Strategic Regional Water Resource Solutions: Annex B3.4: Macroinvertebrates / Other Freshwater Ecology Assessment

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

Date: November 2022

Severn to Thames Transfer

Macroinvertebrates / Other Freshwater Ecology Assessment

STT-G2-S3-115

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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

Macroinvertebrates and other ecology 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 (STT) Description

The aim of the Severn Thames Transfer is to provide additional raw water resources of 300 to 500Ml/d to the South East of England during drought, with 500Ml/d preferred by the Water Resources in the South East (WRSE) group's emerging regional plan. The water would be provided from 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 25Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy;
- **Vyrnwy Reservoir**: Utilisation of 155Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline ("Vyrnwy Bypass") to the River Severn;
- **Shrewsbury**: Diversion of 25Ml/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**: 15Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst;
- **Minworth**: The transfer of 115Ml/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 35Ml/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. The guidance stated the environmental assessment methodologies should be consistent with any relevant legislation and guidance and follow best practice.

[1] RAPID (2022) Strategic regional water resource solutions guidance for gate two

This includes, where relevant, WRMP24, 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 assessment; (ii) assessment reports were then produced using the evidence to determine the potential effects 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 macroinvertebrate and other freshwater communities. It informs other assessments, including the statutory assessments.

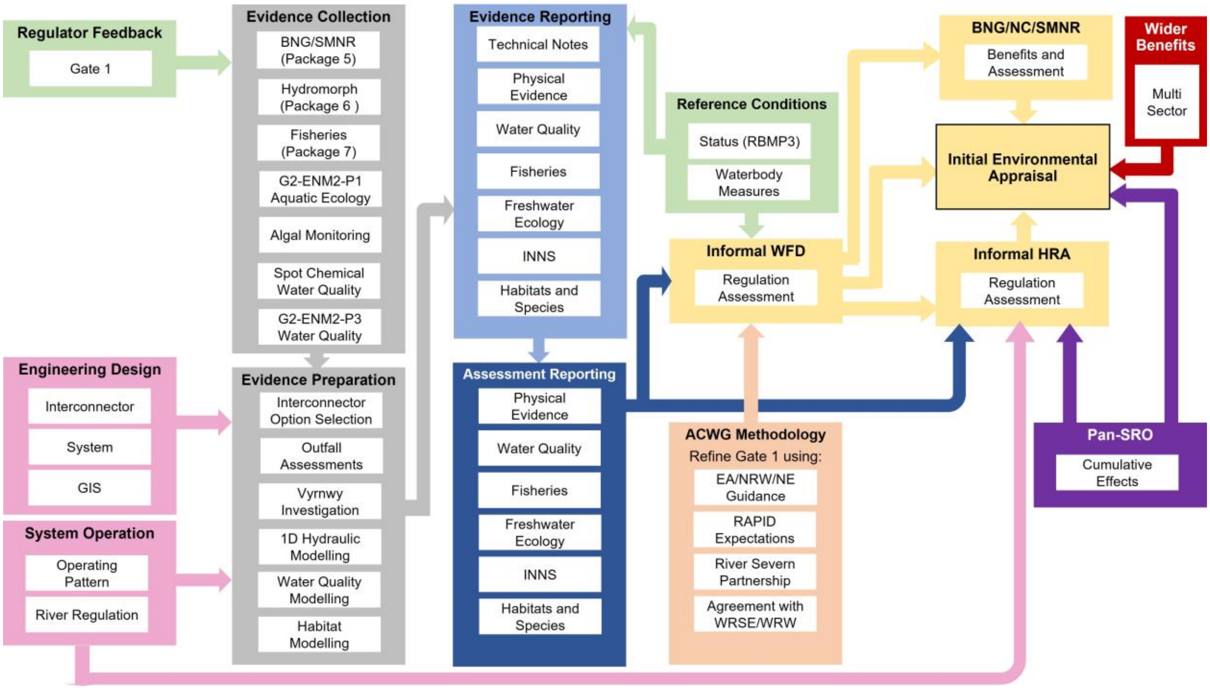

Figure 1.1 Flow chart showing the scope of investigations for STT Gate 2 and their interactions

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

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
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 Solution and therefore excluded from the STT solution assessment.

Similarly, the STT solution assessment accounts for the effects from the relevant solutions 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.

