Strategic Regional Water Resource Solutions: Annex B3.3: Fisheries Assessment Report

Standard Gate Two Submission for River Severn to River Thames Transfer (STT)

Date: November 2022

Severn to Thames Transfer

Fisheries assessment

STT-G2-S3-114

November 2022

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

SEVERN THAMES TRANSFER (STT) SOLUTION

Fisheries Assessment Report

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1. INTRODUCTION

1.1 BACKGROUND AND DESCRIPTION OF THE STT SCHEME

1.1.1 The River Severn to River Thames Transfer Description

The aim of the Severn Thames Transfer is to provide additional raw water resources of 300 to 500 Ml/d to the South East of England during drought, with 500 Ml/d preferred by the Water Resources in the South East (WRSE) group's emerging regional plan. The water would be provided from augmented flows in the River Severn and transferred via an interconnector to the River Thames. For the completion of the Gate 2 assessment, a pipeline "Interconnector" has been selected as the preferred option to transfer water from the River Severn to the River Thames.

Due to the risk of concurrent low flow periods in both river catchments, additional sources of water, apart from those naturally occurring in the River Severn, have been identified to augment the baseline flows. These multiple diverse sources of additional water provide resilience in the provision of raw water transfer to the River Thames. A 'put and take' arrangement has been agreed in principle with the Environment Agency (EA) and Natural Resources Wales (NRW) which means that if additional source water is 'put' into the river, then the Interconnector can 'take' that volume, less catchment losses, regardless of the baseline flows in the River Severn itself.

The regional planning process will determine the volume, timing, and utilisation of water to be transferred. The diversity of sources means they can be developed in a phased manner to meet the ultimate demand profile as determined by the regional planning. These additional sources of water are being provided by United Utilities (UU) and Severn Trent Water (STW) who are working in collaboration with Thames Water (TW) to develop this solution. The additional sources are:

- **Vyrnwy Reservoir**: Release of 25 Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy;
- **Vyrnwy Reservoir**: Utilisation of 155 Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline ("Vyrnwy Bypass") to the River Severn;
- **Shrewsbury**: Diversion of 25 Ml/d treated water from UU's Oswestry Water Treatment Works (WTW) via an existing emergency transfer (the Llanforda connection), thus enabling a reduction in abstraction from the River Severn at Shelton WTW to remain in the River Severn for abstraction at Deerhurst;
- **Mythe**: 15 Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst;
- **Minworth**: The transfer of 115 Ml/d of treated wastewater discharge from Severn Trent Water's Minworth Wastewater Treatment Works (WwTW) via a pipeline, to the River Severn via the River Avon at Stoneleigh; and
- **Netheridge**: The transfer of 35 Ml/d of treated wastewater discharge at Severn Trent Water's Netheridge WwTW to the River Severn at Haw Bridge, via a pipeline, upstream of the current discharge to the River Severn.

The STT Gate 1 submission was assessed by the Regulators' Alliance for Progressing Infrastructure Development (RAPID) who concluded that it should progress to standard Gate 2. The recommendations and actions received from RAPID and feedback from stakeholders from the Gate 1 process have been reflected in the scheme development and environmental assessments.

1.1.2 Gate 2

RAPID issued a guidance document[1] in April 2022 to describe the Gate 2 process and set out the expectations for solutions at standard Gate 2.

[1] RAPID (2022) Strategic regional water resource solutions guidance for Gate 2

The guidance stated the environmental assessment methodologies should be consistent with any relevant legislation and guidance and follow best practice. This includes, where relevant, Water Resource Management Plan (WRMP) guidance for 2024, All Company Working Group (ACWG) guidance[2] and the Environment Agency Invasive Non-native Species risk assessment tool.

Figure 1.1 shows the investigations being undertaken for STT Gate 2 and their interactions, in order to show the full scope of work across both environmental and engineering disciplines. Reporting for the environmental investigations has been undertaken in a phased way to account for, and incorporate all previous assessments, data collection and feedback: (i) the evidence reports were produced first, and set out the data and evidence to be used in the assessments; (ii) assessment reports were then produced using the evidence to determine the potential effect of the STT solution on the physical environment, water quality and ecological receptors (dark blue box in in Figure 1.1); (iii) based on the evidence and assessments, the statutory reports, and assessments required to meet the RAPID and regulatory expectations for solutions at Gate 2 were produced.

This report presents an assessment of the effect of the solution on fisheries, as an ecological receptor. It informs other assessments, including the statutory assessments.

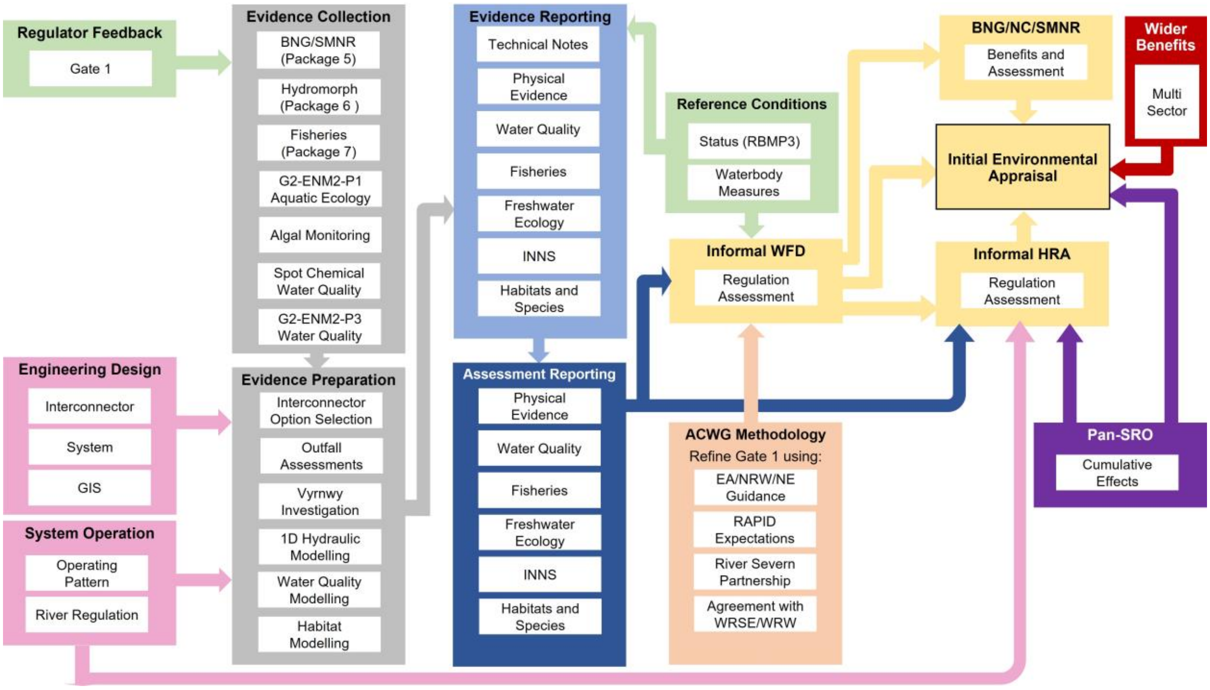

Figure 1.1 Flow chart showing the scope of investigations for STT Gate 2 and their interactions

1.2 STUDY AREA

The study area for the STT solution for Gate 2 assessment is limited to specific reaches, as shown in **Figure 1.2**:

1. The River Vyrnwy catchment (River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn);
2. The River Severn catchment (River Severn from the confluence with the River Vyrnwy to the Severn Estuary), as well as those tributaries of the River Severn which could indirectly be affected by the operation of the STT solution;
3. The Warwickshire River Avon upstream of Warwick to the River Severn confluence; and

[2] All Companies Working Group (2020) WRMP environmental assessment guidance and applicability with SROs

4. The River Thames catchment (River Thames from Culham to Teddington Weir)

It should be noted that the consideration of impacts in the River Tame and Trent, from the transfer of treated discharge from Minworth Wastewater Treatment Works (WwTW) to the River Avon, is included in Severn Trent Water's Minworth Strategic Resource Option (SRO) and therefore excluded from the STT solution assessment.

Similarly, the STT solution assessment accounts for the effects from the relevant SROs related to the supply of water into the STT system (United Utilities and Severn Trent Water Sources). It therefore includes an assessment of the potential effects of the water arising from the outfalls from the transfers (Minworth and Netheridge). It does not cover the impact of infrastructure construction as this is included in Severn Trent Water's Minworth and Sources Solution assessments.

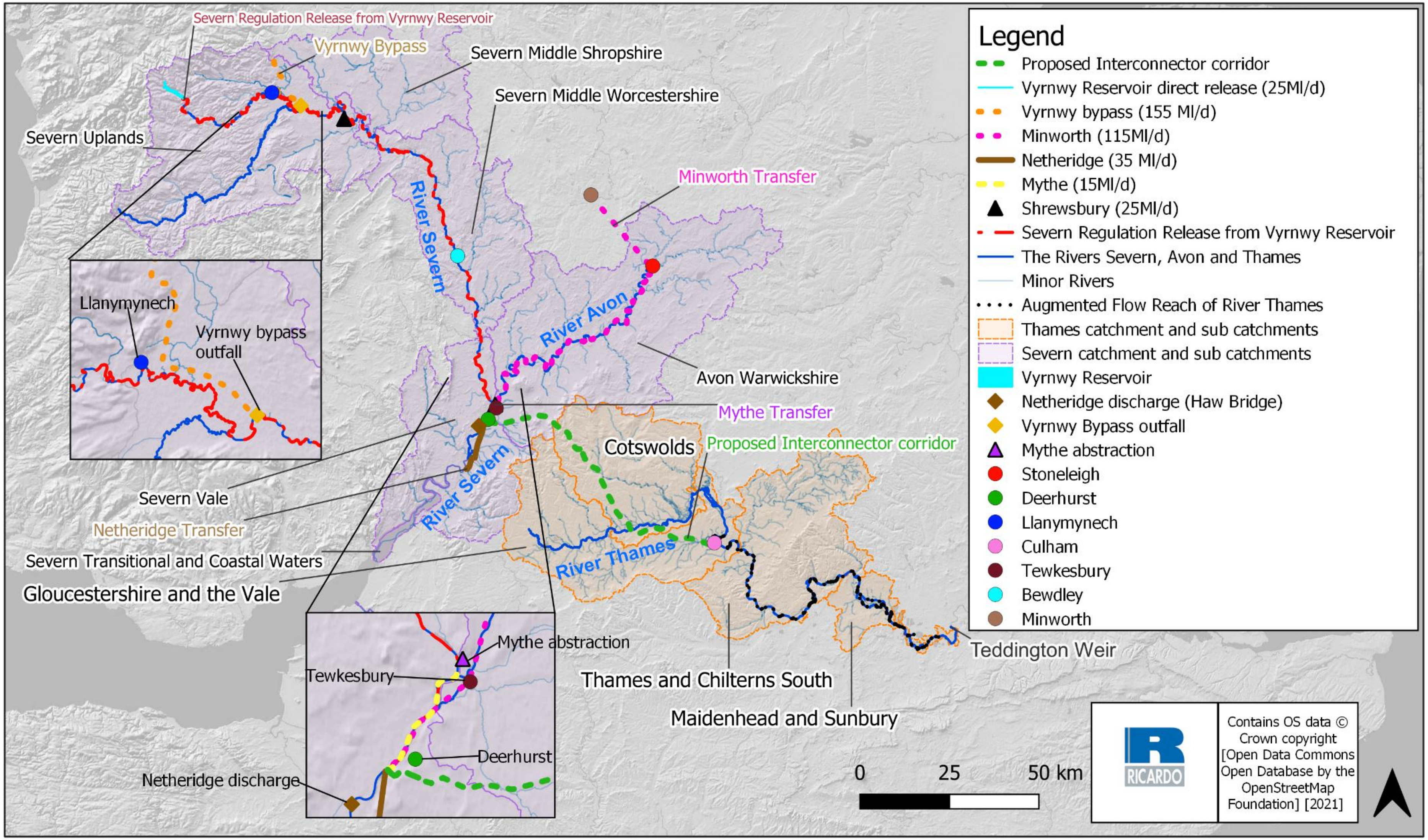

Figure 1.2 Map showing the proposed interconnector corridor

1.3 SUMMARY OF THE SOLUTION COMPONENTS AND OPERATION

The STT solution developed for Gate 2 is described through its engineering components in the Conceptual Design Report. For environmental assessment purposes, as these relate to in-river physical environment effects, the solution has been split into two phases, with and without support, described as (i) an *early phase* of the STT solution, which is without the inclusion of most of the support options that augment flow in the River Severn (see Section 1.1.1), and (ii) a *full STT* solution, which includes all the support options. The river flow changes that comprise these two phases are set out in the Physical Environment Assessment Report[3].

Supporting options would be operational at those times when the STT is transferring water from the River Severn to the River Thames, and when flows in the River Severn are lower than hands-off flow (HoF) thresholds in the River Severn. The EA has advised that a STT abstraction licence would be imposed so flows at Deerhurst flow gauging station do not drop below 2,568 Ml/d. Above this HoF, there is a maximum abstraction limit of 172 Ml/d, up to the next HoF condition of 3,333 Ml/d, where 335 Ml/d can be abstracted, in addition to the available 172 Ml/d unsupported[4]. This is summarised in Table 1-2.

The EA has advised the STT Group of appropriate values of "in-river losses" to include in the hydraulic modelling[5] and subsequent environmental assessments. The advised values include a 20% loss in the River Vyrnwy, and the consequent 13 km of the River Severn to the Montford gauging station, with the loss occurring evenly over the distance. Separately, a 10% loss for water transferred into the River Avon, in the augmented flow reach between Stoneleigh and the River Severn confluence at Tewkesbury, with the loss occurring evenly over the distance. As such, of the total 370 Ml/d supporting flows augmenting flows into the River Severn catchment for full STT, the equivalent re-abstraction value at Deerhurst used for the environmental assessment is 353 Ml/d as represented in Figure 1.3.

To support the environmental assessments at Gate 2, an indicative operating pattern has been developed. The approach uses the 19,200 year stochastic flow series developed separately for the River Severn catchment for the Water Resources West (WRW) group and for the River Thames catchment for the WRSE group.

The stochastic flow series represent contemporary climate conditions and provide information on the return frequency, or regularity, of both the likely river flow conditions and STT operation. The stochastic years have been made available as 48-year continuous periods, and one of those has been selected as having representative flow characteristics to inform the environmental assessments. The selected 48-year series[6] includes a suitable range of regular low and moderate low flow periods. It does not include extreme low flows that are considered to be less regular than once every fifty years. This is described further in the Physical Environment Assessment Report, with the derived representation of dates with the full STT in operation (for water resources purposes) as used in environmental assessment shown in Figure 1.4. It should be noted that this operating pattern is for the STT solution used on its own for Thames Water, without conjunctive use with other Thames Water SROs (such as the South East Strategic Resource Option (SESRO)). It also uses the controlling triggers developed by Thames Water for SESRO based on lower River Thames flows and Thames Water's total London reservoir storage.

[3] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

[4] Email from Caroline Howells (Environment Agency Environment Planning Officer) to Peter Blair (Thames Water, Water Resources Modelling Specialist) 27 February 2020.

[5] Email from Alison Williams (Environment Agency Senior Water Resources Officer) to Helen Gavin (Ricardo) and Valerie Howden (HRW) on 10 February 2022.

[6] Note these are 48 calendar years. The environmental assessment period has been selected as a water resources year (1 April to 31 March) and as such the selected period includes 47 water resources years from the 48 calendar years,

Table 1-1 Components of Early Phase and Full STT Operation

<table>
<tr><th>Early Phase STT</th><th>Full STT</th></tr>
<tr><td>500 Ml/d interconnector pipeline.</td><td>500 Ml/d interconnector pipeline</td></tr>
<tr><td>Part-time, unsupported abstraction up to 500 Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, subject to hands-off flow conditions identified by the EA.</td><td>Part-time, unsupported abstraction up to 500 Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, subject to hands-off flow conditions identified by EA</td></tr>
<tr><td>Part-time, supported abstraction up to 35 Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, at flows constrained by hands-off flow conditions, provided by 35 Ml/d flow volume from the Netheridge Transfer.

The early phase STT solution does not include the full range of support options and as such supported abstraction is limited to the value of the Netheridge Transfer, 35 Ml/d.</td><td>Part-time, supported abstraction up to 353 Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, at flows constrained by hands-off flow conditions, and accounting for assumed river transfer losses. Flow provided by UU and STW sources. The order in which these sources are utilised has been determined by optimising the engineering solution and through the regional water resilience modelling by Water Resource South East (WRSE):
1. Vyrnwy Reservoir: Release of 25 Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy;
2. Vyrnwy Reservoir: Utilisation of 155 Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline (“Vyrnwy Bypass”) to the River Severn;
3. Shrewsbury: Diversion of 25 Ml/d treated water from UU’s Oswestry Water Treatment Works (WTW) via an existing emergency transfer (the Llanforda connection), thus enabling a reduction in abstraction from the River Severn at Shelton WTW to remain in the River Severn for abstraction at Deerhurst;
4. Mythe: 15 Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst;
5. Minworth: The transfer of 115 Ml/d of treated wastewater discharge from Severn Trent Water’s Minworth Wastewater Treatment Works (WwTW) via a pipeline, to the River Severn via the River Avon at Stoneleigh; and
6. Netheridge: 35 Ml/d of the Severn Trent Water licensed abstraction piped to the River Severn for abstraction at Deerhurst.</td></tr>
<tr><td>Continuous abstraction from River Severn at Deerhurst of 20 Ml/d to provide a pipeline maintenance flow, with continuous transfer to River Thames at Culham:
• Either unsupported abstraction when not limited by hands-off flow conditions; or
• Supported abstraction by flow volume matching from Netheridge Transfer</td><td>Continuous abstraction from River Severn at Deerhurst of 20 Ml/d to provide a pipeline maintenance flow, with continuous transfer to River Thames at Culham:
• Either unsupported abstraction when not limited by hands-off flow conditions; or
• Supported abstraction by flow volume matching from Netheridge Transfer</td></tr>
</table>

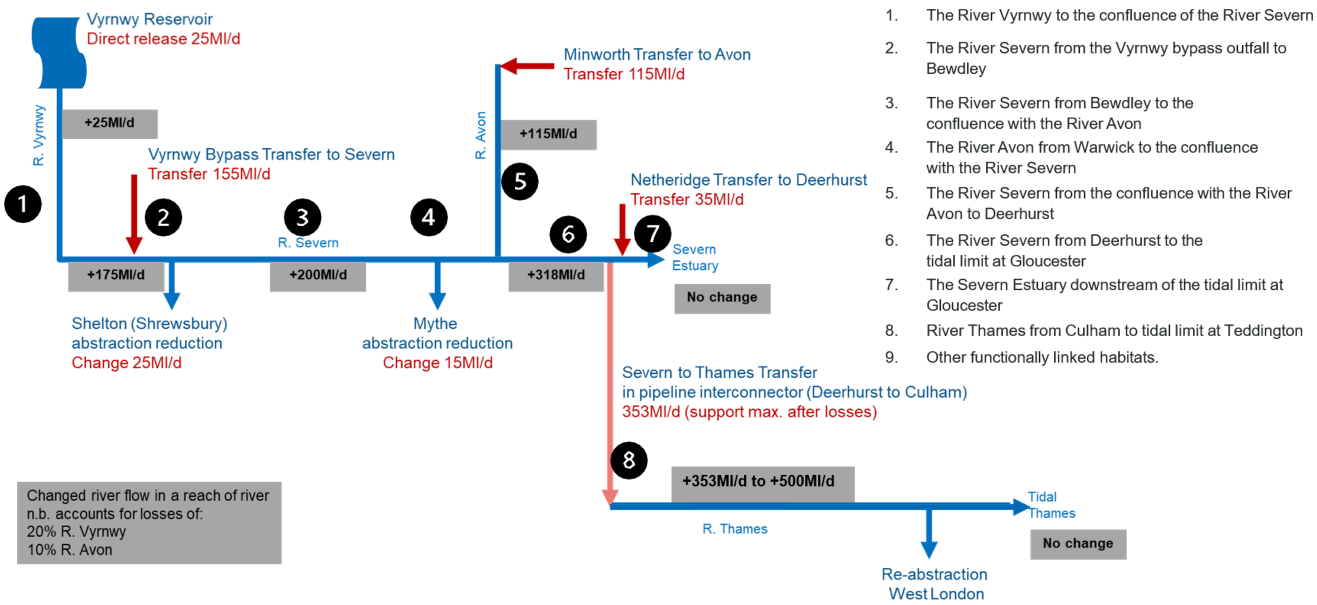

Figure 1.3 Schematic representing flow changes (accounting for losses) of STT Solution

Table 1-2 River Severn at Deerhurst: HoF conditions provided by EA

HoF	Flow threshold (Ml/d)	Maximum abstraction value at flows greater than the threshold (Ml/d)
1	2,568	172
2	3,333	527

The general description in Figure 1.4 identifies periods in purple when the early phase STT pattern would be in operation: the combined purple and blue periods show the periods when the full STT operation pattern is being deployed. The review of river flows and operating patterns for the environmental assessment has identified that all support options would be on at the same time, rather than any selective or preferential use of support sources. These patterns of river flow and operational need inform the range of likely environmental effects of the scheme. Having identified these patterns, selected return frequencies have been selected for the detailed assessment for Gate 2, which has included hydraulic modelling of different scenarios. The scenarios modelled are:

- a 1:5 return frequency year with moderate-low flows in the River Severn at Deerhurst with a 1:5 return frequency operating pattern in terms of duration and season (model reference A82);
- a 1:20 return frequency year with very low flow years in the River Severn at Deerhurst with a 1:20 return frequency operating pattern in terms of duration and season (model reference M96).

Noting the scheme would only be used on a 1:2 return frequency, these scenarios capture a suitable range of circumstances and have been discussed and reviewed with the regulators during Gate 2.

It should be noted that, in addition to the above, a 1:50 return frequency year of extremely low flows in the River Severn at Deerhurst and with a 1:20 return frequency operating pattern in terms of duration and season (model reference N17), has been prepared and reviewed for the consideration of scheme resilience. Such a low return frequency is outside the regularity of occurrence included in WFD assessments and is thus not described further in this report.

The Gate 2 assessment also incorporates climate change scenarios into 1D hydraulic models for the assessment for the rivers and Severn Estuary pass-forward flows. The A82 Future and M96 Future years are illustrative of the potential types of changes to river flows and operating patterns in the future. This is described further in the Physical Environment Assessment Report. At this stage, as the full 19,200 stochastic years have not been reworked as 2070s RCM8.5 futures, it is not possible to derive a suitable 48 year period that is representative of the return frequencies for the environmental assessments.

Figure 1.4 Representation of dates full STT solution would be on (for water resources purposes) as used in environmental assessment

Where: purple indicate periods when the early phase STT would be in operation (unsupported abstraction); and the combined purple and blue periods (supported abstraction) indicate the full STT

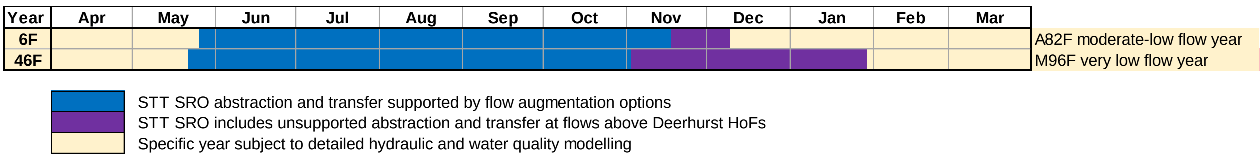

Figure 1.5 Representation of dates full STT solution would be on (for water resources purposes) for selected future scenarios as used in the environmental assessment

Where: purple indicates periods of unsupported abstraction and blue indicates periods of supported abstraction

1.4 SCOPE OF THIS REPORT

This report assesses the potential impacts of the STT solution on fisheries. It analyses the information and data set out in the Fisheries Evidence Report[6]. The findings of the analysis are presented on a reach-by-reach basis, addressing each metric of change. The information is presented in this way so there is clarity over where effects from the scheme are observed.

This report also identifies where more confidence could be placed in the results, through further evidence collection and analysis. NB The Evidence Report also identifies remaining data/evidence gaps, provides a summary of the proposed programme of works and approach to address any data/evidence gaps as part of RAPID's gated assessment for the SRO.

1.4.1 Link with other Reports

The Fisheries Evidence Report[7] sets out a data catalogue of the information sources that have been used to perform the assessment.

The results and findings presented in this report shows the potential effect of the STT scheme on the fish communities as a result of changes in flow, velocity, depth, level and water quality. These findings are used by other STT Gate 2 Environmental Assessment and Statutory reports which interpret the significance of the changes for their specific feature(s) or topic of interest.

The findings have been informed by the Physical Environment Assessment Report[8] (and associated Annex) and the Water Quality Assessment Report[9]. Together, these reports provide an assessment of the impacts on flow, water level, velocity changes and water quality as a result of the operation of STT. The results of the impacts on flow, water level, velocity changes and water quality are summarised in this report (where applicable).

[7] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Fisheries Evidence Report. Report for United Utilities on Behalf of the STT Group. February 2022.

[8] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

[9] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Water Quality Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

2. ASSESSMENT APPROACH

2.1 SUMMARY OF THE APPROACH

The scope of assessment and approach used to undertake the assessment of STT operation and effects on the fish community is described in **Table 2.1**. This table is replicated from the Gate 2 Fisheries Evidence Report.

