2.76	3.95	50	July 2021	15
Atrazine	15	0.02	0.03	0.20	0.6	March 2021	1
Benzene	15	0.10	0.22	1.00	10	June 2021	2
Benzo(a)pyrene	15	0.0004	0.0021	0.0046	0.0017	March 2021	15
Benzo(b)fluoranthene	15	0.0004	0.0018	0.0039	0.017 (short-term)	March 2021	15
Benzo(g,h,i)perylene	15	0.0004	0.0018	0.004	0.0082 (short-term)	March 2021	15
Benzo(k)fluoranthene	15	0.0002	0.001	0.0019	0.017 (short-term)	March 2021	15
Benzyl butyl phthalate	15	0.20	0.36	2.60	7.5	June 2021	1
C10-13 chloroalkanes (total)	15	0.40	0.44	1.00	0.4	May 2021	1
Total cadmium	15	0.02	0.023	0.07	0.08	May 2021	1

[8] It is noted that EA Environmental Permitting recognises a minimum of 12 samples for screening and modelling and a preference for 36 samples. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1038777/Guidance_part_b6_new_bespoke_water_discharge_gw_activity_point_source_discharge.pdf

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
Chlorothalonil	15	0.04	0.06	0.35	0.035	January 2021	1
Chromium (III) dissolved	15	1.00	1.89	12.00	4.7	October 2021	5
Dissolved copper	15	0.80	1.44	2.80	1 (bioavailable)	August 2021	15
Total cyanide	15	40.00	40.47	47.00	1	March 2021	1
Cybutryne (Irgarol)	15	0.0025	0.004	0.025	0.0025	March 2021	1
Di(2-ethylhexyl)phthalate (DEHP)	15	0.15	0.16	0.24	1.3	May 2021	2
Dichloromethane	15	1.00	1.73	6.00	20	March 2021	3
Dicofol	15	0.0013	0.0013	0.0014	0.0013	April 2021	1
Diuron	15	0.05	0.09	0.50	0.2	May 2021	3
Fluoranthene	15	0.0015	0.004	0.0064	0.0063	March 2021	15
Glyphosate	15	0.16	0.39	0.98	196	May 2021	15
Hexabromocyclododecane (HBCDD)	15	0.0003	0.0007	0.0013	0.0016	March 2021	15
Indeno(1,2,3-cd)pyrene	15	0.0004	0.0019	0.004	N/A	March 2021	15
Dissolved iron	15	12.00	48.53	61.00	1000	June 2021	15
Isoproturon	15	0.002	0.0032	0.02	0.3	March 2021	1
Dissolved lead	15	0.09	0.43	0.74	1.2 (bioavailable)	September 2021	14
Linuron	15	0.01	0.02	0.10	0.5	March 2021	1
Dissolved manganese	15	15.00	21.93	32.00	123 (bioavailable)	May 2021	15
Mecoprop	15	0.02	0.03	0.09	18	July 2021	4
Dissolved mercury	15	0.001	0.0087	0.048	0.07 (short-term)	April 2021	9
Dissolved nickel	15	0.50	2.17	3.60	4 (bioavailable)	August 2021	14
Nonylphenols (4-nonylphenol technical mix)	15	0.10	0.16	0.23	0.3	January 2021	15
Perfluorooctane sulfonic acid and its derivatives	14	0.0037	0.0064	0.0104	0.00065	July 2021	14
Permethrin	15	0.001	0.00167	0.005	0.001	March 2021	15
Polycyclic aromatic hydrocarbons (PAH) sum	15	0.05	0.05	0.05	N/A	Consistent across all dates	15
Simazine	15	0.02	0.03	0.20	1	March 2021	1
Terbutryn	15	0.02	0.03	0.20	0.065	March 2021	1
Tetrachloroethane	15	0.10	0.25	1.00	140	February and March 2021	3
Toluene	15	0.10	0.25	1.00	74	February and March 2021	4
Tributyltin compounds (as tributyltin cation)	15	0.00	0.00	0.0001	0.0002	May 2021	15
Trichlorobenzenes	15	0.40	0.48	1.00	0.4	February and March 2021	2
Trichloromethane (chloroform)	15	1.00	1.07	2.00	2.5	March 2021	1
Triclosan	15	0.01	0.013	0.04	0.1	April 2021	2
Zinc dissolved	15	5.30	32.42	140.00	12.9	March 2021	15

The following shows which of those analysed 45 chemicals have frequent and occasional exceedances of the standard within the data sets. 'Occasional' has been defined here as single occurrences throughout the data set up to five occurrences through-out the data set, while 'frequent' occurrences are numbered above this.

Frequent exceedances:

- Dissolved copper
- Perfluorooctane sulfonic acid and its derivatives
- Dissolved zinc
- Permethrin

Occasional exceedances:

- C10-13 chloroalkanes (total)
- Total cyanide
- Dicofol
- Chlorothalonil
- Cybutryne
- Trichlorobenzenes

The Environmental Quality Standards Directive (EQSD) suite of chemical determinands for Beckton STW was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 59 EQSD chemicals, 39 were found to be consistently below the LOD, leaving 20 determinands for analysis. Table 2-2 shows a summary of those 20 chemicals.

Table 2-2 Summary of EQSD chemicals in the Beckton STW final effluent (2020-2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
Total boron	15	57	79.93	100	2000	July 2021	15
Bromine - total residual oxidant	15	0.05	0.09	0.15	2	June 2021	12
Chloride	15	62	97.4	150	250,000	June 2021	15
Chlorotoluron	15	0.05	0.08	0.5	2	March 2021	1
Dissolved cobalt	15	0.17	0.42	1.6	3	June 2021	15
Dibutyl phthalate	15	0.02	0.034	0.15	8	April 2021	2
Dichlorobenzene, total isomers	15	0.1	0.22	1	20	February and March 2021	2
Diflubenzuron	15	0.001	0.0016	0.01	0.001	March 2021	1
EDTA	15	100	144.4	212	400	March 2021	11
Fluoride	15	0.15	0.12	0.24	5000	March 2021	15
Mancozeb	15	0.1	0.96	5.8	2	May 2021	10
Maneb	15	0.1	0.19	0.5	3	September, October and December 2021	3
MCPA	15	0.02	0.04	0.27	80	July 2021	2
Pirimicarb	15	1	1	1	1	Consistent across dates	15
Prochloraz	15	0.1	0.16	1	4	March 2021	1
Propyzamide	15	0.01	0.016	0.1	100	March 2021	1
Styrene	15	0.1	0.22	1	50	February and March 2021	2
Sulphate	15	48	79.6	98	400,000	February 2021	15
Total tin	15	0.4	0.52	1.5	25	October 2021	4
Tributyl phosphate	15	0.02	0.03	0.07	50	September 2021	6

WFD chemicals in Mogden STW final effluent

The WFD suite of chemical determinands for Mogden STW was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 81 determinands in the chemical suite, 33 were found to be consistently below the LOD in final effluent, leaving 47 determinands for analysis. This is prior to treatment through the AWRP for a Mogden water recycling scheme or Teddington DRA scheme. Table 2-3 shows a summary of those 47 chemicals. The 47 determinands which were above the LOD were then assessed against the WFD standard.

Table 2-3 Summary of WFD chemicals in the Mogden STW final effluent (2020-2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
2,4-dichlorophenoxyacetic acid (2,4-D)	15	0.02	0.028	0.07	4.2	March and May 2021	4
Total arsenic	15	0.88	1.22	1.6	50	May 2021	15
Atrazine	15	0.02	0.032	0.2	0.6	March 2021	1
Benzene	15	0.1	0.22	1	10	February and March 2021	2
Benzo(a)pyrene	15	0.0004	0.0022	0.0096	0.0017	February 2021	15
Benzo(b)fluoranthene	15	0.0004	0.0021	0.0065	0.017 (short-term)	February 2021	15
Benzo(g,h,i)perylene	15	0.0005	0.0020	0.0065	0.0082 (short-term)	February 2021	15
Benzo(k)fluoranthene	15	0.0003	0.0012	0.0042	0.017 (short-term)	February 2021	15
Benzyl butyl phthalate	15	0.2	0.35	2.4	7.5	June 2021	2
Total cadmium	15	0.02	0.029	0.1	0.08	May 2021	5
Total chlorine	15	0.1	0.107	0.2	2	June 2021	1
Chlorothalonil	14	0.035	0.058	0.35	0.035	January 2021	1
Chromium (III) dissolved	14	1	1.05	1.4	4.7	May 2021	2
Dissolved copper	14	1.3	2	3	1 (bioavailable)	August 2021	14
Cybutryne (Irgarol)	14	0.0025	0.0041	0.025	0.0025	March 2021	1
Cypermethrin	14	0.0001	0.0005	0.0013	0.0001	March 2021	2
Di(2-ethylhexyl)phthalate (DEHP)	14	0.15	0.17	0.48	1.3	August 2021	1
Dichloromethane	14	1	1.43	5	20	July 2021	3
Dicofol	14	0.0013	0.0015	0.0038	0.0013	April 2021	1
Diuron	14	0.05	0.084	0.5	0.2	March 2021	2
Fluoranthene	14	0.0018	0.0037	0.0106	0.0063	February 2021	14
Glyphosate	14	0.14	0.33	0.54	196	May 2021	13
Hexabromocyclododecane (HBCDD)	14	0.0004	0.001	0.0018	0.0016	January 2021	14
Hexachlorocyclohexane	14	0.02	0.026	0.11	0.02	June 2021	1
Indeno(1,2,3-cd)pyrene	14	0.0005	0.0022	0.0086	N/A	February 2021	14
Dissolved iron	14	17	50.36	73	1000	April 2021	14
Isoproturon	14	0.002	0.0033	0.02	0.3	March 2021	1
Dissolved lead	14	0.09	0.26	0.39	1.2 (bioavailable)	May 2021	13

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
Linuron	14	0.01	0.016	0.1	0.5	March 2021	1
Dissolved manganese	14	12	21.14	38	123 (bioavailable)	January 2021	14
Mecoprop	14	0.02	0.031	0.13	18	May 2021	4
Dissolved mercury	14	0.001	0.0031	0.01	0.07 (short-term)	April and May 2021	9
Naphthalene	14	0.02	0.021	0.03	0.02	August 2021	1
Dissolved nickel	14	0.5	2.11	2.9	4 (bioavailable)	July 2021	13
Nonylphenols (4-nonylphenol technical mix)	14	0.04	0.20	0.44	0.3	January 2021	13
Pentachlorophenol	14	0.02	0.023	0.05	0.4	June 2021	2
Perfluorooctane sulfonic acid and its derivatives	13	0.0057	0.0094	0.016	0.00065	June 2021	13
Permethrin	14	0.001	0.0025	0.011	0.001	March 2021	14
Polycyclic aromatic hydrocarbons (PAH) sum	14	0.05	0.051	0.06	N/A	January 2021	14
Simazine	14	0.02	0.033	0.2	1	March 2021	1
Terbutryn	14	0.02	0.033	0.2	0.065	March 2021	1
Tetrachloroethane	14	0.1	0.19	1	140	February 2021	1
Toluene	14	0.1	0.17	1	74	February 2021	1
Tributyltin compounds (as tributyltin cation)	14	0.0001	0.0001	0.0003	0.0002	September 2021	14
Trichlorobenzenes	14	0.4	0.44	1	0.4	February 2021	1
Triclosan	14	0.01	0.016	0.03	0.1	February 2021	7
Dissolved zinc	14	9.3	23.52	29	12.9	April, May and December 2021	14

The following shows which of those 47 chemicals have frequent and occasional exceedances of the standard within the data sets. ‘Occasional’ has been defined here as single occurrences throughout the data set up to five occurrences through-out the data set, while ‘frequent’ occurrences are numbered above this.

Frequent exceedances:

- Dissolved copper
- Perfluorooctane sulfonic acid and its derivatives
- Dissolved zinc

Occasional exceedances:

- Chlorothalonil
- Cybutryne (Irgarol)
- Cypermethrin
- Dicofol
- Hexachlorocyclohexane
- Permethrin
- Trichlorobenzenes
- Napthalene

The EQSD suite of chemical determinands for Mogden STW was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 59 EQSD chemicals, 42 were found to be consistently below the LOD, leaving 17 determinands for analysis.

Table 2-4 shows a summary of those 17 chemicals.

Table 2-4 Summary of EQSD chemicals in the Mogden STW final effluent (2020-2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
Total boron	15	61	79.07	94	2000	August 2021	15
Bromine - total residual oxidant	15	0.05	0.1	0.17	2	June 2021	13
Chloride	15	57	92.64	120	250,000	August 2021	15
Chlorotoluron	15	0.05	0.082	0.5	2	March 2021	1
Dissolved cobalt	15	0.33	0.4	0.46	3	February 2021	15
Dibutyl phthalate	15	0.02	0.026	0.07	8	April 2021	3
Dichlorobenzene, total isomers	15	0.1	0.16	1	20	February 2021	1
Diflubenzuron	15	0.001	0.0016	0.01	0.001	March 2021	1
Fluoride	15	0.13	0.19	0.21	5000	May 2021	15
Mancozeb	15	0.1	0.82	3	2	March 2021	9
Maneb	15	0.1	0.19	0.5	3	September, October and December 2021	3
Pirimicarb	15	1	1	1	1	Consistent across dates	15
Propyzamide	15	0.01	0.02	0.1	100	March 2021	1
Styrene	15	0.1	0.16	1	50	February 2021	1
Sulphate	15	47	83.71	120	400,000	December 2021	15
Total tin	15	0.4	0.51	1.3	25	September 2021	2
Tributyl phosphate	15	0.02	0.06	0.16	50	January 2021	7

Chemicals associated with inhibition of olfaction in Mogden STW final effluent

Following the process outlined above, the Mogden STW olfaction suite of chemical determinands were assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 53 determinands in the olfactory suite, two had no available data, 19 were found to be consistently below the LOD, leaving 32 determinands for analysis. It should be noted that data availability is not consistent across those determinands and dates.

1,6-hexanediamine and benzalkonium chlorides (as BAC10, 12, 14 & 16) only have two data points available across the monitoring period, in November and December 2021. Measurements of benzalkonium chlorides were consistent across the two dates, whilst the measurements of 1,6-hexanediamine exhibit greater variability.

Metals (total and dissolved) generally had monthly monitoring across the period for Mogden STW final effluent. It is observed that concentrations of cadmium (total and dissolved) and dissolved chromium (III) were typically at or below LOD with occasional higher readings, whereas variability in the measured data was observed for other monitored metal species, including iron (total and dissolved), total aluminium, total copper, mercury (total and dissolved) and nickel (total and dissolved). Dissolved copper exhibited a particularly strong seasonal trend with elevated concentrations during the months of April to August. Dissolved aluminium showed a similar trend with concentrations reaching a large peak in June and decreasing below LOD before and after. Measurements of selenium exhibit clear patterns with dissolved selenium decreasing gradually throughout the monitoring period with a peak in June and total selenium increasing gradually throughout the monitoring period with two significantly higher values recorded during April and December. Cobalt measurements showed a similar pattern with dissolved cobalt concentrations showing a gradual decline throughout the monitoring period and total cobalt showing a gradual increase. Zinc concentrations follow a clear pattern throughout the monitoring period with an initial increase followed by a decrease and then a final increase until the end of the period. Dissolved and total chromium measurements both exhibited small fluctuations throughout the monitoring period with a spike in concentrations in March and September respectively.

Measurements of chlorotoluron returned values that did not exceed the LOD other than a single measurement taken in March 2021. This pattern was also observed for isoproturon, linuron, methiocarb and monuron. Diuron measurements exhibit a similar pattern with values only exceeding the LOD during March and May 2021. Measurements of permethrin exceeded the LOD significantly in February and March with four smaller exceedances following. Concentrations of pirimicarb remained consistent throughout the monitoring period with all measurements returning values of 1 µg/l. In contrast, cypermethrin measurements exhibit considerable variability throughout the monitoring period with the greatest concentrations recorded in March and December 2021.

2.3 WATER TEMPERATURE

2.3.1 Overview

This section sets out the reference conditions for the environmental water temperature for the following water courses in the study area:

- Freshwater Lee Diversion Channel - Section 2.3.2
- Freshwater River Thames - Section 2.3.3
- Estuarine Thames Tideway - Section 2.3.4

The evidence available, the general patterns observed in the data and any notable pressures are outlined for each of these reaches.

2.3.2 Freshwater Lee Diversion Channel

Data used for characterisation of the Lee Diversion Channel have been taken from the Environment Agency Meteor Data Cloud for the following locations operated as part of the Pan-SRO monitoring programme:

- Enfield Island Loop of the Lee Diversion Channel upstream of King George V Reservoir Intake
    - AT_KGVINTAKE_RVR_LEE_E_202101_T02039A

At this location, the data spans from the 29th January 2021 until the 15th December 2021 in 15-minute increments. The temperature ranges from 3.1°C to 23.7°C with a mean of 13.2°C and a median of 12.9°C. Seasonality is present at this location with temperatures below 10°C observed from November to April and temperatures higher than 15°C from June to September. Daily temperatures rise in the daytime and lower at night.

2.3.3 Freshwater River Thames

This section draws on the following data sources to establish the water temperature reference conditions for the freshwater River Thames at Walton and Teddington Weir. Reference conditions for the Thames at Surbiton and Thames at Hampton have also been included.

- **River Thames at Walton**
    - Pan-SRO monitoring programme data (2020-2022) – spot sample data

The Walton water temperature dataset is a daily sampling regime in late 2021. Spot sampling regime shows no trend, with temperatures fluctuating between the minimum value of 4.6°C and the maximum value of 20.9°C. During 2021, a daily sampling regime took place between September and December 2021 where temperatures exhibited a seasonal downward trend with 19.1°C in September to 12.2°C in November, followed by a short uptrend in December. The mean value for the two datasets is 11.9°C and the median is 12.07°C.

A modelled temperature series for Walton has not been used as the identified relationship was weaker and less accurate than at Teddington and so the predicted values were deemed unsuitable for assessment. Comparison of the Thames at Walton and the Thames at Teddington temperature data identified a relationship of R^2 = 0.98 giving confidence to this approach. As such the Thames at Teddington predictions have been taken forward for the assessment.

- **River Thames at Hampton**

  - Pan-SRO monitoring programme data (2020-2022) – continuous data (15-minute)

At this location, the data spans from the 9th January 2022 until the 01st July 2022 in 15-minute increments. The temperature ranges from 4.8°C to 22.1°C with a mean of 12.0°C and a median of 10.8°C.

- **River Thames at Surbiton**
  - Pan-SRO monitoring programme data (2020-2022) – continuous data (15-minute)

At this location, the data spans from the 9th January 2022 until the 1st July 2022 in 15-minute increments. The temperature ranges from 4.8°C to 22.1°C with a mean of 12.0°C and a median of 10.8°C.

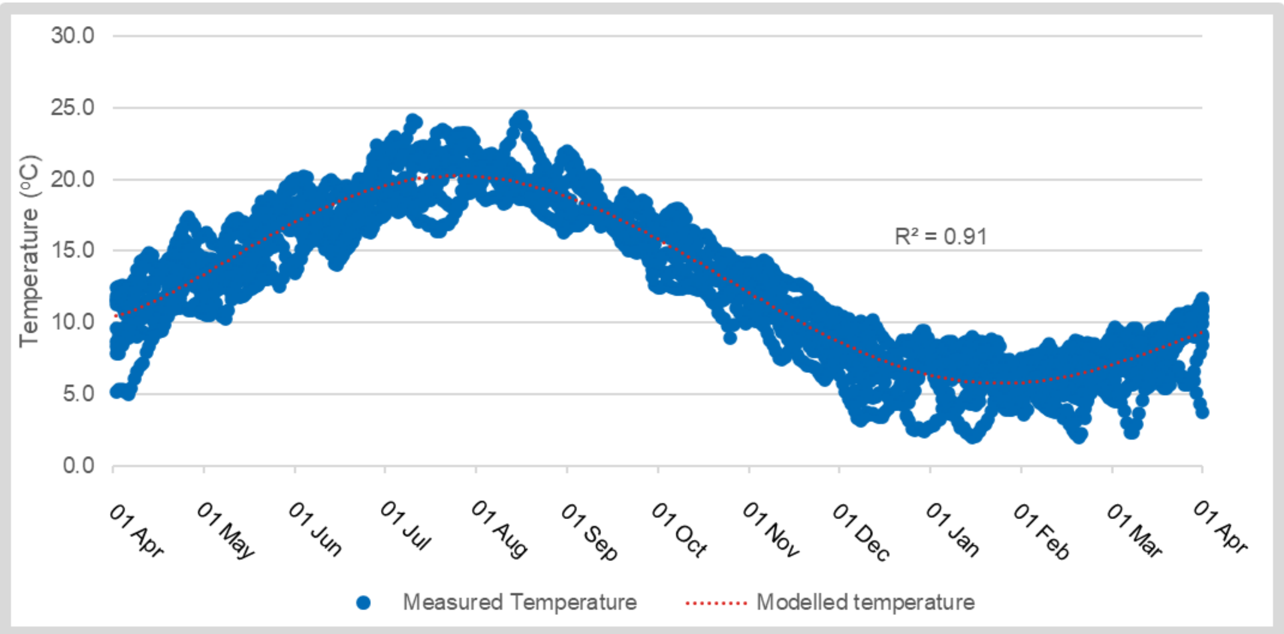
- **River Thames at Teddington**
  - Environment Agency AQMS 2010 – 2015 (15-minute continuous)
  - Teddington Weir AQMS (Ricardo) 2017 – 2020 (15-minute continuous)
  - Teddington Weir AQMS (Pan-SRO monitoring programme) January 2021 – June 2022 (15-minute continuous)
    - This probe remains in place and continue monitoring at the time of writing.

Temperatures measured in Teddington followed a season trend with highs in July – August, and lows in December – March. The mean temperature across the dataset spanning 2010 – 2022 is 12.3°C and the median is 12.0°C. The maximum temperature in the dataset is 24.4°C and the minimum temperature is 2.0°C.

A daily water temperature profile was derived from the 15-minute measured reference conditions, as displayed in Figure 2-1. Temperature data from the Teddington Weir AQMS were used to develop the relationship for the temperature assessment in the water temperature assessments for the Mogden water recycling scheme and Teddington DRA scheme. The fitted 6th order polynomial (to represent the wave form of the relationship) has a strong relationship with an R^2 of 91%. This gives high confidence in the temperature profile used for modelling at Gate 2.

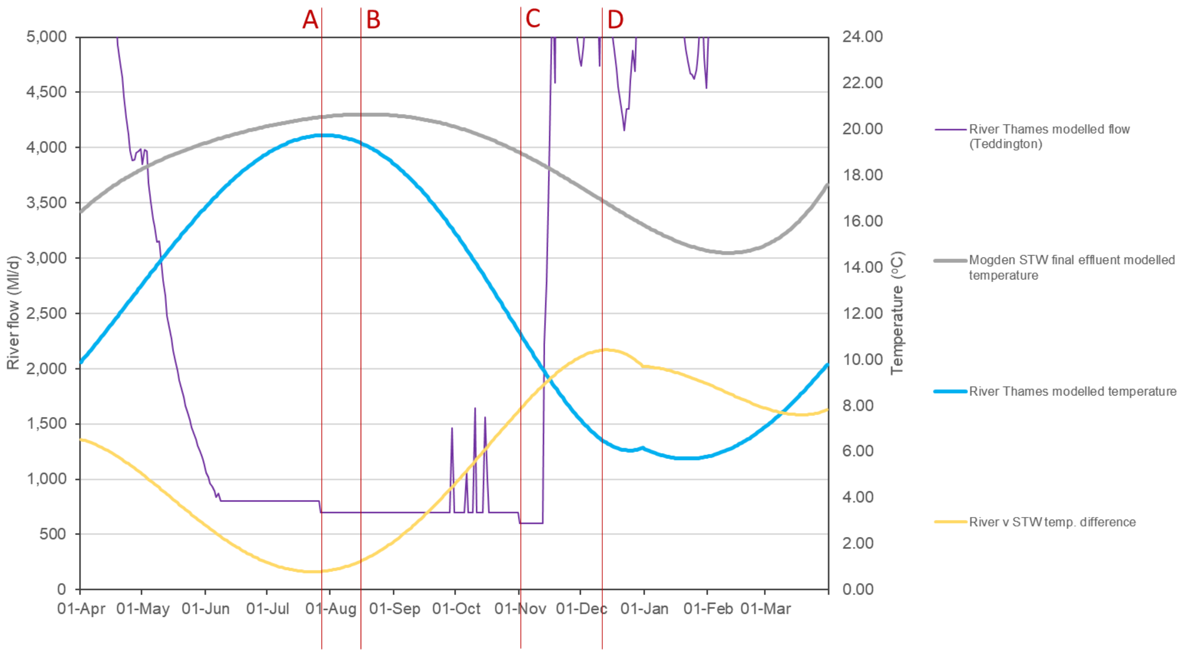
Temperature data for the River Thames at Teddington has been used for the Mogden water recycling scheme assessment in lieu of Walton Bridge as limited continuous monitoring data for the Walton site in Gate 2 yielded an incomplete annual series from which to make a reliable profile. From the available measured data at both sites, the relationship between temperatures at Walton and Teddington was identified as highly correlated (R^2 = 98%). As such the modelled Teddington temperatures were deemed appropriate for Gate 2 assessment at Walton Bridge.

Figure 2-1 Daily water temperatures and modelled reference conditions for River Thames at Teddington Weir 2010-2022



The modelled data displayed in Figure 2-2 indicates that the warmest river temperatures occur during July and August peaking at 19.7°C (line A). Warmest effluent temperatures are seen during August and September peaking at 20.7°C (line B). The maximum temperature difference at low river flows (at Teddington) is 8.9°C (line C). The maximum temperature difference between the River Thames and a Mogden water recycling outfall is 10.4°C (line D).

Figure 2-2 Modelled water temperature for River Thames at Teddington Weir



2.3.4 Estuarine Thames Tideway

Water temperature reference conditions for the Tideway were parameterised using the Mogden STW and Thames at Teddington temperature data and used as model inputs. Measured sea temperature data were also incorporated.

2.4 GENERAL PHYSICO-CHEMICAL

2.4.1 Overview

This section sets out the reference conditions for the general physico-chemical parameters for the following water courses in the study area:

- Freshwater Lee Diversion Channel - Section 2.4.2
- Freshwater River Thames - Section 2.4.3
- Estuarine Thames Tideway - Section 2.4.4

The evidence available, the general patterns observed in the data and any notable pressures have been outlined for each of these reaches.

2.4.2 Freshwater Lee Diversion Channel

The following data sources have been used to establish the general physico-chemical reference conditions for the freshwater Lee Diversion Channel:

- Thames Water water quality data – Spot sample and sonde data (January 2021-February 2022) at Enfield Island Loop included as part of the Pan-SRO monitoring programme
- Environment Agency Meteor Data Cloud – continuous monitoring (15-minute intervals) (June 2017 – December 2021)
- Environment Agency WIMS (Spot sample) (February 2021 – May 2022)

Dissolved oxygen

Dissolved oxygen data is available at Enfield Island and showed an average value of 105.4 %saturation, above the threshold for 'high' water quality according to WFD status bandings (70 %sat). The lowest DO values were all recorded in July and September with a minimum of 54.4 %sat ('moderate' – 54 %sat) while the highest values were recorded in February, with other peaks also recorded in April, the maximum DO value recorded was 106.6 %sat.

Acid neutralising capacity

Acid neutralising capacity (ANC) is indicative of meeting 'high' water quality according to WFD status bandings (80). Again, there are no clear seasonal trends, however, during two sampling days in February and March 2021, a cluster of three low values were observed.

Ammoniacal nitrogen

Ammoniacal nitrogen is typically below the threshold for 'good' water quality according to WFD status bandings (0.6 mg/l). However, this was briefly exceeded twice throughout out the monitoring period.

Biochemical oxygen demand

The threshold for 'good' water quality according to WFD status bandings (5 mg/l) is frequently exceeded for BOD. There is no clear seasonal trend within the BOD values.

Nitrate and nitrite

Concentrations of nitrate within the freshwater Lee Diversion Channel were very consistent between both sites, with concentrations increasing steadily from January to April, decreasing until July and then increasing to a peak in November 2021. Nitrite concentrations flowed a similar pattern and showed a peak during October 2021. A peak which was mirrored in the nitrate data.

pH

pH was measured between 6 and 9, indicative of 'high' water quality. There are no clear seasonal trends within the pH data.

Soluble reactive phosphorous

SRP measured concentrations show a gradual increase from the start of the monitored years which culminates in a peak in July. The high measured concentration observed in the freshwater River Thames in February is also observed within this Lee Diversion Channel data, though the June peak is not seen.

2.4.3 Freshwater River Thames

The following data sources have been used to establish the general physico-chemical reference conditions for the freshwater River Thames:

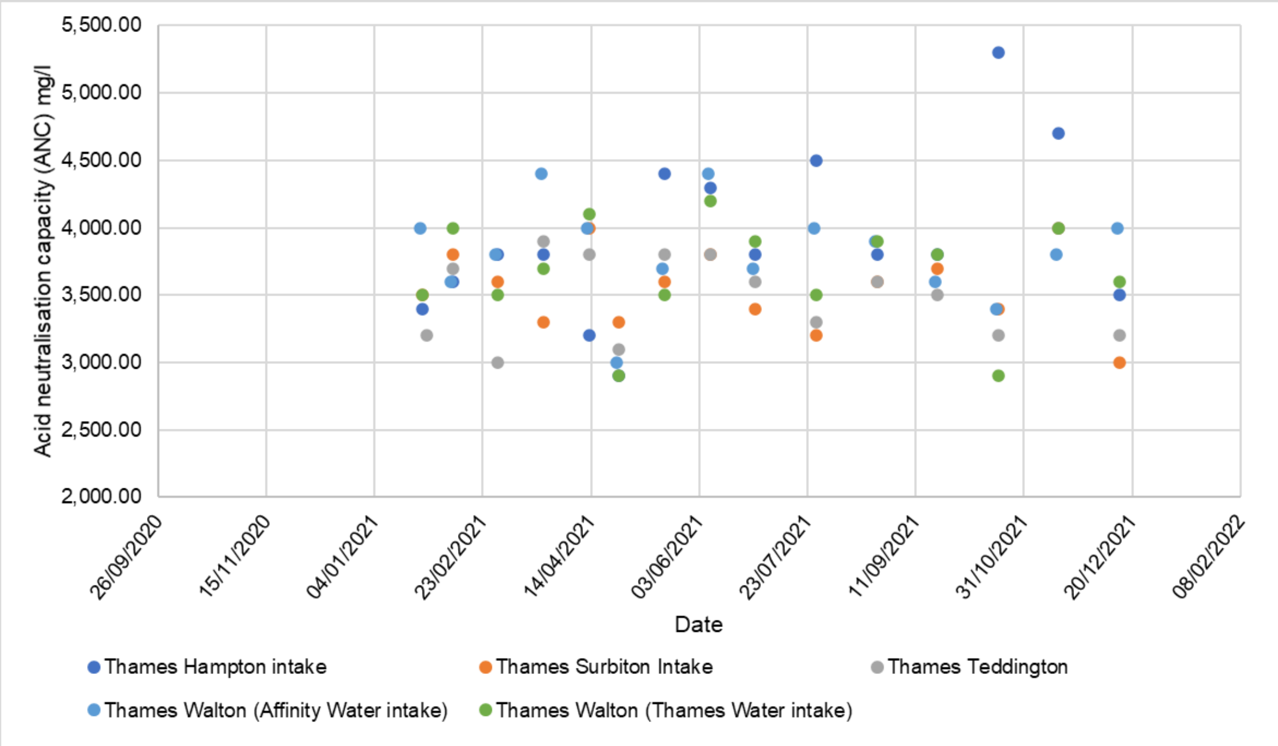
- Thames Water water quality data – Spot sample and sonde data (January 2021 – February 2022) at six sites: Hampton intake, Surbiton intake, Kingston, Teddington, Walton (Thames Water intake) and Walton (Affinity Water intake) included as part of the Pan-SRO monitoring programme
- Environment Agency Meteor Data Cloud – continuous monitoring (15-minute intervals) (February 2021-July 2022) included as part of the Pan-SRO monitoring programme
- Environment Agency WIMS (Spot sample) (September 2020 – August 2022)

The water quality assessments of London Effluent Reuse SRO at Gate 2 have been undertaken to assess change from a range of different appropriate reference conditions at times when a London Effluent Reuse SRO could be utilised. These reference conditions are different patterns of river flow and STW final effluent flow (see Section 1.2 of the Physical Environment Assessment Report): a 1:5 return frequency moderate-low flow year (A82); and a 1:20 return frequency very low flow year (M96). Water quality determinand data was also provided to enable reference condition parameterisation within the modelling undertaken for the freshwater River Thames and the estuarine Thames Tideway and these conditions are presented alongside the assessments. However, this did not include pH or ANC data as this was not modelled.

Acid neutralising capacity

ANC at all sites is indicative of meeting 'high' water quality according to WFD status bandings (80). While there are no clear seasonal trends, values appear to be slightly higher during the summer months at all monitored sites (Figure 2-3).

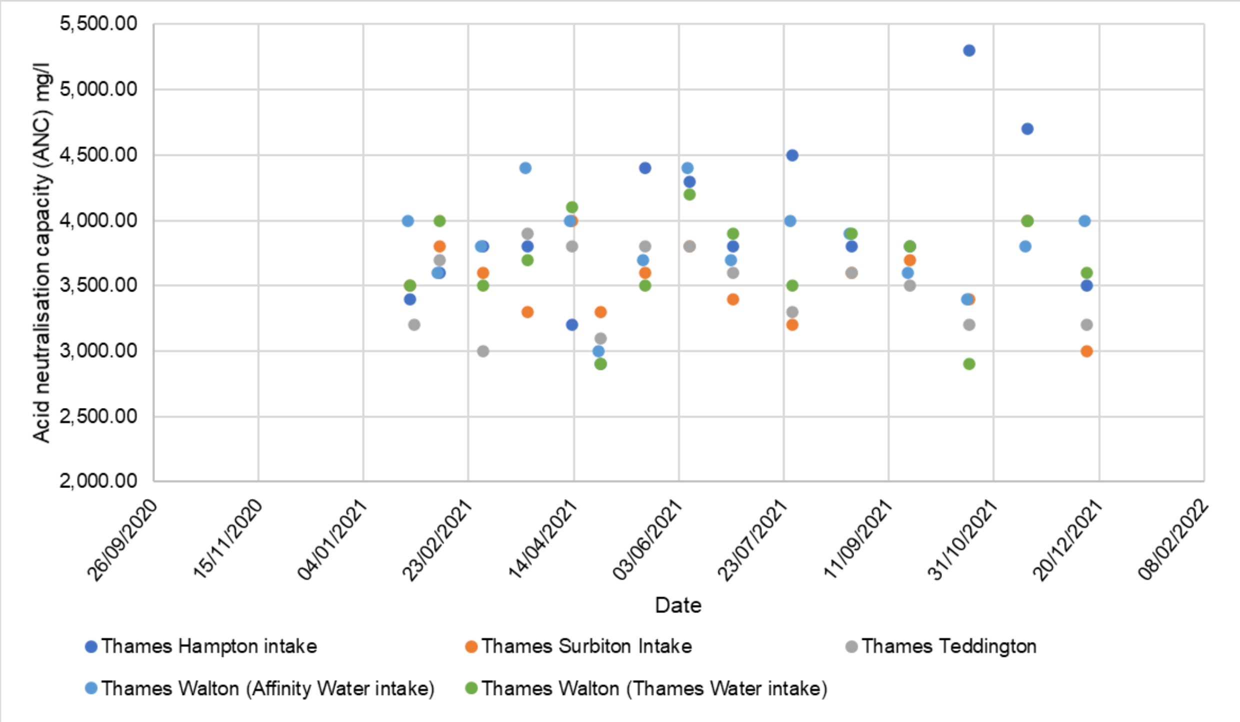
Figure 2-3 Monitored acid neutralising capacity data in the freshwater River Thames



pH

pH at all sites was measured between 6 and 9, indicative of 'high' water quality. A slight decrease in pH is observed at all sites throughout the monitoring period (Figure 2-4). Maximum pH values of 8.4 were observed across the sites, and minimum values of 7.8. This range was then used to inform the environmental requirements for remineralisation targets (see Section 4.2.3).

Figure 2-4 Monitored pH data in the freshwater River Thames



2.4.4 Estuarine Thames Tideway

This section draws on the following data sources to establish the general physico-chemical reference conditions for the estuarine Thames Tideway:

- Environment Agency Meteor Data Cloud – continuous monitoring (15-minute intervals) (March 2021 - May 2022)
- Environment Agency WIMS (Spot sample) (September 2020 – August 2022)

Dissolved oxygen

DO data in the tideway at Kew Bridge (Thames Water) between March 2021 and May 2022 shows an average of 12.5 mg/l, with a minimum of 9.3 mg/l in April and a maximum of 15.9 mg/l in May all data values were indicative of 'high' water quality according to WFD status bandings (5.7).

Dissolved inorganic nitrogen

This section describes the physio-chemical reference conditions of the estuarine Thames Tideway, including only the site where data regarding existing nutrient conditions is available: Site 11: River Thames at Teddington Weir

At Teddington Weir the ammonia (NH_3), nitrite (NO_2^-) and nitrate (NO_3), collectively as DIN, concentrations are amongst the lowest of all monitored sites within the estuarine Thames Tideway averaging at 0.03, 0.3 and 18.1 mg/l respectively. These values are consistently below the average concentrations.

Ammonia concentrations were often too low to establish a seasonal trend. DIN, however, remained relatively consistent throughout the year apart from all trending significantly downwards in October. All other variables remained consistent through the sampling year.

The determinands below are presented as the Upper Tideway is non-brackish and therefore the physico-chemical data remain as per freshwater.

Phosphorus

The soluble reactive phosphorus (SRP) and total phosphorus (TP) average concentrations (0.19 and 0.39 mg/l respectively) are also below the averages, with the average TP concentration being the lowest amongst all sites.

Acid neutralising capacity

ANC in the tideway shows a weak seasonal trend, with higher concentrations in the winter months, and lower values in the summer months. ANC ranged from 2,900 mg/l to 4,200 mg/l with an average of 3,414 mg/l.

Ammoniacal nitrogen

Ammoniacal nitrogen is typically below 0.6 mg/l. However, this was briefly exceeded during September 2021 with a measured concentration of 16 mg/l.

Biochemical oxygen demand

BOD was highly variable throughout the monitoring period with distinct peaks during April and September 2021. BOD averaged 3.8 mg/l with a minimum of 1.1 mg/l and a maximum of 7.4 mg/l.

pH

pH was highly variable throughout the monitoring period with peaks in April, June and December 2021. pH ranged from 7.7 to 8.4 with a mean of 7.8.

Soluble reactive phosphorous

SRP measured concentrations fluctuated between 0.13 and 1.1 mg/l during the monitoring period with concentrations gradually increasing from January to September and then decreasing toward the end of the year.

2.5 CHEMICALS

2.5.1 Overview

This section sets out the reference conditions for the WFD and EQSD chemical parameters[9] for the following water courses in the study area:

- Freshwater Lee Diversion Channel - Section 2.5.2
- Freshwater River Thames - Section 2.5.3
- Estuarine Thames Tideway - Section 2.5.4

The analysed chemicals are listed as priority substances and certain other polluting chemicals in the WFD and EQSD. This list does not include the Drinking Water Safety Plan (DWSP) suite which are reviewed separately as part of the Gate 2 Raw Water Risk Assessment.

The evidence available, the general patterns observed in the data and any notable pressures have been outlined for each of these reaches.

2.5.2 Freshwater Lee Diversion Channel

The following data sources have been used to establish the chemical reference conditions for the Lee Diversion Channel:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (01/2021 – 02/2022) at one site: Enfield Island included as part of the Pan-SRO monitoring programme

The WFD suite of chemical determinands for the freshwater Lee Diversion Channel was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further. Of the 81 determinands in the chemical suite, 46 were found to be consistently below the LOD, leaving 35 determinands for analysis. It should be noted that data availability is not consistent across those determinands at all sites and dates. The 35 determinands which were above the LOD were then assessed against the WFD standard. Table 2-5 shows a summary of those 35 chemicals.

[9] Ricardo (2022) London Effluent Strategic Resource Option, Gate 2 Water Quality Evidence Report.

Table 2-5 Summary of WFD chemicals in the freshwater Lee Diversion Channel (2021 – 2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
2,4-dichlorophenoxyacetic acid (2,4-D)	15	0.02	0.03	0.15	4.2	October 2021	15
Total arsenic	15	0.61	1.05	1.52	50	July & August 2021	15
Alachor	15	0.02	0.02	0.03	0.3	April 2021	15
Benzene	15	0.1	0.22	1	10	February & March 2021	15
Benzo(a)pyrene	15	0.002	0.01	0.04	0.0017	May 2021	15
Benzo(b)fluoranthene	15	0.002	0.01	0.03	0.017 (short-term)	May 2021	15
Benzo(g,h,i)perylene	15	0.002	0.01	0.03	0.0082 (short-term)	May 2021	15
Benzo(k)fluoranthene	15	0.001	0.004	0.02	0.017 (short-term)	May 2021	15
Total cadmium	15	0.02	0.04	0.09	0.08	October & December 2021	15
Total chlorine	15	0.1	0.11	0.2	0.035	January 2021	15
Chromium (III) dissolved	15	1	1.32	5.2	4.7	May 2021	15
Dissolved copper	15	2	2.7	3.6	1 (bioavailable)	April 201	15
Dichloromethane	15	1	1.53	5	20	June & July 2021	15
Fluoranthene	15	0.003	0.01	0.03	0.0063	May 2021	15
Glyphosate	15	0.1	0.27	0.87	196	July 2021	15
Hexabromocyclododecane (HBCDD)	15	0.00014	0.00015	0.00033	0.0016	June 2021	15
Indeno(1,2,3-cd)pyrene	15	0.001	0.01	0.04	N/A	May 2021	15
Dissolved iron	15	13	32.8	110	1000	October 2021	15
Isoproturon	15	0.002	0.002	0.01	0.3	January 2021	15
Dissolved lead	15	0.09	0.4	1.9	/	April 2021	15
Dissolved manganese	15	3.4	8.74	15	123 (bioavailable)	October 2021	15
Mecoprop	15	0.02	0.02	0.04	18	March, May & June 2021	15
Dissolved mercury	15	0.001	0.01	0.04	0.07 (short-term)	April 2021	15
Dissolved nickel	15	2.1	2.76	3.6	4 (bioavailable)	October 2021	15
Nonylphenols (4-nonylphenol technical mix)	15	0.04	0.05	0.08	0.3	January 2021	15
Pendimethalin	15	0.02	0.03	0.22	0.3	January 2021	15
Perfluorooctane sulfonic acid and its derivatives	15	0.01	0.01	0.02	0.00065	October 2021	15
Permethrin	15	0.001	0.001	0.01	0.001	February 2021	15
Polycyclic aromatic hydrocarbons (PAH) sum	15	0.05	0.07	0.2	N/A	May 2021	15

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time of max	No. >LOD
Simazine	15	0.02	0.02	0.03	1	April 2021	15
Tetrachloroethane	15	0.1	0.25	1	140	February & March 2021	15
Toluene	15	0.1	0.22	1	74	February & March 2021	15
Tributyltin compounds (as tributyltin cation)	15	0.00003	0.000064	0.00012	0.0002	July 2021	15
Trichlorobenzenes	15	0.4	0.48	1	0.4	February & March 2021	15
Zinc dissolved	15	2.4	7.15	17	12.9	October 2021	15

The following shows which of those 35 chemicals have frequent and occasional exceedances of the standard within the data sets. 'Occasional' has been defined here as single occurrences throughout the dataset up to five occurrences through-out the data set, while 'frequent' occurrences are numbered above this.

Frequent exceedances:

- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Total chlorine
- Dissolved copper
- Dissolved zinc

Occasional exceedances:

- Benzo(k)fluoranthene
- Dissolved chromium (III)
- Benzo(a)pyrene
- Trichlorobenzenes
- Perfluorooctane sulfonic acid and its derivatives
- Fluoranthene

The EQSD suite of chemical determinands for the freshwater Lee Diversion Channel was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 59 EQSD chemicals, 40 were found to be consistently below the LOD, leaving 19 determinands for analysis.

Table 2-6 shows a summary of those 19 chemicals.

Table 2-6 Summary of EQSD chemicals in the freshwater Lee Diversion Channel (2021 – 2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time and location of max	No. >LOD
Bentazone	15	0.02	0.03	0.12	500	May 2021, Enfield Island	2
Total boron	15	57	74	110	2,000	November 2021, Enfield Island	15
Bromine total residual oxidant	15	50	90	190	2	February 2021, Enfield Island	9
Chloride	15	47,000	90,000	440,000	250,000	August 2021, Enfield Island	15
Dissolved cobalt	15	0.29	0.47	0.97	3	September 2021, Enfield Island	15
Dibutyl phthalate	15	0.02	0.03	0.09	8	April 2021, Enfield Island	4
Dichlorobenzene total isomers	15	0.1	0.22	1	20	February and March 2021, Enfield Island	2

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Time and location of max	No. >LOD
Diethyl phthalate	15	0.02	0.02	0.06	200	June 2021, Enfield Island	3
Dimethyl phthalate	15	0.02	0.02	0.07	800	June 2021, Enfield Island	2
Fluoride	15	130	180	210	500	February 2021, Enfield Island	15
Mancozeb	15	0.1	0.4	2.4	2	June 2021, Enfield Island	7
Maneb	15	0.1	0.18	0.5	3	September, October and December 2021, Enfield Island	3
Pirimicarb	15	1	1	1	1	Consistent across dates at Enfield Island	15
Propyzamide	15	0.01	0.06	0.36	100	December 2021, Enfield Island	5
Styrene	15	0.1	0.2	1.0	50	February and March 2021, Enfield Island	2
Sulphate	15	33,000	54,000	86,000	400,000	August 2021, Enfield Island	15
Total tin	15	0.4	0.4	0.7	25	October 2021, Enfield Island	2
Triallate	15	0.02	0.02	0.05	0.25	December 2021, Enfield Island	1
Tributyl phosphate	15	0.02	0.03	0.12	50	December 2021, Enfield Island	3

2.5.3 Freshwater River Thames

The following data sources were used to establish the chemicals reference conditions for the freshwater Thames:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (01/2021-02/2022) at six sites: Hampton intake, Surbiton intake, Kingston, Teddington, Walton (Thames Water intake) and Walton (Affinity Water intake) included as part of the Pan-SRO monitoring programme

It is noted that the most significant of these for assessment of the London Effluent Reuse schemes is the Thames at Teddington site with respect to discharges from a Teddington DRA scheme, which is not subject to reverse osmosis treatment. The WFD suite of chemical determinands for the freshwater River Thames was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 81 determinands in the chemical suite, 41 were found to be consistently below the LOD, leaving 40 determinands for analysis. It should be noted that data availability is not consistent across those determinands at all sites and dates. The 40 determinands which were above the LOD were then assessed against the WFD standard. Table 2-7 shows a summary of these 41 chemicals.

Table 2-7 Summary of WFD chemicals in the freshwater River Thames (2021 – 2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long term)	Time and location of max	No. >LOD
2,4-dichlorophenoxyacetic acid (2,4-D)	75	0.02	0.03	0.09	4.2	June 2021, Thames Walton (Thames Water Intake)	14
Alachor	75	0.02	0.02	0.03	0.3	April 2021, Thames Walton (Affinity Water Intake)	1

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long term)	Time and location of max	No. >LOD
Total arsenic	75	0.57	1.02	2.94	50	August 2021, Thames Teddington	75
Benzene	75	0.1	0.2	1.0	10	February and March 2021, all sites	11
Benzo(a)pyrene	75	0.0009	0.009	0.3	0.0017	May 2021, Thames Surbiton Intake	75
Benzo(b)fluoranthene	75	0.0008	0.008	0.05	0.017 (short-term)	January 2021, Thames Teddington	75
Benzo(g,h,i)perylene	75	0.001	0.008	0.04	0.0082 (short-term)	January 2021, Thames Teddington	75
Benzo(k)fluoranthene	75	0.0005	0.005	0.03	0.017 (short-term)	January 2021, Thames Teddington	75
Total cadmium	75	0.02	0.3	0.12	0.08	October 2021, Thames Walton (Thames Water Intake)	32
Total chlorine	75	0.1	0.1	0.3	2	January 2021, all sites	7
Chromium (III) dissolved	77	1	2.9	110	4.7	September 2021, Thames Walton (Thames Water Intake)	14
Dissolved copper	75	1.2	2.1	3.3	1 (bioavailable)	March 2021, Thames Teddington	75
Total DDT	75	0.025	0.26	0.09	0.025	June 2021, Thames Walton (Affinity Water Intake)	2
Di(2-ethylhexyl)phthalate (DEHP)	75	0.15	0.15	0.17	1.3	April 2021, Thames Walton (Thames Water Intake)	1
Dichloromethane	75	1	1.4	5	20	March and July 2021, all sites	8
Dicofol	75	0.0013	0.0013	0.0016	0.0013	September 2021, Thames Walton (Affinity Water Intake)	2
Fluoranthene	75	0.002	0.008	0.037	0.0063	October 2021, Thames Walton (Affinity Water Intake)	75
Glyphosate	75	0.1	0.156	0.56	196	July 2021, Thames Surbiton Intake	57
Hexabromocyclododecane (HBCDD)	75	0.00014	0.00017	0.0004	0.0016	January 2021, Thames Teddington	75
Hexachlorobenzene	75	0.02	0.02	0.06	0.05 (short-term)	June 2021, Thames Walton (Affinity Water Intake)	2
Indeno(1,2,3-cd)pyrene	75	0.001	0.009	0.046	N/A	January 2021, Thames Teddington	75
Dissolved iron	75	5.5	45.2	450	1000	January 2021, Thames Teddington	73
Isoproturon	75	0.002	0.002	0.003	0.3	May 2021, Thames Walton (Affinity Water Intake)	1
Dissolved lead	75	0.09	0.14	0.87	1.2 (bioavailable)	May 2021, Thames Walton (Affinity Water Intake)	31

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long term)	Time and location of max	No. >LOD
Dissolved manganese	75	1.7	11.9	24	123 (bioavailable)	January 2021, Thames Teddington	75
Mecoprop	75	0.02	0.03	0.24	18	June 2021, Thames Walton (Affinity Water Intake)	14
Dissolved mercury	75	0.001	0.008	0.055	0.07 (short-term)	March 2021, Thames Walton (Affinity Water Intake)	49
Naphthalene	75	0.02	0.02	0.03	0.02	April and December 2021, Thames Hampton, Teddington and Walton (Thames Water Intake)	4
Dissolved nickel	75	0.5	1.8	3.2	4 (bioavailable)	July 2021, Thames Surbiton Intake	69
Nonylphenols (4-nonylphenol technical mix)	75	0.04	0.04	0.08	0.3	January 2021, Thames Teddington	69
Pendimethalin	75	0.02	0.02	0.1	0.3	January 2021, Thames Surbiton and Walton (Affinity Water Intake)	4
Pentachlorobenzene	75	0.007	0.0071	0.011	0.007	June 2021, Thames Walton (Affinity Water Intake)	2
Perfluorooctane sulfonic acid and its derivatives	75	0.003	0.006	0.01	0.00065	June 2021, Thames Surbiton	75
Permethrin	75	0.001	0.00105	0.002	0.001	May and August 2021, Thames Surbiton, Walton (Affinity Water Intake), Walton (Thames Water Intake)	75
Polycyclic aromatic hydrocarbons (PAH) sum	75	0.05	0.07	0.24	N/A	January 2021, Thames Teddington	N/A
Tetrachloroethane	75	0.1	0.26	1	140	February and March 2021, all sites	16
Toluene	75	0.1	0.23	1	74	February and March 2021, all sites	12
Tributyltin compounds (as tributyltin cation)	75	0.00002	0.002	0.11	0.0002	March 2021, Thames Hampton Intake	74
Trichlorobenzenes	75	0.4	0.5	1	0.4	February and March 2021, all sites	11
Dissolved zinc	75	0.5	7.6	74	12.9	September 2021, Thames Hampton Intake	74

The following shows which of those 40 chemicals have frequent and occasional exceedances of the standard within the data sets. ‘Occasional’ has been defined here as single occurrences throughout the data set up to five occurrences through-out the data set, while ‘frequent’ occurrences are numbered above this.

Frequent exceedances:

- 2,4-dichlorophenoxyacetic acid
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Dissolved Copper
- Dissolved zinc

Occasional exceedances:

- Benzo(k)fluoranthene
- Dissolved chromium (III)
- Total DDT
- Dicofol
- Hexachlorobenzene
- Pentachlorobenzene
- Tributyltin
- Trichlorobenzenes

The EQSD suite of chemical determinands for the freshwater River Thames was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 59 EQSD chemicals, 39 were found to be consistently below the LOD, leaving 20 determinands for analysis.

Table 2-8 shows a summary of those 20 chemicals.

Table 2-8 Summary of EQSD chemicals in the freshwater River Thames (2021 – 2022)

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Location and time of max	No >LOD
Bentazone	45	0.02	0.02	0.08	500	June 2021, Walton (Thames Water intake)	5
Total boron	60	35	41	55	2,000	July 2021, Walton (Thames Hampton intake and Thames Water intake)	60
Bromine total residual oxidant	30	50	110	250	2	January and July 2021, Walton (Thames Water intake)	21
Chloride	60	21,000	40,600	60,000	250,000	September 2021, Walton (Thames Water intake)	60
Dissolved cobalt	47	0.16	0.25	0.38	3	October 2021, Teddington	45
Dibutyl phthalate	30	0.02	0.04	0.17	8	April 2021, Walton (Thames Water intake)	8
Dichlorobenzene total isomers	30	0.1	0.25	1	20	January to March 2021, Walton (Thames Water intake) and Teddington	5
Diethyl phthalate	30	0.02	0.04	0.29	200	June 2021, Teddington	9
Dimethyl phthalate	30	0.02	0.03	0.1	800	January to March 2021, Walton (Thames Water intake) and Teddington	4
Dioctyl phthalate	30	0.02	0.02	0.03	20	April 2021, Walton (Thames Water intake)	1
Fluoride	60	110	150	170	500	No peak	60
Mancozeb	30	0.1	0.5	3.2	2	April 2021, Walton (Thames Water intake)	18
Maneb	30	0.1	0.2	0.5	3	September, October, December 2021, Teddington and Walton (Thames Water intake)	6
MCPA	45	0.02	0.02	0.03	80	May 2021, Teddington and June 2021, Hampton	2
Pirimicarb	32	1	1	1	1	Consistent across sites and dates	32
Propyzamide	60	0.01	0.02	0.11	100	December 2021, Walton (Thames Water intake) and Hampton	14

Determinand	No. of samples	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long Term)	Location and time of max	No >LOD
Styrene	30	0.01	0.22	1.00	50	February and March 2021, Walton (Thames Water intake) and Teddington	4
Sulphate	60	35,000	83,700	1,800,000	400,000	September 2021, Walton (Affinity Intake)	60
Total tin	30	0.4	0.5	1.3	25	September and October 2021, Teddington	4
Tributyl phosphate	30	0.02	0.03	0.09	50	September 2021, Teddington	6

2.5.4 Estuarine Thames Tideway

The following data sources have been used to establish the chemical reference conditions for the estuarine Thames Tideway:

- HR Wallingford's Upper Tideway model

Data and analysis for chemical parameters for the estuarine Thames Tideway reach can be found in the following sections:

- Water quality assessment of Beckton water recycling scheme – WFD chemicals – Estuarine Thames Tideway, Section 3.5.3,
- Water quality assessment of Mogden water recycling scheme – WFD chemicals – Estuarine Thames Tideway, Section 4.5.3,
- Water quality assessment of Teddington DRA scheme – WFD chemicals – Estuarine Thames Tideway, Section 5.5.3.

2.6 OLFACTORY WATER QUALITY

2.6.1 Overview

This section sets out the reference conditions for the olfactory water quality for the following water courses in the study area:

- Freshwater Lee Diversion Channel – Section 2.6.2
- Freshwater River Thames – Section 2.6.3
- Estuarine Thames Tideway – Section 2.6.4

Olfactory cues play an important role in the behavioural ecology of many fish species governing their navigation, predator avoidance, social dynamics, prey detection and homing in migratory species. The presence of chemical olfactory inhibitors (as well as other factors) has been shown to increasingly impact the success of migratory species by limiting their ability to access watercourses as a result of their influence on migratory cues, natal stream imprinting and navigation. A list of all chemicals in the olfactory suite is in Appendix 2 for reference. Olfactory inhibitors in the Thames are likely not typical of an estuary and are likely to be higher given the significant pressure in the lower Thames catchment. Further detail around olfactory inhibitors are outlines in the London Effluent Reuse SRO Olfactory Technical note.

In relation to the London Effluent Reuse SRO there is the potential to influence diadromous fish species migration via:

1. The weakening of olfactory cues into the River Thames at Teddington due to changes in the composition of the pass-forward flow.
2. The potential that olfactory inhibitors present within the Mogden STW effluent at Isleworth Ait may become more concentrated.
3. The potential that olfactory inhibitors may be discharged into the lowest freshwater River Thames through a DRA outfall which then extends the zone of inhibitor accumulation to Teddington Weir.

A combination of all the above coupled with environmental parameters such as river flow, temperature and dissolved oxygen may influence the olfactory cues of diadromous fish.

The evidence available, the general patterns observed in the data and any notable pressures will be outlined for each of these reaches. The freshwater Lee Diversion Channel is only considered to be affected by changing olfactory cues due to the presence of European Eel within the reach.

2.6.2 Freshwater Lee Diversion Channel

It is noted that olfaction was not scoped into the Gate 2 assessment of the River Lee study area therefore the full monitoring suite is not available in Gate 2. Where there are overlaps between the olfactory inhibitor suite (as reviewed by the Environment Agency) and either the WFD, EQSD or DWSP monitoring suites undertaken in the Enfield Island Loop as part of the Pan-SRO monitoring programme these have been reported below.

This section draws on the following data source to establish the olfactory inhibitors reference conditions for the freshwater Lee:

- Thames Water WFD, EQSD analytical suites – Spot sample data (January 2021 – February 2022) at one site: Enfield Island Loop included as part of the Pan-SRO monitoring programme

Data for olfactory inhibitors for the freshwater Lee reach can be found in the annex report. Detailed analysis can be found in the accompanying Evidence Report.

The olfaction suite of chemical determinands for the Freshwater Lee Diversion Channel was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD will not be presented or analysed further.

Of the 53 determinands in the olfactory suite, 27 were found to be consistently below the LOD, leaving 26 determinands for analysis.

Metals (total and dissolved) generally had monthly monitoring across the period. It is observed that, dissolved chromium and cadmium concentrations were typically at or below LOD with occasional higher readings, with more variability in total concentrations. Whereas variability in the measured data was observed for the other monitored metal species, such as cobalt, iron and selenium, with cobalt and iron showing a slight seasonal trend of higher concentrations observed in winter months. Iron (total) also had elevated concentrations in May 2021, and (dissolved) in October 2021, while selenium (dissolved and total) showed elevated concentrations during February and March 2021. Copper and chromium (dissolved and total) had a notably strong seasonal trend, peaking in late summer. Copper showed a small spike in concentrations in May 2021. Aluminium (total) also shows a seasonal trend with elevated concentrations from December to February, though dissolved aluminium is relatively consistent in concentrations. A spike is observed in May 2021. Mercury concentrations were elevated from March to May 2021. Dissolved zinc showed a seasonal trend with observed concentration increasing in October 2021. Total zinc concentrations were very variable. Dissolved and total nickel show a seasonal trend, with occasional lower measured concentrations observed in the dissolved fraction.

Permethrin was elevated above LOD during February 2021. While concentrations of pirimicarb remained consistent throughout the monitoring period recording values of 1 μg/l. Isoproturon was elevated above the LOD during February and March 2021, before returning to LOD measurement values for the rest of the monitoring period.

2.6.3 Freshwater River Thames

The following data sources have been used to establish the olfactory inhibitors reference conditions for the freshwater Thames:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (January 2021 – February 2022) at six sites: Hampton intake, Surbiton intake, Kingston, Teddington, Walton (Thames Water intake) and Walton (Affinity Water intake)

The olfaction suite of chemical determinands for the freshwater River Thames was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 53 determinands in the olfactory suite, 27 were found to be consistently below the LOD, leaving 26 determinands for analysis. It should be noted that data availability is not consistent across those determinands at all sites and dates.

1,6-hexanediamine and benzalkonium chlorides (as BAC10, 12, 14 & 16) only have two data points available across the monitoring period, both determinands were consistent in their measured concentrations across monitored sites.

Metals (total and dissolved) generally had monthly monitoring across the period though not all sites have available data on every metal. It is observed that, dissolved chromium and cadmium concentrations were typically at or below LOD with occasional higher readings, whereas variability in the measured data was observed for the other monitored metal species, such as cobalt, iron and selenium. Copper (dissolved and total) had a notably strong seasonal trend, peaking in late summer, though variation between monitored sites was small. Aluminium (dissolved and total) also shows a seasonal trend with elevated concentrations from December to February observed at all sites. The highest concentrations were frequently observed at Teddington, indicating a pressure in that area. Zinc showed a similar concentration increase in September 2021 where a concentration of 74 µg/l was observed at the Surbiton intake, though similar, but smaller increases were also observed at Teddington and Walton (Thames Water intake) at this time. Dissolved nickel shows a seasonal trend, however this is not observed in total nickel, which typically remains steady at ~1.1 µg/l with a spike at Surbiton in September 2021, though this may be anomalous due to it being significantly higher than the other concentrations.

Chlorpyrifos (chlorpyrifos-ethyl) measurements returned values that did not exceed LOD other than a single measurement taken in May 2021 at Walton (Thames Water intake). This site also had concentrations of permethrin elevated above LOD during March and May 2021. While concentrations of pirimicarb remained consistent throughout the monitoring period with all monitored sites recording values of 1 µg/l.

2.6.4 Estuarine Thames Tideway

The following data sources were used to establish the olfactory inhibitors supporting information for the freshwater River Thames:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (January 2021 – February 2022) at one site: Kew Bridge

The olfaction suite of chemical determinands for the estuarine Thames Tideway was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 53 determinands in the olfactory suite, 29 were found to be consistently below the LOD, with two determinands having no available data, leaving 24 determinands for analysis.

1,6-hexanediamine and benzalkonium chlorides (as BAC10, 12, 14 & 16) only have two data points available across the monitoring period in November and December 2021, with the November value being elevated above December for 1,6-hexanediamine and data values being consistent in their measured concentrations for benzalkonium chlorides (as BAC10, 12, 14 & 16).

Metals (total and dissolved) generally had monthly monitoring across the period. It is observed that dissolved chromium (III) concentrations were typically at or below LOD with occasional higher readings, whereas variability in the measured data was observed for the other monitored metal species, such as cadmium, chromium and iron (total and dissolved). Dissolved chromium shows a brief peak in March 2021, this is mirrored in total chromium as well. Total cadmium had observed elevated concentrations during January and May 2021. Copper, (dissolved and total) in particular, had a strong seasonal trend, peaking in late summer, with a spike in total concentrations seen in January 2021. Iron (total and dissolved) showed higher concentrations at the start of the monitoring period. Aluminium (total) and both dissolved and total cobalt and selenium had a single data value in November 2021. Dissolved mercury concentrations showed a brief increase during March 2021, also seen in the total mercury data set. Both total and dissolved zinc datasets showed highly variable concentrations across the monitoring period. Dissolved nickel shows a seasonal trend; however, this is less pronounced in total nickel, which shows a significant decrease in concentration during June 2021 before a sharp increase in July 2021.

Permethrin was elevated above LOD during January and May 2021. While the two measured concentrations of primicarb remained consistent throughout the monitoring period recording values of 1 µg/l.

2.7 RICHMOND POUND DRAWDOWN WATER QUALITY

2.7.2 Overview

The Richmond Pound reach of the estuarine Thames Tideway begins at Teddington Weir and travels northwards seawards to Richmond Half-tide sluice.

Baseline data for the Richmond Pound was modelled as part of the Richmond pound assessment by HR Wallingford and presented below in Section 4.7.

Salinity

The modelled baseline data indicate that there is an increase in salinity from ~0 ppt to <3 ppt between approx. 1.5km to >20km seawards of Teddington Weir, with ranges from 0 ppt to <1 ppt during November during the A82 scenario, this increases slightly to <5 ppt under the M96 scenario.

Suspended sediment

The modelled data indicate that there is a decrease in suspended sediment from ~0.3 kg/m^3 to <0.1 kg/m^3 scenario compared with baseline from approx. 0.2 km to >20km seawards of Teddington Weir, with ranges from 0-<0.5 kg/m^3 during November during the A82 scenario, this decreases slightly to <0.5 kg/m^3 under the M96 scenario.

Dissolved oxygen

The modelled data indicate that there is a decrease in dissolved oxygen from 11 mg/l to 7 mg/l from approx. 6.5km (just seawards of Mogden STW outfall) to 16km seawards of Teddington Weir. This increases from 11.5 mg/l to ~9.2 mg/l under the M96 scenario.

Temperature

The modelled data indicate that temperature is steady at between 9°C and 9.5°C under the A82 scenario from approx. 1km - 20km seawards of Teddington Weir, increasing during November to between 11 and 14°C. This decreases during the M96 scenario to between 9 and 12°C.

3. WATER QUALITY ASSESSMENT OF BECKTON WATER RECYCLING SCHEMES

3.1 INTRODUCTION

This section sets out the assessment for the tasks set out in Table 1-1 relevant to the Beckton water recycling scheme. The study area for each task has been set out per task as it is not consistent across tasks. A conceptualisation of the key water quality issues of the scheme is presented in Figure 3-1. The Beckton water recycling scheme assessment for each of the following tasks has been set out in the following sections:

- Beckton water recycling scheme's AWRP discharge quality– Section 3.2
- Water temperature – Section 3.3
- General physico-chemical – Section 3.4
- WFD chemicals – Section 3.5
- Olfactory water quality – Section 3.6
- Richmond Pound drawdown water quality – Section 3.7

The data used for undertaking the assessments has been outlined in the Gate 2 Water Quality Annex Report and in Table 1-1.

The assessments have been undertaken for the following for each task:

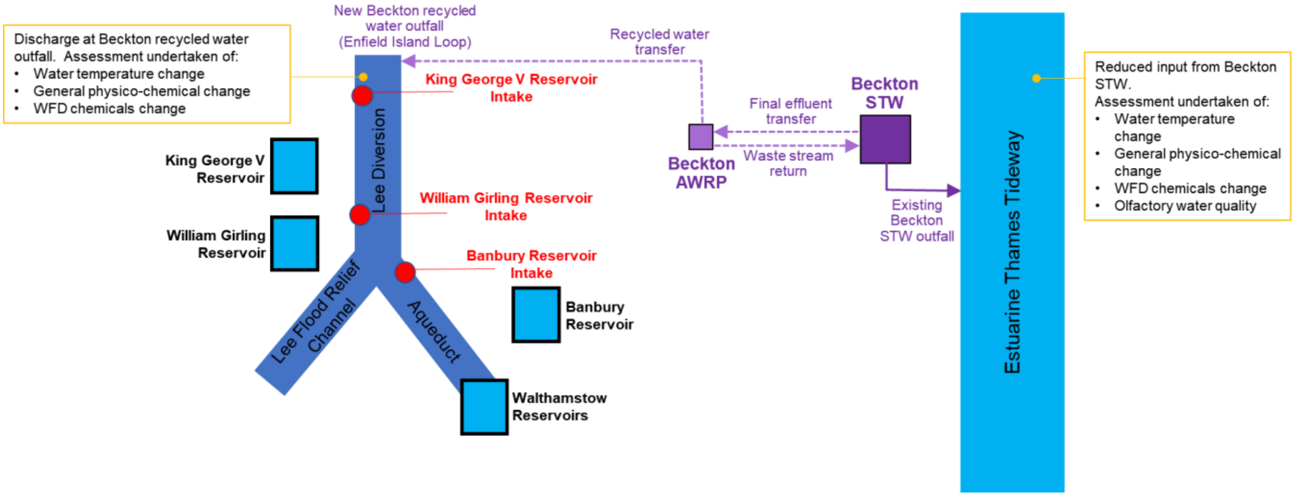
- Source water of Beckton STW final effluent including effluent temperature, general physico-chemical parameters, and effluent chemicals, including olfactory inhibitors.
- Water temperature across the estuarine Thames Tideway and freshwater Lee Diversion Channel.
- WFD physico-chemical supporting elements to ecological status, including dissolved oxygen saturation, total ammonia, reactive phosphorus, water temperature, pH and BOD across the estuarine Thames Tideway and freshwater Lee Diversion Channel.
- WFD chemical suite across the estuarine Thames Tideway and freshwater Lee Diversion Channel.

Bespoke modelling datasets with parameterised reference conditions (see section 2) were reviewed to determine the extent of variability with site or seasonality from the reference conditions with the Beckton water recycling scheme in operation. This provided the range and variability of water qualities across the range of monitored sites. The modelling data sets examined are as follows:

- Spreadsheet stochastic modelling of the Enfield Island Loop undertaken by Ricardo,
- Telemac modelling of the Thames Tideway undertaken by HR Wallingford,

Where text makes reference to A82 and M96 flow series, respectively these refer to 1 in 5 year and 1 in 20-year flow events respectively.

Figure 3-1 Schematic for Beckton Water Recycling Scheme



3.2 BECKTON AWRP DISCHARGE QUALITY

3.2.1 Overview

This section sets out the supplementary information for the source water (effluent) parameters for Beckton STW used in the environmental assessments.

- Recycled water temperature - Section 3.2.2
- Recycled water general physico-chemical parameters - Section 3.2.3
- Langelier Saturation Index – Section 3.2.4
- Recycled water chemical quality - Section 3.2.5
- Environmental fate of chemicals reduced during AWRP treatment – Section 3.2.6

As set out in the Gate 2 Conceptual Design Report[10] for a Beckton water recycling scheme, the source water of Beckton STW final effluent would be subject to advanced treatment in an AWRP. The AWRP would include the following water treatment processes: reverse osmosis, UV advanced oxidation process (includes peroxide dosing) and remineralisation. To support the environmental assessments at Gate 2, an indicative operating pattern has been developed, as described in the B.2.1. Gate 2 Physical Environment assessment. Outside the normal operating pattern the Gate 2 engineering design includes a 15 Ml/d tunnel maintenance flow, with the recycled water being discharged to the Enfield Island Loop of the Lee Diversion Channel. A tunnel maintenance flow would not be discharged to the Enfield Island Loop at times of flood risk in the Lower Lee.

3.2.2 Recycled water temperature

The effect of the AWRP on the water temperature of the recycled water of the Beckton water recycling Scheme is currently not well understood but is not expected to lead to significant differences across the reverse osmosis membranes. For the Beckton water recycling scheme the 22.3km transmission pathway and thus the time of travel in the tunnel is considered to have an over-riding influence on discharged temperature. As such the ground temperature for a local reference point from the CEDA MIDAS soil temperature network has been used to represent the discharge temperature.

3.2.3 Recycled water general physico-chemical water quality

The recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. Reverse osmosis (RO) is a type of filtration method used for the removal of molecules and ions from solution. As a result, the recycled water is effectively deionised and therefore an in-river assessment approach

[10] Jacobs (2022) Beckton water recycling SRO: Conceptual Design Report.

has been adopted to determine and describe the change of the WFD physico-chemical supporting elements to ecological status.

As set out in Gate 2 Conceptual Design Report, the AWRP source water and recycled water quality are as presented in Table 3-1. In addition, for in-river modelling purposes, an indicative value of 11.0 mg/l dissolved oxygen has been used at all times, noting the inclusion of a hydrogen peroxide dosing unit as part of the Gate 2 AWRP design. It is noted that the remineralisation design at present is to ensure corrosivity indices for conveyance are complied with and do not represent the end-point of design for environmental discharge.

Table 3-1 Beckton water recycling scheme AWRP source water and process water quality

Parameter (showing mean value)	Source water (Beckton STW final effluent)	Recycled water for river discharge
pH	7.6	8.4
Total Ammonia	0.5 mgN/l	Trace
Phosphorus	13.5 mg/l	0.04 mg/l
BOD	5.5 mg/l	Trace
Suspended solids	34.0 mg/l	0.07 mg/l
Alkalinity ($CaCO_3$)	240 mg/l	60 mg/l

pH

The data was not available to model the pH changes in the freshwater Lee Diversion Channel, at Enfield Island Loop.

Hardness

The RO water, as an additional treatment process, also undergoes remineralisation. The Gate 2 estimate for remineralisation is 60 mg $CaCO_3$ mg/l. However, it is considered that this estimate should be revised to provide a target which meets the environmental needs described in the reference conditions and below.

3.2.4 Langelier Saturation Index

The Langelier Saturation Index (LSI) is a measure of how saturated the water is with calcium carbonate ($CaCO_3$). Perfect saturation is 0.00 LSI, with an acceptable range considered to be between -0.30 to +0.30 LSI. At < -0.31 water is under-saturated with $CaCO_3$ and will dissolve calcium from available sources, while at > +0.31, the water begins to precipitate $CaCO_3$ out. As described above, following treatment, the RO water will require remineralisation treatment to address the LSI of the water, the below displays an assessment to establish recycled water determinand targets to maintain both the pipes and environmental needs.