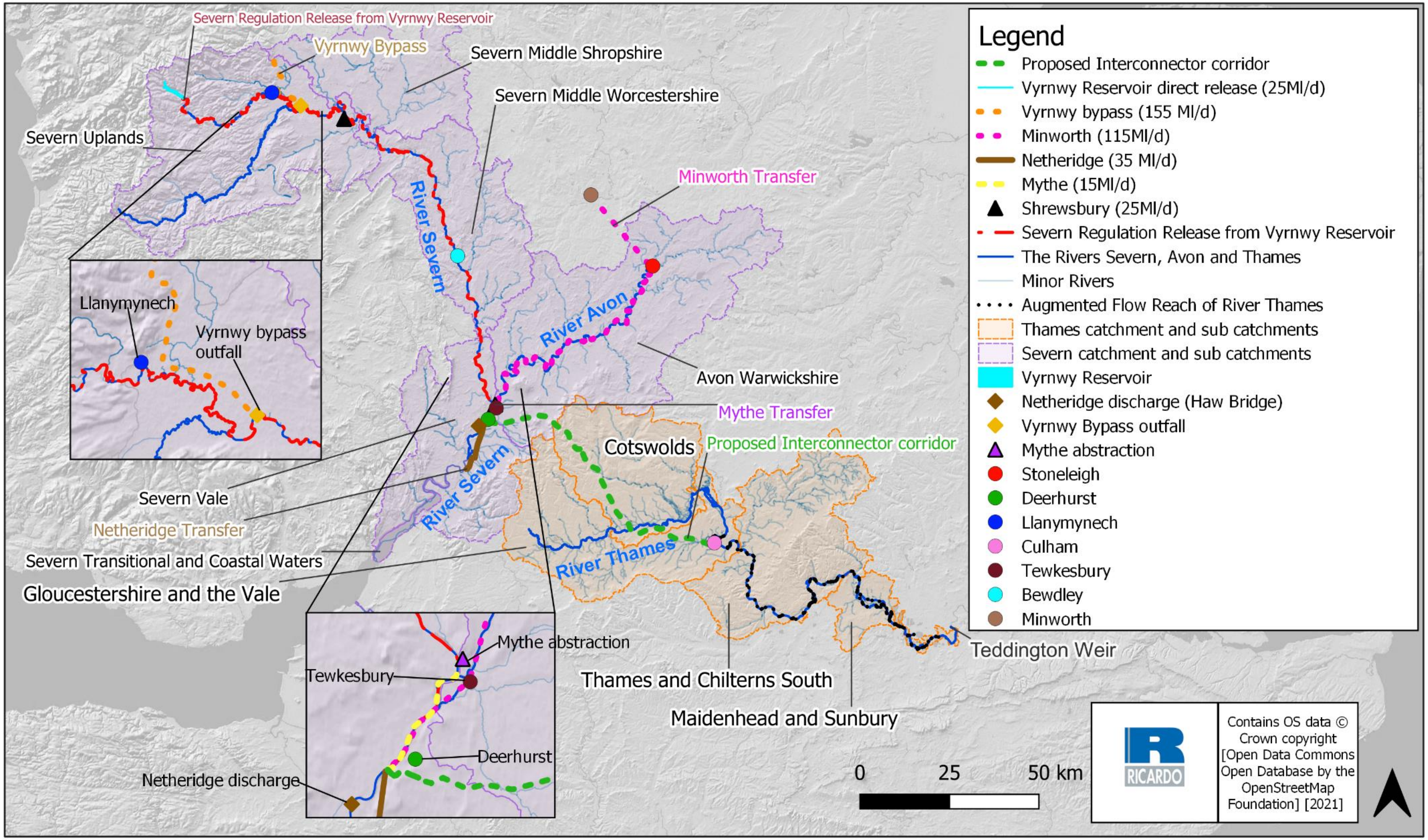

Figure 1.2 Map showing the study area and associated catchments

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[3]. 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 Table 1-1.

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 unsupported4. 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 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 370Ml/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 353Ml/d, as represented in Figure 1.3.

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

Early Phase STT	Full STT
500Ml/d interconnector pipeline.	500Ml/d interconnector pipeline
Part-time, *unsupported* abstraction up to 500Ml/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.	Part-time, *unsupported* abstraction up to 500Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, subject to hands-off flow conditions identified by EA
Part-time, *supported* abstraction up to 35Ml/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 35Ml/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.	Part-time, supported abstraction up to 353Ml/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 25Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy; 2. **Vyrnwy Reservoir**: Utilisation of 155Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline ("Vyrnwy Bypass") to the River Severn; 3. **Shrewsbury**: Diversion of 25Ml/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;

[3] STT-G2-S3-359-STT Gate 2 Design Principles

[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.

Early Phase STT	Full STT
	4. **Mythe**: 15Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst; 5. **Minworth**: The transfer of 115Ml/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**: 35Ml/d of the Severn Trent Water licensed abstraction piped to the River Severn for abstraction at Deerhurst.
Continuous abstraction from River Severn at Deerhurst of 20Ml/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	Continuous abstraction from River Severn at Deerhurst of 20Ml/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

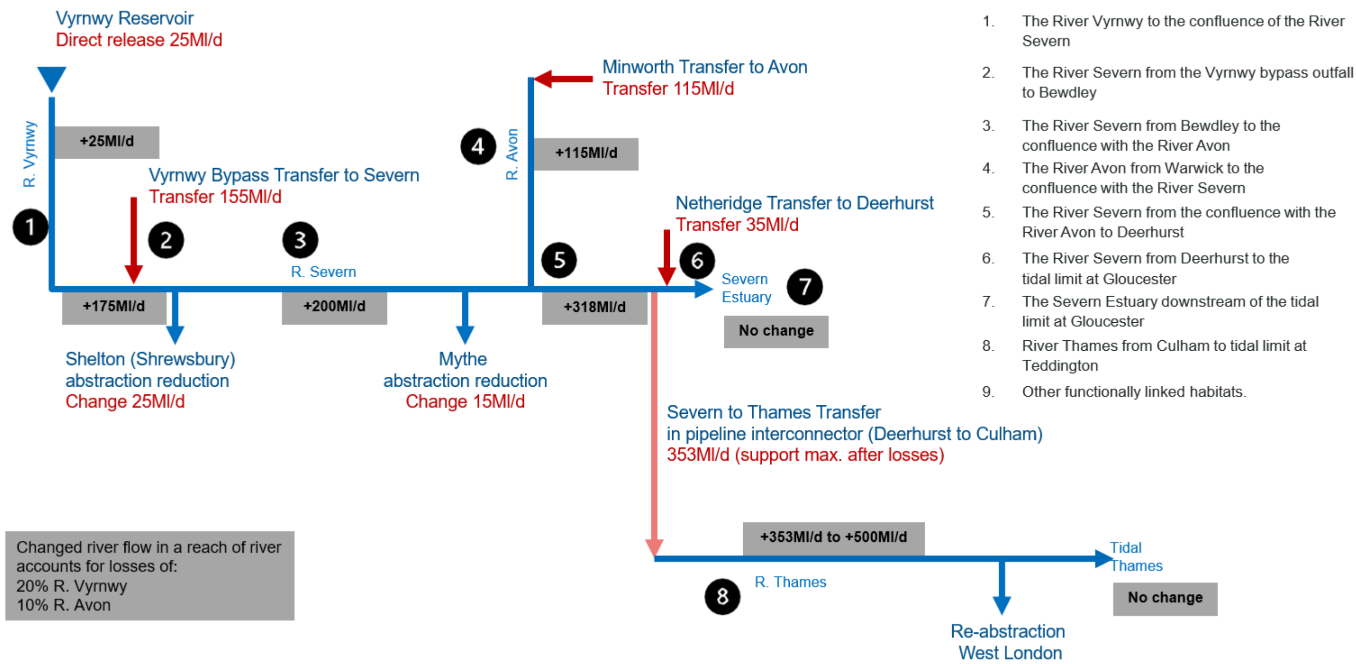

Figure 1.3 Schematic representing flow changes (accounting for losses) of STT Solution

Table 1-2 River Severn at Deerhurst: HoF conditions

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

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 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.

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 shows 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); and
- 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 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.

[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,

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

Where: purple indicates periods when the early phase STT would be in operation; and the combined purple and blue periods indicate the full STT

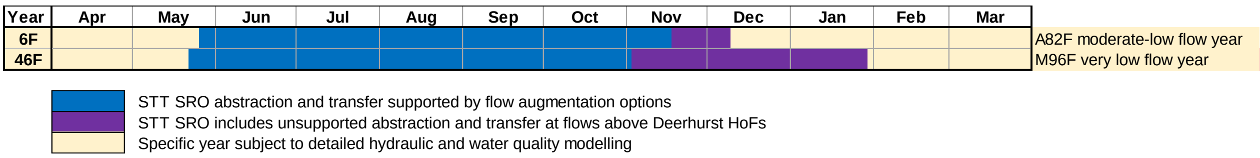

Figure 1.5 Representation of dates full STT solution would be on (for water resources purposes) for selected future scenarios as used in the environmental assessment

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 macroinvertebrates and other freshwater ecology communities. It analyses the information and data set out in the Macroinvertebrate and other Freshwater Ecology 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 this Strategic Resource Option (SRO).