Table 2-1 Approach to the Gate 2 assessment of the fish community

Item	Scope of assessment	Approach to assessment	Evidence Base for Task
a. Fish (WFD/NERC) Freshwater and Estuarine	Build upon the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2 and the updated physical environment and water quality assessments (including modelling outputs)	• Update the assessment to consider additional species/community data collected during Gate 1 and Gate 2 • Update assessment in consideration of the 1D hydraulic model outputs, including water and flow at key locations to consider the risk of changes in velocities, depth and wetted margins that may result in changes in community structure, loss of preferred habitat, etc. under a range of scenarios • Update assessment in consideration of the interpretation of the fluvial modelling of abstraction/outfall locations and the 2/3D habitat model at selected sites • Include relevant monitoring programme survey data such as Acoustic Doppler Current Profiler (ADCP), habitat walkovers and River MoRPh survey[10] outputs and additional habitat modelling at key locations • Update assessment in consideration of the interpretation of the water quality assessment and model outputs to consider the potential for water quality changes to drive changes in community structure • Suggest further mitigation measures (where required) for the scheme design/engineering • Review data collected on barrier passability in the R. Avon	• The physical environment and water quality assessments of the hydraulic and water quality model outputs. • Habitat assessment results based on the hydraulic and water quality model outputs. • EA Ecology & Fish Data Explorer data (2000-present) throughout the study area[11]. • NRW data for the River Vyrnwy and wider catchment obtained through data request.[12] • Targeted electrofishing surveys completed since 2020 at freshwater sites within the project area by the STT group. • eDNA results from INNS surveys undertaken by the STT Group which included a wide range of groups/species. • Salmonid redd counts completed by the STT Group. • Targeted walkovers, mapping and surveys for lamprey species completed by the STT Group. • Targeted walkovers and mapping of shad habitat completed by the STT Group. • Barrier assessment on the River Avon completed by the STT Group. • Location of barriers on the associated waterbodies from open-source data, including the EA river obstruction database[13] and the Catchment Based approach datahub[14]. • EA eel manual to determine compliance[15]. • Guidance from The Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) for temperature standards for marine and freshwater environments[16] to understand risk associated with operation. • Monitoring completed during trial releases to support the assessment of physical losses from the Vyrnwy Reservoir[17]. • Evidence and literature collated as part of the initial gap analysis of the STT which includes

[10] Modular River Survey
[11] https://environment.data.gov.uk/ecology/explorer/
[12] Obtained via data request: ATI22731a
[13] https://data.gov.uk/dataset/cda61957-f48b-4b75-b855-a18060302ed1/potential-sites-of-hydropower-opportunity
[14] https://data.catchmentbasedapproach.org/datasets/all-barriers/explore?location=30.720208%2C135.924750%2C2.96
[15] Environment Agency (2011). Eel and elver passes: manual for the design and implementation of passage solutions (Now Withdrawn)
[16] Water Framework Directive - United Kingdom Technical Advisory Group (WFD-UKTAG). (2008) UK Environmental Standards and Conditions. (Phase 2)
[17] Ricardo Energy & Environment (2021). Seven to Thames Transfer SRO River Vyrnwy Test Releases – Initial Ecological Findings. Report for United Utilities on behalf of the STT Group. November 2021

Item	Scope of assessment	Approach to assessment	Evidence Base for Task
			information on fish passes on the River Severn [18]. • Fish pass design and operational requirements as provided by the EA.
b. Olfactory cues[19]	• Update the Gate 1 assessment using the desktop review of available information on olfactory cues • Assess the potential for the masking of migratory salmonid olfactory cues	• Update assessment in consideration of the outputs of the hydraulic and water quality model, including the flow series at key locations and extent of mixing zones • Update the assessment in terms of the risk to olfactory cues using data as required on the ratio of treated effluent to river water under baseline conditions and modelled under various scenarios	• Outputs from the hydraulic and water quality model. • Review of olfactory cues of migratory fish[20]. • Flow, velocity, water quality data (spot samples and continuous sondes). • Assessment of WFD and EQSD chemical quality throughout the study area for the range of reference conditions and scenarios with STT operation.

2.1.1 Engagement with Stakeholders

In order to engage with regulators over the approach, evidence collection, monitoring programmes, and data analysis for Gate 2, the environmental assessment team have held monthly meetings with the Environment Agency (EA), Natural Resources Water (NRW) and Natural England (NE), in addition to topic-specific sessions and workshops with technical specialists. The regulators were asked to provide insights and inputs on specific aspects where needed in order to ensure the work undertaken is as robust as possible. They will review the Gate 2 assessment reports and findings.

In the monthly meetings, the programme, progress and deliverables are reviewed; issues are raised for clarification and resolution, and the regulators are asked for their views and advice on different topics or issues.

2.2 DATA AND EVIDENCE

The assessment of the sensitivity of the fish communities to physical environment changes has been informed by the consideration of relevant baseline data as summarised in the Physical Environment Assessment Report, Water Quality Assessment Report and the Fisheries Evidence Report (Section 1.4.1). Many of the data (indices and diversity data) were obtained from the Environment Agency (EA) Ecology Data Explorer and through data requests submitted to Natural Resources Wales (NRW). Where available, these data have been supplemented by data from the Strategic Resources Options (SRO) monitoring programme, data collected by water company investigations and third-party monitoring data. In addition, EA Fisheries Classification Scheme 2 (FCS2) and NRW National Fisheries Classification Scheme (NFCS) data have also been considered. Where available, the FCS2 data includes an individual species ecological quality ratio (EQR), a site EQR and a Water Body EQR.

The individual species EQR is interpreted as the probability of observing the number of individuals which were actually observed, or less, if the site were at reference conditions. The site EQR combines the probabilities obtained for each individual species and the Water Body. The NFCS classifies juvenile salmonid communities into categories A (excellent) through to F (fishless). These grades have been developed to evaluate and compare the results of fish population surveys in a consistent manner. The NFCS ranks survey data by comparing fish abundance at the survey sites with sites across Wales and England where juvenile salmonids are present. Where applicable, the assessment of salmon stocks and fisheries in England and Wales and the

[18] APEM (2020). STT Ecological Literature Review. APEM Scientific Report P00004288. Severn Thames Transfer Partnership, September 2020, v2.0 Final, 480 pp

[19] Olfaction, the sense of smell, is of great importance for species survival in terms of both reproduction and food selection, especially when taken together with the sense of taste. The detection of volatile chemical compounds is an important attribute for any animal to survive and reproduce in the natural environment.

[20] Ricardo Energy & Environment (2021). Technical Note: Severn Thames Transfer SRO – Impact of determinands on olfaction and fish populations in the Severn Estuary. Report for United Utilities on behalf of the Severn Thames Transfer Programme. 01 December 2021.

relevant Conservation Limits also has been considered to describe the baseline community along with the distribution of rivers considered as principal to the protection of salmon, sea trout, brown trout and coarse fisheries.

2.3 IDENTIFYING RELEVANT IMPACT PATHWAYS

Based on the modelled operational pattern of a supported and unsupported STT (see **Section 1.3**), the potential changes in hydrology, water quality and in-stream physical habitat will not coincide with all life stages of the fish community in all reaches, as summarised in Table 2-2.

As the STT (unsupported or supported) operations are not proposed to run during February, March, and April, corresponding life stages of fish species that typically take place across these months, have therefore been excluded from the Gate 2 assessment. Future assessment at the Gate 3 stage should go further and incorporate a precautionary approach that considers the potential for less direct impacts on these life stages. For instance, impacts on prior year spawning and growth may be observed owing to differences in flow manipulation across the prior 12 month period; or unpredictable climate change scenarios could place earlier demands on the operational system.

Where the operation of the STT will coincide, or may prospectively coincide (e.g., drier conditions and sooner than anticipated low flows) with a particular life stage of any of the associated species, the potential changes in hydrology, water quality and in-stream physical habitat needs to be considered in the context of the preferences/tolerance of the relevant life stage. For example:

- Flow and water depth play an important role in the movement of salmonid fry. This includes the movement of fry to establish feeding grounds (during low flow periods) and movement from redds. While increased flow may help to disperse fry, significant flow peaks over an extended period can be responsible for wash-out of weaker-swimming juvenile life stages and this is a potential risk with additional flow releases on top of existing River Severn Regulation Strategy scheme releases[21], such as the STT scheme.
- Flow and water depth also play an important role in providing sufficient habitat for other juvenile species. This includes lamprey ammocoete (nursery) habitat which could be inundated as a result of support releases or exposed due to abstraction.

The relevant species and life stages have been informed by the baseline data for each reach, as captured in the Fisheries Evidence Report (see Table 2.3). The physical environmental requirements of the relevant species (and life stages) have been considered in view of the modelled changes in velocity and depth and where possible, data collated as part of on-going monitoring programmes.

[21] Regulation of the River Severn balances the needs of water users with the protection of the environment. This balance is managed by the EA and NRW in liaison with water users, to ensure that the river and the estuary are protected from damage resulting from low flows.

Table 2-2 Summary of life stages of key fish species included and excluded from the assessments based on the modelled operational patters of the STT

Species	Life stages considered in the assessment	Life stages excluded from the assessment
Atlantic salmon (*Salmo salar*)	• In the Severn catchment, adult fish will migrate into the river throughout the year, holding in deep pools before moving upstream to spawning grounds during October and November. As such, this will coincide mainly with an unsupported abstraction and occasionally a supported abstraction (N17). • Spawning typically occurs between November and January, followed by egg incubation for up to 145 days (depending on water temperature) and would partly coincide with support releases • After hatching, fry move to nursery habitat and this movement may and would partly coincide with support releases. • In late spring, larger fry moves from nursery to feeding habitats. These nursery and feeding habitats are important all year and could be affected by support releases. • The majority of salmon smolts on the River Severn have historically migrated to sea. between mid-April and mid-June annually , with the smolt run peaking in May[22]. As such, downstream smolt migration may be affected by support releases	
Sea / brown trout (*Salmo trutta*)	• Upstream spawning migration of sea trout and local migration by brown trout occurs during autumn and winter (October-December) and would partly coincide with support releases. • In late spring, larger fry move from nursery to feeding habitats. These nursery and feeding habitats are important all year and could be affected by support releases. • Adult brown trout that don't migrate from sea may be affected by support releases.	• Smolts will shoal together and migrate out to sea between March and April annually, and will not be affected by support releases. • Egg incubation usually occurs between January and March and will be outside the period of support releases.
Sea lamprey (*Petromyzon marinus*)	• The support flows will coincide with at least part of the downstream migration of the metamorphosed sea lamprey which occurs during the July to September period. • Spawning migration usually takes place between April and May, and would partly coincide with support releases. • Sea lamprey usually spawns in late May or June, when the water temperature reaches at least 15 ºC. As such, support releases could coincide with part of the spawning period in a A82 and M96 scenario. • The support flows would also coincide with any egg incubation which generally occurs between June and July and this period is followed by the migration of juveniles to nursery habitats. • Metamorphoses occurs between July - September followed by downstream migration. As such, the support releases could coincide with this life stage. • Lamprey ammocoete in nursery habitats would also be at risk.	• Adult sea lamprey will move into the upper estuary during April but this holding stage will not coincide with the operation of the STT.
River lamprey (*Lampetra fluviatilis*)	• Upstream migration of adults generally occurs between October - December and will partly coincide with support releases and unsupported abstraction. • Support releases could coincide with egg incubation and migration of juveniles to nursery habitats. • After metamorphosis (July–September), individuals migrate to the estuary, and this will coincide with support releases • Lamprey ammocoete in nursery habitats would also be at risk.	• Spawning starts when the water temperature reaches 10–11 ºC, usually in March and April, and will not coincide with support releases.
Brook lamprey (*Lampetra planeri*)	• Support releases could coincide with egg incubation and migration of juveniles to nursery habitats • The adults usually migrate upstream after metamorphosis (July-September) but continue to burrow like ammocoetes and this will coincide with support releases. • Lamprey ammocoete in nursery habitats would also be at risk.	• This species only undertakes short migration runs prior to spawning which will be outside the operation of the STT.

[22] Jason Jones, NRW Fisheries Technical Specialist & Charles Crundwell, EA. Senior Technical Specialist Fisheries, *Pers Comm*

Species	Life stages considered in the assessment	Life stages excluded from the assessment
		• Spawning starts when the water temperature reaches 10–11 ºC, usually in March and April, and will not coincide with support releases.
Twaite (*Alosa fallax*) and allis (*Alosa alosa*) shad	• Adult twaite shad will migrate from coastal waters into the Severn Estuary during mid to late spring (April – June) which would coincide with support releases. • Spawning of twaite shad has been recorded during mid-July on the River Severn coinciding with the support releases. • Eggs hatch within a week, after which juvenile shad will drift the slower flowing waters of the upper estuary and this could coincide with support releases.	• N/A
Bullhead (*Cottus gobio*)	• Bullheads spawn from February to June with egg incubation approximately 30 days (temperature dependent) and this would coincide with the support releases. • Juveniles drift downstream after hatching and this will coincide with the support release.	• N/A
European eel (*Anguilla anguilla*)	• Mature adult eel undertake downstream migrations to sea in the autumn (typically September to December) and this would partially coincide with support releases and unsupported abstraction. • Juvenile to sub-adult eel will be present throughout the catchment, and within a range of aquatic habitats. • Support releases will also coincide with the upstream migration of elver.	• N/A
Coarse fish	• Most coarse fish spawn between March and June which will coincide with support releases. • Free embryos and larvae will be present throughout March-June which will also coincide with support releases.	• N/A

Table 2-3 Summary of depth and flow requirements for key fish species (modified from Cowx *et al*, 2004)[23].

The information in this table has been used to define critical habitat parameters. The depth and velocity requirements for roach have been used as the representative requirements for coarse fish absent within Cowx et al 2004. Note that this might differ between coarse fish species and further literature has been used to support the depth and flow requirements[24].

Species	Life stage	Depth requirement (cm)	Velocity requirement (cm/s)
Atlantic salmon	Fry	<10 - 40 (20 preferred)	5 - 65 (~15 - 40 preferred)
	0+	<100 (<25 preferred)	5 - 65 (~15 – 50 preferred)
	Juvenile	5 - 100 (~20 - 40 preferred)	0 - <100 (~5 – 50 preferred)
	Parr	>10 - <100 (~25 - 60 preferred)	4 - <120 (~10 - 60 preferred)
	Spawning	15 - 91(~25 – 50 preferred)	>15 - 90 (~20 - 50 preferred
Brown trout	Fry	60	0 - <30
	0+	20 - 30 (~20 – 30 preferred)	<10 – 50 (~10 - 20 preferred)
	Juvenile	5 – 240 (~20 - 30 preferred)	0 – 44 (<25 preferred)
	Parr	5.1 – 300 (~40 - 75 preferred)	0 – 65 (~20 - 30 preferred)
	Adult	9 – 305 (~40 - 75 preferred)	0 – 142 (~25 preferred)
	Spawning	6 – 91 (~25 - 50 preferred)	10.8 - 81 (~20 – 50 preferred)
Grayling (*Thymallus thymallus*)	Larvae	10-90	6-50
	Juvenile	40-60	<10-110
	Adult	20-400	20-110
	Spawning	10-50	23-92
Sea lamprey	Larvae	0 - 220	0 - 17
	Spawning	13-170	30 - 200
River Lamprey	Larvae	0 - 100	1-50
	Spawning	20 - 150	100-200
Brook lamprey	Larvae	<50	1-50
	Spawning	20-150	30-50
Bullhead	Juvenile	Shallow	Elevated
	Adult	>5 - 40	10 - >40
	Spawning	>5 cm	
Stone loach *(Barbatula barbatula)*	Juvenile	0 - 20	Still - elevated
European eel	Juvenile	<600	>10
Allis shad	Larvae	Shallow	Slow
	Juvenile	- 300	
	Spawning	50 - 300	50 - 200
Twaite shad	Larvae	Shallow	Slow
	Juvenile	- 300	
	Spawning	15 - 300	50 - 200
Dace (*Leuciscus leuciscus*)	Larvae	2-50	<2.5
	Juvenile	<50	Still – elevated
	Adult	17-113	0-57
	Spawning	25-40	20-50
Chub (*Squalius cephalus*)	Larvae	20 - <100	<5
	Juvenile	<20 - <100	<5
	Spawning	>0-128	<5-75
Bream *(Abramis brama)*	Larvae	20 - <150	<5
	Juvenile	<100 - ~125	<5
	Spawning	23 - ~50	<20
Barbel *(Barbus barbus)*	Larvae	0-40	<20
	Juvenile	<20-100	still – 120
	Adult		40-100
	Spawning	15 - 40	25-49
Roach *(Rutilus rutilus)*	Larvae	20 - 150 (<100 preferred)	<5 (lentic preferred)
	Juvenile	20 - ~175 (~50 - 100 preferred)	0 – 40 (lentic preferred)
	Spawning	15 - 45	- >20

[23] Cowx IG, Noble RA, Nunn AD, Harvey JP, Welcomme RL, and Halls AS (2004). Flow and Level Criteria for Coarse Fish and Conservation Species. Report for the Environment Agency. Science Report SC020112/SR.

[24] Cowx IG, Pitts, C.S, Smith, K.L, Hayward, P.J. and van Breukelen, S.W.F. (1995), Coarse fish populations in rivers: Literature Review. Report for the National Rivers Authority, R&D Note 459.

Kottelat, M. and Freyhof, J. (2007). Handbook of European freshwater fishes. Kottelat publications, Switzerland. pp646.

3. REACH BY REACH ASSESSMENT

3.1 INTRODUCTION

3.1.1 Relevant reaches

This section addresses the effects of the STT Scheme on a reach-by-reach basis, addressing each metric of change in turn. The reaches, as shown on **Figure 1.3** and with reference to **Figure 1.2**, are as follows:

- The River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn
- The River Severn from the confluence with the River Vyrnwy to Bewdley
- The River Severn from Bewdley to the confluence with the River Avon
- The River Avon from Stoneleigh to the confluence with the River Severn
- The River Severn from the confluence with the River Avon to Deerhurst
- The River Severn from Deerhurst to the tidal limit at Gloucester
- The Severn Estuary downstream of the tidal limit at Gloucester
- River Thames D/S Culham to tidal limit at Teddington
- Other functionally linked habitats

For each reach, an assessment has been made first of the baseline conditions to establish the relevant species and life stages to consider (i.e., the relevant pathways), before assessing the effect of the STT operation on current and then future flow, physicochemical and water quality conditions.

3.2 THE RIVER VYRNWY FROM THE VYRNWY RESERVOIR TO THE CONFLUENCE WITH THE RIVER SEVERN

3.2.1 Baseline

From Vyrnwy Reservoir to Llanymynech

The available data indicate that the fish community within the River Vyrnwy from Vyrnwy Reservoir Llanymynech largely of brown trout, bullhead and Atlantic salmon, with records of European eel, lamprey species, stone loach, minnow (*Phoxinus phoxinus*), three spined stickleback (*Gasterosteus aculeatus*) and grayling. In the lower sections of this reach, several coarse fish species such as barbel, chub and dace have also been recorded.

It is well known that the waterfalls at Dolanog creates a natural barrier that presents the upstream limit for migratory species such as Atlantic salmon, sea lamprey, river lamprey and European eel. Upstream of the waterfall the fish community is dominated by brown trout and bullhead. Habitat mapping undertaken prior to the Gate-2 assessments also suggest that suitable shad spawning habitat is present throughout the River Vyrnwy.

The fish community within this reach is representative of the geomorphology of this reach. Upstream of the waterfall at Dolanog the river is characterised by extensive bedrock dominated areas, interspersed with riffle/rapid habitats. Overhanging trees provide extensive cover with spawning habitat for brown trout available within the main river and the various tributaries. Migration is fairly uninterrupted with no significant barriers between the reservoir and the waterfall. Downstream of the waterfall, the river widens, and extensive riffle and rapids provides excellent spawning and juvenile habitats for salmonids. Downstream of the confluence with the River Banwy up to the Llanymynech area, the river changes again and it becomes much wider with less overhanging trees. Riffle/rapid habitat becomes less dominant with much deeper pools present, interspersed by long run/glide habitats.

Walkovers completed in 2021 of the River Vyrnwy, downstream of Dolanog Falls, in January 2021 found frequent areas of appropriate juvenile salmonid habitat, with suitable depth, velocity and substrate, most notably for parr. Connectivity between areas of juvenile habitat within the watercourse is considered good, with areas of run and glide interspersed with regularity across the full length of the survey reach. The conditions within the reach also provide suitable connectivity for upstream and downstream migrating fish.

Walkovers completed in 2022 also identified lamprey spawning habitat in the River Vyrnwy with ammocoete habitat mapping also showing optimal and sub-optimal ammocoete habitat in the River Vyrnwy. Shad spawning habitat has also been identified within the reaches of the River Vyrnwy but there are no records of shad being found within the Vyrnwy catchment.

From Llanymynech to the confluence with the River Severn

The available data indicate that the fish community within the reach (River Vyrnwy Llanymynech to the River Severn confluence) consists largely of European eel, bullhead, lamprey species, stone loach, Atlantic salmon, brown trout, minnow and three spined stickleback. An individual grayling was also observed in 2009.

The lower river within this reach remains characterised by a mixture of low and moderate energy flow types, with runs and riffles predominating and occasional glides and pools. Sediment bars are abundant throughout the reach, with particularly extensive point bars and most are unvegetated. In several areas, the bars create a wide diversity of flow habitats, while there are a number of complex side channels around several of these point bars related to channel migration and there are a number of cut-off meanders along the reach

Walkover surveys completed in 2022 also identified lamprey spawning habitat in the River Vyrnwy with ammocoete habitat mapping also showing optimal and sub-optimal ammocoete habitat in the River Vyrnwy. Sea lamprey eDNA has also been confirmed in the lower reaches of the River Vyrnwy[25]. Shad spawning habitat has also been identified in the reaches of the River Vyrnwy.

3.2.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Impacts on the upstream and/or downstream migration of Atlantic salmon, brown/sea trout, European eel, shad, bullhead and lamprey through changes in olfactory cues and impacts on passability of existing barriers.
- Changes in water quality (in particular temperature and dissolved oxygen) as a result of support flows with changes in temperature potentially impacting on egg incubation periods for coarse fish, bullhead, shad and lamprey species.
- Loss/decrease in fish habitat quantity and quality due to changes in hydraulics (i.e., increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities.
- Risk of displacement of juvenile fish due to increased flows, especially during movement from nursery to feeding habitats and from spawning beds to nursery habitats.
- Changes in optimum (and sub-optimum) ammocoete habitats if wetted width and depth increases significantly, including a loss of fine sediments.
- Negative impacts on the possibility of barriers during the upstream migration of adult lamprey to spawning areas.
- Loss of and redistribution of fine sediment in sensitive spawning habitats which could affect spawning success after operation of the STT.
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

3.2.3 STT operation – current conditions

This section sets out the findings of the effect of the STT scheme operation during current or contemporary (‘now’) climate conditions.

3.2.3.1 Changes to flows

In this reach STT SRO would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir at selected times. Flow changes in this reach would typically be in the months July to October, peaking in August at 47% of days in August. Outside this period, there would be less regular flow changes in June and November, with changes very rare in May, December and January and not anticipated in February, March or April.

In A82, STT solution releases of 25 Ml/d potentially coincide with Severn Regulation releases on 31 dates in July and August, with other managed releases (compensation flow, Severn Regulation Release) up to 95 Ml/d. In M96, STT solution releases of 25 Ml/d potentially coincide with Severn Regulation releases on 115 dates

[25] Jason Jones, NRW Fisheries Technical Specialist, *Pers Comm.*

between mid-June and mid-October, with other managed releases (compensation flow, Severn Regulation Release) at a higher rate in this representative very low flow year, up to 120 Ml/d.

Downstream of the confluence with the River Banwy, the absolute difference between the reference and fully supported condition is slightly reduced compared to immediately downstream of the reservoir due to losses. The percentage of flow due to the supported release from the reservoir reduces to 23% of the flow downstream of the River Banwy, because the River Banwy increases the reference flow in the river from 77 to 193 Ml/d on the 25th of August. The reference flow increases from 45 Ml/d to 960 Ml/d on the 5th of December. In the A82 scenario, the percentage change of flow in the River Vyrnwy is significantly reduced in September and October due to the higher flow from the River Banwy. This does not occur in the lower flow scenario (M96) due to the lower flow in River Banwy under this scenario.

3.2.3.2 Change to river level, velocity and wetted habitat

The data indicate that, on the whole there is a wide range of suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, notably for Atlantic salmon (all life stages), brown trout (juvenile and spawning), lamprey (ammocetes), chub (spawning), roach (juvenile) and juvenile to adult European eel. There are notable variations in the presence of suitable hydraulic habitat based on fish life cycle, with brown trout (0+), lamprey (spawning) and chub (juvenile) habitat indicated as being relatively rare within the reach.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is limited change in this baseline habitat for most species, with approximately 98% habitat remaining unchanged for the A82 flows and approximately 98% for the M96 flows. Under A82 flows, habitat gains and losses average 0.7% and 1.7% respectively, while for the M96 flows, habitat gains decrease to 0.5%, while habitat losses remain at 1.7% on average.

The data show that that there is a wide range of suitable habitat present in the reach for the key fish species considered, and there are likely to be only limited and localised change in habitat as flows change during releases, with some losses and some small gains in hydraulic habitat.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A of the Physical Environment Assessment Report should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes[26].

3.2.3.3 Changes in water quality

Assessment of changes to temperature with changes in outflow volume show a week relationship. Under the STT scheme operation, to release an additional 25 Ml/d, similar scale increase in outflow monitored have not resulted in clear temperature changes in the River Vyrnwy above the scale of background variability already present.