For the freshwater Lee Diversion Channel at Enfield Island Loop, an LSI of zero is not achievable with the suggested values in Table 3-2. The measured river water values produce an LSI of 1.53 meaning that limescale build-up will occur in the pipes. The minimum LSI achievable at this location whilst staying within the target range is 0.53 however this requires a drop in water temperature from 13˚c to 0˚c, which is not feasible. The suggested values are within the target range for the river whilst providing the lowest LSI possible. The chosen temperature is within one standard deviation of the mean within the annual recorded temperatures. The suggested values provide an LSI of 0.83 which would indicate limescale build-up however as the bottom of the waterway is paved in concrete, a negative and therefore corrosive value would not be advisable.

Table 3-2 LSI suggested target values for Beckton water recycling scheme discharge the freshwater Lee Diversion Channel at Enfield Island Loop

Parameter	Measured in river value	Target range	Suggested values
pH	8.03	7.83-8.59	7.83
Temperature (°C)	13	<25	9
Ca hardness (mg/l)	118	75-125	77

Parameter	Measured in river value	Target range	Suggested values
Total alkalinity ($CaCO_3$ mg/l)	215	115-245	215
TDS (mg/l)	11	<25	11

3.2.5 Recycled water chemical quality

As described above, the recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of WFD chemicals.

The AWRP processes will return all treated water to Beckton STW as liquid waste. This will affect the concentration of chemicals in the final effluent of Beckton STW discharged to the Thames Tideway. Using measured data from Beckton STW final effluent, 'reconcentration' calculations were performed for each determinand within the WFD and EQSD suites. These values have been used in dispersion modelling of the Beckton STW final effluent plume in the Thames Tideway.

3.2.6 Environmental fate of chemicals reduced during reuse treatment

The fate of organic compounds during water treatment is determined by a combination of their physico-chemical properties and the treatment operation parameters and design of the process and their fate is typically down to biodegradation. Synthetic compounds are removed from waste streams during wastewater treatment either by biological or chemical degradation, sorption to the solid phase or volatilisation. Pharmaceuticals are not likely to adsorb to sludge and their removal mostly occurs as a result of degradation, while metals are typically removed via sorption and transport.

Most synthetic chemicals are either not susceptible to volatilisation or have a low tendency to volatilise, however, those which are volatile may volatilise at a faster rate due to the proposed temperature increases. Synthetic chemicals with a tendency to adsorb will likely be retained within the sewage sludge, a mechanism which is not expected to alter with the scheme. However, chemicals such as Perfluorooctanesulfonic acid (PFOS) do not adsorb and are likely to remain within the water column increasing its distance of transportation. A few synthetic chemicals (e.g. PFOS) have no known degradation process; the only dissipation mechanisms in water are dilution, advection, and sorption. Nonylphenols are known to persist in sludge and water posing a greater threat to the environment. Several synthetic chemicals have the potential to bioaccumulate, increasing risk of adverse health reactions in the food chain.

The behaviour of metals in the environment depends upon factors including pH, temperature, and the microorganisms present, however, most metals adsorb to sediment particles where they may remain long term. Some metals may interact with key nutrients within the water and sediment such as aluminium (Al) and iron (Fe) which have the potential to transiently bind phosphorus, retaining the nutrient within the sediment. However, changing water conditions (for example a decrease in redox conditions and an increase water temperature) can result in the release of phosphorus and aluminium/iron to the water, potentially leading to water quality deterioration through fuelling phytoplankton development.

It is therefore considered that the environmental fate of most chemicals will not change during scheme operation on, though there may be an increase in the rate of volatilisation and a release of adsorbed particles with water temperature increases.

3.3 WATER TEMPERATURE

3.3.1 Overview

This section outlines the water temperature change associated with a Beckton water recycling scheme. Assessments undertaken include:

- Temperature change in the freshwater River Lee Diversion Channel – Section 3.3.2
- Temperature change in the estuarine Thames Tideway – Section 3.3.3

3.3.2 Freshwater Lee Diversion Channel, at Enfield Island Loop

An assessment of the water temperature impacts as a result of the Beckton water recycling recycled water discharge into the freshwater Lee Diversion Channel has been undertaken for the three sizes of the Beckton water recycling scheme. Water temperature data for the recycled water discharge was derived using local soil temperature data[11] to incorporate the effect on recycled water temperature during conveyance. Using the tunnel dimensions for Gate 2, the conveyance time would be 17 hours for a 300 Ml/d transfer rate; 25 hours for a 200Ml/d transfer rate; 51 hours for a 100 Ml/d transfer rate; and 14 days for a 15 Ml/d tunnel maintenance flow transfer rate. A 5th order polynomial using the 100cm soil temperature daily measurement from the High Beach (Essex) site for years between 2013-2020 was used to estimate a daily representation of the recycled water discharge temperature (R^2 of 96%). Compared to the years-worth of measured sonde water temperature data in the freshwater Lee Diversion Channel there are three occasions where the recycled water temperature is greater than the in-channel temperature by more than 3°C, a four-day period in early November, a 16-day period between late November to mid-December and a two-day period in mid-February. The greatest increase in recycled water temperature compared to the in-channel water temperature data was 5.2°C, achieved on 29/11/2021. There are also periods throughout the year, notably in June and July, where the in-channel water temperature was greater than the recycled water temperature by more than 3°C.

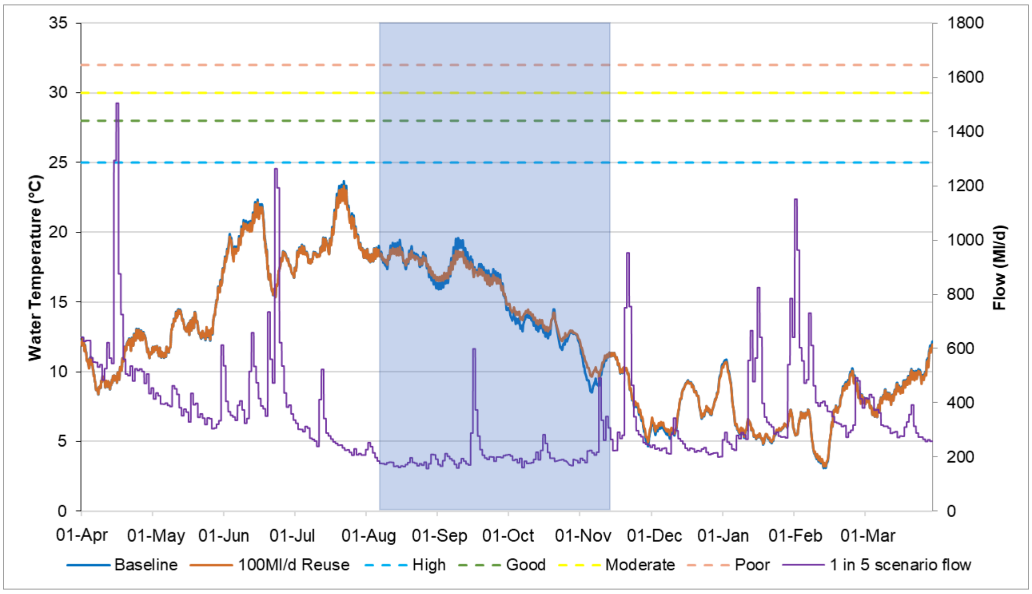
A simple fixed (single) point deterministic spreadsheet model has been used to represent the impact of the recycled water discharge on the in-channel water temperature downstream of the outfall after the discharged recycled water has been fully mixed with the in-channel water.

<u>100 Ml/d Beckton water recycling scheme</u>

Figure 3-2 demonstrates the results from the modelling of the river water temperature for the Beckton water recycling scheme at 100 Ml/d downstream of the Beckton water recycling outfall. Generally, when the Beckton water recycling scheme is in operation the variation in the water temperature is smoothed with any peaks and troughs being reduced across both scenarios. The water temperature when the scheme is on is within the ranges experienced in the baseline. Over the annual period, the 98th percentile for the 1 in 5-year (A82) scenario reduced by 0.2°C to 21.5°C and in the 1 in 20 (M96) scenario the 98th percentile was reduced by 1.1°C to 20.6°C, well within the High WFD status threshold. As a result, there would not be deterioration in water temperature status as a result of a 100 Ml/d Beckton water recycling scheme.

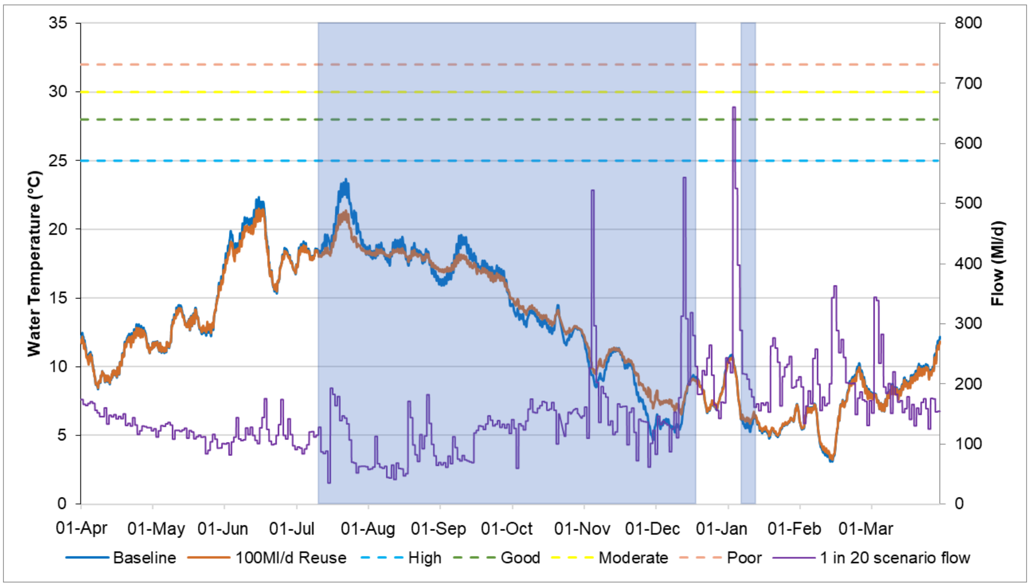
Figure 3-2 River water temperature downstream of the Beckton water recycling outfall. Graphs display the baseline water temperature compared to the modelled water temperature in a 100 Ml/d Beckton water recycling scenario. The WFD status bands as a 98th percentile are indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario



[11] Met Office (2019): MIDAS Open: UK soil temperature data, v201908. Centre for Environmental Data Analysis, *30 October 2019*.

1 in 20-year flow scenario

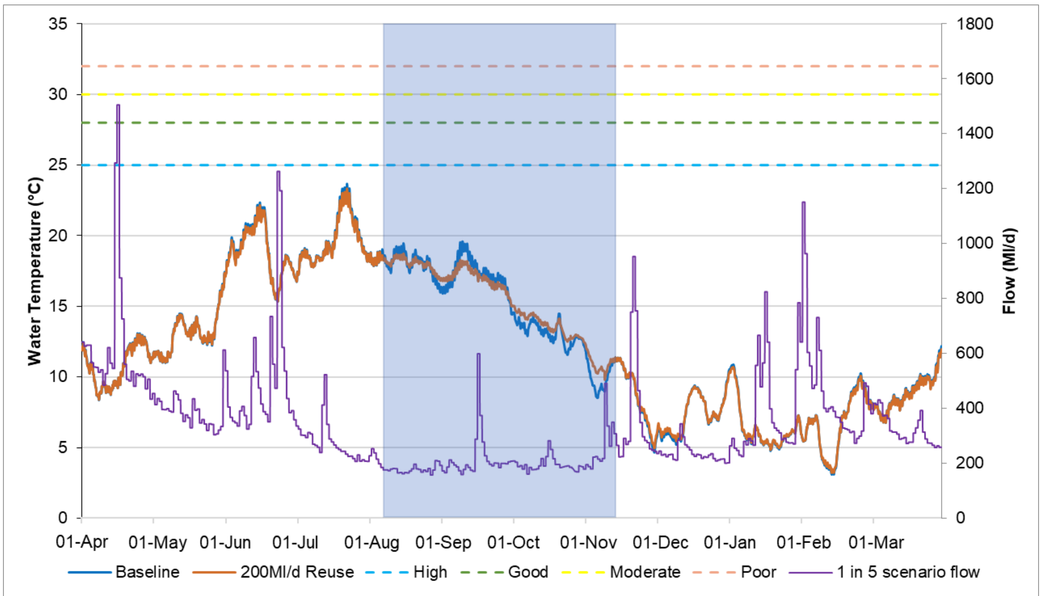


200 Ml/d Beckton water recycling scheme

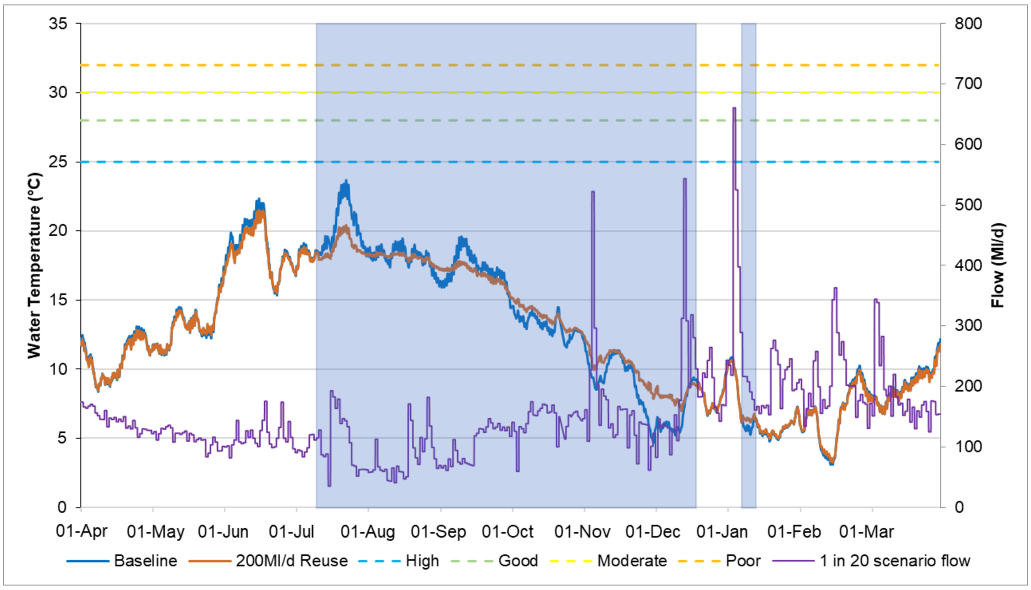
Figure 3-3 demonstrates the results from the modelling of the river water temperature for the 200 Ml/d Beckton water recycling scheme downstream of the Beckton water recycling outfall. Similar to the 100 Ml/d scheme, when the 200 Ml/d Beckton water recycling scheme is in operation the variation in the water temperature is smoothed with any peaks and troughs being reduced across both scenarios. This smoothing is more pronounced in the 200 Ml/d scheme compared to the 100 Ml/d scheme. The water temperature when the scheme is on is within the ranges experienced in the baseline. Over the annual period, the 98th percentile for the 1 in 5-year (A82) scenario reduced by 0.2°C to 21.5°C and in the 1 in 20 (M96) scenario the 98th percentile was reduced by 1.5°C to 20.1°C, well within the High WFD status threshold. As a result, there would not be deterioration in water temperature status as a result of a 200 Ml/d Beckton water recycling scheme.

Figure 3-3 River water temperature downstream of the Beckton water recycling outfall. Graphs display the baseline water temperature compared to the modelled water temperature in a 200 Ml/d Beckton water recycling scenario. The WFD status bands as a 98th percentile are indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario



1 in 20-year flow scenario

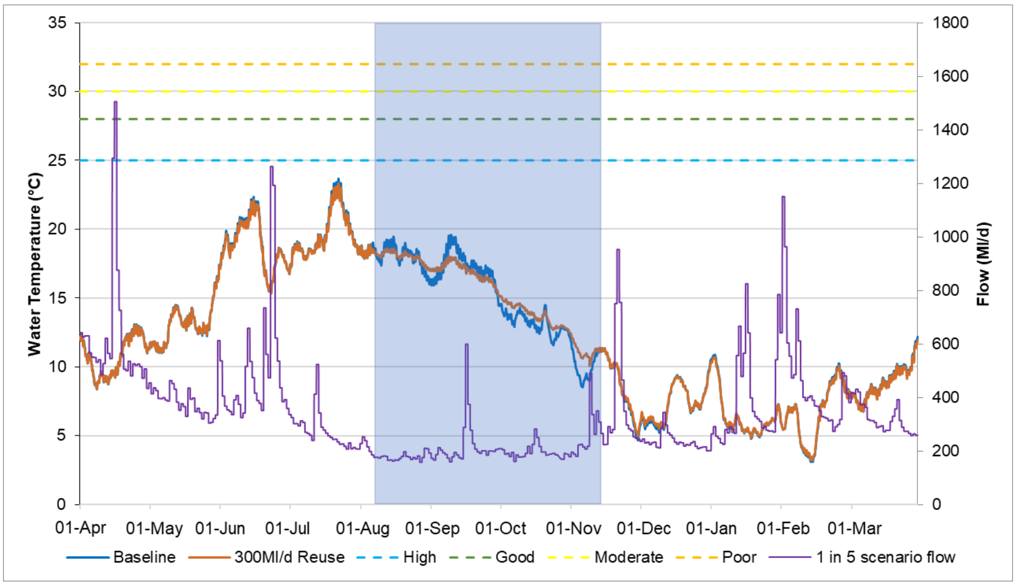


300 Ml/d Beckton water recycling scheme

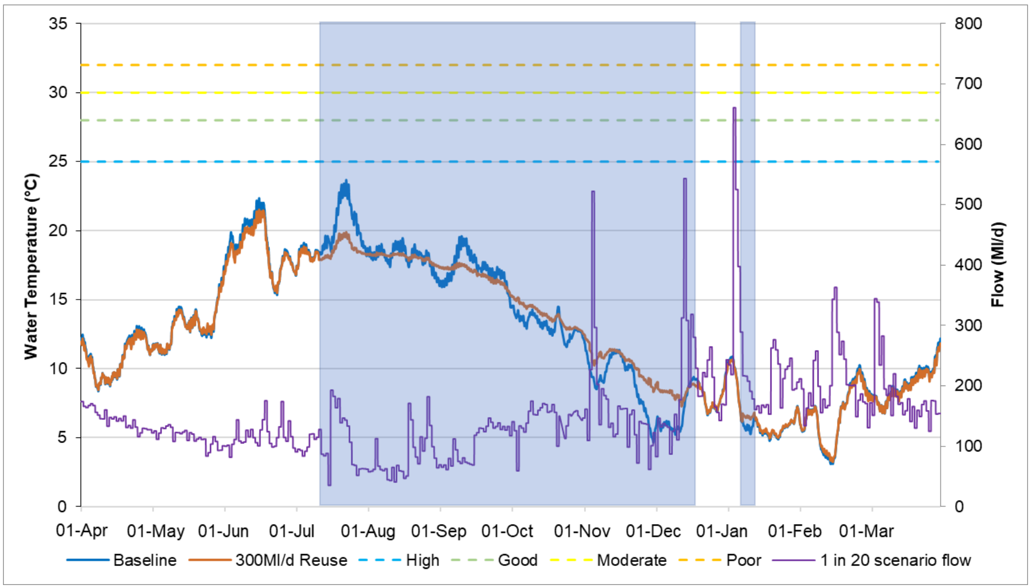
Figure 3-4 demonstrates the results from the modelling of the river water temperature for the 300 Ml/d Beckton water recycling scheme downstream of the Beckton water recycling outfall. Similar to the 100 Ml/d and 200 Ml/d sized scheme, when the 300 Ml/d Beckton water recycling scheme is in operation, the variation in the water temperature is smoothed with any peaks and troughs being reduced across both scenarios. This smoothing is more pronounced in the 300 Ml/d scheme compared to the smaller schemes. The water temperature when the scheme is on is within the ranges experienced in the baseline. Over the annual period, the 98th percentile for the 1 in 5-year (A82) scenario reduced by 0.2°C to 21.5°C and in the 1 in 20 (M96) scenario the 98th percentile was reduced by 1.7°C to 20.0°C, well within the High WFD status threshold. As a result, there would not be deterioration in water temperature status as a result of a 300 Ml/d Beckton water recycling scheme.

Figure 3-4 River water temperature downstream of the Beckton water recycling outfall. Graphs display the baseline water temperature compared to the modelled water temperature in a 300 Ml/d Beckton water recycling scenario. The WFD status bands as a 98th percentile are indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario



1 in 20-year flow scenario



3.3.3 Estuarine Thames Tideway

As the Beckton water recycling scheme will result in a reduction of the final effluent discharge to the Thames tideway, water temperature in the middle Thames Tideway would not change due to the small proportionality of the Beckton STW final effluent discharge compared to the middle Thames Tideway. As such water temperature has not been included in the modelling suite for the 2D/3D Telemac modelling for the Beckton water recycling scheme.

3.4 GENERAL PHYSICO-CHEMICAL

3.4.1 Overview

This section sets out the change for the general physico-chemical parameters associated with the Beckton water recycling scheme. Assessments undertaken include:

- Freshwater Lee Diversion Channel - Section 3.4.2
- Estuarine Thames Tideway - Section 3.4.3

The evidence available, the general patterns observed in the data and any particular pressures are outlined for each of these reaches.

3.4.2 Freshwater Lee Diversion Channel, at Enfield Island Loop

An assessment of the impacts on the general physico-chemical status elements as a result of the recycled water discharge into the freshwater Lee Diversion Channel has been undertaken for the three sizes of Beckton water recycling scheme. Using the measured sonde and spot sampling data, this section uses a simple fixed (single) point deterministic spreadsheet model to represent the impact of the recycled water discharge on the dissolved oxygen saturation, ammonia and phosphate water quality elements downstream of the outfall after the discharged recycled water has been fully mixed with the in-channel water. Note that 'scheme on' is referring to the period of effluent reduction at the existing discharge and the discharge (at scheme size) of reverse osmosis water at the proposed outfall. 'Scheme off' refers to other periods, with a 15 Ml/d tunnel maintenance flow discharge to the Enfield Island Loop.

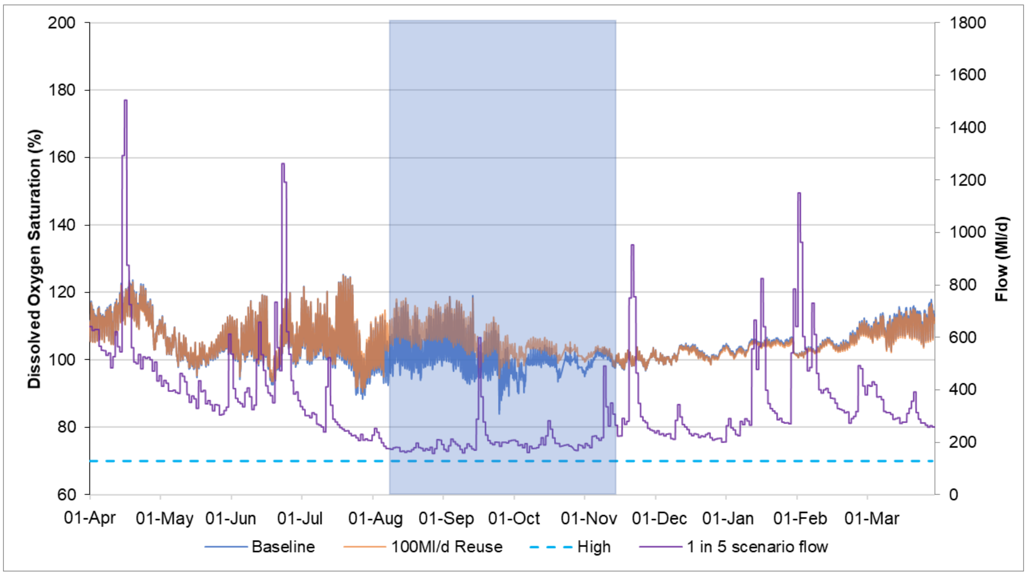
Dissolved Oxygen Saturation

100 Ml/d Beckton water recycling scheme

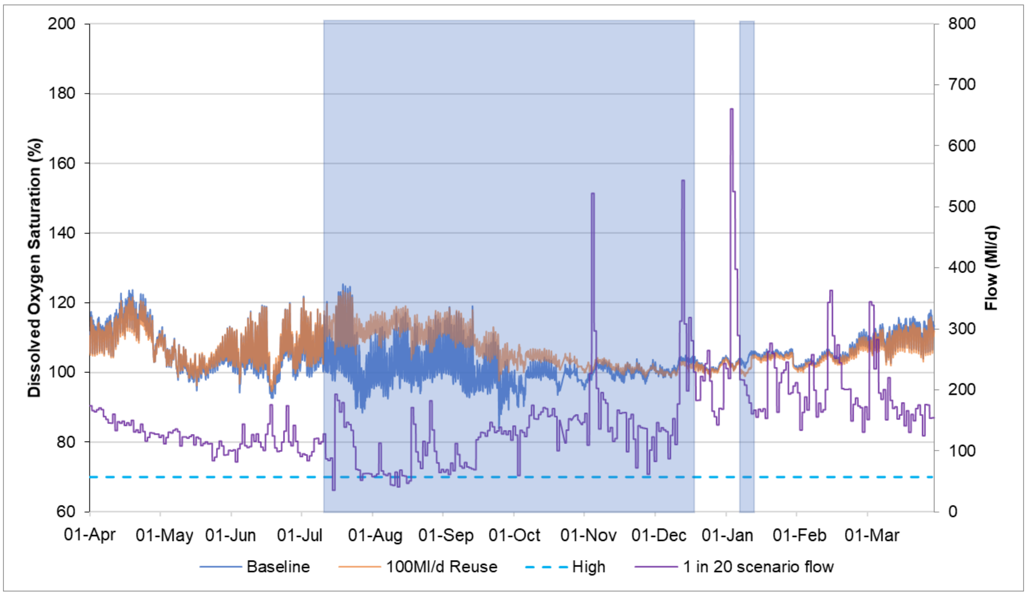
Figure 3-5 displays the results from the modelling of the dissolved oxygen saturation for a 100 Ml/d Beckton water recycling scheme. For modelling purposes this has included a discharge concentration of 11 mg/l dissolved oxygen, noting that the AWRP includes a hydrogen peroxide dosing unit. Generally, when the scheme is not on (i.e. just discharging a maintenance flow), the 100 Ml/d Beckton water recycling scenario tracks the baseline scenario closely .When the scheme is on, in both the 1 in 5 (A82) and 1 in 20 (M96) flow scenarios, the diurnal variation in the dissolved oxygen saturation is reduced. There is also a general increase in dissolved oxygen saturation throughout the on period though the 10th percentile across the annual period for the 1 in 5 (A82) scenario remains unchanged at 113.1%. the 10th percentile over the annual period in the 1 in 20 (M96) scenario increases from 113.1% to 114.0%. As a result, there would not be deterioration in the high dissolved oxygen saturation WFD status associated with the 100 Ml/d Beckton water recycling scheme.

Figure 3-5 Dissolved oxygen saturation downstream of the Beckton water recycling outfall. Graphs display the baseline dissolved oxygen saturation compared to the modelled dissolved oxygen saturation in a 100 Ml/d Beckton water recycling scenario. The WFD high status band as a 10th percentile is indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario



1 in 20-year flow scenario

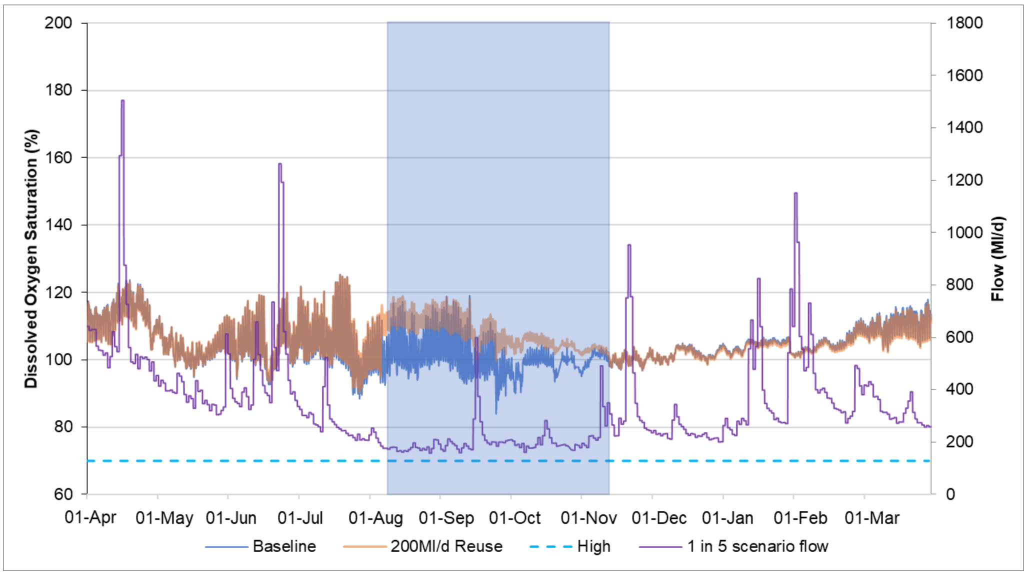


<u>200 Ml/d Beckton water recycling scheme</u>

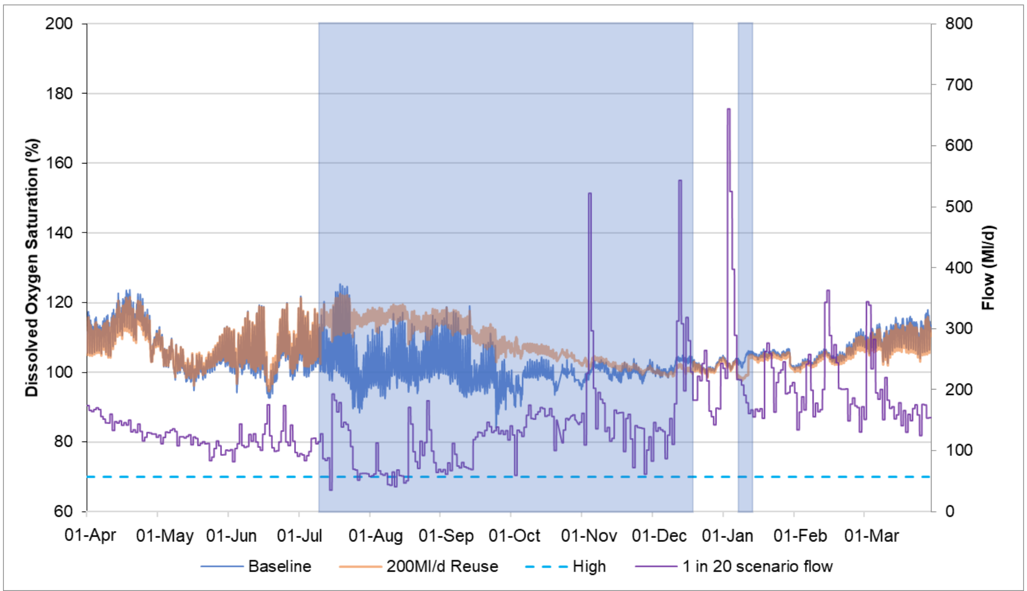
Figure 3-6 displays the results from the modelling of the dissolved oxygen saturation for a 200 Ml/d Beckton water recycling scheme. For modelling purposes this has included a discharge concentration of 11 mg/l dissolved oxygen, noting that the AWRP includes a hydrogen peroxide dosing unit. As with the 100 Ml/d scheme, when the scheme is not on (i.e. just discharging a maintenance flow), the 100 Ml/d reuse scenario tracks the baseline scenario. When the scheme is on, in both the 1 in 5 (A82) and 1 in 20 (M96) flow scenarios, the diurnal variation in the dissolved oxygen saturation is reduced to a greater extent than it is by the 100 Ml/d scheme. There is also a general increase in dissolved oxygen saturation throughout the on period leading to an increase in the annual 10th percentile in the 1 in 5 (A82) scenario from 113.1% to 113.6% and the annual 10th percentile in the 1 in 20 (M96) scenario increasing from 113.1% to 115.5%. As a result, there would not be deterioration in the high dissolved oxygen saturation WFD status associated with the 200 Ml/d Beckton water recycling scheme.

Figure 3-6 Dissolved oxygen saturation downstream of the Beckton water recycling outfall. Graphs display the baseline dissolved oxygen saturation compared to the modelled dissolved oxygen saturation in a 200 Ml/d Beckton water recycling scenario. The WFD high status band as a 10thth percentile is indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario



1 in 20-year flow scenario

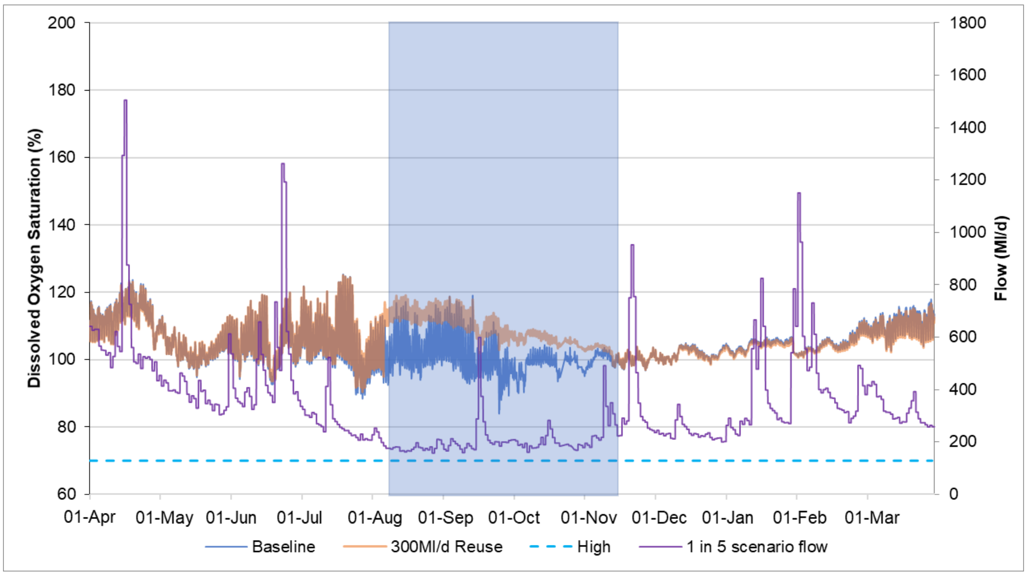


300 Ml/d Beckton water recycling scheme

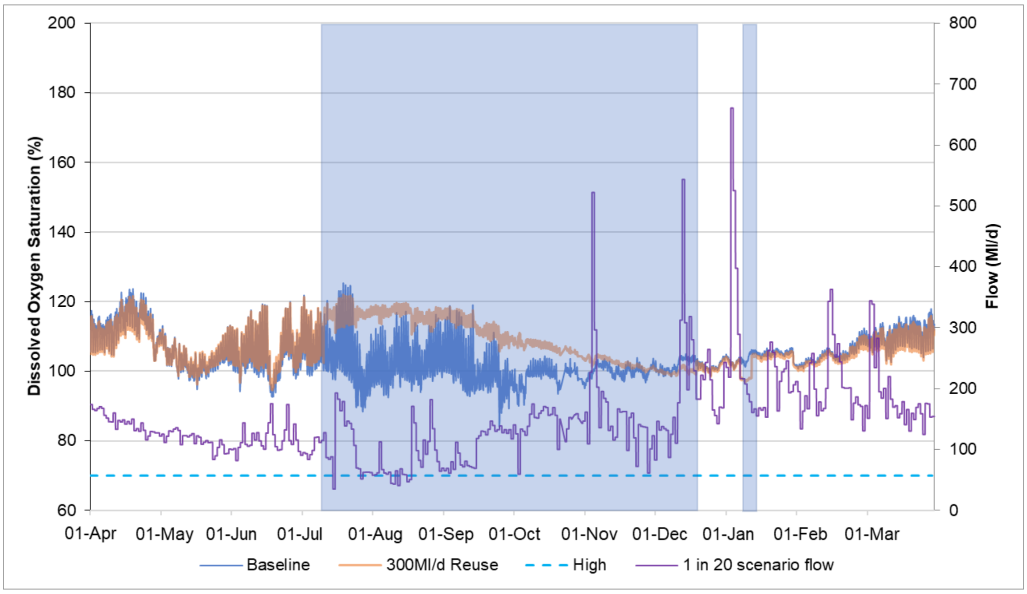
Figure 3-7 displays the results from the modelling of the dissolved oxygen saturation for a 300 Ml/d Beckton water recycling scheme. For modelling purposes this has included a discharge concentration of 11 mg/l dissolved oxygen, noting that the AWRP includes a hydrogen peroxide dosing unit. As with the smaller versions of the Beckton water recycling scheme, when the scheme is not on (i.e. just discharging a maintenance flow), the 300 Ml/d Beckton water recycling scenario tracks the baseline scenario closely. When the scheme is on, in both the 1 in 5 (A82) and 1 in 20 (M96) flow scenarios, the diurnal variation in the dissolved oxygen saturation is reduced to an even greater extent than in the smaller versions of the scheme. There is also a general increase in dissolved oxygen saturation throughout the on period leading to an increase in the annual 10th percentile in the 1 in 5 (A82) scenario from 113.1% to 114.1% and the annual 10th percentile in the 1 in 20 (M96) scenario increasing from 113.1% to 116.5%. As a result, there would not be deterioration in the high dissolved oxygen saturation WFD status associated with the 300 Ml/d Beckton water recycling scheme.

Figure 3-7 Dissolved oxygen saturation downstream of the Beckton water recycling outfall. Graphs display the baseline dissolved oxygen saturation compared to the modelled dissolved oxygen saturation in a 300 Ml/d Beckton water recycling scenario. The WFD high status band as a 10th percentile is indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario



1 in 20-year flow scenario

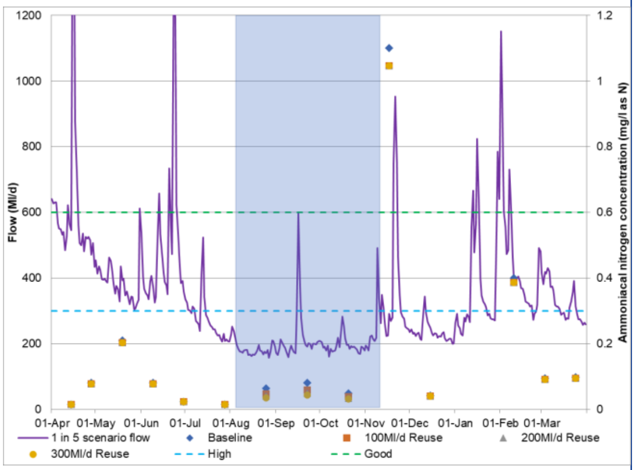
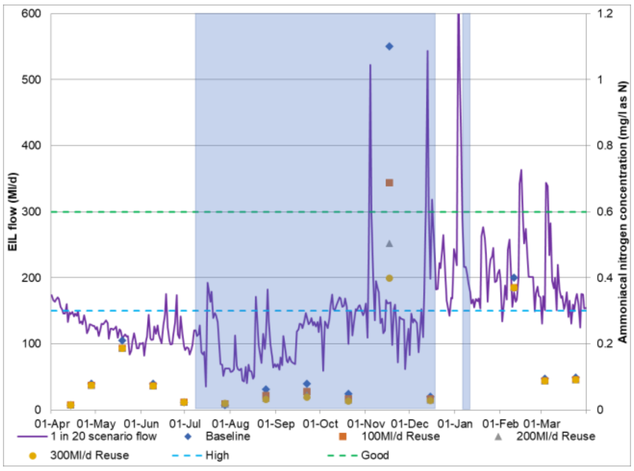


<u>Ammonia</u>

Figure 3-8 displays the results from the modelling of the ammonia for the range of Beckton water recycling scheme sizes. Across both flow scenarios there is a clear reduction in ammoniacal nitrogen concentration compared to the baseline concentration with the decrease becoming greater with the increase in scheme size.

The greatest decreases are experienced when the scheme is on however there is still a slight decrease when the scheme is not on. The 1 in 20 (M96) year scenario is where there is the greatest decrease, particularly with the 300 Ml/d Beckton water recycling scheme where the ammoniacal nitrogen concentration would be sufficiently reduced to cause the WFD status to improve on one occasion in November. Overall, there would not be deterioration in the ammonia status associated with any of the Beckton water recycling scheme sizes.

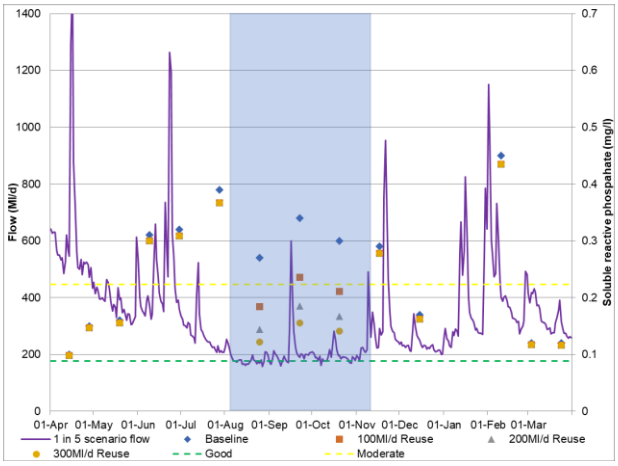
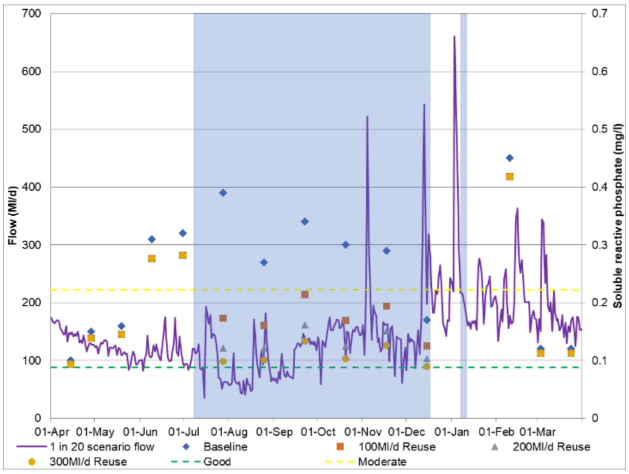
Figure 3-8 Ammoniacal nitrogen concentration downstream of the Beckton water recycling outfall. Graphs display the baseline ammoniacal nitrogen concentration compared to the modelled ammoniacal nitrogen across the range of Beckton water recycling scheme sizes. The WFD high and good status bands as a 90th[th] percentile are indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario	1 in 20-year flow scenario
	

Phosphate

Figure 3-9 displays the results from the modelling of the phosphate for the range of Beckton water recycling scheme sizes. Across both flow scenarios there is a clear reduction in soluble reactive phosphate concentration (due to dilution) compared to the baseline concentration with the decrease becoming greater with the increase in scheme size. The greatest decreases are experienced when the scheme is on however there is still a sizable decrease when the scheme is not on and just discharging a maintenance flow. Across each flow scenario there are occasions where the soluble reactive phosphate concentration is reduced sufficiently to cause an improvement in WFD status, even under the smallest sized scheme. Overall, there would not be deterioration in the phosphorus status associated with any of the Beckton water recycling scheme sizes.

Figure 3-9 Soluble reactive phosphate concentration downstream of the Beckton water recycling outfall. Graphs display the soluble reactive phosphate concentration compared to the modelled soluble reactive phosphate across the range of Beckton water recycling scheme sizes. The WFD good and moderate status bands as an annual mean are indicated. The blue area indicates periods where the scheme is on under each scenario.

1 in 5-year flow scenario	1 in 20-year flow scenario
	

<u>Acid neutralising capacity</u>

Acid neutralising capacity (ANC) has been calculated using a charge balance approach using estimated data from recycled water discharge and measured EA in-river spot data. Daily time-step mass balance (Figure 3-10, Figure 3-11) shows that minimum ANC under the A82 flows and M96 flows is indicative of poor water quality, indicating that some buffering capacity is present. Mean daily ANC change is between 50 and 60 mg/l (for both A82 and M96 under all scheme sizes). Under all scheme sizes ANC increases while the scheme in operation. ANC under both A82 and M96 Scenarios are indicative of ‘Good’ WFD water quality.

Figure 3-10 ANC in the freshwater Lee Diversion Channel for the Beckton 300, 200 and 100 Ml/d A82 scenario. Scheme in operation at Beckton A82 is indicated by the grey box

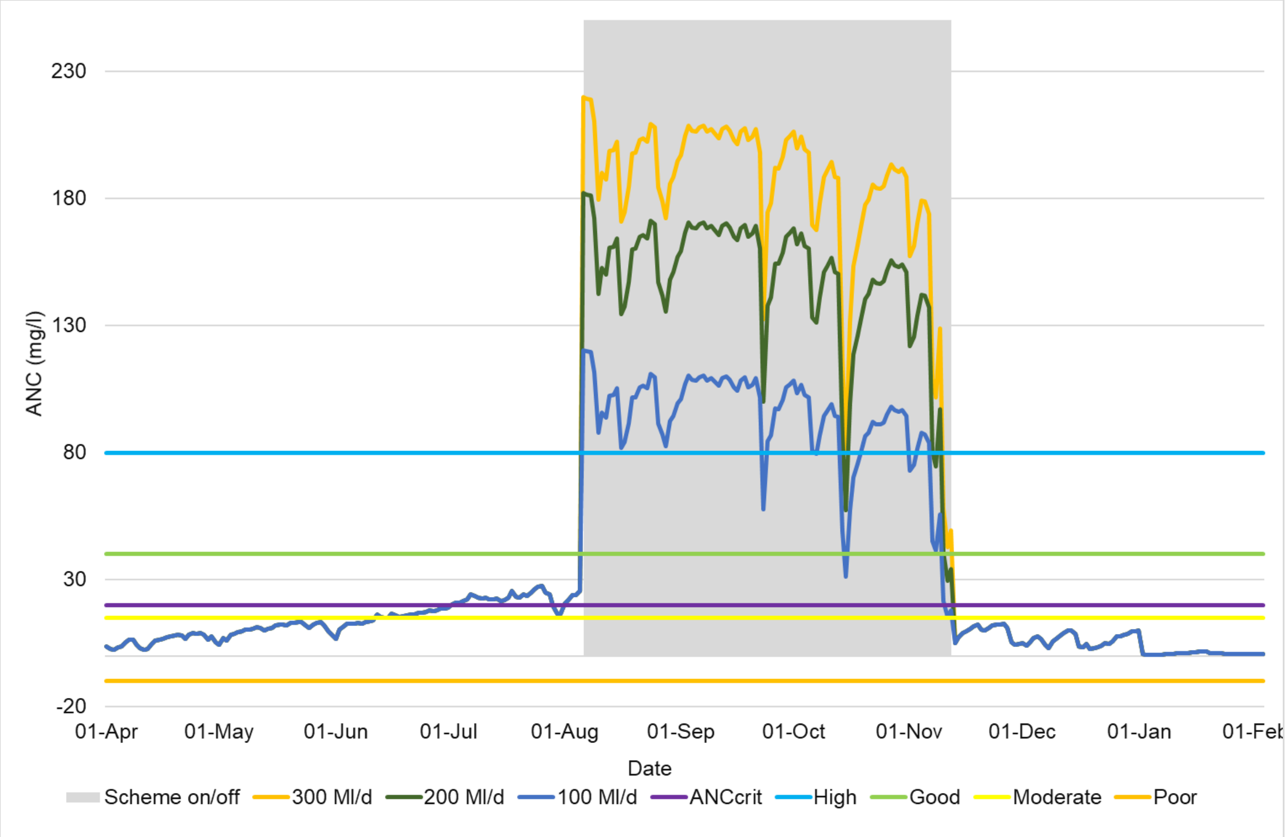
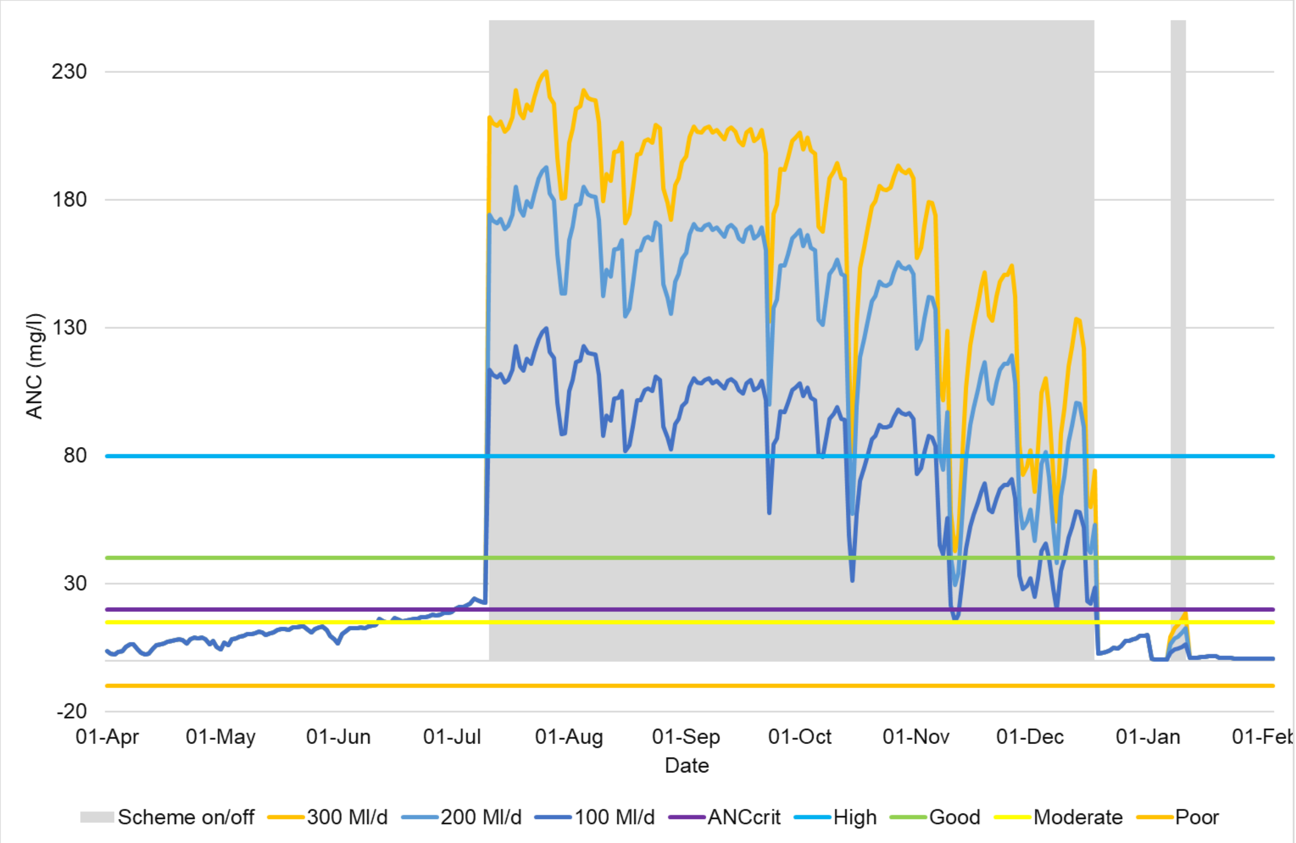


Figure 3-11 ANC in the freshwater Lee Diversion Channel for the Beckton 300, 200 and 100 Ml/d M96 scenario. Scheme in operation at Beckton M96 is indicated by the grey box



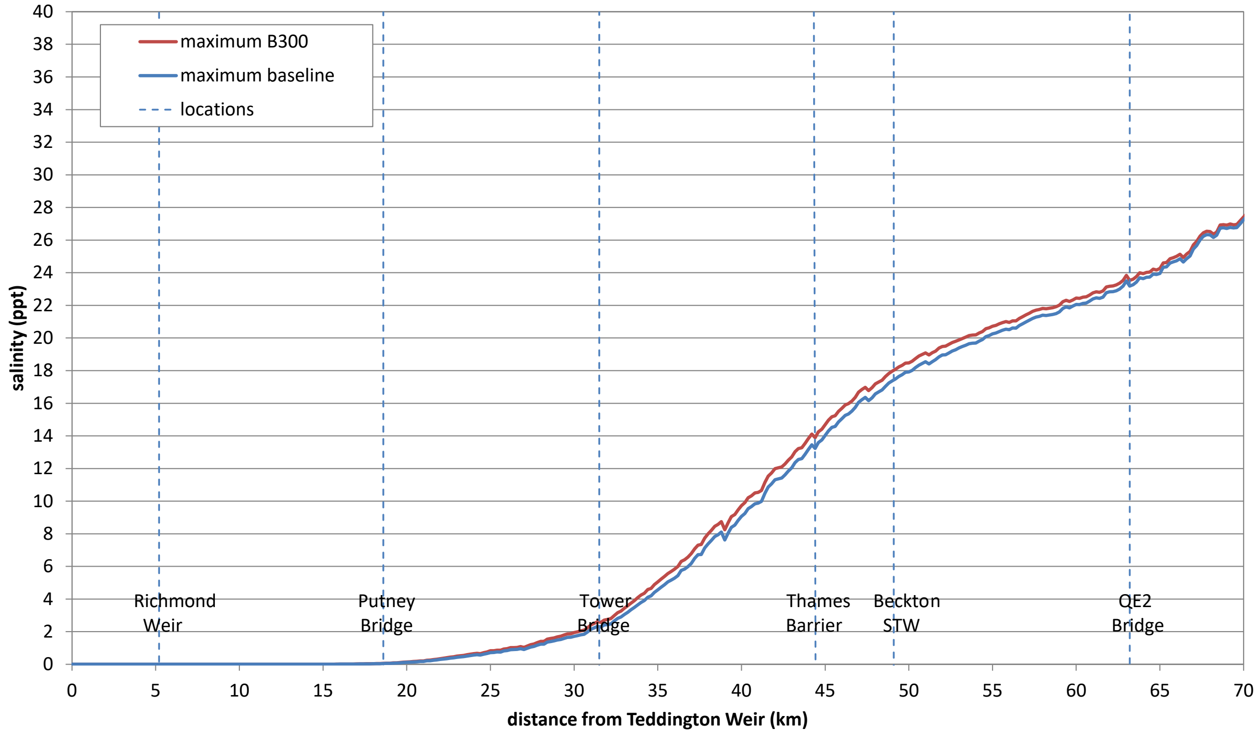
3.4.3 Estuarine Thames Tideway

Salinity

An assessment of the salinity impacts in the estuarine Thames Tideway arising from Beckton STW final effluent reduction associated with a Beckton water recycling scheme has been undertaken for the 300 Ml/d size of scheme and A82 and M96 flow scenarios.

Outputs from HR Wallingford's Upper Tideway model are presented below (Figure 3-12, Figure 3-13 and Figure 3-14):

Figure 3-12 Maximum salinity along thalweg (6th August – 12th November) in the estuarine Thames Tideway at baseline and for the 300 Ml/d Beckton water recycling scheme under the A82 scenario



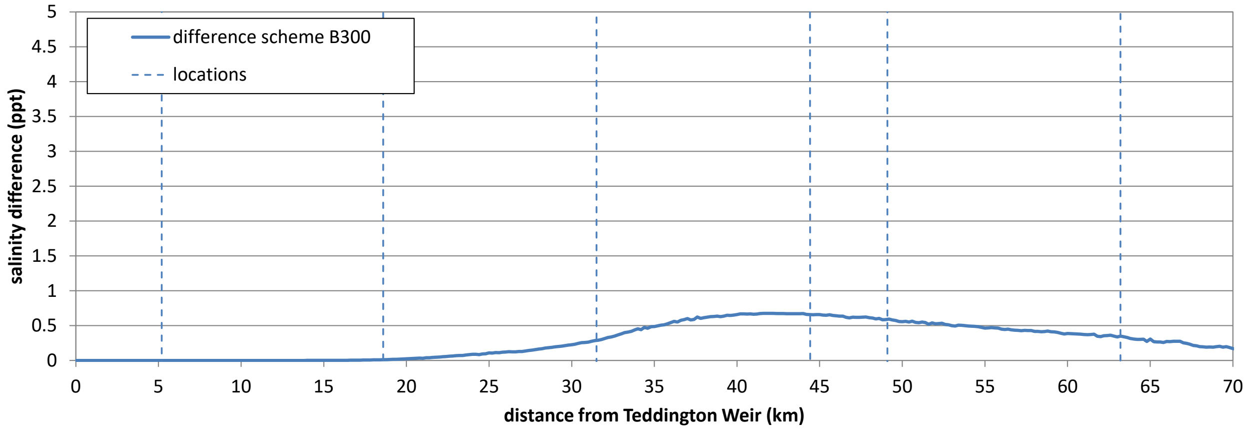


Figure 3-13 Mean salinity along thalweg (6th August – 12th November) in the estuarine Thames Tideway at baseline and for the 300 Ml/d Beckton water recycling scheme under the A82 scenario

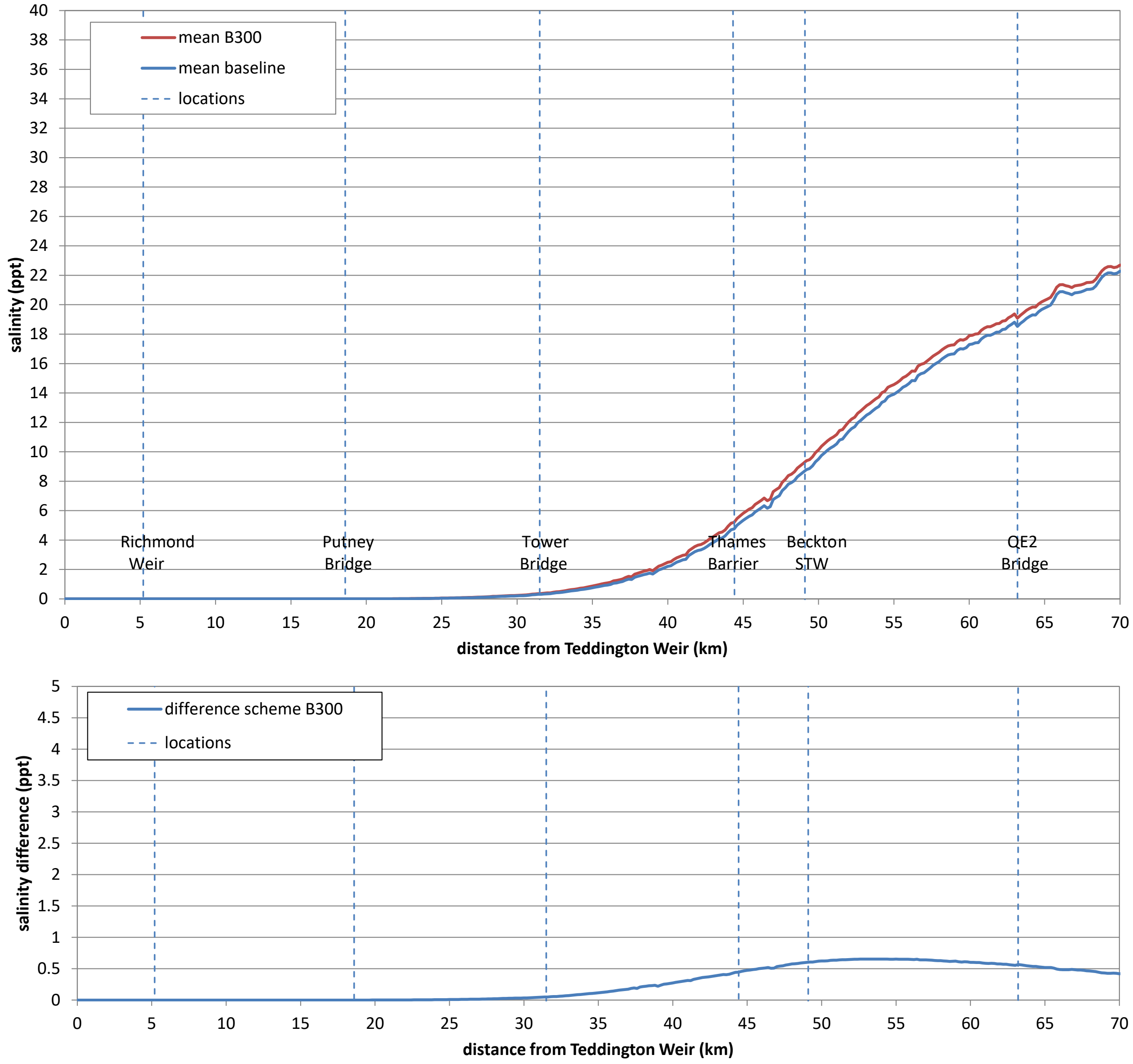
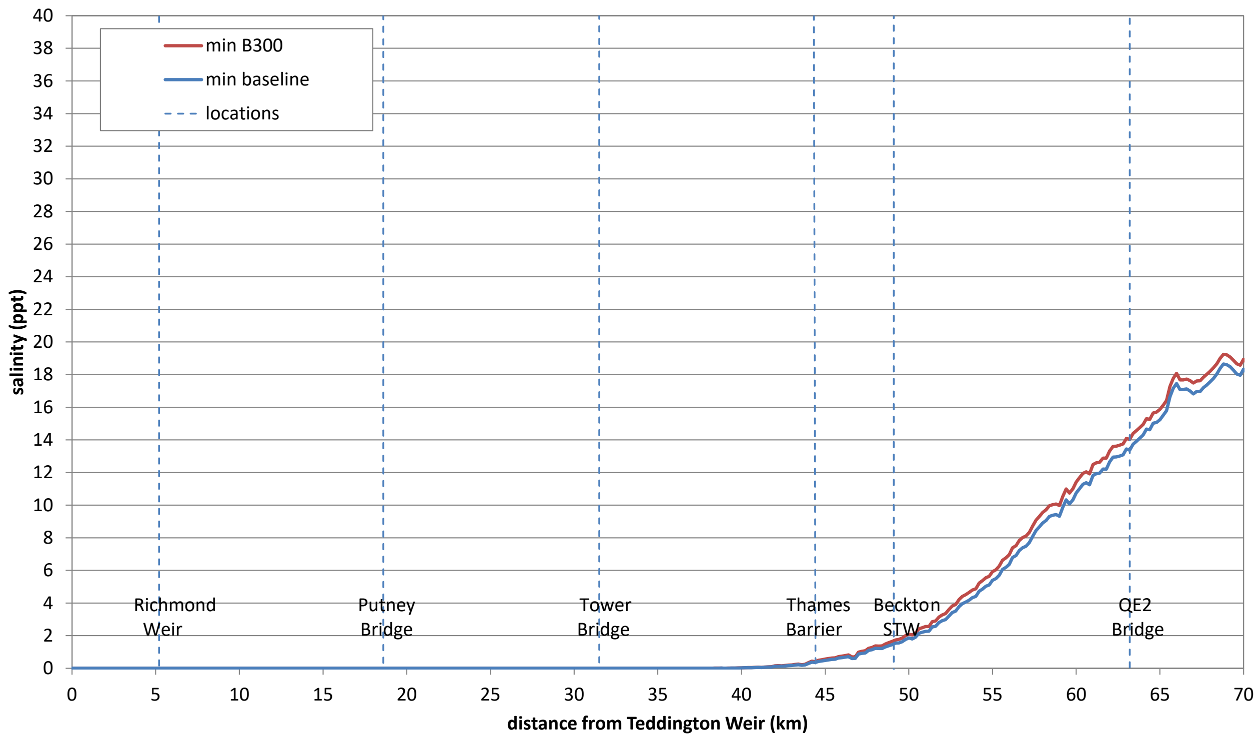
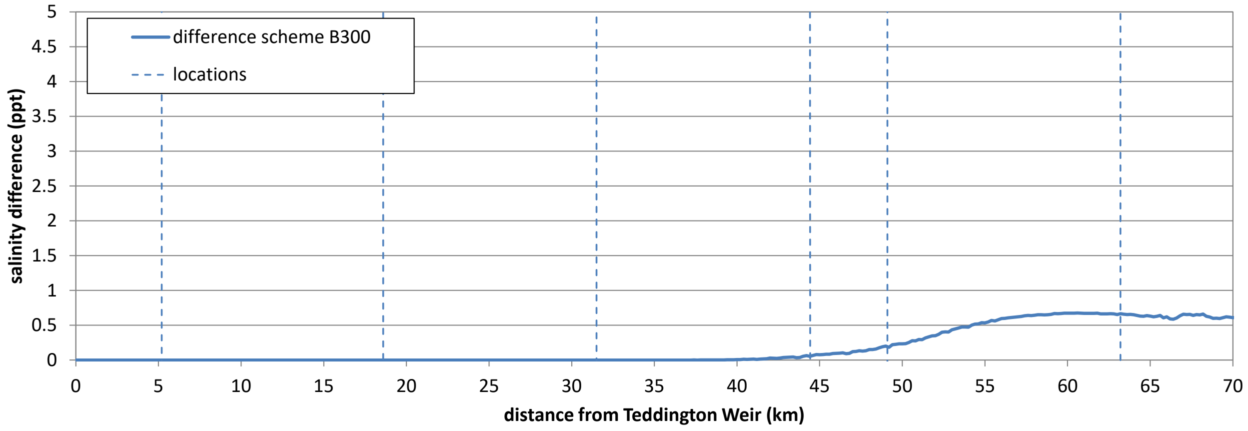


Figure 3-14 Minimum salinity along thalweg (6th August – 12th November) in the estuarine Thames Tideway at baseline and for the 300 Ml/d Beckton water recycling scheme under the A82 scenario





The modelled data displayed in Figure 3-12, Figure 3-13 and Figure 3-14 indicate that there is an increase in salinity under the A82 Beckton-300 scenario compared with baseline from approximately 30km seawards of Teddington Weir. Salinity is consistent between baseline and the A82 Beckton-300 scenario in the first 30km seawards of Teddington Weir. The graphs above display salinity modelled for the Beckton 300 Ml/d scheme and so represent the greatest salinity differences associated with the various scheme sizes at Beckton. The greatest increase in maximum, mean and minimum salinity from baseline is approx. 0.7ppt.

Figure 3-15 Maximum salinity along thalweg (1st August –30th November) in the estuarine Thames Tideway at baseline and for the 300 Ml/d Beckton water recycling scheme under the M96 scenario

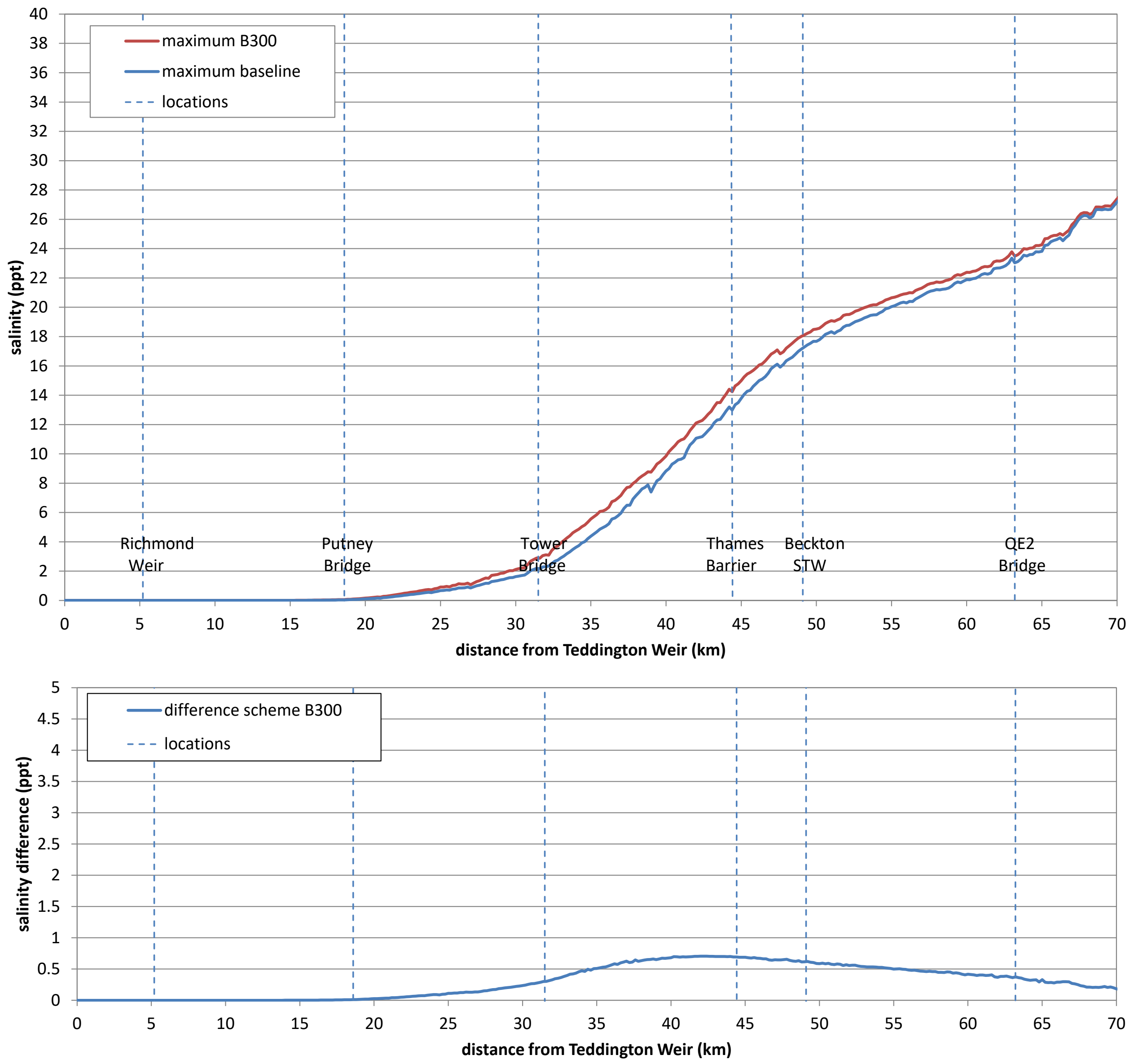


Figure 3-16 Mean salinity along thalweg (1st August –30th November) in the estuarine Thames Tideway at baseline and for the 300 Ml/d Beckton water recycling scheme under the M96 scenario

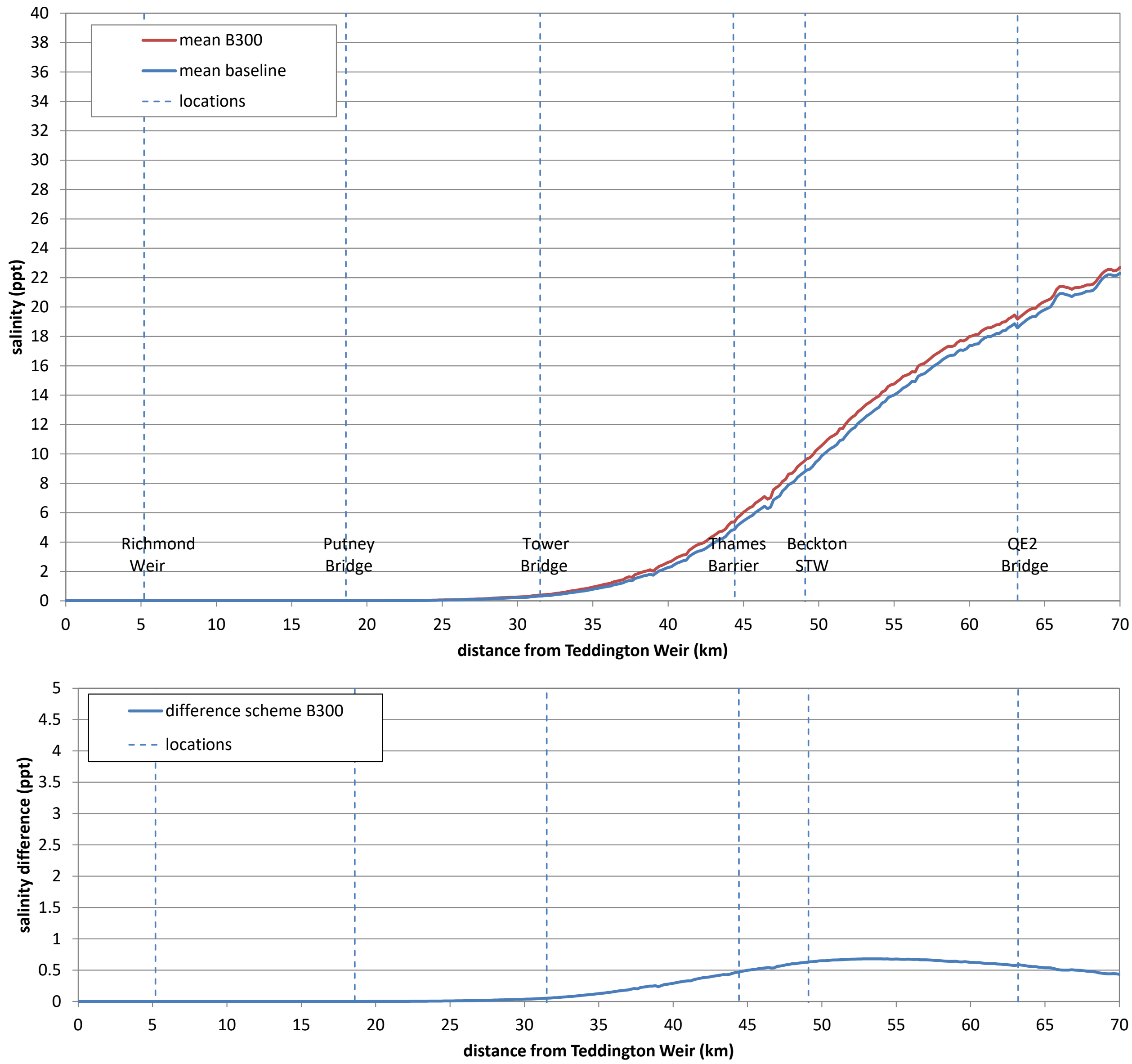
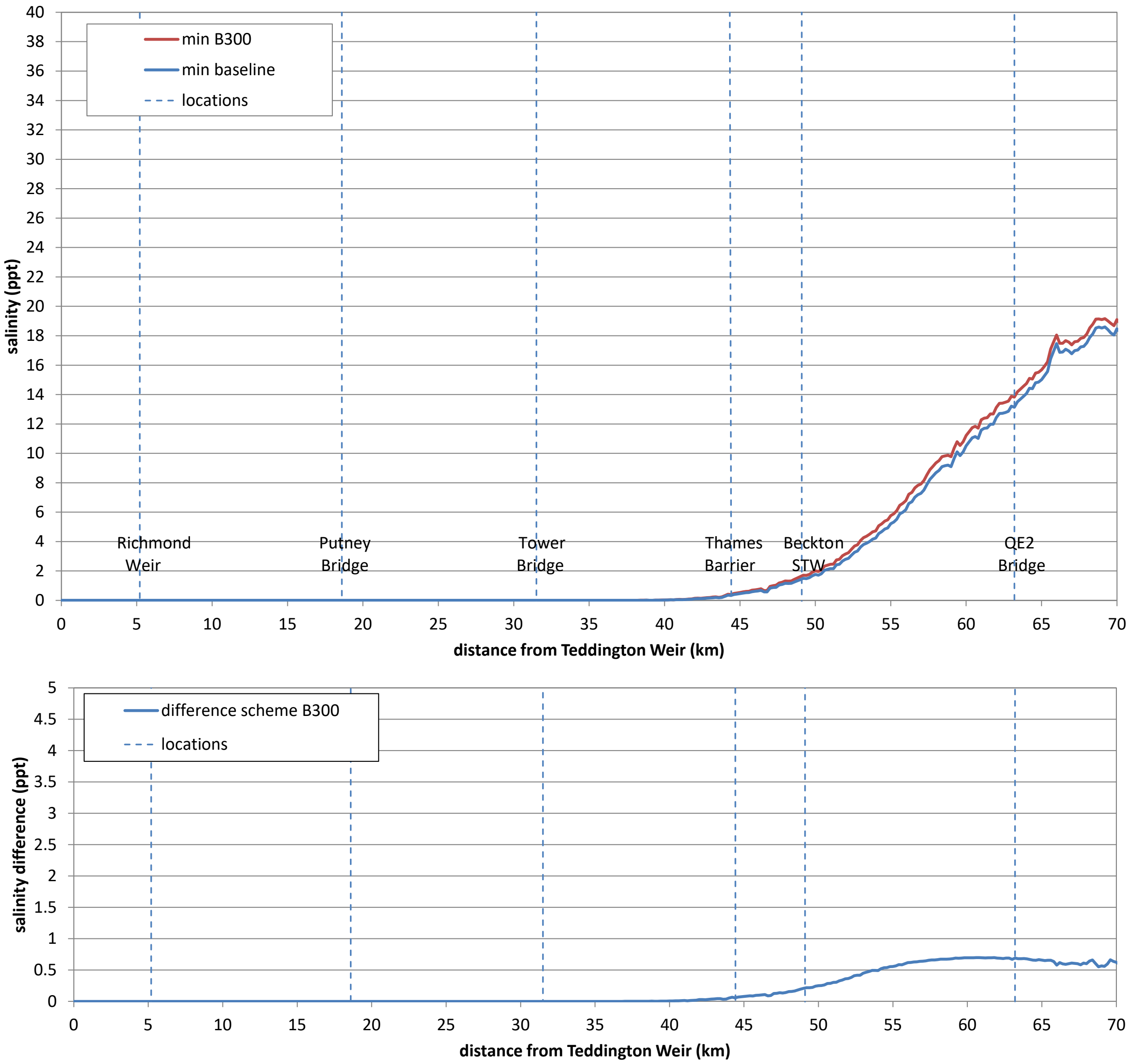


Figure 3-17 Minimum salinity along thalweg (1st August –30th November) in the estuarine Thames Tideway at baseline and for the 300 Ml/d Beckton water recycling scheme under the M96 scenario



The modelled data displayed in Figure 3-15, Figure 3-16 and Figure 3-17 indicate that there is an increase in salinity under the M96 Beckton-300 scenario compared with baseline from approx. 30km seawards of Teddington Weir. Salinity is consistent between baseline and the M96 Beckton-300 scenario in the first 30km seawards of Teddington Weir. The graphs above display salinity modelled for the Beckton 300 Ml/d scheme and so represent the greatest salinity differences associated with the various scheme sizes at Beckton. The greatest increase in maximum, mean and minimum salinity from baseline is approx. 0.7ppt, showing minimal difference between flow scenarios.