1.4.1 Link with other Reports

The Macroinvertebrate and other Freshwater Ecology 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 show the effect of the STT scheme on the macroinvertebrate and other freshwater communities as a result of changes in flow, velocity, depth, level and water quality. These findings are used by the STT Gate 2 Environmental Assessment and Statutory reports which interpret the significance of the changes.

The findings have been informed by Physical Environment Assessment Report8 (and its associated Annex) and the Water Quality Assessment Report[9]. Together, these reports provide an assessment of the impact on flow, water level, velocity changes and water quality as a result of the operation of STT. The effects 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. Macroinvertebrate and other Freshwater Ecology Assessment Report. Report for United Utilities on Behalf of the STT Group. May 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

2.1 SUMMARY OF THE APPROACH

Overview

The scope of the assessment of effects on the macroinvertebrate and other freshwater communities arising from the STT operation required for Gate 2 and the approach to undertaking this assessment is described in **Table 2.1**. This table is replicated from the Gate 2 Macroinvertebrate and other Freshwater Ecology Evidence Report.

Table 2-1 Approach to the Gate 2 assessment of macroinvertebrates and other freshwater communities

Task item	Scope of assessment	Approach to assessment	Evidence Base for Task
Aquatic macroinvertebrates and other freshwater ecology	• Update the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2.	• Update the assessment to consider additional species/community data collected during Gate 1 and Gate 2. • Update assessment in consideration of the interpretation of the fluvial (flow) model, including the flow series at key locations for different scenarios to consider the risk of changes in velocities, depth and wetted margin that may result in changes in community structure, loss of preferred habitat, scouring of biofilm, etc. • Include relevant SRO 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 risk of water quality driven changes in community structure. • Suggest further mitigation measures (where required) for design/engineering interface. • Review additional studies on flow related impacts on diatoms/phytobenthos to understand the potential risks.	• Physical Environment and Water quality assessments will provide scenario outputs to consider in the assessments. • Data from Environment Agency Ecology & Fish Data Explorer from 2011-2021. • Data obtained through data request to NRW • Targeted monitoring completed since 2020 at freshwater sites within the project area (see Section 2.2). • EA, NRW and STT Group macroinvertebrate data, WHPT scores, ASPT, NTAXA, LIFE and PSI metrics and thresholds, including Ecological Quality Ratios (EQRs). • EA, NRW and STT Group macrophyte data using RMNI, RMHI, NTAXA, NFG and ALG metrics and thresholds, including Ecological Quality Ratios (EQRs). • EA, NRW and STT Group diatom data using TDI5, TDI4 %motile, %organic tolerant and %saline metrics and thresholds. • Studies/investigations on flow related impacts on diatom communities.

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

[10] Modular River Survey

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 sensitivity of the macroinvertebrate, diatom, and macrophyte communities to physical environment changes has been informed by considering the relevant baseline data as summarised in the Macroinvertebrate and other Freshwater Ecology Evidence Report[11]. 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.

2.3 IDENTIFYING RELEVANT IMPACT PATHWAYS

Macroinvertebrate communities and other freshwater ecological features (such as macrophytes and phytobenthos) play a critical role in maintaining healthy, functioning river systems. These features form a critical component of the food-web that support other species, provide habitats and can also influence physical environmental processes. Many macroinvertebrate species are sensitive to water temperature or water quality and changes could result in a change in the community structure or changes in the timing of lifecycle stages. Similarly, diatoms and macrophyte are particularly sensitive to water quality.

The assessment of impacts on the macroinvertebrate and other freshwater communities as a result of the operation of the STT has been considered in the context of the ecological requirements of each baseline community and the extent to which these requirements will be altered as a result of the operation of the STT. Where the supporting environmental variables for the macroinvertebrate and other freshwater ecological communities (e.g., flow, depth, velocity, habitat quality, dissolved oxygen levels and temperature) are modified to take them outside of their preferred habitat envelope, it can be assumed that there will be an impact on the freshwater communities as a result of changes in the community structure.

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

3. REACH BY REACH ASSESSMENT

3.1 INTRODUCTION

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, before assessing the effects of the STT solution on current and then future flow conditions. The potential effects have been considered in view of the baseline community and ecological requirements/preferences of the community.

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

3.2.1 Baseline

The macroinvertebrate, macrophyte and phytobenthos communities of this reach is representative of the local geomorphology. 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 and detritus inputs. Downstream of the waterfall, the river widens, and extensive riffle and rapids provides excellent habitat. 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.

Downstream of Llanymynech the extended and repeated walkover hydromorphological surveys undertaken12 reveal that the lower part of the 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.

The baseline data suggest that the macroinvertebrate, macrophyte and phytobenthos community within the reach from the Vyrnwy Reservoir to the confluence with the River Banwy is sensitive to water quality and flow changes. It is noted that the communities generally have a preference for fast flowing water and are dominated by taxa with a low tolerance for pollution (i.e., sensitive to water quality changes). This is also represented by the Ecological Quality Ratios (EQRs) for the NRW and STT Group monitoring locations which are indicative of a high ecological status (i.e., the community composition and abundances are as expected/better than expected based on the baseline physical environment characteristics).

The baseline data suggest that the macroinvertebrate, macrophyte and phytobenthos community within the reach from the confluence with the River Banwy to Llanymynech is also sensitive to water quality and flow changes. It is noted that the macrophyte and phytobenthos communities in this reach include taxa that are more tolerant to pollution and indicative of increased nutrients.

It should be noted that the riverine plant community in this reach is dominated by lichens and bryophytes and NRW has noted that the bryophytes are notable in a Montgomeryshire context because there are few other watercourses that have this (relatively low) diversity of oceanic species in the study area. The potential impacts on bryophytes and lichens are assessed separately in the Protected Species Assessment Report.

[12] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 1 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

3.2.2 Relevant impact pathways

The support releases could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species, macrophytes and phytobenthos (including the inundation of riffle/rapid habitats;
- Direct washout of macroinvertebrate eggs and macrophyte seeds and plant fragments;
- Direct washout/loss of species with a preference for slow/moderate flows;
- Direct washout of allochthonous food sources such as leaf litter;
- Increased velocities could result in scour of biofilm;
- Changes in local water levels, splash zones and humidity which could impact on diatom community composition;
- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa, change phytobenthos community composition and result in the proliferation of algal growth;
- Inundation of marginal habitats where macrophyte species provide cover and spawning habitat for certain fish species;
- Washout of early plant growth in spring;
- Increased erosion and siltation in some areas including the loss of fine sediment in sensitive habitats;
- Changes in water quality (in particular temperature) could impact on emergence patterns of Ephemeroptera, Plecoptera and Trichoptera (EPT); and

Increased water depth and higher velocities in summer could affect invertebrate community composition causing a knock on effect on food sources for higher species such as brown trout and bullhead. For example: benthic invertebrates comprise the bulk of the diet of bullhead. Bullheads select for their preferred habitat rather than for particular prey[13]. Diet therefore changes with the seasons and the availability of different food items. Generally, crustaceans (particularly *Gammarus* spp. and *Asellus* spp.) are taken in the winter months, and a wide range of insect larvae in the summer.