Other than the assessed general water quality parameters above, there is no pathway of general water quality change in this reach from STT SRO operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. The potential for water quality benefits in this reach associated with the enhanced dilution, of polluting pressures, from the flow augmentation are not included in this assessment.

3.2.3.4 Chemicals

There is no pathway of chemical change in this reach from STT SRO operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here.

3.2.3.5 Olfaction

There is no pathway of chemical change in this reach from STT SRO operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here.

3.2.4 STT operation - future climate

This section sets out the findings of the effect of the STT scheme operation during future climate conditions. In comparison with the A82 scenario the A82 Future scenario would include a 40% longer period of flow augmentation releases - with extension both 35 days earlier, to include late May and all of June; and 36 days

[26] Ricardo (2022). STT Solution –Physical Environment Assessment Report. Report for United Utilities.

later, to include all of October and the first half of November. The increase in regularity of the need for STT support options in late spring, early summer and later into autumn is a significant change.

3.2.4.1 Change to flow

Downstream of the reservoir, the flow is increased by 25 Ml/d from 23rd of May to 20th of November in the A82 Future scenario. This is a percentage change in flow of between 10 and 100% depending on the baseline flow.

Downstream of the confluence with the River Banwy, the absolute increase in flow with the fully supported condition is slightly reduced to ~22 Ml/d compared to immediately downstream of the reservoir due to losses. The percentage of flow due to the supported release from the reservoir increases to between 5% and 35% of the flow downstream of the River Banwy, because the River Banwy increases the reference flow in the river. The long section shows that during low flows in the Future Scenario, on 18th of October, the reference flow is only increased by 50% after the Banwy, whereas in current conditions, the flow more than doubles at low flows.

With the A82 Future flow scenario, the flow is increased by approximately 22 Ml/d from 24th of May to 20th of November from the reservoir release (less the losses between the reservoir and Llanymynech) at Llanymynech. The flow increase with the scheme is around 15% of the total flow in the river under Future conditions on 18th of October. Again, the flow increase is less than the release flow because of losses.

3.2.4.2 River level, velocity and wetted habitat

The data presented within the STT Physical Environment Report shows that that there is a wide range of suitable habitat present in the reach for the key fish species considered (particularly Atlantic salmon, at all life stages), brown trout (juvenile and spawning), lamprey (ammocetes), chub (spawning), roach (juvenile) and European eel (juvenile to adult). With the A82 and M96 scenarios, hydraulic habitats remain fairly constant, although there are some losses averaging between 0.6% (A82) and 1.7% (M96) and slight gains.

With future flow changes, both an increase in flow volume and duration in the reach, it is likely that there will be an increasing loss of hydraulic habitats in response to increasing velocity and depth of flows, although, based on the current A82 and M96 data, these losses are not likely to be extensive in both magnitude and distribution. However, as noted for the current climate, there could also be some gains, which would contribute marginally to offsetting any losses as other areas of the river within the reach trend towards suitable hydraulic habitat with increasing flows.

3.2.4.3 Fish pass and barrier passability

There are no weir pool habitats within this reach and there are no weirs identified for review of fish passability in this reach.

3.2.4.4 Changes in water quality

A future flow assessment of environmental water quality effects from STT SRO operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways.

3.3 THE RIVER SEVERN FROM THE CONFLUENCE WITH THE RIVER VYRNWY TO BEWDLEY

3.3.1 Baseline

The river is characterised by a mixture of deep glides and runs, with occasional riffle sections. Sediment bars are rare throughout the reach, although there are multiple islands scattered throughout the reach. The reach is of a very low gradient, and is fairly sinuous. River channel widths vary from ~40-45m throughout the majority of the reach.

The STT Fisheries Evidence Report indicates that the fish community of this reach of the River Severn is diverse and representative of the dominant habitats. Several species dominate the fish community in most years including: Three spined stickleback, barbel, bleak (*Alburnus alburnus*), bullhead, chub, dace, gudgeon (*Gobio gobio*), minnow, roach, ruffe (*Gymnocephalus cernua*) and stone loach. Perch (*Perca fluviatilis*) and pike (*Esox Lucius*) are also observed frequently at some sites. Less frequent is the occurrence of species such as lamprey and Atlantic salmon in the community. European eel has also been recorded throughout the reach with individuals varying from 17-700 mm. The highest abundances have been recorded at the Shrewsbury fish pass in 2014.

There are few areas of essential habitat on the lower and middle reaches of the River Severn for salmonid fish. These reaches also serve as a migration route for adult fish (upstream) and smolts (downstream). Areas of key spawning and nursery habitat are known to occur on the upper River Severn and several larger tributaries, including the River Tanat, River Vyrnwy and the River Rhiw. The "Unlocking the Severn"[27] (UtS) project reintroduced free passage to 158 miles of river, previously blocked off in the 1840s to migratory species such as shad and ensures access to areas of essential habitat going forward. However, it should be noted that no historical records of shad have been recorded within this section of the waterbody. The reach additionally provides some limited nursery habitat for salmonids, although the reach is considered of significant importance for juvenile coarse fish and lamprey ammocoete habitat.

3.3.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities and the resulting impact on the upstream and/or downstream migration of Atlantic salmon, sea / brown trout, shad (considering the Unlocking the Severn Scheme) and European eel.
- Increased velocities and the resulting impact on the local migration of coarse fish and brown trout to spawning areas.
- Loss/decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities, including habitats for lamprey ammocoetes.
- Risk of displacement of juvenile fish due to increased flows.
- Changes in water quality could have a direct impact on fish populations (e.g. mortality as a result of localised dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

Several weirs are present within this reach with one fish pass 'Shrewsbury right bank' considered within the hydraulic modelling work.

3.3.3 STT operation – current conditions

This section sets out the findings of the effect of the STT scheme operation during current or contemporary ('now') climate conditions.

3.3.3.1 Change to flow

In this reach, the STT solution would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir; an additional 155 Ml/d Vyrnwy bypass release at the confluence of the Weir Brook with the River Severn (upstream of Montford); and an abstraction reduction at Shelton intake at Shrewsbury, at selected times. Accounting for flow losses in the river systems, STT solution flow augmentation in this reach would be up to 200 Ml/d.

The A82 scenario would include a continuous 105 day period of flow augmentation from late June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

On the River Severn, downstream of the confluence with the River Vyrnwy, the flow is increased by approximately 20 Ml/d from the 28th of June to the 10th of October in the A82 scenario. Once the STT supported flows ramp up, the flow is increased by approximately 23% during July and August. The percentage increase is variable during September due to moderate flow events increasing the baseline flows. In the M96 scenario the flow is increased by approximately 20 Ml/d on the 13th and 62 Ml/d on the 14th of June, then by approximately 160 Ml/d from the 16th of June to 2nd November. The low flow period is longer in the M96 scenario compared to A82, even after the confluence of the Rivers Vyrnwy and Severn. Once the STT supported flows ramp up, the flow is increased by approximately 23% during July, August, September and October.

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[27] Unlocking the Severn. A partnership between Canal & Rivers Trust; Severn Rivers Trust; Environment Agency and Natural England. Available at: https;//www.unlockingthesevern.co.uk Accessed on: 19/08/2022.

Downstream of the Vyrnwy Bypass the flow is increased by a further 155 Ml/d which is a total increase of 175 Ml/d. In the A82 Scenario, this occurs from the 28th of June until the 9th of October and is a flow increase of around 22%, and in the M96 Scenario from the 18th of June until the 2nd of November and the flow increase is around 24%.

At Bewdley on the River Severn the flow is increased by approximately 35 Ml/d from the 28th of June then increases by approximately 201 Ml/d from the 4th of July to the 10th of October in the A82 scenario. The flow increases then reduces and drops off by the 12th of October. The timing of the flow increase is delayed compared to the locations further upstream due to the travel time along the river. The increase in flow at Bewdley is greater than at the location of the River Vyrnwy bypass outfall upstream of Montford because of the Shrewsbury component of the fully supported scheme. Once the STT supported flows ramp up the flow is increased by approximately 23% during July and August. The percentage increase is variable during September due to moderate flow events increasing the baseline flows.

In the M96 scenario, the flow is increased by approximately 20 Ml/d on the 15th to the 18th of June, then by approximately 201 Ml/d from the 20th of June to 2nd November. This is because when the transfer of water is required the flow in the River Severn is low and full support is required from both the reservoir, the reservoir bypass and Shrewsbury. Once the STT supported flows ramp up, the flow is increased by approximately 24% during July, August, September and October.

The modelling results shows that after the confluence of the Vyrnwy bypass with the River Severn at 69 km, just upstream of Montford, the flow from the STT scheme is approximately 16% of the total flow. At Bewdley, the percentage of flow from the scheme increases to around 17% of the total flow, due to the flow not abstracted from Shrewsbury.

3.3.3.2 Change to river level, velocity and wetted habitat

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is limited change in the baseline habitat for most fish species, with the majority of suitable habitat remaining unchanged for the A82 and M96 flows. Under A82 flows, habitat gains and losses average 0.3% and 2.0% respectively, while for the M96 flows, habitat gains remain unchanged, while habitat losses increase to 2.6% on average.

The STT Physical Environment Report data show that, except for a few specific fish species life stages, there is a very limited range of suitable hydraulic habitat present in the reach for the key fish species considered, and there are likely to be only very limited and localised change in habitat as flows change during releases, with losses being larger than gains.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A of the Physical Environment Report should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.3.3.3 Fish pass and barrier passability

One fish pass site in this reach has been modelled to review the changes in level associated with the STT solution. This is the 'Shrewsbury right bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage).

For the Shrewsbury right bank, under the A82 scenario, there is an increase in level between 27th June and 10th October. From 27th June to 25th August the level increases by between 0.010 m and 0.039 m with a mean level of 47.50 m AOD compared to the mean baseline level of 47.47 m AOD over this period. Between 26th August and 10th October, the level increase is more variable, fluctuating between 0.011 m and 0.036 m with a mean level of 47.62 m AOD compared to a mean baseline level of 47.59 m AOD.

Under the M96 scenario the level change is relatively consistent throughout the period from 18th June to 3rd November. Generally, the change in level fluctuates between 0.050 m and 0.039 m increase in level with the mean level over the period being 47.53 m AOD compared to 47.49 m AOD in the baseline.

It is noted that the River Severn from its confluence with the River Vyrnwy to Bewdley is of particular importance as a migratory route for anadromous and catadromous fish of the Severn Estuary and will also provide supporting habitat for lamprey ammocoetes. Direct impacts on the ammocoetes could in turn impact on the number of retuning adults in the future which would undermine the conservation objectives of the Severn Estuary European Marine Site.

From the results it is evident that the change in flow is not discernible and will not impact on migration for the anadromous and catadromous species associated with the Severn Estuary. This is because hydrological cues for migration will not be impacted, and the increased flows will not impact on the passability of any barriers. Flows and velocities will also remain sufficient to support the downstream drift of post-metamorphic transformers and juvenile shad. Flows and velocities will also not result in the washout of any incubating eggs or juveniles.

The potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on habitat availability for the fish community in this reach with the velocity and depths that would be observed under an unsupported and fully supported STT remaining similar to baseline conditions and within the preferred and optimum requirements for the baseline fish community associated with the reach.

This is evident when comparing photographs taken under different flow conditions in 2021. **Figure 3.1** shows the River Severn near Atcham (downstream of Shrewsbury and upstream of the confluence with the River Tern) on two separate survey dates. This includes a survey on 15th June 2021 when water levels in the River Severn were at 0.644 m (as measured on the River Severn at Montford) and 14th October 2021 when water levels in the River Severn was at 0.644 m (as measured on the River Severn at Montford) 0.813 m. This represents a level increase of ~17 cm and despite the noticeable level increase habitat availability has not changed. While there is a noticeable increase in wetted margins, no significant change in depth is observed with extensive marginal habits still available for lamprey ammocoete and other juvenile fish. It is important to note this represent an increase in flow of 251 Ml/d and not the 205 Ml/d that would be observed in this reach.

The conclusion that the potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on habitat availability in relation to the fish community within this reach is further supported by targeted hydraulic surveys that were completed in June and October 2021 at a site on the River Severn near Montford with two surveys completed under flows of 697 Ml/d measured on 15 June 2021 and 948 Ml/d measured on 14 October 2021, a difference of 251 Ml/d, representing flows that are slightly above those that would be observed during a fully supported STT in this reach. It is also considered that the potential changes and depth and flow are not at a magnitude to change the availability of food for any fish species present within this reach.

At site STT Montford, the hydraulic data indicates that there is a very limited amount of suitable flow habitat for Atlantic salmon and brown trout 0+ and juveniles individuals with spawning habitat also very limited (as expected). Data captured during extended hydromorphological and water quality walkover surveys (including an evaluation of substrate type and macrophyte cover)[28], also indicates limited habitat suitability for lamprey ammocoetes, but extensive flow habitats available for coarse fish. The measured data shows a slight increase in habitat under higher flows which is likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins. There appears to be a slight decrease in habitat suitability for juvenile coarse fish, noting that the measured data was at flows that will exceed the support flows and remain within the preferred tolerances for juvenile coarse fish (i.e., <0.2 m s^{-1}). The changes are also likely to be within the inter-annual variations experienced at this site. The results of the analyses are provided in Annex A of the Physical Environment Assessment Report[29].

The assessment is also supported by the results of the study area habitat assessment. As noted in Section 3.2, the habitat loss for ammocoete is mostly expected to occur in the 60 km downstream of the River Vyrnwy, with no significant habitat loss observed in the River Severn (based on hydraulic preferences)

Although there is currently insufficient information to derive the critical levels for fish passage, the change in level is considered non-discernible and likely within the natural inter annual variation that would be observed under reference conditions. As such, the operation of the STT is not expected to impact on the functionality of the fish pass, however, careful analysis of any gravity fed eel passes may also need to be taken into consideration.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions. Furthermore, the operation of the STT will not impact on barrier

[28] Ricardo (2022). Severn Thames Transfer SRO – Hydromorphology and water quality surveys. Final version | Issue number 1 | Date 07/07/2022 | Our ref: ED14950100.

[29] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site.

Figure 3.1 Photographs showing the River Severn downstream of Shrewsbury (at Atcham on 15th June 2021 (top) and 14th October 2021 (bottom) when levels were at 0.644m and 0.813m respectively (as measured at Montford)

3.3.3.4 Change to water quality

There is no pathway of general water quality, chemical water quality change or changes in olfaction change in this reach from STT operation. This is because the water that would be discharged in this reach is from the same source (i.e., the Vyrnwy Reservoir) and will simply be discharged in the River Severn instead of entering the River Severn via the River Vyrnwy. As such no assessment is included at Gate 2 in this reach. Information on the general water quality parameters: pH, acid neutralising capacity, biochemical oxygen demand, ammoniacal nitrogen, nutrients (reactive phosphate) is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report[30]. This bespoke evidence for the STT solution is available for one site in the reach: 25 River Severn (upper) downstream Option 4.

3.3.4 STT operation - future climate

This section sets out the findings of the effects of the STT operation during future climate conditions. In comparison with the A82 scenario the A82 Future scenario would include a 40% longer period of flow augmentation releases - with extension both 35 days earlier, to include late May and all of June; and 36 days later, to include all of October and the first half of November. The increase in regularity of the need for STT support options in late spring, early summer and later into autumn is a significant change.

3.3.4.1 Change to flow

On the River Severn downstream of the confluence with the River Vyrnwy, the flow is increased by approximately 20 Ml/d on from the 24th of May to the 21st of November in the A82 Future scenario. The flow is increased by approximately 3% during July to October.

Downstream of the Vyrnwy Bypass the flow is increased by a further 155 Ml/d which is a total increase of 175 Ml/d. In the A82 Future Scenario this occurs from the 25th of May until the 21st of November and is a flow increase of around 22%.

At Bewdley on the River Severn the flow in the A82 Future scenario is increased by approximately 28 Ml/d from the 24th May then increases by approximately 198 Ml/d from the 6th of May to the 22nd of November. The flow increase then reduces and drops off by the 23rd of November.

The long section shows that after the outfall from the Vyrnwy bypass pipeline at 69 km, the flow increases by 175 Ml/d or 24% of the total flow in the Future flow scenario on the 18th of October. The flow in the River Severn with the Full STT scheme in this lowest flow period is similar in magnitude to the Reference flow under A82 present day conditions.

3.3.4.2 Change to river level, velocity and wetted habitat

The change in depth-average velocity and water depth at the Severn at Bewdley assessment point from the 1D hydraulic model has been reviewed. There are 141 days in the A82 Futures scenario with modelled river flows of less than 900 Ml/d in the reference conditions and with direct release from Vyrnwy Reservoir; Vyrnwy bypass release; and abstraction reduction at Shelton intake at Shrewsbury. On these dates, the mean change in depth-average velocity is modelled as 0.028 m s^{-1} (a 3% increase) and the mean change in water depth is modelled as 0.068 m (a 7% increase).

The baseline and scheme hydraulic habitats for fish species within the reach are outlined within the STT Physical Environment Report. These data show that that there is generally very limited suitable baseline hydraulic habitat present throughout the reach, with only brown trout (juvenile), chub (spawning), roach (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat. With the A82 and M96 scenarios, hydraulic habitats remain fairly constant, although there are some losses averaging between 0.3% (A82) and 2.0% (M96) and minimal gains.

With future flow changes, the data for the Severn at Bewdley assessment point indicates relatively small increases in velocity and depth. It is likely that there will be an increase in the loss of hydraulic habitats in response to this increase in velocity and depth of flows. However, given the relatively low magnitude of change simulated, these losses are likely to be very limited in both magnitude and distribution.

3.3.4.3 Fish pass and barrier passability

One fish pass site in this reach has been modelled to review the changes in level associated with the STT solution. This is the ‘Shrewsbury right bank’ site. The level change can then be used to inform the impact on

[30] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Water Quality Evidence Report. Report for United Utilities on Behalf of the STT Group. February 2022.

the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage).

For the Shrewsbury right bank, under the A82 futures scenario, there is an increase in level between 23rd May and 22nd November. For this period, the level increases by between 0.01 m and 0.04 m, with a mean level of 47.54 m AOD, compared to the mean baseline level of 47.51 m AOD over this period.

As earlier identified, the River Severn from its confluence with the River Vyrnwy to Bewdley is of particular importance as a migratory route for anadromous and catadromous fish of the Severn Estuary and will also provide supporting habitat for lamprey ammocoetes. Again, results indicate that the change in flow is not discernible, and while there is currently insufficient information to derive critical levels for fish passage, any change is likely to be within the natural inter-annual variation that would be observed under reference conditions and is not likely to impact the functionality of any fish passes, or passability of any barriers. That said, careful analysis of any gravity fed eel passes may also need to be taken into consideration.

3.3.4.4 Changes in water quality

A future flow assessment of environmental water quality effects from STT solution operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways.

3.4 THE RIVER SEVERN FROM BEWDLEY TO THE CONFLUENCE WITH THE RIVER AVON

3.4.1 Baseline

A total of thirty species of fish have been recorded across 39 sites on the River Severn, including the tributaries associated with this reach. Species captured during surveys are predominantly coarse fish with a medium – high tolerance to environmental pressures such as; chub, roach, gudgeon, dace and minnow present at more than half of sites. Bullhead are also present at more than half of sites and represent the most prevalent low tolerance species within the dataset. Migratory species European eel (are also recorded at the majority of sites and Atlantic salmon are also recorded relatively frequently, present at 14 sites, whereas sea/ brown trout are recorded at five sites.

There are few areas of essential habitat on the lower and middle reaches of the River Severn for salmonids. Instead, these areas serve as a migration route for adult fish (upstream) and smolts (downstream). Areas of key spawning and nursery habitat are known to occur on the upper River Severn and several larger tributaries, including the River Tanat, River Vyrnwy and the River Rhiw.

This reach also provides migratory passage for Atlantic salmon to the River Clun Special Area of Conservation (SAC), with the reach again benefiting from the reconnectivity efforts of the UtS[31] project (e.g., positive eDNA detection of migrating shad between 2017-2019)[32]. The site is designated for freshwater pearl mussel (*Margaritifera margaritifera*). The freshwater pearl mussel life cycle involves an adult stage, living as a filter feeder, a juvenile stage living interstitially in sediment, and a larval (or glochidial) stage living attached to the gills of trout or salmon. All life stages are important, as is the viability of the host species of fish, such as the Atlantic salmon that migrate to the site via the River Severn. The Conservation Objectives for the River Clun SAC indicate that favourable condition status for this site is dependent upon maintaining the free movement of the host fish population for freshwater pearl mussel, both into, and through the SAC river catchment.

3.4.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities and the resulting impact on the upstream and/or downstream migration of Atlantic salmon, sea / brown trout, shad (considering the unlocking the Severn Scheme) and European eel.

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[31] Unlocking the Severn. A partnership between Canal & Rivers Trust; Severn Rivers Trust; Environment Agency and Natural England. Available at: https;//www.unlockingthesevern.co.uk Accessed on: 19/08/2022.

[32] Antognazza, C.M., Britton, J.R., De Santis, V., Kolia, K., Turunen, O.A., Davies, P., Allen, L., Hardouin, E.A., Crundwell, C., & Andreou, D. Environmental DNA reveals the temporal and spatial extent of spawning migrations of European shad in a highly fragmented river basin. *Aquat. Conserv.* 31(8), pp. 2029-2040 (2021).

- Increased velocities and the resulting impact on the local migration of coarse fish and brown trout to spawning areas.
- Loss/decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities.
- Risk of displacement of juvenile fish due to increased flows.
- Changes in water quality could have a direct impact on fish populations (e.g. mortality as a result of localised dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

Several weirs are present within this reach with fish passes also present on all weirs found on the main stem of the River Severn. The operation/functionality of these fish passes could also be impacted by increased flows and water levels.

3.4.3 STT operation – current conditions

This section sets out the findings of the effects of the STT operation during current or contemporary ('now') climate conditions.

3.4.3.1 Change to flow

In this reach, the STT solution would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir; an additional 155 Ml/d Vyrnwy bypass release at the confluence of the Weir Brook with the River Severn (upstream of Montford); and an abstraction reduction at Shelton intake at Shrewsbury, at selected times. Accounting for flow losses in the river systems, STT solution flow augmentation in this reach would be up to 200 Ml/d. The operating pattern remains as per that previously described, albeit at a higher rate of flow augmentation. The A82 scenario would include a continuous 105 day period of flow augmentation from late June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

On the River Severn upstream of the confluence with the River Avon [S11 and S12] the increase in flow due to the fully supported STT scheme (direct release from Vyrnwy Reservoir, Vyrnwy Bypass and Shrewsbury Redeployment) is approximately 14% of the reference flow during the summer period in both scenarios. The flow increase due to the scheme is around 200 Ml/d.

The fully supported flow increases are noticeable between 30th June and 12th October in the A82 scenario and between 15th June and 2nd November in the M96 scenario.

The long profile [V13] shows that on the 25$^{th\ of}$ August (low flow) the proportion of the total flow contributed by the scheme is approximately 17% at Bewdley and 11% at Saxons Lode. This is because of the increase in flow in the river due to tributaries, the major ones being the River Stour (at 183 km) and River Teme (at 206 km).

3.4.3.2 Change to river level, velocity and wetted habitat

The STT Physical Environment Report provides summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the River Severn from Bewdley to the confluence with the River Avon reach.

The data indicate that, on the whole there is very limited suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, with only Brown trout (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is very limited change in this baseline habitat for most species, with the already limited majority of suitable habitat remaining unchanged for the A82 and M96 flows. Under A82 flows, there are very limited gains, with Brown trout (juvenile) and European eel seeing gains of 1.2% and 6.3% and Brown trout (juvenile), Roach (juvenile) and European eel seeing losses of 4.7%, 3.7% and 1.2% respectively. For the M96 flows, gains and losses are slightly high for these species and life stages with the remaining specifies and life stages remaining relatively unchanged.

The data show that, except for a very few specific fish species life stages, there is a very limited range of suitable hydraulic habitat present in the reach for the key fish species considered, and only very limited and localised change in habitat as under the A82 and M96 flow releases.

Due to the complexity and volume of data, this is a brief overview of the potential changes only and Annex A of the Physical Environment Report should be referred to for the full assessment (including spatial plots of hydraulic habitat distribution and changes).

3.4.3.3 Change to weir pool wetted habitat or weir passability

Four fish pass sites in this reach have been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on the efficacy of these fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage).

Four fish pass sites in this reach have been modelled to review the changes in level associated with the STT solution (see **Table 3-1**). The level change was used to inform the impact on the efficacy of these fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage).

Under both the A82 and M96 model scenarios, there is an increase in level between the end of June and mid-October with increased levels also observed into late October at the Holt fish pass. The magnitude of the change when compared to baseline levels are provided in **Table 3-1**.

Table 3-1 Potential changes in level under different conditions at the four main fish passes identified within this reach

Fish Pass Name and Design	A82 Scenario, mean increase in level in metres (showing % increase from baseline)	M96 Scenario, mean increase in level in metres (showing % increase from baseline)
Lincomb (Vertical Slot)	0.02 m - 0.08 m (0.028% - 0.263%)	0.03 m (0.19% - 0.28%), noting towards the end of October levels decrease towards the end of the period.
Holt (Vertical Slot)	0.03 m - 0.04 m (0.21% – 0.27%)	0.03 m (0.20% – 0.28%), noting towards the end of October levels decrease towards the end of the period.
Bevere Bypass Channel	0.02 m - 0.03 m (0.04% - 0.52%)	0.03 m (0.30% – 0.38%), noting towards the end of October levels decrease towards the end of the period.
Diglis (Vertical Slot)	0.01 m – 0.03 m (0.02% - 0.26%)	0.03 m (0.20% – 0.27%), noting towards the end of October levels decrease towards the end of the period.