Dissolved oxygen concentration

The data was not available to complete the assessment for dissolved oxygen concentration in the estuarine Thames Tideway. Dissolved oxygen was not directly scoped into the Gate 2 estuarine modelling as it was considered that the pathways of change of dissolved oxygen within the middle Tideway are weak in comparison to the strength of estuarine processes.

Dissolved inorganic nitrogen

DIN has been assessed in the estuarine Thames Tideway using measured effluent data for ammonia, nitrate and nitrite. Scheme sizes have been proportionally removed from the concentrations to reflect scheme on and the reduction in effluent entering the Tideway through the Beckton STW outfall. It should be noted that this assessment assumes full removal of the diverted effluent and does not account for other discharge pathways back into the Tideway as, at this point, this is not known.

<u>100 Ml/d Beckton water recycling scheme</u>

The data displayed in Figure 3-18 and Figure 3-19 shows a reduction in DIN within the estuarine Thames Tideway during the scheme on period, though peaks are seen, particularly around October. During scheme on the maximum DIN concentrations displayed is 261 µMol/l (A82) and 338.6 µMol/l (M96), with averages of 197 µMol/l (A82) and 265.8 µMol/l (M96).

The scheme on period only overlaps with WFD status time periods during early November (A82) and during this time is indicative of 'good' status (mean, 270 µMol/l – 1st Nov – 28th Feb). While the scheme overlaps with WFD status time period during November to mid-December and for a few days in January (M96) during this time is indicative of 'moderate' status (mean, 405 µMol/l – 1st Nov – 28th Feb). However, overall, DIN status within the estuarine Thames Tideway from Beckton effluent is of 'moderate' status.

Figure 3-18 Dissolved inorganic nitrogen in the estuarine Thames Tideway for the 100, 200 and 300 Ml/d Beckton water recycling scheme under the A82 scenario

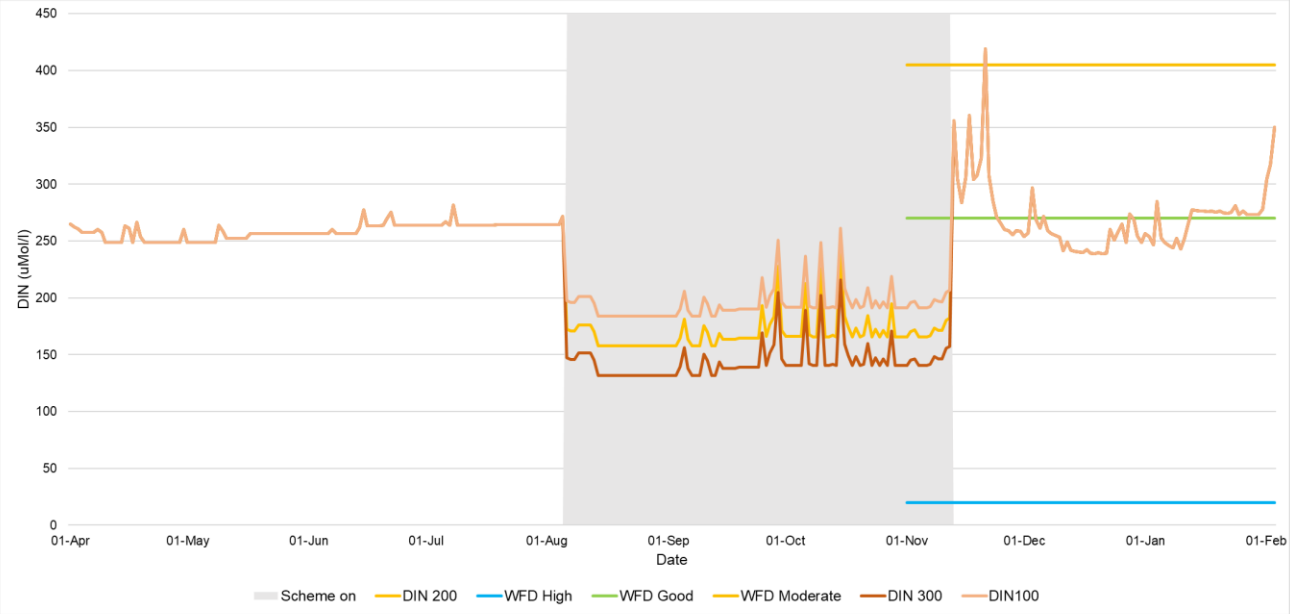
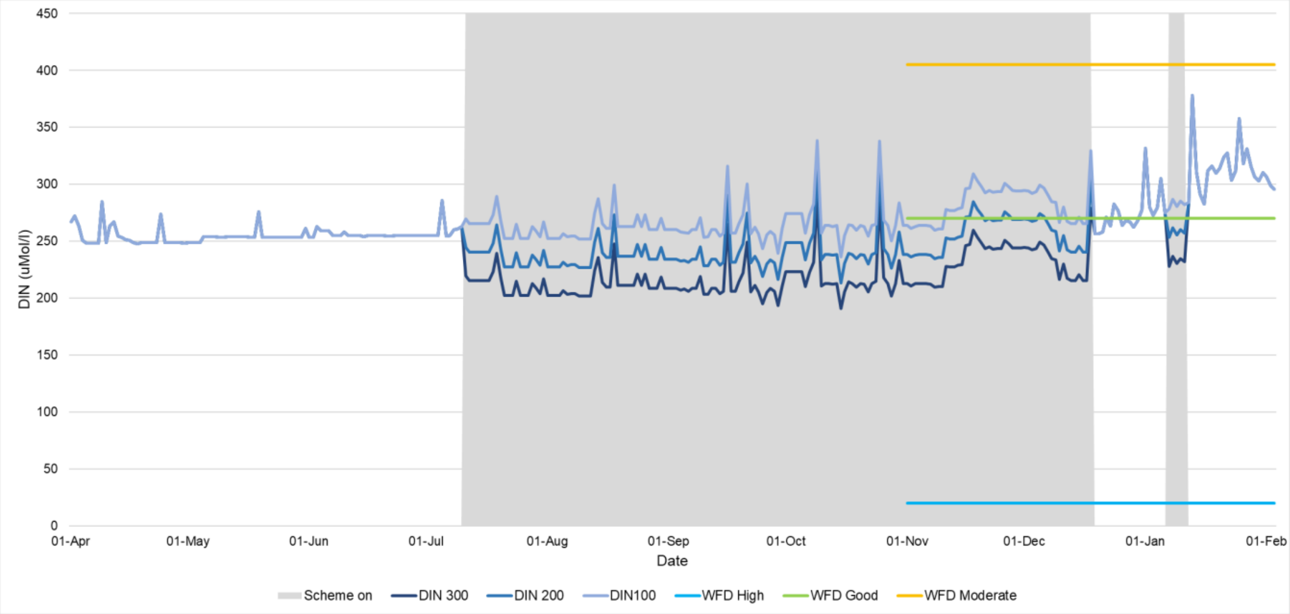


Figure 3-19 Dissolved inorganic nitrogen in the estuarine Thames Tideway for the 100, 200 and 300 Ml/d Beckton water recycling scheme under the M96 scenario



<u>200 Ml/d Beckton water recycling scheme</u>

The pattern of DIN concentrations is as described above for the 100 Ml/d Beckton water recycling scheme. During scheme on the maximum DIN concentrations displayed is 238.4 µMol/l (A82) and 313.2 µMol/l (M96), with averages of 172.9 µMol/l (A82) and 240.5 µMol/l (M96).

<u>300 Ml/d Beckton water recycling scheme</u>

Again, the pattern of DIN concentrations is as described above for the 100 Ml/d Beckton water recycling scheme. However, the M96 WFD status improves to 'good' status. During scheme on the maximum DIN concentrations displayed is 215.6 µMol/l (A82) and 284.3 µMol/l (M96), with averages of 148.8 µMol/l (A82) and 215.2 µMol/l (M96).

3.5 WFD CHEMICALS

3.5.1 Overview

This section sets out the change for the WFD and EQSD parameters associated with the Beckton water recycling scheme. Assessments undertaken include:

- Freshwater Lee Diversion Channel – Section 3.5.2
- Estuarine Thames Tideway – Section 3.5.3

The analysed chemicals are listed as priority substances and certain other polluting chemicals in the WFD and Environmental Quality Standards Directive (EQSD). This list does not include the Drinking Water safety Plan (DWSP) suite.

The evidence available, the general patterns observed in the data and any particular pressures are outlined for each of these reaches.

3.5.2 Freshwater Lee Diversion Channel, at Enfield Island Loop

As described in Section 3.2 above, the recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of chemicals.

3.5.3 Estuarine Thames Tideway

As described in Section 3.2 above, the AWRP processes will return all treated water to Beckton STW as liquid waste. This will affect the concentration of chemicals in the final effluent of Beckton STW discharged to the

Thames Tideway. Using measured data from Beckton STW final effluent, 'reconcentration' calculations were performed for each determinand within the WFD and EQSD suites. These values have been used in dispersion modelling of the Beckton STW final effluent plume in the Thames Tideway.

The risk assessment has been undertaken using the SRO water quality dataset. Specifically the Beckton STW final effluent sampling point, with typically 15 values reported in Gate 2. The risk assessment is not against EQS. It is an assessment of where individual reported chemical values are in exceedance of EQS values, without recourses to considering mean or percentile values at this stage. It is noted that the assessment is of the dispersion of the STW discharge itself and does not account for concentrations in the Thames Tideway. It is noted that monitoring of the Thames Tideway itself would identify chemical concentrations as amended by Beckton STW and would not indicate the reference conditions without Beckton STW for inclusion in modelled assessment. As such it is not a statement of EQS pass or fail according to how EQS is derived.

Fifteen chemical determinands within the WFD suite were identified as exceeding the standard in the Estuarine Thames Tideway under baseline conditions.

Beckton water recycling 1 in 5-year (A82) scenario WFD Chemicals

<u>100 Ml/d Beckton water recycling scheme</u>

Of the 15 chemical determinands which were identified as exceeding the standard in the Estuarine Thames Tideway under baseline conditions (in the Beckton STW discharge), the following 12 continued to exceed the standard (in the Beckton STW discharge) under the 100 Ml/d Beckton water recycling scheme 1 in 5 year (A82) scenario:

- Benzo(a)pyrene
- C10-13 chloroalkanes (total)
- Cadmium Dissolved
- Copper Dissolved
- Cyanide Total
- Indeno(1,2,3-cd)pyrene
- Dicofol
- Polycyclic aromatic hydrocarbons
- Permethrin
- Total DDT
- Trichlorobenzenes
- Zinc Dissolved

There are no new pressures under the 1 in 5 year (A82) 100 Ml/d Beckton water recycling scenario.

<u>200 Ml/d Beckton water recycling scheme</u>

Of the 15 chemical determinands which were identified as exceeding the standard in the Estuarine Thames Tideway under baseline conditions (in the Beckton STW discharge), the following 12 chemical determinands continued to exceed the standard (in the Beckton STW discharge) under the Beckton water recycling scheme 1 in 20 year (M96) 200 Ml/d scenario:

- Benzo(a)pyrene
- C10-13 chloroalkanes (total)
- Cadmium Total
- Copper Dissolved
- Cyanide Total
- Dicofol
- Indeno(1,2,3-cd)pyrene
- Polycyclic aromatic hydrocarbons
- Permethrin
- Total DDT
- Trichlorobenzene
- Zinc Dissolved

There are no new pressure under the 1 in 5 year (A82) 200 Ml/d Beckton water recycling scenario.

<u>300 Ml/d Beckton water recycling scheme</u>

Of the 15 chemical determinands which were identified as exceeding the standard in the Estuarine Thames Tideway under baseline conditions (in the Beckton STW discharge) all 15 chemical determinands continued to exceed the standard (in the Beckton STW discharge) under the 1 in 5 year (A82) 300 Ml/d Beckton water recycling scenario.

- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- benzo(g,h,i)perylene
- C10-13 chloroalkanes (total)
- Cadmium Total
- Copper Dissolved
- Cyanide Total
- Dicofol
- Indeno(1,2,3-cd)pyrene
- Permethrin
- Polycyclic aromatic hydrocarbons
- Total DDT
- Trichlorobenzenes
- Zinc Dissolved

Although remaining above the standard, benzo(a)pyrene exhibits a decrease in concentrations under the 1 in 5 year (A82) 300 Ml/d Beckton water recycling scenario compared with baseline. Dissolved copper, dicofol, permethrin, trichlorobenzenes and dissolved zinc all exhibit increased concentrations under the 1 in 5 year (A82) 300 Ml/d Beckton water recycling scenario.

There is a new pressure under the 1 in 5 year (A82) 300 Ml/d Beckton water recycling scenario, with an additional chemical determinand exceeding the standard (in the Beckton STW discharge) as follows (Table 3-3).

- Dissolved mercury

Table 3-3: WFD chemical determinand exceeding standards (in the Beckton STW discharge) under A82 Beckton 300 Ml/d water recycling scenario.

Determinand	Average (µg/l)	EQS (µg/l)
Dissolved mercury	0.09	0.07

Beckton water recycling 1 in 20-year (M96) scenario WFD Chemicals

100 Ml/d Beckton water recycling scheme

Although remaining above the standard concentrations of the determinants listed above exhibit a slight improvement in mean concentrations under the 1 in 20 year (M96) 100 Ml/d Beckton water recycling scenario compared with baseline.

There are some no pressures under the 1 in 20 year (M96) 100 Ml/d Beckton water recycling scenario in comparison to reference conditions.

200 Ml/d Beckton water recycling scheme

The changes to the WFD suite of chemical determinands under the 1 in 20 year (M96) 200 Ml/d Beckton water recycling scenario compared with reference conditions are the same as those described above for the 1 in 5 year (A82) 200 Ml/d Beckton water recycling scenario.

300 Ml/d Beckton water recycling scheme

The changes to the WFD suite of chemical determinands under the 1 in 20 year (M96) 300 Ml/d Beckton water recycling scenario compared with reference conditions are the same as those described for the 1 in 5 year (A82) 300 Ml/d Beckton water recycling scenario, except for a decrease to below the standard observed for dissolved mercury.

Beckton water recycling scheme 1 in 5-year (A82) scenario EQSD Chemicals

Under reference conditions, two of the chemical determinands within the EQSD chemical suite (Bromine – total residual oxidant and Diflubenzuron) exceeded the standard (in the Beckton STW discharge).

Under the Beckton water recycling 1 in 5 year (A82) 100, 200 and 300 Ml/d scenarios, there is one new pressure of pirimicarb (AA EQS) chemicals exceeding the standard (in the Beckton STW discharge).

Beckton water recycling scheme 1 in 20-year (M96) scenario EQSD Chemicals

The changes to the EQSD suite of chemical determinands under the 1 in 20 year (M96) 300 Ml/d Beckton water recycling scenario compared with reference conditions are the same as those described for the Beckton water recycling scheme 1 in 5 year (A82) for 100, 200 and 300 Ml/d scenarios, showing minimal difference between flow scenarios.

3.6 OLFACTORY WATER QUALITY

An initial screening assessment has been undertaken to identify potential new or increased pressures to the study areas. This assessment uses reconcentration calculations to compare in-river concentrations to baseline and highlights determinands which exceed or approach (within 10% of) the EQS (if applicable). This assessment is intended as a guide for future investigations, see Section 6.

3.6.1 Overview

This section sets out the change for the olfactory parameters associated with the Beckton water recycling option. Assessments undertaken include:

- Freshwater Lee Diversion Channel - Section 3.6.2
- Estuarine Thames Tideway - Section 3.6.3

The evidence available, the general patterns observed in the data and any notable pressures will be outlined and where to view this evidence have been set out for each of these reaches. It is noted that olfaction was not scoped in to the Gate 2 fisheries assessment of the River Lee study area therefore the full monitoring suite is not available in Gate 2. Where there are overlaps between the olfactory inhibitor suite and either the WFD, EQSD or DWSP monitoring suites undertaken in the Enfield Island Loop as part of the Pan-SRO monitoring programme these have been reported below.

3.6.2 Freshwater Lee Diversion Channel, at Enfield Island Loop

As described in Section 3.23.2.5 above, the recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of chemicals.

3.6.3 Estuarine Thames Tideway

Beckton A82

As per Section 2.6.4, 24 chemical determinands within the olfaction suite were identified as exceeding the LOD in the Estuarine Thames Tideway under reference conditions. Of these 24 determinands, 15 were analysed against the EQS for both reference conditions and the A82 Beckton-300 scenario. Table 3-4 shows the exceedances of the EQS for these 15 determinands. It is noted that EQS relate to eco-toxicity and not to olfaction inhibition.

Under reference conditions, five chemical determinands were identified as exceeding the EQS. Of these, dissolved copper, dissolved mercury, permethrin and dissolved zinc remained above the EQS under the A82 Beckton-300 scenario. Pirimicarb exhibits a decrease in concentrations to below the EQS under the A82 Beckton-300 scenario.

There is one additional pressure under the A82 Beckton-300 scenario, with total cadmium concentrations increasing to above the EQS.

Table 3-4 Olfaction chemicals exceeding the EQS within the Estuarine Thames Tideway under reference conditions and under the A82 Beckton-300 scenario

Chemical determinand	Reference conditions	A82 Beckton-300
Total cadmium	No	Yes
Chlorotoluron	No	No
Dissolved chromium (III)	No	No
Dissolved cobalt	No	No
Dissolved copper	Yes	Yes
Cypermethrin	No	No
Diuron	No	No
Dissolved iron	No	No
Isoproturon	No	No
Linuron	No	No
Dissolved mercury	Yes	Yes
Dissolved nickel	No	No
Permethrin	Yes	Yes
Pirimicarb	Yes	No
Dissolved zinc	Yes	Yes

Beckton M96

The changes to the olfaction suite of chemical determinands in the Estuarine Thames Tideway under the M96 Beckton-300 scenario compared with reference conditions are the same as those described for the A82 Beckton-300 scenario, with two exceptions. Under the M96 Beckton-300 scenario, dissolved mercury concentrations decrease to below the EQS and pirimicarb remains above the standard. It is noted that EQS relate to eco-toxicity and not to olfaction inhibition.

3.7 SUMMARY OF WATER QUALITY ASSESSMENT OF BECKTON WATER RECYCLING SCHEMES

Table 3-5 summarises the potential water quality impacts for each of the sizes of a Beckton water recycling scheme.

Table 3-5 Summary of Gate 2 assessment of potential water quality impacts for Beckton water recycling schemes

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality
100 Ml/d	Freshwater Lee Diversion Channel: Negligible change in water temperature. Estuarine Thames Tideway: No change.	Freshwater Lee Diversion Channel: Dissolved oxygen: No deterioration. Ammonia: No deterioration. Phosphate: No deterioration. ANC: No deterioration. Estuarine Thames Tideway: Dissolved oxygen: Screened as negligible DIN: Reductions in DIN during scheme operation Salinity: Minimal salinity changes modelled for 300Ml/d scheme under both scenarios	Freshwater Lee Diversion Channel: No chemicals in recycled water following AWRP Estuarine Thames Tideway: 15 WFD chemicals exceeded the standard (in the STW discharge) in the baseline scenario. With the scheme in operation no further chemicals modelled to exceed the standard (in the STW discharge).	Freshwater Lee Diversion Channel: No chemicals in recycled water following AWRP Estuarine Thames Tideway: With the scheme in operation one further chemical modelled to exceed the standard (in the STW discharge).	Freshwater Lee Diversion Channel: No chemicals in recycled water following AWRP Estuarine Thames Tideway: Of the chemicals analysed at Gate 2, 24 identified as detected.
200 Ml/d					
300 Ml/d			Freshwater Lee Diversion Channel: No chemicals in recycled water following AWRP Estuarine Thames Tideway: 15 WFD chemicals exceeded the standard (in the STW discharge) in the baseline scenario. With the scheme in operation one further chemical modelled to exceed the standard (in the STW discharge).		

In conclusion, the Beckton water recycling schemes may have only negligible changes in the general physico-chemical environment compared to the baseline conditions of the freshwater Lee Diversion Channel. The 300 Ml/d, 200 Ml/d and 100 Ml/d schemes have a negligible impact on WFD chemicals, EQSD and olfactory chemicals in the freshwater Lee Diversion Channel. The Olfactory water quality information is used to support the fisheries assessment in B.2.3 Fish Assessment Report. Within the estuarine Thames Tideway, the discharge of reverse osmosis concentrate in the Beckton STW final effluent may have a negligible/minor change of the discharged WFD and EQSD chemicals. This would not affect the load discharged but may have a consequent negligible/minor effect on concentrations within the estuarine Thames Tideway. This needs to be investigated further in Gate 3.

3.8 POTENTIAL MITIGATION REQUIREMENTS

Dependent on the updated findings of the Gate 3 water quality assessment on the effect of the reverse osmosis concentrate being discharged into the estuarine Thames Tideway, there may be a requirement for further mitigation in the form of additional treatment solutions to be considered to reduce the chemical content of the discharge.

4. WATER QUALITY ASSESSMENT OF MOGDEN WATER RECYCLING SCHEMES

4.1 INTRODUCTION

This section sets out the assessment for the tasks set out in Table 1-1 relevant to Mogden water recycling. The study area for each task has been set out per task as it is not consistent across tasks. A conceptualisation of the key water quality issues of the scheme is presented in Figure 4-1. The Mogden water recycling assessment for each of the following tasks has been set out in the following sections:

- Mogden water recycling scheme AWRP discharge quality– Section 4.2
- Water temperature – Section 4.3
- General physico-chemical – Section 4.4
- WFD chemicals – Section 4.5
- Olfactory water quality – Section 4.6
- Richmond Pound drawdown water quality – Section 4.7

The data used for undertaking the assessments has been outlined in the Gate 2 Water Quality Evidence Report and in Table 1-1.

The assessments have been undertaken for the following for each task:

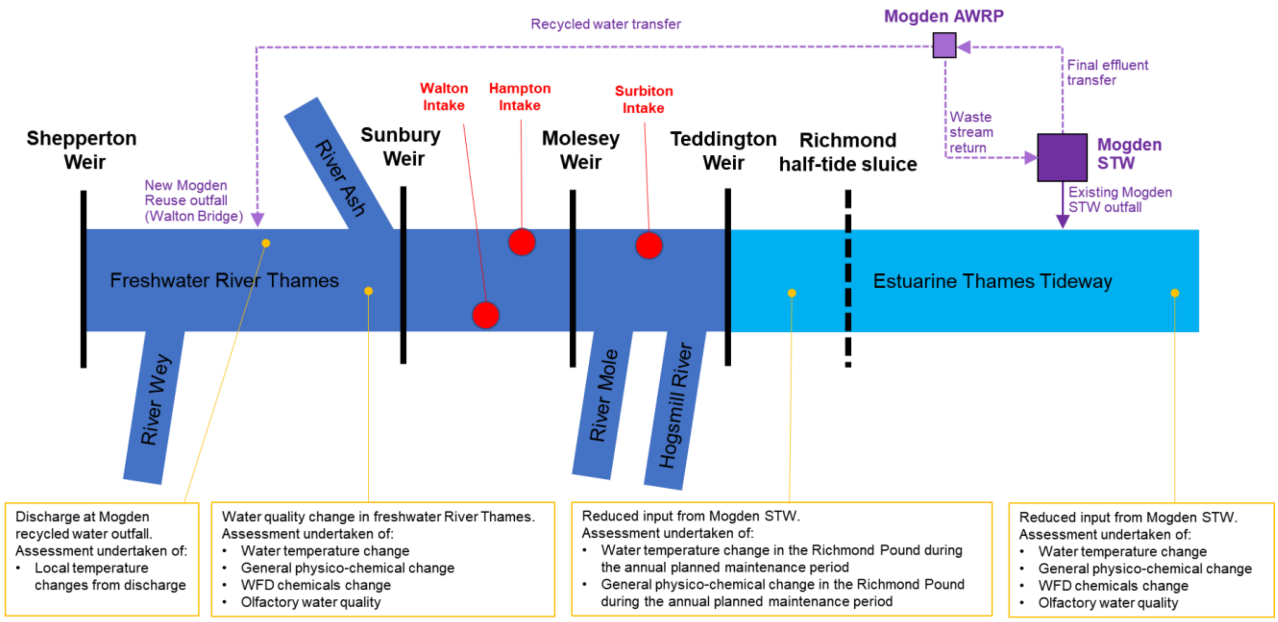
- Source water of Mogden STW final effluent including effluent temperature, general physico-chemical parameters, and effluent chemicals, including olfactory inhibitors.
- Water temperature across the freshwater River Thames and estuarine Thames Tideway.
- WFD physico-chemical supporting elements to ecological status, including dissolved oxygen saturation, total ammonia, reactive phosphorus, water temperature, pH and BOD across the freshwater River Thames and estuarine Thames Tideway.
- WFD chemical suite across the freshwater River Thames and estuarine Thames Tideway.
- Olfactory water quality, including those determinands which were added for the assessment at Gate 2 and for which data was available.
- Richmond Pound drawdown water quality, including water temperature, conductivity, and dissolved oxygen for the Thames Tideway reach between Teddington Weir and Richmond Half-tide Sluice for the period without tidal level management.

Bespoke modelling datasets with parameterised reference conditions (see Section 2) were reviewed to determine the extent of variability with site or seasonality from the reference conditions with the Mogden water recycling scheme in operation. This provided the range and variability of water qualities across the range of monitored sites. The modelling data sets examined are as follows:

- Discharge plume modelling in the freshwater River Thames, undertaken by HR Wallingford
- Hydrodynamic and water quality modelling in the estuarine Thames Tideway undertaken by HR Wallingford
- Hydraulic and water quality modelling in the freshwater River Thames undertaken by Atkins.

Where text makes reference to A82 and M96 flow series, respectively these refer to 1 in 5 year and 1 in 20-year flow events.

Figure 4-1 Schematic for Mogden Water Recycling Scheme



4.2 MOGDEN WATER RECYCLING AWRP DISCHARGE QUALITY

4.2.1 Overview

This section sets out the supplementary information for the source water (effluent) parameters for Mogden STW used in the environmental assessments.

- Recycled water temperature - Section 4.2.2
- Recycled water general physico-chemical parameters - Section 4.2.3
- Langelier Saturation Index – Section 4.2.4
- Recycled water stream chemical quality - Section 4.2.5
- Environmental fate of chemicals reduced during AWRP treatment – Section 4.2.6.

As set out in the Gate 2 Conceptual Design Report[12] for a Mogden water recycling scheme, the source water of Mogden STW final effluent would be subject to advanced treatment in an AWRP. The AWRP would include the following water treatment processes: reverse osmosis, UV advanced oxidation process (includes peroxide dosing) and remineralisation. To support the environmental assessments at Gate 2, an indicative operating pattern has been developed, as described in the B.2.1. Gate 2 Physical Environment assessment. Outside the normal operating pattern the Gate 2 engineering design includes a 25% plant maintenance flow, with the recycled water being discharged to the River Thames at Walton Bridge but not re-abstracted.

4.2.2 Recycled water temperature

The effect of the AWRP on the water temperature of the recycled water of the Mogden water recycling scheme is currently not well understood but is not expected to lead to significant differences across the reverse osmosis membranes. As such the Mogden STW final effluent temperature is taken as a conservative estimate of the temperature of the recycled water at point of discharge to the freshwater River Thames.

4.2.3 Recycled water general physico-chemical water quality

The recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis (RO). RO is a type of filtration method used for the removal of molecules and ions from solution. As a result, the recycled water is effectively deionised. The in-river assessment approach has been adopted to determine and describe the change of the WFD physico-chemical supporting elements to ecological status.

[12] Jacobs (2022) Mogden water recycling SRO: Conceptual Design Report.

As set out in Gate 2 Annex A. Conceptual Design Report[13], the AWRP source water and recycled water quality are as presented in Table 4-1. In addition, for in-river modelling purposes, an indicative value of 11.0 mg/l dissolved oxygen has been used at all times, noting the inclusion of a hydrogen peroxide dosing unit as part of the Gate 2 AWRP design. It is noted that the remineralisation design at present is to ensure corrosivity indices for conveyance are complied with and do not represent the end-point of design for environmental discharge.

Table 4-1 Mogden water recycling scheme AWRP source water and process water quality

Parameter (showing mean value)	Source water (Mogden STW final effluent)	Recycled water for river discharge
pH	7.6	8.4
Total Ammonia	1.7 mgN/l	Trace
Phosphorus	5.4 mg/l	0.04 mg/l
BOD	12.2 mg/l	Trace
Suspended solids	36.0 mg/l	0.07 mg/l
Alkalinity ($CaCO_3$)	230 mg/l	60 mg/l

Hardness

The RO water, as an additional treatment process, also undergoes remineralisation. The Gate 2 estimate for remineralisation is 60 mg $CaCO_3$ mg/l. However, it is considered that this estimate should be revised to provide a target which meets the environmental needs described in the reference conditions and below.

4.2.4 Langelier Saturation Index

There are two key factors when deciding on the physico-chemical composition of the water; the water being safe to reintroduce to the river and for it to be non-damaging to the pipes.

LSI considers pH, temperature, calcium (hardness), alkalinity, and total dissolved solids to provide a calculated numeric indicator of the possible corrosiveness or limescale build-up in the pipes with the goal to be a value as close as possible to 0 with neither limescale nor corrosiveness occurring. For this location, an LSI of zero is achievable with the suggested values in Table 4-2. The suggested values are all ideal for the river water other than pH where a value of 6.9 is suggested. If all ideal river water values are used, including a pH of 7.09, the LSI will be 0.19.

Table 4-2 LSI suggested target values for the freshwater River Thames

Parameter	Measured in river value	Target range	Suggested values
pH	7.09	6.85-7.09	6.9
Temperature (°C)	16	<25	16
Ca hardness (mg/l)	84	75-100	84
Total alkalinity ($CaCO_3$ mg/l)	166	150-200	166
TDS (mg/l)	11	<25	11

4.2.5 Recycled water chemical quality

As described above, the recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of WFD chemicals.

The AWRP processes will return all treated water to Mogden STW as liquid waste. This will affect the concentration of chemicals in the final effluent of Mogden STW discharged to the Thames Tideway. Using measured data from Mogden STW final effluent, 'reconcentration' calculations were performed for each

[13] Jacobs (2022) Mogden water recycling SRO: Conceptual Design Report.

determinand within the WFD and EQSD suites. These values have been used in dispersion modelling of the Mogden STW final effluent plume in the Thames Tideway.

4.2.6 Environmental fate of chemicals reduced during AWRP treatment

Overall, the changes to the environmental fate of most chemicals will be the same as described above in Section 3.2.6 in relation to the Beckton water recycling scheme, a possible increase in the rate of volatilisation and a release of adsorbed particles with water temperature increases.

4.3 WATER TEMPERATURE

4.3.1 Overview

This section outlines the water temperature change associated with a Mogden water recycling scheme. Assessments undertaken include:

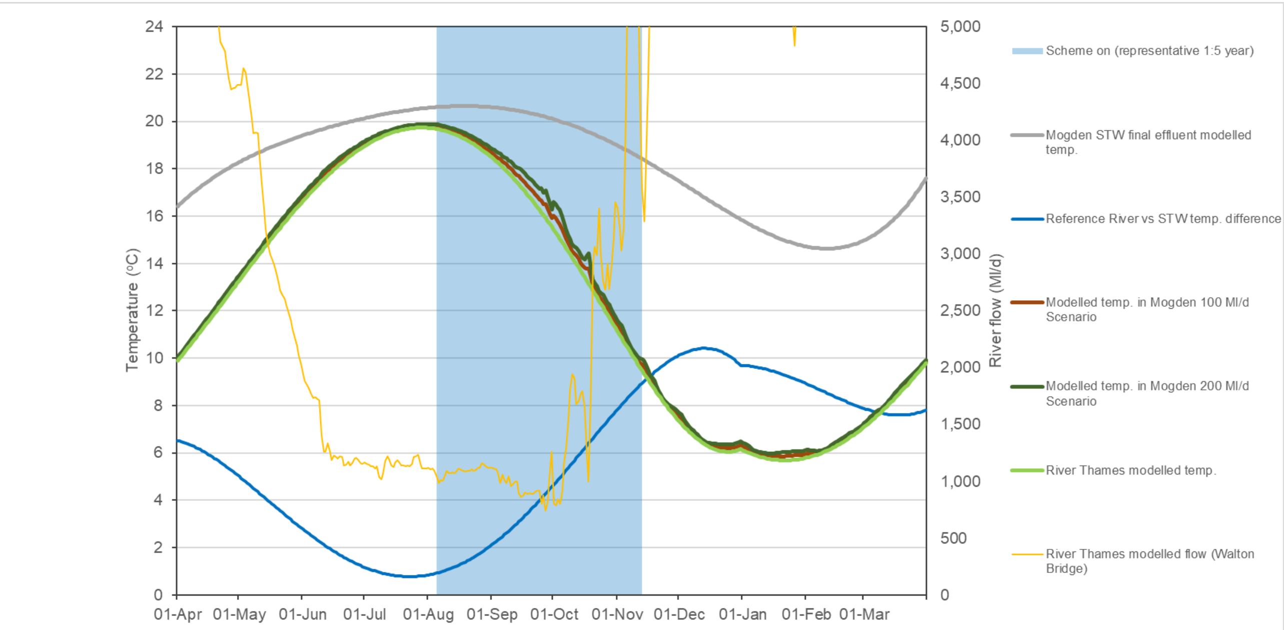
- Temperature change in the freshwater River Thames – Section 4.3.2
- Temperature change in the estuarine River Thames – Section 4.3.3

4.3.2 Freshwater River Thames

An assessment of the water temperature impacts arising from a new Mogden water recycling scheme discharge into the freshwater River Thames has been undertaken for the four sizes of recycling scheme; 50 Ml/d, 100 Ml/d, 150 Ml/d and 200 Ml/d.

A water temperature assessment has been undertaken for the 1:5 return frequency A82 flow scenario. This used flow data for the River Thames at Walton Bridge for the A82 scenario (see B.2.1 Physical Environment Assessment Report) together with scenario flow changes for the Mogden water recycling scheme – both scheme operational and plant maintenance flows. Input water temperature data are the River Thames at Teddington Weir profile described in Section 2.3.3; and the discharge temperature for the Mogden water recycling scheme is the profile described in Section 2.2.2. The results for the 100 Ml/d and 200 Ml/d Mogden water recycling scheme are shown on Figure 4-2; other scheme sizes are not included in order to improve figure clarity.

Figure 4-2 Mogden water recycling modelled temperatures in the River Thames for the A82 moderate-low flow scenario. The blue area indicates periods where the scheme is on under each scenario.



The modelled data displayed in Figure 4-2 are summarised in Table 4-3.

Table 4-3 Summary of Mogden water recycling scheme modelled temperatures in the River Thames for the A82 moderate-low flow scenario

	Reference conditions	50Ml/d scheme	100 Ml/d scheme	150Ml/d scheme	200 Ml/d scheme
Maximum daily temperature modelled	19.7°C	19.8°C	19.8°C	19.8°C	19.9°C
Greatest daily temperature difference	N/A	0.3°C	0.6°C	0.8°C	1.1°C

With respect to WFD, it is anticipated that 'High' WFD status for salmonid category rivers (20°C, 98%ile) will always be achieved with peak river temperatures estimated at 19.8°C - 19.9°C for Mogden water recycling scheme. This is with medium confidence, but with high confidence that the "Good" WFD status (23°C, 98%ile) will be achieved. It is noted that the 2019 WFD temperature status for this water body, as a whole, is listed by the Environment Agency as Moderate.

An analysis of extremes has been undertaken to support assessment of 3D modelling of discharge plume, through discussion with the Environment Agency. The Environment Agency has advised that a discharge plume of 2°C or more temperature uplift cannot occupy more than 25% of the cross-sectional area of the river for more than 2% of the time[14]. These conditions advised from permiting of thermal discharges, are advised by the Environment Agency as not definitive, but to be used to support a fisheries-led assessment of appropriate plume. A wider range of gauged river flows from the River Thames at Walton flow gauge, as described in the Gate 2 London Effluent Reuse scheme Annex B.2.1. Physical Environment Assessment Report, have been used to support this assessment. Analysis of modelled river water temperature at Walton Bridge verses measured river flow at Walton (Figure 4-3) indicates that the greatest temperature change occurs at lower river temperatures with smaller degrees of change seen at higher temperatures. At lowest flows (600 Ml/d) the Mogden water recycling scheme would discharge at River Thames temperatures of 16.9°C (mean) when discharged temperatures would be 3.0°C warmer. During the coldest river temperatures, the Mogden water recycling scheme would operate at times that would correspond moderate flows (780 Ml/d). The mean temperature difference between the tertiary treated water and the river temperature during (8.9°C) at these times is 6.1°C. Either of those conditions could describe the 2% exceedance statistic for a plume, and as such have been included in model parameterisation. At more typical flows (950 Ml/d) mean river temperatures during these times are 16.9°C. The mean temperature difference between the Mogden effluent and the river temperature during these times is 3.3°C.

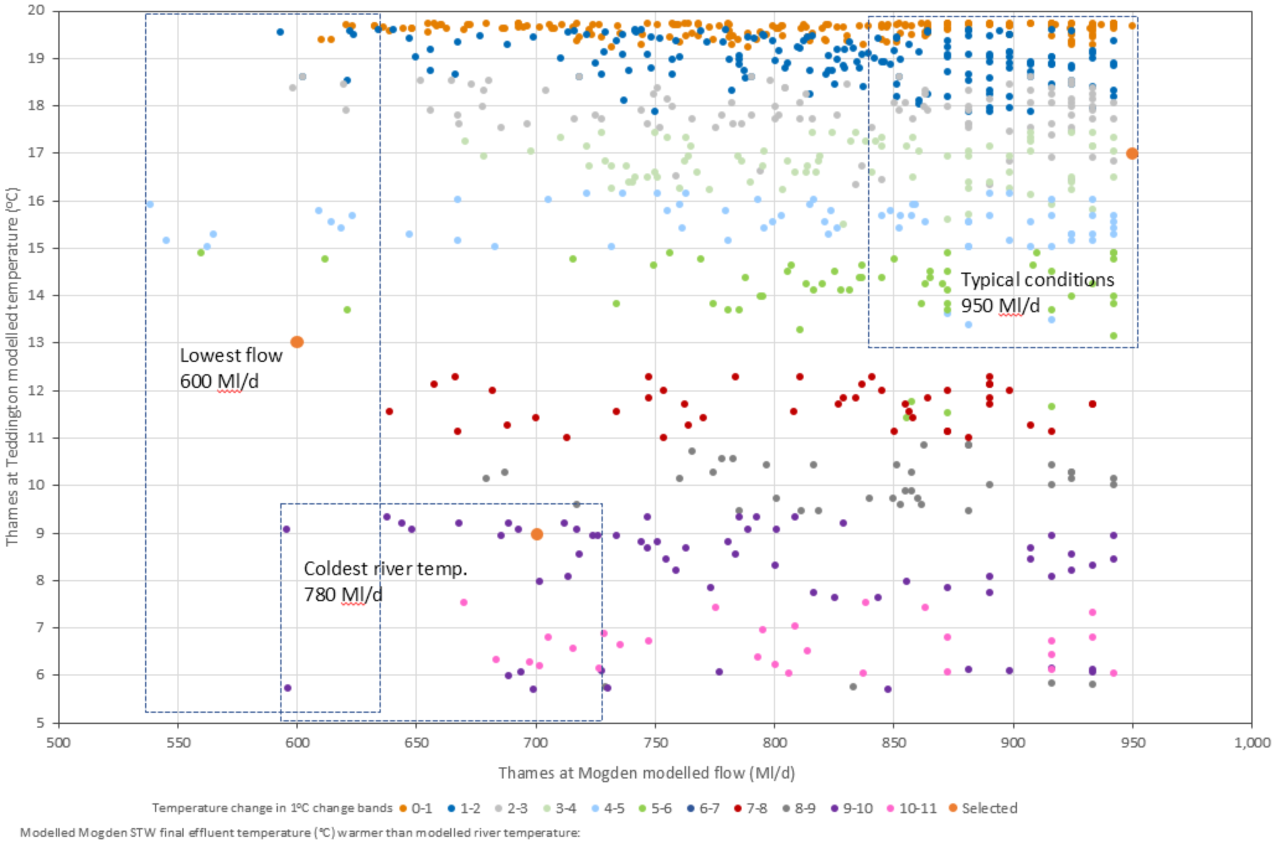
[14] 26 August 2021: NAU Gate 1 Environmental Comments

13 October 2021: Email clarification on 'Teddington temperature questions' Katy Steed (Environment Agency) to Rob Bromley (Thames Water (Jacobs).

13 October 2021: Deephams Reuse Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd

26 October 2021: London Reuse Temperature Workshop between Thames Water, Environment Agency and Ricardo.

Figure 4-3 Mogden water recycling modelled temperatures for River Thames at Walton Bridge against measured flow for River Thames at Walton flow gauge (truncated at 950 Ml/d)

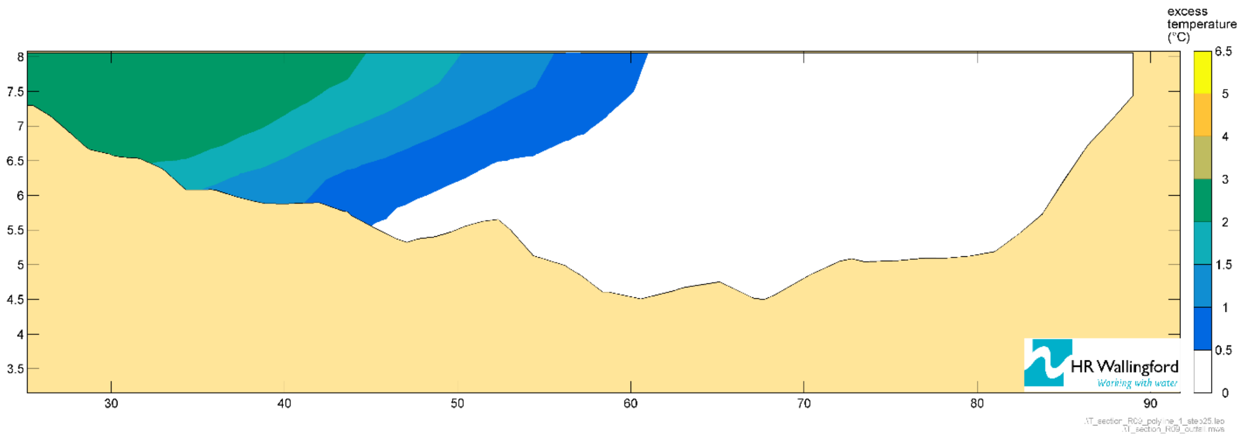


Temperature effects at the discharge location have been modelled by HRW. Modelling was undertaken for the 200 and 150 Ml/d discharge variants.

The first scenario presented is a 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow (Figure 4-4), discharge excess temperature of +3ºC. Plume extent for this scheme size and river flow are presented in Figure 4-4.

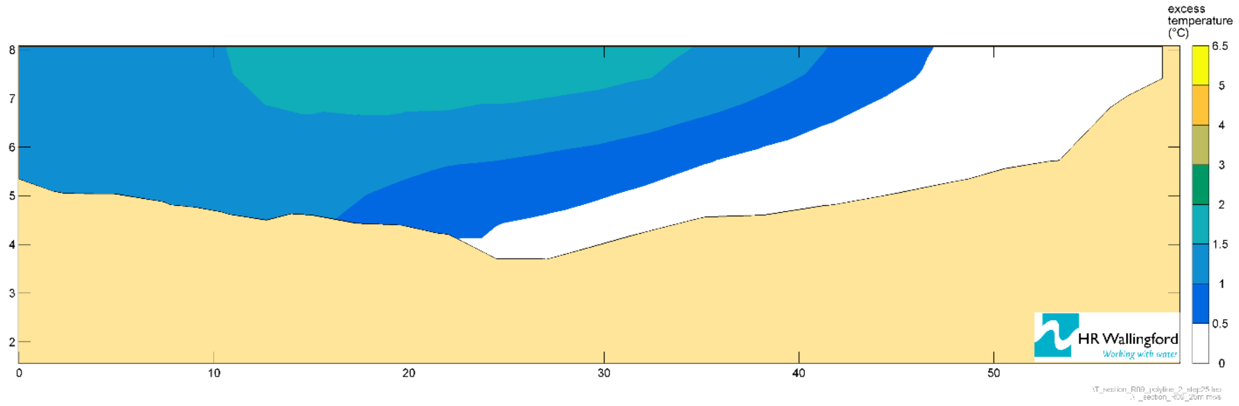
Figure 4-4 Temperature plume extent in River Thames downstream from discharge of 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow

Figure 4-5 Temperature change in River Thames at Outfall from discharge of 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow



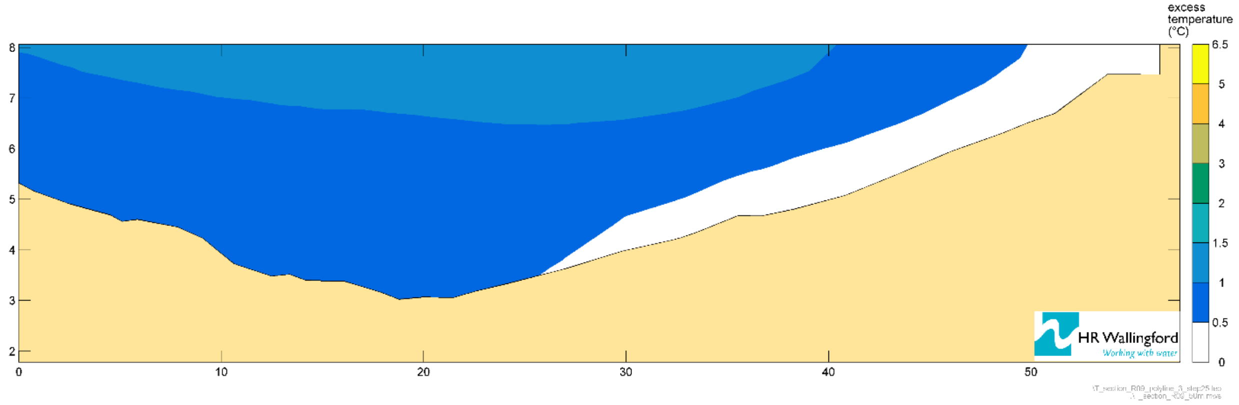
Under a 200 Ml/d Mogden water recycling scheme DRA at 600 Ml/d river flow at the outfall (Figure 4-5), 13.4% of the channel is affected by a temperature increase of >2.0^{o}C.

Figure 4-6 Temperature change in River Thames at 25m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow



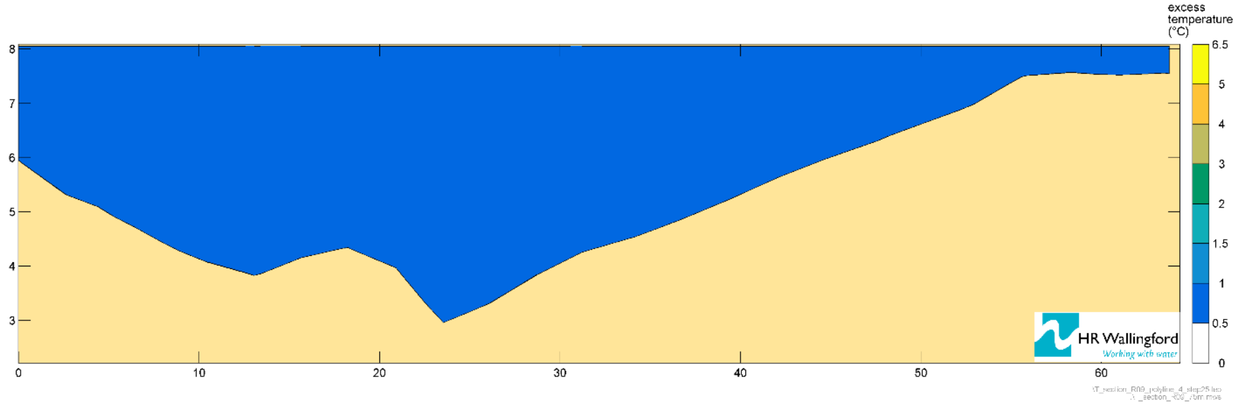
Under a 200 Ml/d Mogden water recycling scheme DRA at 600 Ml/d river flow 25m downstream of the outfall (Figure 4-6), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-7 Temperature change in River Thames at 50m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow



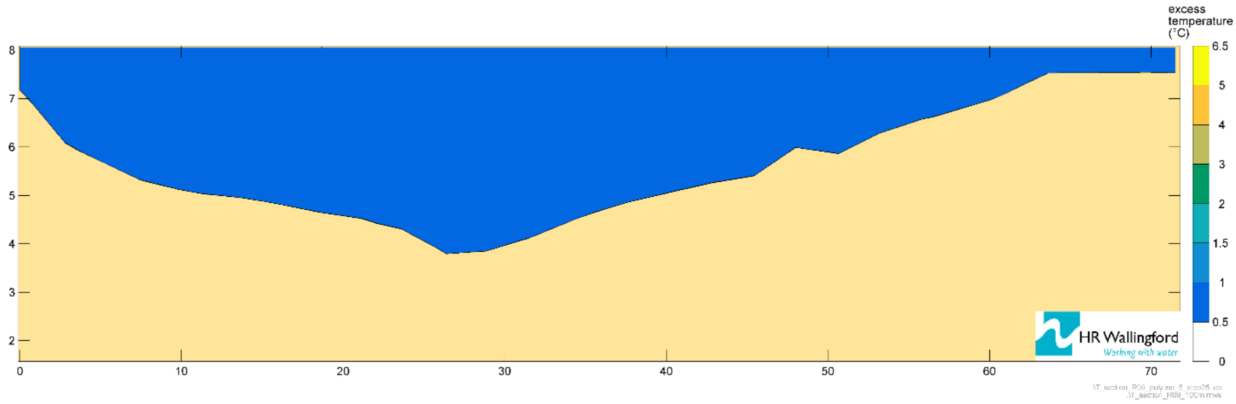
Under a 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow 50m downstream of the outfall (Figure 4-7), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-8 Temperature change in River Thames at 75m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow



Under a 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow 75m downstream of the outfall (Figure 4-8), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-9 Temperature change in River Thames at 100m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow



Under a 200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow 100m downstream of the outfall (Figure 4-9), 0% of the channel is affected by a temperature increase of >2.0°C.

Temperature remains in the same band to Sunbury Weir more than 1km downstream of outfall.

The second scenario presented is a 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow, discharge excess temperature of +6.1°C. Plume extent for this scheme size and river flow are presented in Figure 4-10.

Figure 4-10 Temperature plume extent in River Thames downstream from discharge of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow

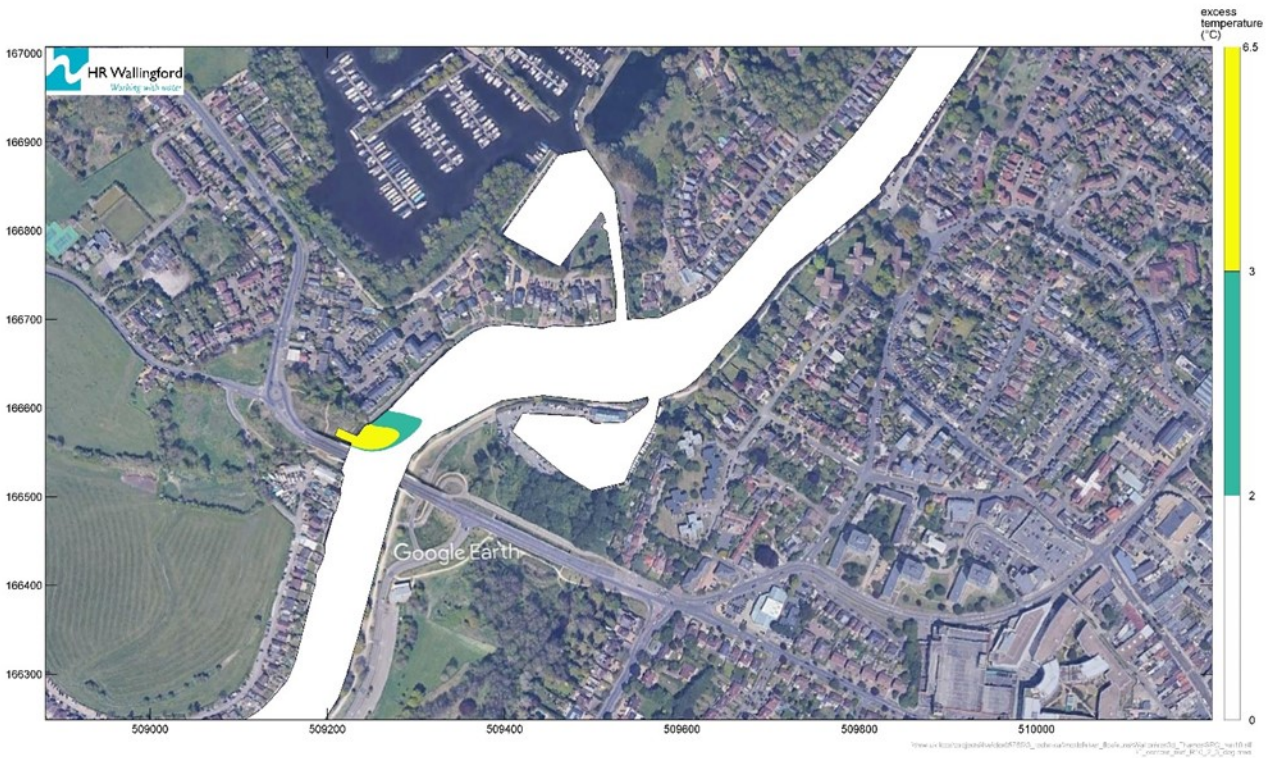
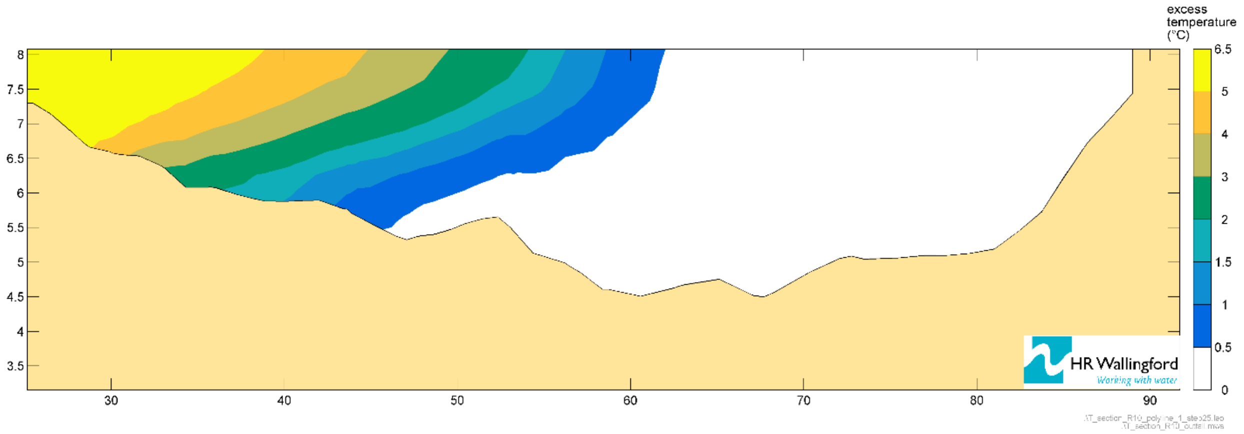
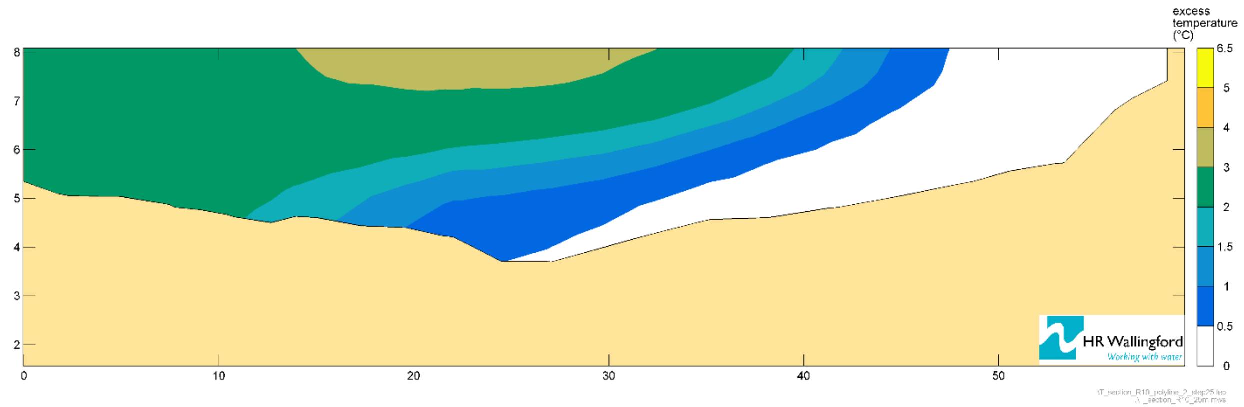


Figure 4-11 Temperature change in River Thames at outfall of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



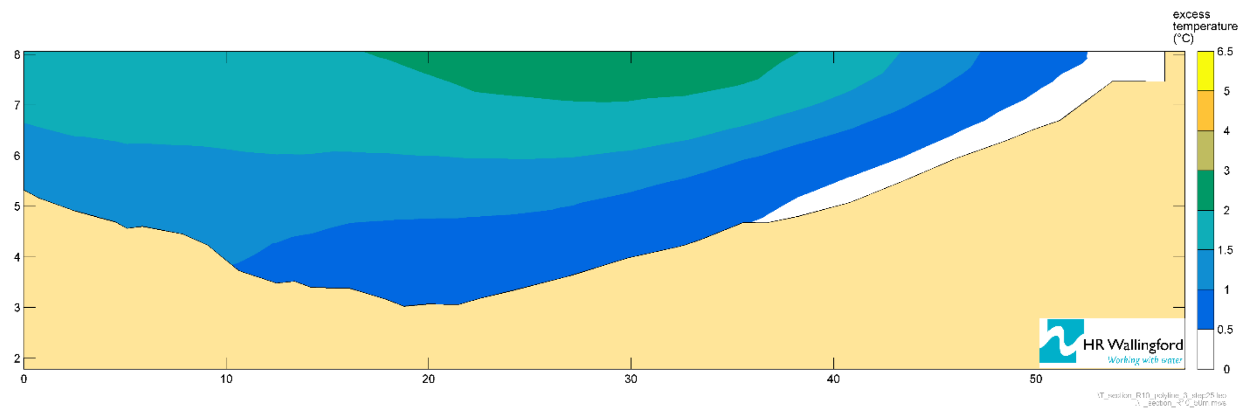
Under a 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow at the outfall (Figure 4-11), 24% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-12 Temperature change in River Thames at 25m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



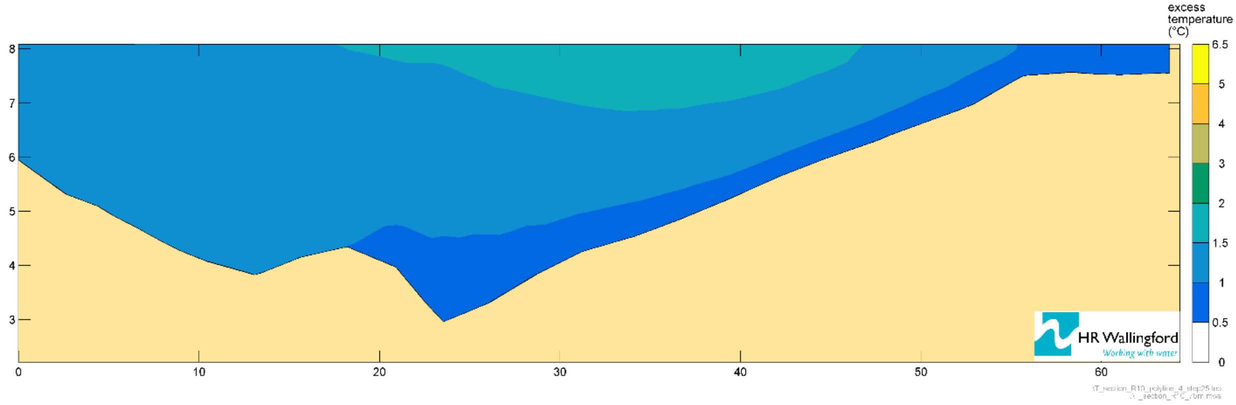
Under a 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 25m downstream of the outfall (Figure 4-12), 47.2% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-13 Temperature change in River Thames at 50m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



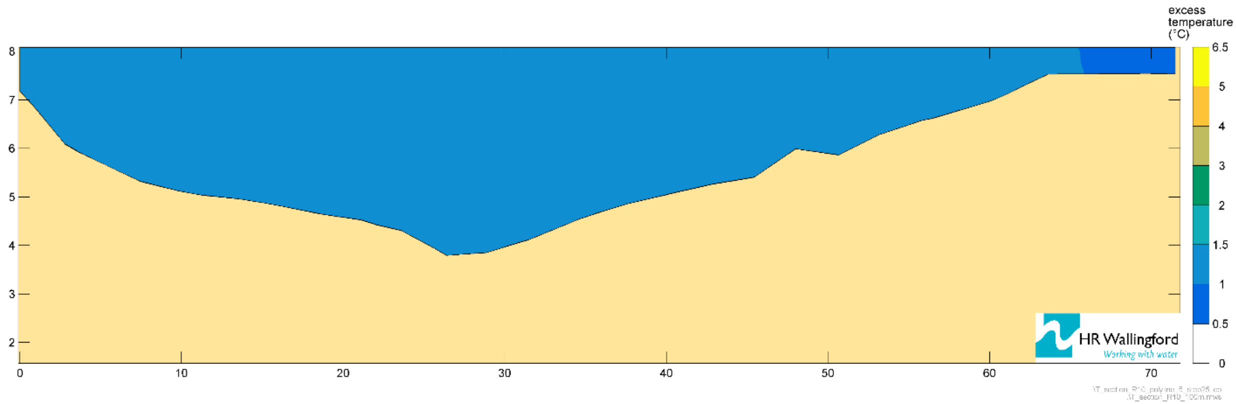
Under a 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 50m downstream of the outfall (Figure 4-13), 9.8% of the channel is affected by a temperature increase of >2.0ºC.

Figure 4-14 Temperature change in River Thames at 75m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



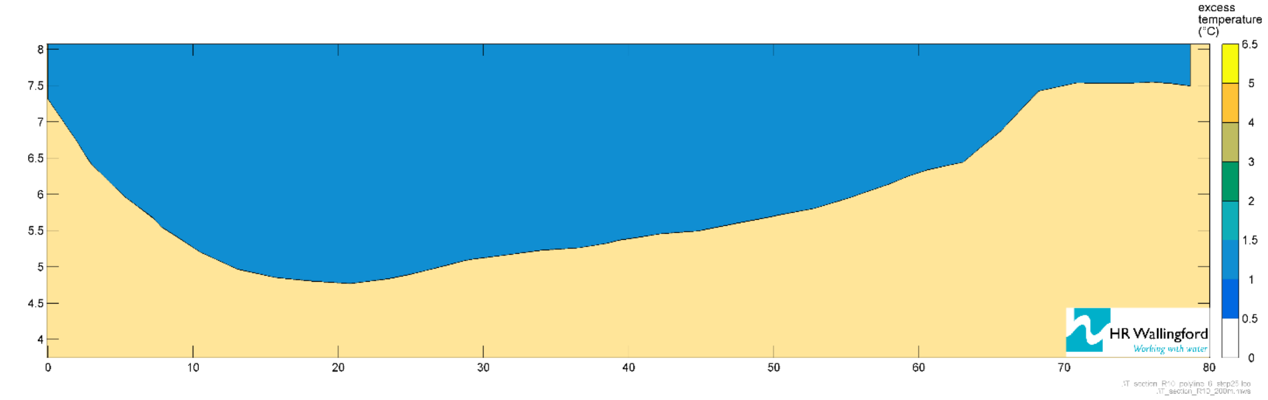
Under a 200 Ml/d Mogden water recycling scheme DRA at 780 Ml/d river flow 75m downstream of the outfall (Figure 4-14), 0% of the channel is affected by a temperature increase of >2.0ºC.

Figure 4-15 Temperature change in River Thames at 100m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



Under a 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 100m downstream of the outfall (Figure 4-15), 0% of the channel is affected by a temperature increase of >2.0ºC.

Figure 4-16 Temperature change in River Thames at 200m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



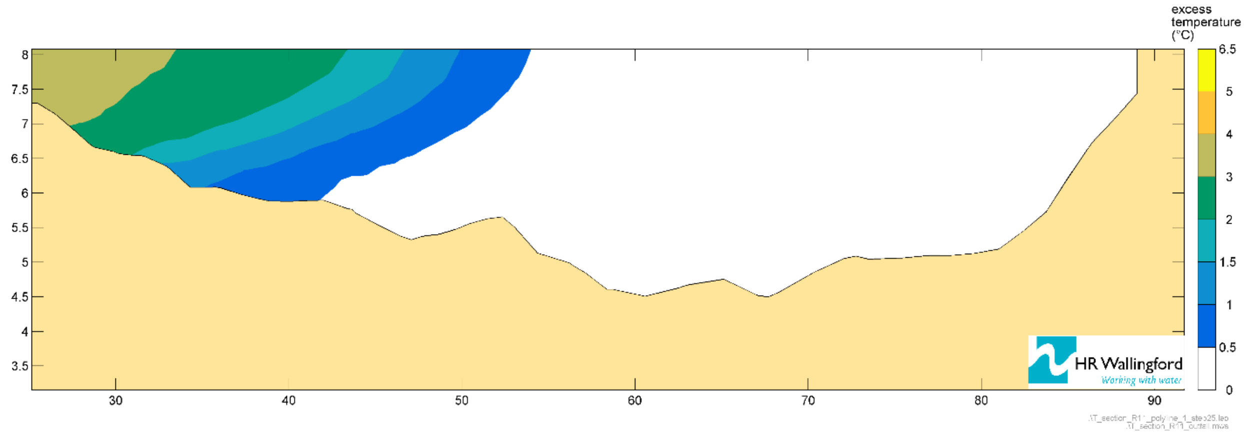
Under a 200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 200m downstream of the outfall (Figure 4-16), 0% of the channel is affected by a temperature increase of >2.0°C.

Temperature remains in the same band to Sunbury Weir more than 1km downstream of outfall.

The third scenario presented is a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow, discharge excess temperature of +3.3ºC. Plume extent for this scheme size and river flow are presented in Figure 4-17.