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 *Change to flow, velocity and depth*

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.

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. In A82, STT SRO releases potentially coincide with Severn Regulation releases on 31 dates in July and August, with managed releases (compensation flow, Severn Regulation Release and STT SRO release) up to 170 Ml/d. In M96, STT SRO releases potentially coincide with Severn Regulation releases on 115 dates between mid-June and mid-October, with managed releases (compensation flow, Severn Regulation Release and STT SRO release) up to 195 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.

[13] Welton JA, Mills CA & Pygott JR (1991).The effect of interaction between stone loach Noemacheilus barbatulus (L.) and the bullhead Cottus gobio (L.) on prey and habitat selection. Hydrobiologia 220, 1–7.

Figure 3.1 Photographs showing the River Vyrnwy at Meifod on 16th of June 2021 (top) and 7th of September 2021 (bottom)

Note: Water levels were 1.30m and 0.93m on 15th June 2021 and 7th September 2021 respectively (as measured at Pont Robert). Measured data indicates a difference in flow of 320Ml/d

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.

As noted above, the habitat availability and the resulting impacts of the increased flows on habitat quality and quantity as a result of changes in velocity and depth will differ when comparing the sections downstream of the reservoir and downstream of the River Banwy. The modelled changes are summarised as follows:

At the River Vyrnwy upstream Conwy site, under the A82 scenario, there is an increase in depth between 27th June and 9th October. Over this period the depth increases by between 10.3 % and 34.0 % with the depth ranging between 0.29 m and 0.42 m (with a mean depth of 0.34 m compared to the reference, which ranged between 0.22 m and 0.38 m (with a mean depth of 0.29 m).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 4.4 % and 14.8 % with the scenario velocities ranging between 0.85 m/s and 1.00 m/s (with a mean velocity of 0.92 m/s) compared to the reference which ranged between 0.74 m/s and 0.96 m/s (with a mean velocity of 0.84 m/s).

Under the M96 scenario, there is an increase in depth between 12th June and 2nd November. Over this period the depth increases by between 8.2 % and 34.2 % with the depth ranging between 0.29 m and 0.46 m (with a mean depth of 0.39 m) compared to the reference which ranged between 0.21 m and 0.42 m (with a mean depth of 0.34 m Above Ordnance Datum (AOD)).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 3.5 % and 14.9 % with the scenario velocities ranging between 0.82 m/s and 1.04 m/s (with a mean velocity of 0.96 m/s) compared to the reference which ranged between 0.74 m/s and 1.00 m/s (with a mean velocity of 0.91 m/s).

Submerged surfaces in rivers host communities of algae and microbes that live in a layer of polysaccharide exudates, organic matter, and inorganic sediment called a 'biofilm'[14]. Biofilms are a key site for autotrophic production and an important sink for transported organic matter[15], thus serving as a vital resource for invertebrate grazers, scrapers, and detritivores that feed on algae, microbes, and detritus[16]. In the River Vyrnwy, the biofilm will play an important role in the food web, particularly in the areas downstream of Dolanog to Llanymynech where the canopy starts to open, and sunlight can penetrate most of the water column. The structure and function of river biofilms is chiefly regulated by flow variability[17].

Changes in flow affect the availability of nutrients and light, controlling rates of growth and reproduction, and can remove biofilms from substratum through scouring or desiccation[18]. The intensity and frequency of disturbance thus affects the accrual of mass in the biofilm as well as the community composition of phytobenthos. Small changes in flow occur frequently in rivers, disturbing relatively small areas of biofilm. Larger disturbances such as scouring events (where benthic shear stress exceeds thresholds for periphyton attachment during high flows) are typically less frequent.

The proposed operation of the STT support releases would result in an increase in velocity, particularly during periods when support releases coincide with Severn Regulation releases. Surveys during trial releases to inform the physical losses from the Vyrnwy reservoir support releases identified that, at flows in excess of 174Ml/d, fine sediment movement was observed within this reach of the River Vyrnwy. The increased flows could, therefore, impact on the accrual of mass in the biofilm as well as the community composition of phytobenthos which could also impact on food availability for macroinvertebrates, especially has the higher flows will experienced within the main growing season of the phytobenthos.

3.2.3.2 *Changes to water quality*

Additional information on other 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. This bespoke evidence for the STT SRO is available for five sites in the reach: Site 22 UU intake at Vyrnwy dam; Site 23 River Vyrnwy downstream of Vyrnwy dam; Site 39 River Vyrnwy Meifod Valley; 40 River Vyrnwy downstream Llanymynech; and 24 River Vyrnwy.

Reservoirs and associated releases can drastically affect the thermal regime of the river downstream, which may result in a reduction of summer temperatures and an increase in winter temperatures[19]. One of the most substantial ecological factors of rivers is temperature as species have evolved to exist in specific temperatures [20]. Diatom communities are considered to react to changes in environmental factors far quicker than larger communities such as macroinvertebrates[1]. It is suggested that diatom communities are negatively affected by changes in thermal regime with high-profile taxa being reduced by changes in temperature and flow from reservoir releases[1]. Literature associated with changes in diatom communities is rare however a lab-based

[14] Lock, M 1993, Attached microbial communities in rivers, In, Aquatic Microbiology. (Ed. T. Ford), Blackwell.

[15] Graham, AA 1990, Siltation of stone-surface periphyton in rivers by clay-sized particles from low concentrations in suspension, Hydrobiologia, vol.199, pp.107–115.

[16] Burns, A, Walker, KF 2000, Biofilms as food for decapods (Atyidae, Palaemonidae) in the River Murray, South Australia, Hydrobiologia vol.437, pp.83–90.

[17] Burns, A, Ryder, DS 2001, Potential for biofilms as biological indicators in Australian riverine systems, Ecological Management & Restoration vol.2 no.5, pp.3–64.

[18] Ryder, DS 2004, Response of epixylic biofilm metabolism to water level variability in a regulated floodplain river, Journal of the North American Benthological Society, vol.23, pp.214–223.

[19] Krajenbrink, H.J., White, J.C., Dunbar, M.J. and Wood, P.J., 2021. Macroinvertebrate and diatom community responses to thermal alterations below water supply reservoirs. *River Research and Applications*.