It is noted that this reach is of particular importance as a migratory route for anadromous and catadromous fish of the Severn Estuary and the River Clun SAC and will also provide supporting habitat for lamprey ammocoetes. Direct impacts on the ammocoetes could in turn impact on the number of retuning adults in the future which would undermine the conservation objective so the Severn Estuary European Marine sites while impacts on migration could impact on the conservation objectives of the River Clun SAC.

From the results it is evident that the change in flow is not discernible and will not impact on migration for the anadromous and catadromous species associated with the Severn Estuary. This is because hydrological cues for migration will not be impacted, and the increased flows will not impact on the passability of any barriers, however, it should be noted that eel passes are far more flow level critical. Flows and velocities will also remain sufficient to support the downstream drift of post-metamorphic transformers and juvenile shad. Flows and velocities will also not result in the washout of any incubating eggs or juveniles.

The potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on habitat availability for the fish community in this reach with the velocity and depths that would be observed under an unsupported and fully supported STT remaining similar to baseline conditions and within the preferred and optimum requirements for the baseline fish community associated with the reach. This is evident when comparing photographs that were taken on different days when the change in depth/level was similar to the potential changes that will be observed under the STT fully supported scenario.

Figure 3.2 shows the River Severn downstream of the confluence with the River Teme on two separate dates in July 2021. This includes 14th July when water levels (as measured at Saxon Lode was at 0.482 m) and 20th July 2021 (when flows were at 0.420 m). This represents a difference in level of ~0.06 m and there is no perceptible change in habitat availability for fish in at this location.

Figure 3.2 Photographs showing the River Severn downstream of the River Teme confluence on 14th July 2021 (left) and 20th July 2021 (right) when levels were at 0.482 m and 0.420 m respectively (as measured at Saxons Lode)

Although there is currently insufficient information to derive the critical levels for fish passage, the change in level is considered non-discernible and likely within the natural inter seasonal/annual variation that would be observed under reference conditions. As such, the operation of the STT is not expected to impact on the functionality of the fish pass.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions. Furthermore, the operation of the STT will not impact on barrier passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site or the River Clun SAC.

3.4.3.4 Changes to water quality

A current flow conditions assessment of environmental water quality effects from STT solution operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways. The potential for water quality benefits in this reach associated with the enhanced dilution, of wastewater discharges (e.g., Worcester WwTW) and other pollution pressures, from the flow augmentation are not included in this assessment.

3.4.4 STT operation - future climate

This section sets out the findings of the effects of the STT scheme operation during future climate conditions.

3.4.4.1 Change to flow

On the River Severn upstream of the confluence with the River Avon the increase in flow due to the fully supported STT scheme (Vyrnwy Reservoir, Vyrnwy bypass, abstraction reduction at Shelton and Mythe licence transfer) is approximately 20% of the reference flow during the summer period in the A82 Future scenario at Bewdley and around 14% prior to the confluence with the Avon. The flow increase due to the scheme is around 180 Ml/d, the same as with baseline conditions.

The fully supported flow increases are noticeable between 26th May and 18th November in the A82 Future scenario which is a longer duration than in the M96 baseline scenario.

3.4.4.2 Change to river level, velocity and wetted habitat

The change in depth-average velocity and water depth at the Severn at Bewdley assessment point from the 1D hydraulic model has been reviewed. There are 141 days in the A82 Futures scenario with modelled river flows of less than 900 Ml/d in the reference conditions and with direct release from Vyrnwy Reservoir; Vyrnwy bypass release; and abstraction reduction at Shelton intake at Shrewsbury. On these dates, the mean change in depth-average velocity is modelled as 0.028 m s^{-1} (a 3% increase) and the mean change in water depth is modelled as 0.068 m (a 7% increase).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.4.3.2. The data indicate that, on the whole there is very limited suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, with only brown trout (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat. With the A82 and M96 scenarios, hydraulic habitats remain fairly constant, although there are some losses ranging between 1.2-4.7% for brown trout (juvenile), roach (juvenile) and European eel, with slight gains of 1.2-6.3% for brown trout (juvenile) and European eel.

With future flow changes, the data for the Severn at Bewdley assessment point indicates relatively small increases in velocity and depth. It is likely that there will be an increase in the loss of hydraulic habitats in response to this increase in velocity and depth of flows. However, given the relatively low magnitude of change simulated, these losses are likely to be very limited in both magnitude and distribution and are likely only to affect those few species where suitable (but albeit greatly restricted) hydraulic habitat is present in the reach.

3.4.4.3 Fish pass and barrier passability

Table 3-2 sets out the changes in level associated with the STT solution for the four fish pass sites in this reach, for the A82 Futures scenario.

Table 3-2 Changes in water level at barriers and fish passes in the River Avon associated with STT operation for the A82 Futures Scenario

Fish Pass Name and Design	A82 Futures Scenario, mean increase in level in metres (showing % increase from baseline)
Lincomb (Vertical Slot)	0.01 m - 0.06 m (0.063% - 0.376%), noting increased variability from start of September
Holt (Vertical Slot)	0.01 m - 0.06 m (0.071% – 0.426%), noting reduced variability between mid-June and start of September
Bevere Bypass Channel	0.02 m - 0.06 m (0.186% - 0.557%), noting reduced variability between start of June and start of September
Diglis (Vertical Slot)	0.01 m – 0.04 m (0.093% - 0.371%), noting reduced variability between start of June and start of September

As aforementioned, this reach is of particular importance as a migratory route for anadromous and catadromous fish of the Severn Estuary and the River Clun SAC and will also provide supporting habitat for lamprey ammocoetes. Although there is currently insufficient information to derive the critical levels for fish passage, the change in level is considered non-discernible and likely within the natural inter seasonal/annual variation that would be observed under reference conditions. As such, the operation of the STT is not expected to impact on the functionality of the fish pass.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions. Furthermore, the operation of the STT will not impact on barrier passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site or the River Clun SAC.

3.4.4.4 Changes to water quality

There is no pathway of general water quality change in this reach from STT solution operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. At the one STT solution monitoring site in the reach, physico-chemical water quality data are not part of the analysis suite.

3.5 THE RIVER AVON FROM STONELEIGH TO THE CONFLUENCE WITH THE RIVER SEVERN

3.5.1 Baseline

The fish community in this reach is representative of the geomorphology. The River Avon is used extensively for navigation, which is supported by a large number of impounding structures (locks and weirs) throughout the river. Weirs have also been constructed for water abstraction. As a result of the numerous locks and weirs the Warwickshire Avon can be separated into two distinct sections from a fish community perspective. This includes the River Avon upstream of Alveston which is not navigable and the River Avon downstream Alveston to confluence with the River Severn which is navigable.

The available data indicate that the fish community within the River Avon (Warwickshire Avon) are predominantly coarse fish with species with a medium – high tolerance to environmental pressures such as chub, perch, roach, gudgeon, dace and minnow present throughout the reach. Salmonid species such as brown/sea trout[33] are also known to be present in the lower reaches.

Many of the locks and weirs are impassable under all conditions. There are ~26 weirs located along the reach. Of these 26 weirs, at least 17 are located on bifurcations and have associated bypass locks for navigation purposes on the opposite bifurcation arm. This includes the Strensham Lock Sluice in the lower reaches of the River Avon (sluice gate which is 4.3 m wide and 1.7 m high) and the associated Strensham Lock both of which are considered to be a significant barrier to migratory fish. As a result, the only migratory fish that is able to pass through the River Avon is the European eel, either via upstream migration (elvers climbing the sluice or passing through the lock gates) or as silver eel moving downstream over the sluice or through the navigation lock gates, or through the numerous eel passes present on many of the weirs throughout this reach.

Apart from the reaches downstream of the Strensham Lock Sluice (i.e., within the River Avon downstream of Alveston to confluence with the River Severn), the River Avon is not considered to provide supporting habitat for other migratory fish species of the Severn Estuary European Marine Site.

It is noted that the weir pools and the bifurcations within the River Avon, downstream of Alveston, provide some habitat diversity. Studies have shown that fish species diversity was higher downstream of weir structures compared to upstream with rheophilic specialists such as brown trout, grayling, bullhead and barbel more abundant downstream of weir structure[34]. Pool habitats downstream of weir structures also provide suitable holding areas for spawning species such as barbel, which occupy these deeper habitats downstream of suitable spawning habitat[35]. APEM (2021)[36] indicated that the large weir pools immediately downstream of the weirs Abbey Mill, Stanchard Pit and Strensham Lock are likely to provide suitable habitat for a number of fish species, particularly rheophilic specialists.

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[33] Note: While brown trout on the Avon are predominantly confined to the headwaters of various tributaries, NFPD datasets record all *Salmo trutta* individuals as brown trout/sea trout, and therefore for lower river data, the two cannot be differentiated.

[34] Mueller, M., Pander, J. and Geist, J. (2011). *The effects of weirs on structural stream habitat and biological communities*. Journal of Applied Ecology, vol. 48(6), pp. 1450-1461.

[35] Melcher, A.H. and Schmutz, S. (2010). The importance of structural features for spawning habitat of nase Chondrostoma nasus (L.) and barbel Barbus (L.) in a pre-Alpine river. River Systems, vol. 19(1), pp. 33-42.

[36] APEM (2021). Severn Thames Transfer: River Avon Barrier Update. APEM Scientific Report P00006085. United Utilities, September 2021, 29 pp.

3.5.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities and the resulting impact upon the upstream and/or downstream migration of European eel.
- Increase in river flow resulting impact on the local movements of coarse fish and brown trout migration to spawning areas.
- Changes in weir pool habitats which provide some habitat diversity within the navigable reaches.
- Loss/decrease in habitat quantity/quality due to changes in hydraulics (i.e., increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within the river margins due to increase wetted width and velocities.
- Risk of downstream displacement of juvenile fish due to increased flows.
- In the reaches downstream of Strensham Lock Sluice, the potential changes in optimum (and sub-optimum) ammocoete habitats should also be considered.
- Changes in water quality could have a direct impact on fish populations (e.g., mortality as a result of dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

3.5.3 STT operation – current conditions

This section sets out the findings of the effects of the STT operation during current or contemporary ('now') climate conditions.

3.5.3.1 Change to flows

In this reach, the STT solution would augment flows through a 115 Ml/d advanced treated effluent transfer from Minworth WwTW at selected times. The indicative system operation pattern of the STT solution involves discharges releases only in 24 of the 47 years, and on 15% of days overall. Flow changes in this reach would typically be in the months July to October, peaking at 46% of days in September. Outside this period, there would be less regular flow changes in June and November, with changes very rare in May, December and January and not anticipated in February, March, or April.

The A82 scenario would include a continuous 99 day period of flow augmentation from early July to early October. The M96 scenario would include a continuous 138 day period of flow augmentation from mid-June to early November.

Immediately downstream of the Minworth Transfer outfall, the flow in the River Avon is increased by 115 Ml/d due to the flow augmentation from Minworth in the fully supported STT scheme, which is approximately 60% in A82 and 64% in M96 compared to the reference conditions summer flow.

Downstream of Warwick the flow is increased by around 41% in A82 and 50% in M96 compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 113 Ml/d at Warwick due to losses. At Evesham the flow is increased by around 25% in A82 and 28% in M96 compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 107 Ml/d at Evesham due to losses. Upstream of the confluence with the River Severn the flow is increased by around 20% in A82 and 23% in M96 compared to the reference conditions due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 103 Ml/d at the downstream end of the River Avon due to losses of 10% along the River Avon.

The model outputs show that the STT Solution increases flow by 115 Ml/d initially downstream of the Minworth transfer outfall. At Warwick the increase is 114 Ml/d. At Evesham the increase in flow is 107 Ml/d and 103 Ml/d at the downstream end of the River Avon due to losses of 10% spread along the length of the Avon. On the 5$^{th\ of}$ December the flows in the River Avon are similar in magnitude to those on 25th August, around 10% higher prior to the confluence with the Severn.

3.5.3.2 Change to river level, velocity and wetted habitat

Results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach are provided within the STT Physical Environment Report.

The data indicate that, on the whole there is a fairly wide range of suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs. There is notable habitat availability for brown trout (juvenile), chub (spawning), roach (juvenile) and European eel. There are notable variations in the presence of suitable hydraulic habitat based on fish life cycle, with Atlantic salmon (0+ and spawning), brown trout (0+ and spawning), lamprey (ammocetes and spawning), chub (juvenile) and roach (spawning) habitat indicated as being relatively rare or not present within the reach.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is limited change in this baseline habitat for most species. Gains are relatively minor (generally <0.2%), though lamprey (ammocetes) and European eel see gains of 0.4% and 10.0% for A28 runs, increasing slightly for M96 runs. Notably, for M96, 0+ brown trout hydraulic habitat sees a 33.1% increase. For the A82 and M96 scenarios, there are a range of losses, averaging 1.9% for the A82 scenario and increasing to an average of 2.4% for the M96 scenario, with most of these losses occurring in the upper 30 km of the reach.

The data show that that there is a fairly wide range of suitable hydraulic habitat present in the reach for the key fish species considered. There are very minor gains in habitat for the A82 and M96 releases while there are some elevated losses of habitat for a range of species for both A82 and M96 scenarios.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. The STT Physical Environment Report should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.5.3.3 Fish pass and barrier passability

Seventeen fish pass sites or barriers in this reach have been identified by the Gate 1 review of barriers in the River Avon[37]. River levels in the hydraulic model have been assessed to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on barriers and the efficacy of fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage) or the passability of the identified barriers.

Under both the A82 and M96 scenarios, there is an increase in level between the end of June and mid-October with increased levels also observed into late October at the numerous fish pass in this reach. The magnitude of the change when compared to baseline levels is provided in **Table 3-3** .

The potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on habitat availability for the fish community in this reach with the velocity and depths that would be observed under an unsupported and fully supported STT remaining similar to baseline conditions and within the preferred and optimum requirements for the baseline fish community associated with the reach. The most significant increase in velocity would be observed upstream of Alveston where the maximum proportionate increase in velocity of 50% would equate to a maximum increase of 0.02m/s m s^{-1}. The result will be that velocities in this reach will be ~ 0.07 m s^{-1} m/s instead of 0.05m/s m s^{-1} and still within the preferred velocity ranges for the fish communities associated with this reach, although some marginal areas of wetted habitat (including macrophyte assemblages) which provide refuge for juvenile coarse fish will be lost.

The assessment is further supported by data collected during extended hydromorphological and water quality walkover surveys (including an evaluation of substrate type and macrophyte cover) surveys undertaken in 2021[38]. These surveys were completed under two different flows, 229 Ml/d measured on 16 and 20 July 2021 and 381 Ml/d measured on 26 October 2021, a difference of 152 Ml/d. The surveys were completed in the reach downstream of Warwick and it is noted that the flows during the surveys was higher than the proposed release of 115 Ml/d. That said, modification to flow from naturally variable regimens are normal, with habitat generalists tending to remain stable within the system[39]. Comparatively, a higher static base flow during periods where flows are normally lower, may result in a shift to fisheries community composition and population dynamics[40].

[37] APEM (2021). Severn Thames Transfer: River Avon Barrier Update. APEM Scientific Report P00006085. United Utilities, September 2021, 29 pp.

[38] Ricardo (2022). Severn Thames Transfer SRO – Hydromorphology and water quality surveys. Final version | Issue number 1 | Date 07/07/2022 | Our ref: ED14950100

[39] Haxton, T. and Findlay, C.S. Meta-analysis of the impacts of water management on aquatic communities. Can. J. Fish. Aquat. Sci. 65, 437-447, 2010.

[40] Murchie, K.J., Hair, K.P.E., Pullen, C.E., Redpath, T.D., Stephens, H.R., and Cooke, S.J. Fish response to modified flow regimes in regulated rivers: research methods, effects and opportunities. River. Res. Appl. 24, 197-217, 2008.

Table 3-3 Changes in water level at barriers and fish passes in the River Avon associated with STT operation

Barrier/ fish pass	Minworth Transfer operational period during A82 scenario			Minworth Transfer operational period during M96 scenario		
	Reference conditions water level	Water level with STT solution	Water level increase with STT solution	Reference conditions water level	Water level with STT solution	Water level increase with STT solution
Stoneleigh Abbey 2	52.97 m - 53.19 m; mean: 53.02 m AOD	53.15 m - 53.27 m; mean: 53.17 m AOD	0.086 m – 0.172 m	52.96 m - 53.35 m; mean: 52.97 m AOD	53.14 m - 53.41 m; mean: 53.15 m AOD	0.065 m – 0.178 m
Warwick Castle 1	44.96 m - 45.17 m; mean: 44.98 m AOD	45.01 m - 45.08 m; mean: 45.03 m AOD	0.007 m – 0.044 m	44.96 m - 45.09 m; mean: 44.97 m AOD.	45.00 m - 45.13 m; mean: 45.01 m AOD	0.009 m – 0.045 m
Barford 2	43.10 m - 43.16 m; mean: 43.12 m AOD	43.14 m - 43.19 m; mean: 43.15 m AOD	0.020 m – 0.030 m	43.10 m - 43.19 m; mean: 43.11 m AOD	43.13 m - 43.21 m; mean: 43.14 m AOD	0.007 m – 0.036 m
Alveston 2	36.41 m - 36.61 m; mean: 36.43 m AOD	36.45 m - 36.63 m; mean: 36.47 m AOD	0.014 m - 0.044 m	36.41 m - 36.75 m; mean: 36.42 m AOD	36.45 m - 36.78 m; mean: 36.46 m AOD	0.012 m – 0.045 m
Stratford Upon Avon	34.48 m - 34.59 m; mean: 34.50 m AOD	34.51 m - 34.60 m; mean: 34.52 m AOD	0.009 m - 0.026 m	34.48 m - 34.67 m; mean: 34.49 m AOD	34.50 m - 34.69 m; mean: 34.51 m AOD	0.008 m – 0.026 m
Marlcliffe Weir	25.52 m - 25.62 m; mean: 25.53 m AOD	25.54 m - 25.64 m; mean: 25.56 m AOD	0.050 m – 0.027 m	25.51 m - 25.73 m; mean: 25.52 m AOD	25.54 m - 25.75 m; mean: 25.55 m AOD	0.009 m – 0.028 m
Harvington	23.85 m - 24.29 m; mean: 23.93 m AOD	23.99 m - 24.30 m; mean: 24.06 m AOD	0.011 m – 0.144 m	23.83 m - 24.40 m; mean: 23.89 m AOD	23.98 m - 24.41 m; mean: 24.02 m AOD	0.006 m – 0.150 m
Anchor Meadow Weir	22.72 m - 22.89 m; mean: 22.75m AOD	22.76 m - 22.92 m; mean: 22.79 m AOD	0.027 m – 0.045 m	22.71 m - 23.16 m; mean: 22.74 m AOD.	22.76 m - 23.18 m; mean: 22.78 m AOD	0.017 m – 0.055 m
Evesham	21.94 m - 21.98 m; mean: 21.94m AOD	21.95 m - 21.99 m; mean: 21.95 m AOD	0.008 m – 0.011 m	21.93 m - 22.05 m; mean: 21.94 m AOD	21.95 m - 22.06 m; mean: 21.95 m AOD	0.007 m – 0.014 m
Fladbury	18.41 m - 18.48 m; mean: 18.42m AOD	18.43 m - 18.50 m; mean: 18.44 m AOD	0.018 m – 0.022 m	18.40 m - 18.63 m; mean: 18.42 m AOD	18.43 m - 18.64 m; mean: 18.44 m AOD	0.009 m – 0.026 m
Wyre Piddle	14.97 m - 15.23 m; mean: 15.03m AOD	15.06 m - 15.33 m; mean: 15.11 m AOD	0.072 m – 0.107 m	14.96 m - 16.05 m; mean: 15.01 m AOD	15.05 m - 16.10 m; mean: 15.10 m AOD	0.048 m – 0.103 m
Pershore	13.00 m - 13.29 m; mean: 13.06m AOD	13.10 m - 13.42 m; mean: 13.17 m AOD	0.082 m – 0.132 m	12.99 m - 14.39 m; mean: 13.05 m AOD	13.09 m - 14.43 m; mean: 13.15 m AOD	0.043 m – 0.120 m
Narfford	12.31 m - 12.39 m; mean: 12.33m AOD	12.34 m - 12.43 m; mean: 12.37 m AOD	0.024 m – 0.040 m	12.30 m - 12.71 m; mean: 12.32 m AOD	12.34 m - 12.72 m; mean: 12.36 m AOD	0.011 m – 0.037 m
Strensham	10.83 m - 10.92 m; mean: 10.86m AOD	10.87 m - 10.97 m; mean: 10.90 m AOD	0.026 m – 0.049 m	10.82 m - 11.24 m; mean: 10.84 m AOD	10.87 m - 11.25 m; mean: 10.89 m AOD	0.090 m – 0.049 m

For coarse fish such as chub, the hydraulic surveys show a slight increase in habitat availability with juvenile chub habitat increasing from 6% suitable habitat to 14% under the higher flows with a similar increase observed in spawning habitat. The data shows a small decline in juvenile chub habitat availability in this reach, however a significant increase in spawning habitat was observed under the higher flow conditions. A similar trend is observed for brown trout habitat with a slight reduction in juvenile habitat, although spawning and 0+ habitat shows an increase during the higher flow conditions. For the juvenile European eel life stages, the habitat data indicate that there is abundance of suitable habitat. Under lower flows during July, 97% of the data indicates that suitable habitat is available, and this reduces slightly to 95% under the higher flows in October.

The minor change in habitat is also evident from photographs taken during the July and October 2021 surveys of the River Avon downstream of Warwick (near Barford). Figure 3.3 shows photographs of the River Avon at the A429 (Barford Bypass), which shows the change in habitat availability during the surveys. In particular the change in the availability of vegetated bars in the margins of the River Avon as a result of the increase in wetted width in October 2021 (noting this represents an increase of 152 Ml/d). The difference in flow when comparing the two surveys in July 2021 was approximately 70 Ml/d.

In order to gain an understanding of the potential impact of the releases across the model period, the 1D modelled data was processed to extract the flow velocity and flow depth data for each of the model nodes for the A82 and M96 reference and full model runs. Data was extracted from each nodes to create a study reach of around ~124 km reach commencing in the River Avon at the River Sowe confluence and extending to the tidal limit of the River Severn to understand the potential impacts on fish habitat for Minworth releases.

In this reach the main risk associated with increased flow is the potential impacts on migration of European eel. Historical studies have also recorded juveniles as far upstream as Chadbury on the R. Avon (~37 km from the confluence with the River Severn), and elvers as far as Nafford (approximately 15 km from the confluence).

The upstream migration of European eel usually occurs between April and May but can continue into summer months. However, within the River Severn the upstream migration may be as early as January and late as June[41]. Upstream migration into freshwater is heavily influenced by hydrological and hydromorphological conditions., The swimming ability of glass eel is poor (prolonged, i.e., over 1-20 mins, and sustained swimming speed, i.e., between 20-200 min, of 0.35 m s^{-1} and 0.04 m s^{-1}, respectively[42,43]) in comparison to salmonids (e.g., minimum burst speed of Atlantic salmon at 4.13 m s^{-1} [44])and therefore upstream migrations are timed to coincide when tidal conditions allow individuals to penetrate further up an estuary with very little effort.

Significant flow increase could, therefore, delay or impact upon upstream migration. As discussed above, although the proportionate increase in velocity would range between 18.6– 26.4%, average velocity would remain <0.04 m /s^{-1} in the lower reaches and <0.15 m/ s^{-1} in the reaches downstream of Evesham. The increased flows will not result in impact on migration of eel or the movement of other fish within the impounded areas between the various locks/weirs.

This is also evident from photographs that were taken during walkovers in 2021 at different water levels. **Figure 3.4** shows the River Avon at Evesham on 20th July 2021 when water levels were 0.420 m (as measured at Evesham) and 5th August 2021 when levels were at 0.513 m (as measured at Evesham). This represents the maximum change in level that would be experienced as a result of a 115 Ml/d discharge and no changes in habitat were discernible.

When considering the changes in level at the various fish passes, it is also evident that the differences in water level associated with STT operation are be small; an increase in level not a decrease; and within normal patterns of fish pass level. Typically, the increase in water level modelled at lowest water levels associated with STT operation, during the period of operation would be ~0.03 m - 0.05 m. Notable exceptions are modelled at Stoneleigh Abbey 2 at the beginning of the reach, where an increase of 0.18 m is modelled at lowest water levels; and in the lower reach at Wyre Piddle and Pershore where an increase of 0.09 m - 0.10 m is modelled at lowest water levels. Nevertheless, water levels modelled have the potential to impact gravity fed eel passes within this section, and may require further assessment.

For the barriers in the lowest part of the River Avon, there is more complex influence on water levels associated with STT operation. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as the next weir on the Severn at Saxons Lode. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. The hydraulic modelling does show that the increase in River Severn low flows from STT operation flow augmentation releases for supported STT raise water levels in the River Severn around the River Avon confluence, including to below hydraulic features in the lower River Avon. The hydraulic modelling also shows that during periods of unsupported STT, where there would be up to 500 Ml/d abstraction from the River Severn at Deerhurst 3.8 km downstream of the River Avon confluence, abstraction would lower water levels in the River Severn around the River Avon confluence, including to below hydraulic features in the lower River Avon.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions[45]. Furthermore, the operation of the STT will not impact on barrier

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[41] Chris Bainger, Environment Agency, *Pers.Comm*.