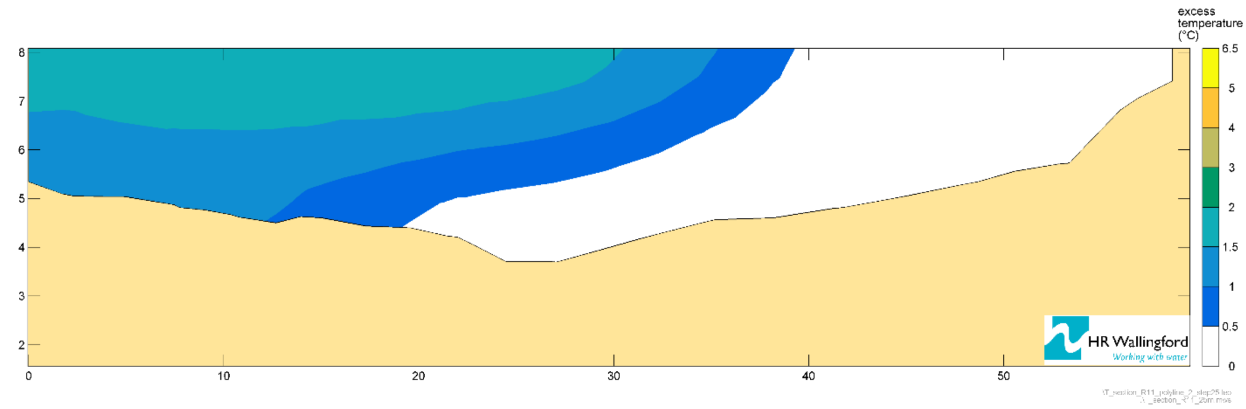
Figure 4-17 Temperature plume extent in River Thames downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow

Figure 4-18 Temperature change in River Thames at outfall of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



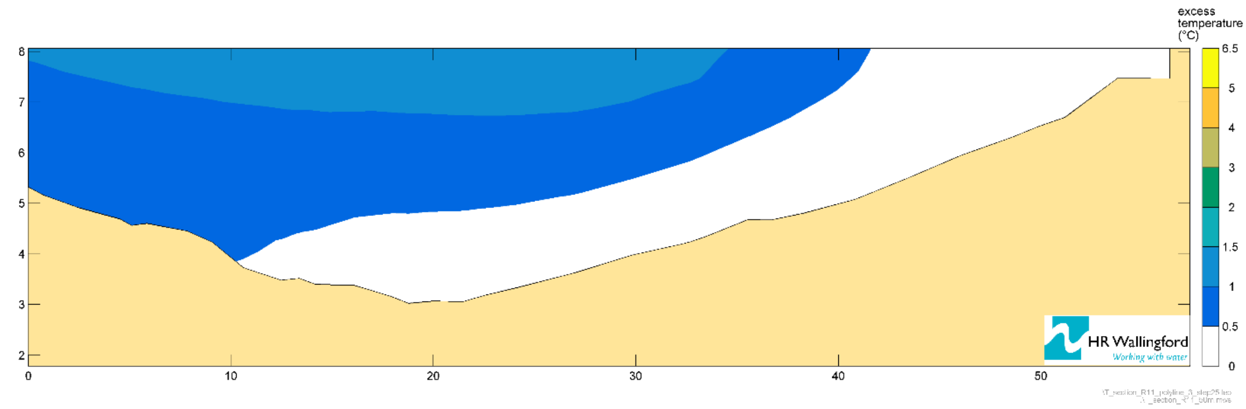
Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow at the outfall (Figure 4-18), 11.3% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-19 Temperature change in River Thames at 25m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



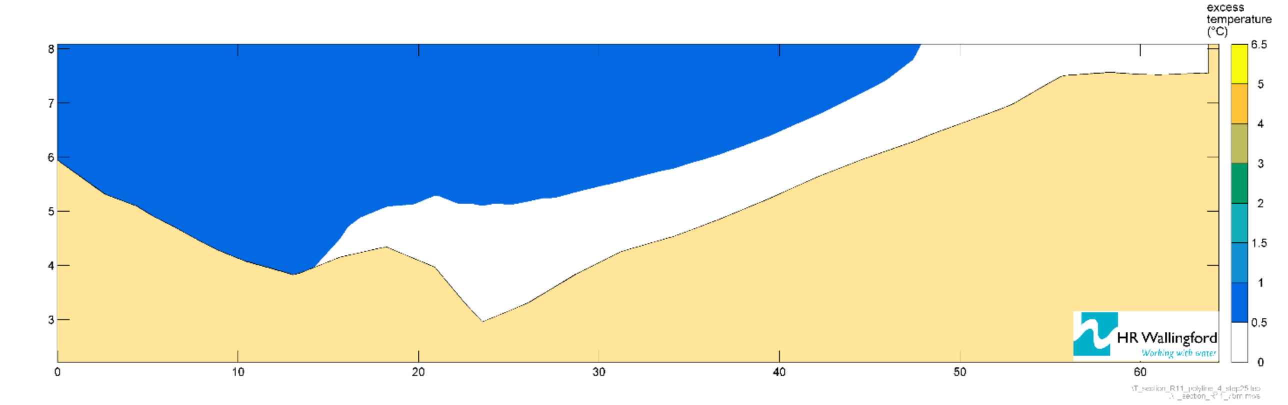
Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 25m downstream of the outfall (Figure 4-19), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-20 Temperature change in River Thames at 50m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



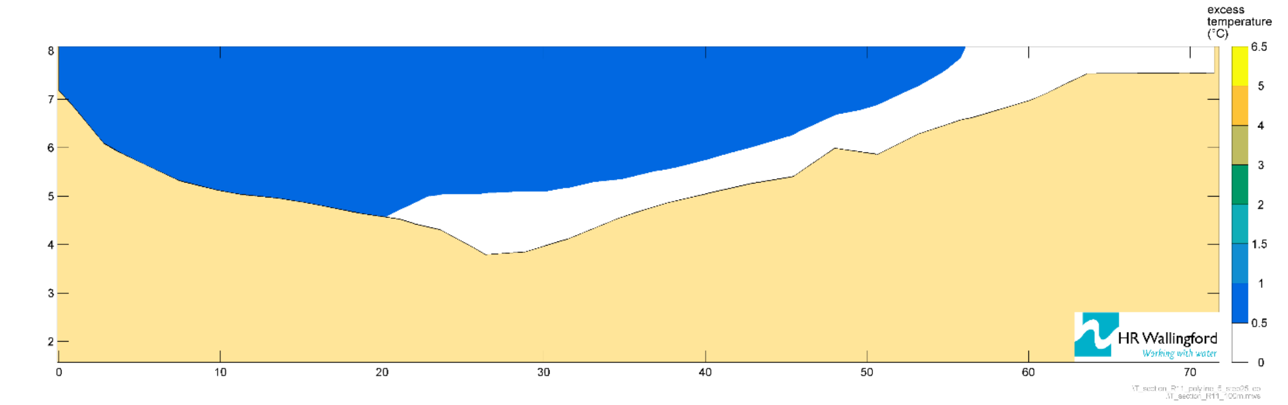
Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 50m downstream of the outfall (Figure 4-20), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-21 Temperature change in River Thames at 75m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



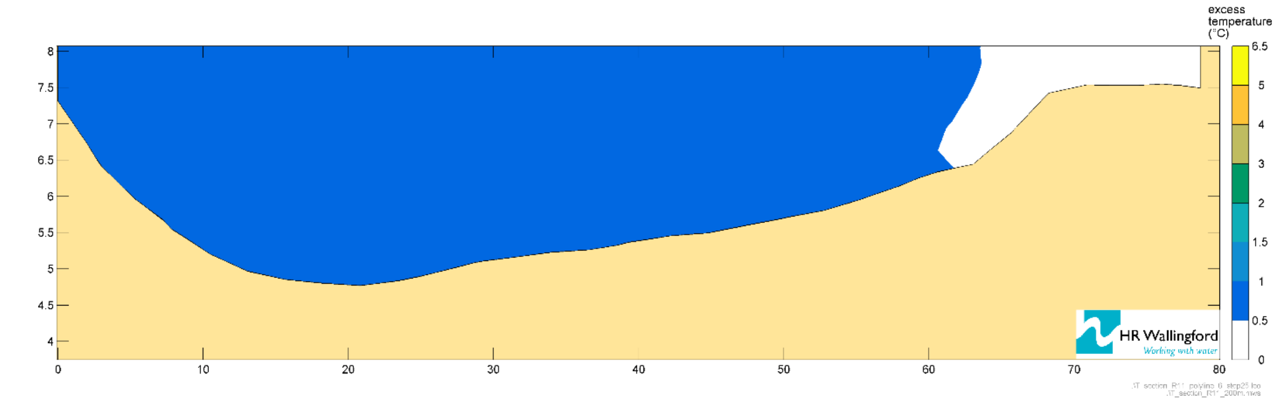
Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 75m downstream of the outfall (Figure 4-21), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-22 Temperature change in River Thames at 100m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



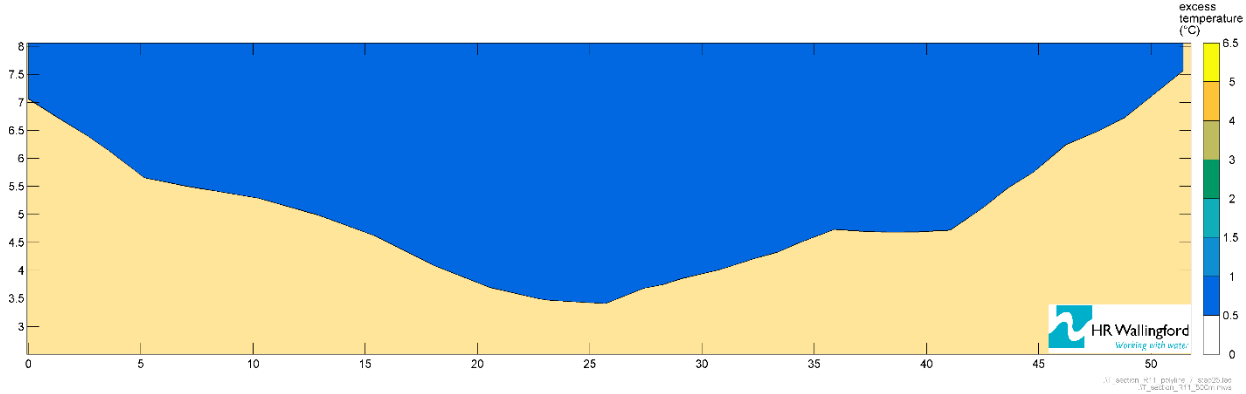
Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 100m downstream of the outfall (Figure 4-22), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-23 Temperature change in River Thames at 200m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



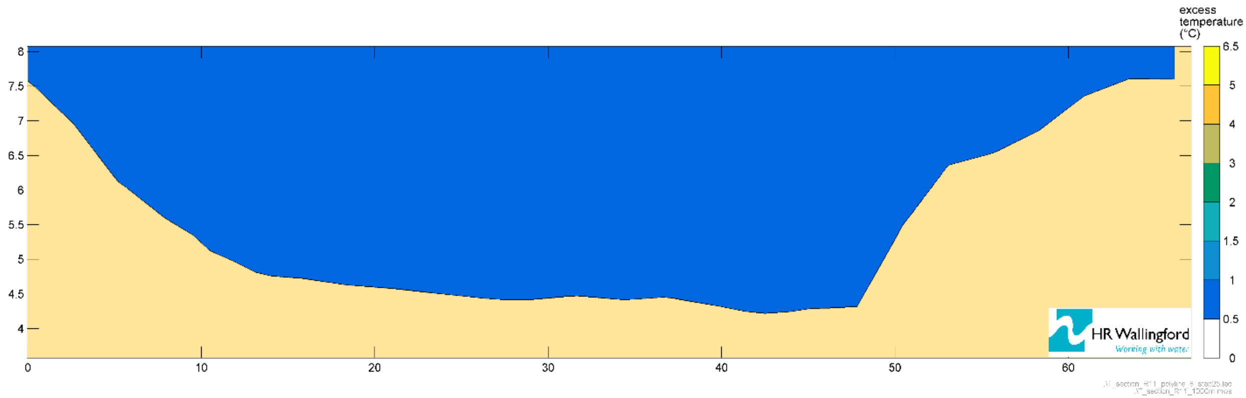
Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 200m downstream of the outfall (Figure 4-23), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-24 Temperature change in River Thames at 500m downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow



Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 500m downstream of the outfall (Figure 4-24), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-25 Temperature change in River Thames at 1Km downstream from discharge of 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow

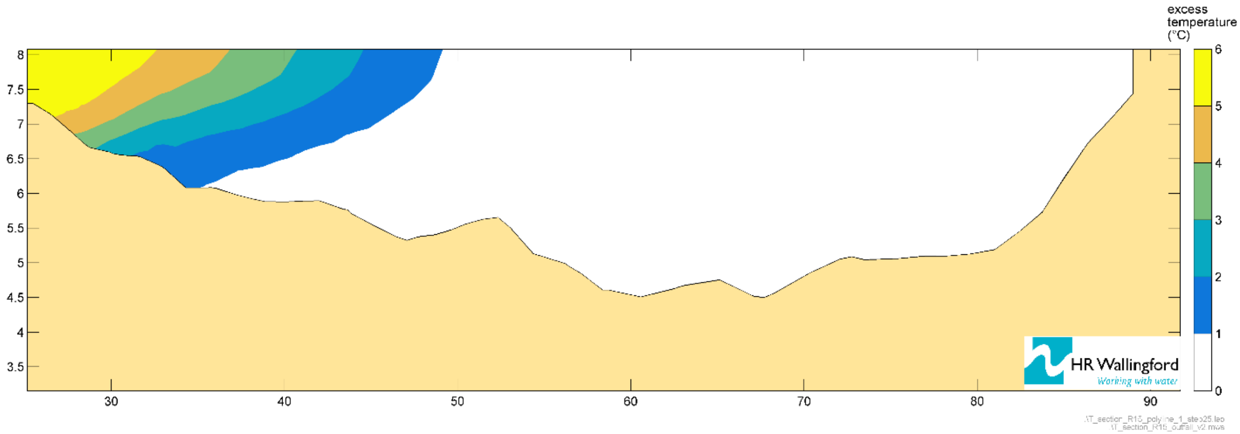


Under a 200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow 1km downstream of the outfall (Figure 4-25), 0% of the channel is affected by a temperature increase of >2.0°C.

Temperature remains in the same band to Sunbury Weir more than 1 km downstream of outfall.

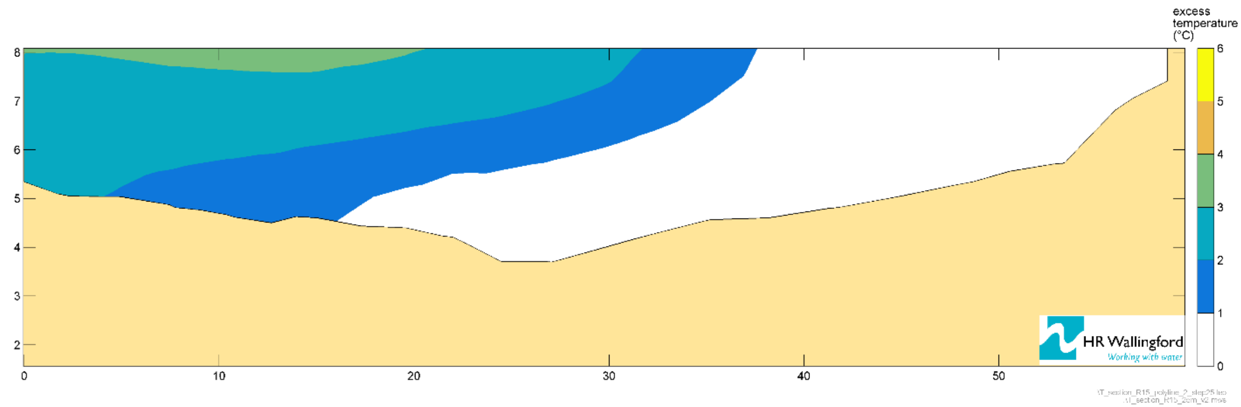
The fourth scenario presented is a 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow (Figure 4-26), discharge excess temperature of +6.1°C.

Figure 4-26 Temperature change in River Thames at outfall of 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



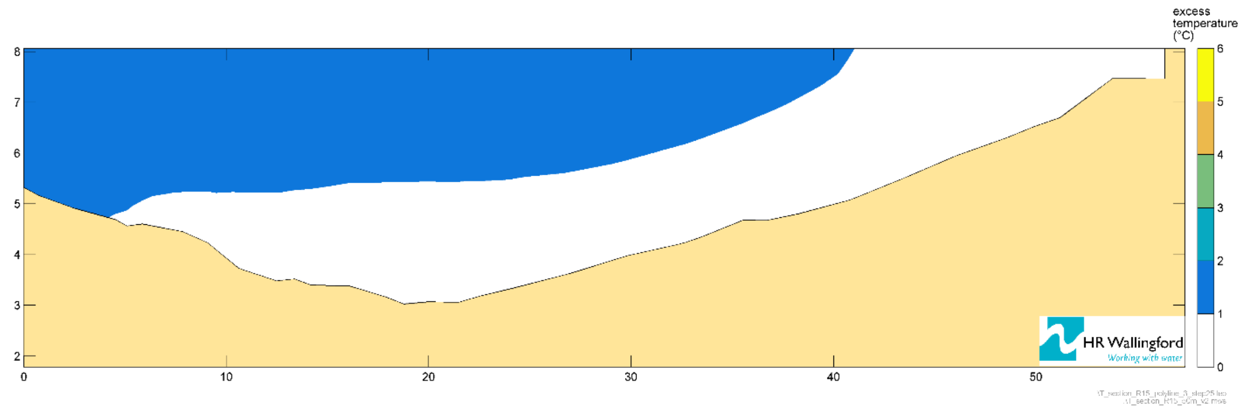
Under a 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow (Figure 4-26), 12.7% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-27 Temperature change in River Thames at 25m downstream of outfall of 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



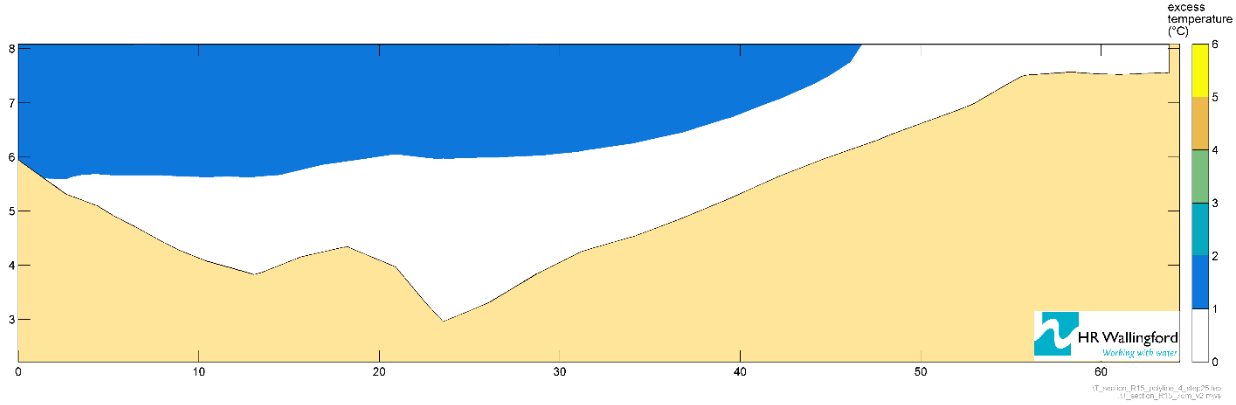
Under a 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 25m downstream of the outfall (Figure 4-27), 31.4% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-28 Temperature change in River Thames at 50m downstream of outfall of 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



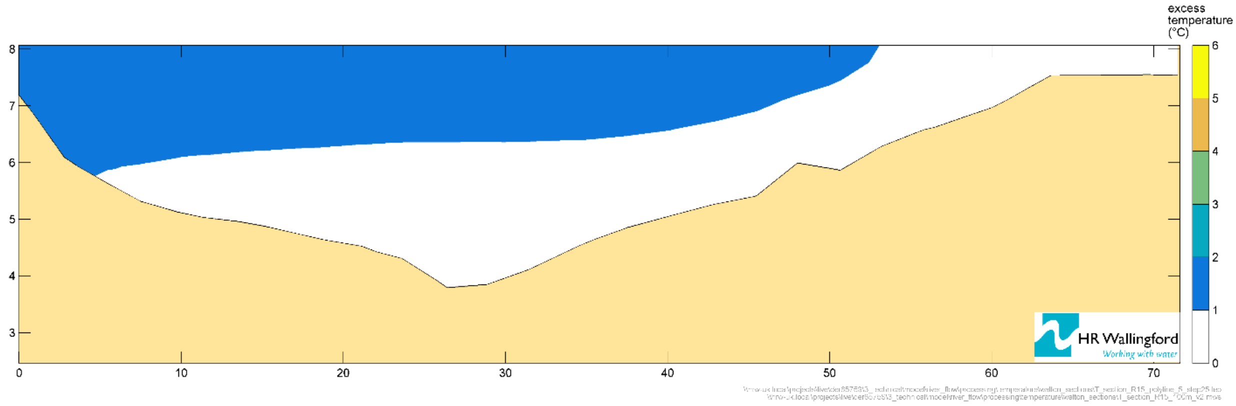
Under a 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 50m downstream of the outfall (Figure 4-28), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-29 Temperature change in River Thames at 75m downstream of outfall of 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



Under a 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 75m downstream of the outfall (Figure 4-29), 0% of the channel is affected by a temperature increase of >2.0°C.

Figure 4-30 Temperature change in River Thames at 100m downstream of outfall of 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow



Under a 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow 100m downstream of the outfall (Figure 4-30), 0% of the channel is affected by a temperature increase of >2.0°C.

Modelled outputs for downstream of the Mogden water recycling scheme discharge location indicate that any temperature effect will have dissipated by Molesey Weir. As such no onward temperature change is included in the assessment of temperature effects in the Thames Tideway.

4.3.3 Estuarine Thames Tideway

An assessment of the water temperature impacts in the estuarine Thames Tideway arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme. The model scenario has been parameterised with the modelled representation of the Mogden STW final effluent temperature and the modelled representation of the River Thames at Teddington temperature and the 1 in 5 (A82) / 1 in 20 (M96) rivers flow series and A82/M96 Mogden STW final effluent flow series.

Outputs from HR Wallingford's Upper Tideway model are presented below:

Figure 4-31 95th percentile temperature change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at A82 flow series

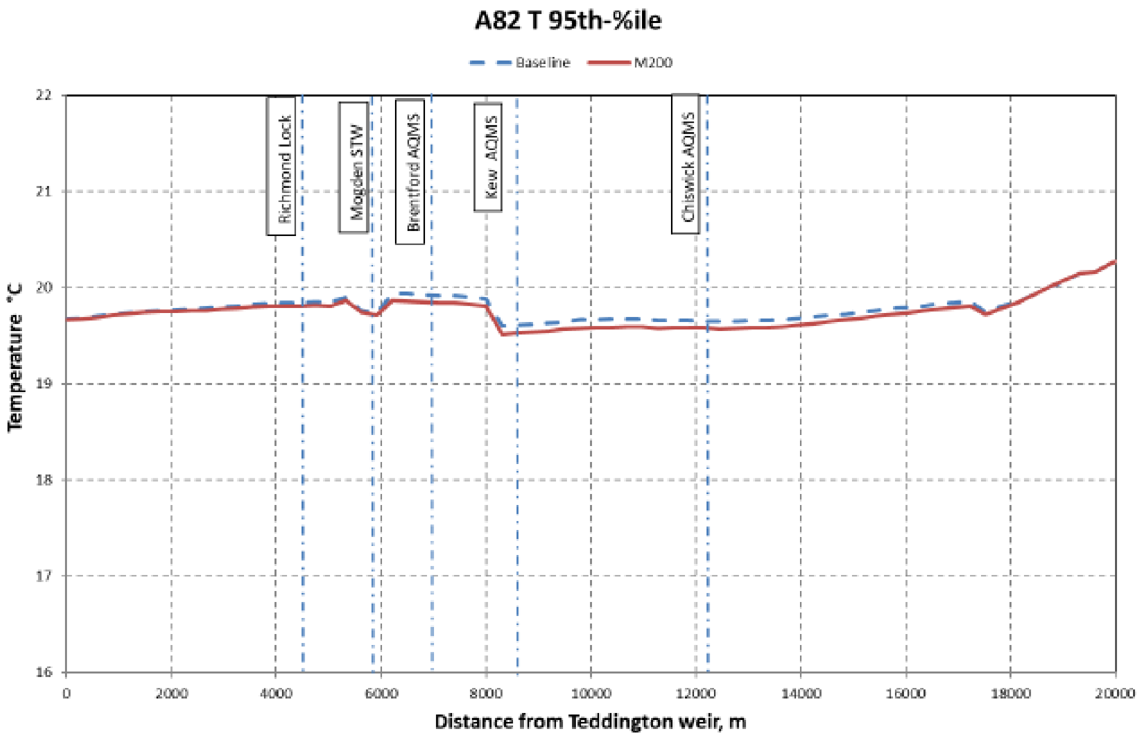
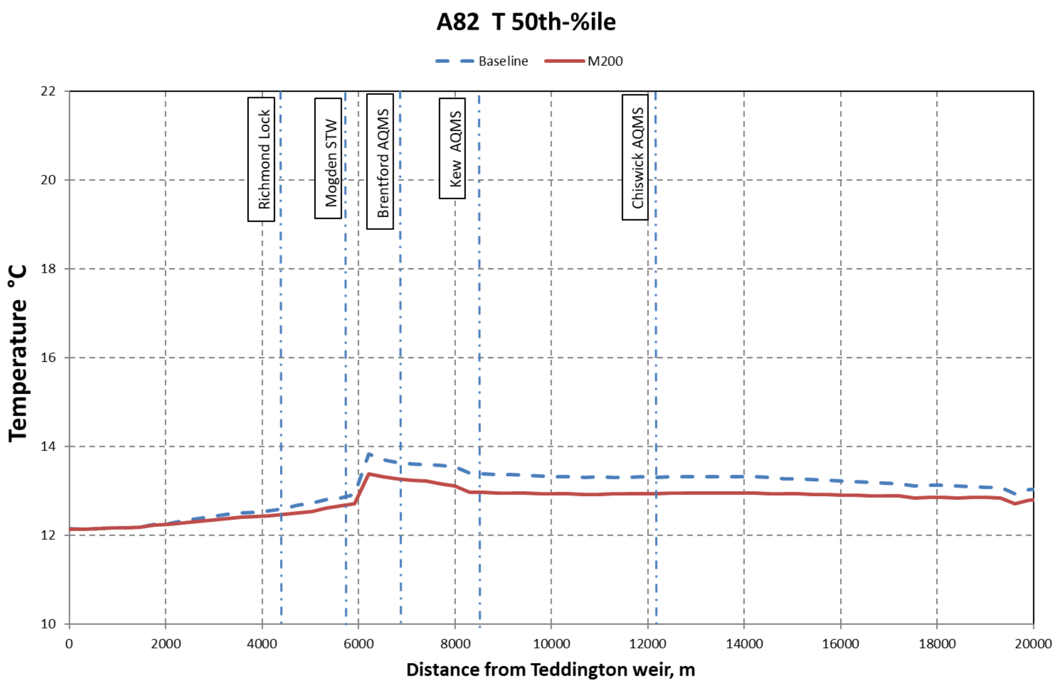


Figure 4-32 50th percentile temperature change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at A82 flow series



The modelled data displayed in Figure 4-31 and Figure 4-32 indicate that there is less warming in the upper Thames Tideway in areas associated with the Mogden STW outfall, due to less effluent in the watercourse at these locations. The graphs above display temperature changes modelled for the 200 Ml/d Mogden water recycling scheme and so represent the greatest temperature differences associated with the various scheme sizes at Mogden STW. Under both the 95th and 50th percentile this represents a difference in temperature of less than a degree.

Figure 4-33 95th percentile temperature change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at M96 flow series

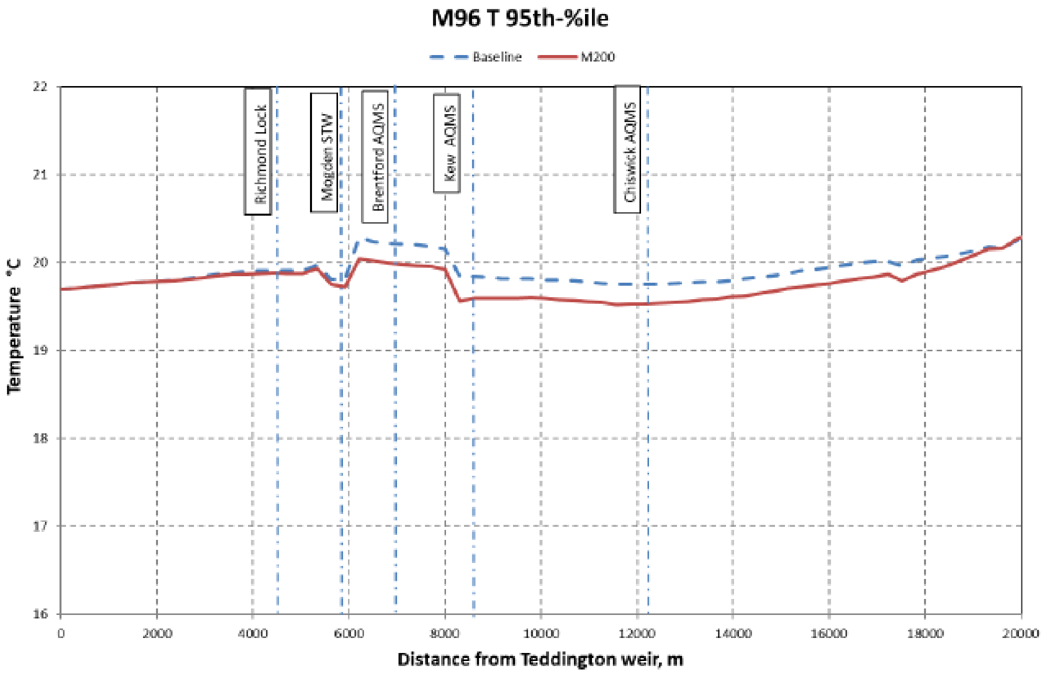
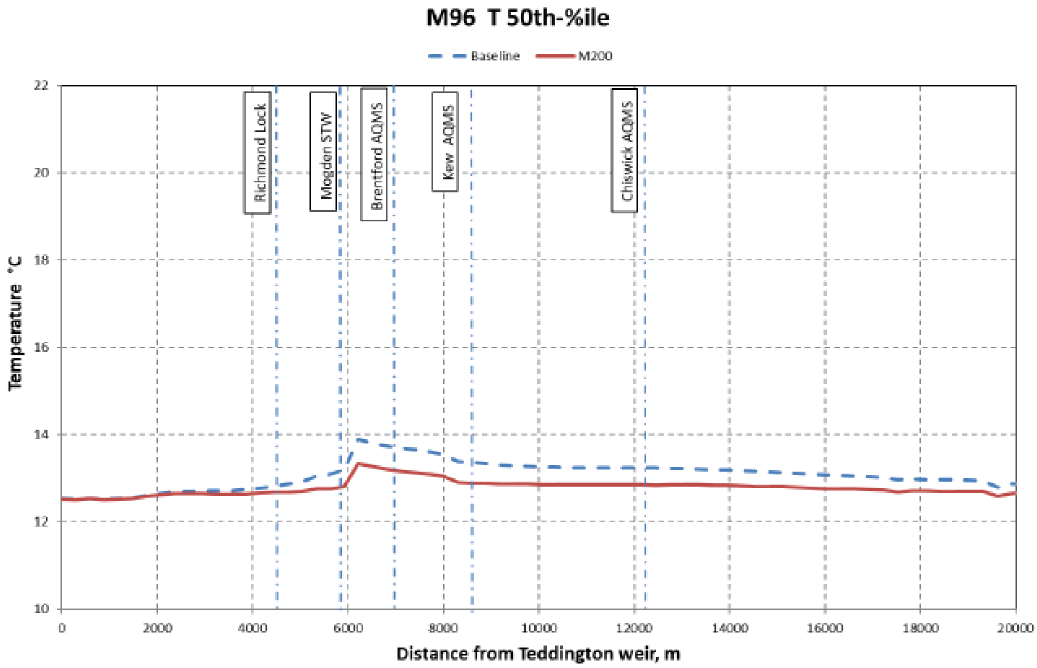


Figure 4-34 50th percentile temperature change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at M96 flow series



The modelled data displayed in Figure 4-33 and Figure 4-34 show a similar pattern to the temperature difference observed above under the A82 flow scenario. As above the graphs above display temperature changes modelled for the 200 Ml/d Mogden water recycling scheme and so represent the greatest temperature differences associated with the various scheme sizes. Under both the 95th and 50th percentile this represents a difference in temperature of approximately 1 °C.

4.4 GENERAL PHYSICO-CHEMICAL

4.4.1 Overview

This section sets out the change for the general physico-chemical parameters associated with the Mogden water recycling scheme. Assessments undertaken include:

- Freshwater River Thames – Section 4.4.2
- Estuarine Thames Tideway – Section 4.4.3

4.4.2 Freshwater River Thames

This section displays the data from the Atkins Infoworks modelling of the freshwater River Thames. Details of the modelling approach are provided in the Gate 2 Water Quality Evidence Report.

Ammoniacal nitrogen A82

Ammoniacal nitrogen exhibits a steady decline in concentrations from Mogden water recycling outfall until approx. At 6.6km upstream of Teddington Weir, downstream of the River Mole, where there is a step increase in concentrations across nearly all scenarios (Figure 4-35 and Table 4-4). This is modelled as related to the input from the River Mole. Concentrations then continue to decrease with increasing proximity to Teddington Weir. At the 90th percentile, ammoniacal nitrogen concentrations under the Mogden-200 scenario are lower than or equal to reference conditions from Mogden water recycling outfall to approx. 6.6km upstream of Teddington. Ammoniacal nitrogen under the Mogden-200 scenario briefly exceeds reference conditions from approx. 6.6km to 4km upstream of Teddington. Under the Mogden-200 scenario, ammoniacal nitrogen still falls within the 'moderate' banding for WFD water quality status except for the brief exceedance exhibited across both scenarios at approx. 6.6km upstream of Teddington. A similar pattern can be observed at both the 75th and 50th percentiles, with concentrations under the Mogden-200 scenario being either less than or equal to reference throughout most of the freshwater River Thames reach with slight exceedances. At the 25th percentile, concentrations under the Mogden-200 scenario exceed reference from approximately 9km-0km upstream of Teddington Weir.

Figure 4-35 Modelled ammoniacal nitrogen under the A82 Mogden-200 scenario compared with reference conditions in the freshwater River Thames reach

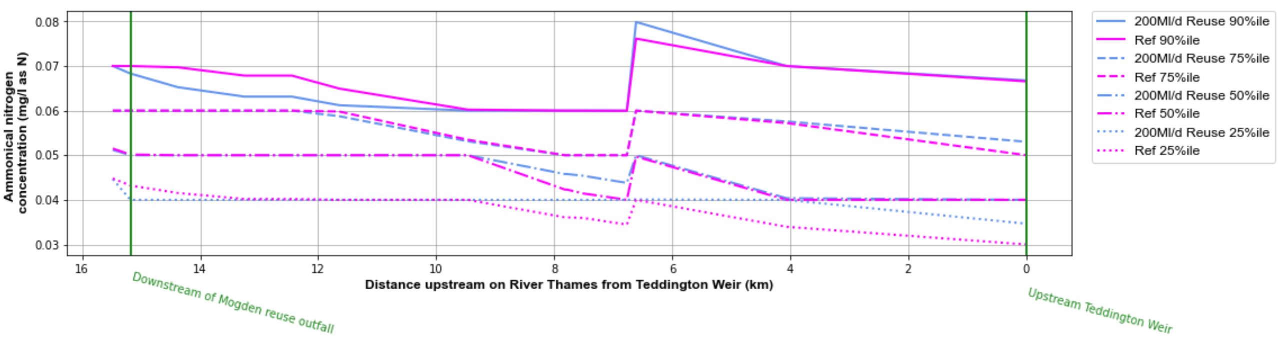


Table 4-4 Percentage change of modelled ammoniacal nitrogen under the A82 Mogden-200 scenario compared with reference at 14 nodes between Mogden water recycling outfall and Teddington Weir

Location (distances are upstream from Teddington weir)	25%ile	50%ile	75%ile	90%ile
Upstream Mogden water recycling Outfall (15 km)	-0.3	-0.6	0.0	0.0
Mogden water recycling Outfall (15 km)	-7.4	-0.3	0.0	-2.4
Downstream 1km Mogden water recycling Outfall (14 km)	-3.7	0.0	0.0	-6.4
Downstream 2km Mogden water recycling Outfall (13 km)	-0.5	0.0	0.0	-6.9
Downstream Sunbury Weir (12 km)	-0.5	0.0	0.0	-6.9

Location (distances are upstream from Teddington weir)	25%ile	50%ile	75%ile	90%ile
Downstream Walton Intake (11.6 km)	0.0	0.0	-1.7	-5.7
Downstream Hampton Intake (9.5 km)	0.0	0.0	-0.6	-0.4
Upstream Molesey Weir (7.8 km)	10.9	8.3	0.0	0.0
Downstream Molesey Weir (7.8 km)	10.9	8.3	0.0	0.0
Downstream of Molesey Lock (7.5 km)	11.2	9.6	0.0	0.0
Upstream of the River Mole (6.8 km)	16.1	9.5	0.0	0.1
Downstream of the River Mole (6.6 km)	0.2	0.6	0.0	4.9
Upstream Hogsmill River (4 km)	17.8	0.9	0.6	0.0
Teddington Weir (0 km)	15.5	8.0	6.0	0.3

<u>Ammoniacal nitrogen M96</u>

Ammoniacal nitrogen exhibits a general downward trend in concentrations from the Mogden Reuse outfall to approx. 6.6km upstream of Teddington Weir (Table 4-5). At the 6.6km mark, downstream of the convergence with the River Mole, there is a clear spike in concentrations which is consistent between reference conditions and Mogden-200. Following this spike, concentrations of ammoniacal nitrogen gradually decrease with increasing proximity to Teddington Weir. The spike is not observed at the 50th percentile. At the 90th percentile, concentrations of ammoniacal nitrogen under the Mogden-200 scenario are either lower than or equal to reference conditions, representing a slight reduction of pressure. Under the Mogden-200 scenario, ammoniacal nitrogen still falls within the 'moderate' banding for WFD water quality status. A similar pattern is observed at the 75th percentile with concentrations of ammoniacal nitrogen generally being lower under the Mogden-200 scenario compared with reference conditions. At the 50th and 25th percentiles, the data shows a slightly different pattern in which Mogden-200 is lower than or equal to reference until approx. 6.6km upstream of Teddington Weir. From this point onwards, Mogden-200 exhibits slightly higher concentrations of ammoniacal nitrogen than reference.

Table 4-5 Percentage change of modelled ammoniacal nitrogen under the M96 Mogden-200 scenario compared with reference at 13 nodes between Mogden Reuse outfall and Teddington Weir.

Location (distances are upstream from Teddington weir)		90%ile	75%ile	50%ile	25%ile
Upstream Mogden water recycling Outfall (15 km)	0.0	0.0	0.0		0.0
Mogden water recycling Outfall (15 km)	-6.6	0.0	-1.1		-4.2
Downstream 1km Mogden water recycling Outfall (14 km)	-8.0	-7.4	-9.5		-10.1
Downstream 2km Mogden water recycling Outfall (13 km)	-8.7	-9.3	-5.7		-8.3
Downstream Sunbury Weir (12 km)	-8.7	-9.3	-5.7		-8.3
Downstream Walton Intake (11.6 km)	-7.3	-1.2	-1.7		-6.4
Downstream Hampton Intake (9.5 km)	0.0	-1.2	0.0		-2.6
Upstream Molesey Weir (7.8 km)	0.0	-5.7	0.0		0.0
Downstream Molesey Weir (7.8 km)	0.0	-5.7	0.0		0.0
Downstream of Molesey Lock (7.5 km)	-5.2	-4.7	0.0		0.0
Upstream of the River Mole (6.8 km)	-4.5	-2.7	0.0		0.0
Downstream of the River Mole (6.6 km)	-8.0	-1.4	0.0		1.6
Upstream Hogsmill River (4 km)	-2.2	-3.9	5.8		2.1
Teddington Weir (0 km)	-3.8	-2.2	-6.2		0.0

Oxygen saturation A82

Oxygen saturation is relatively stable in the 2km immediately downstream of Mogden water recycling outfall. Oxygen saturation increases from this point to approx. 7.8km upstream of Teddington Weir, before stabilising again. At approx. 7.8km upstream of Teddington Weir, upstream of Moseley Weir, there is a sharp increase in oxygen saturation under all scenarios (Figure 4-36 and Table 4-6). At the 75th percentile, oxygen saturation is consistently slightly greater under the Mogden-200 scenario compared with reference conditions. There is no change in the WFD water quality status for oxygen saturation between reference and Mogden-200, with values remaining above the threshold for the 'high' banding (80%). A similar pattern is observed at the 50th, 25th and 10th percentiles in which oxygen saturation is consistently greater under the Mogden-200 scenario compared with reference conditions with the greatest increase observed at the 50th percentile. Across all percentiles the greatest difference between Mogden-200 and reference is observed immediately downstream of Mogden water recycling outfall, with values becoming more consistent between scenarios towards Teddington Weir. This increase in oxygen saturation represents a reduction in pressure between Mogden water recycling outfall and Teddington Weir.

Figure 4-36 Modelled oxygen saturation under the A82 Mogden-200 scenario compared with reference conditions in the freshwater River Thames reach

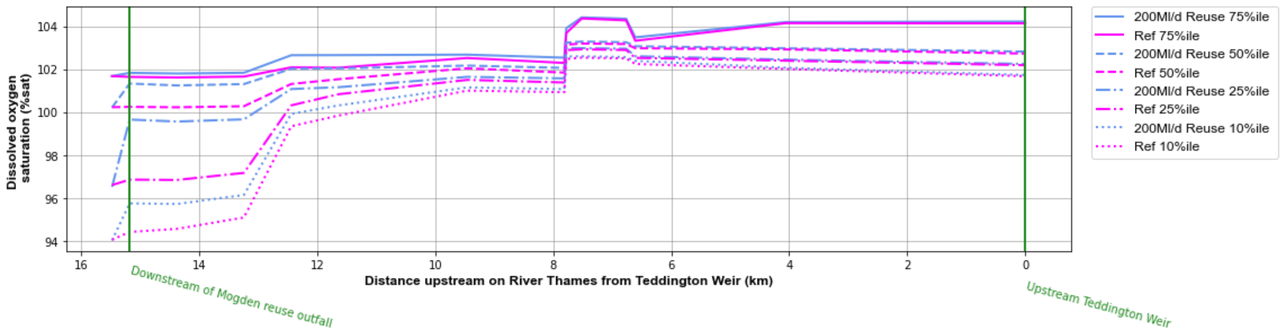


Table 4-6 Percentage change of modelled oxygen saturation under the A82 Mogden-200 scenario compared with reference at 14 nodes between Mogden water recycling outfall and Teddington Weir

Location (distances are upstream from Teddington weir)	25%ile	50%ile	75%ile	10%ile
Upstream Mogden water recycling Outfall (15 km)	-0.1	0.0	0.0	0.0
Mogden water recycling Outfall (15 km)	2.9	1.1	0.2	1.4
Downstream 1km Mogden water recycling Outfall (14 km)	2.8	1.0	0.2	1.2
Downstream 2km Mogden water recycling Outfall (13 km)	2.6	1.0	0.2	1.1
Downstream Sunbury Weir (12 km)	0.8	0.7	0.6	0.6
Downstream Walton Intake (11.6 km)	0.3	0.6	0.6	0.5
Downstream Hampton Intake (9.5 km)	0.1	0.1	0.2	0.2
Upstream Molesey Weir (7.8 km)	0.2	0.2	0.2	0.1
Downstream Molesey Weir (7.8 km)	0.1	0.1	0.2	0.1
Downstream of Molesey Lock (7.5 km)	0.1	0.1	0.1	0.1
Upstream of the River Mole (6.8 km)	0.1	0.1	0.1	0.1
Downstream of the River Mole (6.6 km)	0.1	0.1	0.2	0.1
Upstream Hogsmill River (4 km)	0.1	0.1	0.1	0.1
Teddington Weir (0 km)	0.1	0.1	0.1	0.1

Oxygen saturation M96

Oxygen saturation is relatively stable in the 2km immediately downstream of Mogden Reuse outfall (Table 4-7). Oxygen saturation increases from this point to approx 12.4km upstream of Teddington Weir, where it becomes stable again. At approx 7.8km upstream of Teddington Weir, upstream of Moseley Weir, there is a sharp spike in oxygen saturation under reference conditions and Mogden-200. This is followed by a plateau and decrease in oxygen saturation before becoming slightly more stable in the 6km upstream of Teddington Weir. At the 90th percentile, oxygen saturation is consistently greater under the Mogden-200 scenario than under reference conditions. There is no change in the WFD water quality status for oxygen saturation between reference and Mogden-200, with values remaining above the threshold for the 'high' banding (80%). A similar pattern is observed at the 75th, 50th and 25th percentile in which oxygen saturation is consistely greater under the Mogden-200 scenario than under reference conditions. This increase in oxygen saturation represents a reduction in pressure between Mogden Reuse outfall and Teddington Weir.

Table 4-7 Percentage change of modelled oxygen saturation under the M96 Mogden-200 scenario compared with reference at 14 nodes between Mogden water recycling outfall and Teddington Weir

Location (distances are upstream from Teddington weir)	25%ile	50%ile	75%ile	90%ile
Upstream Mogden water recycling Outfall (15 km)	0%	0%	0%	0%
Mogden water recycling Outfall (15 km)	-2%	0%	0%	1%
Downstream 1km Mogden water recycling Outfall (14 km)	-2%	0%	1%	1%
Downstream 2km Mogden water recycling Outfall (13 km)	-2%	0%	1%	1%
Downstream Sunbury Weir (12 km)	0%	1%	1%	1%
Downstream Walton Intake (11.6 km)	0%	1%	1%	1%
Downstream Hampton Intake (9.5 km)	1%	1%	1%	1%
Upstream Molesey Weir (7.8 km)	1%	1%	1%	1%
Downstream Molesey Weir (7.8 km)	1%	1%	1%	1%
Downstream of Molesey Lock (7.5 km)	1%	1%	1%	1%
Upstream of the River Mole (6.8 km)	1%	1%	1%	1%
Downstream of the River Mole (6.6 km)	1%	1%	1%	1%
Upstream Hogsmill River (4 km)	1%	1%	1%	1%
Teddington Weir (0 km)	1%	1%	1%	1%

Total phosphorous A82

Concentrations of total phosphorous are relatively consistent throughout the freshwater River Thames reach with a step increase observed across all scenarios at approx. 6.6km upstream of Teddington Weir, downstream of the River Mole (Figure 4-37 and Table 4-8). At the 75th and 50th percentiles, total phosphorous concentrations are considerably lower under the Mogden-200 scenario compared with reference conditions, representing a slight reduction in pressure. At the 25th percentile, Mogden-200 exhibits lower concentrations than reference from Mogden water recycling outfall until approx. 6.6km upstream of Teddington where concentrations become consistent across both scenarios.

Figure 4-37 Modelled total phosphorous under the A82 Mogden-200 scenario compared with reference conditions in the freshwater River Thames reach

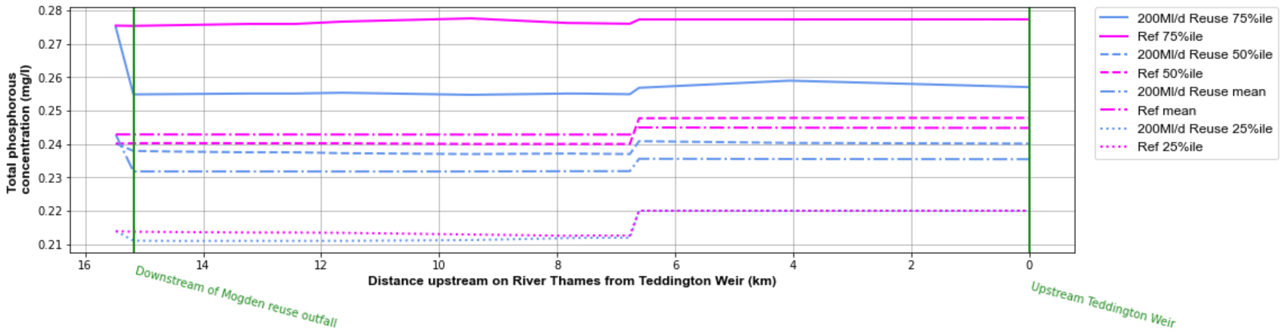


Table 4-8 Percentage change of modelled total phosphorous under the A82 Mogden-200 scenario compared with reference at 14 nodes between Mogden water recycling outfall and Teddington Weir

Location (distances are upstream from Teddington weir)	25%ile	50%ile	75%ile	Mean
Upstream Mogden water recycling Outfall (15 km)	0.1	0.0	-0.2	0.0
Mogden water recycling Outfall (15 km)	-1.3	-1.0	-7.5	-4.6
Downstream 1km Mogden water recycling Outfall (14 km)	-1.2	-1.1	-7.5	-4.6
Downstream 2km Mogden water recycling Outfall (13 km)	-1.2	-1.1	-7.6	-4.6
Downstream Sunbury Weir (12 km)	-1.2	-1.1	-7.6	-4.6
Downstream Walton Intake (11.6 km)	-1.1	-1.2	-7.7	-4.6
Downstream Hampton Intake (9.5 km)	-0.8	-1.3	-8.3	-4.5
Upstream Molesey Weir (7.8 km)	-0.3	-1.2	-7.7	-4.5
Downstream Molesey Weir (7.8 km)	-0.3	-1.2	-7.7	-4.5
Downstream of Molesey Lock (7.5 km)	-0.3	-1.2	-7.7	-4.5
Upstream of the River Mole (6.8 km)	-0.3	-1.3	-7.7	-4.5
Downstream of the River Mole (6.6 km)	0.0	-2.8	-7.4	-3.8
Upstream Hogsmill River (4 km)	0.0	-3.0	-6.6	-3.8
Teddington Weir (0 km)	0.0	-3.1	-7.3	-3.8

Total phosphorous M96

Phosphorous exhibits relatively consistent concentrations from Mogden Reuse outfall to Teddington Weir under reference conditions (Table 4-9). Under the Mogden-200 scenario there is slightly more variability in concentrations with an initial decrease immediately downstream of Mogden Reuse outfall and a further decrease from approx. 4km upstream of Teddington Weir. A small increase or decrease is observed under reference conditions and the Mogden-200 scenario at approx 6.6km upstream of Teddington Weir, downstream of the convergence with the River Mole. At the 90th percentile, phosphorous concentrations are consistently lower under the Mogden-200 scenario than under reference conditions. The same pattern is observed at the 75th, 50th and 25th percentile in which phosphorous concentrations are consistently lower under the Mogden-200 scenario compared with reference conditions. This represents a reduction in pressure at all nodes between Mogden Reuse outfall and Teddington Weir.

Table 4-9 Percentage change of modelled phosphorous under the M96 Mogden-200 scenario compared with reference at 13 nodes between Mogden Reuse outfall and Teddington Weir.

Location (distances are upstream from Teddington weir)	90%ile	75%ile	50%ile	Mean
Upstream Mogden water recycling Outfall (15 km)	0.0	0.0	0.0	0.0
Mogden water recycling Outfall (15 km)	-12.5	-8.9	-6.3	-3.2
Downstream 1km Mogden water recycling Outfall (14 km)	-17.8	-14.2	-10.1	-4.5
Downstream 2km Mogden water recycling Outfall (13 km)	-17.7	-14.6	-10.0	-4.5
Downstream Sunbury Weir (12 km)	-17.7	-14.6	-10.0	-4.5
Downstream Walton Intake (11.6 km)	-17.7	-14.4	-9.9	-4.6
Downstream Hampton Intake (9.5 km)	-17.5	-14.2	-9.9	-4.6
Upstream Molesey Weir (7.8 km)	-17.6	-13.7	-9.9	-4.6
Downstream Molesey Weir (7.8 km)	-17.6	-13.7	-10.0	-4.5
Downstream of Molesey Lock (7.5 km)	-17.7	-13.7	-9.9	-4.4
Upstream of the River Mole (6.8 km)	-17.7	-13.7	-9.9	-4.4
Downstream of the River Mole (6.6 km)	-16.2	-13.3	-9.7	-3.7
Upstream Hogsmill River (4 km)	-16.3	-13.4	-9.8	-3.6
Teddington Weir (0 km)	-23.3	-19.8	-13.5	-6.8

Acid neutralising capacity

Acid neutralising capacity (ANC) has been calculated using a charge balance approach using estimated data from recycled water discharge and measured EA in-river spot data. Daily time-step mass balance (Figure 4-38, Figure 4-39) shows that minimum ANC under the A82 flows and M96 flows is 62 mg/l, indicating that some buffering capacity is present. Mean daily ANC change is 4 mg/l (for both A82 and M96). There is no indication that ANC change is affected by the scheme in operation, however the most significant changes occur during cooler months. ANC under both A82 and M96 Scenarios are indicative of 'Good' WFD water quality.

Figure 4-38 ANC in the freshwater River Thames for the Mogden 200 A82 scenario. Scheme in operation at Mogden A82 is indicated by the grey box

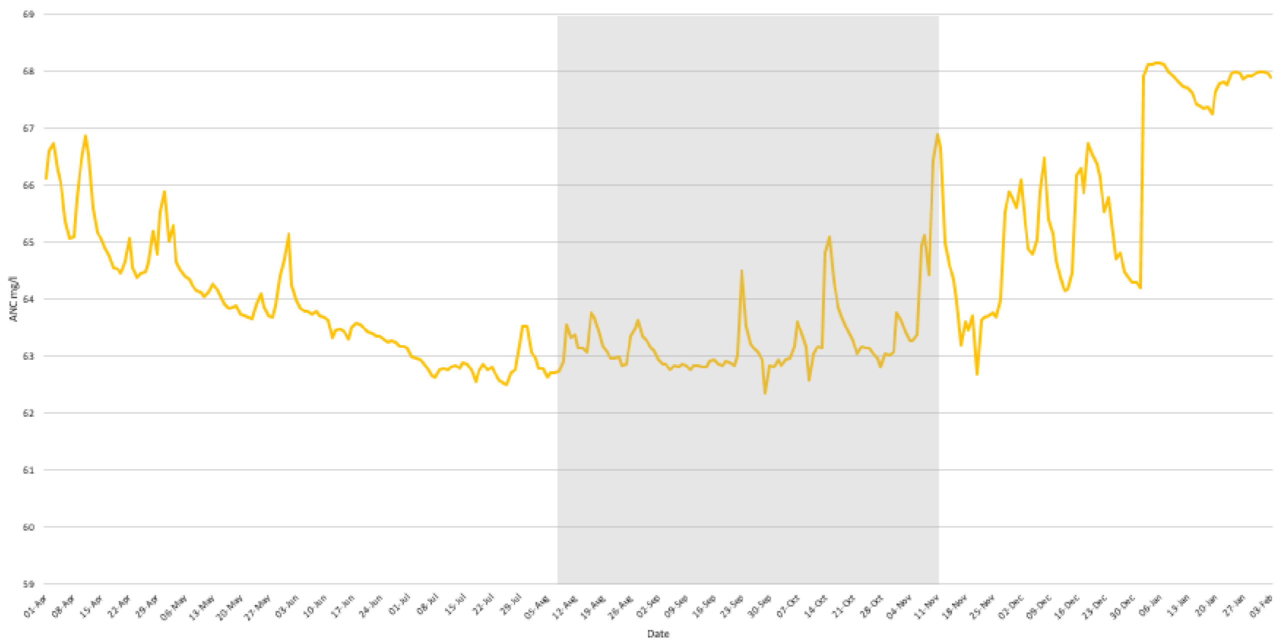
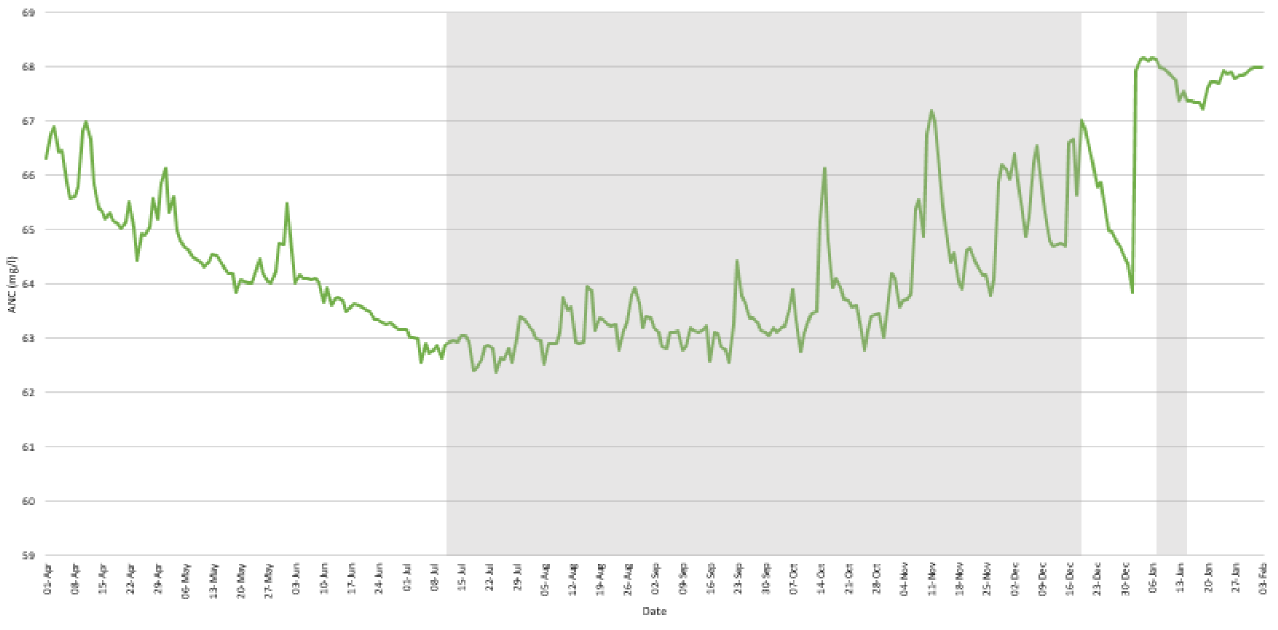


Figure 4-39 ANC in the freshwater River Thames for the Mogden 200 M96 scenario. Scheme in operation at Mogden M96 is indicated by the grey box



pH

pH has been calculated using estimated data from recycled water discharge and measured EA in-river spot data. Daily time-step mass balance (Figure 4-40 and Figure 4-41) shows little variation between the flow scenarios, with minimum pH under both flows being 7.6, and maximum under both flows being 8.6. Mean daily pH change is 0.1. There is no indication that pH change is affected by the scheme in operation and pH which was measured between 6 and 9 remains indicative of 'high' water quality.

Figure 4-40 pH in the freshwater River Thames for the Mogden 200 A82 scenario. Scheme in operation at Mogden A82 is indicated by the grey box

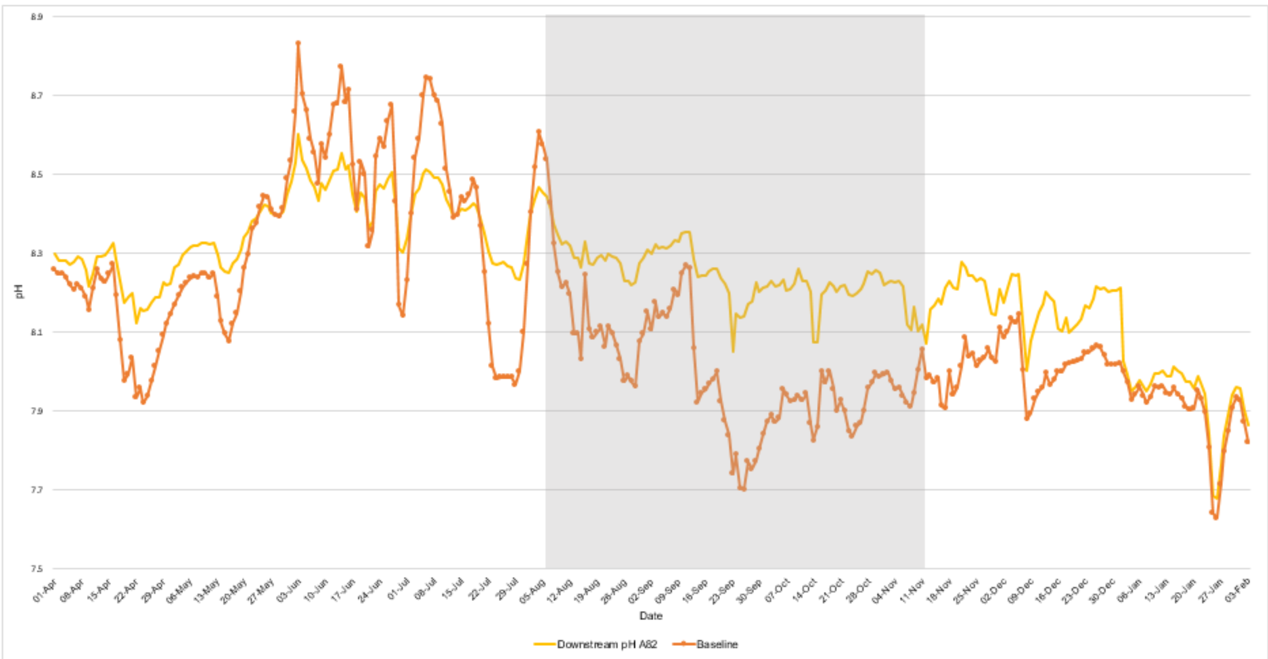
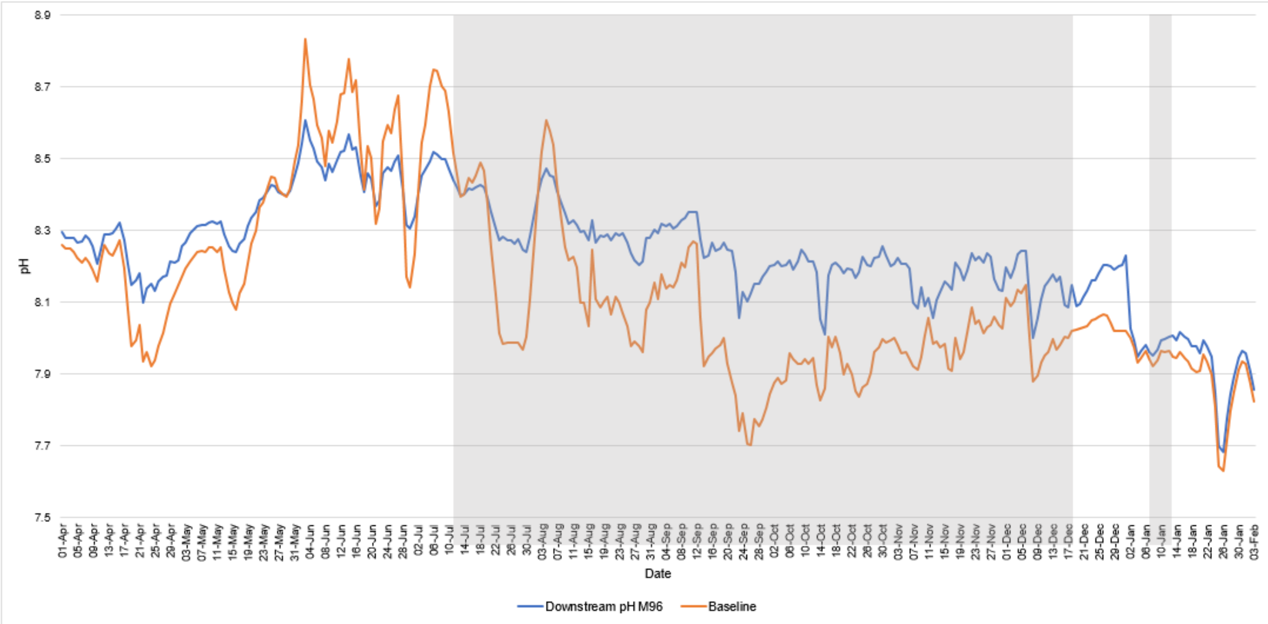


Figure 4-41 pH in the freshwater River Thames for the Mogden 200 A82 scenario. Scheme in operation at Mogden A82 is indicated by the grey box



4.4.3 Estuarine Thames Tideway

Dissolved Oxygen

An assessment of the dissolved oxygen concentration impacts in the estuarine Thames Tideway arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme. The model scenario has been parameterised with the modelled representation of the Mogden STW final effluent dissolved oxygen concentration and the modelled representation of the River Thames at Teddington dissolved oxygen concentration and the A82/M96 rivers flow series and A82/M96 Mogden STW final effluent flow series.

Outputs from HR Wallingford's Upper Tideway model are presented below (Figure 4-42 to Figure 4-45):

Figure 4-42 5th percentile dissolved oxygen concentration change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at A82 flow series

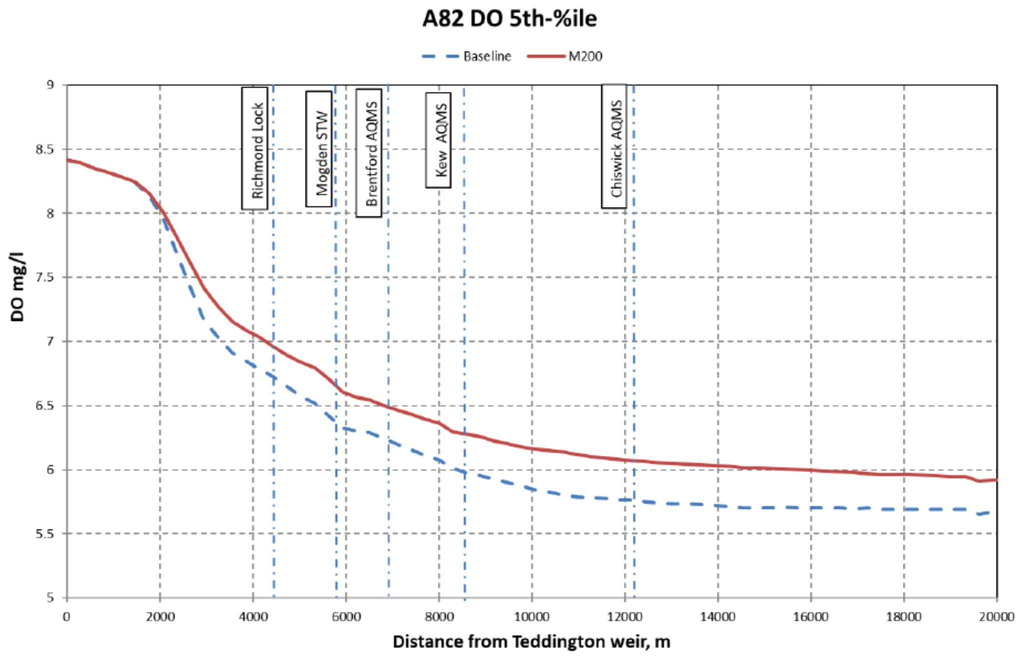
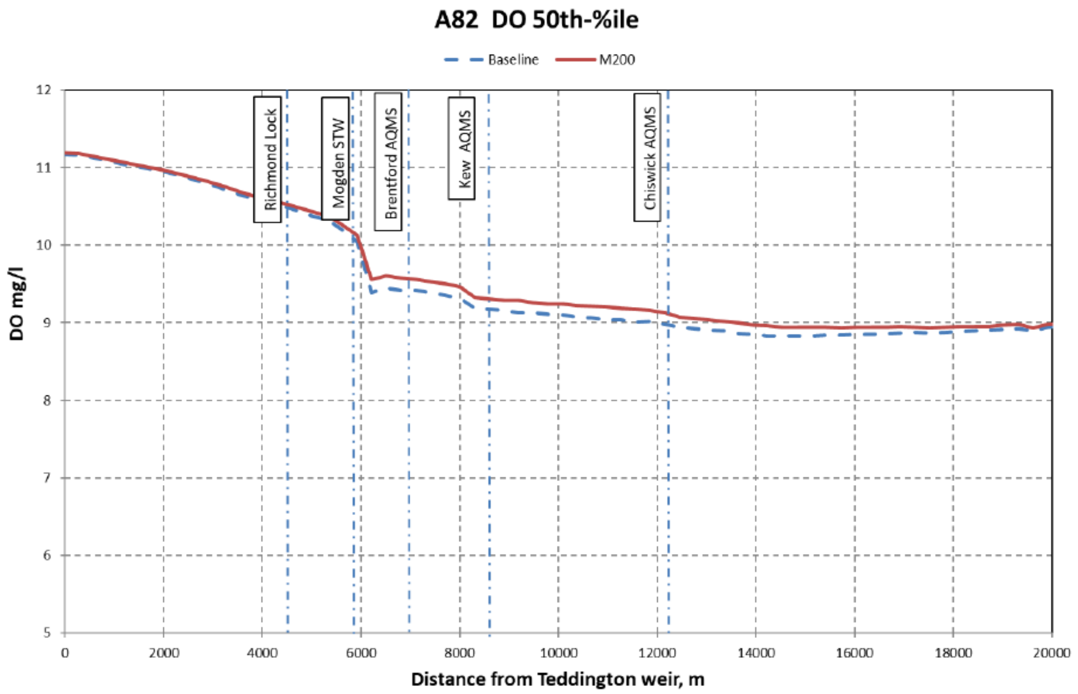


Figure 4-43 50th percentile dissolved oxygen concentration change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at A82 flow series



The modelled data displayed in Figure 4-42 and Figure 4-43 indicate that there is more dissolved oxygen in the upper Tideway in areas associated with the Mogden STW outfall, due to less effluent in the water course at these locations. The graphs above display dissolved oxygen concentration changes modelled for the Mogden 200 Ml/d scheme and so represent the greatest dissolved oxygen differences associated with the various scheme sizes at Mogden. Under the 5th percentile this represents a difference in dissolved oxygen of less than 0.5 mg/l. While under the 50th percentile the represented difference is less, at approximately 0.25 mg/l.

Figure 4-44 5th percentile dissolved oxygen concentration change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at M96 flow series

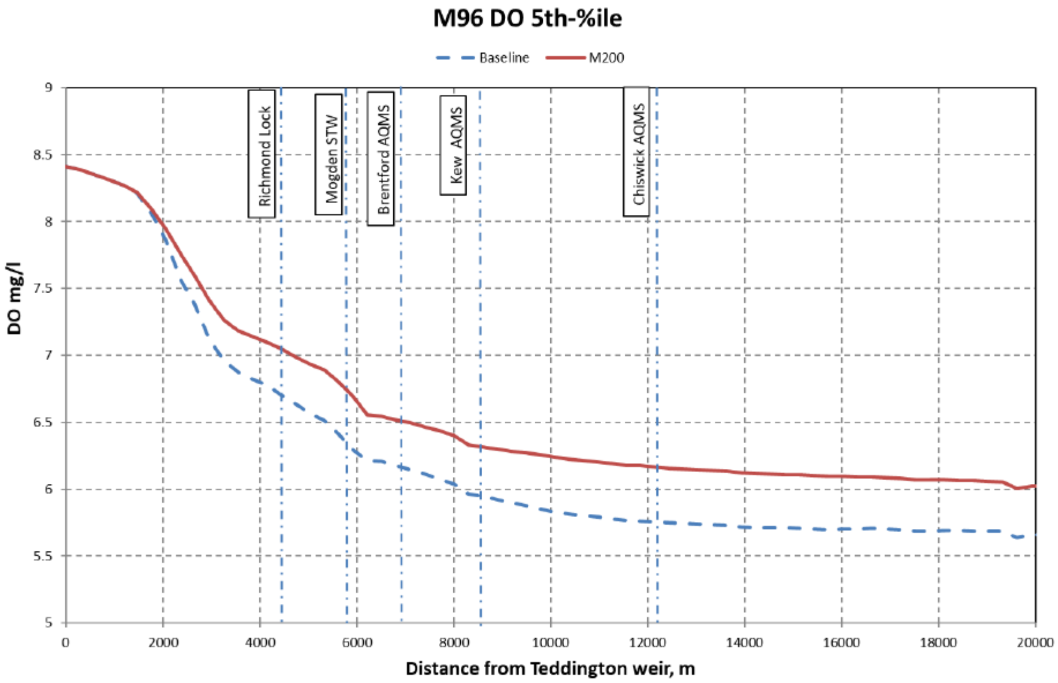
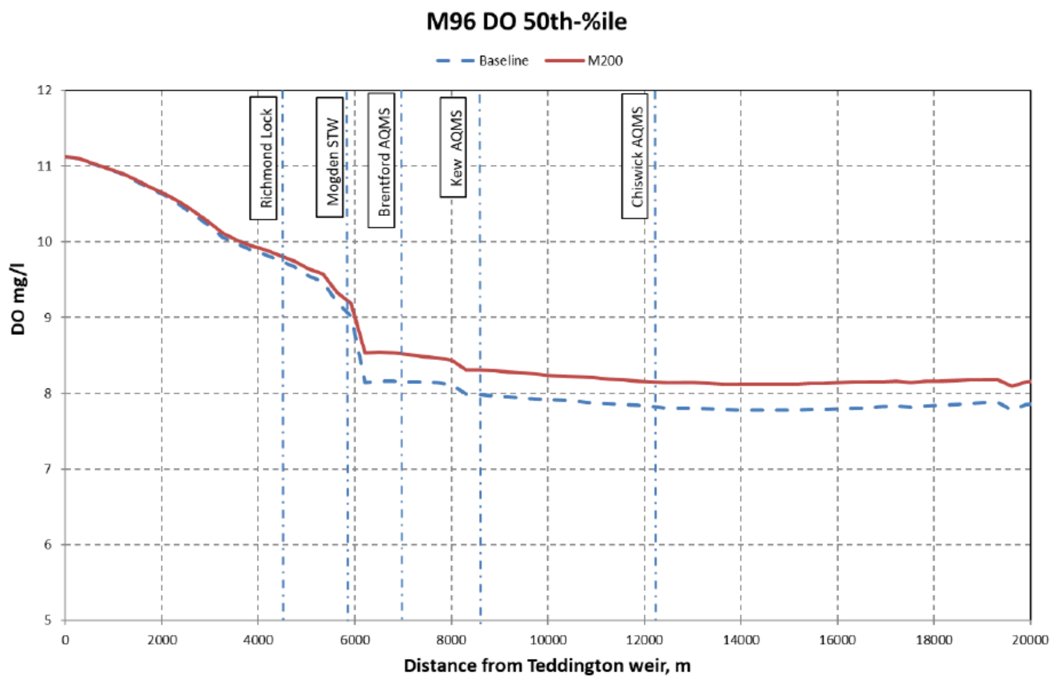


Figure 4-45 50th percentile dissolved oxygen concentration change in the Upper Tideway under a 200 Ml/d Mogden water recycling scheme at M96 flow series



The modelled data displayed in Figure 4-44 and Figure 4-45 show a similar pattern to the dissolved oxygen concentration difference observed above under the A82 flow scenario. Though the difference in dissolved oxygen concentration is greater under the M96 flow scenario. As above the graphs above display dissolved oxygen concentration changes modelled for the 200 Ml/d Mogden water recycling scheme and so represent the greatest dissolved oxygen concentration differences associated with the various scheme sizes. Under both the 5th and 50th percentile this represents a difference in dissolved oxygen concentration of approximately 0.5 mg/l.