[20] Hussain, Q.A., 2012. Macroinvertebrates in streams: A review of some ecological factors. *International Journal of Fisheries and Aquaculture*, *4*(7), pp.114-123.

study in 1989 found that short-term changes in thermal regime significantly reduced high-profile taxa[21]. Similar results were observed in a study carried out downstream of three UK reservoirs, however this will have been affected by other changes in environmental conditions other than temperature[1]. This study aligns closely with the associated temperature and flow changes that will occur in the reservoir releases of this assessment.

Macroinvertebrates follow a similar trend to diatoms, negative responses to changes in temperature have been observed in a number of studies[22]. Macroinvertebrate communities in the river Severn have found to be negatively affected by temperature changes with taxa such as *A.aquaticus* and *E.octoculata* showing increased abundance in reaches of increased summer temperatures [23]. Macroinvertebrate communities have evolved in a way in which high-value taxa survive in constant specific temperature ranges. Emergence and hatching habits, along with other characteristics are affected by temperature[24].

Assessment of changes to temperature with changes in outflow volume show a weak relationship. Under the STT scheme operation to release an additional 25Ml/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.

As there is no distinct substantial water temperature change associated with the STT Solution, there is no pathway to change in the oxygen carrying capacity, the dissolved oxygen saturation, of the River Vyrnwy.

3.2.4 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 discernible change.

3.2.4.1 *Change to flow*

Downstream of the reservoir, the flow is increased by 25 Ml/d from the 23rd of May to the 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 Vyrnwy reservoir increases to approximately 5 % - 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 the 18th of October, the reference flow is 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 the 24th of May to the 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 the 18th of October. Again, the flow increase is less than the release flow because of losses.

Comparison of the baseline habitat at (45 Ml/d) compensation flow only and habitat under the 25 Ml/d Vyrnwy Reservoir flow augmentation release for STT shows only limited reductions in suitable habitat under the A82 Future scenario run, but thus is likely to exacerbate the effects of prolonged, large Severn Regulation releases included in the reference scenario.

Due to the complexity and volume of data, this is a brief overview of the potential changes only.

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

[21] Blinn, D. W., Truitt, R., & Pickart, A. (1989). Response of epiphytic diatom communities from the tailwaters of Glen Canyon Dam, Arizona, to elevated water temperature. *Regulated Rivers: Research & Management*, *4*(1), 91-96.

[22] White, J. C., Hannah, D. M., House, A., Beatson, S. J., Martin, A., & Wood, P. J. (2017). Macroinvertebrate responses to flow and stream temperature variability across regulated and non-regulated rivers. *Ecohydrology*, *10*(1), e1773.

[23] Worthington, T. A., Shaw, P. J., Daffern, J. R., & Langford, T. E. L. (2015). The effects of a thermal discharge on the macroinvertebrate community of a large British river: implications for climate change. *Hydrobiologia*, *753*(1), 81-95.

[24] Hussain, Q.A., 2012. Macroinvertebrates in streams: A review of some ecological factors. *International Journal of Fisheries and Aquaculture*, *4*(7), pp.114-123.

marginally to offsetting any losses as other areas of the river within the reach trend towards suitable hydraulic habitat with increasing flows.

3.2.4.2 *Changes to 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

Aerial imagery and extended and repeated walkover hydromorphological surveys undertaken[25] show that the reach is characterised by a mixture of deep glides and runs, with occasional riffle sections, including a distinctive riffle to rapid section at Ironbridge. Sediment bars are rare throughout the reach, although there are multiple islands scattered throughout the reach. Bed sediments information from the repeated walkovers indicate a range of substrates dependent on site, including clay bed and bedrock sections, gravel dominated sections and some areas of coarser bed material and some of finer. The majority of banks outside of urban areas range from moderate to steep with occasional shallow banks and bank erosion is relatively common. Within urban areas there is increased reinforcement and re-sectioning of banks, especially in the larger urban areas.

The macroinvertebrate, macrophyte and phytobenthos communities are representative of the habitats in this reach. The baseline data suggest that the macroinvertebrate community is sensitive to water quality and flow changes. It is noted that the community has a preference for moderately fast to fast flowing water and appears to be unaffected by high flows. It is noted that the data are reflective of where sampling is usually undertaken as sampling occurs in shallower areas such as riffles. The majority of the reach is characterised by deeper, slow flowing areas.

The macrophyte community within this reach is indicative of a low energy flow velocity community susceptible to increasing flow velocities, dominated by taxa that are indicative of moderately enriched waters. The phytobenthos community is also indicative of moderate nutrient conditions.

Several species of mayfly are present within this reach which are listed as Priority Species (e.g. *Caenis pseudorivulorum*, *C. pusilla*, *Ephemerella notata* and *Rhithrogena germanica*. Additionally, several IUCN Red List of Threatened Species are present in the reach, includes the caddisflies *Setodes punctatus* and *Silo pallipes* and the dwarf pond snail *Galba* (*Galba*) *truncatula*.

3.3.2 Relevant impact pathways

Considering the baselines for the macroinvertebrate, macrophyte, and phytobenthos communities and the operational pattern, the support releases could cause changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species and macrophytes;
- Direct washout of macroinvertebrate eggs and macrophyte seeds and plant fragments;
- Direct washout/loss of species with a preference for slow/moderate flows;
- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa;
- Inundation of marginal habitats where macrophyte species provide cover and spawning habitat for certain fish species;
- Washout of early plant growth in spring; and
- Increased erosion and siltation in some areas including the loss of fine sediment in sensitive habitats.

[25] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 3 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

3.3.3 STT operation – current conditions

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

3.3.3.1 *Change to flow, velocity and depth*

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.

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.

Habitats in this reach are generally uniform with some change in availability near the numerous weirs. The modelled changes are summarised as follows:

- Under the A82 scenario, there is an increase in depth between 28th June and 10th October. Over this period the depth increases by between 0.6% and 15.5% with the depth ranging between 0.68 m and 2.28 m (with a mean depth of 0.97 m) compared to the reference which ranged between 0.59 m and 2.26 m (with a mean depth of 0.91 m).
- Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 0.2 % and 2.1 % with the scenario velocities ranging between 0.55 m/s and 0.70 m/s (with a mean velocity of 0.57 m/s) compared to the reference which ranged between 0.54 m/s and 0.69 m/s (with a mean velocity of 0.57 m/s).
- Under the M96 scenario, there is an increase in depth between 13th June and 30th October. Over this period the depth increases by between 0.4% and 17.3% with the depth ranging between 0.64m and 1.26m (with a mean depth of 0.80m) compared to the reference which ranged between 0.58m and 1.19m (with a mean depth of 0.71m).
- Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 0.2% and 2.5% with the scenario velocities ranging between 0.55 m/s and 0.59 m/s (with a mean velocity of 0.56m/s) compared to the reference which ranged between 0.53 m/s and 0.59 m/s (with a mean velocity of 0.55 m/s).