[42] Benson, T., de Bie, J., Gaskell, J., Vezz, P., Kerr, J.R., Lumbroso, D., Owen, M.R., & Kemp, P.S. Agent-based modelling of juvenile eel migration via selective tidal stream transport. *Ecol. Modell.* 443(1), 109448. (2021).

[43] Vezza, P., Libardoni, F., Manes, C., Tsuzaki, T., Bertoldi, W., & Kemp, P.S. Rethinking swimming performance tests for bottom-dwelling fish: the case of European glass eel (*Anguilla anguilla*). *Sci. Rep.* 10, 16416. (2020).

[44] Colavecchia, M., Katopodis, C., Goosney, R., Scruton, D.A., & McKinley, R.S. Measurement of burst swimming performance in wild Atlantic salmon (*Salmo salar* L.) using digital telemetry. *Regul, Rivers*. 14, pp. 41-51. (1998).

[45] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site.

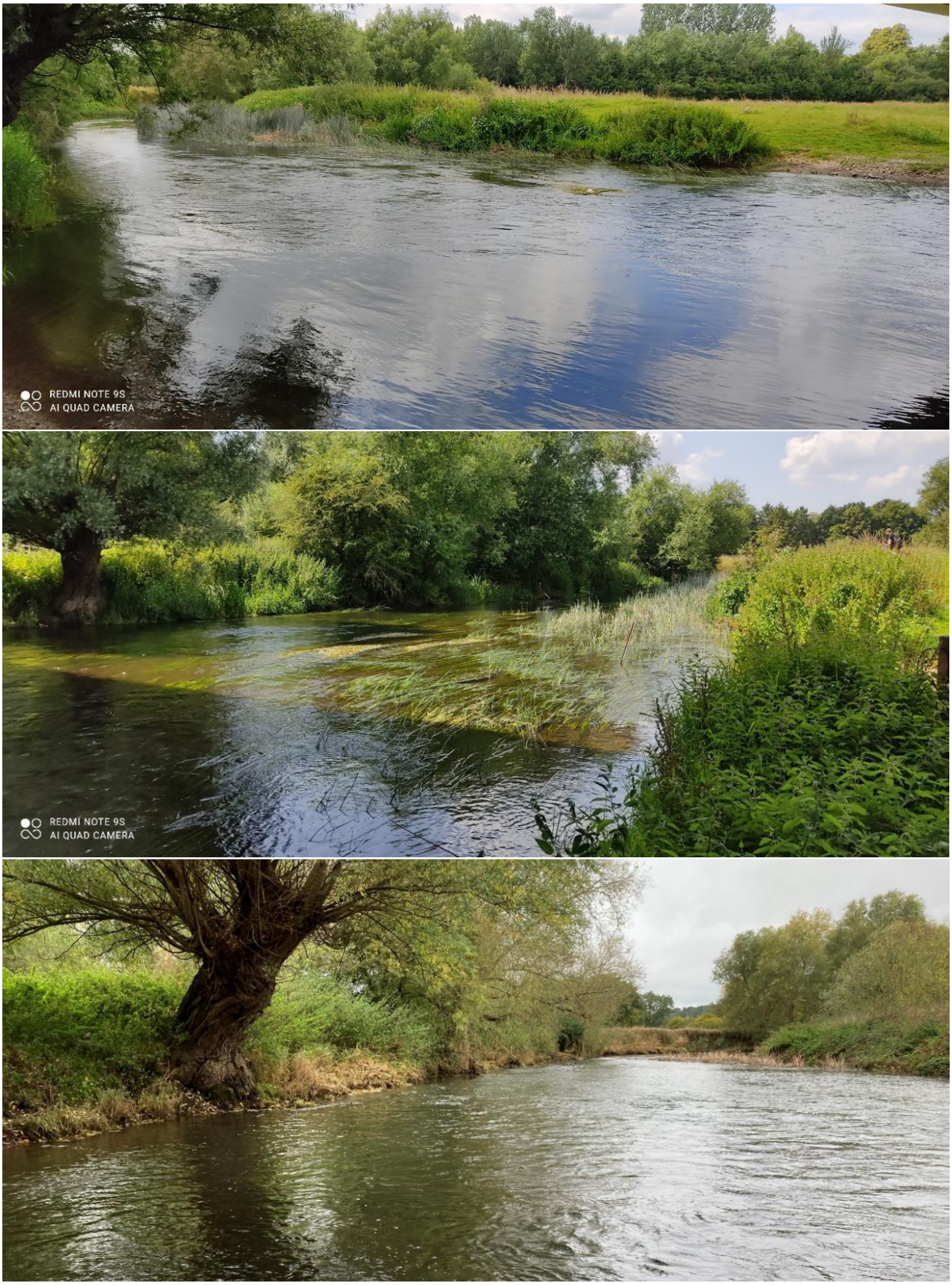

Figure 3.3 Photographs showing the River Avon downstream Warwick on 20th July 2021 (top), 14th July 2021 (middle) and 26th October 2021 (bottom) when levels were at 1.12 m, 1.14 m and 1.53 m respectively (as measured at Warwick).

Figure 3.4 Photographs showing the River Avon at Evesham on 20th July 20210 (top) and 5th August 2021 (bottom) when levels were at 0.420m and 0.513m respectively (as measured at Evesham)

3.5.3.4 Changes in water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme and are summarised below:

- During the scheme operation, the river water temperature would be higher. This increase is similar for both scenarios: up to 0.8 °C upstream of Warwick, and up to 0.5 °C at Evesham and at the confluence with River Severn. Modelled data indicates that in summer temperatures will remain below 17.5 °C[46].
- The discharge will reduce dissolved oxygen immediately downstream of the outfall up to the confluence with the River Leme by ~1.5 mg/l. Dissolved oxygen (as %saturation) will remain above 75% within the first 20 km and remain above 90% for the remainder of the reach, up to the confluence with the River Severn.
- Ammoniacal nitrogen is expected to increase by 0.1-0.15 mg/l downstream of Warwick with the increase of 0.05 mg/l at Evesham and 0.02 mg/l at the confluence with the River Severn. Soluble reactive phosphate concentrations are reduced by the scheme throughout the River Avon by up to 0.1 mg/l.

[46] Note that for salmonid waters the WFD temperature standard to meet high status is 20ºC (calculated as a 98 percentile).

The results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving WFD high ecological status.

Water quality modelling has also considered all chemicals with EQS that are included in permitting guidance from the EA. The risk associated with these chemicals has been reviewed by the process engineers from the Minworth SRO engineering consultant team which identified four (4) WFD chemicals with remaining risk (post treatment)[47]. The magnitude and frequency of the risk has been modelled using the conservative tracer dilution rates in the Severn catchment 1D water quality model. This has been illustrated for 25th August in the A82 modelling – a date selected in the Gate 2 Physical Environment Assessment Report for the reference condition where the low summer flow increases from 60 Ml/d to 205 Ml/d after the confluence with the River Sowe, then to 273 Ml/d at Warwick after the confluence with the River Leam. At Evesham the flow in the river has almost doubled, increasing by 200 Ml/d.

The results can be summarised as follows:

- **Nonylphenols:** Minworth Transfer would increase the concentration of Nonylphenols in the River Avon particularly in the 11 km reach between the transfer outfall and the confluence with the River Leam. This would not lead to increase in concentration of Nonylphenols in the River Avon sufficient to exceed the long-term EQS value.
- **Cypermethrin**: The model outputs illustrate that the Minworth Transfer would increase the concentration of cypermethrin in the River Avon, causing a deterioration of the current water quality. Mean values calculated from the reported concentrations of cypermethrin indicate an EQS failure in relation to WFD for much of the River Avon, and the Minworth Transfer could impede the acquisition of ‘Good’ WFD surface water status in not supporting an EQS pass in relation to ‘chemical status’.
- **Perfluorooctane sulfonic acid (PFOS) and its derivatives:** The model outputs illustrate the Minworth Transfer would increase the concentration of PFOS in the River Avon, a deterioration of the current quality. Mean values calculated from the reported concentrations of PFOS indicate an EQS failure throughout the River Avon in the study reach. The Minworth Transfer could impede the achievement of ‘Good’ WFD surface water status in not supporting an EQS pass in relation to ‘chemical status’.
- **Permethrin**: The model outputs illustrate the Minworth Transfer would increase the concentration of permethrin in the River Avon, a deterioration of the current quality. This risk is limited to the reaches above and below Warwick. At downstream assessment points in the River Avon, the reported data indicate an EQS pass (with no reported detection of permethrin) and a WFD chemical status EQS pass in relation to the Minworth Transfer, albeit with medium confidence.

The potential effect of STT operation contributing to increased concentrations of determinands known to inhibit the olfaction of migratory fish, as applicable to functionally linked habitat associated with the Severn Estuary SAC, has also been considered. The list of chemicals that have been considered in the context of the STT scheme are provided in Section 3.4.1.3 of the water quality assessment report.

A total of 32 determinands that are known to be olfactory inhibitors have been considered in Gate 2. Of these determinands several have been detected in both the Minworth WwTW final effluent and the River Avon. The only determinands that have been detected in the Minworth WwTW final effluent and not detected in the River Avon are chromium(III) (dissolved), chromium(VI) (dissolved), isoproturon, cypermethrin, permethrin and triclosan. An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken. The proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium(III), cobalt, cypermethrin and permethrin.

The effects of increased exposure to pyrethroid insecticides are well understood. This includes behavioural changes (e.g., schooling behaviour, mucus production), reproductive disorders and malformations,

[47] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Water Quality Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022

histopathological alterations, haemato-biochemical alterations, neurotoxicity, endocrine disruption, oxidative stress and immunotoxicity[48]

As noted in the sections above, the River Avon is not considered to provide supporting habitat for other migratory fish species of the Severn Estuary European Marine Site, with the exception of European eel. As glass eel/elver enter the upper estuary or tidal river tidal stream transport becomes less effective, and at this stage a behavioural shift occurs, and individuals begin to actively migrate upstream following a combination of cues including olfactory stimulus[49].

Like salmonids, European eel has a well-developed sense of smell and at this stage are likely to rely upon olfaction as a behavioural and directional cue. The chemical cues utilised by migrating glass eels at this stage are similar to those involved with salmonid homing migration[50]. Studies have shown that Dissolved Free Amino Acids (DFAA), including bile acids and skin mucus, are likely to play an important role as well as chemicals such as geosmin[51] typically found within freshwater habitats. Dilution of olfactory cues and manipulation of natural watercourses with the addition of freshwater from unconnected and non-natural sources has been shown to impact the migratory behaviour of fish.

Significant changes in the concentrations of olfactory inhibitors could therefore impact on the migration of European eel up the River Avon. Selected endocrine disruptors which may act as olfactory inhibitors in the context of SROs have only recently been identified[52] and the monitoring and specific analysis has only recently commenced and has a smaller evidence base at present that should be kept under review in Gate 3.

The assessment has only considered the detection of potential olfactory inhibitors within the River Avon and the Minworth WwTW final effluent (prior to tertiary treatment) and no detailed modelling of the potential change in concentrations has been possible (apart from those chemicals listed above (nonylphenols, cypermethrin, perfluorooctane and permethrin). At this stage the significance/magnitude of the impact on olfaction cannot be assessed and it is only possible to note an increased risk to olfactory inhibition.

It is also noted that the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

3.5.4 STT operation - future climate

This section sets out the findings of the effects of the STT operation during future climate conditions. In comparison with the A82 scenario, the A82 Future scenario would include a 40% longer period of flow augmentation releases - with extension both 35 days earlier, to include late May and all of June; and 36 days later, to include all of October and the first half of November. The increase in regularity of the need for STT support options in late spring, early summer and later into autumn is a significant change.

3.5.4.1 Change to flow

Immediately downstream of the Minworth Transfer outfall, the flow in the River Avon is increased by 115 Ml/d due to the flow augmentation from Minworth in the fully supported STT scheme [A6], which is approximately 64% in A82 Future compared to the reference conditions summer flow. The scheme runs from the 25th of May to the 21st of November in the A82 Future climate.

Downstream of Warwick the flow is increased by around 50% in A82 Future climate (similar to M96 present day) compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 113 Ml/d at Warwick due to losses.

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48 Farag MR, Alagawany M, Bilal RM, Gewida AGA, Dhama K, Abdel-Latif HMR, Amer MS, Rivero-Perez N, Zaragoza-Bastida A, Binnaser YS, El-Saber Batiha G and Mohammed AEN (2021) An Overview on the Potential Hazards of Pyrethroid Insecticides in Fish, with Special Emphasis on Cypermethrin Toxicity. Animals 2021, 11, 1880. https:// doi.org/10.3390/ani11071880.

49 Cresci A. (2020). A comprehensive hypothesis on the migration of European glass eels (Anguilla anguilla). Biological reviews. 95 (5). 1273-1286.

50 Crnjar, R., Slcalera, G., Bigiani, A., Tomassini Barbarossa, I., Magherini, P.C. and Pietra, P., (1992). Olfactory sensitivity to amino acids in the juvenile stages of the European eel *Anguilla* . *Journal of Fish Biology*, *40*(4), pp.567-576.

51 Tosi, L. and Sola, C., (1993). Role of geosmin, a typical inland water odour, in guiding glass eel *Anguilla* (L.) migration. *Ethology*, *95*(3), pp.177-185.

52 Ricardo Energy & Environment (2021). Technical Note. Severn Thames Transfer SRO – Impact of determinands on olfaction and fish populations in the Severn Estuary. United Utilities on behalf of the Severn Thames Transfer Programme. December 2021

At Evesham the flow is increased by around 28% in A82 Future climate compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 107 Ml/d at Evesham due to losses.

Upstream of the confluence with the River Severn the flow is increased by around 24% in the A82 Future climate compared to the reference conditions due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 103 Ml/d (the same as in baseline climate) at the downstream end of the River Avon due to losses of 10% along the River Avon.

The long section plot shows the flow on the 18th of October for the reference and the fully supported STT scheme from the A82 Future scenario. Initially downstream of the Minworth transfer outfall the flow is increased by 115 Ml/d. At Warwick, the increase is 114 Ml/d. At Evesham, the increase in flow is 107 Ml/d and 103 Ml/d at the downstream end of the River Avon due to losses of 10% spread along the length of the Avon. In the future scenario, the flows are approximately 10% lower than the low flow in present conditions.

3.5.4.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth on the River Avon Immediately downstream of the Minworth Transfer outfall assessment point from the 1D hydraulic model has been reviewed. There are 176 days in the A82 Futures scenario with effluent transfer from Minworth WwTW. On these dates, mean modelled flow in the reference conditions is 185 Ml/d; the mean change in depth-average velocity is modelled as 0.024 m s^{-1} (a 5% increase in very low reference condition velocities); and the mean change in water depth is modelled as 0.11 m (a 27% increase).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.5.3.2. These data show that that there is a fairly wide range of suitable habitat present in the reach, particularly for brown trout (juvenile), chub (spawning), roach (juvenile) and European eel. There is indicated to be minimal change in baseline habitat for the A82 and M96 flows, though there are some gains and losses averaging 1.9% for A82 and increasing to 2.4% for the M96 scenario, with most losses concentrated in the upper 30 km of the reach.

With future flow changes, the data for the River Avon Immediately downstream of the Minworth Transfer outfall assessment point indicates a small increase in flow velocity but a relatively large increase in flow depth. It is likely that the increase in depth could lead to increasing loss of hydraulic flow habitats, particularly in the upper reaches of the river, as seen for the increasing hydraulic habitat losses for the A82 and M96 scenarios.

3.5.4.3 Fish pass and barrier passability

The assessment of effects on future baseline and future STT on the seventeen fish pass sites or barriers in this reach have been identified by the Gate 1 review of barriers in the River Avon[53]. River levels in the hydraulic model have been assessed to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on barriers and the efficacy of fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage) or the passability of the identified barriers. These sites are as follows: Stoneleigh Abbey 2, Warwick Castle 1, Barford 2, Alveston 2, Stratford upon Avon, Marlcliffe Weir, Harvington, Anchor Meadow Weir, Evesham, Fladbury, Wyre Piddle, Pershore, Narfford, Strensham, Tewkesbury Marina, Stanchard Pit – Eel Pass, and Abbey Mill – Eel Pass.

As aforesaid, when considering the changes in level at the various fish passes, it is evident that the differences in water level associated with STT operation are small; an increase in level not a decrease; and within normal patterns of fish pass level. Typically, the increase in water level modelled at lowest water levels associated with STT operation, during the period of operation would be ~0.02 m - 0.05 m. Notable exceptions are modelled at Stoneleigh Abbey 2 at the beginning of the reach, where an increase of 0.179 m is modelled at lowest water levels; Harvington where an increase of 0.152 m is recorded; and in the lower reach at Wyre Piddle and Pershore where an increase of 0.095 m - 0.112 m is modelled at lowest water levels. Nevertheless, water levels modelled have the potential to impact gravity fed eel passes within this section, and may require further assessment.

[53] APEM (2021). Severn Thames Transfer: River Avon Barrier Update. APEM Scientific Report P00006085. United Utilities, September 2021, 29 pp.

Table 3-4 Changes in water level at barriers and fish passes in the River Avon associated with STT solution

Barrier/ fish pass	Minworth Transfer operational period during A82 scenario		
	Reference conditions water level	Water level with STT solution	Water level increase with STT solution
Stoneleigh Abbey 2	52.96 m - 53.18 m mean 52.98 m AOD	53.11 m - 53.27 m mean 53.15 m AOD	0.090 m – 0.179 m
Warwick Castle 1	44.96 m - 45.05 m mean 44.97 m AOD	45.00 m - 45.07 m mean 45.01 m AOD	0.011 m – 0.045 m
Barford 2	43.10 m - 43.15 m mean 43.11 m AOD	43.14 m - 43.18 m mean 43.14 m AOD	0.010 m – 0.036 m
Alveston 2	36.40 m - 36.63 m mean 36.42 m AOD	36.45 m - 36.66 m mean 36.47 m AOD	0.016 m – 0.045 m
Stratford Upon Avon	34.48 m - 34.61 m mean 34.49 m AOD	34.51 m - 34.63 m mean 34.52 m AOD	0.090 m – 0.026 m
Marlcliffe Weir	25.51 m - 25.66 m mean 25.52 m AOD	25.54 m - 25.68 m mean 25.55 m AOD	0.050 m – 0.028 m
Harvington	23.82 m - 24.34 m mean 23.90 m AOD	24.04 m - 24.36 m mean 23.97 m AOD	0.010 m – 0.152 m
Anchor Meadow Weir	22.71 m – 23.01 m mean 22.74 m AOD	22.76 m – 23.04 m mean 22.78 m AOD	0.040 m – 0.045 m
Evesham	21.93 m – 22.01 m mean 21.94 m AOD	21.94 m – 22.02 m mean 21.95 m AOD	0.006 m – 0.011 m
Fladbury	18.40 m - 18.56 m mean 18.42 m AOD	18.43 m - 18.57 m mean 18.44 m AOD	0.011 m – 0.023 m
Wyre Piddle	14.95 m - 15.60 m mean 15.01 m AOD	15.05 m - 15.67 m mean 15.10 m AOD	0.006 m – 0.095 m
Pershore	12.98 m - 13.80 m mean 13.05 m AOD	13.08 m - 13.89 m mean 13.15 m AOD	0.008 m – 0.112 m
Narfford	12.30 m - 12.57 m mean 12.32 m AOD	12.34 m - 12.59 m mean 12.36 m AOD	0.004 m – 0.037 m
Strensham	10.81 m - 11.13 m mean 10.84 m AOD	10.86 m – 11.14 m mean 10.89 m AOD	0.006 m – 0.050 m

For the barriers in the lowest part of the River Avon, there is more complex influence on water levels associated with STT operation. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as the next weir on the Severn at Saxons Lode. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. The hydraulic modelling does show that the increase in River Severn low flows from STT operation flow augmentation releases for supported STT raise water levels in the River Severn around the River Avon confluence, including to below hydraulic features in the lower River Avon. The hydraulic modelling also shows that during periods of unsupported STT, where there would be up to 500 Ml/d abstraction from the River Severn at Deerhurst 3.8 km downstream of the River Avon confluence, abstraction would lower water levels in the River Severn around the River Avon confluence, including to below hydraulic features in the lower River Avon.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the future conditions[54]. Furthermore, the operation of the STT will not impact on barrier

[54] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site.

3.5.4.4 Changes to water quality

A future flow assessment of environmental water quality effects from the STT solution operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways.

3.6 THE RIVER SEVERN FROM THE CONFLUENCE WITH THE RIVER AVON TO DEERHURST

3.6.1 Baseline

The fish community in this reach is representative of the geomorphology. The reach is representative of a typical low land river. The river is characterised mostly by deep glides and runs with the bed likely dominated by coarse material based on the upstream reaches. The majority of banks appear to range from moderate to steep with occasional shallow banks. Bank erosion is present but is not common.

The available data indicate that the fish community within the River Severn are predominantly coarse fish with a medium – high tolerance to environmental pressures such as chub, roach, gudgeon, dace and minnow present at all survey events that informed the baseline data.

There are few areas of habitat within the lower and middle reaches of the River Severn that are essential for salmonid fish to support their migration. These reaches serve as a ‘migration stage’ to support the route for adult fish (upstream) and smolts (downstream). This reach also provides migratory passage for Atlantic salmon to the River Clun SAC. The site is designated for freshwater pearl mussel. The freshwater pearl mussel life cycle involves an adult stage, living as a filter feeder, a juvenile stage living interstitially in sediment, and a larval (or glochidia) stage living attached to the gills of trout or salmon. All life stages are important, as is the viability of the host species of fish, such as the Atlantic salmon that migrate to the site via the River Severn. The Supplementary Advice on the Conservation Objectives for the SAC indicates that favourable conditions status for this site is dependent upon the free movement of host fish populations of the pearl mussel into and through the SAC.

3.6.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities and the resulting impact on the upstream and/or downstream migration of Atlantic salmon, sea / brown trout, shad, lamprey and European eel.
- Increased velocities and the resulting impact on the local migration of coarse fish to spawning areas.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities.
- Risk of displacement of juvenile fish due to increased flows.
- Changes in water quality could have a direct impact on fish populations (e.g., mortality as a result of dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

3.6.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary (‘now’) climate conditions. In this reach, the STT solution would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir; an additional 155 Ml/d Vyrnwy bypass release at the confluence of the Weir Brook with the River Severn (upstream of Montford); and an abstraction reduction at Shelton intake at Shrewsbury; and a 115 Ml/d advanced treated effluent transfer from Minworth WwTW at selected times. Accounting for flow losses in the river systems, the STT solution flow augmentation in this reach would be up to 318 Ml/d. The operating pattern remains as per that described in the upstream reach albeit at a higher rate of flow augmentation. The A82 scenario would include a continuous 105 day period of flow augmentation from late

June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

3.6.3.1 Change to flow

The increase in flow upstream of Deerhurst [S15 and S16], due to the fully supported STT scheme is around 15% in the A82 scenario and 17% in the M96 scenario. The period of the scheme is from 30th June to 12th October in the A82 scenario and from 15th June to 2nd November in the M96 scenario [S15 and S16]. The flow increase during the summer period is around 309 Ml/d.

3.6.3.2 Change to river level, velocity and wetted habitat

Summary results within the STT Physical Environment Report show the percentage coverage of the baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach. It should be noted that this is a relatively short reach of around 3 km in length.

The data indicate that, apart from European eel, there is no suitable hydraulic habitat for the fish species and life stages considered in this assessment, though this is variable for the A82 and M96 scenarios (75.3% available hydraulic habitat for the A82 reducing to 46.7% for the M96 scenarios).

Only European eel shows changes in habitat with the A82 and M96 flows, with a gain of 10.8% for the A82 flows, increasing marginally for the M96 flows, and a loss of 5.9% hydraulic habitat for A82 flows, increasing to 9.6% for M96 flows.

The data show that, except for European eel, there is no suitable hydraulic habitat in the reach. For European eel, gains in hydraulic habitat are relatively similar for A82 and M96 flows, with increasing habitat losses for M96 over the A82 flows.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.6.3.3 Change to weir pool wetted habitat or weir passability

One fish pass site in this reach has been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. This is Saxons Lode the 'Upper Lode left bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage). Fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. Below Saxons Weir there is a complex influence on water levels associated with the STT solution. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as Saxons Lode which is the next weir upstream.

For this site, the level varies across the whole annual period [AR] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, 1st April and 20th June the level reduces by a range of 0.004 m and 0.006 m [AS] compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 24th June), the level no longer varies from the baseline until the full STT support commences. When the full support commences (late June) there is a variation in level ranging between a reduction of 0.009 m and an increase of 0.030 m compared to the reference condition over an 18 day period before the level returns to being slightly below the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 30th August) there is a decrease in water level until the STT is turned off in late November. Over this unsupported period, the level changes from an increase of 0.002 m to a reduction of 0.128 m, with the level ranging between 6.70 m AOD and 10.54 m AOD (with a mean level of 7.63 m AOD) compared to the reference levels which range between 6.71 m AOD and 10.60 m AOD (with a mean level of 7.69 m AOD).