Salinity

An assessment of the salinity impacts in the estuarine Thames Tideway arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme and A82 and M96 flow scenarios.

Outputs from HR Wallingford's Upper Tideway model are presented below (Figure 4-46, Figure 4-47 and Figure 4-48):

Figure 4-46 Maximum salinity along thalweg (9th-24th September) in the estuarine Thames Tideway at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

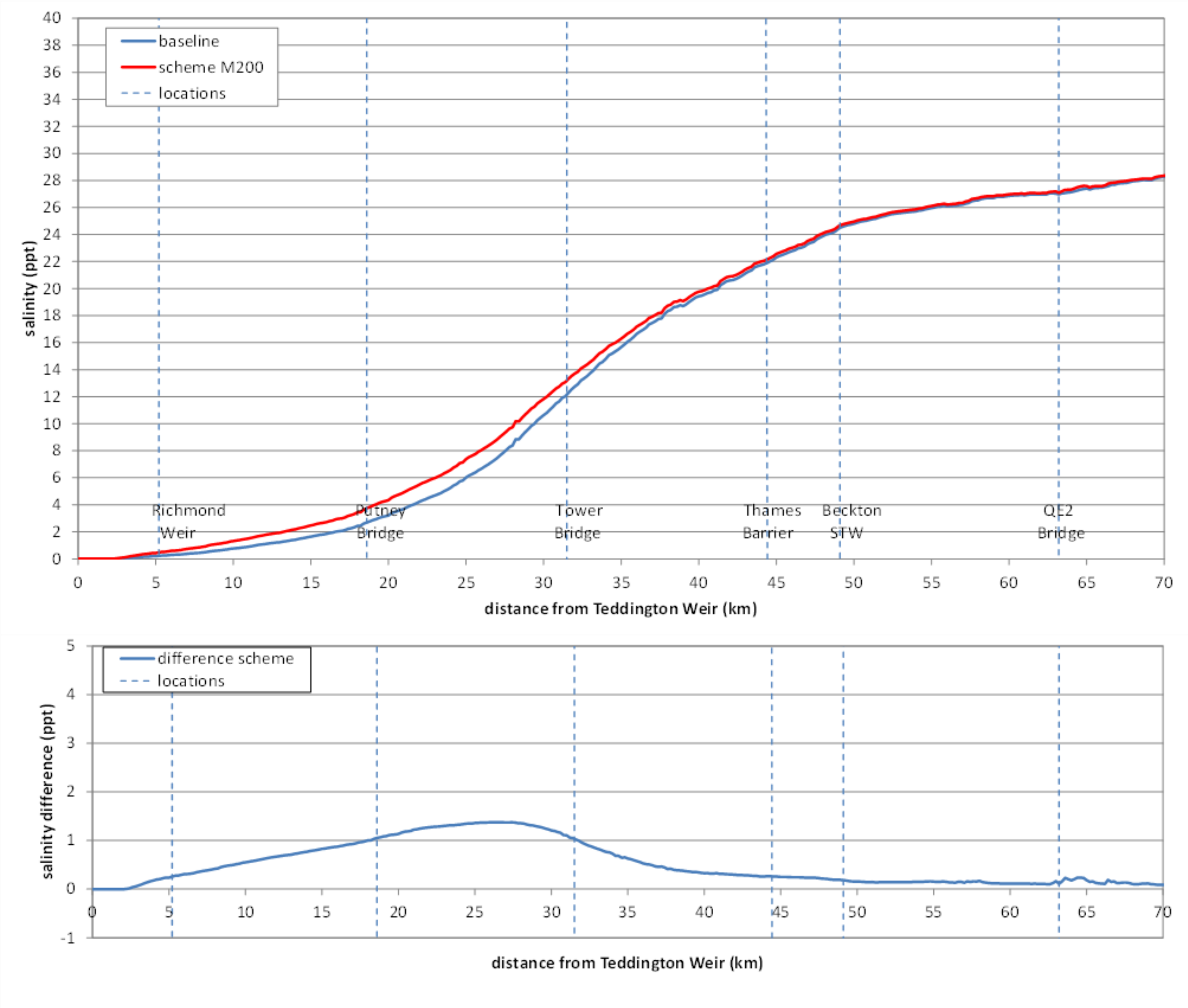


Figure 4-47 Mean salinity along thalweg (9th-24th September) in the estuarine Thames Tideway at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

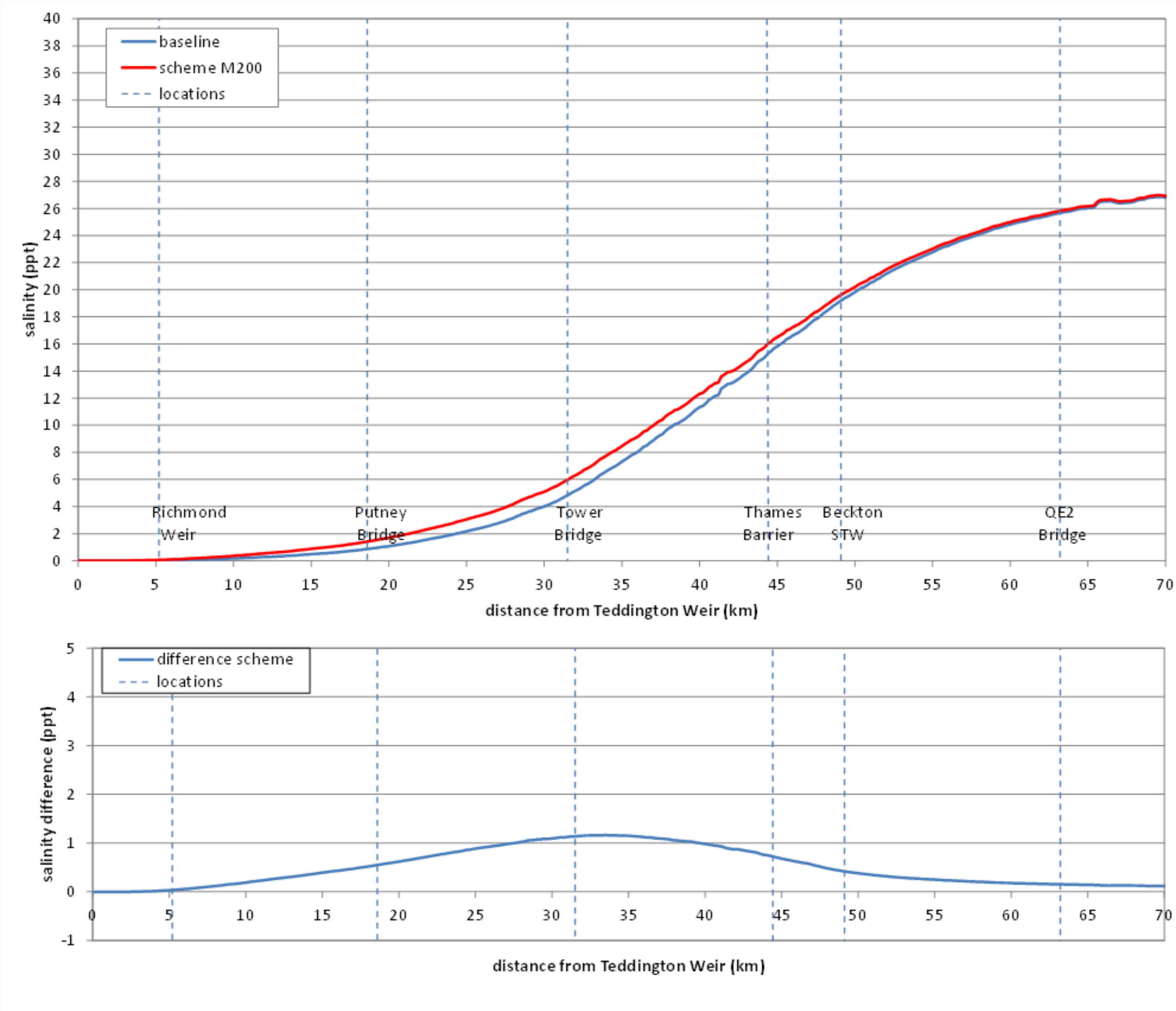
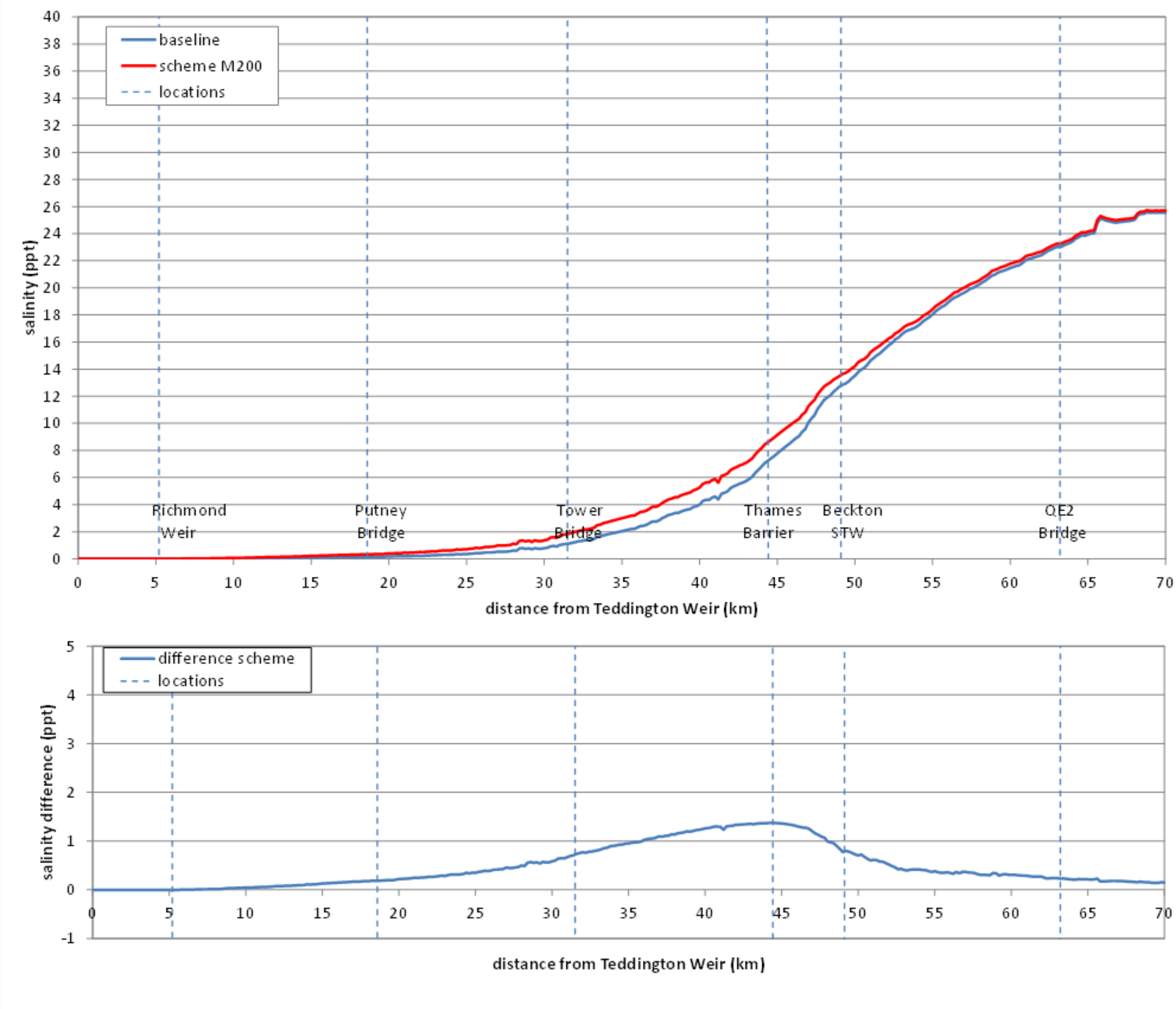


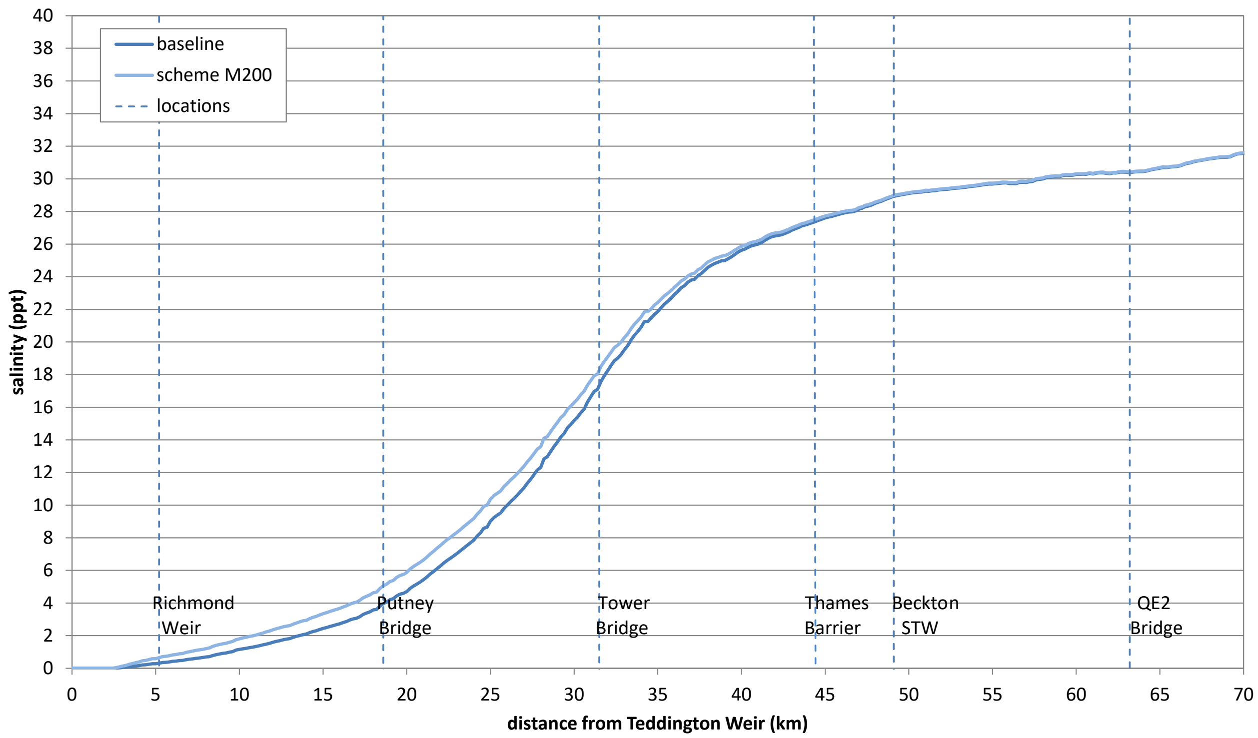
Figure 4-48 Minimum salinity along thalweg (9th-24th September) in the estuarine Thames Tideway at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario



The modelled data displayed in Figure 4-46, Figure 4-47 and Figure 4-48 indicate that there is an increase in salinity under the A82 Mogden-200 scenario compared with baseline from approx. 5km to 50km seawards of Teddington Weir. Salinity becomes more consistent between baseline and the A82 Mogden-200 scenario from approx. 50km seawards of Teddington Weir, seawards of Beckton STW. The graphs above display salinity modelled for the Mogden 200 Ml/d scheme and so represent the greatest salinity differences associated with the various scheme sizes at Mogden. The greatest increase in maximum salinity from baseline is approx. 1.3ppt and the greatest increase in both mean and minimum salinity is 1ppt.

Outputs from HR Wallingford's Upper Tideway model are presented below (Figure 4-49, Figure 4-50 and Figure 4-51):

Figure 4-49 Maximum salinity along thalweg (24th-31st July) in the estuarine Thames Tideway at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



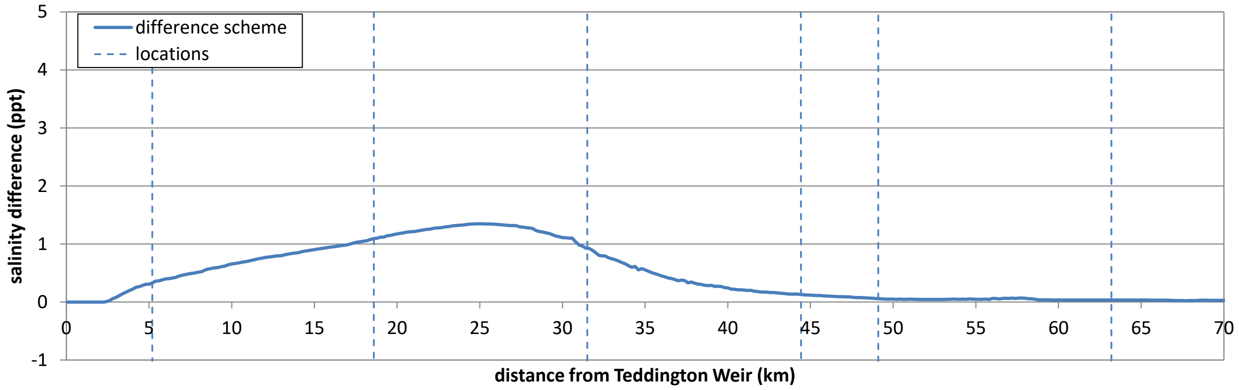


Figure 4-50 Mean salinity along thalweg (24th-31st July) in the estuarine Thames Tideway at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

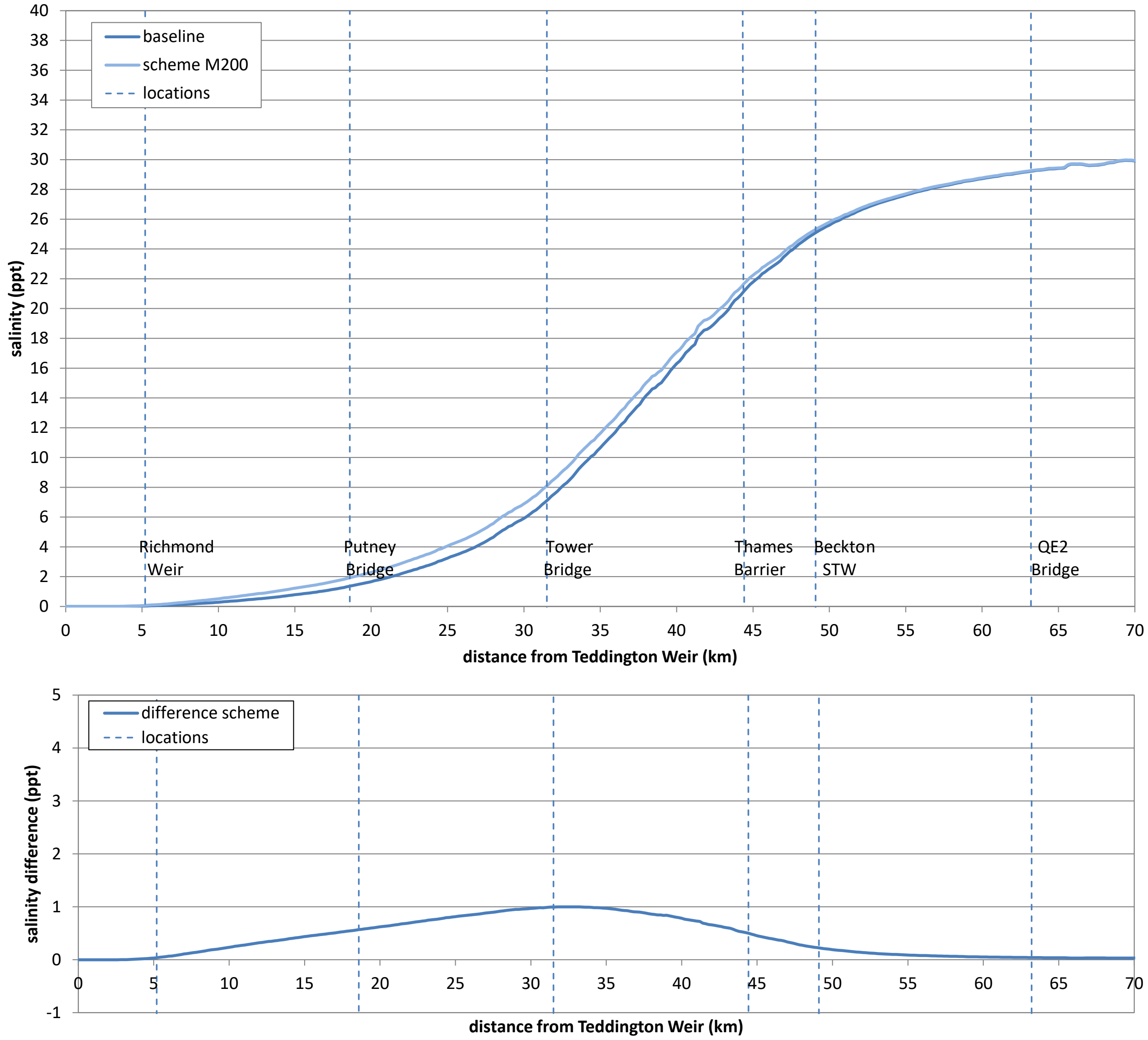
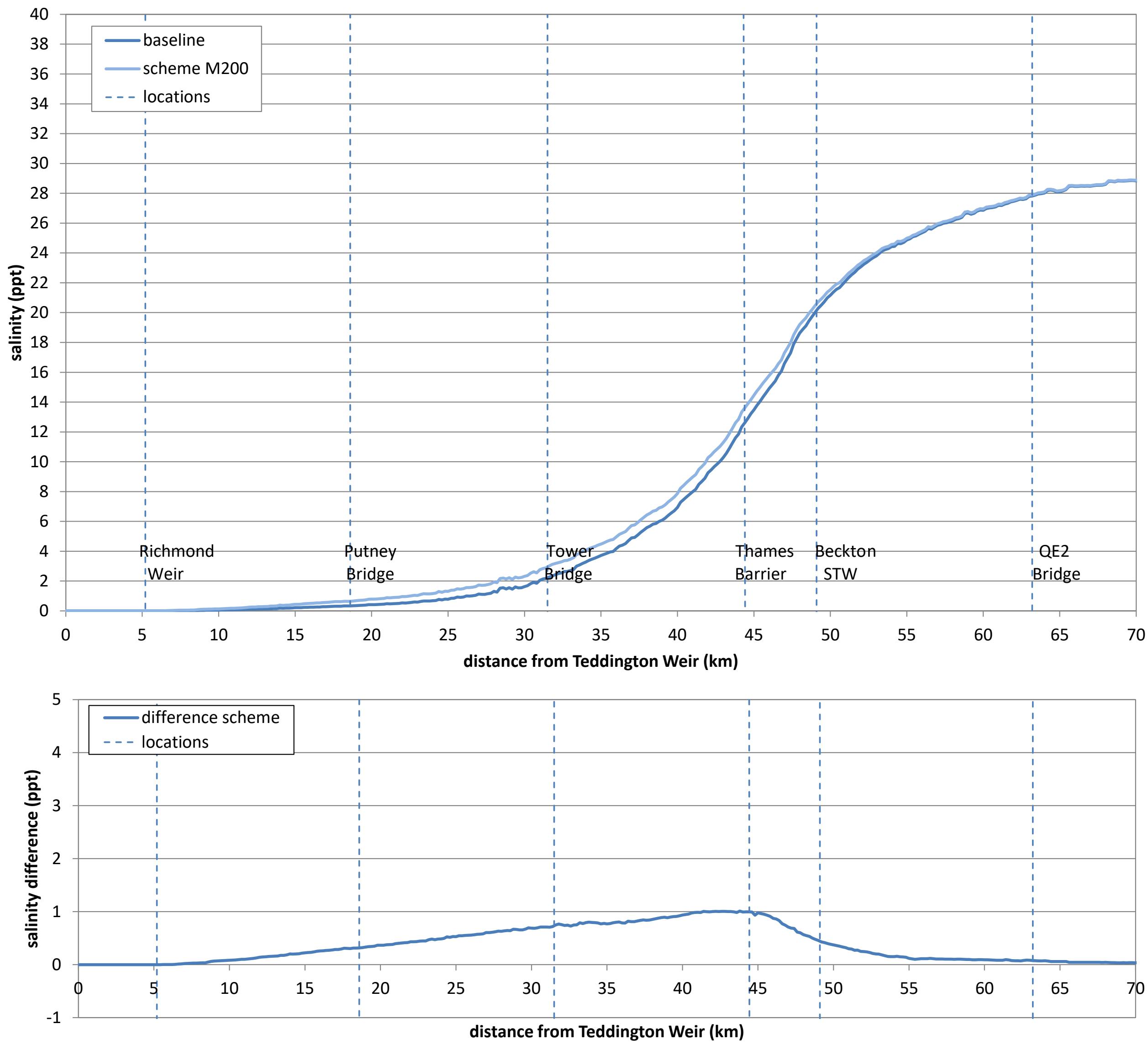


Figure 4-51 Minimum salinity along thalweg (24th-31st July) in the estuarine Thames Tideway at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



The modelled data displayed in Figure 4-49, Figure 4-50 and Figure 4-51 indicate that there is an increase in salinity under the M96 Mogden-200 scenario compared with baseline from approx. 5km to 50km seawards of Teddington Weir, similarly to the A82 scenario. Salinity becomes more consistent between baseline and the M96 Mogden-200 scenario from approx. 50km seawards of Teddington Weir, seawards of Beckton STW. The graphs above display salinity modelled for the Mogden 200 Ml/d scheme and so represent the greatest salinity differences associated with the various scheme sizes at Mogden. The greatest increase in maximum salinity from baseline is approx. 1.3ppt and the greatest increase in both mean and minimum salinity is 1ppt.

Dissolved Inorganic Nitrogen

DIN has been assessed in the estuarine Thames Tideway using measured effluent data for ammonia, nitrate and nitrite. The 200 Ml/d scheme size has been proportionally removed from the concentrations to reflect scheme on and the reduction in effluent entering the Tideway through the Mogden outfall.

The data displayed in Figure 4-52 and Figure 4-53 shows a reduction in DIN within the estuarine Thames Tideway during the scheme on period. During scheme on the maximum DIN concentrations displayed is 278.3 µMol/l (A82) and 426.9 µMol/l (M96), with averages of 181.6 µMol/l (A82) and 331.9 µMol/l (M96).

The scheme on period only overlaps with WFD status time period during early November (A82) and during this time is indicative of 'good' status (mean 270 µMol/l – 1st Nov – 28th Feb). While the scheme overlaps with

WFD status time period during November to mid-December and for a few days in January (M96) during this time is also indicative of 'good' status. However, overall, DIN status within the estuarine Thames Tideway from Mogden effluent is of 'good' status under both schemes. It should be noted that this assessment assumes full removal of the diverted effluent and does not account for other discharge pathways back into the Tideway as, at this point, this is not known.

Figure 4-52 Dissolved inorganic nitrogen in the estuarine Thames Tideway for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

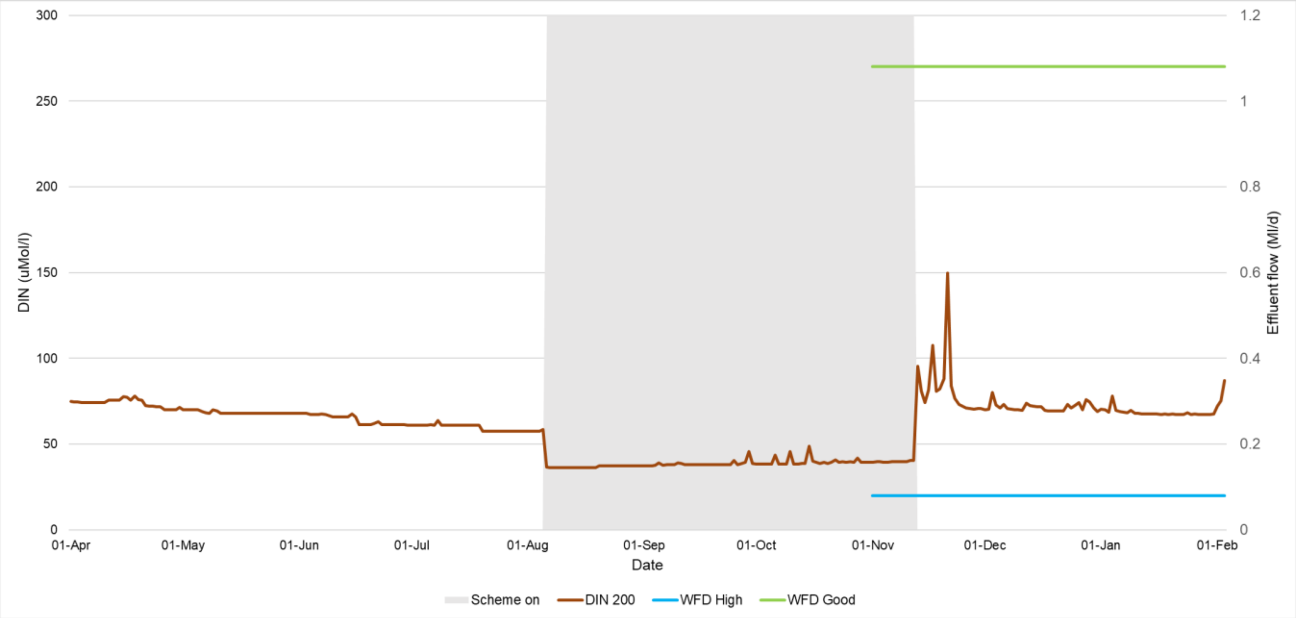
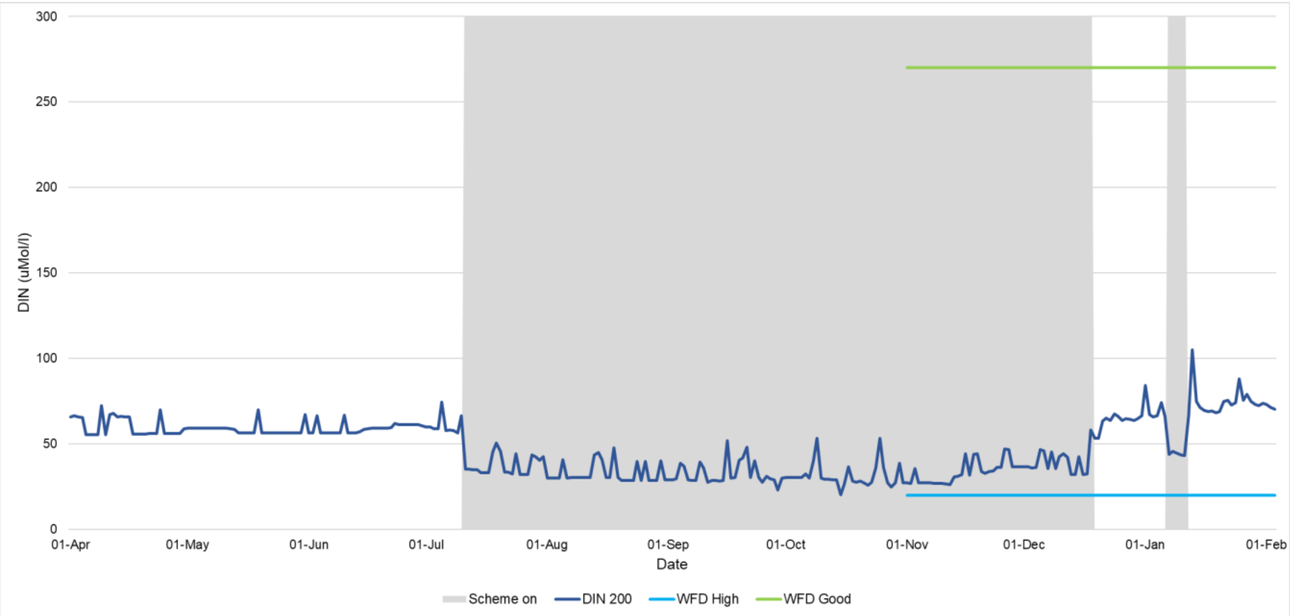


Figure 4-53 Dissolved inorganic nitrogen in the estuarine Thames Tideway for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



4.5 WFD CHEMICALS

4.5.1 Overview

This section sets out the change for the WFD and EQSD parameters associated with the Mogden water recycling scheme. Assessments undertaken include:

- Freshwater River Thames - Section 4.5.2
- Estuarine Thames Tideway - Section 4.5.3

The analysed chemicals are listed as priority substances and certain other polluting chemicals in the WFD and Environmental Quality Standards Directive (EQSD). This list does not include the Drinking Water Safety Plan (DWSP) suite.

4.5.2 Freshwater River Thames

As described in Section 4.2.53.2.5 above, the recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of chemicals.

4.5.3 Estuarine Thames Tideway

As described in Section 4.2.5 above, the AWRP processes will return all treated water to Mogden STW as liquid waste. This will affect the concentration of chemicals in the final effluent of Mogden STW discharged to the Thames Tideway. Using measured data from Mogden STW final effluent, 'reconcentration' calculations were performed for each determinand within the WFD and EQSD suites. These values have been used in dispersion modelling of the Mogden STW final effluent plume in the Thames Tideway.

The risk assessment has been undertaken using the SRO water quality dataset. Specifically the Mogden STW final effluent sampling point, with typically 15 values reported in Gate 2. The risk assessment is not against EQS. It is an assessment of where individual reported chemical values are in exceedance of EQS values, without recourses to considering mean or percentile values at this stage. It is noted that the assessment is of the dispersion of the STW discharge itself and does not account for concentrations in the Thames Tideway. It is noted that monitoring of the Thames Tideway itself would identify chemical concentrations as amended by Mogden STW and would not indicate the reference conditions without Mogden STW for inclusion in modelled assessment. As such it is not a statement of EQS pass or fail according to how EQS is derived.

Fifteen chemical determinands within the WFD suite were identified as exceeding the standard in the Estuarine Thames Tideway under baseline conditions.

Mogden A82 WFD Chemicals

Of those 15 chemicals exceeding the standard under reference conditions, the following six are decreased to below the standard under the A82 Mogden-200 scenario:

- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Indeno(1,2,3-cd)pyrene
- Total cadmium
- Total cyanide
- Total DDT

The following eight chemical determinands that exhibited exceedance of the standard under reference conditions still exceed the standard under the A82 Mogden-200 scenario:

- Benzo(a)pyrene
- Benzo(g,h,i)perylene
- Copper dissolved
- Dicofol
- Permethrin
- Polycyclic aromatic hydrocarbons
- Trichlorobenzenes
- Zinc dissolved

Although remaining above the standard, benzo(a)pyrene and benzo(g,h,i)perylene both exhibit a decrease in concentrations under the A82 Mogden-200 scenario compared with baseline. Dissolved copper, dicofol, permethrin, trichlorobenzenes and dissolved zinc all exhibit increased concentrations under the A82 Mogden-200 scenario.

There are some new pressures under the A82 Mogden-200 scenario, with an additional eight chemical determinands exceeding the standard as follows:

- Benzyl butyl phthalate
- Total chlorine
- Chlorothalonil
- Cybutryne (Irgarol)
- Cypermethrin
- Hexachlorocyclohexane
- Perfluorooctane sulfonic acid and its derivatives
- Terbutryn

The determinands which were identified as new pressures to the study area under scheme in operation conditions were then modelled by HR Wallingford using their estuarine model.

For each determinand the same day (August 15^{th}) was displayed in a dot plot to visualize the change in concentration across space and time with a comparison between the baseline and the scheme in operation M200 scenario. The plot ranges from Richmond Pier to Battersea Bridge with the current Mogden STW outflow represented by the Isleworth Ait. These plots can be seen below. The arrows on each colour scale indicate where the average EQS is for that determinand.

Hexachloro-Cyclohexane (Figure 4-54) and PFOS and its derivatives (Figure 4-55) both exceeded the EQS average in some points but did not exceed the maximum value.

It is noted for Hexachloro-Cyclohexane and PFOS and its derivatives that there is an observable phenomenon whereby at high slack tides concentrations are moved up the watercourse to Richmond where they then remain. This does not appear to occur with other determinands and is noted to occur at both baseline and under scheme. It is considered that the Richmond Pound is acting as a sink for these determinands and therefore concentrations are elevated here in comparison to the rest of the watercourse. Detailed analysis of the Richmond Pound is underway which will provide clarity on any effects here related to dissolved oxygen, though initial assessments indicate an improvement in dissolved oxygen which may help to mitigate any impacts from the elevated concentrations and their subsequent degradation.

Figure 4-54: Dot Plot of Hexachloro-Cyclohexane concentration across space and tide time.

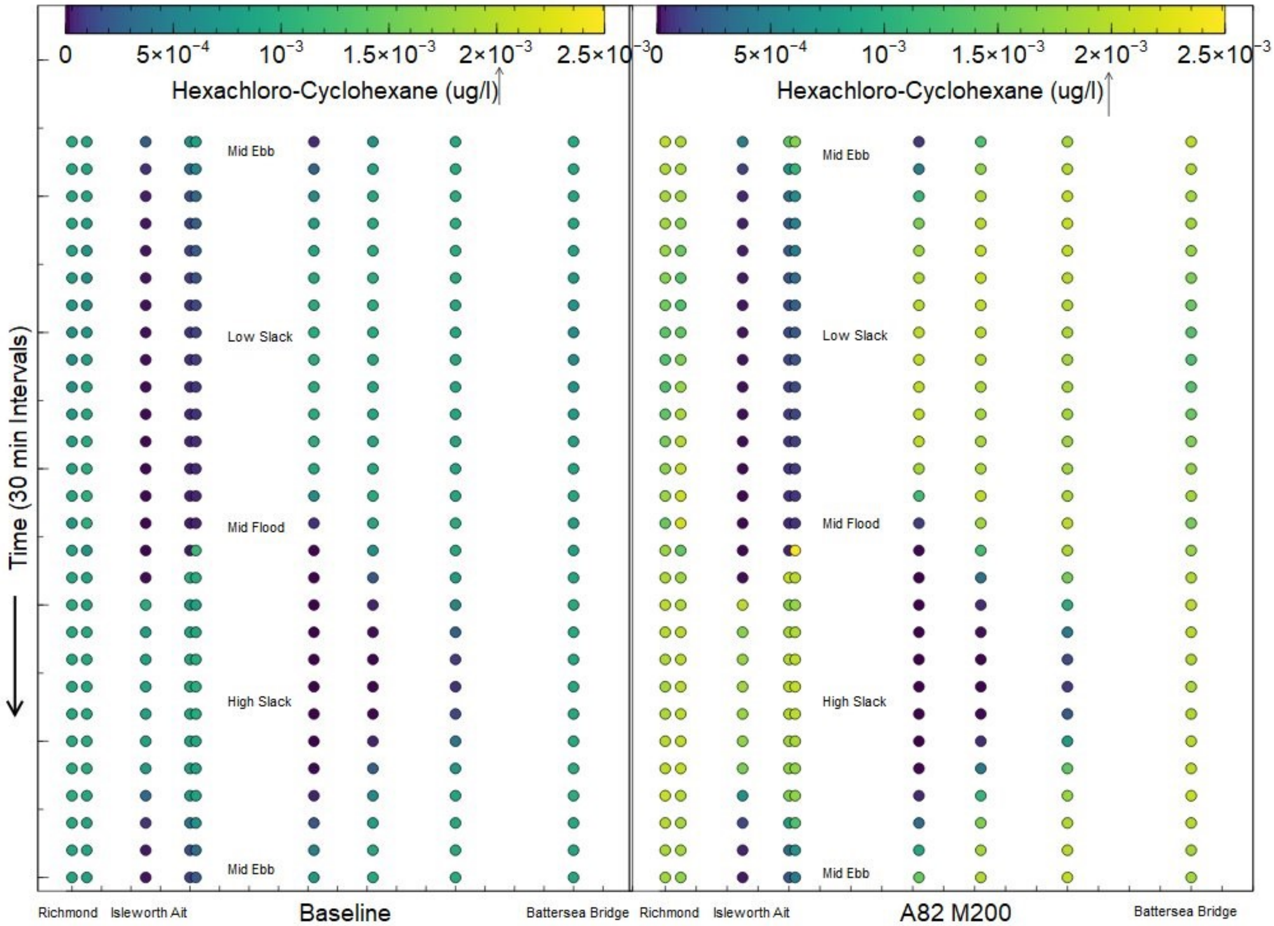
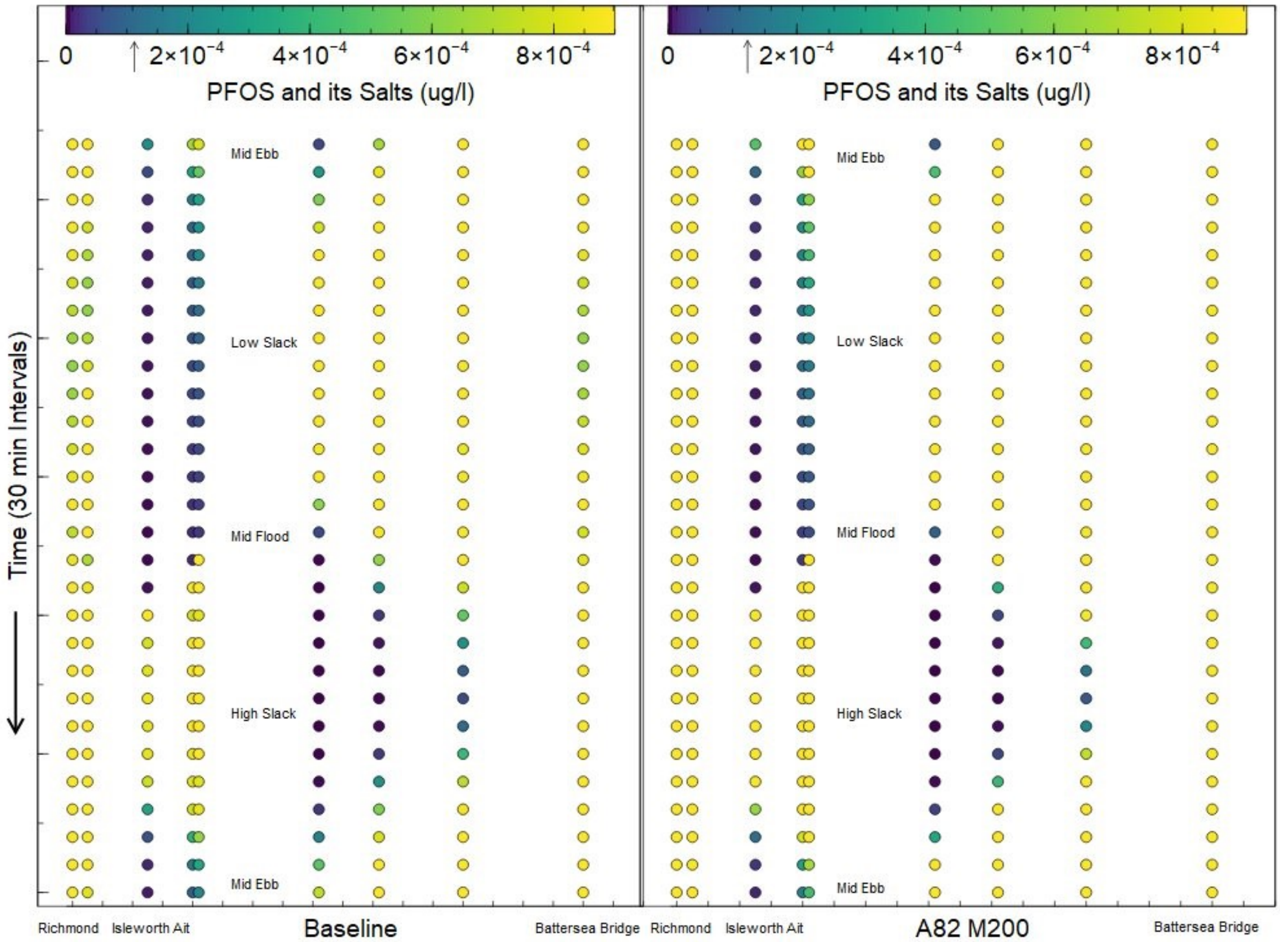
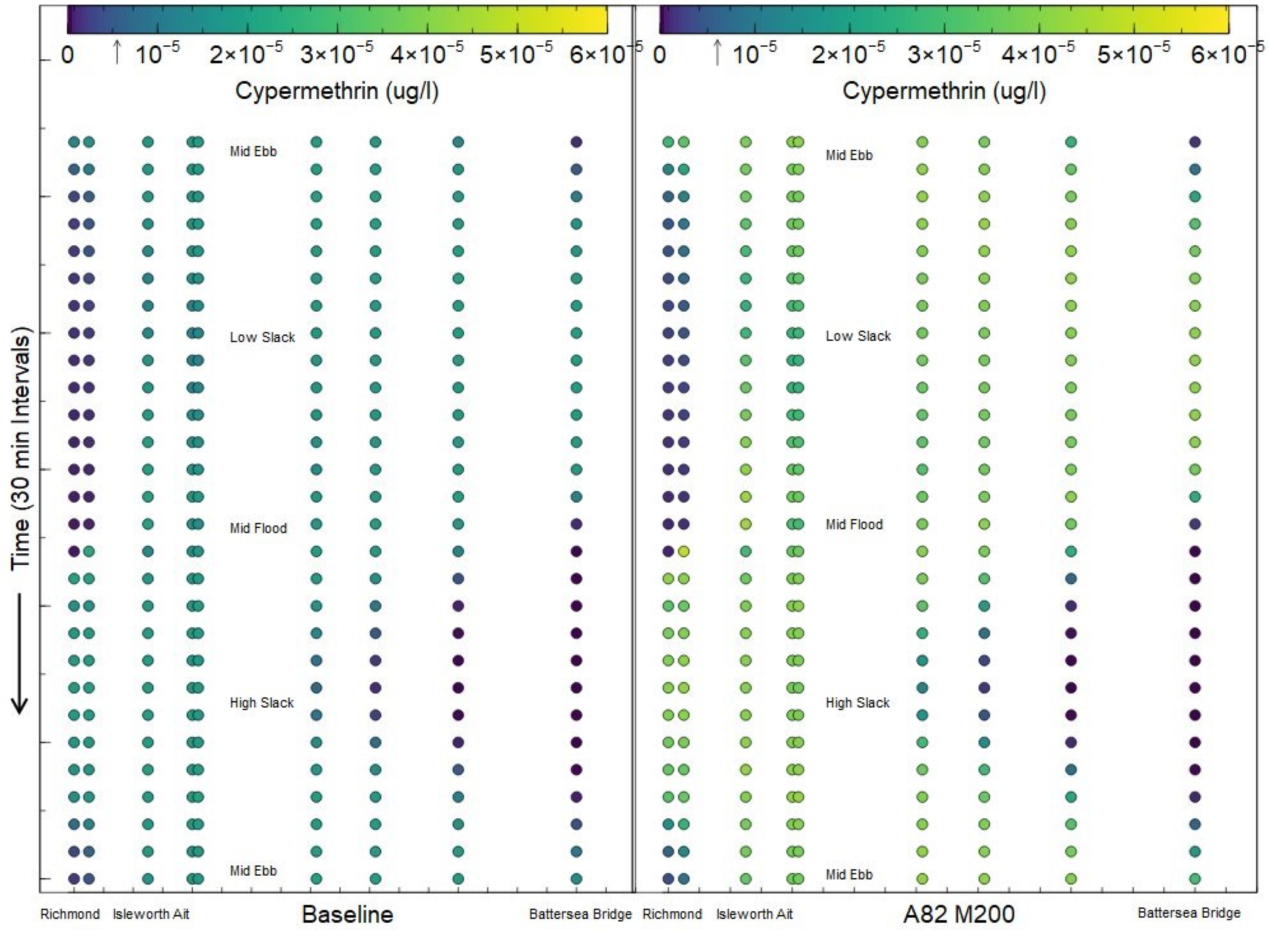


Figure 4-55 Dot Plot of PFOS and its Salts concentration across space and tide time



Cypermethrin did not appear above the max EQS but also displayed concentrations above the average EQS as seen in the figure below (Figure 4-56). As above the arrow on the colour scale indicates the average EQS and the max EQS is 6e-5 whereas the max value from the model is 4.93e-5.

Figure 4-56: Dot Plot of Cypermethrin concentration across space and tide time.



Benzyl butyl Phthalate (Figure 4-57), Cybutryne (Figure 4-60) and Terbutryn (Figure 4-61) all fell below the average EQS as determined in the Water Framework Directive (2015).

Whereas Chlorine (Figure 4-58) displayed concentrations above the maximum EQS and Chlorothalonil did not appear above the max EQS but did display concentrations above the average EQS as seen in the figure below (Figure 4-59).

Figure 4-57: Dot Plot of Benzyl Butyl Phthalate concentration across space and tide time.

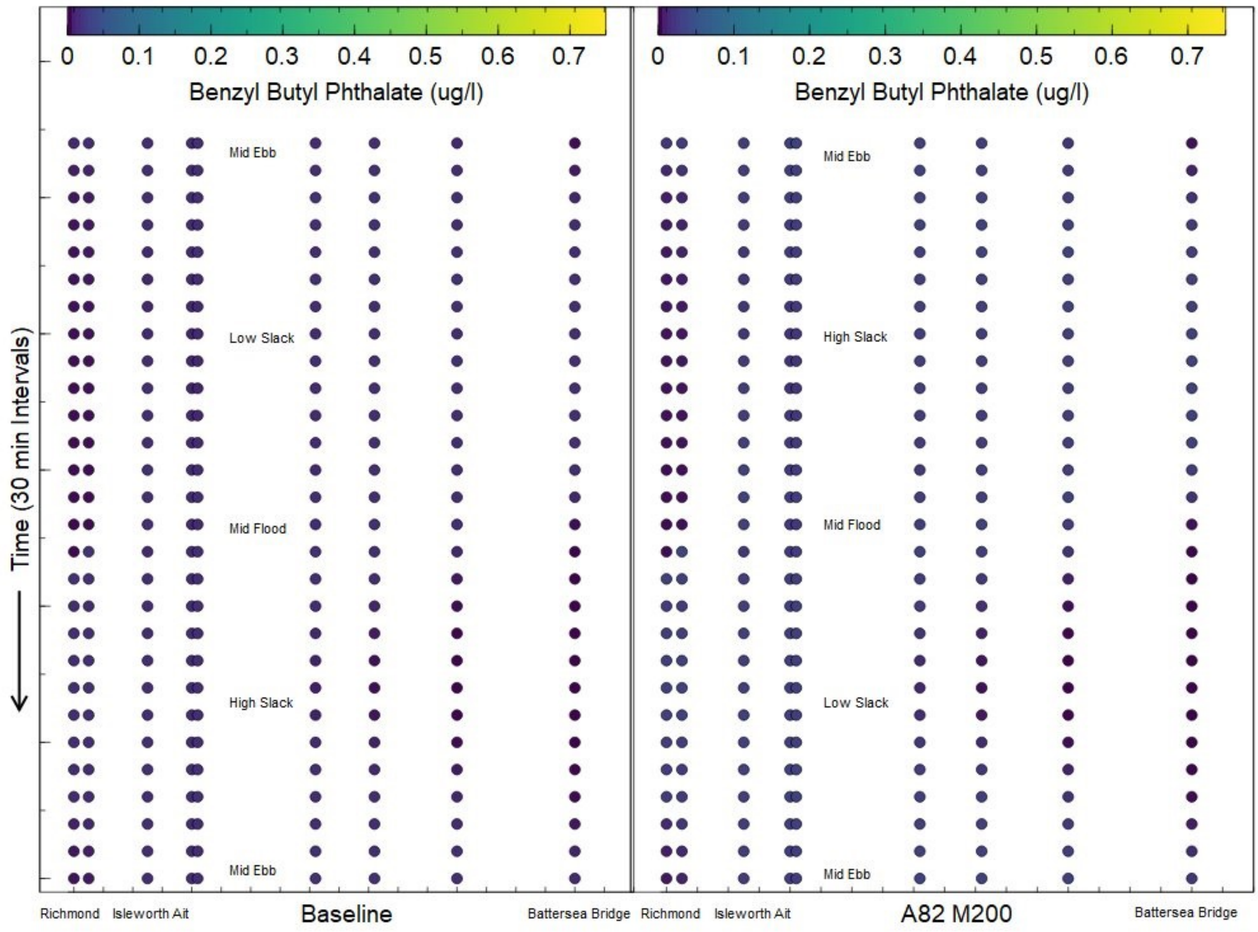


Figure 4-58: Dot Plot of Chlorine concentration across space and tide time.

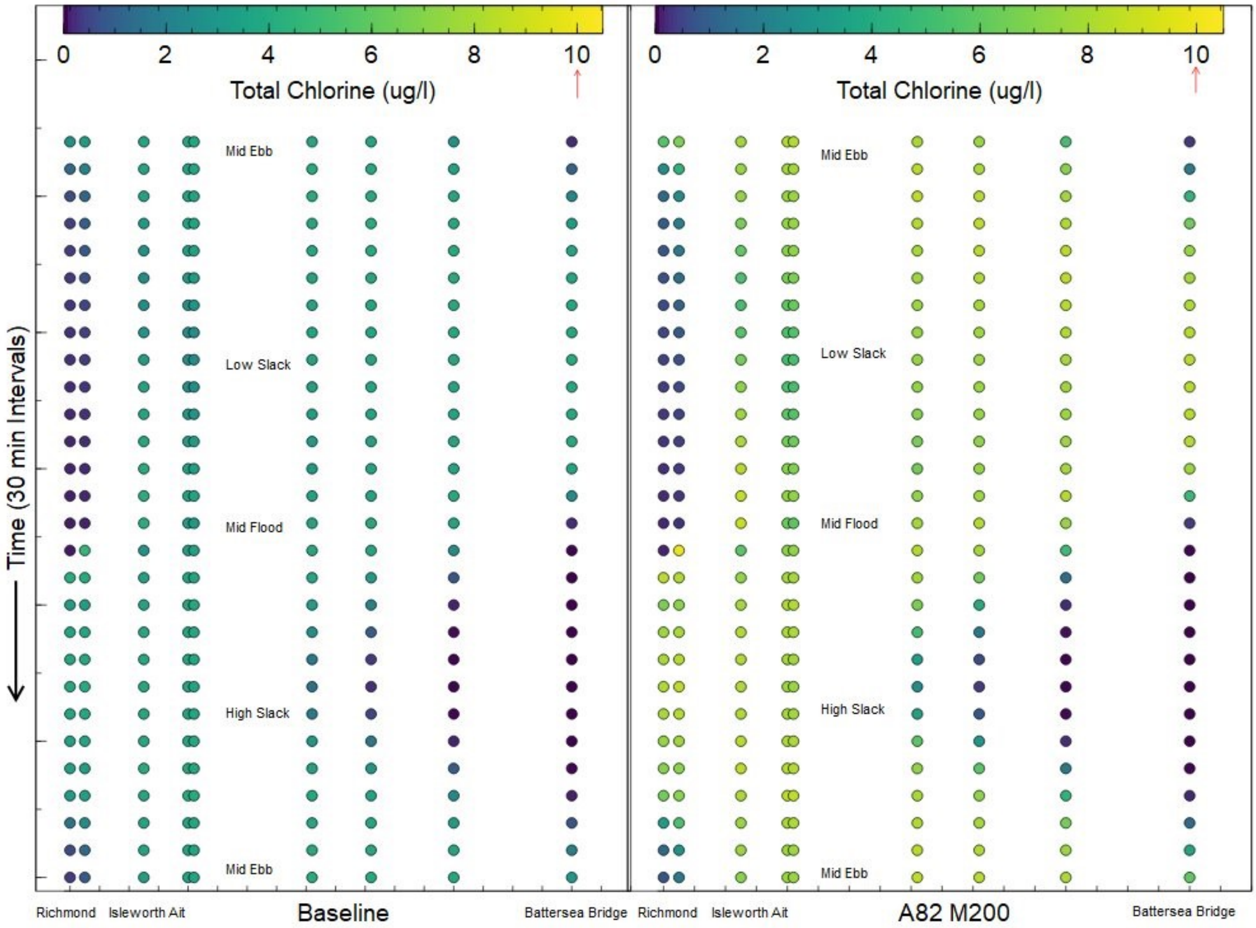


Figure 4-59: Dot Plot of Chlorothalonil concentration across space and tide time.

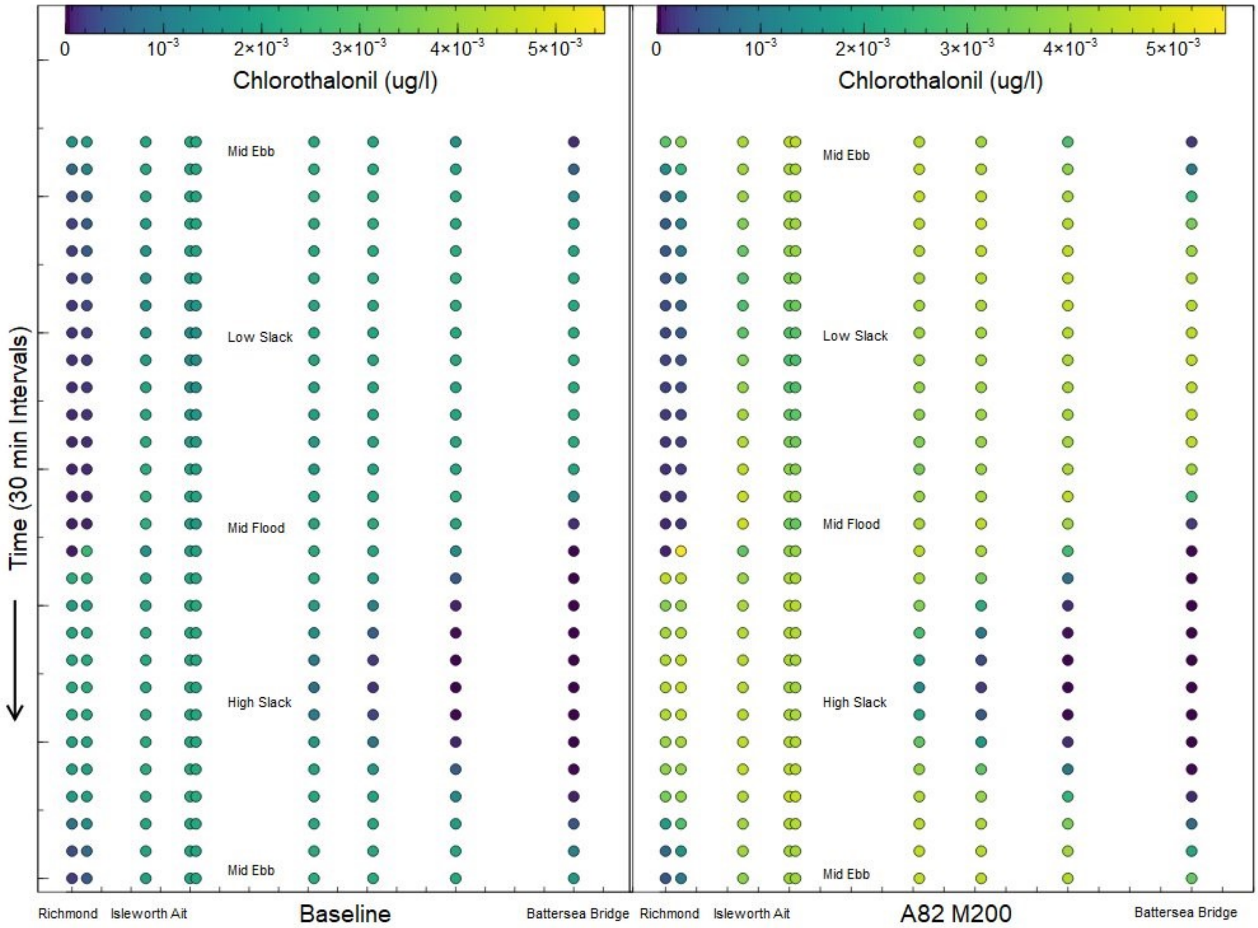


Figure 4-60: Dot Plot of Cybutryne concentration across space and tide time.

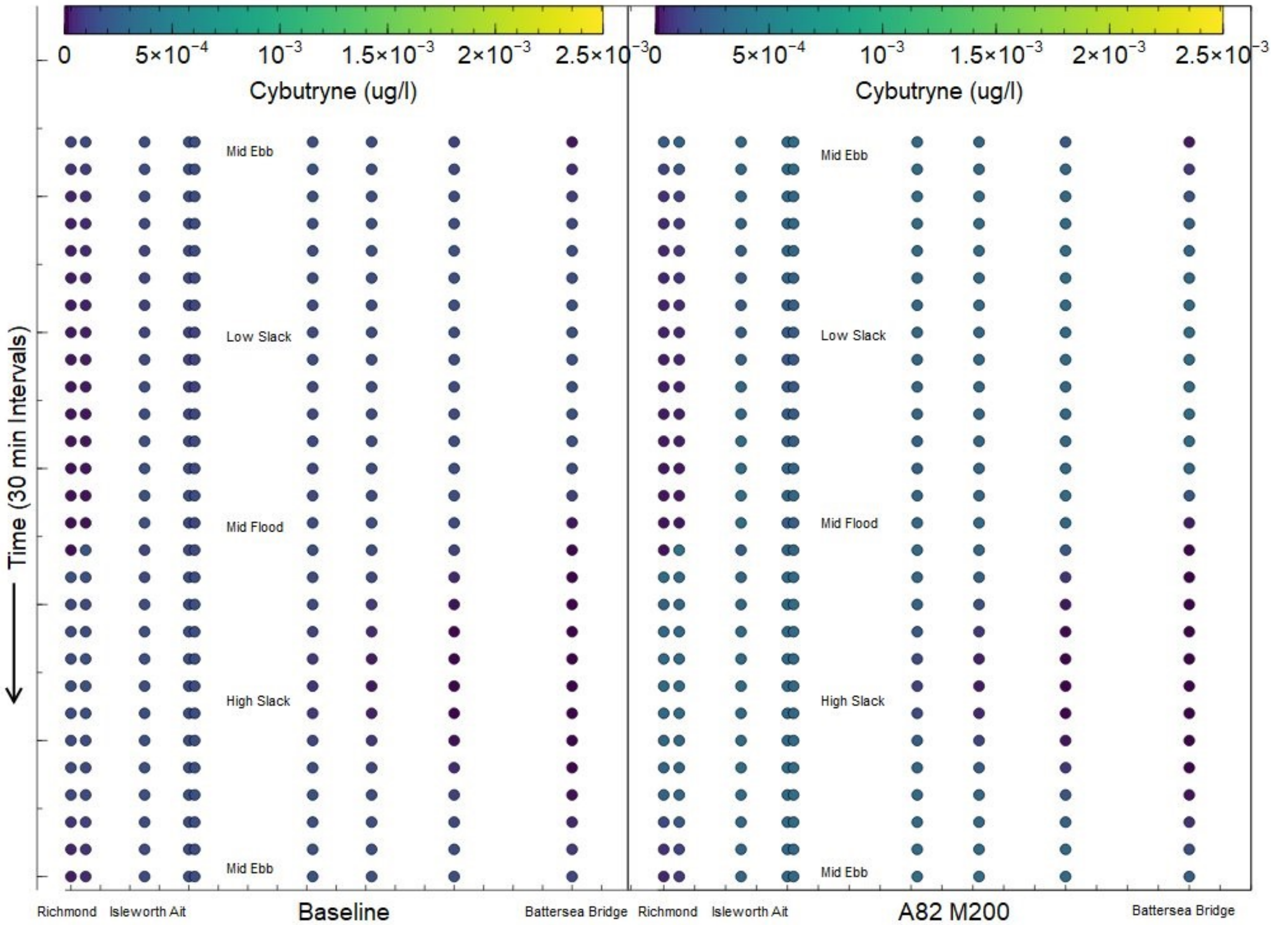
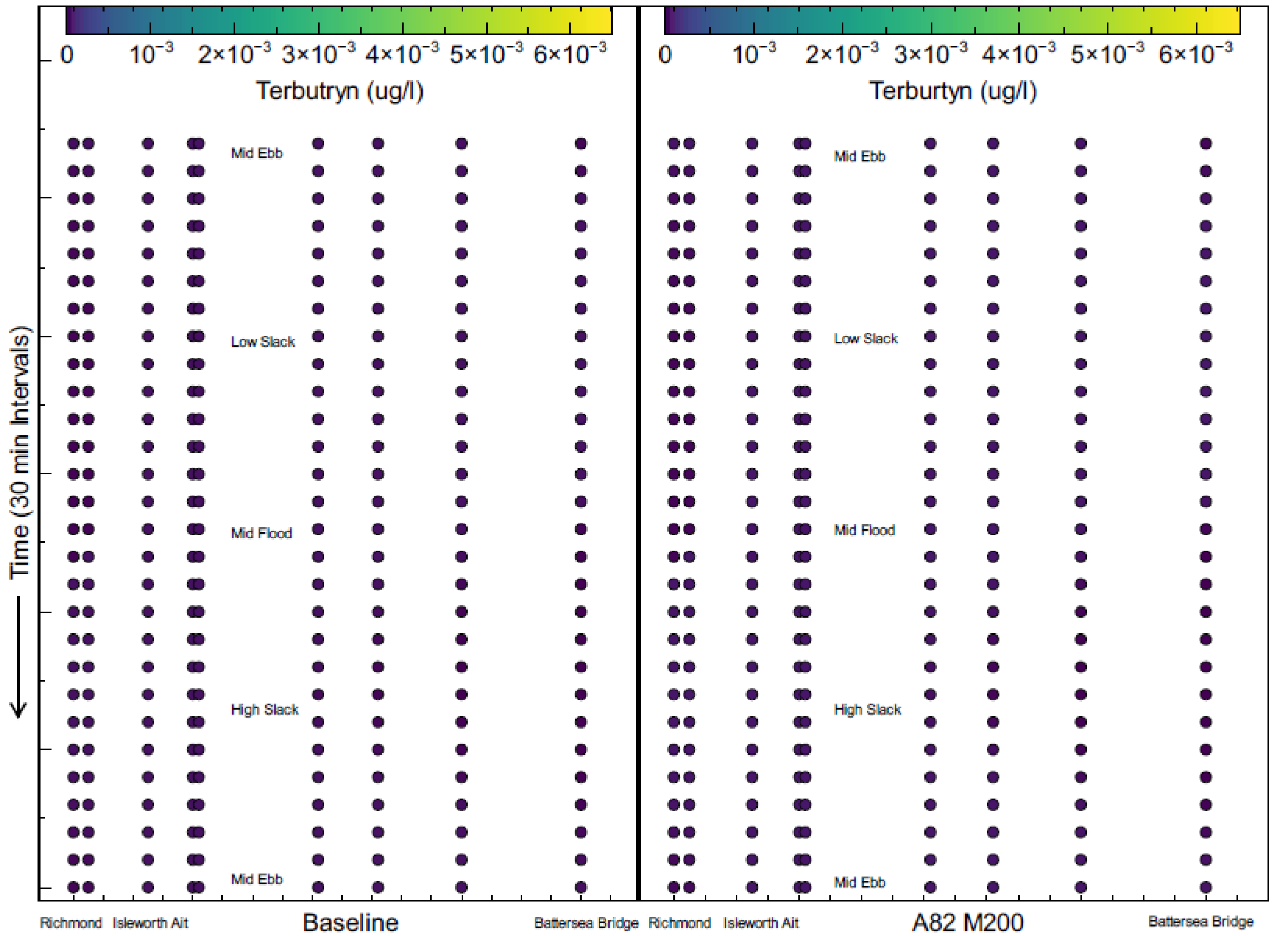


Figure 4-61 Dot Plot of Terbutryne concentration across space and tide time.



Mogden M96 WFD Chemicals

The changes to the WFD suite of chemical determinands under the M96 Mogden-200 scenario compared with reference conditions are the same as those described for the A82 Mogden-200 scenario with the one additional new pressure, showing minimal difference between flow scenarios.

Under the M96 Mogden-200 scenario there is an additional new pressure with an increase in concentrations of nonylphenols (4-nonylphenol technical mix) to within 10% of the standard.

However, there was insufficient data to model this determinand in the estuarine Thames Tideway.

Mogden A82 EQSD Chemicals

Under reference conditions, none of the chemical determinands within the EQSD chemical suite exceed environmental quality standards.

Under the A82 Mogden-200 scenario, there are some new pressures with the following three chemicals exceeding the standard.

- Bromine - total residual oxidant
- Diflubenzuron
- Pirimicarb

These determinands were modelled as above and both the Diflbenzuron (Figure 4-63) and the Pirimicarb (Figure 4-64) both fell well below the average EQS. The max of the modelled Bromine (Figure 4-62) fell just below the max EQS it should be noted that bromine does not have an average EQS as seen in the figure below.

Figure 4-62: Dot Plot of Bromine across space and tide time.

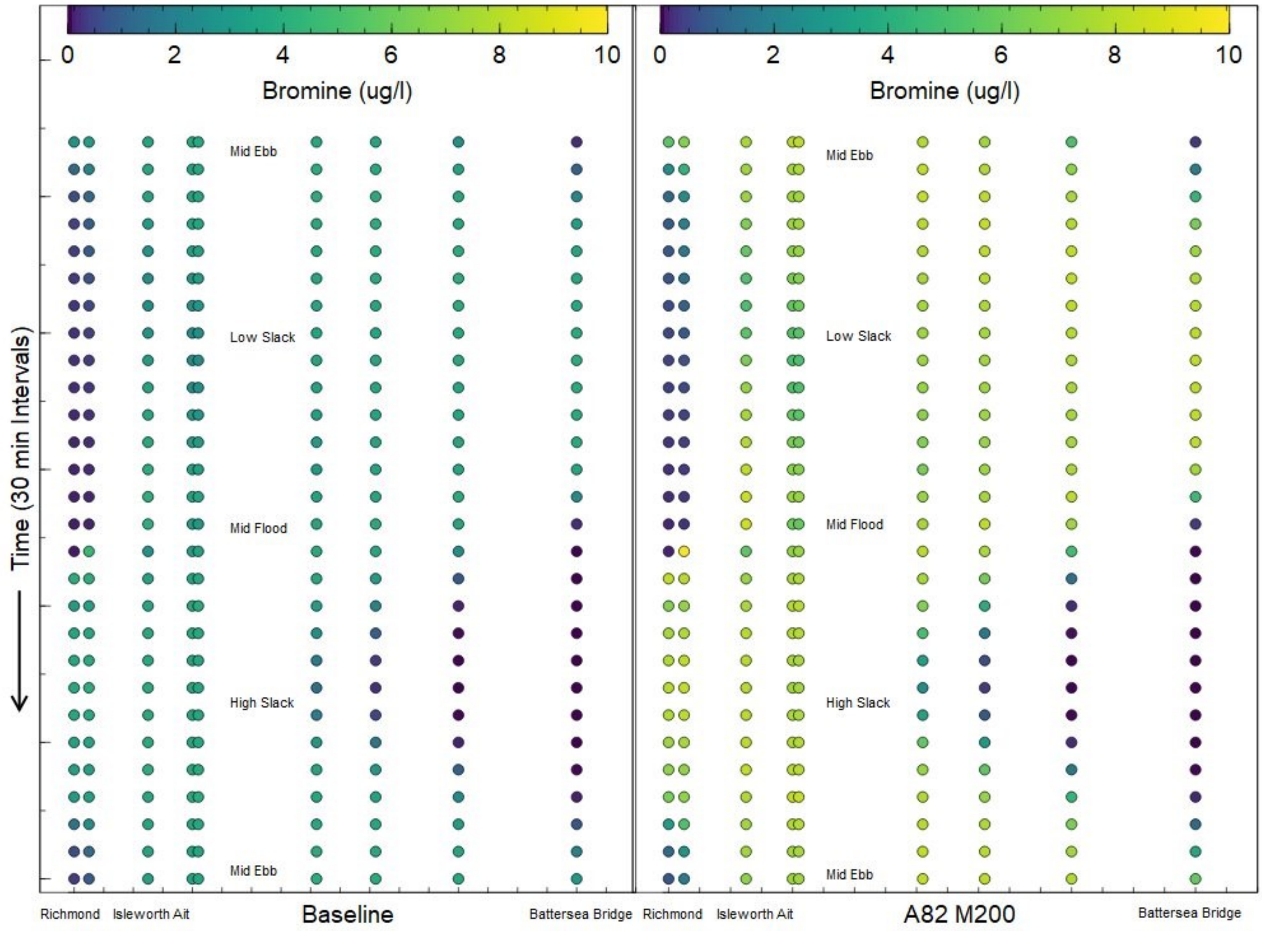


Figure 4-63 Dot Plot of Diflubenzuron across space and tide time.