As noted above, the overall dominant habitats within the reach will remain present through the operation of the scheme. The results show that the change in flow is not discernible and will not impact on aquatic communities assessed within this report. The changes in depth and velocity detailed above will not likely result in an adverse impact on the preferred flows of the macroinvertebrate communities within the reach, which are typically representative of a deep, slow and generally uniform watercourse.

This conclusion is evidenced when comparing photographs taken under different flow conditions in 2021. **Figure 3.2** 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 of June 2021 when water levels in the River Severn were at 0.644m (as measured on the River Severn at Montford) and 14th of October 2021 when water levels in the River Severn was at 0.813m (as measured on the River Severn at Montford). This represents a level increase of ~17cm and despite the noticeable level increase the dominant preferred habitat remained and the overall habitat availability has not changed. While there is a slight increase in wetted margins, no significant change in depth is observed and extensive marginal habitats are still available. The slight increases seen in habitat under higher flows are likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins. It is important to note this represents an increase in flow of 251Ml/d and not the 205Ml/d that would be observed in this reach under the STT scheme, and so the effect is greater than the STT operation.

This conclusion is further supported by targeted hydraulic surveys that were completed in June and October 2021 at a site on the River Severn near Montford. Two surveys were completed with flows of 697Ml/d on 15 June 2021 and 948Ml/d on 14 October 2021 (a difference of 251Ml/d), representing flows that are slightly above those that would be observed during a fully supported STT in this reach. The results of the analyses are provided in Annex A of the Physical Environment Assessment Report[26].

Velocities during these surveys showed an increase from 0.202m/s to 0.272m/s. Similarly, the surveys on the River Severn (upstream of the confluence with the River Tern) shows that total flow as measured during the June and October surveys increased by up to 320Ml/d. This is on account of accretion from tributaries between Montford and downstream Shrewsbury. Despite the significant increase in flow, average velocities only increased by 0.07m/s and the change in average velocities will be much lower when considering the discharge upstream will only be 180Ml/d.

The associated changes in flow are not considered to be significant enough to result in a noticeable or measurable change in the marginal macrophyte community. The uniform, slow and deep nature of the reach is likely to be retained and hence there is unlikely to be any change in the macrophyte community. Overall, no impact is expected on the macroinvertebrate, macrophyte, and phytobenthos communities as a result of hydrological and hydraulic changes in this reach under the current scenario conditions. This includes those protected species listed above.

3.3.3.2 *Changes to water quality*

There is no pathway for changes in general or chemical water quality changes, nor changes in olfaction change in this reach from STT operation. 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) can be reviewed in the Gate 2 Environmental Water Quality Evidence Report [27]. This bespoke evidence for the STT solution is available for one site in this reach:[25] River Severn (upper) downstream Option 4.

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[26] 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.

[27] 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.

Figure 3.2 Photographs showing the River Severn downstream of Shrewsbury (at Atcham on 15th of June 2021 (top) and 14th of October 2021 (bottom)

Note: Water levels were 0.644m and 0.813m on 15th June 2021 and 14th October 2021 respectively (as measured at Montford). Measured data indicates a difference in flow of 320Ml/d

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 current condition 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 discernible 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 within the reach are outlined within Section 3.3.3.1 of the STT Physical Environment Report. 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 *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

Aerial imagery and the extended and repeated walkover hydromorphological surveys[28] show that the river is characterised by deep glides in this reach. Sediment bars are rare throughout the reach, although there are multiple islands scattered throughout the reach. No information on bed sediments within the reach is available. The majority of banks outside of urban areas appear to range from moderate to steep with occasional shallow banks, and bank erosion is relatively common. Within urban areas there is increased reinforcement and re-sectioning of banks, especially in the larger urban areas.

The macroinvertebrate, macrophyte, and phytobenthos communities are representative of the habitats in this reach. The baseline data suggest that the macroinvertebrate is sensitive to water quality and flow changes. It is noted that the community has a preference for moderately fast to fast flowing water and appears to be unaffected by high flows. It is noted that the data are reflective of where sampling is usually undertaken as sampling occurs in shallower areas such as riffles. The majority of the reach is characterised by deeper, slow flowing areas.

The macrophyte community is indicative of a low energy flow velocity community susceptible to increasing flow velocities, dominated by taxa that are indicative of some moderately enriched waters. The phytobenthos community is also indicative of moderate nutrient conditions.

Several species of macroinvertebrate are present within this reach which are listed as Priority Species, including caddisflies such as *Allotrichia pallicornis* and *Oecetis notata*, the mayfly *Caenis beskidensis*, the riffle beetle *Oulimnius troglodytes* and the water snipe fly *Atrichops crassipes*.

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[28] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 3 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

3.4.2 Relevant impact pathways

Considering the baselines for the macroinvertebrate, macrophyte, and phytobenthos communities in relation to the STT operational pattern, the support releases could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species and macrophytes;
- Direct washout of macroinvertebrate eggs and macrophyte seeds and plant fragments;
- Direct washout/loss of species with a preference for slow/moderate flows;
- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa;
- Inundation of marginal habitats where macrophyte species provide cover and spawning habitat for certain fish species;
- Washout of early plant growth in spring; and
- Increased erosion and siltation in some areas including the loss of fine sediment in sensitive habitats.

3.4.3 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.

3.4.3.1 *Change to flow, velocity and depth*

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 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 205 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 modelled long profile shows that on the 25th 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 Kidder Callows (at 183 km) and Knightsford (at 206 km).

Habitats in this reach are generally uniform with some change in availability near the numerous weirs. The modelled changes are summarised as below.

- The most discernible change **at Bewdley** as a result of the increased flows will be an average daily velocity increase of 0.1 – 15.5% from June to October in the A82 scenario and an average daily increase in velocity of 8.5 – 16.7% from June – November in the M96 scenario. The average daily increase in water depth will be 1.6 – 3.3% from June to October in the A82 scenario, and 8.5 – 16.7% increase in June – November in the M96 scenario. The resulting change in velocity and depth will not be discernible, with velocity in summer expected to increase by ~0.03m/s and depths by ~3cm. As a result, average velocity in summer will remain at ~0.18m/s and depths will remain at ~1.9m.