The level change in the unsupported STT A82 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer. Under the full STT M96 scenario, between, roughly, 1st April and 9th May the level reduces by a range of 0.004 m and 0.006 m compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 10th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (roughly 15th June) there is a variation in level ranging between a 0.009 m reduction to a 0.033 m increase compared to the reference conditions over an eight day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 27th October) there is a decrease in water level until the STT is turned off in early January. Over this unsupported period, the level reduces by between 0.005 m and 0.113 m, with the level ranging between 6.78 m AOD and 11.41 m AOD (with a mean level of 9.12 m AOD) compared to the reference levels which range between 6.79 m AOD and 11.45 m AOD (with a mean level of 9.16 m AOD). The level change in the unsupported STT M96 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

It is noted that this reach is of particular importance as a migratory route for anadromous and catadromous fish of the Severn Estuary and the River Clun SAC and will also provide supporting habitat for lamprey ammocoetes. Direct impacts on the ammocoetes could in turn impact on the number of retuning adults in the future which would undermine the conservation objective so the Severn Estuary European Marine sites while impacts on migration could impact on the conservation objectives of the River Clun SAC.

The results of the Physical Environment Assessment Report show that the change in flow is not discernible and will not impact on migration for the anadromous and catadromous species associated with the Severn Estuary or the River Clun SAC. This is because hydrological cues for migration will not be impacted, and the increased flows will not impact on the passability of any barriers. Flows and velocities will also remain sufficient to support the downstream drift of post-metamorphic transformers and juvenile shad. Flows and velocities will also not result in the washout of any incubating eggs or juveniles.

The potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on habitat availability for the fish community in this reach with the velocity and depths that would be observed under an unsupported and fully supported STT remaining similar to baseline conditions and within the preferred and optimum requirements for the baseline fish community associated with the reach.

This conclusion is further supported by targeted hydraulic surveys that were completed in July and October 2021 at a site on the River Severn near Deerhurst with two surveys completed under flows of 1,926 Ml/d measured on 15th and 21st July 2021 and 3,367 Ml/d measured on 28 October 2021, a difference of 1,441 Ml/d. The results of the analyses are provided in Annex A of the STT Physical Environment Assessment Report. The hydraulic data indicates that there is relatively limited suitable flow habitat for juvenile coarse fish and lamprey in this reach. Any changes in juvenile habitat availability under decreasing flows are likely in response to decreasing hydraulic radius and decreasing marginal inundation. Due to the lowland nature of the River Severn at this point, the impacts on habitat availability will be limited.

The modelling shows that at the `Upper Lode left bank` fish pass, the level varies across the whole annual period due to a range of complex factors affecting the level at this site.

Under the full STT A82 scenario, between, roughly, 1st April and 20th June the level reduces by a range of 0.05% and 0.09% compared to the reference level. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 24th June), the level no longer varies from the baseline until the full STT support commences. When the full support commences (late June) there is a variation in level ranging between -0.11% and 0.44%. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 30th September) there is a decrease in water level until the STT is turned off in late November. Over the unsupported period in the A82 scenario, the level reduces by 0.18% and 1.75% with the change in level ranging between 0.01 and 0.06 m in a A82 scenario. The level change for a fully supported STT is within a similar range in the A82 scenario.

Under the full STT M96 scenario, between, roughly, 1st April and 10th May the level reduces by a range of 0.03% and 0.08% compared to the reference level, likely driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 10th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (roughly 16th June) there is a variation in level ranging between a -0.14% and 0.49% change. Over this unsupported period in the M96 scenario, the level reduces by 0.08% and 1.48% with the change in level ranging from 0.01 – 0.04 m. The level change in the unsupported STT M96 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

Although there is currently insufficient information to derive the critical levels for fish passage, the change in level is considered non-discernible and likely within the natural inter annual variation that would be observed under reference conditions. As such, the operation of the STT is not expected to impact on the functionality of the fish pass.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions. Furthermore, the operation of the STT will not impact on barrier passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site.

3.6.3.4 Changes in water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme and are summarised below:

- In the River Severn upstream of Deerhurst, water temperature is not predicted to change due to the STT operation.
- Dissolved oxygen concentrations are predicted to change by around 0.1 mg/l (~1% saturation) due to the scheme.
- Ammoniacal nitrogen concentrations are predicted to change by a maximum of 0.006 mg/l due to the scheme, compared to a baseline range of 0.04-0.18 mg/l. .
- Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.05 mg/l during the operation of the STT

The carry-forward of risk from the River Avon into the River Severn as a result of the discharge of treated effluent into the River Avon can be summarised as follows:

- Nonylphenols: Mean values calculated from the reported concentrations indicate EQS pass at Deerhurst, with nonylphenols not detected at the Severn Deerhurst monitoring site. A concentration increase could be associated with the Minworth Transfer during the 15% of time that transfer would be in operation, but that would not lead to EQS failure.
- Cypermethrin: Mean values calculated from the reported concentrations indicate EQS fail at the Severn Deerhurst monitoring site, with four of the 15 reported values greater than the limit of detection which mirrors the EQS. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets as the main pressures to the reach lie with the upstream River Severn, not the River Avon.
- Perfluorooctane sulfonic acid and its derivatives: Mean values calculated from the reported concentrations indicate routine EQS fail at the Severn Deerhurst monitoring site. A concentration increase could be associated with the Minworth Transfer and it is considered with medium confidence to potentially impede achievement of targets in the lower River Severn where the River Avon is a significant pressure to PFOS concentration in the downstream River Severn.
- Permethrin: Mean values calculated from the reported concentrations indicate EQS fail at the Severn Deerhurst monitoring site, with one of the 15 reported values greater than the limit of detection which mirrors the EQS. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets, noting the very low detection rate at the assessment point.

The potential effect of STT operation on inhibiting olfaction of migratory fish, as applicable to functionally linked habitat associated with the Severn Estuary SAC, has also been considered. The list of chemicals that have been considered in the context of the STT Solution are provided in Section 3.4.1.3 of the water quality assessment report.

A total of 32 determinands that are known to be olfactory inhibitors have been considered in Gate 2. Of these determinands several have been detected in both the Minworth WwTW final effluent and the River Avon. The only determinands that have bene detected in the Minworth WwTW final effluent and not detected in the River Avon is Chromium(III) (dissolved), Chromium(VI) (dissolved), Isoproturon, Cypermethrin, Permethrin and Triclosan. An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken. The proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium(III), cobalt, cypermethrin and permethrin.

As noted in the sections above, this reach serves as a migration route for adult diadromous fish (upstream), post spawning adult fish that return downstream, postmetamorphic lamprey, adult European eel and smolts (downstream). This reach also provides migratory passage for Atlantic salmon to the River Clun SAC. During the upstream and downstream migration of the anadromous and catadromous species, exposure to any olfactory inhibitors will be acute (short-term) as the fish move from and/or to the Severn Estuary. Significant impacts during these migratory periods in the freshwater River Severn are not expected, given the relatively short distance from the tidal limit to past the River Avon.

It is, however, important to consider any chronic (long-term) exposure to increased concentrations of the determinands and the possible bioaccumulation of olfactory inhibitors in juvenile species that reside in this reach for many months/years. In this particular reach, this would be of concern for the lamprey ammocoete as there are extensive nursery habitats present within this reach.

Significant changes in the concentrations of olfactory inhibitors could therefore impact on the migration up the River Severn. Selected endocrine disruptors which may act as olfactory inhibitors in the context of SROs have only recently been identified[55] and the monitoring and specific analysis has only recently commenced and has a smaller evidence base at present that should be kept under review in Gate 3. As such, detailed modelling of the potential increase/changes in concentrations has not been undertaken.

It is noted that the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

The assessment has only considered the detection of potential olfactory inhibitors within the River Severn and the Minworth WwTW final effluent (prior to tertiary treatment) and no detailed modelling of the potential change in concentrations has been possible. At this stage the significance/magnitude of the impact on olfaction cannot be assessed and it is only possible to note an increased risk to olfactory inhibition.

Overall, as there are no changes in the physic-chemical characteristics of the water, impacts on the fish community are not expected. Decreased phosphate concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not impact on any macrophytes that may provide some cover/habitat for fish in this reach.

There remains some uncertainty with regards to the impact of olfactory inhibitors (including the bioaccumulation of selected determinands). Overall, the risk not considered to be discernible (low confidence) given that the assessment has not considered the minimum 1:37 dilution rate of the River Severn downstream of Deerhurst or the change in total load as a result of any abstraction at Deerhurst.

3.6.4 STT operation - future climate

This section sets out the findings of the effects of the STT operation during future climate conditions. In comparison with the A82 scenario, the A82 Future scenario would include a 40% longer period of flow augmentation releases - with extension both 35 days earlier, to include late May and all of June; and 36 days later, to include all of October and the first half of November. The increase in regularity of the need for STT support options in late spring, early summer and later into autumn is a significant change.

3.6.4.1 Changes in flow

The increase in flow upstream of Deerhurst, due to the fully supported STT scheme is around 17% in the A82 Future climate scenario. The period of the scheme is 28th May to the 20th of November in the A82 Future scenario, which is longer than in the M96 baseline scenario. The flow increase during the summer period is around 283 Ml/d.

The low flow in the future scenario is around 30% less than the low flow in present conditions.

3.6.4.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth at the Severn at Deerhurst upstream offtake assessment point from the 1D hydraulic model has been reviewed. There are 166 days in the A82 Futures scenario with modelled river flows of less than the HoF2 value of 3,333 Ml/d in the reference conditions and with direct release from Vyrnwy Reservoir; Vyrnwy bypass release; abstraction reduction at Shelton intake at

[55] Ricardo Energy & Environment (2021). Technical Note. Severn Thames Transfer SRO – Impact of determinands on olfaction and fish populations in the Severn Estuary. United Utilities on behalf of the Severn Thames Transfer Programme. December 2021

Shrewsbury; and effluent transfer from Minworth WwTW. On these dates, the mean change in depth-average velocity is modelled as 0.016 m s^{-1} (a 18% increase in very low reference condition velocities) and the mean change in water depth is modelled as 0 m.

The baseline and scheme hydraulic habitats for fish species within the reach are outlined within the STT Physical Environment Report. The data indicate that, apart from European eel, there is no other suitable hydraulic habitat present in the reach for the fish species and life cycles considered in the assessment. For the A82 and M96 flows, hydraulic habitat for European eel show gains of ~11% and losses of between 5.9% (A82) to 9.6% (M96).

With future flow changes, the data for the Severn at Deerhurst assessment point indicates small increases in velocity and depth. Given the nature of the channel and the limited hydraulic habitat potential identified here, these changes are not likely to lead to any significant change in available hydraulic habitat in the reach.

3.6.4.3 Fish pass and barrier passability

One fish pass site in this reach has been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. This is Saxons Lode the 'Upper Lode left bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage). Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. Below Saxons Weir there is a complex influence on water levels associated with the STT solution. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as Saxons Lode which is the next weir upstream.

For this site, water level varies across the whole annual period [AL] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 14th May, the level varies from a reduction of 0.03 m to 0.07 m compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 17th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (early June) there is a variation in level ranging between a reduction of 0.202 m and an increase of 0.406 m compared to the reference conditions until mid-November. From mid-November, the STT scheme is stopped, and the abstraction is unsupported until mid-December. Over this unsupported period, the level varies from +0.258 m to -1.757 m compared to the reference level, which corresponds to the level ranging between 6.79 m AOD and 9.74 m AOD (with a mean level of 8.26 m AOD) compared to the reference levels which range between 6.74 m AOD and 9.80 m AOD (with a mean level of 8.26 m AOD).

3.6.4.4 Changes in water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future.

Under Scenario A82F, the predicted water quality in the River Severn between the River Avon confluence and Deerhurst is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters.

It is noted that for the Severn Estuary, sea level rise 2100 RCP8.5 UKCIP[56] is between 0.51 m (5th percentile) and 1.13 m (5th percentile). At Deerhurst River Severn water level varies in a normal range between 6.5 m and 10.5 m AoD[57]. Projected 2100 sea level rise will not be enough to induce brackish conditions at Deerhurst. However, Severn Bore events may be greater intensity, and high suspended sediment concentrations associated with the bore could influence operational controls at the Deerhurst intake for the STT solution.

[56] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/summaries/headline-findings
[57] https://check-for-flooding.service.gov.uk/station/2078

3.7 THE RIVER SEVERN FROM DEERHURST TO THE TIDAL LIMIT AT GLOUCESTER

3.7.1 Baseline

The fish community in this reach is representative of the geomorphology. The reach is representative of a typical large lowland river. The river is characterised mostly by deep glides and runs with the bed likely dominated by coarse material based on the upstream reaches. The majority of banks appear to range from moderate, to steep, with occasional shallow banks. Bank erosion is present but is not common.

The available data indicate that the fish community within the River Severn are predominantly coarse fish with a medium – high tolerance to environmental pressures such as chub, roach, gudgeon, dace and minnow present at all survey events that informed the baseline data.

There are few areas of essential habitat on the lower and middle reaches of the River Severn for salmonids. Instead, these reaches serve as a migration route for adult fish (upstream) and smolts (downstream). This reach also provides migratory passage for Atlantic salmon to the River Clun SAC. The site is designated for freshwater pearl mussel. The freshwater pearl mussel life cycle involves an adult stage, living as a filter feeder, a juvenile stage living interstitially in sediment, and a larval (or glochidial) stage living attached to the gills of trout or salmon. All life stages are important, as is the viability of the host species of fish, such as the Atlantic salmon that migrate to the site via the River Severn. The Supplementary Advice on the Conservation Objectives for the SAC indicates that favourable conditions status for this site is dependent on the maintain the free movement of host fish populations into and through the SAC. This reach includes the Maisemore weir.

3.7.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases and/or unsupported could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Decreased velocities and the resulting impact on the upstream and/or downstream migration of Atlantic salmon, sea / brown trout, shad, lamprey and European eel.
- Decreased velocities and the resulting impact on the local migration of coarse fish to spawning areas.
- Loss of juvenile and adult habitats within margins due to changes wetted width and velocities.
- Changes in water quality could have a direct impact on fish populations (e.g., mortality as a result of dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

3.7.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary ('now') climate conditions. For the early phase STT, abstraction would be unsupported up to 500 Ml/d at selected times, subject to hands-off flow conditions identified by EA. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple periods of the 47 water resources years in Figure 1.4, describes a typical pattern of early phase STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution abstraction only in 24 of the 47 years, and on 11% of days overall.

Flow changes in this reach would typically be in the months October to December, peaking at 35% of days in November. Outside this period, there would be less regular flow changes in August, September and January, with changes very rare in June, July and February and not anticipated in March, April or May. As well as this pattern, there would be a continuous abstraction of 20 Ml/d at Deerhurst to maintain a constant minimum flow and maintain water quality in the interconnector pipeline at all other times. As well as these patterns of abstraction, there would be flow augmentation releases from advanced treated wastewater transfer from Netheridge WwTW to the River Severn upstream Haw Bridge. These Netheridge Transfers would enable a pipeline maintenance flow to continue to be abstracted at Deerhurst, some 2 km upstream, when River Severn flows are less than hands-off flow conditions. The controls on this part-time transfer are not well understood at Gate 2 but could be in the order of an additional 17% of time, including parts of most years, typically in the months May to November, at times when river flows are low.

The A82 scenario would include a period of unsupported abstraction for 60 days from late September to late November, including 25,400 Ml abstracted; at peak rate of 500 Ml/d for 53, non-continuous days. The M96 scenario would include a period of unsupported abstraction for 70 days from late September to early January, including 32,900 Ml abstracted: at peak rate of 500 Ml/d for 64, non-continuous days.

For the full STT, abstraction would be unsupported up to 500 Ml/d at selected times, subject to hands-off flow conditions identified by EA, and supplemented by flow augmentation releases at additional times. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple and blue periods of the 47 water resources years in Figure 1.4, describes a typical pattern of full STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution abstraction only in 24 of the 47 years, and on 23% of days overall.

The A82 scenario would see abstraction for transfer on 153 continuous days between the end of June and late November. That period includes unsupported abstraction for 60 days from late September to late November, including 25,400 Ml abstracted: at peak rate of 500 Ml/d for 53, non-continuous days. Supported abstraction would take place between end of June and late September, with supported transfers maintained until river flows significantly increase in early October in the scenario year.

The M96 scenario would see abstraction for transfer on 208 days from mid-June to early January. That period includes unsupported abstraction for 70 days from late September to early January, including 32,900 Ml abstracted; at peak rate of 500 Ml/d for 64, non-continuous days. Supported abstraction would take place between mid-June and late September, with supported transfers maintained until river flows significantly increase in early November in the scenario year.

3.7.3.1 Change to flow

Early phase (Unsupported)

Water is abstracted at Deerhurst in the unsupported STT scheme when the flow in the River Severn is above the HOF and water is required for the River Thames. In scenario A82, this occurs from the 30th of September to the 30th of November, and in Scenario M96 from the 31st of October to the 9th of January. This leads to a reduction in the flow in the River Severn downstream of Deerhurst by 5 to 15% depending on the flow in the river.

The modelled long profile of flow on the 5th of December shows that the flow is above HOF 2 and there is unsupported abstraction at Deerhurst of 500 Ml/d. This is approximately 10% of the total flow in the river. These proportions are maintained to the normal tidal limit at Gloucester.

Full STT

In the fully supported STT scheme, there is a flow reduction of approximately 1.5% during the summer. This is due to the Mythe licence transfer of 15 Ml/d. In the autumn and early winter when flow is abstracted without support, the reduction in flow is similar to the unsupported STT scheme.

The modelling results show that the flow is below HOF 1 and there is fully supported abstraction at Deerhurst of 353 Ml/d. After the Netheridge outfall, the flow in the river with the fully supported STT scheme is slightly lower than in reference condition due to the Mythe licence transfer.

3.7.3.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach, are provided in the Physical Environment Assessment Report. It should be noted that this is a relatively short reach of around 13 km in length.

The data indicate that, apart from brown trout (juvenile) and European eel, there is no suitable hydraulic habitat for any of the other fish species and life stages considered in this assessment. Habitat for European eel is extensive at 96.6% for the A82 scenario and 92.5% for the M96 scenario. Hydraulic habitat for juvenile brown trout is very limited at 4.4% for the A82 scenario and 6.5% for the M96 scenario.

For European eel, hydraulic habitat remains relatively similar, though there are gains of 8.7% and 17.4% under A82 and M96 flows respectively, with small losses of 2.1% and 3.5% under A82 and M96 flows respectively. The small amount of juvenile Brown trout hydraulic habitat remains relatively invariant, with some marginal gains of 0.2% under A82 and M96 flows and only a slight loss of 0.1% under M96 flows.

The data show that, except for European eel and limited juvenile Brown trout, there is no suitable hydraulic habitat in the reach. For eel, gains in hydraulic habitat for M96 are nearly double those for A82. Gains and losses for Juvenile Brown trout hydraulic habitat are marginal for releases under A82 and M96 scenarios.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Reference should be made to the Physical Environment Assessment Report for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.7.3.3 Change to weir pool wetted habitat or weir passability

There are no weir pool habitats in this reach. There are no weirs identified for review of fish passability in this reach.

From the results it is evident that the change in flow is not discernible and will not impact on migration for the anadromous and catadromous species associated with the Severn Estuary or the River Clun SAC. This is because hydrological cues for migration will not be impacted, and the increased flows will not impact on the passability of any barriers. Flows and velocities will also remain sufficient to support the downstream drift of post-metamorphic transformers and juvenile shad. Flows and velocities will also not result in the washout of any incubating eggs or juveniles.

The potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on habitat availability for the fish community in this reach with the velocity and depths that would be observed under an unsupported and fully supported STT remaining similar to baseline conditions and within the preferred and optimum requirements for the baseline fish community associated with the reach.

This is evident when comparing photographs that were taken on different days when the change in depth/level was similar to the potential changes that will be observed under the STT fully supported scenario. Figure 3.5 shows the River Severn downstream of the Deerhurst on two separate dates in 2021. This includes 21st July 2021 when water levels (as measured at Deerhurst) was at 0.584 m and 13th August 2021 (when flows were at 0.692 m). This represents a difference in level of ~0.10 m and there is no perceptible change in habitat availability for fish in at this location.

This conclusion is further supported by targeted hydraulic surveys that were completed in July and October 2021 at a site on the River Severn near Deerhurst with two surveys completed under flows of 1,926 Ml/d measured on 15th and 21st July 2021 and 3,367 Ml/d measured on 28th October 2021, a difference of 1,441 Ml/d. The results of the analyses are provided in Annex A of the Physical Environment Assessment Report[58]. The hydraulic data indicates that there is relatively limited suitable flow habitat for juvenile coarse fish and lamprey in this reach. Any changes in juvenile habitat availability under decreasing flows are likely in response to decreasing hydraulic radius and decreasing marginal inundation. Due to the lowland nature of the River Severn at this point, the impacts on habitat availability will be limited.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions. Furthermore, the operation of the STT will not impact on barrier passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site.

[58] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

Figure 3.5 Photographs showing the River Severn downstream of the Deerhurst on 21st July 2021 (top) and 13th August 2021 (bottom) when levels were at 0.584 m and 0.692 m respectively (as measured at Deerhurst)

3.7.3.4 Change in water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme. These are summarised below:

- In the River Severn downstream of Deerhurst (upstream of the Netheridge discharge) and at the tidal limit, the STT operation is predicted to reduce water temperature by 0.2 °C (A82) and 0.3 °C (M96);
- Dissolved oxygen concentrations are predicted to be reduced by about 0.1 mg/l at both sites (a reduction of less than 1% saturation);
- Ammoniacal nitrogen concentrations are predicted to be increased by about 0.02 mg/l at both sites; and
- Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.02 mg/l during the operation of the scheme at both sites.

With regards the Netheridge Transfer and the planned advanced treatment processes included in the Severn Trent Sources SRO Gate 2 scheme. For those chemicals with an EQS, there would be no change in concentration that changes from EQS pass to EQS fail; no reduction in quality where there is an EQS pass; no further reduction in quality where there is currently an EQS fail; and for chemicals with current EQS fail, no impediments to achieving EQS pass. The review has been undertaken using River Severn at Deerhurst chemical concentrations and post-removal treatment efficacy from Severn Trent Sources Solution engineers and is without recourse to the minimum 1:37 dilution rate of the River Severn at the Netheridge Transfer outfall.

The potential effect of the STT Solution on inhibiting olfaction of migratory fish, as applicable to functionally linked habitat associated with the Severn Estuary SAC, has also been considered. The list of chemicals that have been considered in the context of the STT Solution are provided in Section 3.7.2.3 of the water quality assessment report.

A total of 32 determinands that are known to be olfactory inhibitors have been considered in Gate 2. Of these determinands several have been detected in both the Minworth WwTW final effluent and the River Avon. The only determinands that have bene detected in the Minworth WwTW final effluent and not detected in the River Avon is chromium(III) (dissolved), chromium(VI) (dissolved), isoproturon, cypermethrin, permethrin and triclosan. An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken. The proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium(III), cobalt, cypermethrin and permethrin.

As noted in the sections above, this reach serves as a migration route for adult fish (upstream) and post-metamorphic lamprey and salmonid smolts (downstream). This reach also provides migratory passage for Atlantic salmon to the River Clun SAC. During the upstream and downstream migration of the anadromous and catadromous species, exposure to any olfactory inhibitors will be acute (short-term) as the fish move from and/or to the Severn Estuary. Significant impacts during these migratory periods in the freshwater River Severn are not expected, given the relatively short distance from the tidal limit to past the River Avon.

It is, however, important to consider any chronic (long-term) exposure to increased concentrations of the determinands and the possible bioaccumulation of olfactory inhibitors in juvenile species that reside in this reach for many months/years. In this particular reach, this would be of concern for the lamprey ammocoetes as there are extensive nursery habitats present within this reach.

Significant changes in the concentrations of olfactory inhibitors could therefore impact on the migration up the River Severn. Selected endocrine disruptors which may act as olfactory inhibitors in the context of STT Solutions have only recently been identified[59] and the monitoring and specific analysis has only recently commenced and has a smaller evidence base at present that should be kept under review in Gate 3. As such, detailed modelling of the potential increase/changes in concentrations has not been undertaken.

It is noted that the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

The assessment has only considered the detection of potential olfactory inhibitors within the River Severn and the Minworth WwTW final effluent (prior to tertiary treatment) and no detailed modelling of the potential change in concentrations has been possible. At this stage the significance/magnitude of the impact on olfaction cannot be assessed and it is only possible to note an increased risk to olfactory inhibition.

Overall, as there are no changes in the physico-chemical characteristics of the water, no impacts on the fish community are expected. Decreased phosphate concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not impact on any macrophytes that may provide some cover/habitat for fish in this reach.

There remains some uncertainty with regards to the impact of olfactory inhibitors (including the bioaccumulation of selected determinands).

3.7.4 STT operation - future climate

This section sets out the findings of the effects of the STT operation during future climate conditions. In comparison with the A82 scenario, the A82 Future scenario would include a 40% longer period of flow augmentation releases - with extension both 35 days earlier, to include late May and all of June; and 36 days later, to include all of October and the first half of November. The increase in regularity of the need for STT support options in late spring, early summer and later into autumn is a significant change. In the A82 Future reference conditions River Severn flows are below hands-off flow conditions for later in the autumn which

[59] Ricardo Energy & Environment (2021). Technical Note. Severn Thames Transfer SRO – Impact of determinands on olfaction and fish populations in the Severn Estuary. United Utilities on behalf of the Severn Thames Transfer Programme. December 2021

drives the need to augmentation releases later in the autumn. Noting that in the A82 Future scenario abstraction from the River Severn for transfer to the River Thames would be required for 10 days later into autumn, the total period of unsupported abstraction would reduce from 60 days by 38 days to only 22 days. The 22 days of unsupported abstraction would be in the mid-November to early December period.