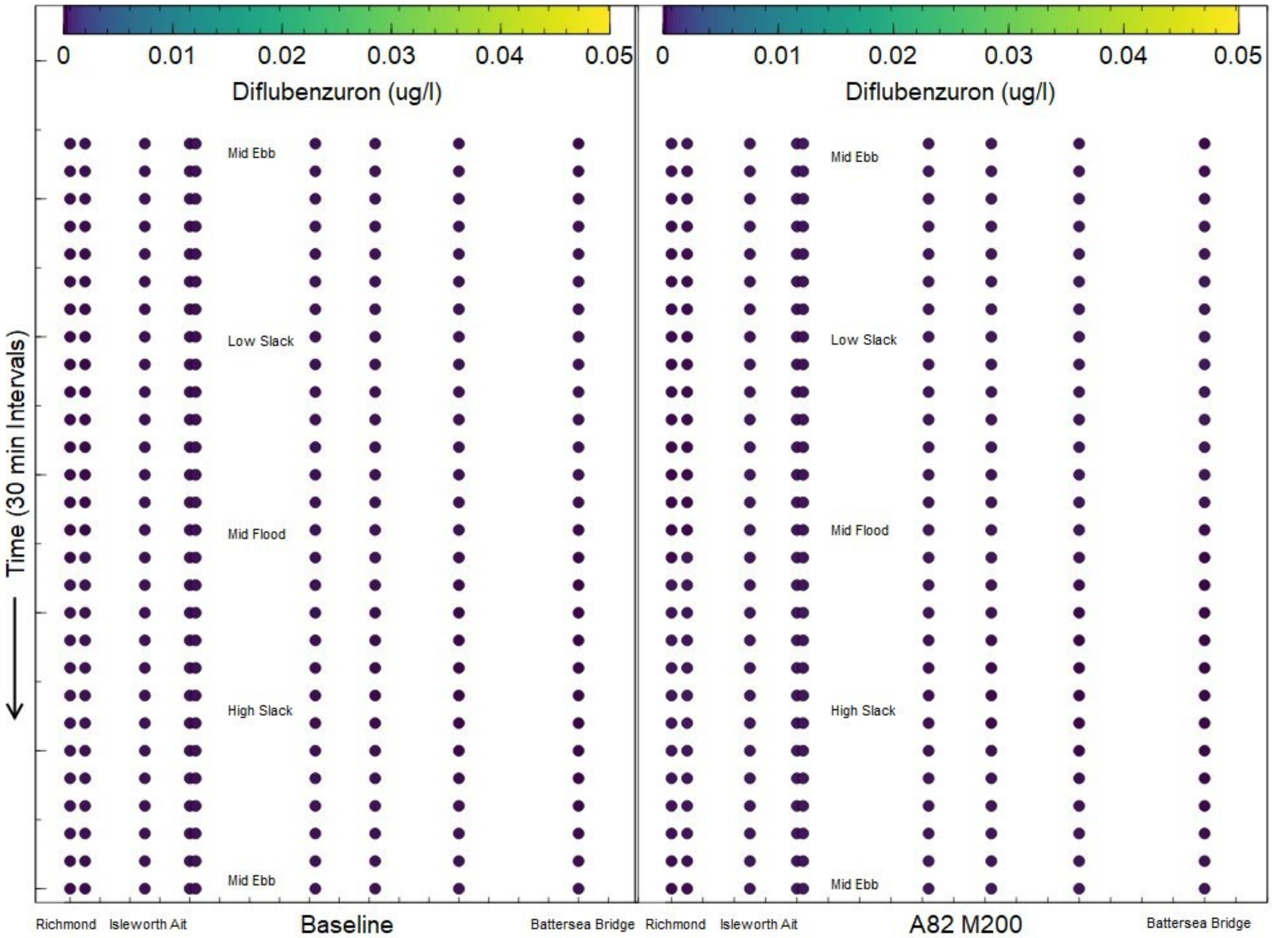


Figure 4-64 Dot Plot of Pirimicarb across space and tide time.

The changes to the EQSD suite of chemical determinands under the M96 Mogden-200 scenario compared with reference conditions are the same as those described for the A82 Mogden-200 scenario, showing minimal difference between flow scenarios.

4.6 OLFACTORY WATER QUALITY

An initial screening assessment has been undertaken to identify potential new or increased pressures to the study areas. This assessment uses reconcentration calculations to compare in-river concentrations to baseline and highlights determinands which exceed or approach (within 10% of) the EQS (if applicable). This assessment is intended as a guide for future investigations, see Section 6.

4.6.1 Overview

This section sets out the change for the olfactory parameters associated with the Mogden water recycling scheme. Assessments undertaken include:

- Freshwater River Thames - Section 4.6.2
- Estuarine Thames Tideway - Section 4.6.3

The evidence available, the general patterns observed in the data and any notable pressures will be outlined for each of these reaches. Where to find this evidence is also outlined in the following section.

4.6.2 Freshwater River Thames

As described in Section 4.2.53.2.5 above, the recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of chemicals.

4.6.3 Estuarine Thames Tideway

As described in Section 4.2.5 above, the AWRP processes will return all treated water to Mogden STW as liquid waste. This will affect the concentration of chemicals in the final effluent of Mogden STW discharged to the Thames Tideway. Using measured data from Mogden STW final effluent, 'reconcentration' calculations were performed for each determinand within the WFD and EQSD suites. These values have been used in dispersion modelling of the Mogden STW final effluent plume in the Thames Tideway.

Mogden A82

As per Section 2.6.4, 24 chemical determinands within the olfaction suite were identified as exceeding the LOD in the estuarine Thames Tideway under reference conditions. Of these 24 determinands, 15 were analysed against the EQS for both reference conditions and the A82 Mogden-200 scenario. Table 4-10 shows the exceedances of the EQS for these 15 determinands. It is noted that EQS relate to eco-toxicity and not to olfaction inhibition.

Under reference conditions, five chemical determinands were identified as exceeding the EQS. Of these, dissolved copper, permethrin, pirimicarb and dissolved zinc remained above the EQS under the A82 Mogden-200 scenario. Dissolved mercury exhibits a decrease in concentrations to below the EQS under the A82 Mogden-200 scenario.

There is one additional pressure under the A82 Mogden-200 scenario, with cypermethrin concentrations increase to above the EQS.

Table 4-10 Olfaction chemicals exceeding the EQS within the estuarine Thames Tideway under reference conditions and under the A82 Mogden-200 scenario

Chemical determinand	Reference conditions	A82 Mogden-200
Total cadmium	No	No
Chlorotoluron	No	No
Dissolved chromium (III)	No	No
Dissolved cobalt	No	No
Dissolved copper	Yes	Yes
Cypermethrin	No	Yes
Diuron	No	No
Dissolved iron	No	No
Isoproturon	No	No
Linuron	No	No
Dissolved mercury	Yes	No
Dissolved nickel	No	No
Permethrin	Yes	Yes
Pirimicarb	Yes	Yes
Dissolved zinc	Yes	Yes

Mogden M96

The changes to the olfaction suite of chemical determinands in the freshwater River Thames under the M96 Mogden-200 scenario compared with reference conditions are the same as those described for the A82 Mogden-200 scenario, showing minimal difference between flow scenarios.

4.7 RICHMOND POUND DRAWDOWN WATER QUALITY ASSESSMENT

The drawdown of reservoirs is known to directly impact upon water quality both within and downstream of the reservoir, with the greatest impacts observed when water levels are at their lowest[15]. There is considerable evidence reporting an increase in both suspended sediment concentrations and turbidity resulting from lake

[15] Hamilton, S.K., Murphy, C.A., Johnson, S.L. and Pollock, A. (2021) Water quality ramifications of temporary drawdown of Oregon reservoirs to facilitate juvenile Chinook salmon passage. *Lake and Reservoir Management*. DOI: 10.1080/10402381.2021.2017082

and reservoir drawdowns, with studies reporting an increase in turbidity of up to 25 times that recorded prior to drawdown[16,17,18]. The increase in water turbidity occurs due to resuspension of sediments and erosion of newly exposed substrate. Studies have also reported significant increases in ammoniacal nitrogen and total phosphorous concentrations during the emptying period and when water levels are at their lowest[19,20]. Increased ammonia and phosphorous concentrations can be attributed partly to the exported sediment which carries nutrients. Several studies have also reported significant drops in DO during drawdown, most often associated with changes to temperature and a breakdown of the thermocline[21]. The temperature changes and associated anoxic conditions can also promote the release of nutrients from sediment. In addition to nutrients, it is also possible for legacy contaminants, such as DDT and mercury, to be mobilised from sediments and transported downstream[22,23,24].

Salinity

An assessment of the salinity impacts in the Richmond Pound arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme and A82 and M96 flow scenarios.

Outputs from HR Wallingford's Upper Tideway model for salinity under A82 flow conditions are presented below (Figure 4-65, Figure 4-66 and Figure 4-67).

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[16] Hauer, C., Haimann, M., Holzapfel, P., Flodl, P., Wagner, B., Hubmann, M., Hofer, B., Habersack, H. and Schletterer, M. (2020) Controlled reservoir drawdown- challenges for sediment management and integrative monitoring: an Austrian case study. *Water,* 12, 1058. DOI: 10.3390/w12041058

[17] Grant, G.E., Lewis, S.L., Stewart, G. & Glasmann, J.R. (2014) Sediment problems and consequences during temporary drawdown of a large flood control reservoir for environmental retrofitting. *Engineering Geology for Society and Territory*, 3, pp. 27-30. DOI: 10.1007/978-3-319-09054-2_6

[18] Perrin, C.J., Ashley, K.I. & Larkin, G.A. (2000) Effect of drawdown on ammonium and iron concentrations in a coastal mountain reservoir. *Water Quality Research*, 35 (2), pp. 231-244. DOI: 10.2166/wqrj.2000.015

[19] Geraldes, A,M. & Boavida, M. (2005) Seasonal water level fluctuations: implications for reservoir limnology and management. *Lakes & Reservoirs Research and Management*, 10 (1), pp. 59-69. DOI: 10.1111/j.1440-1770.2005.00257.x

[20] Baldwin, D.S., Gigney, H., Wilson, J.S., Watson, G. and Boulding, A.N. (2008) Drivers of water quality in a large water storage reservoir during a period of extreme drawdown. *Water Research*, 42, pp. 4711-4724. DOI: 10.1016/j.watres.2008.08.020

[21] Schenk, L. and Bragg, H. (2021) Sediment transport, turbidity, and dissolved oxygen responses to annual streambed drawdowns for fish passage in a flood control reservoir. *Journal of Environmental Management*, 295. DOI: 10.1016/j.jenvman.2021.113068

[22] Anderson, C. (2007) Influence of Cougar Reservoir drawdown on sediment and DDT transport and deposition in the McKenzie River basin, Oregon, water years 2002–04. *US Geological Survey Scientific Investigations Report 2007–5164*.

[23] Eckley, C.S., Luxton, T.P., McKernan, J.L., Goetz, J. and Goulet, J. (2015) Influence of reservoir water level fluctuations on sediment methylmercury concentrations downstream of the historical Black Butte mercury mine, OR. *Applied Geochemistry*, 61, pp. 284-293.

[24] Ni, F.J., Bhavsar, S.P., Poirer, D., Branfireun, B., Petro, S., Arts, M.T., Chong-Kit, R., Mitchell, C.P.J. & Arhonditsis, G.B. (2021) Impacts of water level fluctuations on mercury concentrations in hydropower reservoirs: a microcosm experiment. *Ecotoxicology and Environmental Safety*, 220. DOI: 10.1016/j.ecoenv.2021.112354

Figure 4-65 Maximum salinity along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

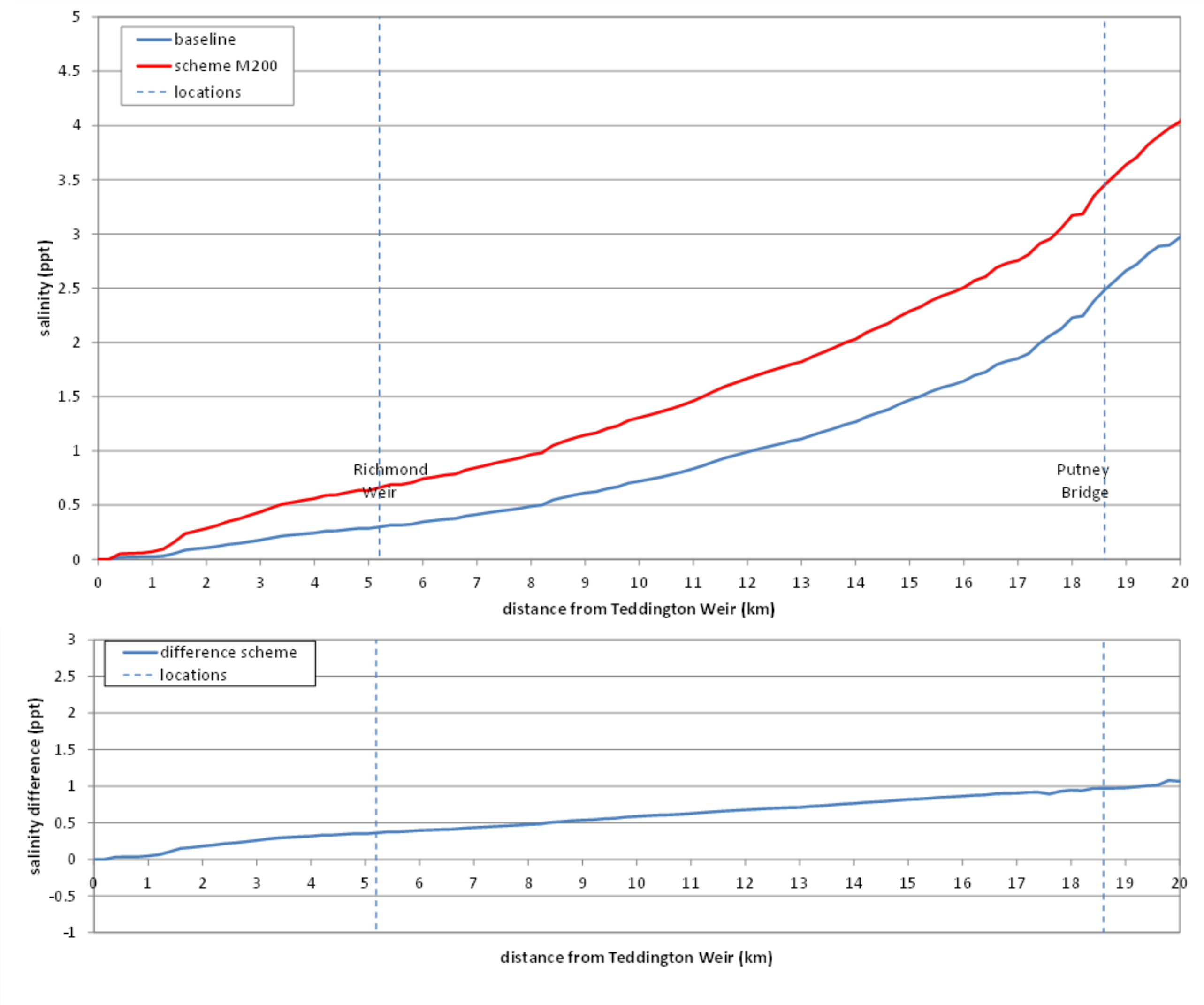


Figure 4-66 Mean salinity along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

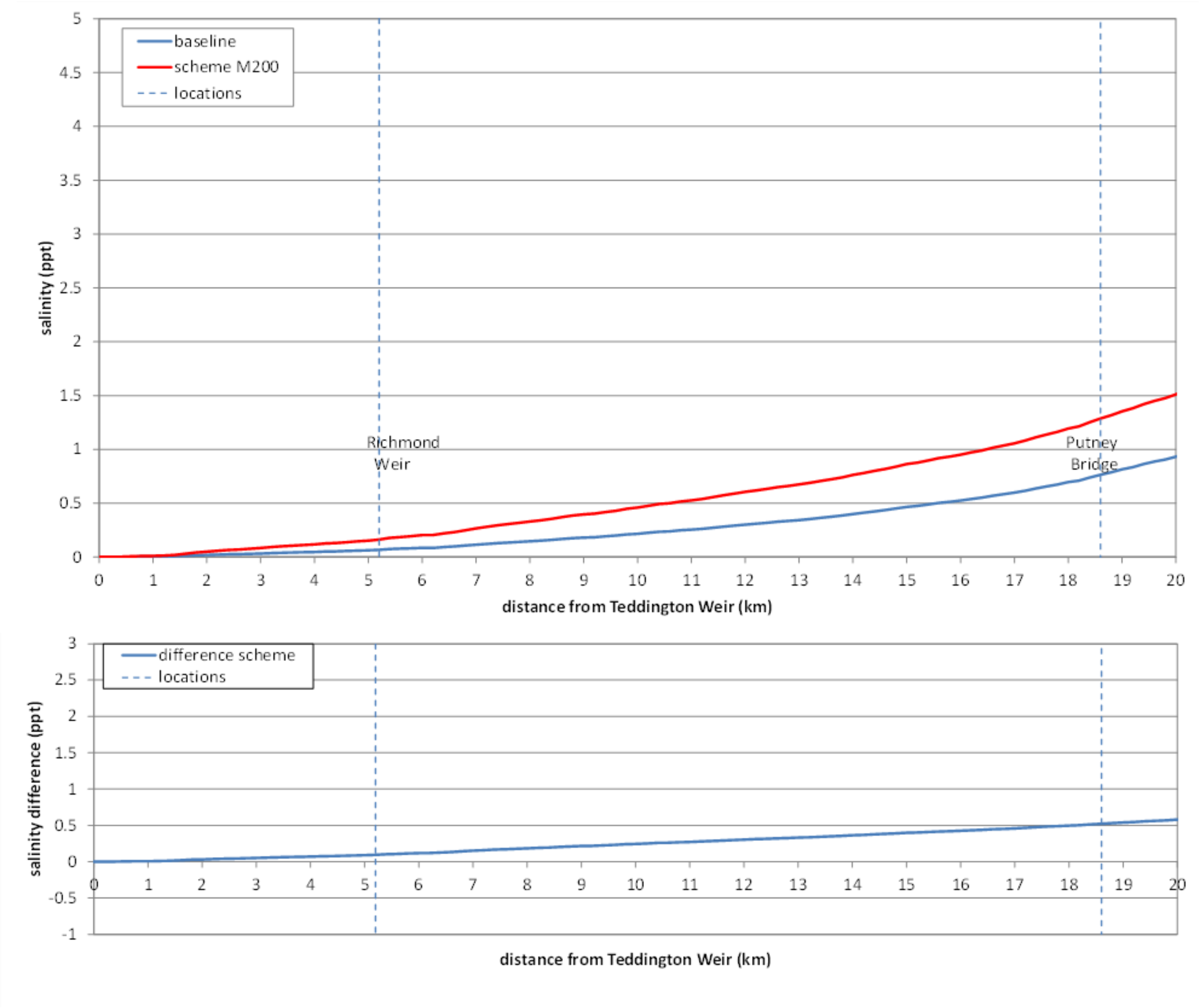
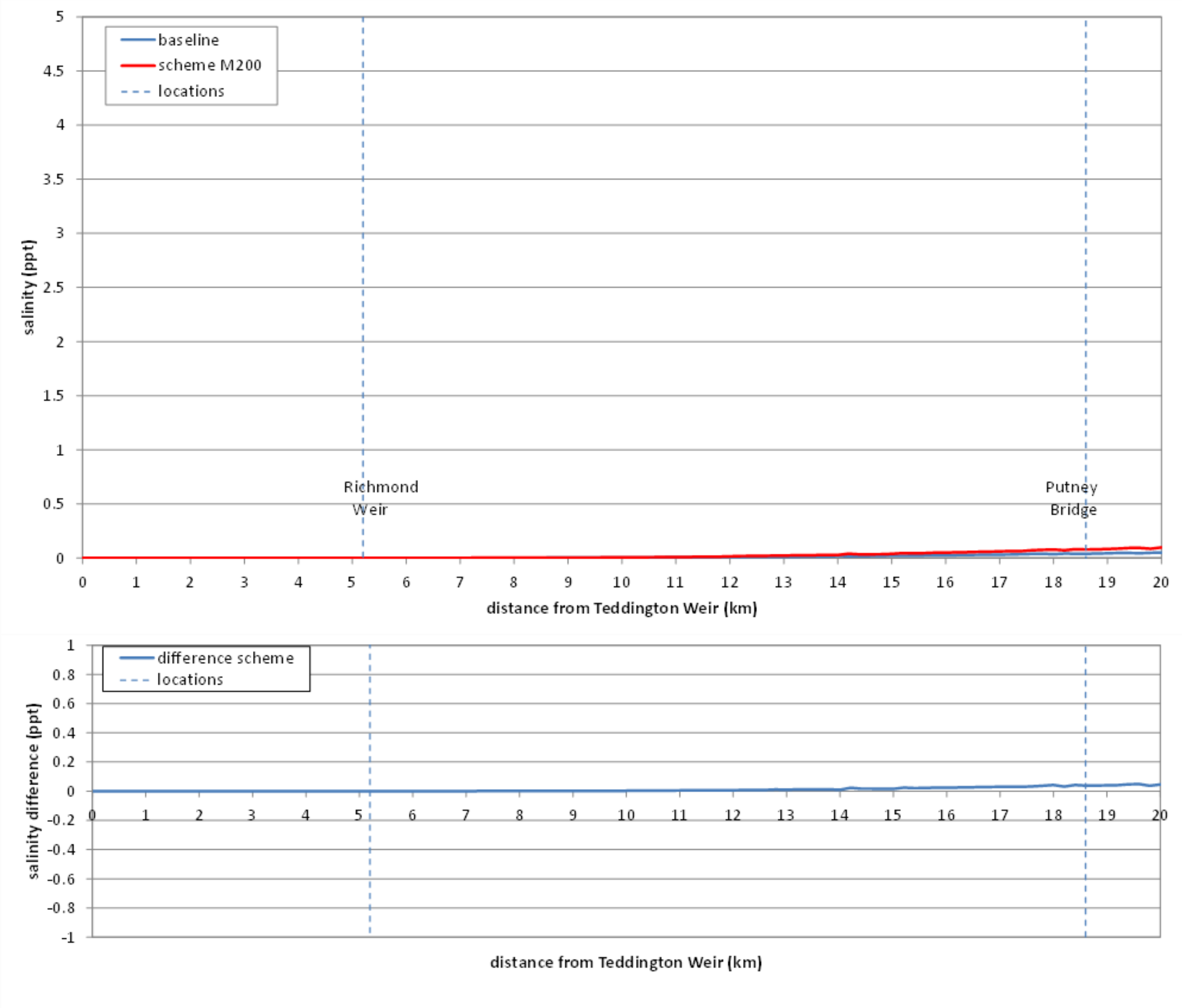


Figure 4-67 Minimum salinity along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario



The modelled data displayed in Figure 4-65, Figure 4-66 and Figure 4-67 indicate that there is an increase in salinity under the A82 Mogden-200 scenario compared with baseline from approx. 1.5km to >20km seawards of Teddington Weir. The graphs above display salinity modelled for the 200 Ml/d Mogden water recycling scheme and so represent the greatest salinity differences associated with the various scheme sizes at Mogden. The greatest increase in maximum and mean salinity from baseline is approx. 0.55 ppt and the greatest increase in minimum salinity is <0.1ppt.

Outputs from HR Wallingford's Upper Tideway model for salinity under M96 flow conditions are presented below (Figure 4-68, Figure 4-69 and Figure 4-70).

Figure 4-68 Maximum salinity along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

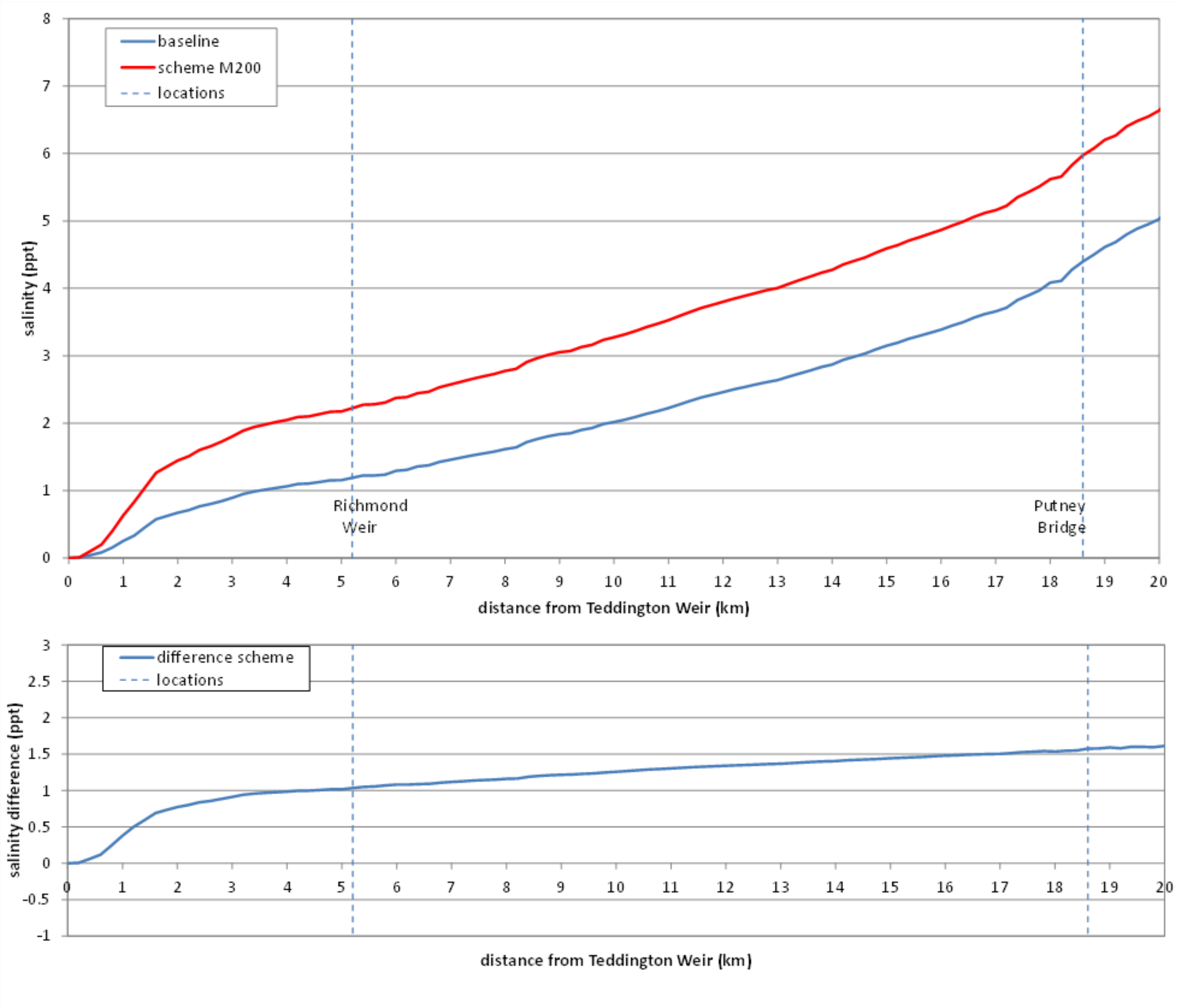


Figure 4-69 Mean salinity along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

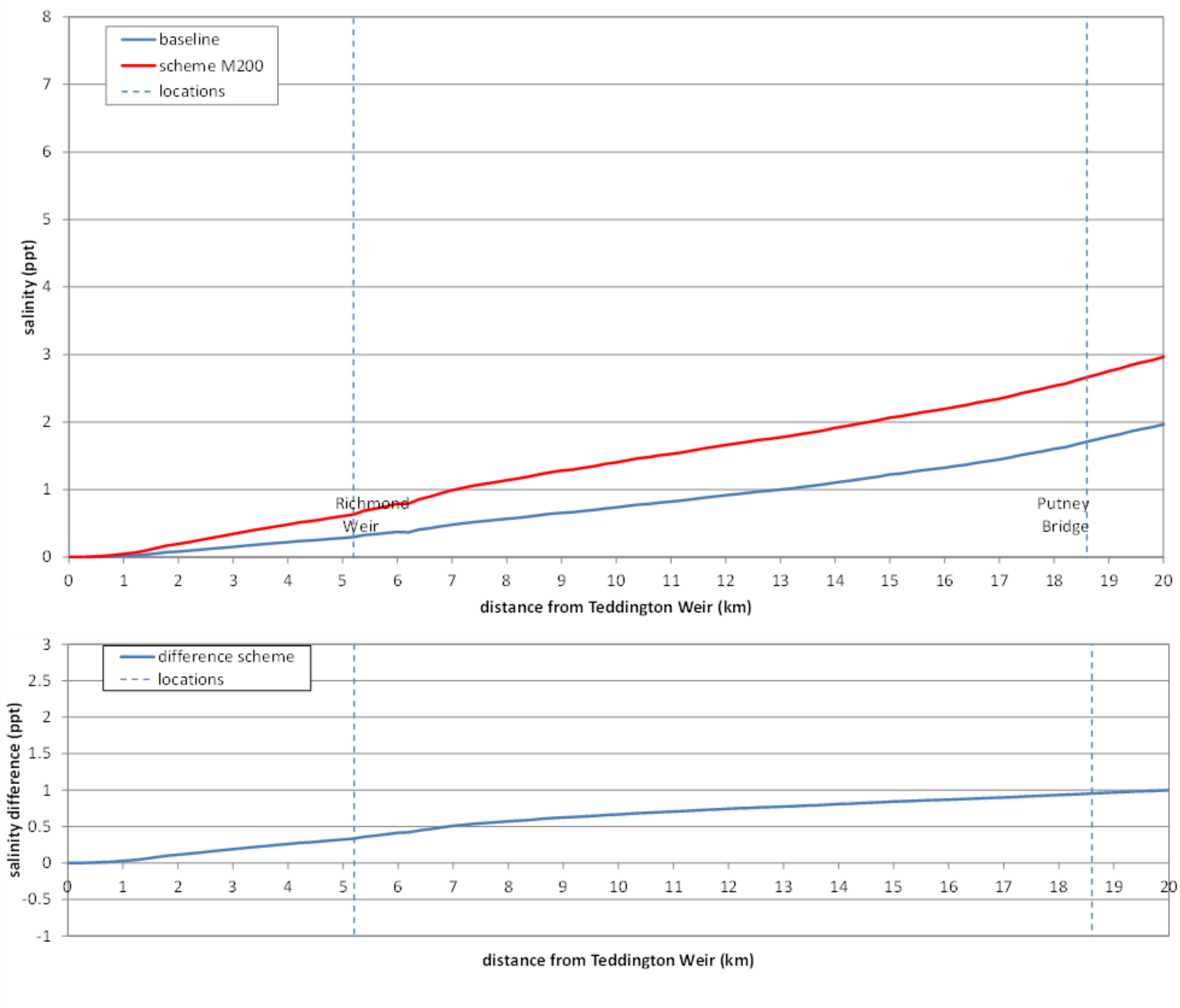
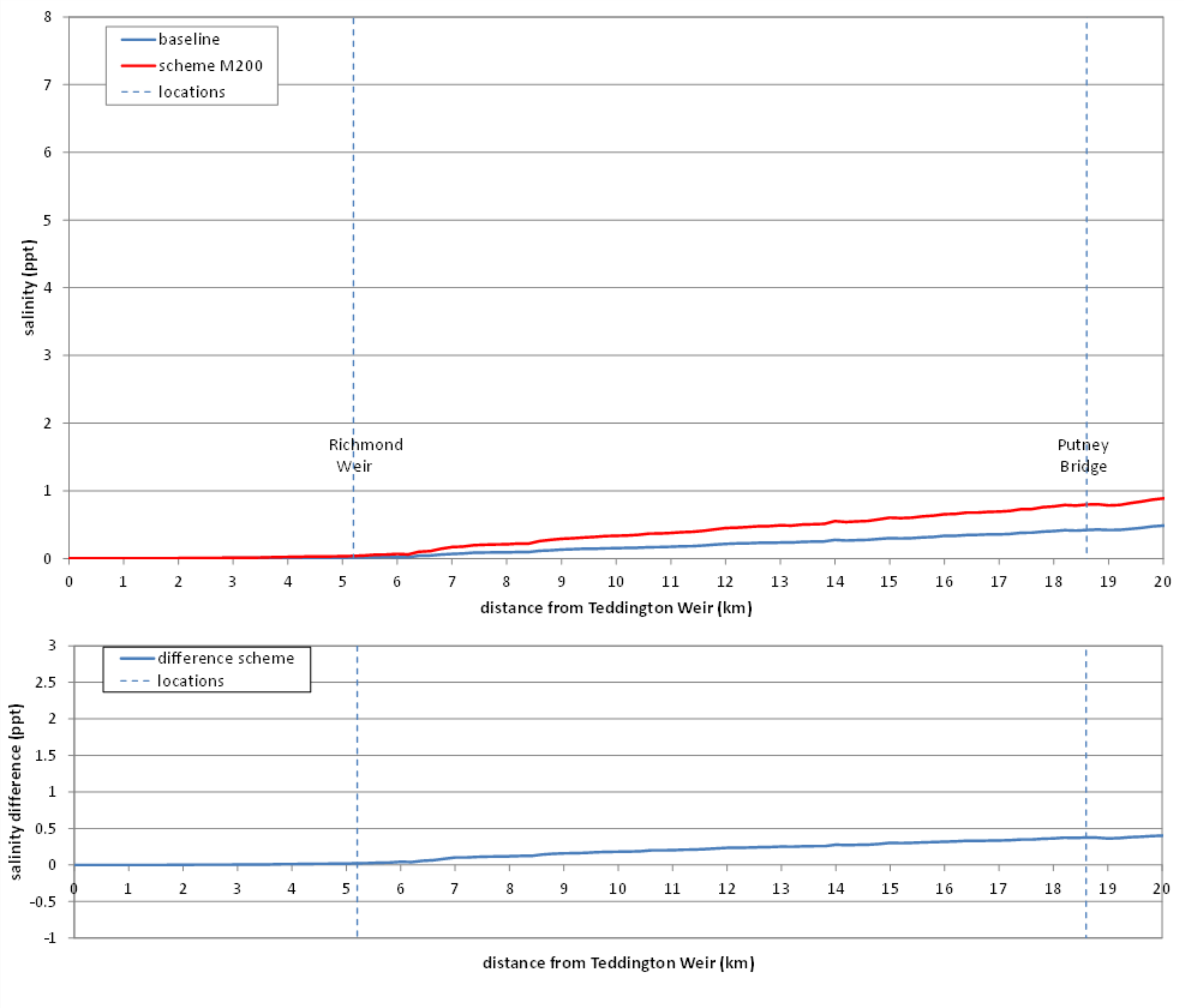


Figure 4-70 Minimum salinity along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



The modelled data displayed in Figure 4-68, Figure 4-69 and Figure 4-70 indicate that there is an increase in salinity under the M96 Mogden-200 scenario compared with baseline from approx. 1.5km to >20km seawards of Teddington Weir. The graphs above display salinity modelled for the 200 Ml/d Mogden water recycling scheme and so represent the greatest salinity differences associated with the various scheme sizes at Mogden. The greatest increase in maximum salinity from baseline is approx. 0.55 ppt, mean salinity from baseline is approx. 1 ppt and the greatest increase in minimum salinity is approx. 0.45 ppt.

Suspended sediment

An assessment of the suspended sediment impacts in the Richmond Pound arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme and A82 and M96 flow scenarios.

Outputs from HR Wallingford's Upper Tideway model for suspended sediment under A82 flow conditions are presented below (Figure 4-71, Figure 4-72 and Figure 4-73).

Figure 4-71 Maximum suspended sediment along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

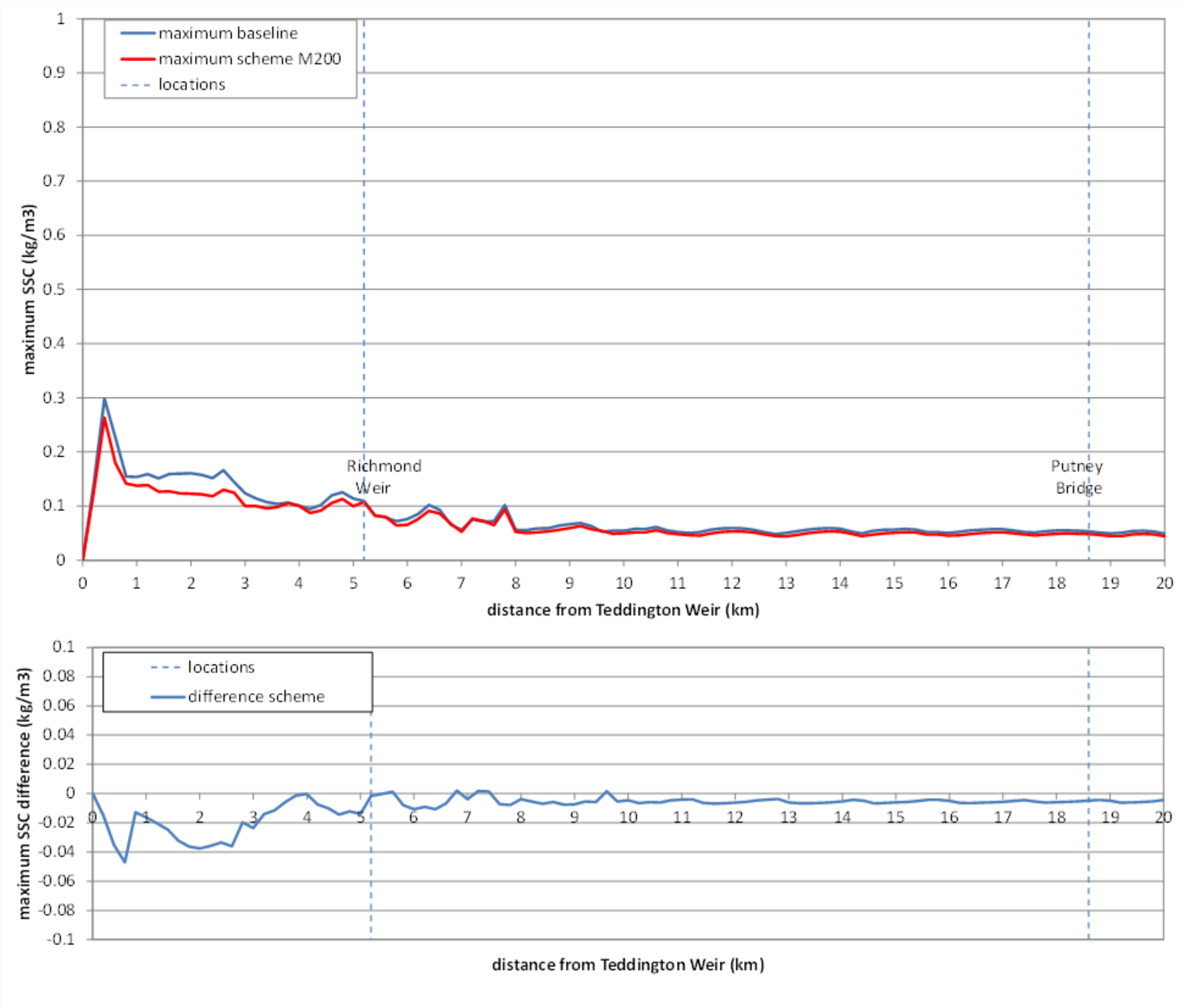


Figure 4-72 95th %ile suspended sediment along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

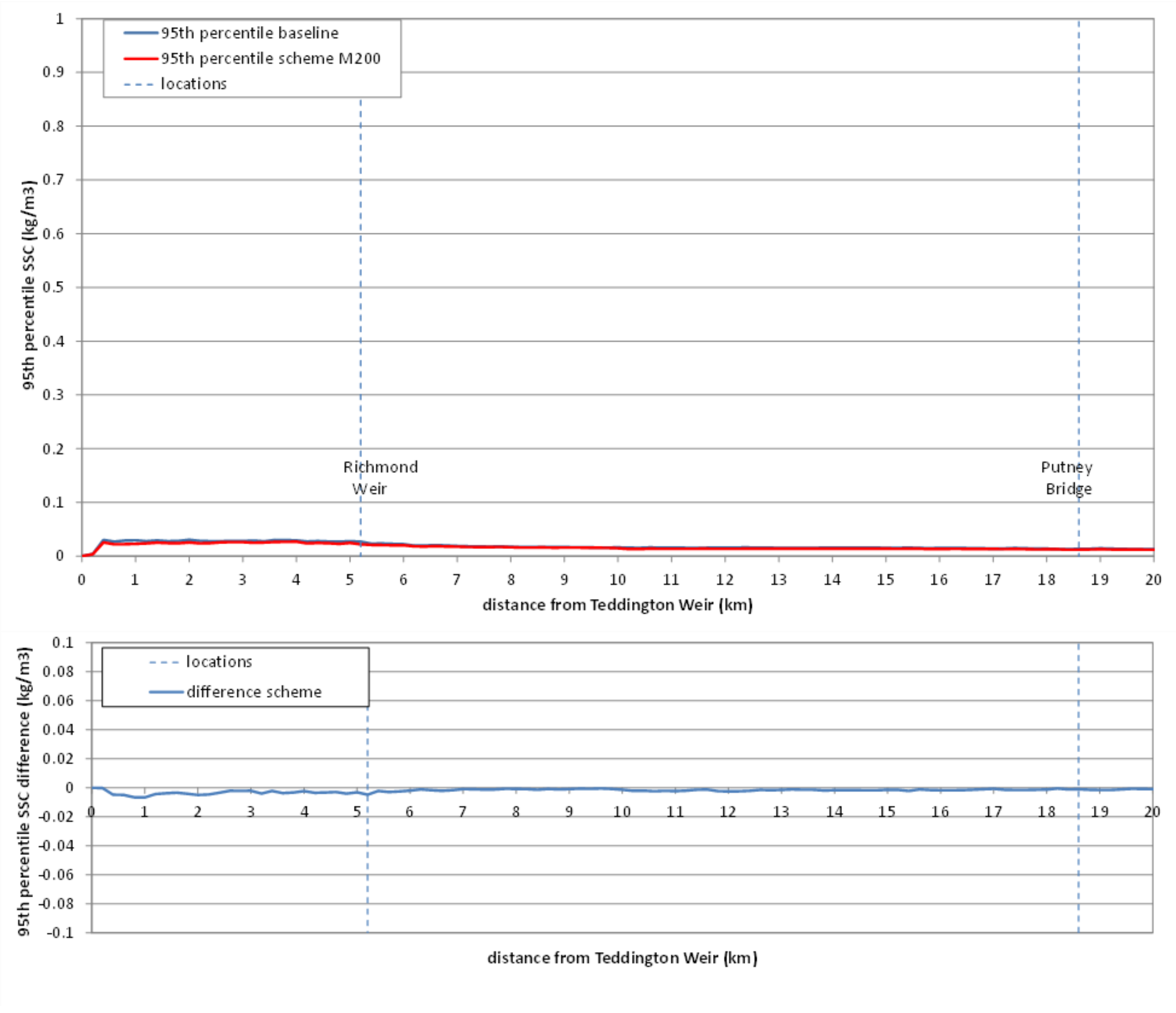
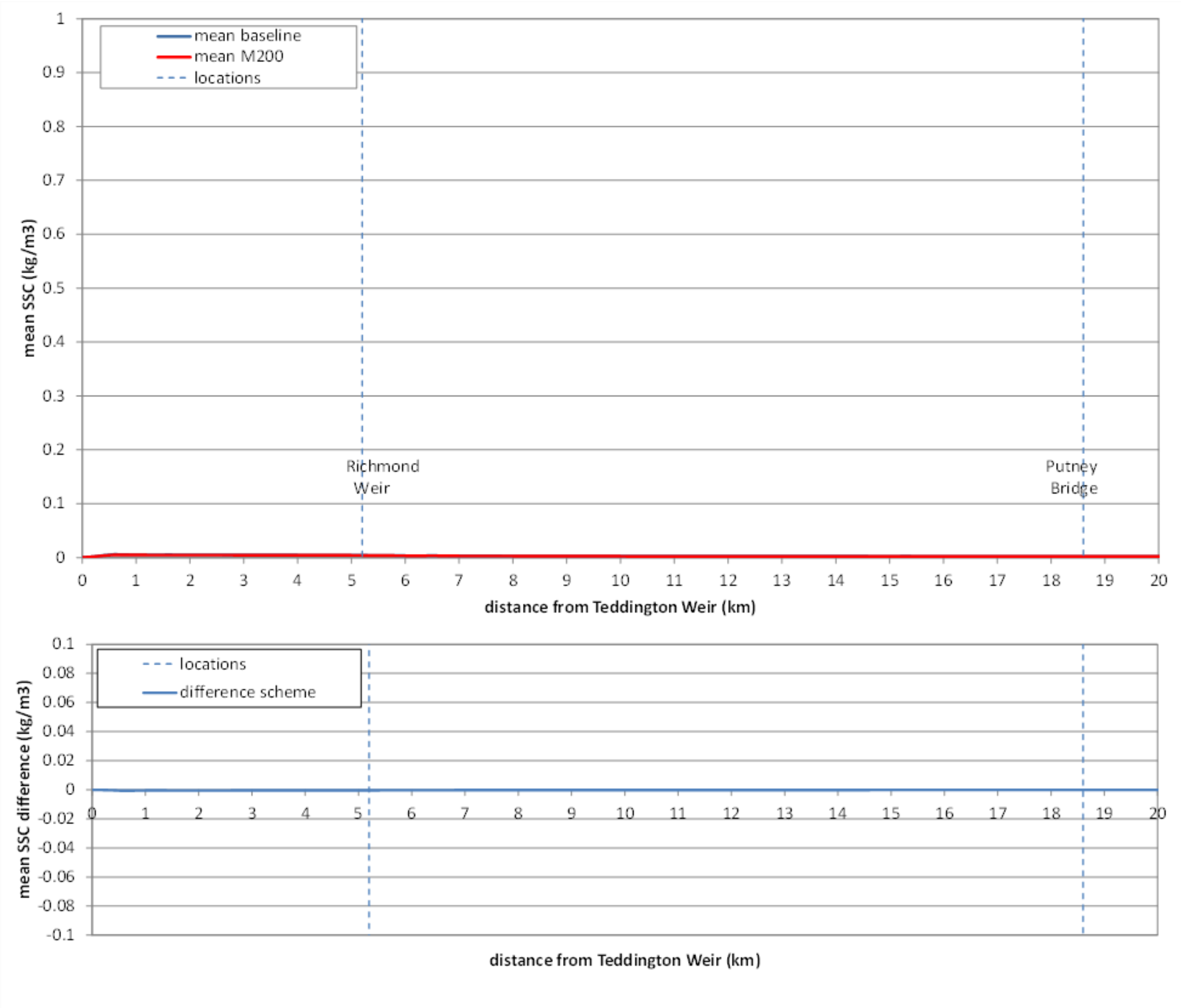


Figure 4-73 Mean suspended sediment along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario



The modelled data displayed in Figure 4-71, Figure 4-72 and Figure 4-73 indicate that there is a decrease in suspended sediment under the A82 Mogden-200 scenario compared with baseline from approx. 0.2 km to >20km seawards of Teddington Weir. The graphs above display suspended sediment modelled for the Mogden 200 Ml/d scheme and so represent the greatest suspended sediment differences associated with the various scheme sizes at Mogden. The greatest decrease in maximum suspended sediment from baseline is approx. 0.045 kg/m^3 and the greatest decrease in 95th %ile and mean suspended sediment from baseline is approx. 0 kg/m^3.

Outputs from HR Wallingford's Upper Tideway model for suspended sediment under M96 flow conditions are presented below (Figure 4-74, Figure 4-75 and Figure 4-76).

Figure 4-74 Maximum suspended sediment along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

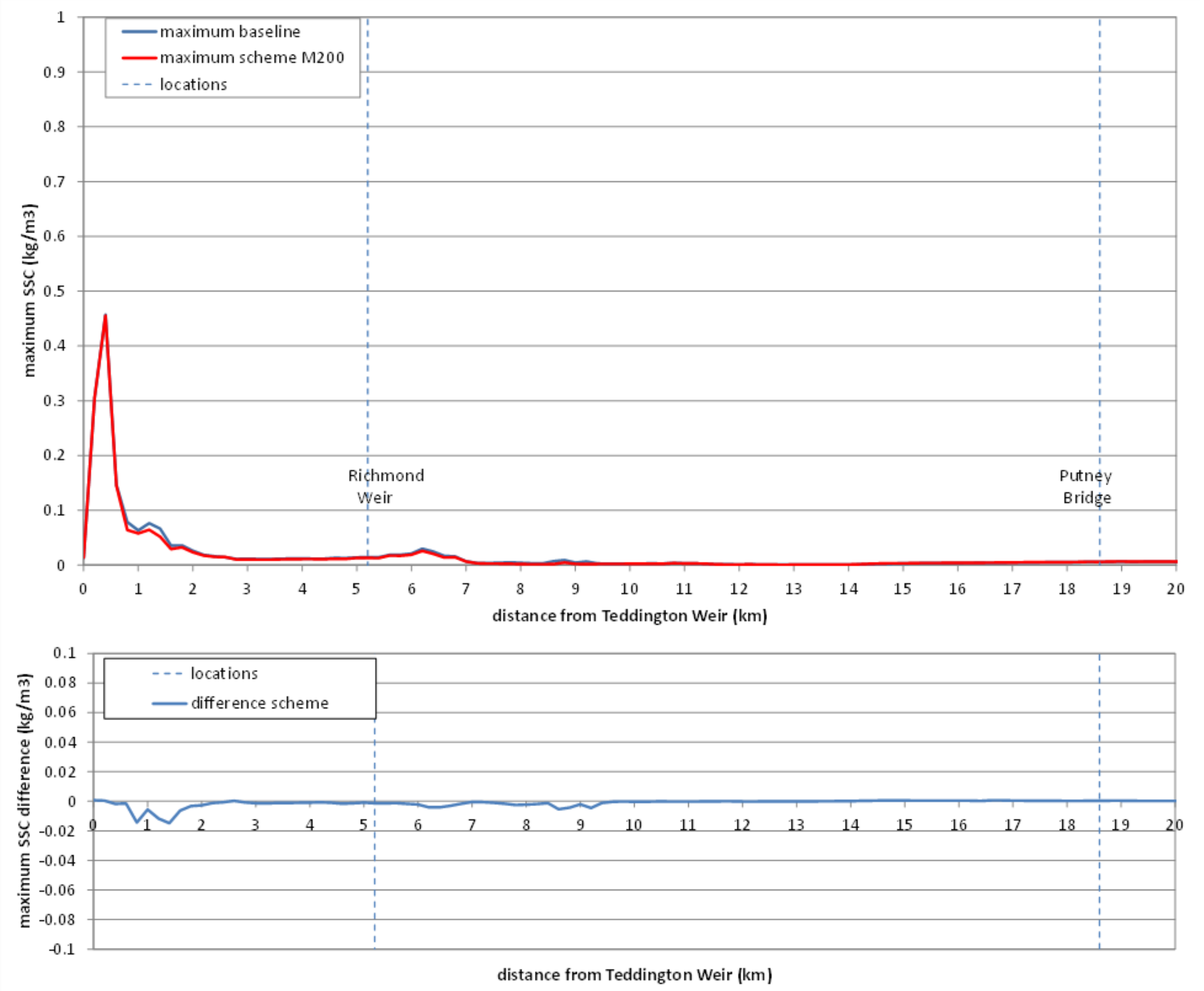


Figure 4-75 95th %ile suspended sediment along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

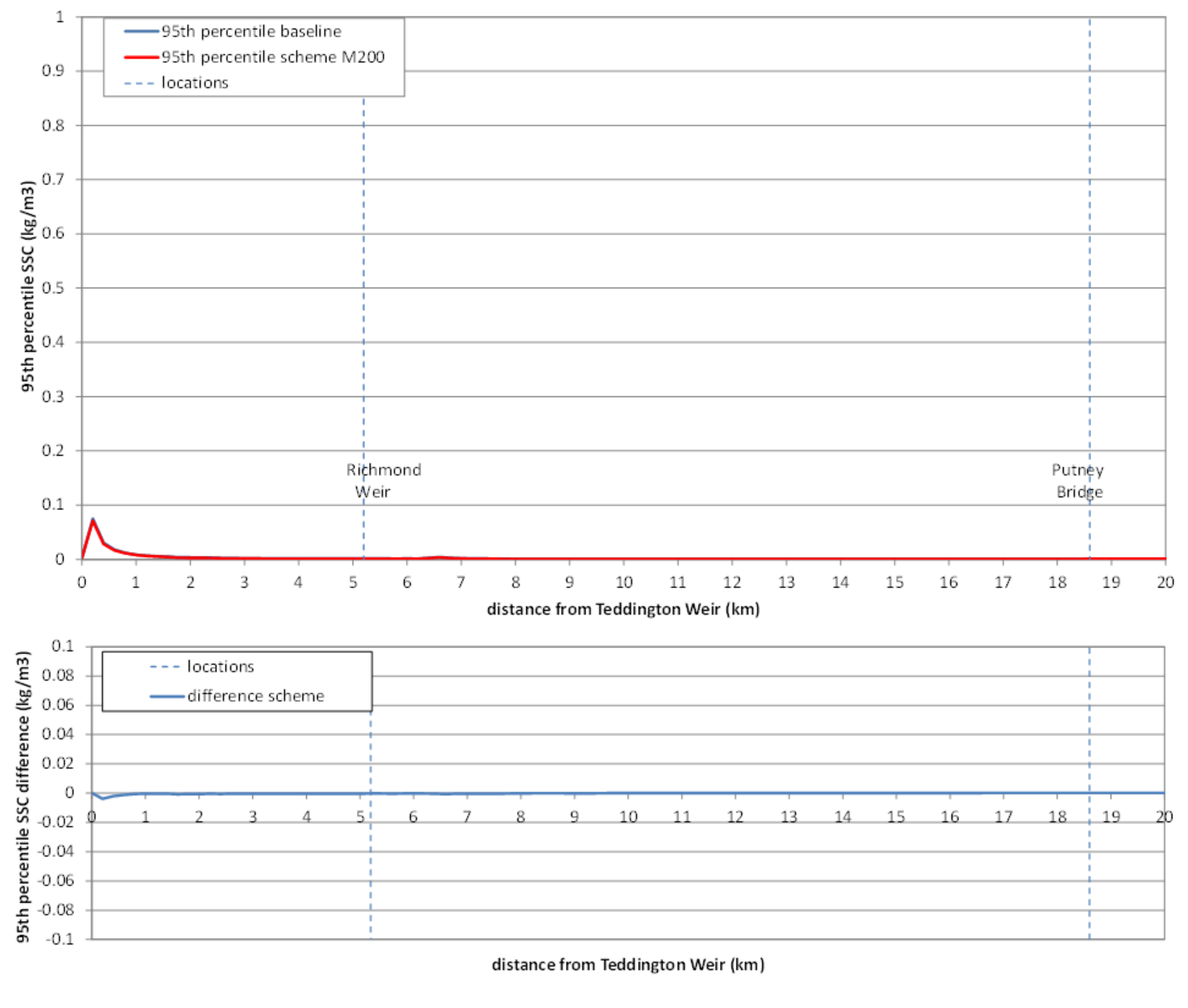
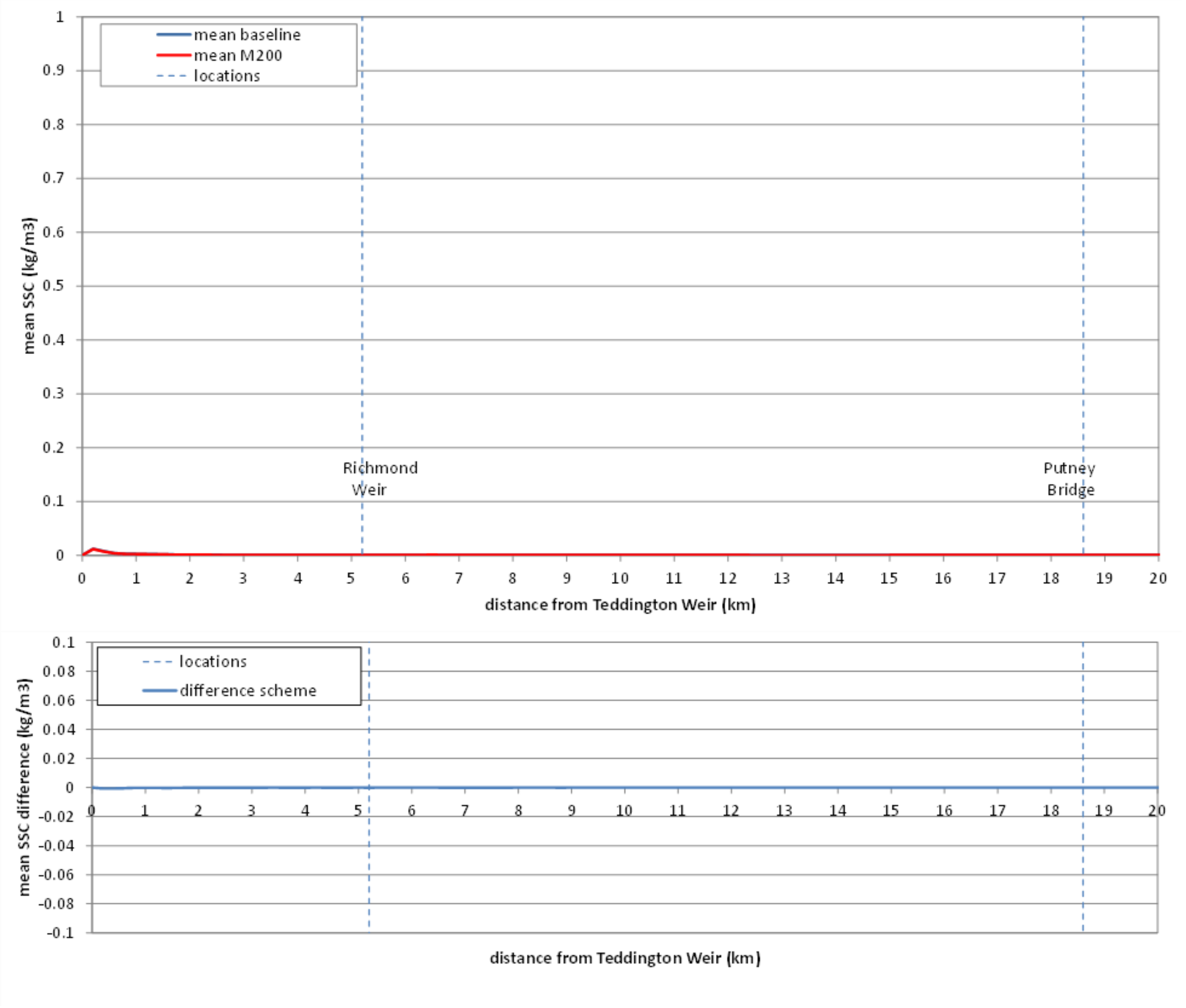


Figure 4-76 Mean suspended sediment along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



The modelled data displayed in Figure 4-74, Figure 4-75 and Figure 4-76 indicate that there is a decrease in suspended sediment under the M96 Mogden-200 scenario compared with baseline from approx. 0.2 km to 10km seawards of Teddington Weir. The graphs above display suspended sediment modelled for the Mogden 200 Ml/d scheme and so represent the greatest suspended sediment differences associated with the various scheme sizes at Mogden. The greatest decrease in maximum suspended sediment from baseline is approx. 0.015 kg/m^3 and the greatest decrease in 95th %ile and mean suspended sediment from baseline is approx. 0.05 and 0 kg/m^3 respectively.

Dissolved oxygen

An assessment of the DO impacts in the Richmond Pound arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme and A82 and M96 flow scenarios.

Outputs from HR Wallingford's Upper Tideway model for dissolved oxygen under A82 flow conditions are presented below (Figure 4-77 and Figure 4-78).

Figure 4-77 5th %ile dissolved oxygen along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

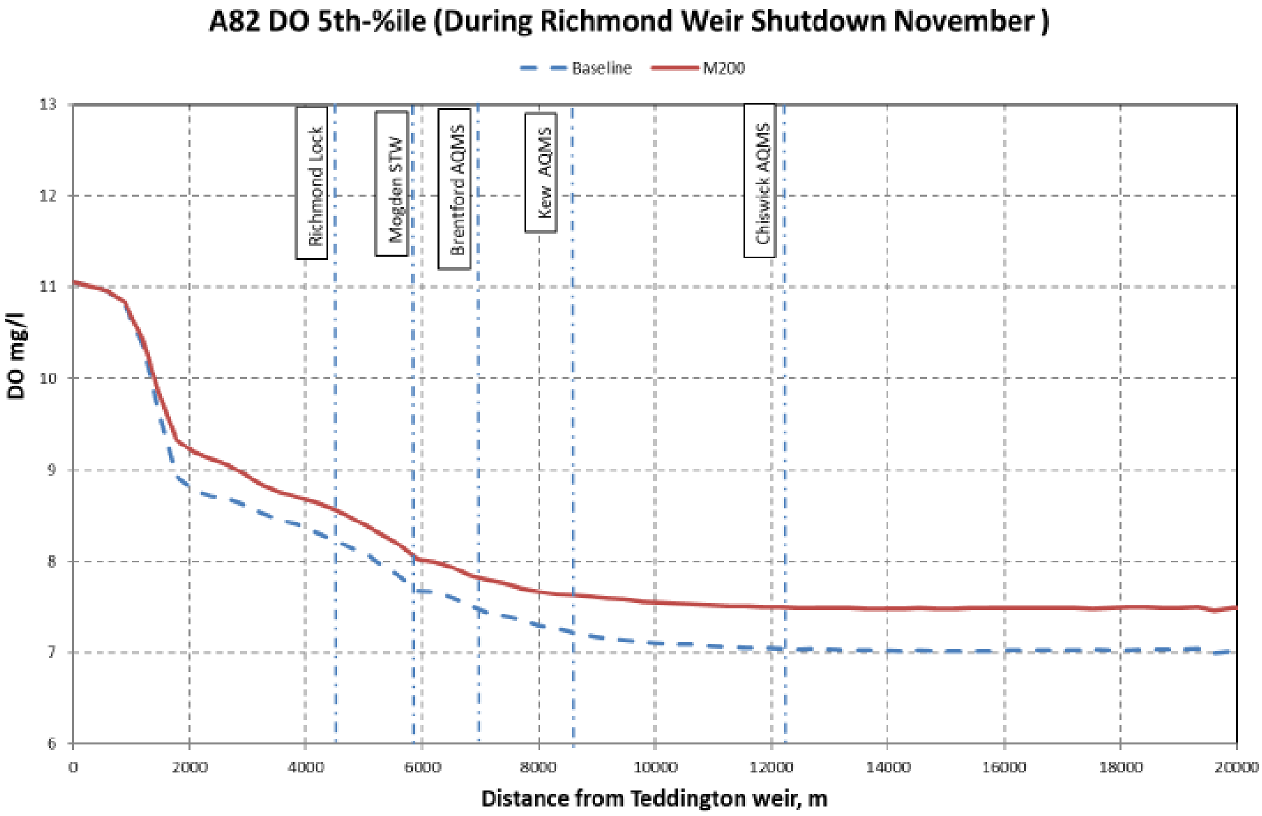
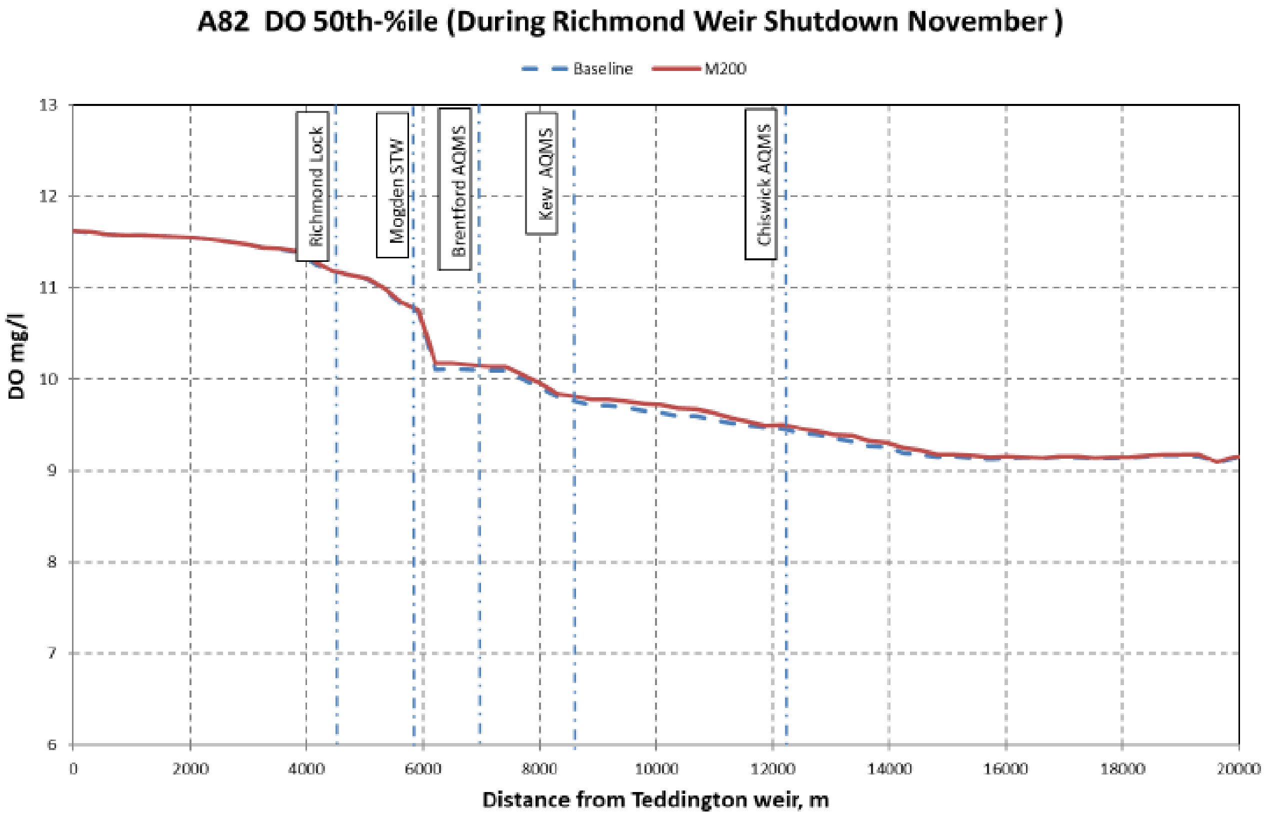


Figure 4-78 50th %ile dissolved oxygen along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario



The modelled data displayed in Figure 4-77 and Figure 4-78 indicate that there is an increase in dissolved oxygen under the A82 Mogden-200 scenario compared with baseline from approx. 6.5km (just after the Mogden outfall) to 16km seawards of Teddington Weir. The graphs above display dissolved oxygen modelled for the Mogden 200 Ml/d scheme and so represent the greatest dissolved oxygen differences associated with the various scheme sizes at Mogden. The greatest decrease in 5th %ile dissolved oxygen from baseline is approx. 0.5 mg/l and the greatest increase in 50th %ile dissolved oxygen from baseline is approx. 0.1 mg/l.

Outputs from HR Wallingford's Upper Tideway model for dissolved oxygen under M96 flow conditions are presented below (Figure 4-79 and Figure 4-80).

Figure 4-79 5th %ile dissolved oxygen along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

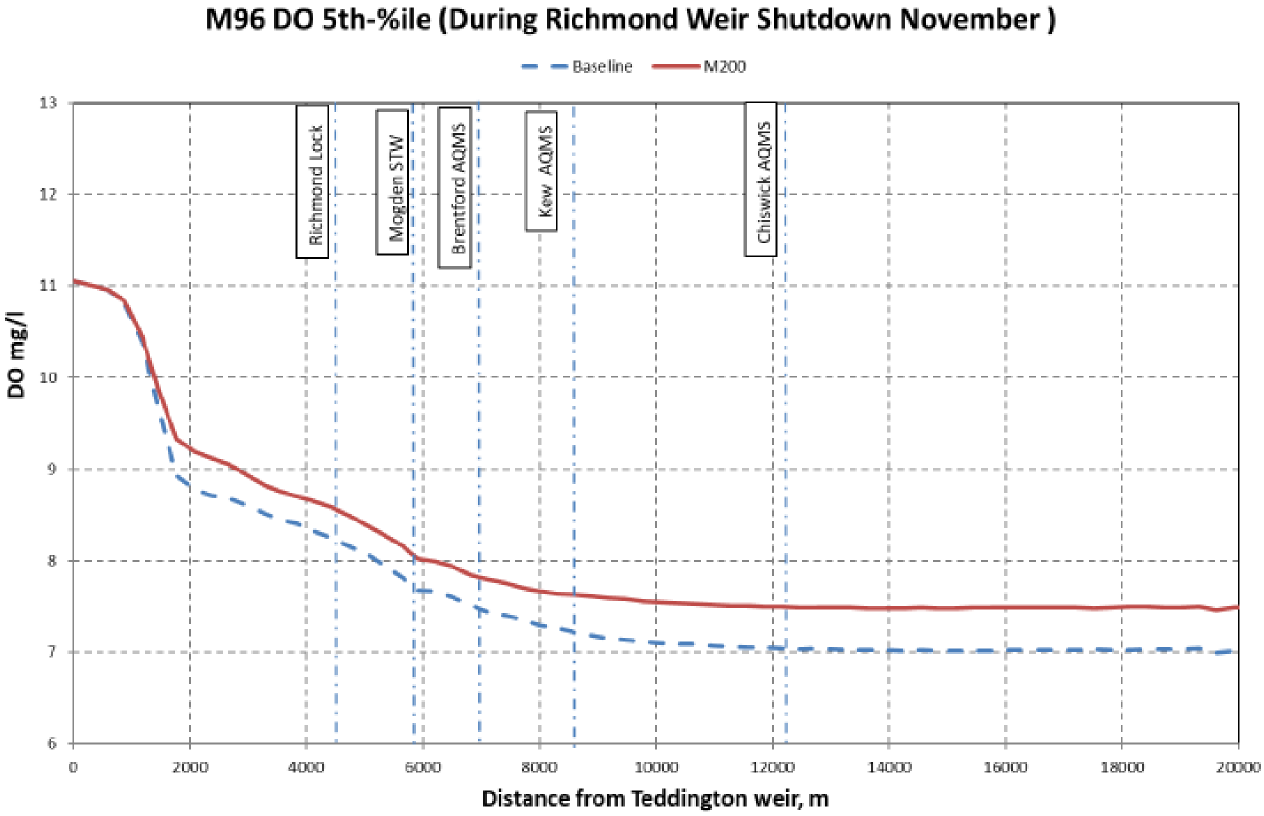
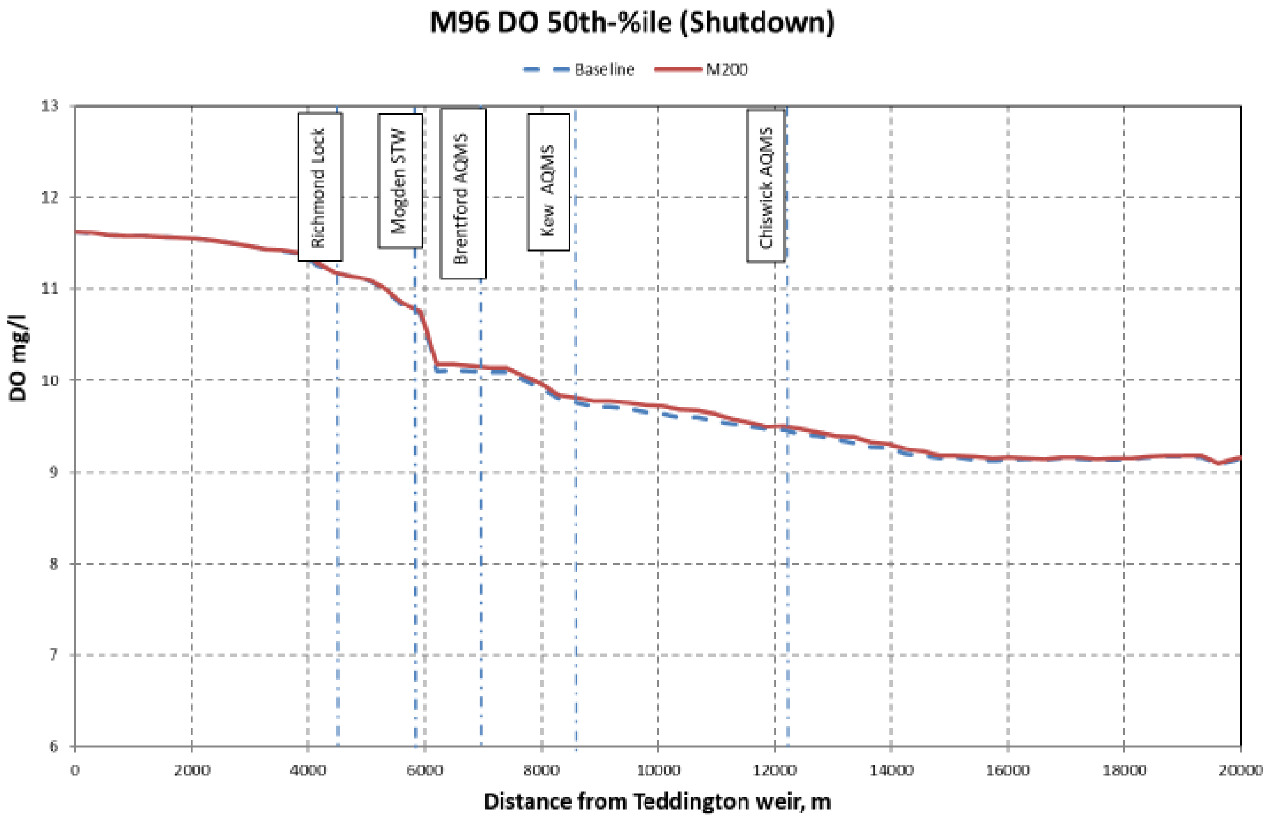


Figure 4-80 50th %ile dissolved oxygen along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



The modelled data displayed in Figure 4-79 and Figure 4-80 indicate that there is an increase in dissolved oxygen under the M96 Mogden-200 scenario compared with baseline from approx.1.5km (5th %ile) and approx. 6.5km (just after the Mogden outfall) (50th %ile) to >20km (5th %ile) and approx. 16km (50th %ile) seawards of Teddington Weir. The graphs above display dissolved oxygen modelled for the Mogden 200 Ml/d scheme and so represent the greatest dissolved oxygen differences associated with the various scheme sizes at Mogden. The greatest decrease in 5th %ile dissolved oxygen from baseline is approx. 0.5 mg/l and the greatest increase in 50th %ile dissolved oxygen from baseline is approx. 0.1 mg/l.