The impact of the STT scheme near Upton Ham is taken from the change at the Saxon Lode gauge, with supported flow increase of 2.55 m^3/s. The flow is increased by 0.6 % in the 50 % Annual Exceedance Probability (AEP) (2 year return period) and by 0.3 % in the 2 % AEP (50 year return period). The impact on the frequency at which flooding occurs is therefore, minor. The flood levels are increased by around 15 mm in the frequent AEPs based on the change at the Bewdley gauge, as extreme water level results were unavailable at Saxon Lode[29].

[29] HR Wallingford (2022). Severn Thames Transfer SRO – Hydraulic and Water Quality Modelling, Flooding Assessment. Report for Ricardo, 1 – 43.

As noted above, the overall dominant habitats within the reach will remain present through the operation of the scheme. The results show that the change in flow is not discernible and will not impact the aquatic communities assessed within this report. The change in depth and velocity detailed above will not likely result in a change to the preferred flows of the macroinvertebrate communities within the reach, which are typically representative of a deep, slow and generally uniform watercourse.

The potential changes in velocity and depth are not considered to be of a magnitude to affect habitat availability for the macroinvertebrate, macrophyte, and phytobenthos communities in this reach. The velocity and depth that would be observed under an unsupported and fully supported STT remain similar to baseline conditions and within the preferred and optimum requirements for the baseline communities associated with the reach.

The associated changes in flow are not considered to be significant enough to result in a noticeable or measurable change in the marginal macrophyte community, as the community's preferred habitat of a generally uniform, slow and deep nature will be retained.

This conclusion is supported by field surveys that were completed in 2021. **Figure 3.3** shows the River Severn downstream of the confluence with the River Teme on two separate dates in July 2021: 14th July when the water level (as measured at Saxon Lode) was at 0.482m and 20th July 2021 when the water level was 0.420m. The results of the analyses are provided in Annex A of the Physical Environment Assessment Report[30].

Figure 3.3 Photographs showing the River Severn downstream of the River Teme confluence on 14th of July 20210 (left) and 20th of July 2021 (right) when levels were at 0.482m and 0.420m respectively (as measured at Saxons Lode)

The water level difference between the two dates represents ~6cm and there is no perceptible change in habitat availability for the macroinvertebrate, macrophyte, and phytobenthos communities at this location. The minimal change in depth was also apparent during surveys completed in October 2021 (when compared to the surveys in July 2021). During the October 2021 surveys the measured flow, at the site on the River Severn downstream of the River Teme, was 2,046Ml/d compared to 1,569Ml/d on 20th July 2021. The resulting change in depth was only ~2cm with average velocities changed by 0.04m/s.

[30] 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.

Overall, no impact on the macroinvertebrate, macrophyte, and phytobenthos communities as a result of hydrological and hydraulic changes are expected in this reach under the current conditions. This includes those protected species listed above.

3.4.3.2 *Changes to water quality*

A current flow conditions assessment of environmental water quality effects from the STT 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 by wastewater discharges (e.g., Worcester WwTW) 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).

With the A82 and M96 scenarios, hydraulic habitats remain fairly constant.

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.

3.4.4.3 *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 macroinvertebrate, macrophyte, and phytobenthos communities in this reach are 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: (a) the River Avon upstream of Alveston which is not navigable and (b) the River Avon downstream Alveston to confluence with the River Severn which is navigable.

The river flows through an extensive and wide floodplain for its length. Aerial imagery and extended and repeated walkover hydromorphological surveys undertaken[31] show that reach is characterised by a mixture of glides and runs, with occasional riffle sections and rapids at weirs. There are ~26 weirs located along the

[31] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 4 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

reach, of which at least 17 are located on bifurcations and have associated bypass locks for navigation purposes on the opposite bifurcation arm.

The baseline data suggest that the macroinvertebrate community within the River Avon, from downstream of Warwick to the confluence with the River Severn, has a low to moderately sensitivity to water quality and flow changes, with a weak negative downstream trend indicative of cumulative pressures such as water quality and habitat loss.

Similarly, the macrophyte community is representative of a community of low energy flows and a medium to highly enriched watercourse. The available phytobenthos data also suggest that the community is indicative of moderate nutrient conditions.

Several species of macroinvertebrate are present within this reach which are listed as Priority Species, including caddisflies such as Ceraclea albimacula and Potamophylax rotundipennis, the riffle beetle Oulimnius troglodytes and the water beetle, Peltodytes caesus.

It is noted that the weir pools and the bifurcations within the River Avon, downstream of Alveston, provide some habitat diversity. There is little information (published research or anecdotal) as to the importance of weir pools for macroinvertebrates and aquatic plants. However, good habitat and greater species richness is often found downstream of weirs, with both faster and slower flow loving taxa found in the downstream reach particularly in tail riffle/bar areas downstream.

3.5.2 Relevant impact pathways

Considering the baselines for the macroinvertebrate, macrophyte, and phytobenthos communities in relation to the operational pattern, the STT releases could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species, macrophytes and phytobenthos;
- Direct washout of macroinvertebrate eggs and macrophyte seeds and plant fragments;
- Direct washout/loss of species with a preference for slow/moderate flows;
- Increased velocities could result in scour of biofilm in weir pool habitats;
- Changes in local water levels, splash zones, and humidity affect diatom community composition;
- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa, change phytobenthos community composition and result in the proliferation of algal growth;
- Inundation of marginal habitats where macrophyte species provide cover and spawning habitat for certain fish species; and
- Washout of early plant growth in spring.

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 flow, velocity and depth*

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 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 5th 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.

As noted above, the habitat availability and the resulting impacts of the increased flows on habitat quality and quantity as a result of changes in velocity and depth will differ when comparing the reaches upstream and downstream of Alveston.

- The most discernible change **upstream of Alveston** as a result of the increased flows will be an average daily increase of 35.9 – 42 % in velocity in the months of July, August and September in an A82 scenario and an average daily increase in velocity of 19 – 50 % in the months of June – October in M96 scenario (as measured downstream of Warwick). The potential changes in depths have been assessed as a maximum increase of 1.7% (~4 cm) in both scenarios and is not considered discernible in consideration of the geomorphology. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.02 m/s in both scenarios
- The most discernible changes **downstream of Alveston** as a result of the increased flows will be an average daily increase of 20.9 – 25.7 % in velocity in the months of July, August and September in an A82 scenario and an average daily increase in velocity of 21.7 – 24.5 % in the months of July – October in M96 scenario. The potential changes in depths have been assessed as a maximum increase of 1 % (~2 cm) in both scenarios and is not considered discernible in consideration of the geomorphology. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.03 m/s in both scenarios.
- The most discernible change **upstream of the confluence with the River Severn** as a result of the increased flows will be an average daily increase of 18.6– 26.4 % in velocity in the months of July, August and September in an A82 scenario and an average daily increase in velocity of 21.9 – 25.9 % in the months of July – October in M96 scenario. No change in depth has been identified in either of the scenarios. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.01 m/s in both scenarios.
- The impact of the STT scheme on the lower River Avon is taken from the change at the Evesham gauge, including the additional flow from the Minworth component of the STT scheme, supported flow increase of 1.33 m^3/s. The flow is increased by 0.8 % in the 50 % AEP (2 year return period) and by 0.3 % in the 2 % AEP (50 year return period). The impact on the frequency at which flooding occurs is therefore, minor. The flood levels are increased by around 10 mm in the frequent AEPs[32].