3.7.4.1 Change to flow

In the fully supported STT scheme, there is a flow reduction of approximately 1.5% during the summer. This is due to the Mythe licence transfer of 15 Ml/d. In the autumn and early winter when flow is abstracted without support, the reduction in flow is similar to the unsupported STT scheme.

The long profile of flow on the 18th of October shows that the flow is below HOF 1 and there is fully supported abstraction at Deerhurst of 330 Ml/d. After the Netheridge outfall, the flow in the river with the fully supported STT scheme is slightly lower than in reference condition due to the Mythe licence transfer.

3.7.4.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth at the Severn at Deerhurst downstream offtake assessment point from the 1D hydraulic model has been reviewed. There are 22 days in the A82 Futures scenario with unsupported abstraction above HoF conditions. On these dates, mean modelled flow in the reference conditions is 7,940 Ml/d; the mean change in depth-average velocity is modelled as 0.009 m s^{-1} (a 0.0002% reduction); and the mean change in water depth is modelled as 0.07 m (a 1.6% reduction).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.7.3.2. The data indicate that, apart from Brown Trout (juvenile) (only very limited at 4.4%) and European eel (extensive habitat: ~96%), there is no other suitable hydraulic habitat present in the reach for the fish species and life cycles considered in the assessment. For the A82 and M96 flows, hydraulic habitat for European eel shows small gains (~9-17%) and marginal losses (~2-4%), while juvenile Brown Trout shows only limited marginal losses (0.1%) and gains (0.2%).

With future flow changes, the data for the Severn at Deerhurst assessment point indicates small increases in velocity and depth. Given the nature of the channel and the limited hydraulic habitat potential identified here, these changes are not likely to lead to any significant change in available hydraulic habitat in the reach.

3.7.4.3 Change to weir pool wetted habitat or weir passability

There are no weir pool habitats within this reach and no weirs have been identified for review of fish passability in this reach.

3.7.4.4 Changes to water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future.

Under Scenario A82F, the predicted water quality in the River Severn downstream of Deerhurst is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters.

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Severn has been modelled. This shows limited change in dilution capacity along the River Severn compared with current climate conditions. It is considered that the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term water quality than the magnitude of the concentration increase.

As the assessment of olfaction risk for the current climate conditions is based on discharge rather than dilution, there is no change in the olfaction risk based on future river flows.

3.8 THE SEVERN ESTUARY DOWNSTREAM OF THE TIDAL LIMIT AT GLOUCESTER

3.8.1 Baseline

Downstream of the normal tidal limit (NTL) of the main River Severn at Maisemore Weir and the Eastern Channel at Llanthony Weir, the channel sees normal tidal estuarine hydrodynamics, with a pattern of twice-daily high-low-high tides. The main freshwater flow contribution from the River Severn to the Severn Estuary is over Maisemore Weir, with the Eastern Channel providing further freshwater input at the Lower Parting, some 2.3 km seawards.

There are numerous resident estuarine fish which rely on the Severn Estuary for some aspect of their life cycle. As a result of this dependence, these species are often the most vulnerable to anthropogenic and environmental factors that could affect the habitat and ecology of the estuary. Marine species occurring in large numbers in estuaries are all marine species who spend the first few years of life in the sheltered waters of the estuary where suitable food is abundant and there are fewer predators. The Severn Estuary ranks as one of the top ten estuaries in the UK for the number of marine estuarine-opportunistic species it supports Marine estuarine-opportunists can be present in the estuary in very large numbers at particular times of year. These include sprat (*Sprattus sprattus*), herring (*Clupea harengus*), whiting (*Merlangius merlangus*), bib (*Trisopterus luscus*), poor cod (*Trisopterus minutus*), bass (*Dicentrarchus labrax*) and common goby (*Pomatoschistus microps*). There are a few species that spend their entire life cycle within the estuary. These include common goby, black goby (*Gobius niger*), sand smelt (*Atherina presbyter*) and 3- spined stickleback.

This reach also provides migratory passage for all of the migratory fish associated with the Severn Estuary as well as migratory passage for Atlantic salmon to the River Clun SAC. The site is designated for freshwater pearl mussel. The freshwater pearl mussel life cycle involves an adult stage, living as a filter feeder, a juvenile stage living interstitially in sediment, and a larval (or glochidial) stage living attached to the gills of trout or salmon. All life stages are important, as is the viability of the host species of fish, such as the Atlantic salmon that migrate to the site via the River Severn. The Supplementary Advice on the Conservation Objectives for the SAC indicates that favourable conditions status for this site is dependent on the free movement of host fish populations into and through the SAC.

3.8.2 Relevant impact pathways

In environmental terms, unsupported STT abstraction would specifically be protected by licence hands-off flow conditions as set out in Section 1. Following these conditions, the greatest impact on pass forward flows would either be at the lowest remaining flow conditions, or highest abstraction rate. The greatest STT operational impact under lowest remaining flow conditions would be abstraction of 172 Ml/d at river flows at Deerhurst of 2,740 Ml/d, reducing flow at Deerhurst to 2,568 Ml/d. The greatest STT operational impact under highest abstraction rates would be abstraction of 500 Ml/d at river flows at Deerhurst of 3,661 Ml/d, reducing flow at Deerhurst to 3,161 Ml/d. These changes from STT operation are set against a dynamic flow regime in the River Severn.

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality could have a direct impact on fish populations (e.g., mortality as a result of localised dissolved oxygen sags); and
- Impacts on supporting habitat process due to change in freshwater inflows and changes in water quality.

3.8.3 STT operation – current conditions

This section sets out the findings of the effects of the STT operation during current or contemporary ('now') climate conditions.

3.8.3.1 Change to flow, velocity and depth

The A82 scenario would include a period of unsupported abstraction for 60 days from late September to late November, including 25,400 Ml abstracted; at peak rate of 500 Ml/d for 53, non-continuous days. The M96 scenario would include a period of unsupported abstraction for 70 days from late September to early January, including 32,900 Ml abstracted; at peak rate of 500 Ml/d for 64, non-continuous days.

There are other minor reductions in pass-forward flow to the Severn Estuary associated with the STT solution. These are the periods when abstraction at Deerhurst to provide the 20 Ml/d interconnector pipeline maintenance flow is unsupported. These are outside the times that the STT solution would be in use for water resources transfer purposes, at times when river flows at Deerhurst are above hands-off flow conditions.

In addition, the Mythe temporary licence transfer is considered likely to reduce flows into the Severn Estuary. Severn Trent Water's Mythe licence is accounted for within the hands-off flow conditions and as such the full licence abstraction rate can be abstracted without constraint from the hands-off flow conditions. In the modelling outputs it is noted that the abstraction rate attributed to the Mythe intake in the reference conditions for A82 and M96 affords for 15 Ml/d additional abstraction at Deerhurst in the full STT model scenarios, without the need to reduce the abstraction rate at Mythe. As such there is 15 Ml/d additional abstraction modelled at Deerhurst at times of supported STT abstraction. At these times the pass-forward flow modelled to the Severn Estuary reduces by 15 Ml/d.

Overall, the effect on pass-forward flows to the Severn Estuary from the STT solution is indiscernible on the flow duration curve for the full 47 year representative period (see the Physical Environment Assessment Report[60], Figure 3.9). In terms of the overall pattern of changes to pass-forward flow of freshwater from the River Severn to the Severn Estuary, the effects of the STT solution are indiscernible from the reference conditions pattern without the STT solution. For example, at Q95, full STT flows passed forward to the Severn Estuary would be 0.05% lower than reference conditions.

As such, the changes in pass forward flow are not expected to impact on the resident fish community of the Severn Estuary. This is because the changes in the freshwater inflows will not be of a magnitude to impact on the habitats that support the fish community, and the main habitat process will remain unchanged (considering the tidal regime of the Severn Estuary). It is also noted that flows will remain well above the above the residual flow requirements. Particularly in summer, flow will generally be higher when compared to naturalised flow conditions and the changes will be within the natural annual variations that would be observed under baseline conditions. In July the naturalised flows are around 20% lower than the A82 reference condition.

Overall, impacts on the fish community as a result of hydrological and hydraulic changes in this reach is not expected under the current conditions. Furthermore, the operation of the STT will not impact on barrier passability or hydrological migration cues or impact on the structure and function of the habitats that support the fish community of the Severn Estuary European Marine Site. Including the River Usk and the River Wye.

3.8.3.2 Change to water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme and are summarised below:

- In the River Severn at the tidal limit, the scheme is predicted to reduce water temperature by 0.2 °C (A82) and 0.3 °C (M96).
- Dissolved oxygen concentrations are predicted to be reduced by about 0.1 mg/l for both scenarios .
- Ammoniacal nitrogen concentrations are predicted to be increased by about 0.02 mg/l for both scenarios.
- Oxidised nitrogen is increased by about 0.8 mg/l during the scheme (~10% increase on baseline). Dissolved Inorganic Nitrogen (DIN) concentrations are increased by a similar amount.

Specific additional analysis has been undertaken in relation to DIN using the EA long term water quality monitoring point at Haw Bridge[61] for the 10-year period 2013-2022. The 117 data points identify DIN concentration as 5.65 mg-N/l with a standard deviation of 1.14 mg-N/l. Allowing for the expected removal rates of the Minworth Solution's advanced treatment processes for the Minworth Transfer, discharged concentration to the Avon could be 16.9 mg-N/l. Allowing for the expected removal rates of the Severn Trent Sources Solution's advanced treatment processes for the Netheridge Transfer, discharged concentration to the Severn at Haw Bridge could be 15.8 mg-N/l. Modelled assessment identifies:

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[60] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

[61] https://environment.data.gov.uk/water-quality/view/sampling-point/MD-00025085

- For the full year of the A82 moderate-low flow year scenario, and including abstraction rates for full STT, this could lead to an annual decrease in DIN contribution from the freshwater River Severn to the Severn Estuary of 96 tonnes from a baseline of 15,369 tonnes – a reduction of 0.63%. This includes 192 tonnes/year load addition from Minworth Transfer and 67 tonnes/year addition from Netheridge Transfer; together with a 356 tonnes/year load reduction from STT abstraction. It is noted that under these circumstances at least a further 67 tonnes/year less DIN would be input into the Severn Estuary from Netheridge WwTW at the current outfall.
- For the full year of the M96 very low flow year scenario, and including abstraction rates for full STT, this could lead to an annual decrease in DIN contribution from the freshwater River Severn to the Severn Estuary of 112 tonnes from a baseline of 14,804 tonnes – a reduction of 0.76%. This includes 268 tonnes/year load addition from Minworth Transfer and 90 tonnes/year addition from Netheridge Transfer; together with a 470 tonnes/year load reduction from STT abstraction. It is noted that under these circumstances at least a further 90 tonnes/year less DIN would be input into the Severn Estuary from Netheridge WwTW at the current outfall.

As such there would be an overall reduction in DIN input from the freshwater River Severn and Netheridge WwTW combined into the Severn Estuary as result of the STT Solution. No impacts on supporting habitats within the Severn Estuary are expected.

With regards the Minworth Transfer, four WFD chemicals are at risk of quality deterioration in the River Severn downstream of the River Avon. The carry-forward of that risk into the tidal reach is assessed utilising the modelled conservative tracer analysis presented for each of these chemicals in for the Severn at Deerhurst monitoring point:

- Nonylphenols: EQS for transitional waters match those for freshwaters[62]. A concentration increase could be associated with the Minworth Transfer during the 15% of time that transfer would be in operation, but that would not lead to EQS failure at Deerhurst or in the pass-forward flow to the estuary. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for the final WwTW effluent and accounting for partial re-abstraction at Deerhurst for the STT Solution, indicates an additional 3.6 - 5.0 kg/y for the moderate low flow and very low flow years respectively. As nonylphenols were not detected at Deerhurst, this cannot be expressed as a proportion change.
- Cypermethrin: EQS for transitional waters match those for freshwaters[63]. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets as the main pressures to the reach lie with the upstream River Severn, not the River Avon. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for the final Minworth WwTW final effluent and accounting for partial re-abstraction at Deerhurst for STT Solution, indicates an additional 2.2 – 3.1 g/y for the moderate low flow and very low flow years respectively. As cypermethrin was not regularly detected at the Deerhurst this cannot be expressed as a proportion change.
- Perfluorooctane sulfonic acid and its derivatives: EQS for transitional waters are at 0.00014 µg/l (long term average) tighter than for freshwaters. Mean values calculated from the reported concentrations indicate routine EQS fail at the Deerhurst monitoring site. A concentration increase could be associated with the Minworth Transfer and it is considered with medium confidence to potentially impede achievement of targets in the lower River Severn where the River Avon is a significant pressure to PFOS concentration in the downstream River Severn. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for Minworth WwTW final effluent and accounting for partial re-abstraction at Deerhurst for the STT Solution, indicates an additional 0.21 – 0.29 kg/y for the moderate low flow and very low flow years respectively. Based on the mean reported concentrations at Deerhurst site this represents a 3-5% increase during years when the STT Solution would be in operation.
- Permethrin: A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets, noting the very low detection

[62] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015
[63] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

rate at the assessment point. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for the Minworth WwTW final effluent and accounting for partial re-abstraction at Deerhurst for the STT Solution, indicates an additional 33 - 46 g/y for the moderate low flow and very low flow years respectively. As permethrin was not regularly detected at the Deerhurst monitoring site this cannot be expressed as a proportion change.

Overall, as there are no changes in the physico-chemical characteristics of the water, no impacts on the fish community are expected. Decreased DIN concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not impact on any supporting habitats for the designated fish community of the Severn Estuary.

Selected endocrine disruptors which may act as olfactory inhibitors in the context of SROs have only recently been identified[64] and the monitoring and specific analysis has only recently commenced and has a smaller evidence base at present that should be kept under review in Gate 3. As such, detailed modelling of the potential increase/changes in concentrations has not been undertaken. The assessment has only considered the detection of potential olfactory inhibitors within the River Severn and the Minworth WwTW final effluent (prior to tertiary treatment) and no detailed modelling of the potential change in concentrations has been possible.

Significant changes in the concentrations of selected determinands could result in the bioaccumulation of olfactory inhibitors which could impact on migration into the River Severn, River Wye and the River Usk. However, the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

At this stage the significance/magnitude of the impact on olfaction cannot be assessed and it is only possible to note an increased risk to olfactory inhibition. Considering the potential increase in load in the context of the Severn Estuary, the risk is not considered to be discernible (low confidence). It is noted that the use of many of the determinands that could inhibit olfactory cues are now heavily restricted. This includes cypermethrin which is banned and perfluorooctane sulfonic acid and its derivatives which is heavily restricted. As such the future concentrations of these chemicals at Minworth WwTW should reduce such that the risk recedes.

3.8.4 STT operation - future climate

This section sets out the findings of the effects of the STT operation during future climate conditions. The pass-forward flow to the Severn Estuary from the freshwater River Severn would be amended by unsupported STT abstraction. The daily pattern of unsupported STT solution abstraction rates –are illustrated as the purple periods for A82 Future and M96 Future. Overall, this describes a pattern of unsupported STT solution abstraction only for 22 days in A82 Future in the mid-November to early December period; and 88 days in M96 Future in November, December and January.

3.8.4.1 Change to flow, velocity and depth

Although a fuller context of future operating patterns and flows are not currently available from modelling, review of A82 Future identifies a reduction of 0.7% in the flows passed forward to the Severn Estuary compared with reference conditions. The M96 Future, for which a flow series is only currently available for the River Thames, identifies a pattern of unsupported abstraction which is longer than in the current climate, and this later seasonal trend may be a feature of future operating patterns.

3.8.4.2 Changes to water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future, nor future changes to sea level.

Under Scenario A82F, the predicted water quality in the River Severn at the tidal limit is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F

[64] Ricardo Energy & Environment (2021). Technical Note. Severn Thames Transfer SRO – Impact of determinands on olfaction and fish populations in the Severn Estuary. United Utilities on behalf of the Severn Thames Transfer Programme. December 2021

in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters.

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Severn has been modelled. This shows limited change in dilution capacity along the River Severn compared with current climate conditions. It is considered that the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term pass-forward water quality – including load - than the magnitude of the concentration increase.

As the assessment of olfaction risk for the current climate conditions is based on discharge rather than dilution, there is no change in the olfaction risk based on future river flows.

3.9 THE RIVER THAMES DOWNSTREAM OF CULHAM TO TIDAL LIMIT AT TEDDINGTON

3.9.1 Baseline

The river is characterised as a large lowland river with a mixture of deep glides and runs, with occasional flows over crests of weir structures, which then enter into and support weir pools. These weir pool sites are known areas for angling and recreation value[65] and these weir pools offer a range of habitats that support a greater diversity of aquatic flora and fauna. Notable examples include Sutton Pools at Culham and Clifton Weir Stream.

No sediment bars are visible, although several sub-surface shoal features are of concern to boat navigation. It should be noted that this reach of the River Thames is a navigation, and that the EA are the statutory navigation authority[66]. As such, the EA is obliged to maintain a minimum water depth or draft so that vessels can operate within the navigable channel. There are multiple islands scattered throughout the reach with the river channel bifurcating around these. The majority of banks (outside of urban areas) range from moderate to steep with occasional shallow banks and bank erosion is not common. Within and between urban areas aerial imagery appears to indicate reinforcement and re-sectioning of banks, especially in the larger urban areas where this modification appears to be dominant.

All of the reach is navigable with the exception of backwaters and flood defence structures such as the Jubilee River. In total there are 41 weirs located along the reach and more than half of these weirs are on bifurcations and have associated bypass locks for navigation purposes on the opposite bifurcation arm. These bifurcation channels, below weirs prior to reconnection with the navigable channel, are referred to as weir pools in the scope of the Gate 2 assessment. Examples of these navigation structures include Culham Lock, Clifton Lock and Weir, Days Lock and Weir, Benson Lock and Weir, Goring Lock, Whitchurch Lock, Mapledurham Lock, Sonning Lock, Hambleden Lock, Hurley Lock, Boulters Lock, Romney Lock, Windsor Cut and Old Windsor Lock, Bell Weir Lock, Penton Hook Lock, Chertsey Lock, Shepperton Lock and Weir, Sunbury Locks and Weir, Molesey Lock and Teddington Lock at the end of the reach. As well as the main channel and associated bifurcations, a large side channel, the Jubilee River splits from the reach at ~84.4 km downstream.

The fish community in this reach is representative of the geomorphology and dominated by taxa with a greater tolerance to environmental pressures. Such fish species include bleak, chub, perch, roach, gudgeon, dace and pike, which are present at more than 80% of sites. Migratory species European eel, brown/sea trout and Atlantic salmon are also present within the baseline period dataset for this reach of the freshwater River Thames.

3.9.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

[65] Cove-Smith, C. (1996). The River Thames Book, Imray Laurie Norie & Wilson Ltd. Pp213. ISBN 085288 286 2.

[66] The length of the non-tidal River Thames that is navigable is 135 miles with 45 locks.

- Increased velocities and the resulting impact on the upstream and/or downstream migration of European eel, sea / brown trout and Atlantic salmon.
- Increased velocities and the resulting impact on the local migration of coarse fish and brown trout to spawning areas.
- Changes in weir pool habitats which provide some habitat diversity within the navigable reaches.
- Loss/decrease in habitat quantity and quality due to changes in hydraulics (i.e., increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities.
- Risk of displacement of juvenile fish due to increased flows.
- Changes in water quality could have a direct impact on fish populations (e.g., mortality as a result of dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

3.9.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary (‘now’) climate conditions. In this reach, the STT solution would augment flow via the STT interconnector. The flow augmentation regime is dependent on the maturity of the STT solution.

For the early phase STT, flow augmentation would be unsupported up to 500 Ml/d at selected times, subject to hands-off flow conditions in the River Severn at Deerhurst identified by EA. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple periods of the 47 water resources years. The STT Physical Environment Report describes a typical pattern of early phase STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution flow augmentation only in 24 of the 47 years, and on 11% of days overall.

The seasonality of flow changes in the River Thames for the early phase STT mirror those in the River Severn at point of abstraction as shown within the STT Physical Environment Report and described in Section 3.7.3. Outside of these operating periods, the pipeline maintenance flow of 20 Ml/d would be discharged to the River Thames at all other times. The A82 scenario would include a period of flow augmentation for 60 days from late September to late November, including flow augmentation at peak rate of 500 Ml/d for 53, non-continuous days. The M96 scenario would include a period of flow augmentation for 70 days from late September to early January, including flow augmentation at peak rate of 500 Ml/d for 64, non-continuous days.

For the full STT, flow augmentation would be unsupported up to 500 Ml/d at selected times, subject to hands-off flow conditions in the River Severn at Deerhurst identified by the EA and supplemented by flow augmentation of the River Severn at additional times. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple and blue periods of the 47 water resources years in Figure 1.4, describes a typical pattern of full STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution abstraction only in 24 of the 47 years, and on 23% of days overall.

The seasonality of flow changes in the River Thames for the early phase STT mirror those in the River Severn at point of abstraction. Outside of these operating periods, the pipeline maintenance flow of 20 Ml/d would be discharged to the River Thames at all other times. The A82 scenario would include a period of flow augmentation for 153 continuous days between the end of June and late November, including flow augmentation at peak rate of 500 Ml/d for 53, non-continuous days from late September. Between the end of June and late September, flow augmentation would be at the supported rate of 353 Ml/d. The M96 scenario would include a period of flow augmentation for 208 days from mid-June to early January, including flow augmentation at peak rate of 500 Ml/d for 64, non-continuous days from late September. Between mid-June and late September flow augmentation would be at the supported rate of 353 Ml/d.

3.9.3.1 Change to flow

Early phase (Unsupported)

Flow augmentation at Culham in the early phase STT scheme is when the flow in the River Severn is above the HOF and water is required for the River Thames. In scenario A82, this occurs from the 30th of September to 30th of November, and in Scenario M96 from 31st of October to 9th of January. In both of these scenarios flows have also begun to increase in the River Thames at time of unsupported transfer and the higher rate of flow augmentation of 500 Ml/d does not coincide with periods of lowest river flow in the River Thames. As such, there is no other pattern of introduced flow peaks in the River Thames in either scenario, with the reference condition patterns of flow increases and decreases retained. Flow augmentation leads to an increase in the flow in the River Thames downstream of Culham typically around 20-25%, but by up to 40% depending on the flow in the river. Upstream of the confluence with the River Pang the increase in the flow in the River Thames is lower as a proportion of river flow, typically 20%, but by up to 34% depending on the flow in the river. Upstream of the Datchet intake the increase in the flow in the River Thames is lower still as a proportion of river flow, typically 10-15%, but by up to 32% depending on the flow in the river. Outside of these operating periods the pipeline maintenance flow of 20 Ml/d or a Netheridge Transfer supported rate of 35 Ml/d would be discharged to the River Thames at all other times, both of which are small proportion (less than 10%) flow increases at Culham.

The long profile of flow for A82 on 23rd of October shows a 25% increase in river flow at Culham from 500 Ml/d flow augmentation with that flow increase held to upstream of the Datchet intake ~100 km downstream and then re-abstracted. The long profile of flow for M96 on 5th of December shows a 20% increase in river flow at Culham from 500 Ml/d flow augmentation with that flow increase again held to upstream of the Datchet intake ~100 km downstream and then re-abstracted.

Full STT

Flow augmentation at Culham in the Full STT scheme is more frequent than the Early Phase STT. In scenario A82, this occurs from 30th of June to 30th of November, and in Scenario M96 from 15th of June to 9th January. The supported period of abstraction (in the modelled scenario this is a 330 Ml/d flow increase) this leads to a steady increase in the flow in the River Thames downstream of Culham by 60-86% in A82, depending on the flow in the river, and in the lower flow year M96 an increase of 65-103% depending on flow in the river. Apart from the initial flow increase when flow augmentation commences, there are no other patterns of introduced flow peaks in the River Thames in either scenario, with the reference condition patterns of flow increases and decreases retained. Upstream of the confluence with the River Pang the increase in the flow in the River Thames is lower as a proportion of river flow, typically 33-48% for the A82 scenario and 35-45% for the M96 scenario depending on the flow in the river. Upstream of the Datchet intake the increase in the flow in the River Thames is lower still as a proportion of river flow, typically 22-33% for both the A82 and M96 scenarios depending on the flow in the river. Outside of these operating periods the pipeline maintenance flow of 20 Ml/d would be discharged to the River Thames at all other times which are small proportion (less than 5%) flow increases at Culham.

The long profile of flow for the A82 scenario on the representative low flow date on 18th July shows a 67% increase in river flow at Culham from 330 Ml/d flow augmentation with that flow increase again held to upstream of the Datchet intake ~100 km downstream and then re-abstracted.

3.9.3.2 Change to river level and velocity

The 1D hydraulic model output for water depth variability in the River Thames has not been used in this assessment. This is because water levels in the River Thames are managed for navigation, with the normal operating level varying within one metre. For example at Culham Lock 90% of gauged river levels in the last year have varied within in a 0.26 m range; at Whitchurch Lock (local to the River Pang confluence) by 0.22 m; at Romney Lock (local to the Datchet intake) by 0.40 m. This is in contrast to the differences in water depth which have been greater than one metre during the scenario periods reported for the River Thames at Culham; upstream of the River Pang; and upstream of the Datchet intake.

The 1D hydraulic model output for depth-average velocity variability in the River Thames is considered more reliable. The key summary of the modelled velocity change is that the STT solution would reduce the extent of average velocity reduction within the channel during summer periods of low flow in the River Thames. With the STT solution, average velocity at Culham would not fall below 0.2 m s-1; and upstream of the River Pang and upstream of the Datchet intake average velocity would not fall below 0.25 m s-1 at times of operation of the STT solution.