Temperature

An assessment of the temperature impacts in the Richmond Pound arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme and A82 and M96 flow scenarios.

Outputs from HR Wallingford's Upper Tideway model for temperature under A82 flow conditions are presented below (Figure 4-81 and Figure 4-82).

Figure 4-81 50th %ile temperature along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario

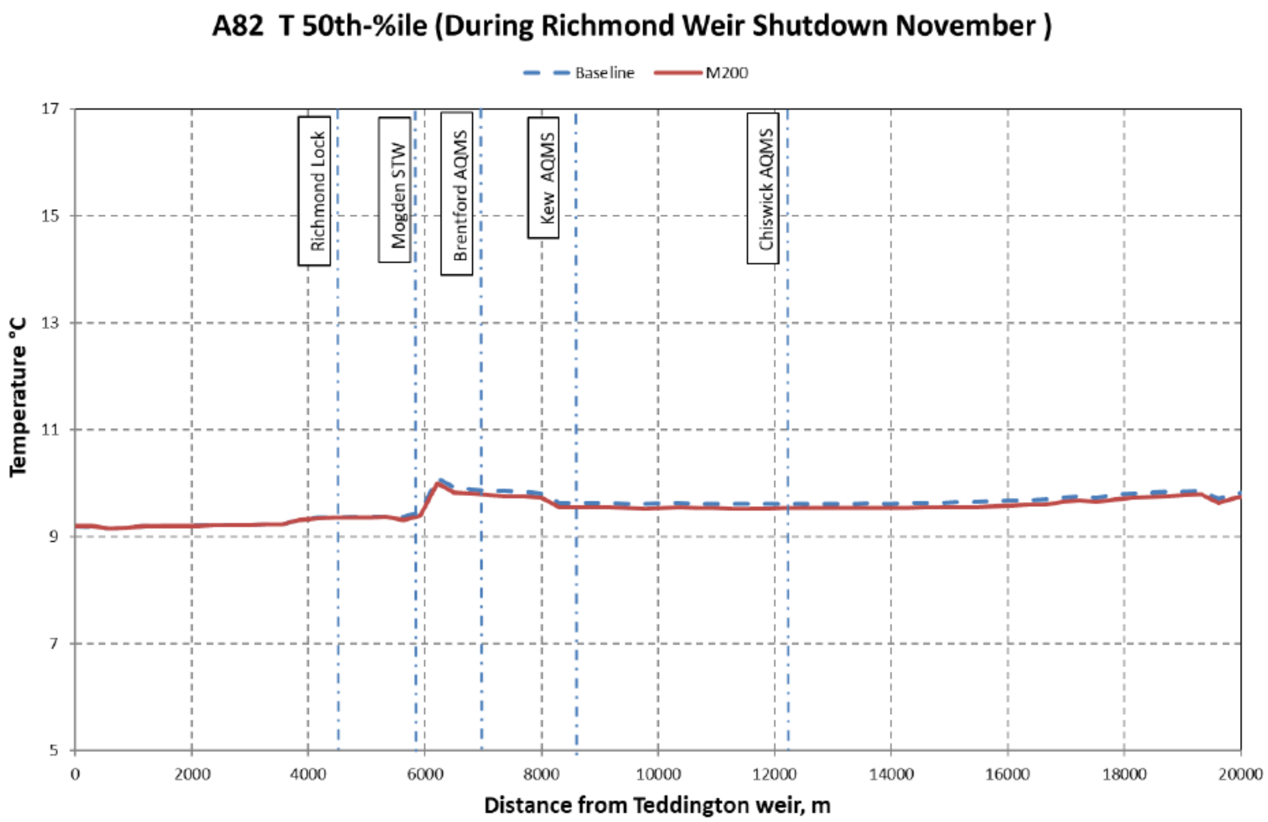
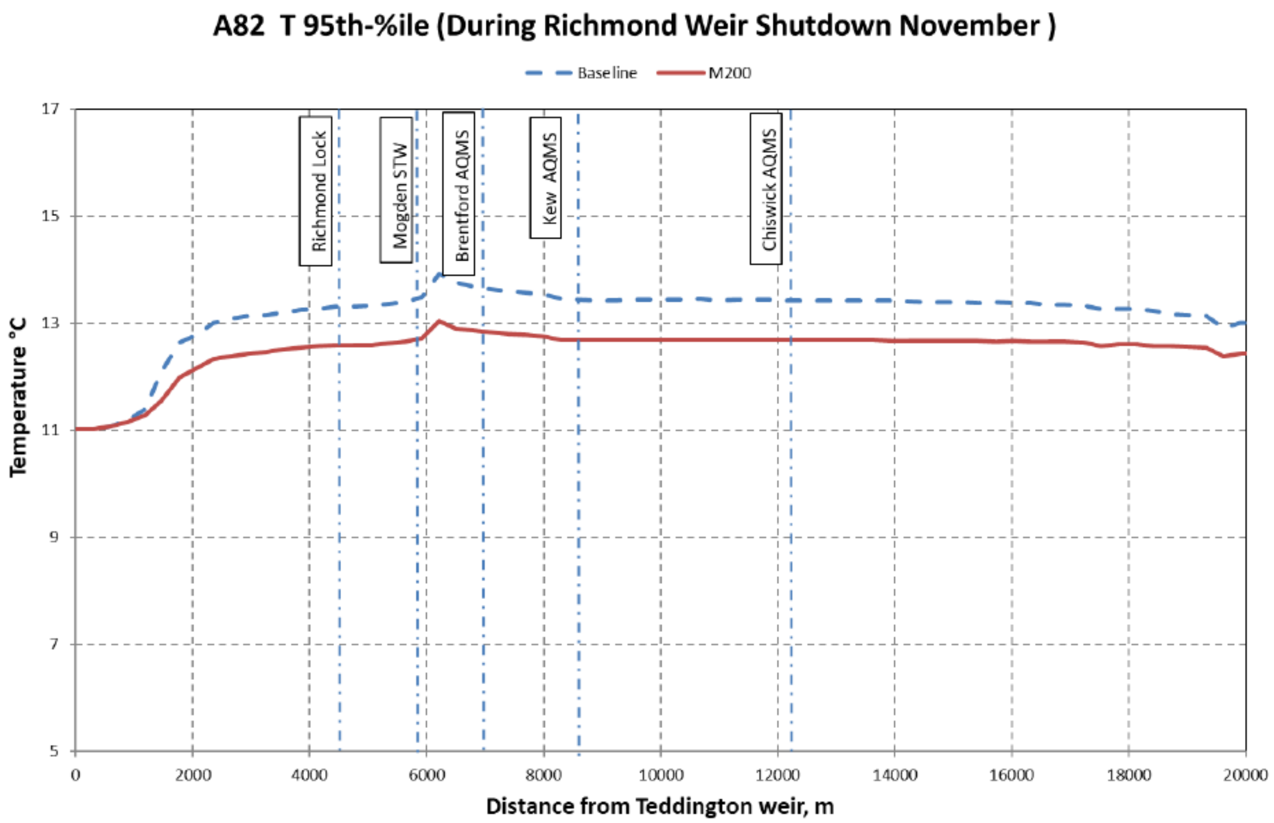


Figure 4-82 95th %ile temperature along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the A82 scenario



The modelled data displayed in Figure 4-81 and Figure 4-82 indicate that there is a decrease in temperature under the A82 Mogden-200 scenario compared with baseline from approx. 1km - >20km seawards of Teddington Weir. The graphs above display dissolved oxygen modelled for the Mogden 200 Ml/d scheme and so represent the greatest temperature differences associated with the various scheme sizes at Mogden. The greatest decrease in 50th %ile temperature from baseline is approx. 0.1°C and the greatest decrease in 95th %ile temperature from baseline is approx. 1°C.

Outputs from HR Wallingford's Upper Tideway model for temperature under M96 flow conditions are presented below (Figure 4-83 and Figure 4-84).

Figure 4-83 50th %ile temperature along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario

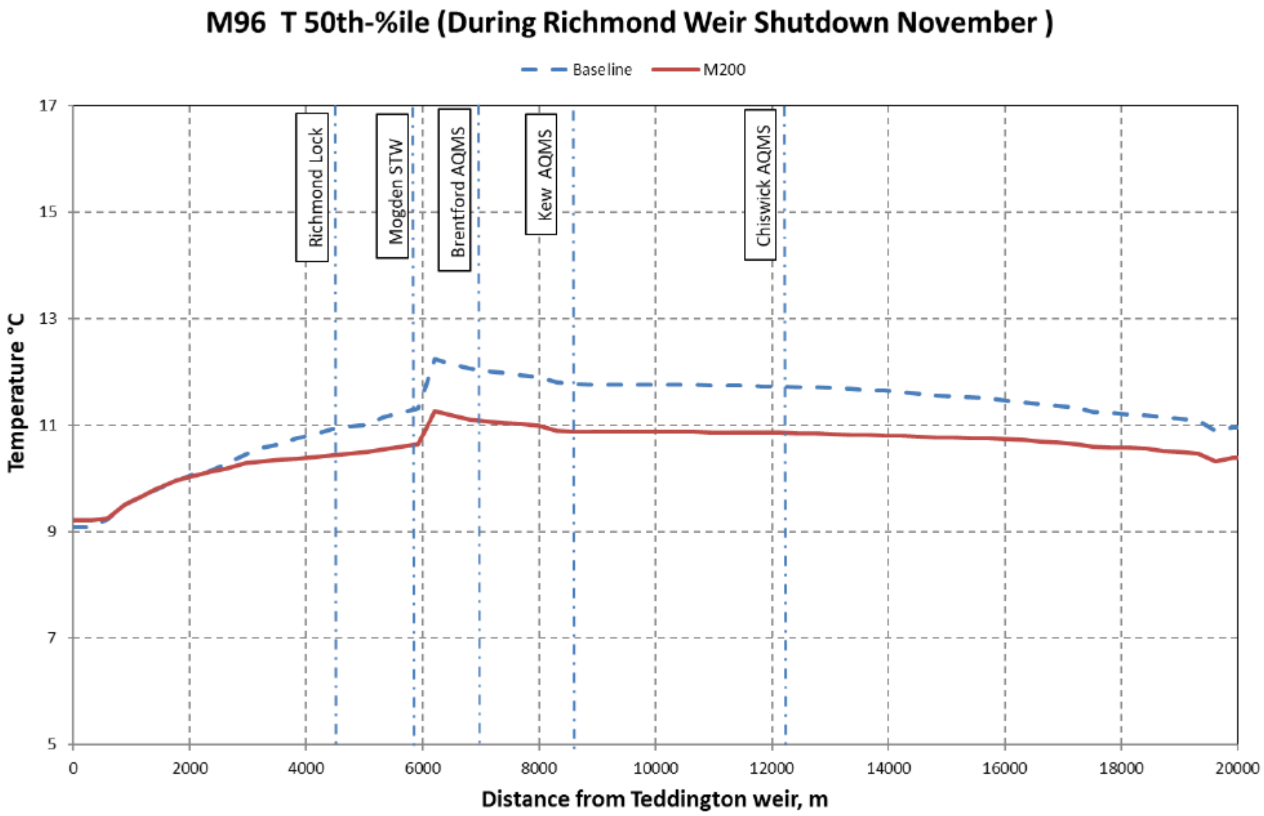
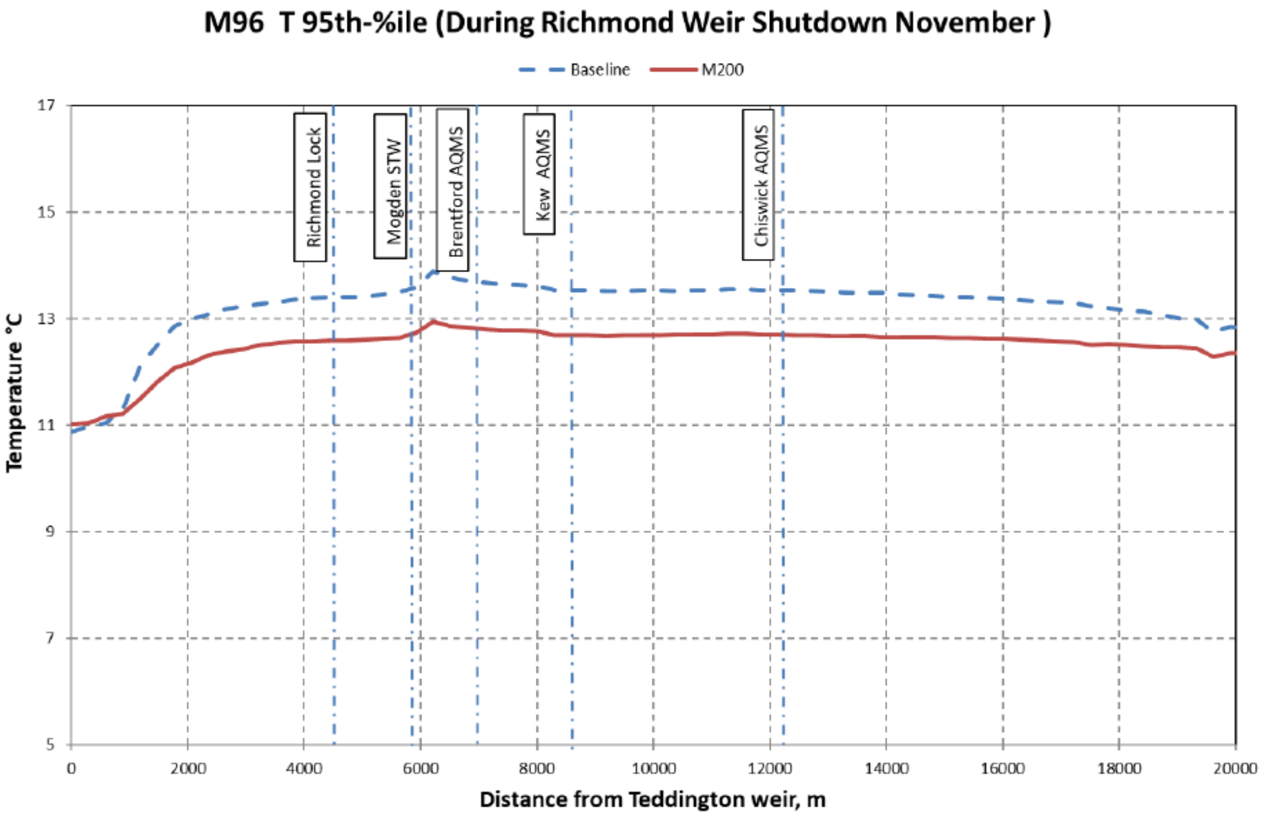


Figure 4-84 95th %ile temperature along thalweg (1st-30th November) in the Richmond Pound at baseline and for the 200 Ml/d Mogden water recycling scheme under the M96 scenario



The modelled data displayed in Figure 4-83 and Figure 4-84 indicate that there is an initial increase in temperature under the M96 Mogden-200 scenario compared with baseline from 0km to approx. 1.5km seawards of Teddington Weir. The greatest increase in both 50th and 95th %ile temperature from baseline is approx. 0.1°C. There is then a decrease in temperature under the M96 Mogden-200 scenario compared with baseline from approx. 1.5km - >20km seawards of Teddington Weir. The graphs above display dissolved oxygen modelled for the Mogden 200 Ml/d scheme and so represent the greatest temperature differences associated with the various scheme sizes at Mogden. The greatest decrease in both 50th and 95th %ile temperature from baseline is approx. 1°C.

4.8 SUMMARY OF WATER QUALITY ASSESSMENT OF MOGDEN WATER RECYCLING SCHEME

Table 4-11 summarises the potential water quality impacts for each of the sizes of a Mogden water recycling scheme.

Table 4-11 Summary of Gate 2 assessment of potential physical environment impacts for Mogden water recycling scheme

<table>
<tr><th>Size</th><th>Water temperature</th><th>General physico-chemical</th><th>WFD chemicals</th><th>EQSD chemicals</th><th>Olfactory water quality</th><th>Richmond Pound Drawdown</th></tr>
<tr><td>50 Ml/d</td><td rowspan="3">Freshwater River Thames: Negligible change in water temperature.
Estuarine Thames Tideway: Negligible change.</td><td rowspan="4">Freshwater River Thames:
Dissolved oxygen:
No deterioration modelled.
Ammonia:
No deterioration modelled
Phosphate:
No deterioration modelled
ANC:
No deterioration modelled.
Estuarine Thames Tideway:
Dissolved oxygen:
No deterioration modelled.
DIN:
Reductions in DIN during scheme operation
Salinity:
Minimal salinity changes modelled (1.3‰ at high tide) for 200Ml/d scheme under both scenarios</td><td rowspan="3">Freshwater River Thames:
No chemicals in recycled water following AWRP
Estuarine Thames Tideway:
Negligible WFD chemicals inferred from larger schemes modelling.</td><td rowspan="3">Freshwater River Thames:
No chemicals in recycled water following AWRP
Estuarine Thames Tideway:
Negligible EQSD chemical effects inferred from larger schemes modelling.</td><td rowspan="4">Freshwater River Thames:
No chemicals in recycled water following AWRP
Estuarine Thames Tideway:
Of the chemicals analysed at Gate 2, 24 identified as detected.</td><td rowspan="3">Negligible changes in Richmond Pound characteristics inferred from larger schemes modelling during the November drawdown period</td></tr>
<tr><td>100 Ml/d</td></tr>
<tr><td>150 Ml/d</td></tr>
<tr><td>200 Ml/d</td><td>Freshwater River Thames: Minor change in water temperature modelled with >25% of channel warmed by 2ºC or more for <50m of river length under extreme (98%ile) conditions.
Estuarine Thames Tideway: Minor temperature reduction of ~1ºC</td><td>Freshwater River Thames:
No chemicals in recycled water following AWRP
Estuarine Thames Tideway:
15 determinands were exceeded standards (in the STW discharge) under baseline conditions of which seven remained above standard (in the STW discharge) under both modelled scenarios and eight new pressures were above standard (in the STW discharge)</td><td>Freshwater River Thames:
No chemicals in recycled water following AWRP
Estuarine Thames Tideway:
With the scheme in operation three further chemicals modelled to exceed the standard (in the STW discharge).</td><td>Negligible changes in Richmond Pound characteristics inferred from reference condition and scenario modelling during the November drawdown period</td></tr>
</table>

In conclusion, the Mogden water recycling schemes may lead up to minor changes in the general physico-chemical environment compared to the baseline conditions of the River Thames. The schemes up to 150 Ml/d have a negligible impact on WFD chemicals, EQSD chemicals and olfactory chemicals in the freshwater River Thames. The Olfactory water quality information is used to support the fisheries assessment in B.2.3 Fish Assessment Report. The 200 Ml/d scheme induces some minor changes in the physico-chemical environment and in water temperature under extreme scenarios local to the discharge location at Walton Bridge. Within the estuarine Thames Tideway, the discharge of reverse osmosis concentrate in the Mogden STW final effluent may have a consequent negligible/minor change of the discharged WFD and EQSD chemicals. This would not affect the load discharged but may have a consequent negligible/minor effect on concentrations within the estuarine Thames Tideway. This needs to be investigated further in Gate 3.

4.9 POTENTIAL MITIGATION REQUIREMENTS

The temperature changes identified for the 150 Ml/d and 200 Ml/d schemes may require mitigation in the form of operating procedures that implement cessation of operation during periods of significant temperature differences between the recycled water and the receiving waterbody when under lower river flow conditions. Alternatively/additionally, identification of potential practicable cooling options of the recycled water may need to be explored.

Dependent on the updated findings of the Gate 3 water quality assessment on the effect of the reverse osmosis concentrate being discharged into the estuarine Thames Tideway, there may be a requirement for further mitigation in the form of additional treatment solutions to be considered to reduce the chemical input.

5. WATER QUALITY ASSESSMENT OF TEDDINGTON DRA SCHEMES

5.1 INTRODUCTION

This section sets out the assessment for the tasks set out in Table 1-1 relevant to Teddington DRA scheme. The study area for each task has been set out per task as it is not consistent across tasks. A conceptualisation of the key water quality issues of the scheme is presented in Figure 5-1. The Teddington DRA scheme assessment for each of the following tasks has been set out in the following sections:

- Teddington DRA Advanced Treatment Unit discharge quality– Section 5.2
- Water temperature – Section 5.3
- General physico-chemical – Section 5.4
- WFD chemicals – Section 5.5
- Olfactory water quality – Section 5.6
- Richmond Pound drawdown water quality – Section 5.7

The data used for undertaking the assessments has been outlined in the Gate 2 London Effluent Reuse scheme Water Quality Evidence Report. Table 1-1

The assessments have been undertaken for the following for each task:

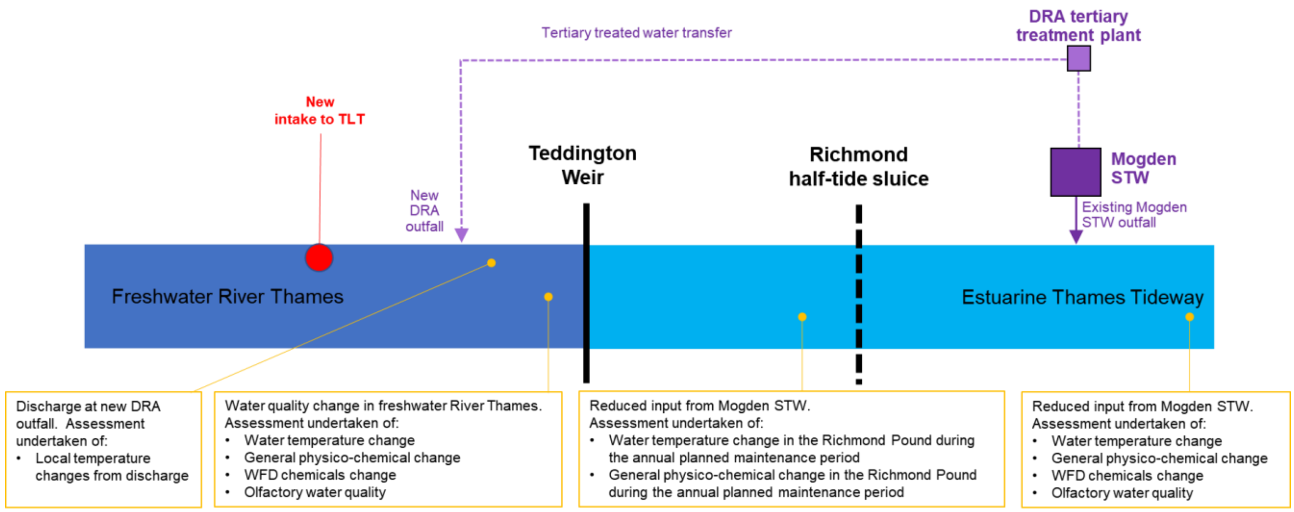
- Teddington DRA Advanced Treatment Unit discharge including effluent temperature, general physico-chemical parameters, and effluent chemicals, including olfactory inhibitors.
- Water temperature across the freshwater River Thames and estuarine Thames Tideway.
- WFD physico-chemical supporting elements to ecological status, including dissolved oxygen saturation, total ammonia, reactive phosphorus, water temperature, pH and BOD across the freshwater River Thames and estuarine Thames Tideway.
- WFD chemical suite across the freshwater River Thames and estuarine Thames Tideway.
- Olfactory water quality, including those determinands which were added for the assessment at Gate 2 and for which data was available.
- Richmond Pound drawdown water quality, including water temperature, conductivity, and dissolved oxygen for the Thames Tideway reach between Teddington Weir and Richmond Half-tide Sluice for the period without tidal level management.

Bespoke modelling datasets with parameterised reference conditions (see section 2) were reviewed in order to determine the extent of variability with site or seasonality from the reference conditions with the Teddington DRA scheme in operation. This provided the range and variability of water qualities across the range of monitored sites. The modelling data sets examined are as follows:

- Discharge plume modelling in the freshwater River Thames, undertaken by HR Wallingford
- Hydrodynamic and water quality modelling in the estuarine Thames Tideway undertaken by HR Wallingford
- Hydraulic and water quality modelling in the freshwater River Thames undertaken by Atkins.

Where text makes reference to A82 and M96 flow series, respectively these refer to 1 in 5 year and 1 in 20-year flow events.

Figure 5-1 Schematic for Teddington DRA Scheme



5.2 TEDDINGTON DRA ADVANCED TREATMENT UNIT DISCHARGE QUALITY

5.2.1 Overview

This section sets out the supplementary information for the source water (discharge) parameters for Teddington DRA scheme used in the environmental assessments.

- Treated effluent water temperature - Section 5.2.2
- Treated effluent general physico-chemical parameters - Section 5.2.3
- Langelier Saturation Index – Section 5.2.4
- Treated effluent chemical quality - Section 5.2.5
- Environmental fate of chemicals reduced during tertiary treatment – Section 5.2.6

The evidence available, the general patterns observed in the data and any notable pressures will be outlined and where to view this evidence have been set out in each of these sections. The Teddington DRA tertiary treatment plant would include the following water quality treatment processes: Ferric sulphate dosing, Nitrifying Sand Filters, Mechanical Cloth Filters and associated backwash and desludging equipment for filter units. To support the environmental assessments at Gate 2, an indicative operating pattern has been developed, as described in the B.2.1. Gate 2 Physical Environment assessment. Outside the normal operating pattern the Gate 2 engineering design includes a 25% plant maintenance flow, with the treated water being discharged to the River Thames at Teddington but not re-abstracted.

5.2.2 Treated effluent water temperature

The treated effluent temperature associated with the Teddington DRA scheme is currently not well understood but is not expected to lead to significant differences across the treatment processes or in the transfer pipeline. As such the Mogden STW final effluent temperature is taken as a conservative estimate of the temperature of the treated effluent at point of discharge to the freshwater River Thames. As set out in Gate 2 Conceptual Design Report[25], the AWRP source water and recycled water quality are as presented in Table 5-1. It is noted that the remineralisation design at present is to ensure corrosivity indices for conveyance are complied with and do not represent the end-point of design for environmental discharge.

Table 5-1 Teddington DRA scheme source water and process water quality

Parameter (showing mean value)	Source water (Mogden STW final effluent)	Treated effluent for river discharge
pH	7.6	6.8

[25] Jacobs (2022) Teddington DRA SRO: Conceptual Design Report.

Parameter (showing mean value)	Source water (Mogden STW final effluent)	Treated effluent for river discharge
Total Ammonia	1.7 mgN/l	0.1 mgN/l
Phosphorus	5.4 mg/l	0.5 mg/l
BOD	12.2 mg/l	6.9 mg/l
Suspended solids	36.0 mg/l	10.1 mg/l
Alkalinity ($CaCO_3$)	230 mg/l	174 mg/l

5.2.3 Treated effluent general physico-chemical water quality

The treated effluent associated with the Teddington DRA is subject to tertiary treatment at Mogden STW. Therefore, an in-river assessment approach has been adopted to determine and describe the change of the WFD physico-chemical supporting elements to ecological status.

5.2.4 Langelier Saturation Index

This is not considered to deviate from the suggestions presented in Section 4.4.2

5.2.5 Treated effluent chemical quality

As described above, the treated effluent associated with the Teddington DRA is subject to tertiary treatment at Mogden STW. An in-river assessment approach has been adopted to determine and describe the change of the determinand concentration from baseline conditions.

5.2.6 Environmental fate of chemicals reduced during tertiary treatment

Overall, the changes to the environmental fate of most chemicals will be the same as described above in Section 3.2.5 in relation to the Beckton water recycling scheme, a possible increase in the rate of volatilisation and a release of adsorbed particles with water temperature increases.

5.3 WATER TEMPERATURE

5.3.1 Overview

This section outlines the water temperature change associated with a Teddington DRA scheme. Assessments undertaken include:

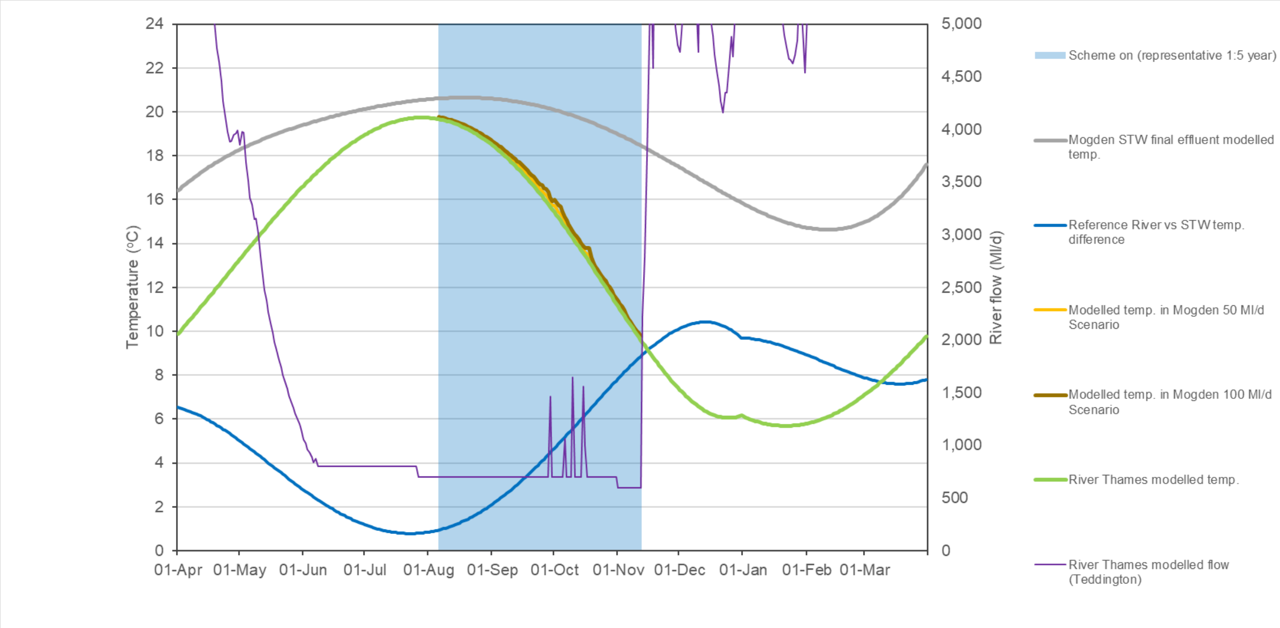
- Temperature change in the freshwater River Thames – Section 5.3.2
- Temperature change in the estuarine Thames Tideway– Section 5.3.3

5.3.2 Freshwater River Thames

An assessment of the water temperature impacts arising from a new Teddington DRA discharge into the freshwater River Thames has been undertaken for the four sizes of DRA scheme; 150 Ml/d, 100 Ml/d, 50 Ml/d and 75 Ml/d.

A water temperature assessment has been undertaken for the 1:5 return frequency A82 flow scenario. This used flow data for the River Thames at Teddington for the A82 scenario (see B.2.1 Physical Environment Assessment Report) together with scenario flow changes for the Teddington DRA scheme – both scheme operational and plant maintenance flows. Input water temperature data are the River Thames at Teddington Weir profile described in Section 2.3.3; and the discharge temperature for the Mogden water recycling scheme is the profile described in Section 2.2.2. The results for the 50 Ml/d and 100 Ml/d Teddington DRA scheme are shown on Figure 5-2; other scheme sizes are not included in order to improve figure clarity.

Figure 5-2 Teddington modelled temperatures in the River Thames for the A82 moderate-low flow scenario. The blue area indicates periods where the scheme is on under each scenario.



The modelled data displayed in Figure 5-2 are summarised in Table 5-2.

Table 5-2 Summary of Teddington DRA scheme modelled temperatures in the River Thames for the A82 moderate-low flow scenario

	Reference conditions	50Ml/d scheme	75 Ml/d scheme	100Ml/d scheme	150 Ml/d scheme
Maximum daily temperature modelled	19.7°C	19.7°C	19.7°C	19.8°C	19.8°C
Greatest daily temperature difference	N/A	0.7°C	1.1°C	1.5°C	2.2°C

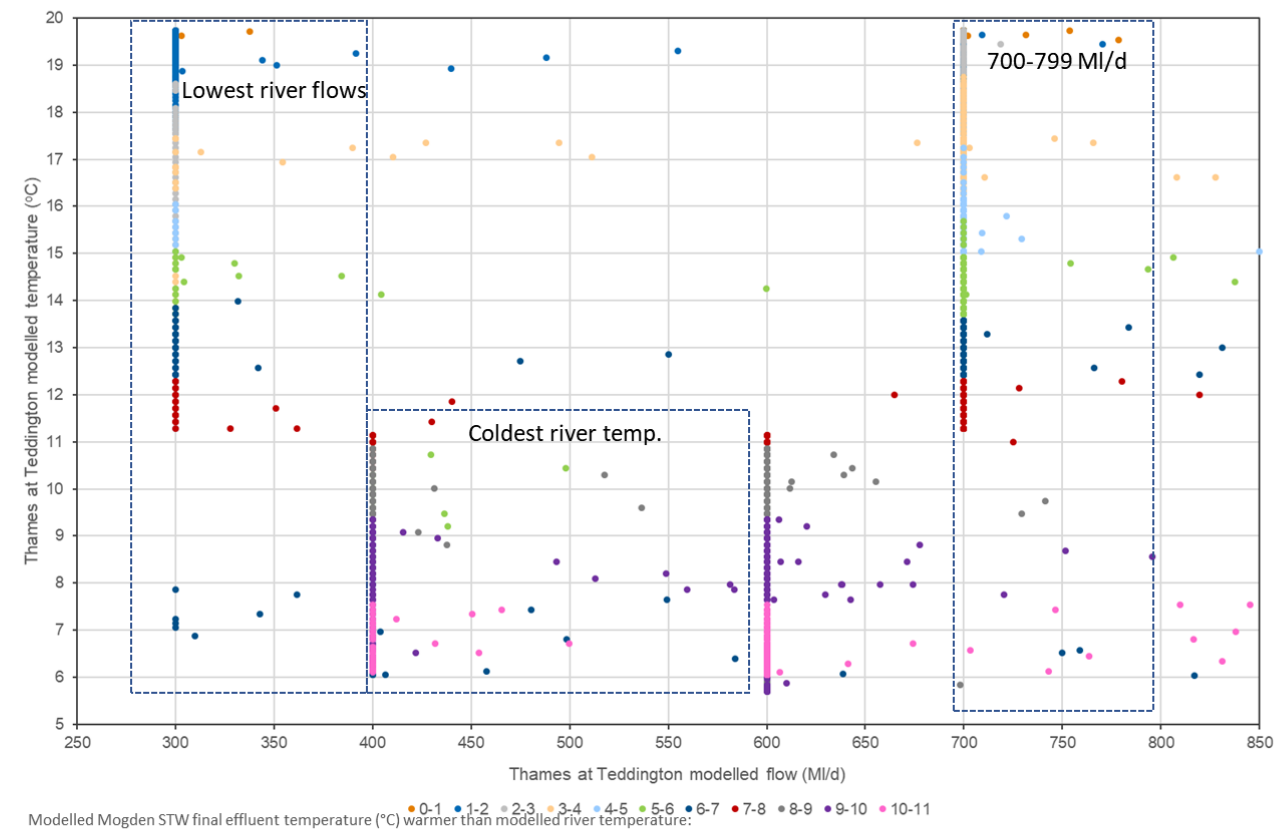
An analysis of extremes has been undertaken to support assessment of 3D modelling of discharge plume, through discussion with the Environment Agency. Analysis of modelled STW flow verses modelled river flow (Figure 5-3) indicates that the greatest temperature change occurs at lower river temperatures with smaller degrees of change seen at higher temperatures.

At lowest flows the Teddington DRA scheme would discharge at River Thames temperatures of 13.0°C (mean), when discharged temperatures would be 3.0°C warmer.

During the coldest river temperatures, the Teddington DRA scheme would operate at times that would correspond with very low river flows. The mean temperature difference between the recycled water and the river temperature (8.9°C) during these times is 6.1°C.

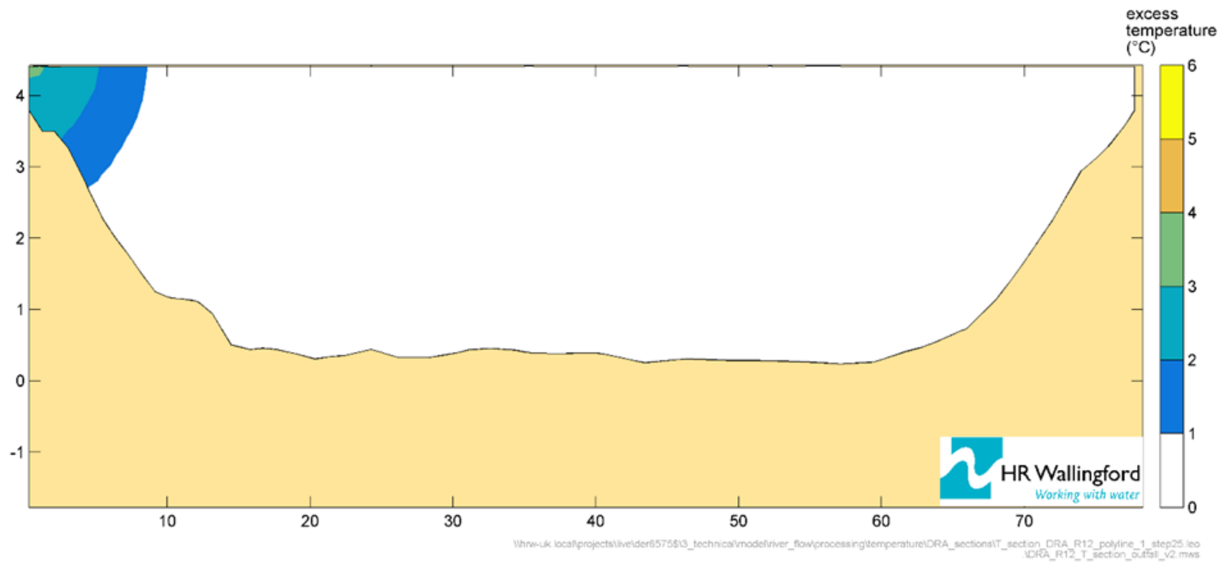
More typically, 58% of Teddington DRA scheme in operation dates lie between 700 – 799 Ml/d. Mean river temperatures during these times are 16.9°C. The mean temperature difference between the recycled water and the river temperature during these times is 3.3°C.

Figure 5-3 Modelled temperatures for River Thames at Teddington against modelled flow for River Thames at Teddington with 1°C temperature change bands indicated



The introduction of a new treated effluent discharge because of a Teddington DRA scheme will result in temperature change downstream of a proposed DRA outfall. The extent of temperature effects has been modelled by HRW for the 75 Ml/d discharge scenarios under, 700 Ml/d, 400 Ml/d and 300 Ml/d river flow scenarios. Discharge effects for each of these are outlined below.

Figure 5-4 Temperature change at River Thames at Teddington under a 75 Ml/d DRA at 700 Ml/d river flow



Under a 75 Ml/d Teddington DRA at 700 Ml/d river flow (Figure 5-4), 1.0% of the channel is affected by a temperature increase of at least 2.0°C. Plume extent is outlined in Figure 5-5.

Figure 5-5 Temperature change plume extent at River Thames at Teddington under a 75 Ml/d DRA at 700 Ml/d river flow

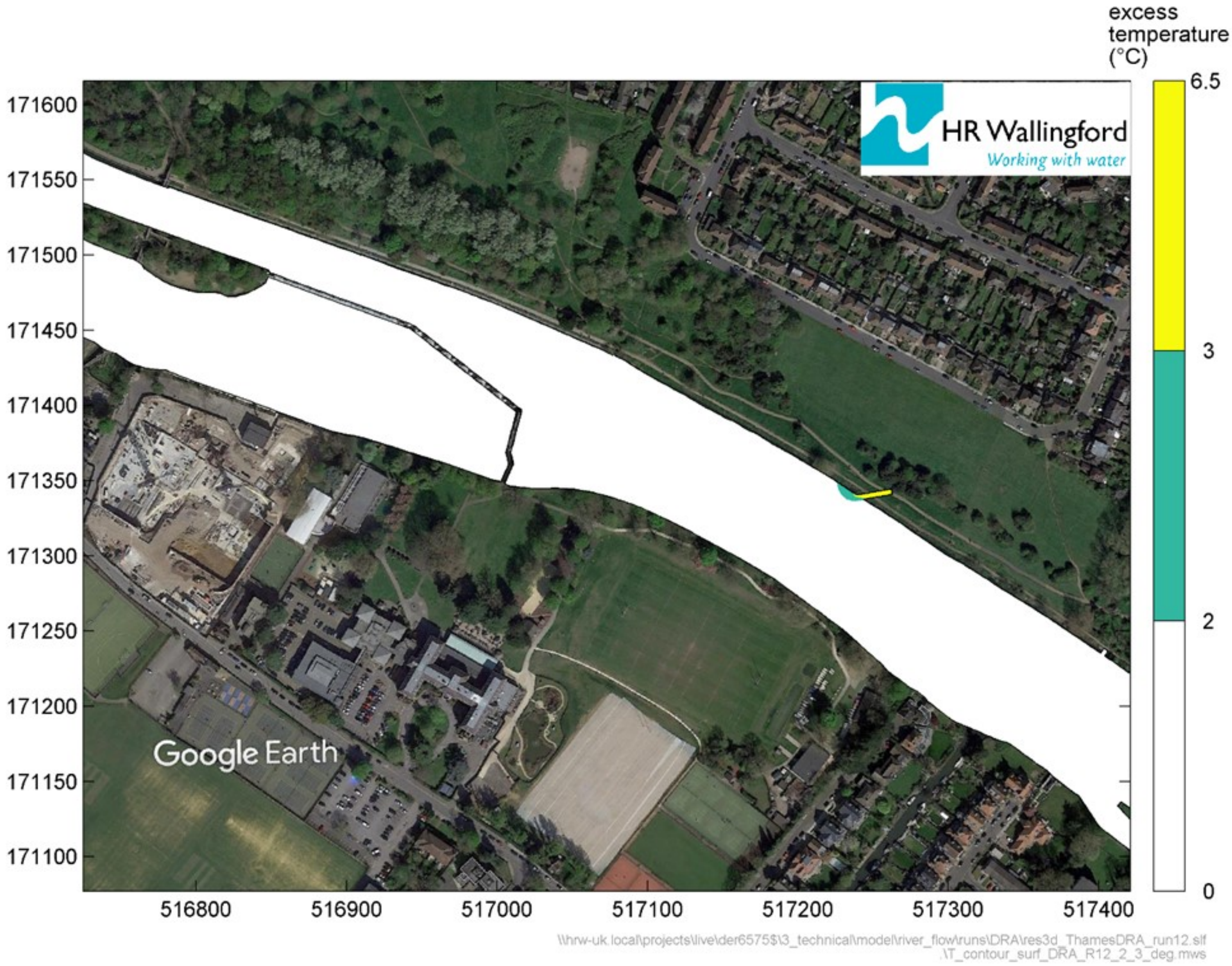
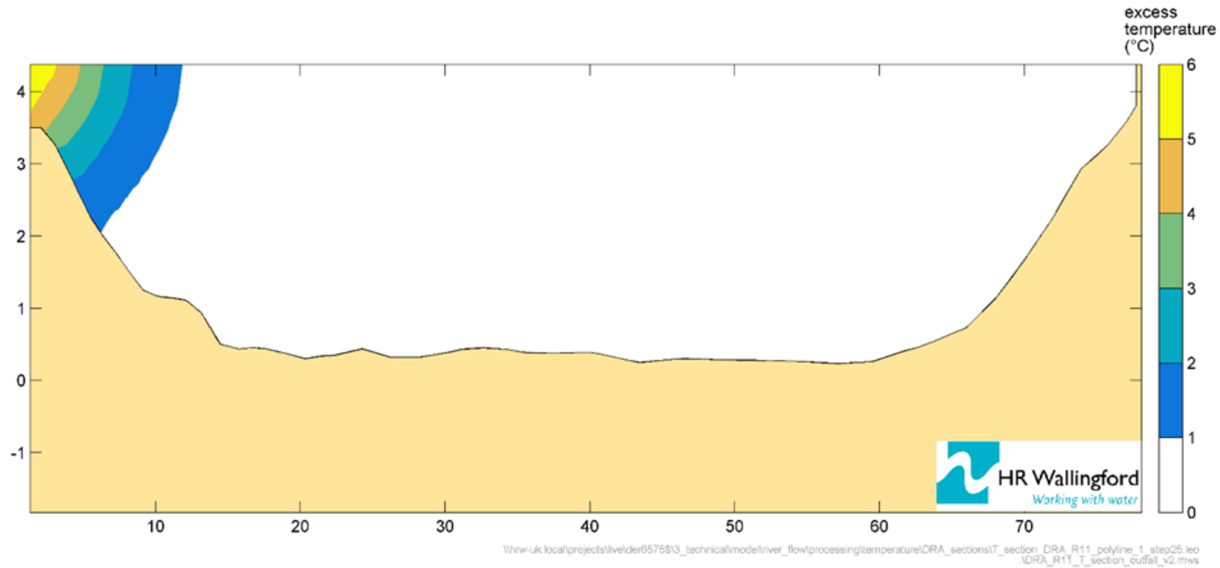


Figure 5-6 Temperature change at River Thames at Teddington under a 75 Ml/d DRA at 400 Ml/d river flow



Under a 75 Ml/d Teddington DRA at 400 Ml/d river flow (Figure 5-6), 2.8% of the channel is affected by a temperature increase of at least 2.0°C. Plume extent is outlined in Figure 5-7.

Figure 5-7 Temperature change plume extent at River Thames at Teddington under a 75 Ml/d DRA at 400 Ml/d river flow

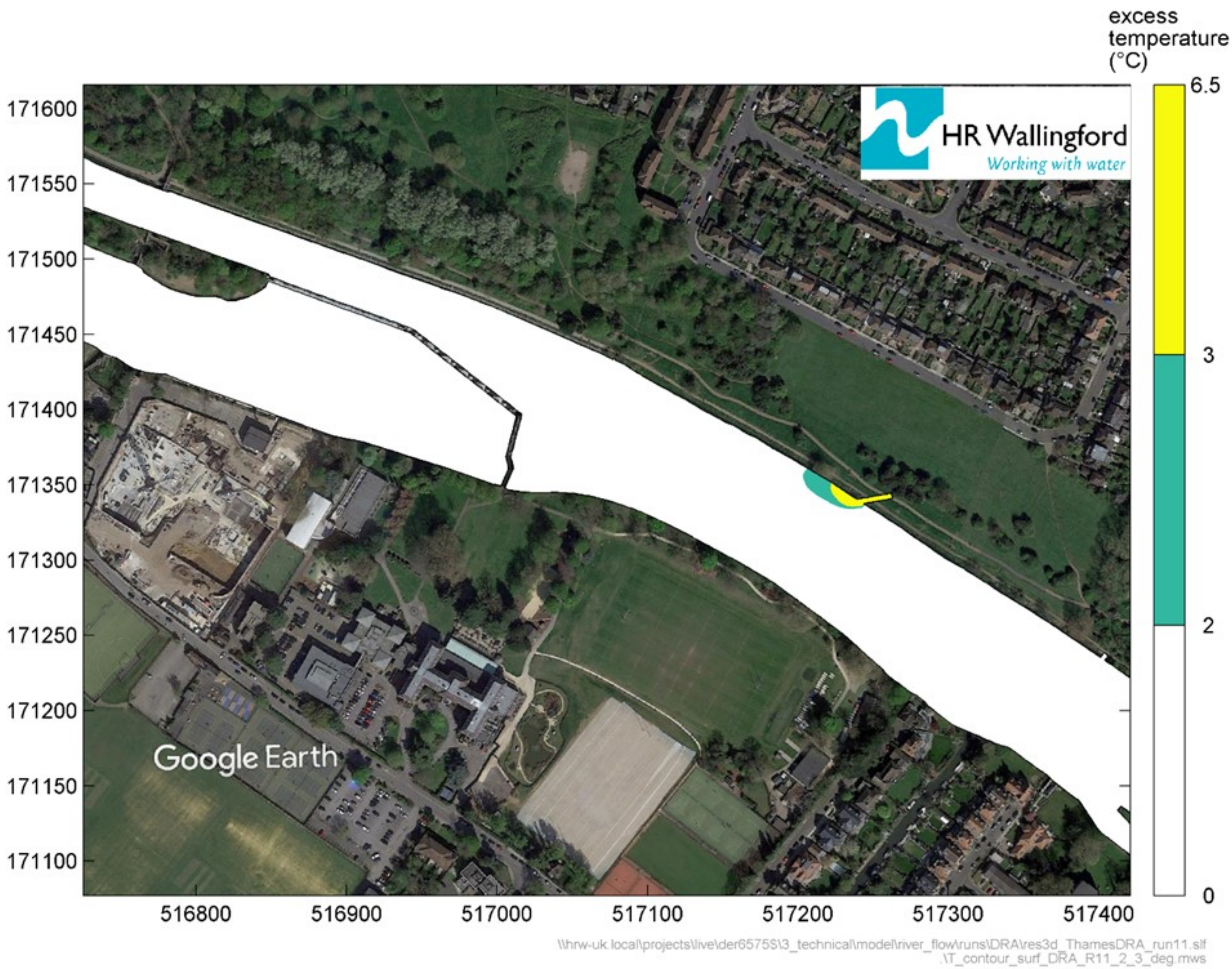
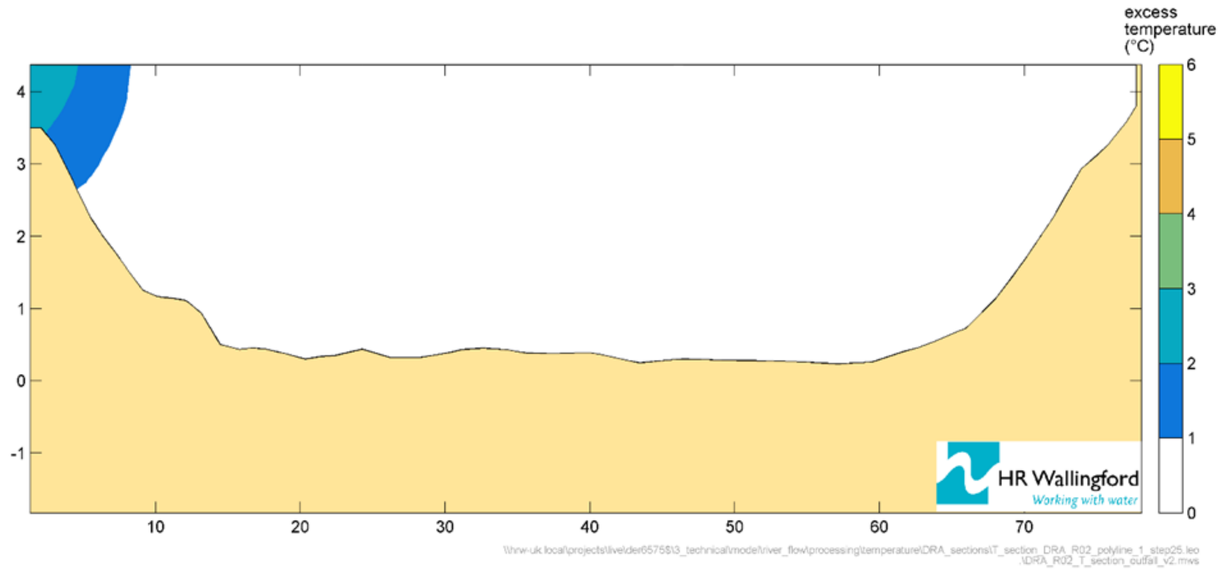


Figure 5-8 Temperature change at River Thames at Teddington under a 75 Ml/d DRA at 300 Ml/d river flow



Under a 75 Ml/d Teddington DRA at 300 Ml/d river flow (Figure 5-8), 0.8% of the channel is affected by a temperature increase of at least 2.0°C. Plume extent is outlined in Figure 5-11.

Figure 5-9 Temperature change plume extent at River Thames at Teddington under a 75 Ml/d DRA at 300 Ml/d river flow

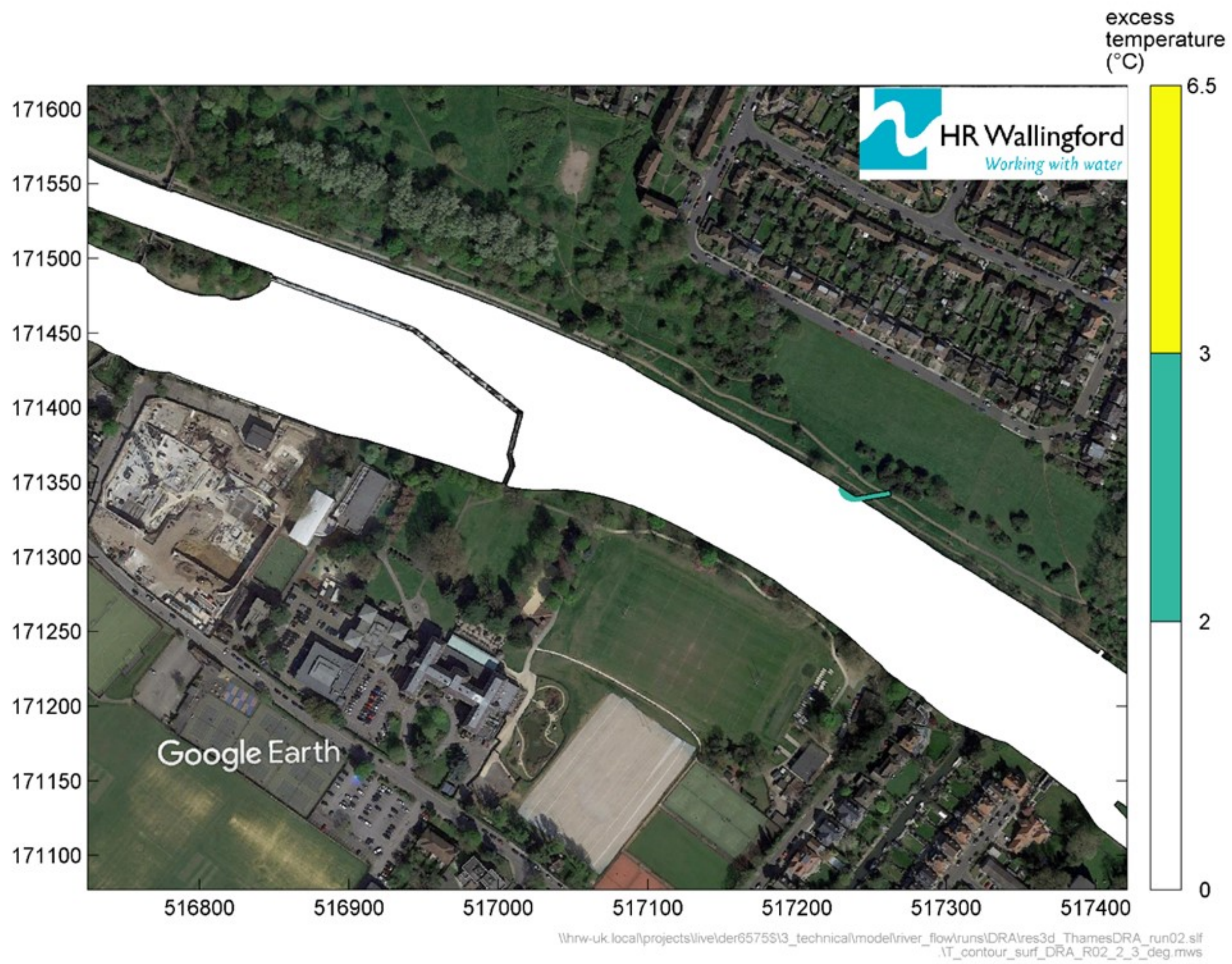
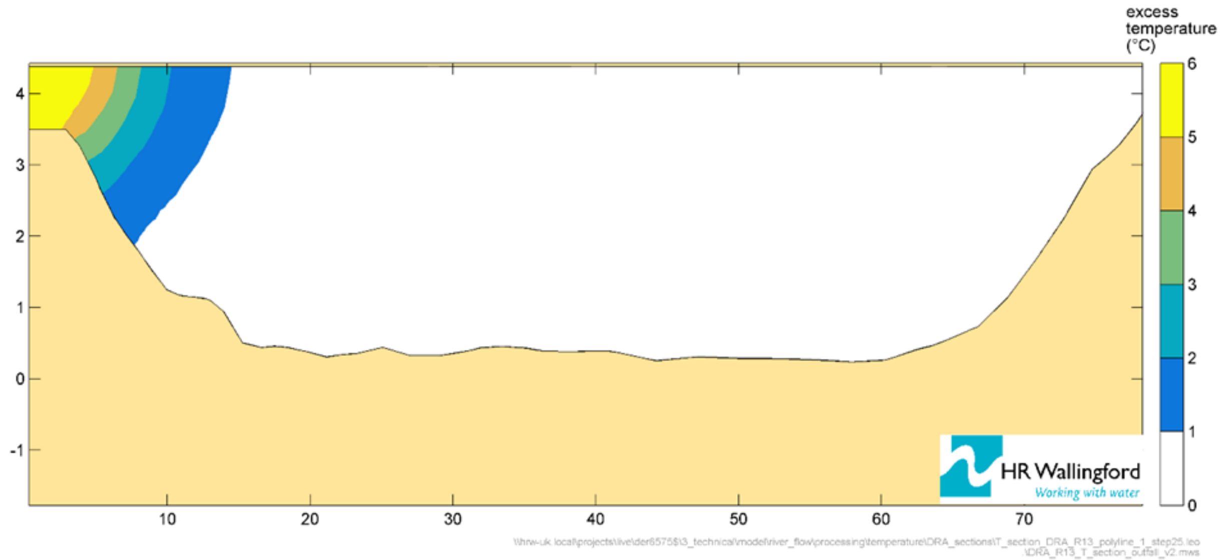
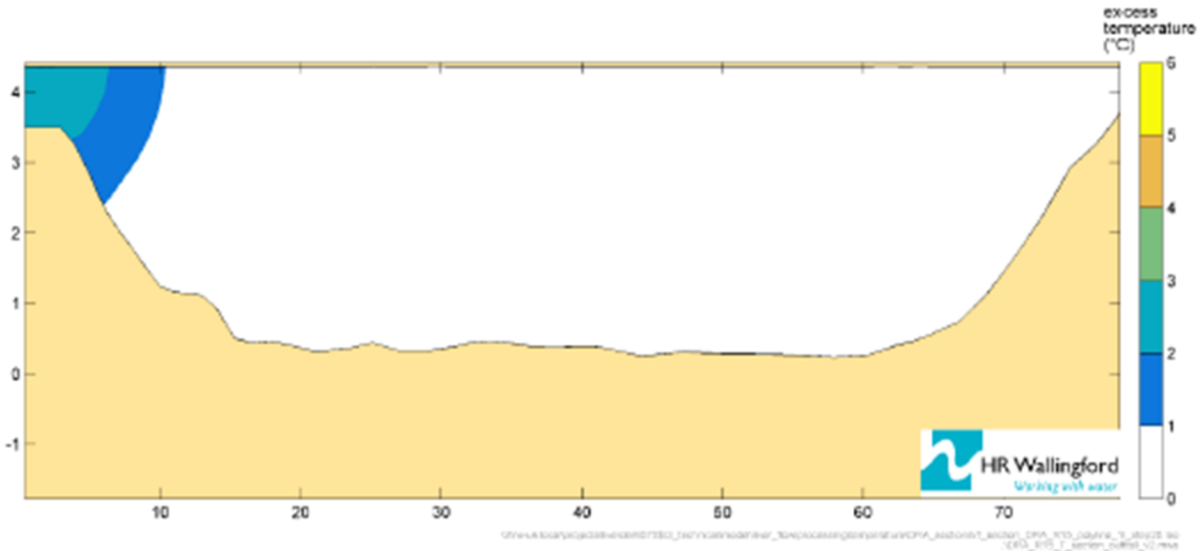


Figure 5-10 Temperature change at River Thames at Teddington under a 100 Ml/d DRA at 400 Ml/d river flow



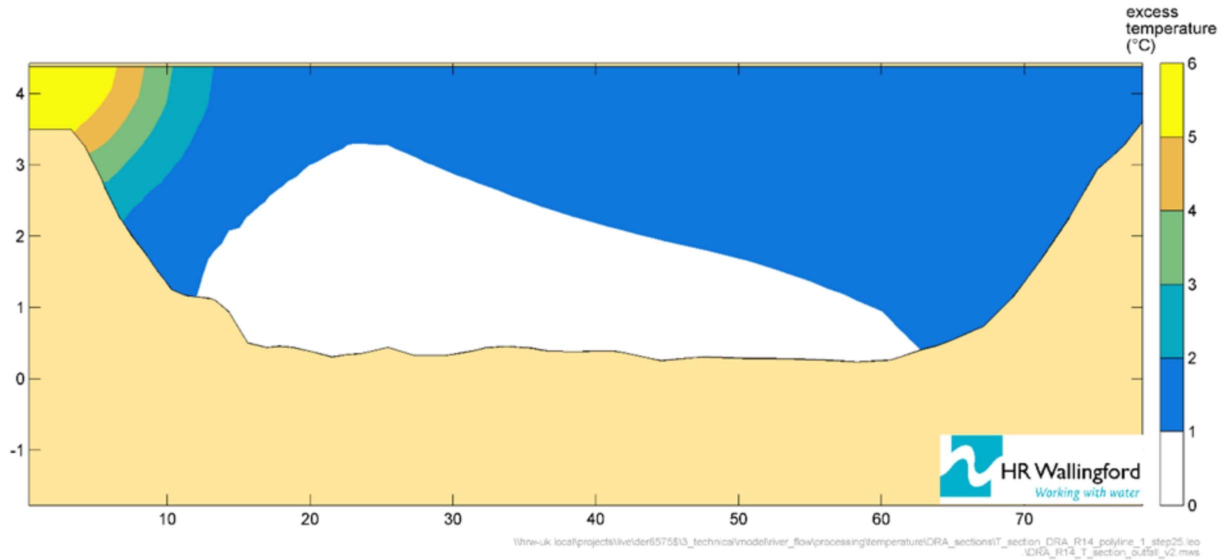
Under a 100 Ml/d Teddington DRA at 400 Ml/d river flow (Figure 5-10), 3.6% of the channel is affected by a temperature increase of at least 2.0°C.

Figure 5-11 Temperature change at River Thames at Teddington under 100 Ml/d DRA at 300 Ml/d river flow



Under a 100 Ml/d Teddington DRA at 300 Ml/d river flow (Figure 5-11), 1.3% of the channel is affected by a temperature increase of at least 2.0°C.

Figure 5-12 Temperature change at River Thames at Teddington under a 150 Ml/d DRA at 400 Ml/d river flow



Under a 150 Ml/d Teddington DRA at 400 Ml/d river flow (Figure 5-12), 5.8% of the channel is affected by a temperature increase of at least 2.0°C.

Under a 150 Ml/d Teddington DRA at 300 Ml/d river flow, 3D modelling identified that in the mixing zone a 150 Ml/d discharge during periods of greatest difference between river and final effluent temperature (6°C) would see the whole cross-section of the channel increase in temperature by 2-3°C 75m downstream of the discharge. These modelled circumstances are included on 1:20 return frequency as for around 40 days in the period November and December. These modelled circumstances do not occur on a 1:5 return frequency basis. WFD 'Good' status would be maintained within a plume, should a thermal discharge permit be applicable.

5.3.3 Estuarine Thames Tideway

It is noted that there would be temperature changes in the estuarine Thames Tideway as consequence of a Teddington DRA scheme associating with less discharge of final effluent from Mogden STW. That assessment of estuarine temperature changes is modelled for a 200 Ml/d Mogden water recycling scheme in Section 4.3.2 and impacts from a 150 Ml/d, 100 Ml/d, 75 Ml/d or 50 Ml/d Teddington DRA scheme are proportionately less than those predicted through the reported modelling.

5.4 GENERAL PHYSICO-CHEMICAL

5.4.1 Overview

This section sets out the change for the general physico-chemical parameters associated with the Teddington DRA scheme. Assessments undertaken include:

- Freshwater River Thames - Section 5.4.2
- Estuarine Thames Tideway - Section 5.4.3

The evidence available, the general patterns observed in the data and any notable pressures will be outlined for each of these reaches.

5.4.2 Freshwater River Thames

Daily step mass balance was undertaken for the freshwater River Thames under the 1 in 5-year (A82) and 1 in 20-year (M96) flow scenarios at Teddington (Site 11) using daily time step data output from reference conditions in the River Thames model for the 150 Ml/d, 100 Ml/d, 75 Ml/d and 50 Ml/d.

The tables below show the minimum, maximum and average concentrations for four of the general physico-chemical determinands assessed, as well as maximum change from baseline concentrations when the schemes are both on and off under both (A82 and M96) flow scenarios. Graphs showing the changes over a year monitoring period can be found in Appendix 1.

Table 5-3 General physio-chemical determinands under A82 scenario. Displaying modelled statistics when scheme is on and off.

		Scheme in operation				Plant maintenance only			
Scheme size	Determinand	Min	Max	Average	Greatest increase/decrease from baseline	Min	Max	Average	Greatest increase/decrease from baseline
50 Ml/d	Dissolved Oxygen (mg/l)	9.7	10.7	10.1	-1.2	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.02	0.09	0.04	0.01	0.02	0.10	0.04	0.00
	BOD (mg/l)	1.3	4.5	3.0	-0.6	1.6	5.1	2.9	0.3
	Suspended Solids (mg/l)	0.0	54.9	4.8	-33.1	0.3	88.1	9.3	0.9
	Total phosphorus (mg/)	0.3	0.9	0.4	0.3	0.2	0.6	0.3	0.0
75 Ml/d	Dissolved Oxygen (mg/l)	9.7	10.7	10.1	-1.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.02	0.09	0.04	0.01	0.02	0.10	0.04	0.00
	BOD (mg/l)	1.3	4.5	3.0	-0.6	1.6	5.1	2.9	0.3
	Suspended Solids (mg/l)	0.0	54.7	4.8	-33.4	0.3	88.1	9.3	0.9
	Total phosphorus (mg/)	0.3	0.9	0.4	0.3	0.2	0.6	0.3	0.0
100 Ml/d	Dissolved Oxygen (mg/l)	9.7	10.7	10.1	-1.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.02	0.09	0.04	0.01	0.03	0.10	0.05	0.01
	BOD (mg/l)	1.3	4.5	2.9	-0.6	1.6	5.1	2.9	0.3
	Suspended Solids (mg/l)	0.0	54.4	4.8	-33.7	0.3	88.1	9.3	0.9
	Total phosphorus (mg/)	0.3	1.0	0.5	0.5	0.2	0.6	0.3	0.1
150 Ml/d	Dissolved Oxygen (mg/l)	9.7	10.7	10.1	-1.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.03	0.09	0.04	0.01	0.02	0.10	0.04	0.00
	BOD (mg/l)	1.3	4.5	2.9	-0.7	1.6	5.1	2.9	0.3
	Suspended Solids (mg/l)	0.0	53.9	4.8	-34.2	0.3	88.1	9.3	0.9

		Scheme in operation				Plant maintenance only			
	Total phosphorus (mg/)	0.3	1.2	0.6	0.7	0.2	0.7	0.3	0.1

Table 5-4 General physio-chemical determinands under M96 scenario. Displaying modelled statistics when scheme is on and off.

		Scheme in operation				Plant maintenance only			
Scheme size	Determinand	Min	Max	Average	Greatest increase/decrease from baseline	Min	Max	Average	Greatest increase/decrease from baseline
50 Ml/d	Dissolved Oxygen (mg/l)	9.3	11.7	10.3	-0.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.03	0.10	0.05	0.01	0.02	0.06	0.04	-0.04
	BOD (mg/l)	1.3	5.1	2.8	-0.1	1.6	4.3	2.7	-0.8
	Suspended Solids (mg/l)	0.0	87.9	8.9	0.5	0.4	37.1	7.3	-51.0
	Total phosphorus (mg/l)	0.2	1.2	0.7	0.6	0.2	0.9	0.3	0.4
75 Ml/d	Dissolved Oxygen (mg/l)	9.3	11.7	10.3	-0.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.03	0.10	0.05	0.01	0.02	0.06	0.04	-0.04
	BOD (mg/l)	1.3	5.1	2.8	-0.1	1.6	4.3	2.7	-0.8
	Suspended Solids (mg/l)	0.0	87.9	8.9	0.5	0.4	37.1	7.3	-51.0
	Total phosphorus (mg/l)	0.2	1.2	0.7	0.6	0.2	0.9	0.3	0.4
100 Ml/d	Dissolved Oxygen (mg/l)	9.3	11.7	10.3	-0.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.03	0.10	0.05	0.01	0.02	0.06	0.04	-0.04
	BOD (mg/l)	1.3	5.1	2.8	-0.1	1.6	4.3	2.7	-0.8
	Suspended Solids (mg/l)	0.0	87.9	8.9	0.5	0.4	37.1	7.3	-51.0
	Total phosphorus (mg/l)	0.3	1.4	0.8	0.9	0.2	1.0	0.4	0.5
150 Ml/d	Dissolved Oxygen (mg/l)	9.3	11.7	10.3	-0.3	9.3	11.9	10.6	0.1
	Ammonia (mg/l)	0.03	0.10	0.05	0.01	0.02	0.06	0.04	-0.04

		Scheme in operation				Plant maintenance only			
	BOD (mg/l)	1.3	5.1	2.8	-0.1	1.6	4.3	2.7	-0.8
	Suspended Solids (mg/l)	0.0	87.9	8.9	0.5	043	37.1	7.3	-51.0
	Total phosphorus (mg/l)	0.3	6.6	1.7	6.1	0.2	6.6	0.7	6.1

<u>50 Ml/d</u>

Under the 1 in 5-year (A82) flow scenario the greatest change is seen for suspended solids with a reduction of 33.1 mg/l from the baseline when the Teddington DRA scheme is on. Ammonia shows a small change from baseline increasing by 0.01 mg/l. With respect BOD show a decrease in concentration of 0.6 mg/l from baseline conditions. For dissolved oxygen concentration a reduction of 1.2 mg/l is observed during scheme on. BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.3 mg/l

Under the 1 in 20-year (M96) flow scenario the greatest change is observed for suspended solids with a reduction of 0.5 mg/l. With respect to ammonia a small increase is noted of 0.01 mg/l. BOD also saw a decrease with a reduction of 0.1 mg/l. For dissolved oxygen concentration a reduction of 0.3 mg/l was noted. Regarding WFD status, BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.6 mg/l

<u>75 Ml/d</u>

Under the 1 in 5-year (A82) flow scenario the greatest change is seen for suspended solids with a reduction of 33.4 mg/l from the baseline when the Teddington DRA scheme is on. Ammonia shows a small change from baseline increasing by 0.01 mg/l. With respect BOD show a decrease in concentration of 0.6 mg/l from baseline conditions. For dissolved oxygen concentration a reduction of 1.3 mg/l is observed during scheme on. BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.3 mg/l

Under the 1 in 20-year (M96) flow scenario the greatest change is observed for suspended solids with a reduction of 0.5 mg/l. With respect to ammonia a small increase is noted of 0.01 mg/l. BOD also saw a decrease with a reduction of 0.1 mg/l. For dissolved oxygen concentration a reduction of 0.3 mg/l was noted. Regarding WFD status, BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.6 mg/l

<u>100 Ml/d</u>

Under the 1 in 5-year (A82) flow scenario the greatest change is seen for suspended solids with a reduction of 34.2 mg/l from the baseline when the Teddington DRA scheme is on. Ammonia shows a small change from baseline increasing by 0.01 mg/l. With respect BOD show a decrease in concentration of 0.7 mg/l from baseline conditions. For dissolved oxygen concentration a reduction of 1.3 mg/l is observed during scheme on. BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.5 mg/l

Under the 1 in 20-year (M96) flow scenario the greatest change is observed for suspended solids with a reduction of 0.5 mg/l. With respect to ammonia a small increase is noted of 0.01 mg/l. BOD also saw a decrease with a reduction of 0.1 mg/l. For dissolved oxygen concentration a reduction of 0.3 mg/l was noted. Regarding WFD status, BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.9 mg/l

<u>150 Ml/d</u>

Under the 1 in 5-year (A82) flow scenario the greatest change is seen for suspended solids with a reduction of 33.7 mg/l from the baseline when the Teddington DRA scheme is on. Ammonia shows a small change from baseline increasing by 0.01 mg/l. With respect BOD show a decrease in concentration of 0.7 mg/l from baseline conditions. For dissolved oxygen concentration a reduction of 1.3 mg/l is observed during scheme on. BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 0.7 mg/l

Under the 1 in 20-year (M96) flow scenario the greatest change is observed for suspended solids with a reduction of 0.5 mg/l. With respect to ammonia a small increase is noted of 0.01 mg/l. BOD also saw a decrease with a reduction of 0.1 mg/l. For dissolved oxygen concentration a reduction of 0.3 mg/l was noted. Regarding WFD status, BOD remains indicative of at least ‘good’ WFD status where ammonia remans indicative of ‘high’ status. Total phosphorus shows an increase from baseline of a maximum of 6.1 mg/l

Acid neutralising capacity

Acid neutralising capacity (ANC) has been calculated using a charge balance approach using measured data from Mogden STW final effluent and EA in-river spot data. ANC was calculated at approximately 40 mg/l. Daily time-step mass balance (Figure 5-13) shows that minimum ANC under the A82 flows is 58, and 56 under M96 flows (Figure 5-14), indicating that buffering capacity is present. Mean daily ANC change is 0.4 mg/l (both for A82 and M96). There is no indication that ANC change is affected by the scheme in operation and concentrations indicate ‘good’ water quality.