3.9.3.3 Change to weir pool wetted habitat or weir passability

An assessment is required of the potential effects from STT solution flow augmentation effects on level, velocity and wetted habitat change at selected weir pool reaches on the River Thames. Weir pool reaches are a feature of the navigation infrastructure of the River Thames, and are that part of the river at a lock, between the weir and the reconnection with the navigable channel. Weir pool reaches represent zones of hydraulic heterogeneity within the otherwise level controlled River Thames. At Gate 1 SESRO identified the first three weir pool reaches downstream of a Culham outfall (same location as the STT Solution outfall) for review: Culham Weir, Clifton Hampden Weir and Days Weir.

A screening review has been undertaken at the weir pools prior to the collection of bathymetry and hydraulic data under suitable flow conditions for inclusion in a 2D model. Those flow conditions were not present in the

River Thames during the Gate 2 survey season. The screening identified there could be velocity increases within each of the weir pools from flow augmentation, but was not able to provide context around the reference condition velocities in a A82 moderate-low flow year or a M96 very low flow year or the seasonal differences from the augmentation pattern.

Therefore change to weir pool wetted habitat or weir passability remains an uncertainty and data collection and assessment will need to occur for Gate 3.

3.9.3.4 Changes to water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme.

During periods of scheme operation in early summer (June and July) when River Thames water temperatures are at their highest (17 °C), flow augmentation from the STT solution could cool river temperatures by up to 1 °C. As river temperatures fall in late summer and early autumn (September and October) there is a slight pattern that the STT solution could shift water temperature decline by 1-4 days. As the model does not allow for any heat exchange with the atmosphere, a temperature change pattern is retained for the remainder of the model extent although this is considered to be an over-representation.

Dissolved oxygen saturation in both scenarios is increased by 4% at times of STT solution augmenting low flows in the River Thames at Culham. However, as this is at times of super-saturation, this may be an over-representation. At higher river flows, the effect of flow augmentation is less. The modelling identifies a potential zone of influence of the increase in saturation as far as the River Thame confluence, 12 km downstream of the STT interconnector outfall.

Ammoniacal nitrogen is predicted to increase during the scheme operation by around 0.03 mg/l (from a baseline of 0.02 – 0.06 mg/l) at Culham downstream of the STT interconnector outfall.

Phosphorus is predicted to increase during the scheme operation by around 0.05 mg/l (from a baseline of 0.12 – 0.35 mg/l) at Culham downstream of the STT interconnector outfall [Workbook [8] – tab 'P'] with a lower rate of increase downstream. Downstream of Culham, the River Thame is modelled to increase pressure on phosphorus concentrations and the Rivers Pang and Kennet to reduce pressure. Increases are greatest at times of low flow in the River Thames, which, in the modelled scenarios, coincide with 353 Ml/d supported transfer from the River Severn (Full STT solution). At times of up to 500 Ml/d unsupported transfer (both early phase and full STT solution), baseline river flows in the River Thames are modelled as higher, and as such phosphorus concentrations are modelled to increase by around 0.03 mg/l. Snapshot longitudinal plot of phosphorus concentrations along the River Thames for 18th July are shown in Figure 3 14 of the STT Water Quality Assessment Report.

The pH change was calculated from pan-SRO monitoring data. Those spot monitoring data identify a pH range in the lower Severn at Deerhurst of 7.5 – 8.7 (mean 8.1). Although there is greater variability in the range of pH In the lower Severn than the middle Thames, the difference in mean value is indiscernible.

The hardness of the lower Severn at Deerhurst is also categorised as very hard, with mean 211 mg/l $CaCO_3$ (range 108 – 318 mg/l $CaCO_3$). Although the calcium ion content of the lower Severn is only 60% that of the middle Thames, the magnesium ion content of the lower Severn is three times as high as the middle Thames. This could result in a reduction in hardness of the middle Thames at Culham under low flow conditions in the River Thames at times of supported STT solution transfer from the River Severn. Supported STT solution transfer is for 12% of time. Despite the reduction, hardness would remain as very hard at around 250 mg/l $CaCO_3$. The zone of influence of the STT solution on the River Thames requires further assessment through consideration of tributary input hardness.

Acid neutralising capacity in the middle Thames is very low. In the lower Severn, acid neutralising capacity is better, and at times of STT solution flow augmentation, there would be a marked improvement in acid neutralising capacity of the middle Thames.

A categorisation of the risk to EQS associated with the STT solution transfer has been undertaken. It is important to note that the STT solution at Gate 2 is proposed to include the treatment processes set out in Section 2.3.5 of the STT Water Quality Assessment Report.

The pan-SRO monitoring data for the Severn at Deerhurst SRO monitoring site has been and four WFD chemicals have been identified as not achieving EQS in the source water for the interconnector treatment unit, These are the polyaromatic hydrocarbon benzo(g,h,i)perylene; two synthetic pyrethroid insecticide (permethrin and cypermethrin); and PFOS. Furthermore, the assessment presented in within the STT Water Quality Report identified that, with a Minworth Transfer supporting abstraction to the STT solution interconnector at Deerhurst, the concentration of permethrin, cypermethrin and PFOS may increase in the River Severn water abstracted to the interconnector pipeline at Deerhurst.

Using the concentrations in the measured dataset, monte-carlo combined distribution modelling has been undertaken, specific to the flow conditions in the River Thames at Culham at times of STT solution transfer. It is noted that the STT solution would discharge continuously to the River Thames and should not be considered as a part-time discharge. Flows are as used in the A82 and M96 scenarios.

The chemical water quality assessment (CWQA) identifies a potential improvement in the maximum concentration of the polyaromatic hydrocarbon benzo(g,h,i)perylene in the River Thames from operation of a STT solution. The assessment applies at all times of STT solution transfer – both supported and unsupported, which is presented as 23% of the time. Both rivers are currently measured as failing benzo(g,h,i)perylene short term EQS. Although this betterment of the River Thames is realistic it would not improve the River Thames to achieving EQS. There is also the retained risk that highest concentrations in the River Thames occur at times when the STT solution is providing pipeline maintenance flow only, with little influence on the concentration in the River Thames. The assessment is based on 16 datapoints for each chemical for each location. Further data will provide further confidence in this assessment.

The CWQA identifies no discernible change in the concentrations of the synthetic pyrethroid insecticides permethrin or cypermethrin in the River Thames from operation of a STT solution. Any change in the concentration of permethrin or cypermethrin in the abstracted water at Deerhurst from Minworth Transfer, at times of supported transfer only, would be low. It is noted that as supported transfer would be in use 12% of time overall, these changes are not considered significant from the perspective of long-term change. As such, for these chemicals measured as failing EQS in the River Thames at Culham, the STT solution is considered to neither cause (further) deterioration or impede betterment to achieving EQS. The assessment is based on 16 datapoints for each chemical for each location. Further data will provide further confidence in this assessment.

The CWQA identifies an improvement in the concentration of PFOS in the River Thames from operation of a STT solution. The assessment applies at all times of STT solution transfer – both supported and unsupported, which is presented as 23% of the time. Both rivers are currently measured as failing PFOS long term EQS. Although this betterment of the River Thames is realistic it would not improve the River Thames to achieving EQS.

As set out in Gate 2 environmental water quality study scope in **Table 2.1**, the review of olfaction has been undertaken to assess risks from the Minworth Transfer only on the River Severn and Severn Estuary as these relate to requirements for HRA of the Severn Estuary SAC, SPA and Ramsar site.

3.9.4 STT operation - future climate

This section sets out the findings of the effects of the STT operation during future climate conditions. In comparison with the M96 scenario the M96 Future scenario would include a 22% longer period of flow augmentation releases - with extension both 24 days earlier, to include late May and all of June; and 21 days later, to include most of January. The M96 Future scenario would include a period of flow augmentation for 253 days from mid-June to early January, including flow augmentation at peak rate of 500 Ml/d for 88 continuous days from early November. Between mid-June and early November flow augmentation would be at the supported rate of 353 Ml/d. The increase in regularity of the need for STT support options in late spring, early summer and later into winter is a significant change.

3.9.4.1 Change to flow

Flow augmentation at Culham in the M96 Future scenario would occur from 22nd of May to 29th of January. This leads to an increase in the flow in the River Thames downstream of Culham, which ranges from a 16% increase to a 132% increase depending on the prevailing flow in the river. Apart from the initial flow increase when flow augmentation commences, there is no other pattern of introduced flow peaks in the River Thames, with the reference condition pattern of flow increases and decreases retained. Upstream of the confluence with the River Pang the increase in the flow in the River Thames is lower as a proportion of river flow, typically 10-61% depending on the flow in the river. Upstream of the Datchet intake the increase in the flow in the River Thames is lower still as a proportion of river flow, typically 5-40% depending on the flow in the river. Outside of these operating periods, the pipeline maintenance flow of 20 Ml/d would be discharged to the River Thames at all other times: this is a small proportion (less than 5%) of the flow increase at Culham.

3.9.4.2 Change to river level and velocity

The 1D hydraulic model output for water depth variability in the River Thames has not been used in this assessment as it requires further development. The 1D hydraulic model output for depth-average velocity variability in the River Thames is considered more reliable and so its outputs have been assessed. The key conclusion of the modelled velocity change is that the STT solution would minimise the extent of average velocity reduction within the channel during summer periods of low flow in the River Thames. With the STT solution, average velocity at Culham would not fall below 0.25 m s^{-1}; and upstream of the River Pang and upstream of the Datchet intake average velocity would not fall below 0.3 m s^{-1} at times of operation of the STT solution.

Reference should be made to the Physical Environment Assessment Report for the full assessment.

3.9.4.3 Change to weir pool wetted habitat or weir passability

The assessment of effects on weir pool reaches under future scenarios has not been specifically undertaken at Gate 2 due to the limitations noted in **Section 3.9.4.3**.

3.9.4.4 Changes to water quality

The future assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future. Note that the simulations only changed the River Thames and tributary flows; the water quality data for all inputs, including the STT interconnector discharge and sewage works flows remained the same in all simulations.

Under Scenario M96F, the predicted water quality in the River Thames is only a minor change from predicted under M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for M96F in the middle Thames at Culham occurs over a longer period, the peak changes in concentrations are very similar to M96 for all parameters.

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Thames has been modelled. This shows around a 20% reduction in dilution capacity along the River Thames. The monte-carlo combined distribution modelling undertaken has been repeated for River Thames at Culham flows during the extended period of 165 consecutive days of supported transfer in the M96F scenario (mean modelled flow in River Thames at Culham 548 Ml/d, Q95 modelled flow 261 Ml/d; mean transferred flow 319 Ml/d, standard deviation 50 Ml/d). For the synthetic pyrethroid insecticides permethrin and cypermethrin, there remains no discernible modelled change in concentration in the River Thames. For polyaromatic hydrocarbon benzo(g,h,i)perylene (currently measured as not achieving short term EQS) and PFOS (currently measured as not achieving long term EQS), the extent of potential betterment of the River Thames is greater in terms of both concentration reduction and duration of benefit – however it is restated that this is not an improvement to achieving EQS.

As set out in Gate 2 environmental water quality study scope in Table 2.1, the review of olfaction has been undertaken to assess risks from the Minworth Transfer only on the River Severn and Severn Estuary as these relate to requirements for HRA of the Severn Estuary SAC, SPA and Ramsar site.

3.10 OTHER FUNCTIONALLY LINKED HABITATS

3.10.1 Baseline

Several important tributaries are associated with the River Severn and the Severn Estuary. These include the River Wye, River Usk, and the River Teme.

Both the rivers Wye and Usk are SACs. The species of migratory fish in the Severn Estuary that could potentially be impacted by the operation of the STT are also qualifying species of the Rivers Wye and Usk and the conservation objectives of the Severn Estuary European Marine Site are linked to the supporting habitats within these tributaries. The River Severn is also a migratory pathway to the River Clun and River Teme SAC, with the latter supporting the shad designation of the Severn Estuary SAC and RAMSAR site. The River Clun

SAC is designated for freshwater pearl mussel and this species is dependent on Atlantic salmon for part of its lifecycle.

3.10.2 Relevant impact pathways

Considering the baseline fish community and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality could have a direct impact on fish populations (e.g., mortality as a result of dissolved oxygen sags).
- Impacts on supporting habitat process due to change in freshwater inflows and changes in water quality (olfaction).

3.10.3 STT operation – current conditions

This section sets out the findings of the effects of the STT operation during current or contemporary ('now') climate conditions.

3.10.3.1 Change to flow, velocity and depth

Any impacts upon fish migration into any of the functionally linked habitats associated with the River Clun SAC would, therefore, impact on the conservation objectives of these sites and/or the SAC. From the assessment above, it is evident that the operation of the STT (either supported or unsupported) will not result in any hydrological or hydraulic impacts that will impact on migration into and upstream of the River Severn. Furthermore, it is evident that the changes in pass forward flow into the Severn Estuary will not be discernible and will not impact on the hydrological migratory cues in the Severn Estuary and subsequently into the rivers Usk, Wye, or Teme.

3.10.3.2 Changes to water quality

The EA, NE and NRW have raised concerns with regards to the impacts on chemical cue (olfaction) detection by migratory fish (e.g., salmonids), for instance, signal masking of natal river homing cues, as a result of the diversion of WwTW discharge from the Teme. The risk of impacts on olfactory cues as a result of the Minworth discharge has also been discussed in the sections above.

The results of the water quality assessment indicate as there are no changes in the physical-chemical characteristics of the water, no impacts on the fish community are expected in response to the STT Solution operations. Decreased DIN concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not impact on any supporting habitats for the designated fish community of the Severn Estuary.

Significant changes in the concentrations of selected determinands could result in the bioaccumulation of olfactory inhibitors which could impact on migration into the River Severn, River Wye, and the River Usk. An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken against the local risk of presence of chemicals of interest as olfactory inhibitors in the lowest freshwater reaches of the River Severn. It is important to note that the Minworth SRO at Gate 2 is proposed to include the advanced treatment processes. The initial risk categorisation in is without consideration of that treatment. It is noted, that of the risk chemicals, the Gate 2 proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium(III), cobalt, cypermethrin and permethrin. Therefore, for those chemicals of interest as olfactory inhibitors which are included in the monitoring programme reported at Gate 2, water passed forward to the Severn Estuary is considered likely to be higher in concentration for:

- Chromium(III) and total
- Selenium
- Zinc
- Cypermethrin
- Permethrin.

It is also noted that for any of the chemicals of interest listed as detected, principally metals, diazinon, isoproturon, cypermethrin, permethrin, triclosan, there would likely be a load increase in the pass forward flow to the Severn Estuary at times the STT Solution operation includes the Minworth Transfer. However, the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

It is also important to consider the potential change in concentration/load in the context of the Severn Estuary and further dilution from other tributaries and the significant influence of the tidal regime of the Severn Estuary. It is noted that the use of many of the determinands that could inhibit olfactory cues are now heavily restricted. This includes cypermethrin which is banned and perfluorooctane sulfonic acid and its derivatives which is heavily restricted. As such the future concentrations of these chemicals at Minworth WwTW should reduce such that the risk recedes.

At this stage the significance/magnitude of the impact on olfaction cannot be assessed and it is only possible to note an increased risk to olfactory inhibition. When considering the potential increase in load against the context of the Severn Estuary, the risk is not considered to be discernible (low confidence).

4. CONCLUSIONS

4.1 SUMMARY OF THE EFFECTS UNDER CURRENT CONDITIONS

From the results it is evident that the potential changes in flow (as associated with either a supported or unsupported STT) are not considered discernible and will likely fall within the inter annual variations that would be observed under reference conditions.

As a result, the potential changes in flow (as associated with either a supported or unsupported STT) will not impact on migration of the anadromous and catadromous species associated with the Severn Estuary European Marine Site or the River Clun SAC. This is because hydrological cues for migration will not be impacted, and the increased/decreased flows will not impact on the passability of any barriers or fish passes. It should be noted, however, that water levels modelled have the potential to impact gravity fed eel passes and will therefore require careful analysis to better understand any associated implications. Flows and velocities will also remain sufficient to support the downstream drift of post-metamorphic lamprey transformers, juvenile shad and salmonid smolt. Flows and velocities will also not result in the washout of any incubating eggs or juveniles.

The potential changes in velocity and depth (as associated with either a supported or unsupported STT) are also not considered to be of a magnitude to affect habitat availability for the fish community. This is because the velocity and depths that would be observed under a supported or unsupported STT will remain mostly similar to baseline conditions and within the preferred and optimum requirements for the baseline fish community associated with the various waterbodies.

The exception appears to be the reaches of the River Avon downstream of Warwick where both modelled and measured data indicates a change in the quantity and/or quality of habitat available for fish (when considering survey data which was collected at a higher flow rate when compared to the proposed 115 Ml/d discharge). The change in habitat is mostly related to the increase in velocities, noting that in most areas the velocities will remain within the preference for juvenile coarse fish and brown trout. It is noted that the modelled data shows that the expected change in habitat quality and quantity will be minor and limited to the reaches upstream of Alveston.

Overall, changes in freshwater flow into the Severn Estuary will be minimal and the supporting habitats for the migratory species of the Severn Estuary European Marine Site (and the River Wye, River Usk, and River Clun SAC), will not be affected by the STT operation.

The results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. Within the Severn Estuary, no changes in the physic-chemical characteristics of the water. Decreased DIN concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not impact on any supporting habitats for the designated fish community of the Severn Estuary.

Taking into account the treatment efficacy provided by Minworth SRO process engineers, three chemicals: cypermethrin, perfluorooctane sulfonic acid and its derivatives, and permethrin are considered a risk. All three would be associated with further deterioration in current EQS failures in the River Avon and impede the River Avon reaching targets. STT monitoring data indicate the lower River Severn fails EQS for cypermethrin and that is the dominant pressure on water quality in the River Severn, not the contribution of the River Avon or Minworth Transfer. Perfluorooctane sulfonic acid and its derivatives have such a large EQS failure in both rivers that increases from the Minworth Transfer could impede targets being reached, noting that PFOS use is heavily restricted which should cause concentrations of this chemical to reduce in the future. Permethrin is rarely detected in the lower Avon or lower Severn at present, and risks to long-term EQS failure from Minworth Transfer are considered low.

These four determinands, along with several others could act as olfactory inhibitors. It is noted that for these determinands along with others such as metals, diazinon, isoproturon, triclosan, there would likely be a load increase in the pass forward flow to the Severn Estuary at times when the STT scheme operation includes the Minworth Transfer. Selected endocrine disruptors which may act as olfactory inhibitors in the context of STT Solutions have only recently been identified and have not been subject to modelling or detailed assessment. These chemicals require specific analysis which has only recently commenced. As a result there is only a small evidence base at present that will be kept under review in Gate 3.

It is important to consider the potential change in concentration/load in the context of the Severn Estuary and further dilution from other tributaries and the significant influence of the tidal regime of the Severn Estuary. It is also noted that the use of many of the determinands that could inhibit olfactory cues are now heavily restricted. This includes cypermethrin which is banned and perfluorooctane sulfonic acid and its derivatives which is heavily restricted. As such the future concentrations of these chemicals at Minworth WwTW should reduce such that the risk recedes.

At this stage the significance/magnitude of the impact on olfaction cannot be assessed and it is only possible to note an increased risk to olfactory inhibition. Considering the potential increase in load in the context of the Severn Estuary, the risk is not considered to be discernible (low confidence).

4.2 SUMMARY OF THE EFFECTS UNDER FUTURE CONDITIONS

From the results it is evident that the potential changes in future flow scenario do not deviate drastically from current climate scenarios, and are not considered discernible. They will likely fall within the inter annual variations that would be observed under baseline reference conditions and within the preferred and optimum requirements for the baseline fish community associated with the various waterbodies.

As per the current climate scenarios, the potential changes in future scenario flow will not impact on migration of the anadromous and catadromous species associated with the Severn Estuary European Marine Site or the River Clun SAC. Flows and velocities will also remain sufficient to support the downstream drift of post-metamorphic lamprey transformers, juvenile shad and salmonid smolt. Flows and velocities will also not result in the washout of any incubating eggs or juveniles.

The potential changes in velocity and depth are also not considered to be of a magnitude to affect habitat availability for the fish community.

Akin to the current climate scenario, for the future scenario, the exception exists within the reaches of the River Avon, immediately downstream of Warwick and the Minworth Transfer outfall, where data indicate increasing losses of fish habitat availability, particularly in the upper reaches of the river. Again, the change in habitat reflects increases in velocities and flow depth, but for most areas, velocities will remain within the preference for juvenile coarse fish species and brown trout. Overall, the change in habitat quality is expected to be minor.

Overall, changes in freshwater flow into the Severn Estuary will be minimal and the supporting habitats for the migratory species of the Severn Estuary European Marine Site (and the River Wye, River Usk, and River Clun SAC), will not be affected by the STT operation.

Future flow assessment of environmental water quality effects from STT SRO operation in reaches from the River Vyrnwy at the Vyrnwy Reservoir to the confluence with the River Severn on the River Avon, were not scoped in for Gate 2 assessment, owing to the absence of pathways.

For reaches from the River Severn confluence with the River Avon, future scenario assessment of the general water quality is an assessment of the change in dilution of the currently legislated chemicals only, and could not account for future climate temperature changes, nor changes to pollutant load in the future. Predicted water quality in these reaches is very similar to current climate scenarios, but with the change in concentrations described for a longer period of impact. Results of the water quality modelling indicate changes are expected to be minimal and will not impact on any supporting habitats for the designated fish community of the Severn Estuary. However, the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term water quality than the magnitude of the concentration increase.

As per current climate conditions, three chemicals: cypermethrin, perfluorooctane, sulfonic acid and its derivatives, and permethrin are considered a risk under future climate scenarios and would be associated with further deterioration in current EQS failures.

Again, these determinands, along with several others could act as olfactory inhibitors, and would likely increase load in the pass forward flow to the Severn Estuary at times when the STT scheme includes the Minworth Transfer. Further analysis and evidence are to be kept under review in Gate 3 to allow for further detailed assessment. At this stage, however, the significance/magnitude of the impact on olfaction cannot be adequately assessed and it is again, only possible to note an increased risk to olfactory inhibition, albeit, discernible (low confidence).

4.3 UNCERTAINTY AND CONFIDENCE DATA GAPS

The available evidence and data are considered sufficient to inform the ecological requirements of the fish communities of the waterbodies associated with the STT operation for Gate 2. Furthermore, the additional evidence collected by the STT group will help to reduce the uncertainty in the assessments by identifying/confirming the extent of supporting habitat for the Severn Estuary SAC and Ramsar site.

There remains some uncertainty in the assessments completed in Gate 2 and further recommendations have been made below to address the uncertainty. The uncertainty is summarised as follows:

- Much of the assessment work is based on Acoustic Doppler Current Profiler (ADCP) data and the application of fish habitat preference hydraulic data to the outputs of a 1D model. It is acknowledged that the 1D model is not entirely suitable for this application due to the nature of its single point hydraulic outputs.
- There is currently no measured data to inform the risk to weir pool habitats in the River Avon and River Thames.
- There is currently insufficient information to derive the critical levels for fish passage at fish passes.
- There remains some uncertainty with regards to the impact of selected determinands on olfaction. This relates to the lack of data to inform the modelling and assessment, but also the potential effect of concentrations of some determinands in the context of the Severn Estuary and the significant total regime and the potential increase in load.
- For some chemicals there are difficulties with commercially available limits of detection not being sufficiently low compared to EQS values and for potential olfactory inhibitors it is recognised that the commercially available limit of detection may be altogether too high to draw conclusions. The main limitation with the chemical data in the Gate 2 assessment however lies with the SRO process engineers designing treatment plant for Minworth Transfer and Netheridge Transfer as there are no cases to date in UK of reduction performance efficacy and operational reliability for the planned treatment processes.

4.4 RECOMMENDATIONS FOR GATE 3

The following recommendations are made for Gate 3 in order to further bolster the fisheries assessment and to provide this with a more robust empirical framework:

- Undertaking more ADCP measurements at a larger number of sites on the River Vyrnwy, River Avon and River Severn. This will include the five sites used as part of this assessment but also expand these to include a further number of sites which cover the characteristic range of flow habitats.
- An increased number of repeat surveys at these sites to capture a much wider range of flows, including the magnitude of flows which would be expected during a release. This will provide more empirical evidence of the degree of flow habitat changes expected. Coverage of a wider range of flow habitats, e.g., runs, riffles and pools will allow increased quantification of potential changes in these areas.
- If possible, use a more detailed model to provide higher resolution outputs of velocity and depth. This would be beneficial in broadening the hydraulic information available to characterise the simulated range of changes at each cross-section within a channel and allow development of a better understanding of these changes, particularly in areas important for fish habitat, e.g., channel margins and side channels.
- If possible, include assessment of extreme low flows that are considered to be less regular than once every fifty years, and to consider pressures from climate change going forward.
- Undertaking ADCP measurements upstream, downstream and within weir pool habitats and bifurcations at representative weirs/locks in the River Avon to improve the uncertainty in the current assessments with regards to potential changes in habitat quality.
- Further assessment of species-specific habitat change/loss per reach, dependent on model scenario. This would include an review of potential flow scenarios which may result in stable/static flows during dry summers that may impact on the level of temporal and spatial variability of fish habitats.
- Further assessment and modelling of the risk to olfaction is required as data from the ongoing monitoring programmes becomes available. This would also include a review of the current olfactory evidence base, which would be updated as new peer reviewed scientific literature becomes available.
- Additional information should be collated on fish pass design to help inform the critical levels for operation at each fish and eel pass.
- Review of the Diglis fish pass data in order to support the movements of migratory fish within the Severn catchment.