Figure 5-13 ANC in the freshwater River Thames for A82 scenario. Scheme in operation at Teddington A82 is indicated by the grey box

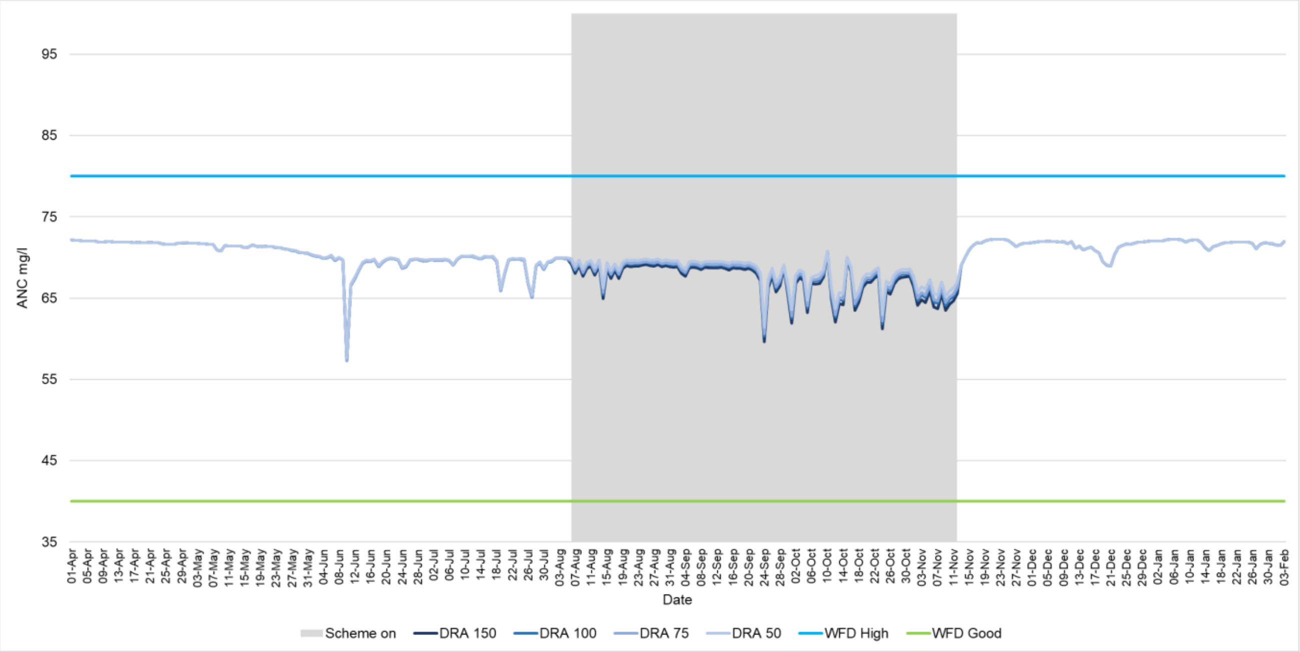
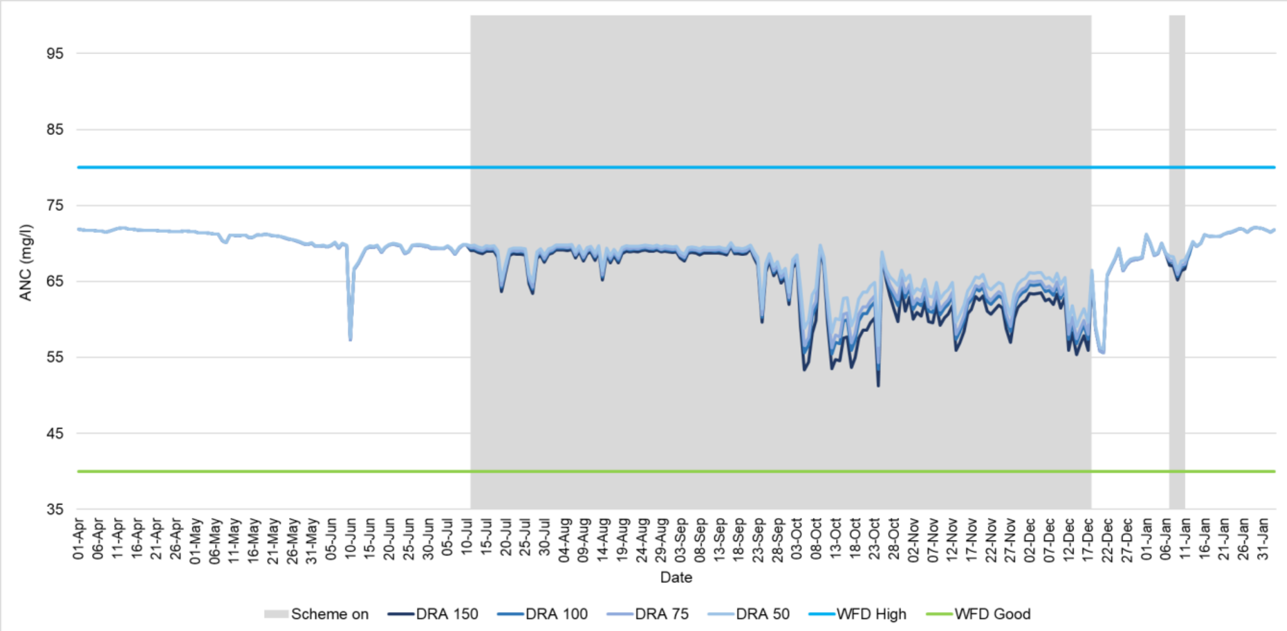


Figure 5-14 ANC in the freshwater River Thames for M96 scenario. Scheme in operation at Teddington M96 is indicated by the grey box



pH

pH has been calculated using measured data from Mogden STW final effluent and EA in-river spot data. Daily time-step mass balance (Figure 5-15 and Figure 5-16) shows little variation between the flow scenarios, with minimum pH under A82 being 7.7 and under M96 being 7.8, and maximum under both flows being 8.8. Mean daily pH change is 0.3 and 0.2 (A82 and M96 respectively). There is little variation between the flow scenarios though measured data is not available past September. As pH was measured between 6 and 9, values remain indicative of 'good' water quality

Figure 5-15 pH in the freshwater River Thames for A82 scenario. Scheme in operation at Teddington A82 is indicated by the grey box

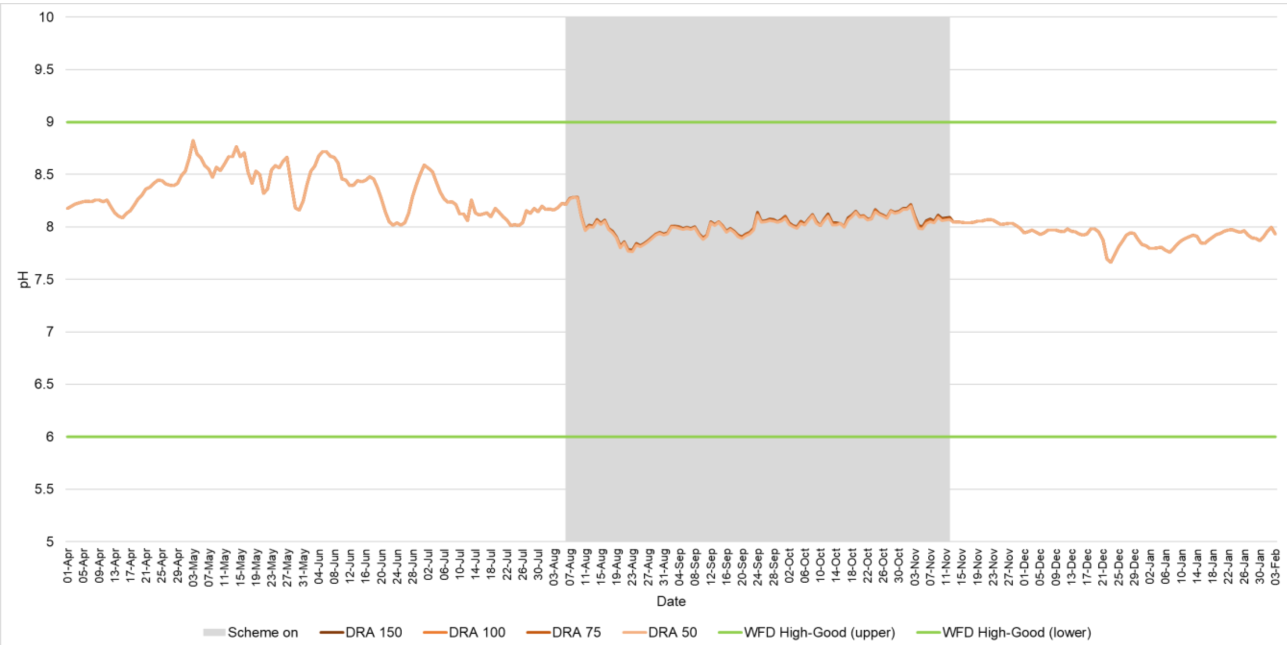
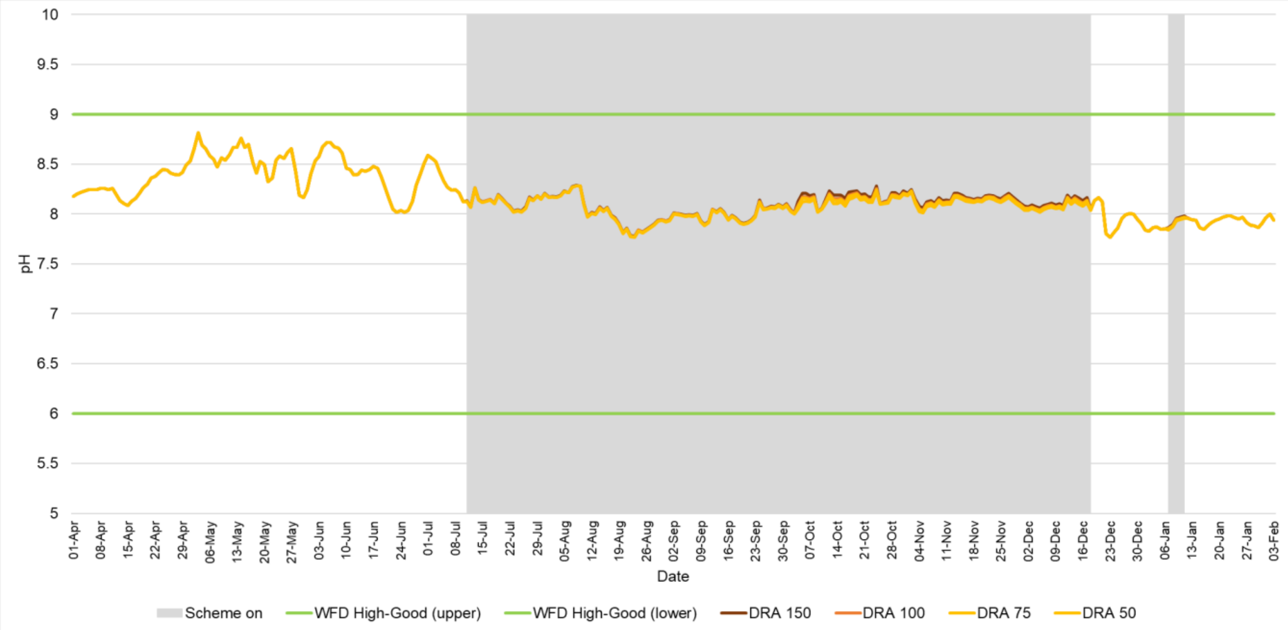


Figure 5-16 pH in the freshwater River Thames for M96 scenario. Scheme in operation at Teddington A82 is indicated by the grey box



5.4.3 Estuarine Thames Tideway

It is noted that there would be dissolved oxygen changes in the estuarine Thames Tideway as consequence of a Teddington DRA scheme associating with less discharge of final effluent from Mogden STW. That assessment of estuarine dissolved oxygen is modelled for a 200 Ml/d Mogden water recycling scheme in Section 4.3.2 and impacts from a 150 Ml/d, 100 Ml/d, 75 Ml/d or 50 Ml/d Teddington DRA scheme are proportionately less than those predicted through the reported modelling.

Dissolved inorganic nitrogen

DIN has been assessed in the estuarine Thames Tideway using measured effluent data for ammonia, nitrate and nitrite. Scheme sizes have been proportionally removed from the concentrations to reflect scheme on and the reduction in effluent entering the Tideway through the Mogden outfall.

<u>50 Ml/d</u>

The data displayed in Figure 5-17 and Figure 5-18 shows a reduction in DIN within the estuarine Thames Tideway during the scheme on period. During scheme on the maximum DIN concentrations displayed is 62.5. µMol/l (A82) and 72.5 µMol/l (M96), with averages of 58.6 µMol/l (A82) and 51.7 µMol/l (M96).

The scheme on period only overlaps with WFD status time periods during early November (A82) and during this time is indicative of 'good' status (mean, 270 µMol/l – 1st Nov – 28th Feb). While the scheme overlaps with WFD status time period during November to mid-December and for a few days in January (M96) during this time is also indicative of 'good' status. With overall DIN status within the estuarine Thames Tideway from Mogden effluent of 'good' status.

Figure 5-17 Dissolved inorganic nitrogen in the estuarine Thames Tideway for the 50, 75, 100 and 150 Ml/d Teddington DRA Reuse scheme under the A82 scenario

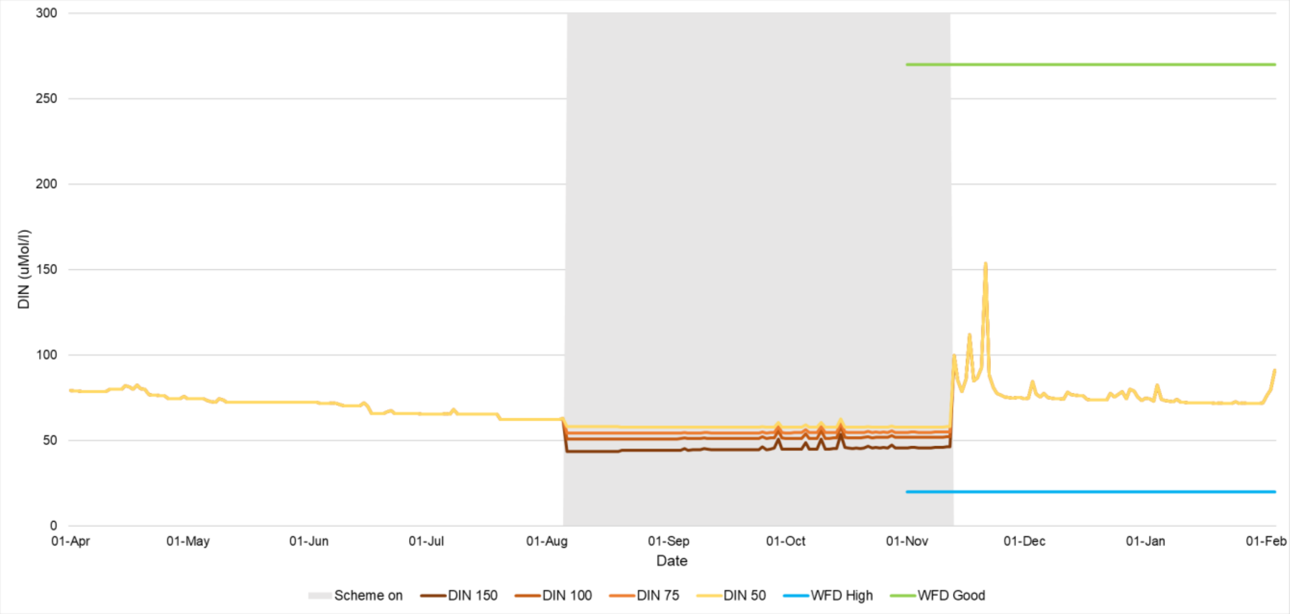
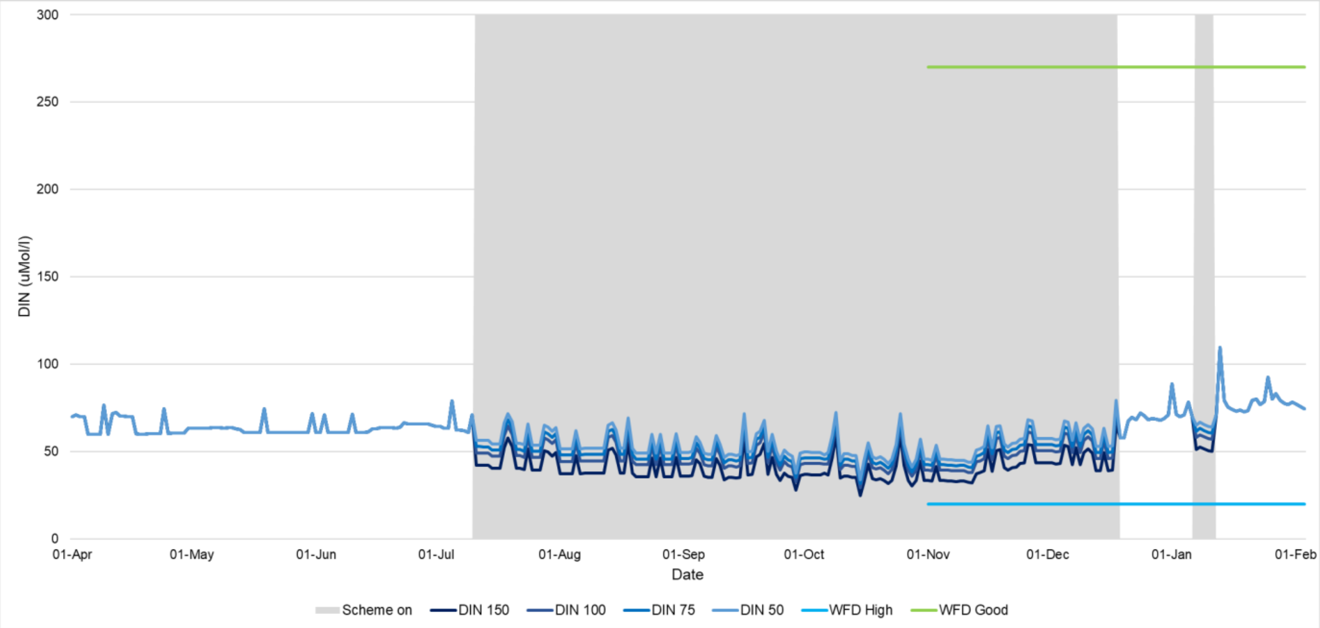


Figure 5-18 Dissolved inorganic nitrogen in the estuarine Thames Tideway for the 50, 75, 100 and 150 Ml/d Teddington DRA Reuse scheme under the M96 scenario



75 Ml/d

The pattern of DIN concentrations is as described above for the 50 Ml/d Teddington DRA scheme. During scheme on the maximum DIN concentrations displayed is 60.2 µMol/l (A82) and 69.3 µMol/l (M96), with averages of 55.6 µMol/l (A82) and 48.5 µMol/l (M96).

100 Ml/d

The pattern of DIN concentrations is as described above for the 50 Ml/d Teddington DRA scheme. During scheme on the maximum DIN concentrations displayed is 58 µMol/l (A82) and 66.1 µMol/l (M96), with averages of 52.5 µMol/l (A82) and 45.3 µMol/l (M96).

150 Ml/d

The pattern of DIN concentrations is as described above for the 50 Ml/d Teddington DRA scheme. During scheme on the maximum DIN concentrations displayed is 53.5 µMol/l (A82) and 59.7 µMol/l (M96), with averages of 46.4 µMol/l (A82) and 38.8 µMol/l (M96).

5.5 WFD CHEMICALS

5.5.1 Overview

This section sets out the change for the WFD and EQSD parameters associated with the Teddington DRA scheme. Assessments undertaken include:

- Freshwater River Thames - Section 5.5.2
- Estuarine Thames Tideway - Section 5.5.3

The analysed chemicals are listed as priority substances and certain other polluting chemicals in the WFD and Environmental Quality Standards Directive (EQSD). This list does not include the Drinking Water safety Plan (DWSP) suite.

The evidence available, the general patterns observed in the data and any notable pressures will be outlined and where to view this evidence have been set out for each of these reaches.

5.5.2 Freshwater River Thames

Teddington DRA scheme 1 in 5-year (A82) scenario WFD Chemicals

The risk assessment has been undertaken using the SRO water quality dataset. Specifically the Mogden STW final effluent sampling point and the River Thames at Teddington sampling point, with typically 15 values per site reported in Gate 2. The risk assessment is not against EQS. It is an assessment of where individual reported chemical values are in exceedance of EQS values, without recourses to considering mean or percentile values at this stage. As such it is not a statement of EQS pass or fail according to how EQS is derived.

As per Section 2.5.2, 13 chemical determinands within the WFD suite were identified as exceeding environmental quality standards at least once in the freshwater River Thames reach under reference conditions.

Of the chemicals exceeding the standard under reference conditions, the following are decreased to below the standard under the 1 in 5-year (A82) Teddington DRA scenario.

- 2,4-dichlorophenoxyacetic acid (2,4-D)
- Dissolved chromium (III)
- Tributyltin compounds (as tributyltin cation)
- Chlorothalonil
- Cybutryne (irgarol)
- Perfluorooctane sulfonic acid and its derivatives
- Permethrin
- Terbutryn

The following chemical determinands that exhibited exceedance of the standard under reference conditions still exceed the standard under the 1 in 5-year (A82) Teddington DRA scenario:

- Benzo(g,h,i)perylene
- Dissolved copper
- Dicofol
- Trichlorobenzenes
- Dissolved zinc
- Dissolved nickel
- Dissolved mercury
- Dissolved manganese
- Dissolved lead
- Indeno(1,2,3-cd)pyrene
- Polycyclic aromatic hydrocarbons (PAH) sum

There are some new pressures under the 1 in 5-year (A82) Teddington DRA scenario, with an additional three chemical determinands exceeding the standard as shown in Table 5-5:

Table 5-5 Additional chemicals under A82 during scheme on

Scheme size	Determinand	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long term)
50 Ml/d	Cypermethrin	0.0004	0.001	0.002	0.0006
	Hexachlorocyclohexane	0.003	0.004	0.04	0.04
	Total chlorine	0.01	0.03	2.0	2
75 Ml/d	Cypermethrin	0.0004	0.001	0.002	0.0006
	Hexachlorocyclohexane	0.003	0.004	0.04	0.04
	Total chlorine	0.02	0.03	2.0	2
100 Ml/d	Cypermethrin	0.0004	0.001	0.002	0.0006
	Hexachlorocyclohexane	0.004	0.004	0.04	0.04
	Total chlorine	0.02	0.03	2.0	2
150 Ml/d	Cypermethrin	0.0004	0.001	0.002	0.0006
	Hexachlorocyclohexane	0.002	0.005	0.04	0.04
	Total chlorine	0.03	0.04	2.0	2

Teddington DRA 1 in 20-year (M96) scenario WFD Chemicals

The changes to the WFD suite of chemical determinands under the 1 in 20-year (M96) Teddington DRA scenario compared with reference conditions are the same as those described for the 1 in 5-year (A82) Teddington DRA scenario with three additional new pressures, showing minimal difference between flow scenarios (Table 5-6).

Table 5-6 Additional chemicals under M96 during scheme on

Scheme size	Determinand	Min (µg/l)	Mean (µg/l)	Max (µg/l)	EQS (µg/l) (Long term)
50 Ml/d	Cypermethrin	0.0002	0.0005	0.001	0.0006
	Hexachlorocyclohexane	0.002	0.003	0.04	0.04
	Total chlorine	0.009	0.03	2.0	2
75 Ml/d	Cypermethrin	0.0002	0.0005	0.001	0.0006
	Hexachlorocyclohexane	0.002	0.004	0.04	0.04
	Total chlorine	0.009	0.03	2.0	2
100 Ml/d	Cypermethrin	0.0002	0.0005	0.001	0.0006
	Hexachlorocyclohexane	0.002	0.004	0.04	0.04
	Total chlorine	0.01	0.03	2.0	2
150 Ml/d	Cypermethrin	0.0003	0.0005	0.001	0.0006
	Hexachlorocyclohexane	0.005	0.005	0.04	0.04
	Total chlorine	0.01	0.04	2.0	2

Teddington DRA 1 in 5-year (A82) scenario EQSD Chemicals

Under reference conditions, the only chemical determinand within the EQSD chemical suite exceeding environmental quality standards in the freshwater River Thames reach is bromine – total residual oxidant.

Under the 1 in 5-year (A82) Teddington DRA scenario, concentrations of bromine remain above the standard and exhibit an increase compared with reference conditions.

There is one additional pressure under the 1 in 5-year (A82) Teddington DRA scenario of Pirimicarb, with the concentrations increasing to above the standard.

Teddington DRA 1 in 20-year (M96) scenario EQSD Chemicals

The changes to the EQSD suite of chemical determinands under the 1 in 20-year (M96) Teddington DRA scenario compared with reference conditions are the same as those described for the 1 in 5-year (A82) Teddington DRA scenario, showing minimal difference between flow scenarios.

It is noted that the section above describes the 150 Ml/d, 100 Ml/d , 75 Ml/d and 50 Ml/d as there are no observed differences in WFD or EQSD chemicals between scheme sizes

5.5.3 Estuarine Thames Tideway

It is noted that there would be chemical dispersal changes in the estuarine Thames Tideway as consequence of a Teddington DRA scheme associating with less discharge of final effluent from Mogden STW. The advanced treatment unit from the Teddington DRA scheme would not return liquid process wastes to Mogden STW for mixing into the final effluent stream. As consequence the concentration of chemicals in the Mogden STW final effluent would remain as per reference conditions. However, as the discharge flow rate would reduce in line with the transfer rate of the Teddington DRA scheme (150 Ml/d, 100 Ml/d, 75 Ml/d or 50 Ml/d or 25% of those values during plant maintenance periods) the total load discharged in Mogden STW final effluent would reduce. Bespoke modelling of the changes in the Thames Tideway from discharge concentrations changing at Teddington Weir and flow rates reducing at Mogden STW have not been undertaken at Gate 2.

5.6 OLFACTORY WATER QUALITY

An initial screening assessment has been undertaken to identify potential new or increased pressures to the study areas. This assessment uses reconcentration calculations to compare in-river concentrations to baseline and highlights determinands which exceed or approach (within 10% of) the EQS (if applicable). This assessment is intended as a guide for future investigations, see Section 6.

5.6.1 Overview

This section sets out the change for the olfactory parameters associated with the Teddington DRA scheme. Assessments undertaken include:

- Freshwater River Thames - Section 5.6.2
- Estuarine Thames Tideway - Section 5.6.3

The evidence available, the general patterns observed in the data and any notable pressures are outlined.

5.6.2 Freshwater River Thames

There are two scenarios to compare to the reference conditions: A82 (1 in 5 year) and M96 (1 in 20 year) flow scenarios.

Of the 15 determinands discussed in Section 2.6, 14 were analysed for different flow scenarios compared to the reference conditions under the 150 Ml/d, 100 Ml/d, 75 Ml/d and 50 Ml/d scheme sizes. These 14 determinands were selected due to the presence of a suitable standard against which to assess them. The determinands were considered to represent an increased or new pressure if the concentration (under analysis) increased to be within 10 % of or exceed the EQS. These pressures can be seen in Table 5-7 with most determinands not approaching the EQS. It is noted that EQS relate to eco-toxicity and not to olfaction inhibition.

Table 5-7 Determinands assessed for olfaction within the freshwater River Thames

Chemical	A82 Teddington	M96 Teddington
Cd total	No	No
Cr (III) dissolved	No	No
Co dissolved	No	No
Cu dissolved	Yes	Yes

Chemical	A82 Teddington	M96 Teddington
Cypermethrin	Yes	Yes
Diuron	No	No
Iron dissolved	No	No
Isoproturon	No	No
Linuron	No	No
Mercury dissolved	No	No
Nickel dissolved	No	No
Permethrin	Yes	Yes
Primicarb	Yes	Yes
Zinc dissolved	Yes	Yes

Chromium (III) dissolved flagged at the baseline conditions but not under the modelled conditions for the Teddington DRA A82 or M96 scenarios. Primicarb and cypermethrin did not exceed the EQS under reference conditions but proved to be a new pressure under both discharge scenarios.

5.6.3 Estuarine Thames Tideway

It is noted that there would be olfactory inhibitors dispersal changes in the estuarine Thames Tideway as consequence of a Teddington DRA scheme associating with less discharge of final effluent from Mogden STW. The advanced treatment unit from the Teddington DRA scheme would not return liquid process wastes to Mogden STW for mixing into the final effluent stream. As consequence the concentration of olfactory inhibitors in the Mogden STW final effluent would remain as per reference conditions. However, as the discharge flow rate would reduce in line with the transfer rate of the Teddington DRA scheme (150, Ml/d, 100 Ml/d, 75 Ml/d or 50 Ml/d or 25% of those values during plant maintenance periods) the total load discharged in Mogden STW final effluent would reduce. Bespoke modelling of the changes in the Thames Tideway from discharge concentrations changing at Teddington Weir and flow rates reducing at Mogden STW have not been undertaken at Gate 2.

5.7 RICHMOND POUND DRAWDOWN WATER QUALITY ASSESSMENT

It is noted that there would be dissolved oxygen, salinity, suspended sediment and temperature changes in the Richmond Pound as consequence of a Teddington DRA scheme associating with increased flow from a new Mogden STW outfall on the River Thames. That assessment of Richmond Pound impacts is modelled for a 200 Ml/d Mogden water recycling scheme in Section 4.7 and impacts from a 150 Ml/d, 100 Ml/d, 75 Ml/d or 50 Ml/d Teddington DRA scheme are proportionately less than those predicted through the reported modelling.

5.8 SUMMARY OF WATER QUALITY ASSESSMENT OF TEDDINGTON DRA SCHEME

Table 5-8 summarises the potential water quality impacts for each of the sizes of a Teddington DRA scheme.

Table 5-8 Summary of Gate 2 assessment of potential water quality impacts for Teddington DRA scheme

<table>
<tr><th>Size</th><th>Water temperature</th><th>General physico-chemical</th><th>WFD chemicals</th><th>EQSD chemicals</th><th>Olfactory water quality</th><th>Richmond Pound Draw Down</th></tr>
<tr><td>50 Ml/d</td><td>Freshwater River Thames: Negligible change in water temperature.
Estuarine Thames Tideway: Negligible change.</td><td rowspan="3">Freshwater River Thames:
Dissolved oxygen:
No deterioration modelled.
Ammonia:
No deterioration modelled
Phosphate:
Minor concentration increase modelled.
ANC:
No deterioration modelled.

Estuarine Thames Tideway:
Dissolved oxygen:
No deterioration modelled.
DIN:
Reductions in DIN during scheme operation
Salinity:
Negligible change inferred from modelling of larger schemes</td><td rowspan="4">Freshwater River Thames:
Eight determinands decreased to be below the standard (noting this is not a comparison against EQS compliance rates). 11 continued to exceed standards (noting this is not a comparison against EQS compliance rates) under the modelled scenarios and three new pressures exceeded standards (noting this is not a comparison against EQS compliance rates).
Relative risk increases with scheme size noting environmental permitting is not a Gate 3 requirement.
Estuarine Thames Tideway:
Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.</td><td rowspan="3">Freshwater River Thames:
Only one determinand exceeds standard (noting this is not a comparison against EQS compliance rates) under reference conditions and there is one additional pressure under modelled scenarios.
Relative risk increases with scheme size noting environmental permitting is not a Gate 3 requirement.
Estuarine Thames Tideway:
Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.</td><td rowspan="4">Freshwater River Thames:
Of the chemicals analysed at Gate 2, 24 identified as detected.
Estuarine Thames Tideway:
Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.</td><td rowspan="4">Negligible impacts inferred from Mogden water recycling scheme at 200 Ml/d modelling</td></tr>
<tr><td>75 Ml/d</td><td>Freshwater River Thames: Minor change in water temperature of 1.1ºC maximum daily difference. Plume modelling identifies <25% of channel warmed by 2ºC or more under extreme (98%ile) conditions.
Estuarine Thames Tideway:
Negligible impacts</td></tr>
<tr><td>100 Ml/d</td><td>Freshwater River Thames: Minor change in water temperature of 1.5ºC maximum daily difference. Plume modelling identifies <25% of channel warmed by 2ºC or more under extreme (98%ile) conditions.
Estuarine Thames Tideway: Negligible impacts</td></tr>
<tr><td>150 Ml/d</td><td>Freshwater River Thames: Major change in water temperature of 2.2ºC maximum daily difference in extreme circumstances (~40 days on 1:20 year return frequency). Plume modelling identifies full</td><td>Freshwater River Thames:
Dissolved oxygen:
No deterioration modelled.
Ammonia:
No deterioration modelled
Phosphate:
Moderate concentration increase modelled.</td><td></td></tr>
</table>

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Draw Down
	channel warmed by 2ºC or more under such conditions. Estuarine Thames Tideway: Negligible impacts	ANC: No deterioration modelled. Estuarine Thames Tideway: Dissolved oxygen: No deterioration modelled. DIN: Reductions in DIN during scheme operation Salinity: Minimal salinity changes inferred from modelling of larger schemes				

In conclusion, the Teddington DRA schemes may lead up to minor changes in the general physico-chemical environment and major changes in temperature (only for the 150mld scheme) compared to the baseline conditions of the River Thames. The Teddington DRA schemes will have a negligible impact on WFD chemicals, EQSD chemicals and Olfactory water quality. Due to the assessment of a major temperature impact from a 150 Ml/d DRA scheme, it is recommended that the 150 Ml/d scheme size is recommended not to progress beyond Gate 2.

5.9 POTENTIAL MITIGATION REQUIREMENTS

Noting the concluding recommendation in Section 5.8, that the 150 Ml/d scheme size is recommended not to progress beyond Gate 2, this section focusses on the mitigation required for scheme sizes of 100 Ml/d and lower.

The temperature changes identified for the 100 Ml/d scheme may require mitigation in the form of operating procedures that implement cessation of operation during periods of significant temperature differences between the recycled water and the receiving waterbody when under lower river flow conditions. Alternatively/additionally, identification of potential practicable cooling options of the recycled water may need to be explored.

Dependent on the updated findings of the Gate 3 water quality assessment on the effect of the DRA discharge on the River Thames immediately upstream of Teddington weir, there may be a requirement for further mitigation in the form of additional treatment solutions to be considered to reduce the chemical content of the discharge in line with permitting requirements that need to be refined during Gate 3. Initial review of the treatment options have focussed on treatment options appropriate for heavy metals and trace organics identified as potential risks in the Gate 2 water quality assessment. Treatment options identified as potentially appropriate for heavy metals removal include:

- flocculation, sedimentation and filtrations approaches
- ion exchange
- absorption
- lime softening.

Treatment options identified as potentially appropriate for trace organics include:

- ozonation
- ultra violet advanced oxidisation process (UVAOP)
- granular activated carbon (GAC) absorption.

Refinement of the type of treatment options needed requires refinement of the consenting requirements for variable rate continuous discharge, such as the DRA, to establish the quality of the discharge that needs to be met, and thus the level of treatment that needs to be implemented. These are tasks that will be progressed through Gate 3.

6. CURRENT KNOWLEDGE GAPS AND FUTURE INVESTIGATIONS AT GATE 3

6.1 PREVIOUSLY IDENTIFIED GAPS IN WATER QUALITY UNDERSTANDING

At Gate 1 the water quality assessment identified evidence gaps which required addressing for Gate 2. A list of these gaps in Gate 1 were:

1. The installation of two additional continuous monitoring sondes at the end of the River Mole and Hogsmill River prior to their confluence with the River Thames measuring temperature conductivity and dissolved oxygen at 15-minute intervals. These two additional sondes would provide important boundary condition data for the modelling of temperature change in Gate 2.

2. At Gate 1 deterministic water quality models of the freshwater reaches were in preparation to provide scenario testing in Gate 2. This included a 1D model covering the entire freshwater River Thames study area from Shepperton Lock to Teddington Weir, and a 3D model for detailed assessment downstream of west London Effluent Reuse SRO discharge locations. The estuarine model used in Gate 1 would also continue to be developed with the inclusion of additional salinity data from the middle tideway collected as part of the Gate 1 continuous water quality monitoring programme.

3. A range of reference condition and SRO operation model runs would be established and reviewed with the Environment Agency during Gate 2. These will test the extent of environmental change from SRO operation under scenarios such as circumstances of normal operation, extremes, climate change, alternative operating patterns.

These gaps in evidence collection and modelling have been filled as part of the Gate 2 assessment.

The two additional continuous monitoring sondes were installed which provided the necessary data to inform the temperature change modelling.

The deterministic water quality models of the freshwater reaches were provided to enable scenario testing. This has been incorporated into the Gate 2 water quality assessment and form evidence for the fisheries and aquatic ecology assessments.

The identified range of reference condition and SRO operation model runs were established and reviewed with the Environment Agency allowing progression with the scenarios.

6.2 KNOWLEDGE GAPS IDENTIFIED DURING GATE 2

The comprehensive water quality assessment at Gate 2 for the London Effluent Reuse schemes has identified the magnitude of water quality effects in both the freshwater and estuarine study areas of the schemes.

Freshwater River Thames

In the freshwater River Thames additional olfactory data is required to assess the full suite of determinands as several were added during the Gate 2 process.

Further pH data would benefit re-mineralisation design for Mogden water recycling schemes at the point of discharge at Walton Bridge. Continuous sonde data would assist understanding of daily and sub-daily variability in pH

Freshwater Lee Diversion Channel

Further pH data would benefit re-mineralisation design for Beckton water recycling schemes at the point of discharge in the Enfield Island Loop. Continuous sonde data would assist understanding of daily and sub-daily variability in pH.

6.3 FUTURE INVESTIGATIONS AT GATE 3

As the engineering design and operational triggers of the London Effluent Reuse schemes are progressed in Gate 3, further specificity can be added to the water quality Gate 2 assessments. This will then allow for the refinement of mitigation requirements.

Olfaction in the freshwater River Thames will be further assessed for Mogden water recycling schemes and Teddington DRA schemes as additional data becomes available, as will pH and ANC.

Below is a list of further determinands that lack sufficient data for a comparative olfaction analysis to take place between reference conditions and different flow scenarios.

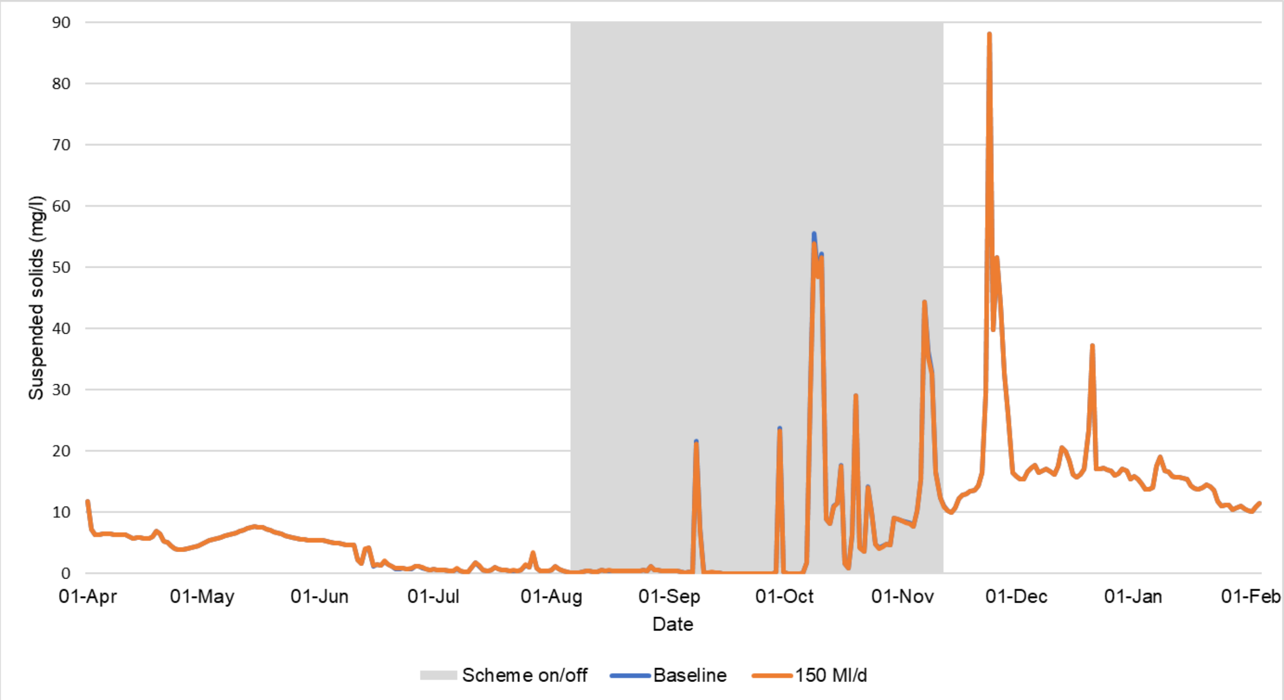
- Aluminium (dissolved and total)
- Chromium (VI) (dissolved)
- Chromium (total)
- Selenium (dissolved and total)
- Silver (dissolved and total)
- Methiocarb
- Oxamyl
- Carbophenothion
- Chlorpyrifos
- Diazinon
- Dichlorvos
- Fenitrothion
- Malathion
- Parathion
- Flucofuron
- Monuron
- Sulcofuron
- Cyfluthrin
- C10-C14 alkyl benzene sulphonic acids
- Branched sodium Dodecylbenzene sulfonate
- Calcium Dodecylbenzene sulfonate
- Linear sodium Dodecylbenzene sulfonate
- Sodium tridecylbenzene sulfonate
- Triethanolammonium dodecylbenzene sulfonate
- 1,6-hexanediamine
- Benzalkonium chlorides
- Di(hydrogenated tallow)dimethylammonium chloride
- Dodecylammonium chloride
- Lauryldimethylbenzyl ammonium chloride
- Stearyldimethylbenzyl ammonium chloride

Appendix 1: Teddington DRA: Graphs showing changes in physio-chemical parameters when scheme is both on and off at 150 Ml/d.

1. A82 SCENARIO

Suspended Solids

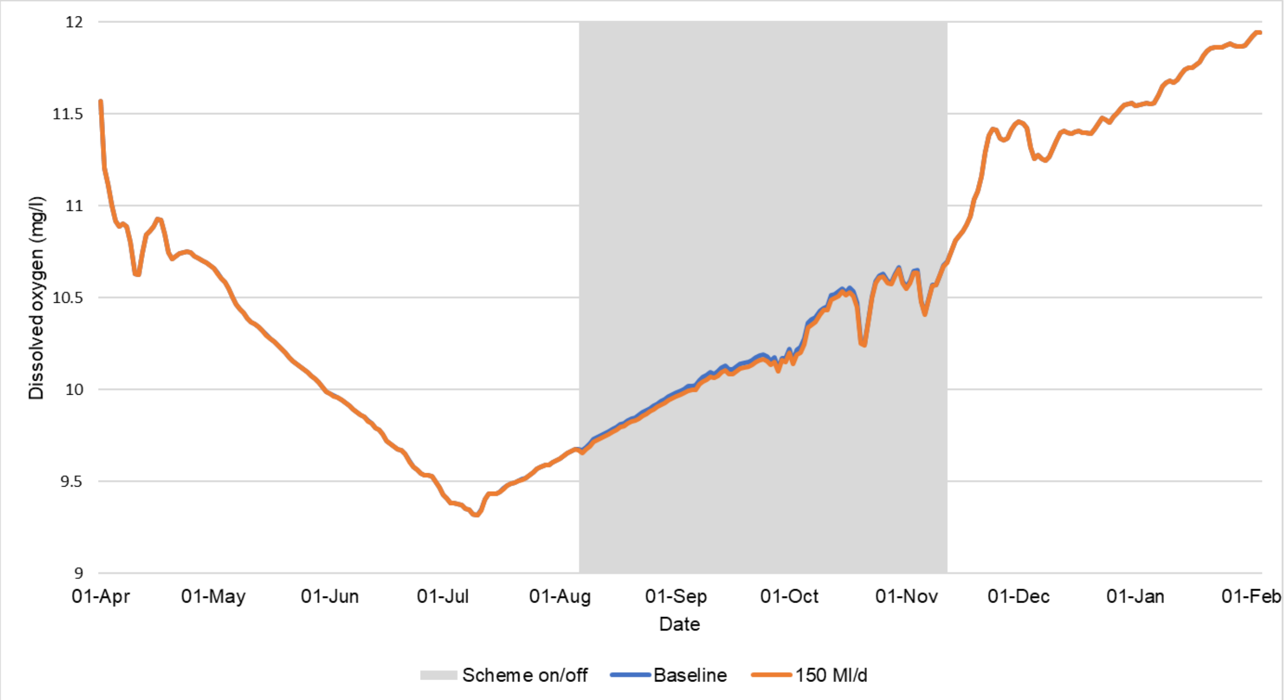
Figure A-1 Suspended solids concentration over time under the A82 flow scenario



The trend of suspended solids in freshwater River Thames is noted to be seasonal with elevated concentrations occurring from September onwards and decreased, more stable concentrations observed between April and August. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline.

Dissolved Oxygen

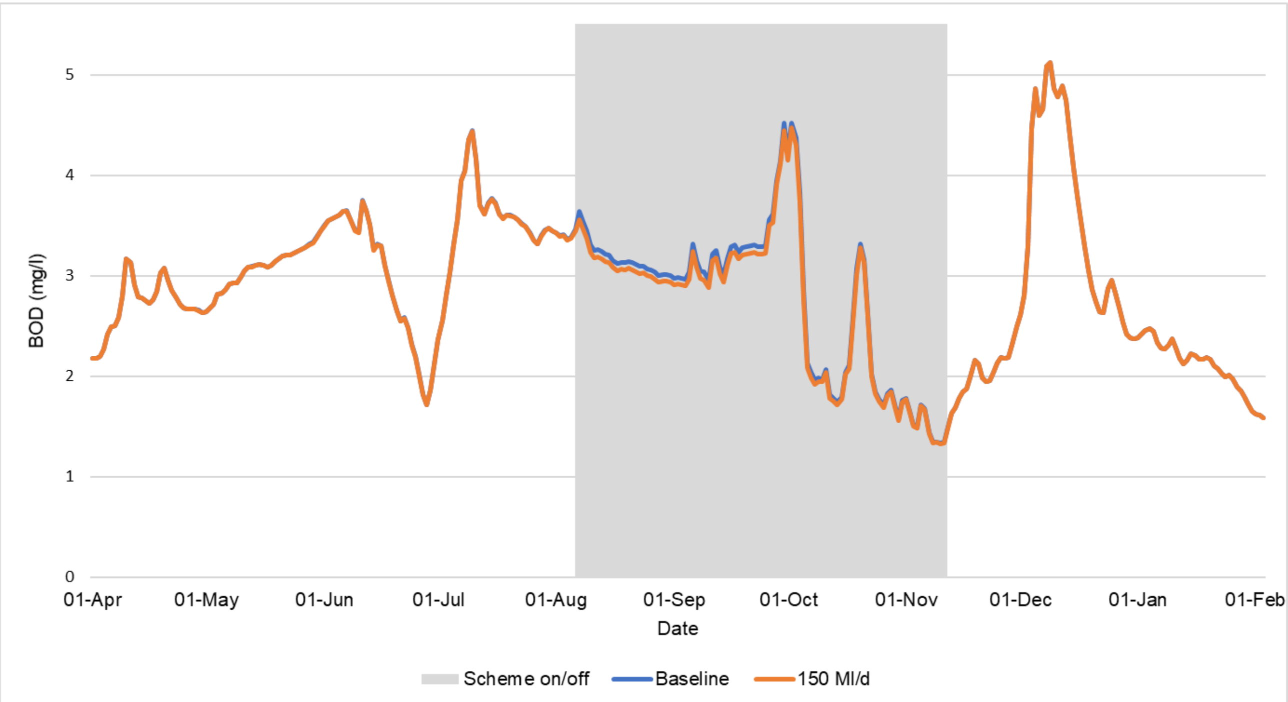
Figure A-2 Dissolved oxygen concentration over time under the A82 flow scenario



Dissolved oxygen in the freshwater River Thames also displays a seasonal trend with lower concentrations observed in the summer months. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline.

BOD

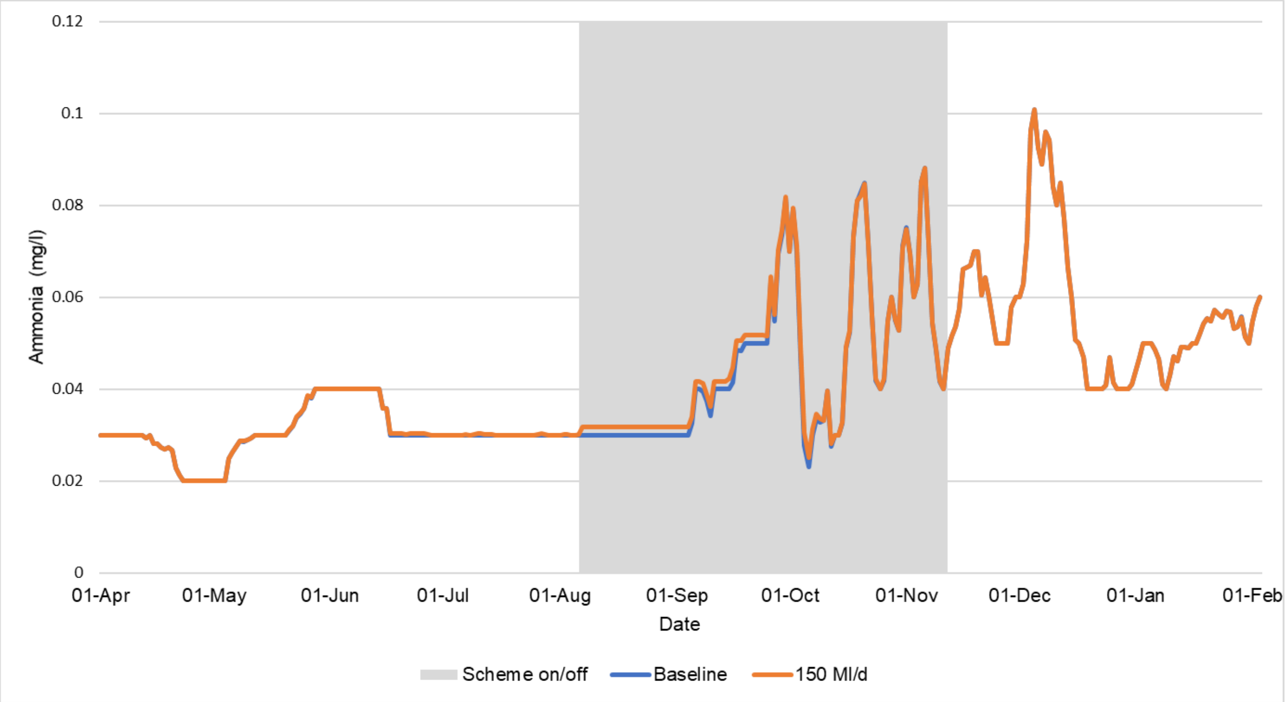
Figure A-3 BOD concentration over time under the A82 flow scenario



BOD concentrations do not display an observable trend, with both decreased and elevated concentrations observed throughout the monitoring period. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline with slight decreases in concentration observed.

Ammonia

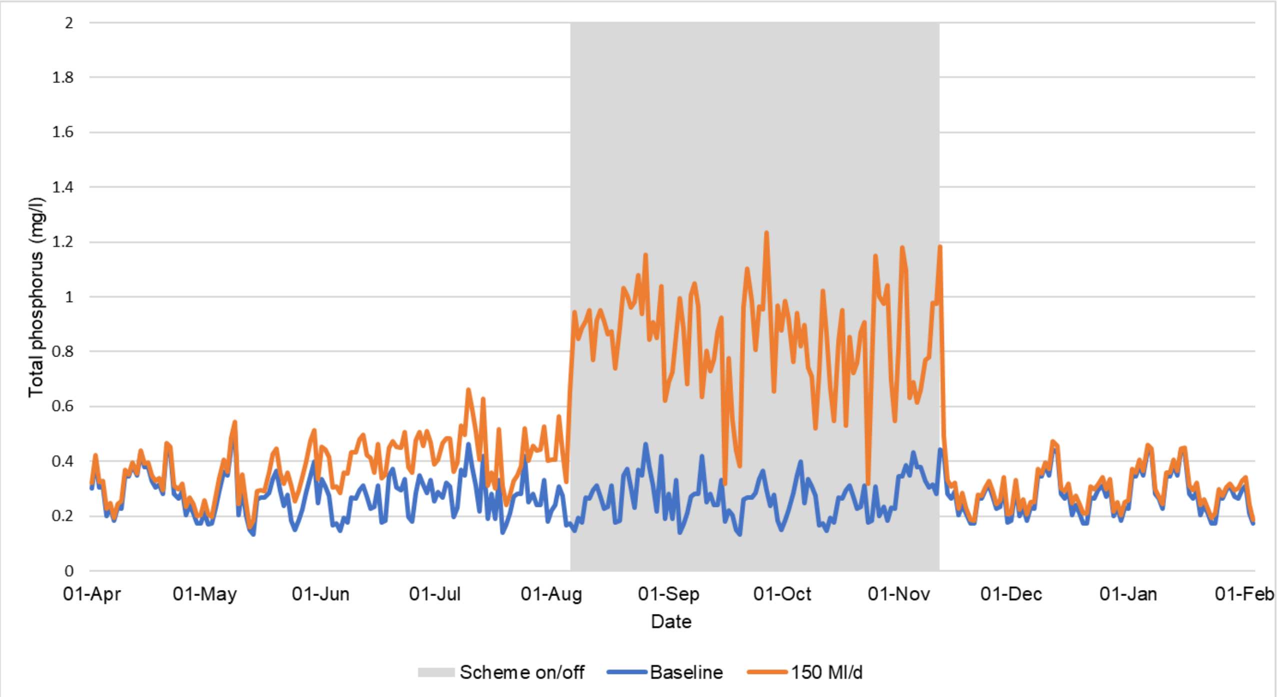
Figure A-4 Ammonia concentration over time under the A82 flow scenario



Ammonia appears to display a seasonal trend with elevated concentrations noted between September and February. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline with slight increases in concentration observed

Total Phosphorus

Figure A-5 Total phosphorus concentration over time under the A82 flow scenario

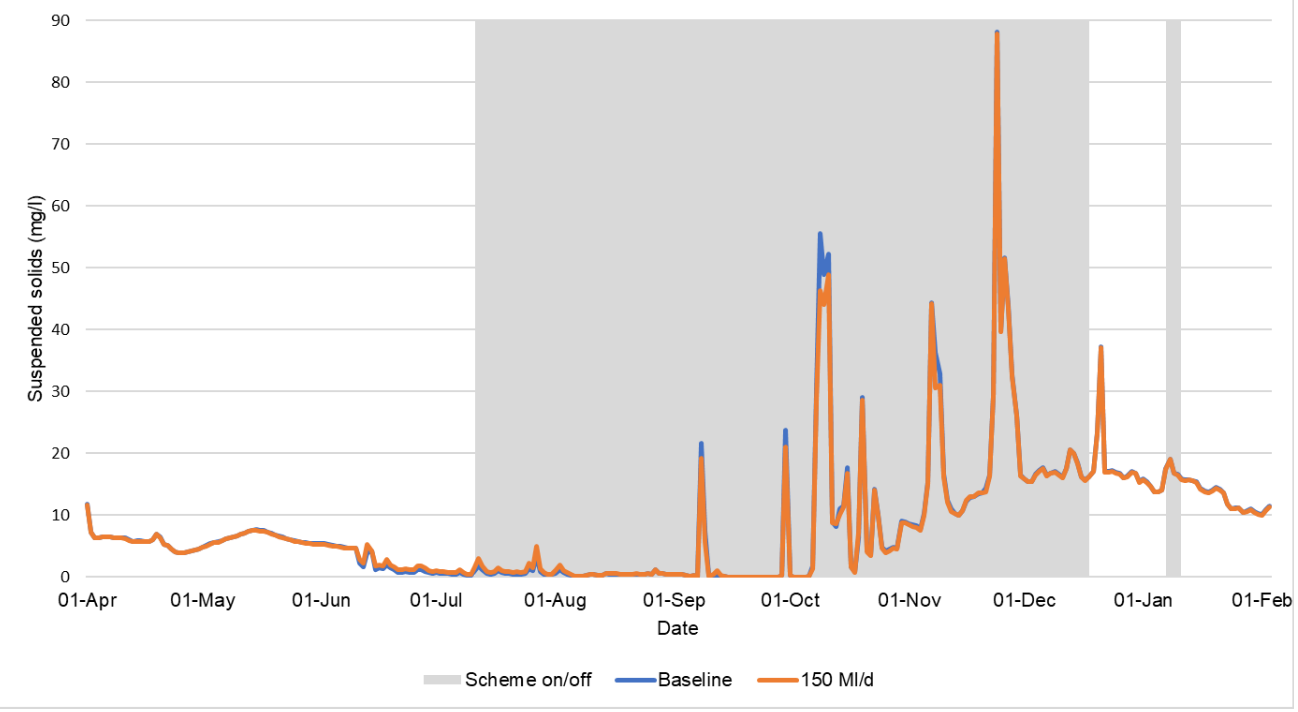


Total phosphorus displays a seasonal trend with elevated concentrations during the summer months. The 150 Ml/d Teddington DRA scheme does alter the concentrations from baseline with increases in concentration observed

1.2 M96 SCENARIO

Suspended Solids

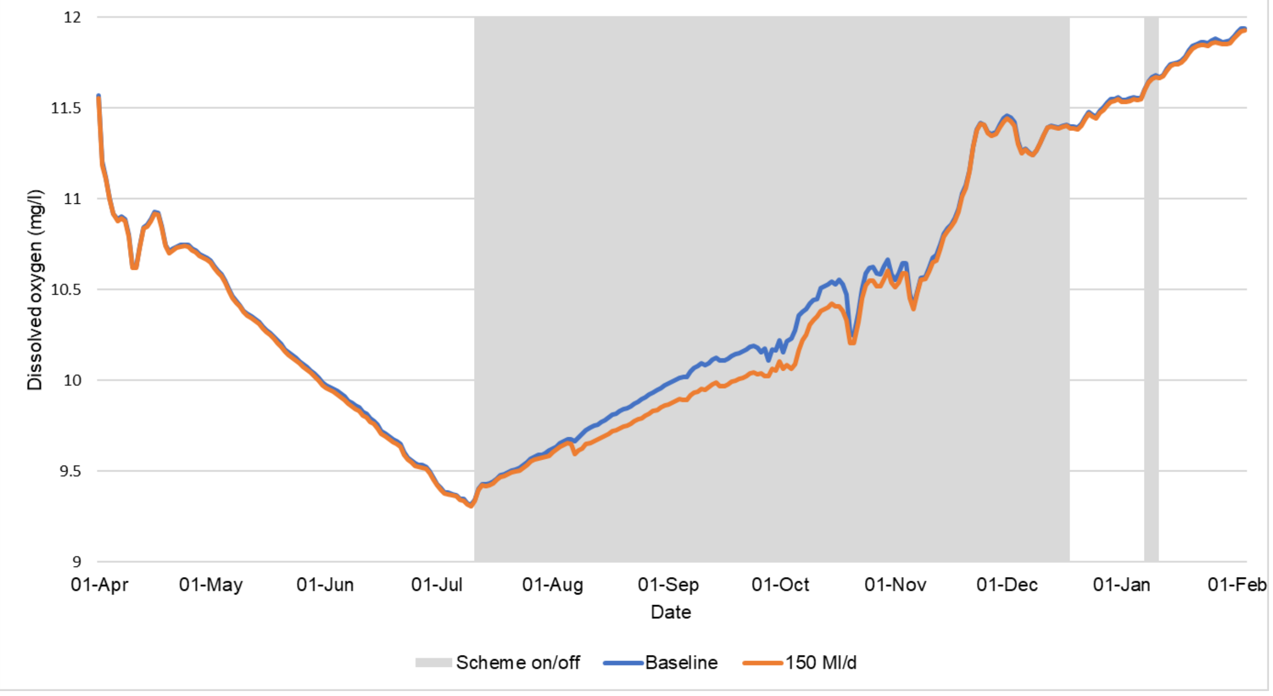
Figure A-6 Suspended solids concentration over time under the M96 flow scenario



The trend of suspended solids in freshwater River Thames is noted to be seasonal with elevated concentrations occurring from September onwards and decreased, more stable concentrations observed between April and August. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline with decreases in concentration observed.

Dissolved Oxygen

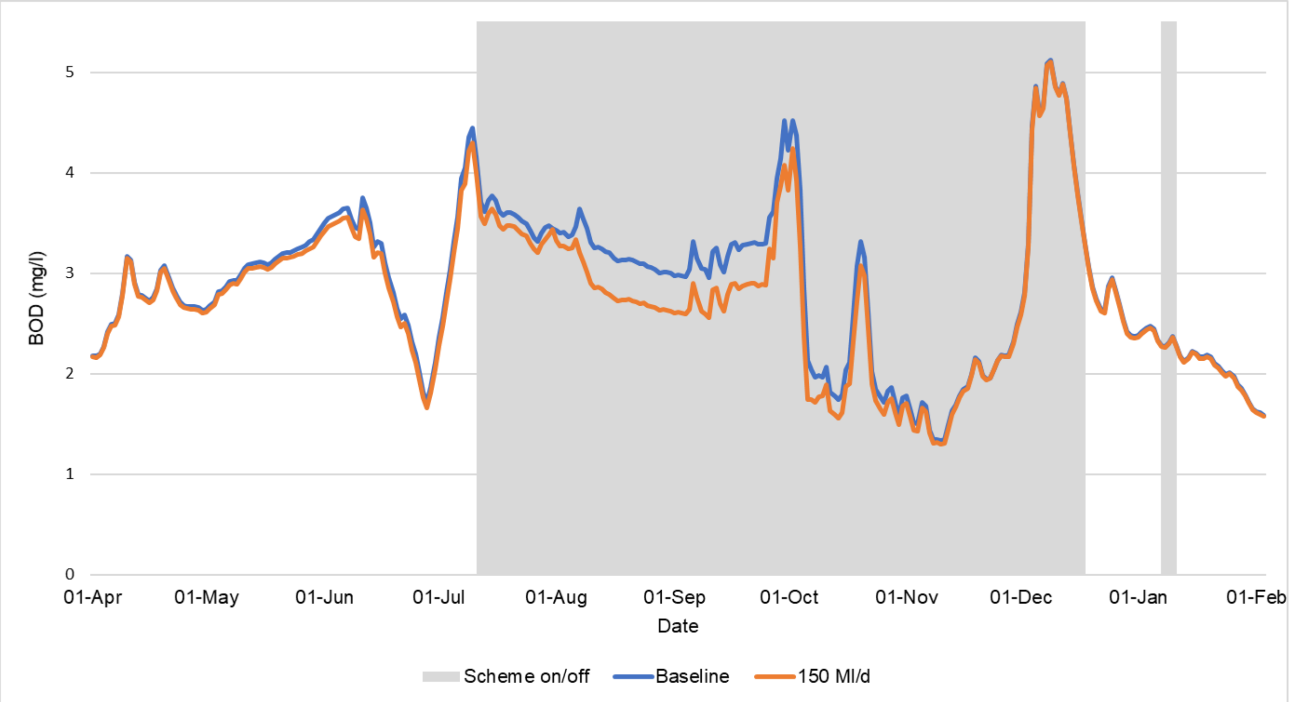
Figure A-7 Dissolved oxygen concentration over time under the M96 flow scenario



Dissolved oxygen in the freshwater River Thames also displays a seasonal trend with lower concentrations observed in the summer months. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline with decreases in concentration observed of <0.5 mg/l.

BOD

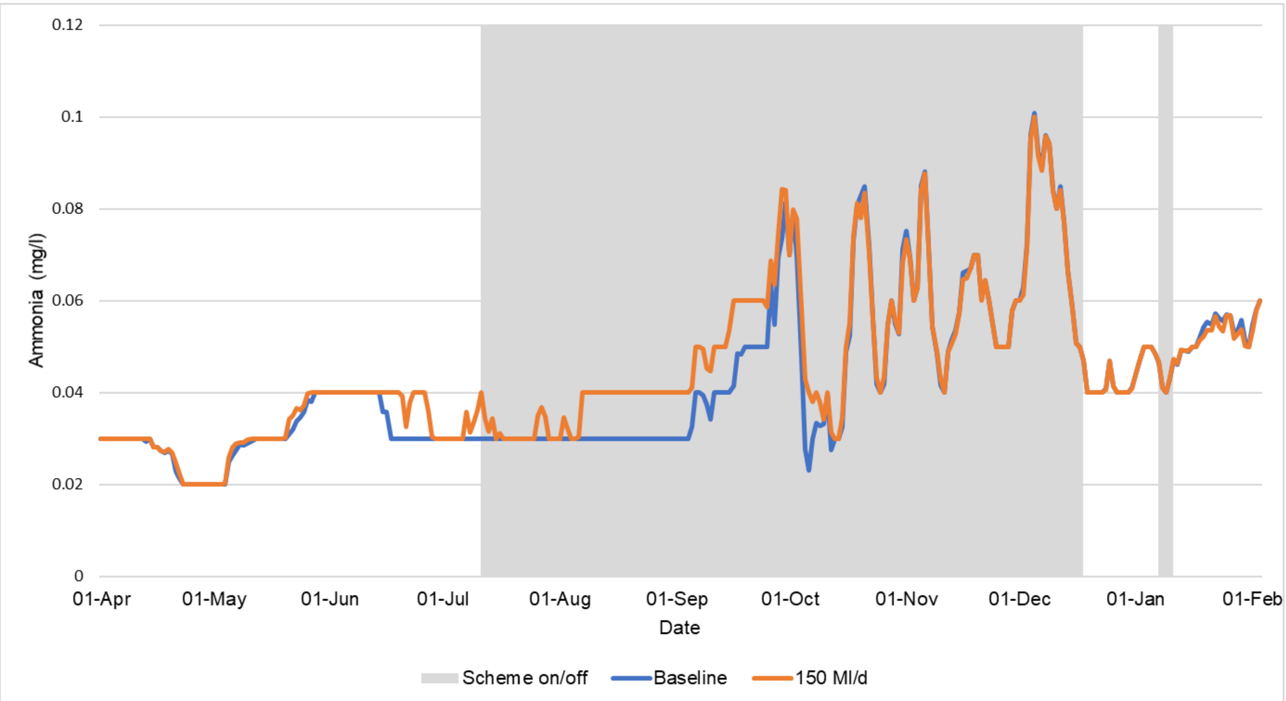
Figure A-8 BOD concentration over time under the M96 flow scenario



BOD concentrations do not display an observable trend, with both decreased and elevated concentrations observed throughout the monitoring period. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline with decreases in concentration observed.

Ammonia

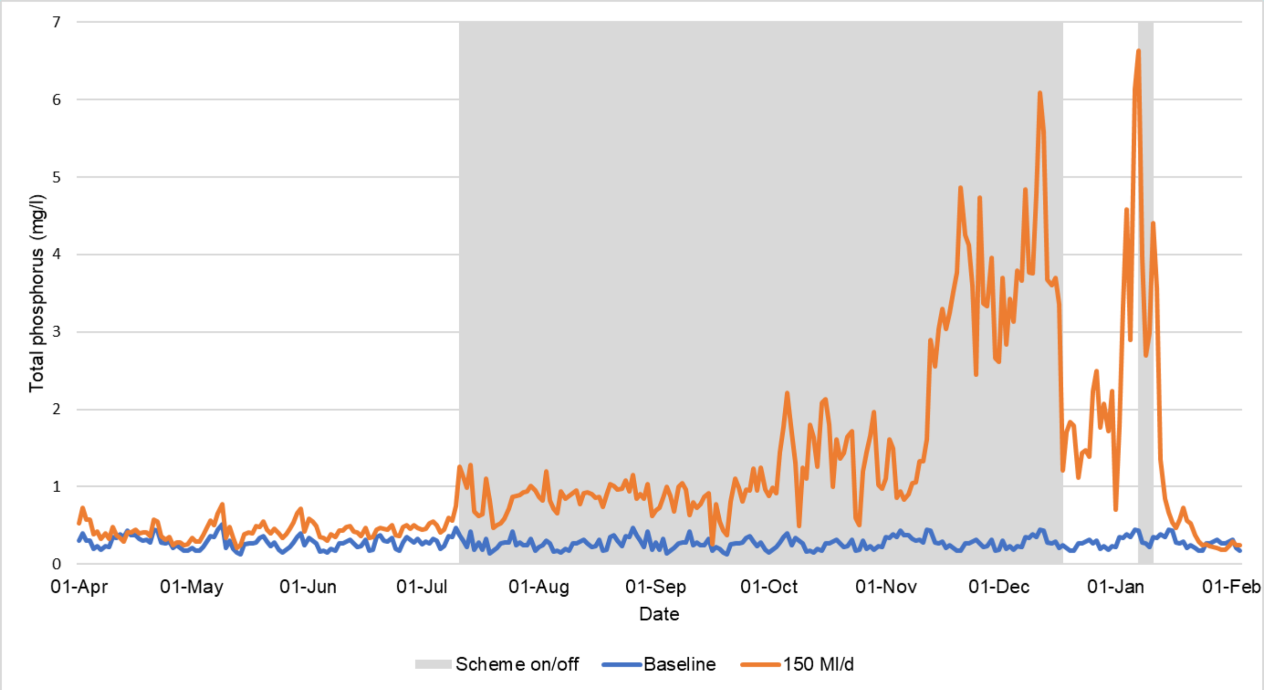
Figure A-9 Ammonia concentration over time under the M96 flow scenario



Ammonia appears to display a seasonal trend with elevated concentrations noted between September and February. The 150 Ml/d Teddington DRA scheme does not significantly alter the concentrations from baseline with some increases in concentration observed

Total Phosphorus

Figure A-10 Total phosphorus concentration over time under the M96 flow scenario



Total phosphorus does not display any particular trend. The 150 Ml/d Teddington DRA scheme does alter the concentrations from baseline with increases in concentration observed.

Appendix 2 Olfactory Chemicals and Additional Information

The olfactory nervous system is particularly vulnerable to disruption by chemical inhibition. These chemicals include:

Metals

- Copper (dissolved and total)
- Mercury (dissolved and total)
- Aluminium (dissolved and total)
- Cadmium (dissolved and total)
- Chromium (III, IV and Cr dissolved and total)
- Cobalt (dissolved and total)
- Iron (dissolved and total)
- Nickel (dissolved and total)
- Zinc (dissolved and total)
- Silver (dissolved and total)

Pesticides/Herbicides

- Carbamates (including Iodopropynyl Butyl Carbamate, Carbyl, oxamyl, pirimicarb and Carbofuran)
- Organophosphate (including chlorpyrifos, carbophenothion, diazinon, dichlorvos, fenitrohion, malathion and parathion)
- Phenylurea (including linuron, chlorotoluron, flucofuron and monuron)
- Pyrethroid pesticides (including cyfluthrin, cypermethrin and permethrin)
- Other pesticides (including diuron, dodecylammoniul chloride, isopropturon and sulcofuron)

Other Contaminants

- Surfactants
  - C10, 11, 12, 13, 14 alkylbenzene sulfonic acid
- 1,6-hexanediamine
- Benzalkonium chlorides (as BAC10, 12, 14 & 16)

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