Under both the A82 and the M96 scenarios, there is an increase in level between the end of June and mid-October with increased levels also observed into late October. The potential changes in velocity and depth are generally not considered to be of a magnitude to result in impacts on the macroinvertebrate, macrophyte, and phytobenthos communities.

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 0.02 m/s. The result will be that velocities in this reach will be ~ 0.07 m/s instead of 0.05 m/s. The assessment is further supported by data collected during hydraulic surveys in 2021. Two surveys were completed under two different flows, 229Ml/d measured on 16 and 20 July 2021 and 381Ml/d measured on 26 October 2021, a difference of 152Ml/d. The surveys were completed in the reach downstream of Warwick and it should be noted that the flows during the surveys was higher than the proposed release of 115Ml/d thus the change observed is greater than to be expected under the operation of the STT scheme.

There is a risk of an impact on the macroinvertebrate and macrophyte communities in the reaches upstream of Alveston with the potential changes in flow. Although depths and velocity will remain within the preferred conditions for the baseline ecological communities, it is evident that there will be an increase in wetted widths (see **Figure 3.4**). The increase in wetted widths could result in a loss of some marginal habitat that will be

[32] HR Wallingford (2022). Severn Thames Transfer SRO – Hydraulic and Water Quality Modelling, Flooding Assessment. Report for Ricardo, 1 – 43.

preferred by macroinvertebrates groups with a preference for slow flowing water (e.g., dragonflies and damselflies). The increase in wetted width could also reduce habitat availability for marginal macrophyte species, although this will provide additional habitat for macrophytes and macroinvertebrates for a preference for moderate to fast flowing water.

The minor change in habitat is 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) and 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 is evident as a result of the increase in wetted width in October 2021 (noting this represents an increase of 152Ml/d). The difference in flow when comparing the two surveys in July 2021 was approximately 70Ml/d.

As discussed above, although the proportionate increase in velocity would range between 18.6– 26.4%, flows would remain <0.04m/s in the lower reaches and <0.15m/s in the reaches downstream of Evesham. Therefore, it is unlikely that an increase in flows will result in an impact on the preferred flows and/or habitats for macroinvertebrate species, macrophytes and phytobenthos within the impounded areas between the various locks/weirs.

This conclusion is also evidenced by photographs that were taken during walkovers in 2021 at different water levels. **Figure 3.5** shows the River Avon at Evesham on 20th July 2021 when water levels were 0.420m and 5th August 2021 when levels were at 0.513m (both as measured at Evesham). This represents the maximum change in level that would be experienced as a result of a 115Ml/d discharge and no changes in habitat were discernible. As discussed above, although the proportionate increase in velocity would range between 18.6–26.4%, flows would remain <0.04m/s in the lower reaches and <0.15m/s in the reaches downstream of Evesham.

Figure 3.4 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 1.12m, 1.14m and 1.53m respectively (as measured at Warwick).

Figure 3.5 Photographs showing the River Avon at Evesham on 20th of July 20210 (top) and 5th of August 2021 (bottom) when levels were at 0.42m and 0.51m respectively (as measured at Evesham)

3.5.3.2 *Changes to water quality*

Similar changes in water quality are generally predicted for both the A82 and the 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^{0}C;
- The discharge will reduce dissolved oxygen immediately downstream of the outfall up to the confluence with the River Leme by ~1.5mg/l. Dissolved oxygen (as % saturation) will remain above 75% within the first 20km and remain above 90% for the remainder of the reach, up to the confluence with the River Severn; and
- Ammoniacal nitrogen is expected to increase by 0.1-0.15mg/l downstream of Warwick with the increase of 0.05mg/l at Evesham and 0.02mg/l at the confluence with the River Severn. Soluble reactive phosphate concentrations are reduced by the scheme throughout the River Avon by up to 0.1mg/l.

The results of the water quality modelling indicate that changes are expected to be minimal with a slight decrease in some nutrients. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. Therefore, no significant impacts are anticipated on the macroinvertebrate, macrophyte, and phytobenthos communities.

Dissolved oxygen is used by all forms of aquatic life in surface water, including macroinvertebrate, macrophyte, and phytobenthos communities. Dissolved oxygen concentrations in shallow vegetated areas of aquatic systems can be dynamic within a watercourse, and are particularly sensitive to water temperature: warmer water can hold less dissolved oxygen, with concentrations generally lowest in summer. As noted above, dissolved oxygen (as % saturation) remains above 75% within the first 20km and remains above 90% for the remainder of the reach, up to the confluence with the River Severn. This effect on dissolved oxygen (as % saturation) reflects a likely reduction of 2% within the first 20km.

As such the change is not considered to be of a magnitude that would affect the macroinvertebrate, macrophyte, and phytobenthos communities.

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, 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.

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 data show that that there is a fairly wide range of suitable habitat present in the reach. There is indicated to be minimal change in baseline habitat for the A82 and M96 flows, though there are some gains and losses for A82 and increasing 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 *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 macroinvertebrate, macrophyte, and phytobenthos communities in this reach are representative of the local geomorphology. The reach is representative of a typical low land river and characterised mostly by deep glides and runs, with the bed 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 baseline data suggest that the macroinvertebrate community within the River Severn from downstream of confluence with the River Avon to the tidal limit has a moderate to low sensitivity to water quality and flow changes. The community is dominated by taxa with a preference for slow flowing water.

The macrophyte community is representative of a community with a preference for moderate energy flow velocities and moderately enriched waters. Similarly, the phytobenthos community is indicative of moderate/high nutrient conditions.

Two species of macroinvertebrate are present within this reach which are listed as Priority Species, including the mayflies *Caenis pusilla* and *Potamanthus luteus*.

3.6.2 Relevant impact pathways

Considering the baselines for the macroinvertebrate, macrophyte, and phytobenthos communities in relation to the operational pattern, the support releases could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species and macrophytes;
- Direct washout of macroinvertebrate eggs and macrophyte seeds and plant fragments;
- Direct washout/loss of species with a preference for slow/moderate flows;
- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa;
- Inundation of marginal habitats where macrophyte species provide cover and spawning habitat for certain fish species;
- Washout of early plant growth in spring; and
- Increased erosion and siltation in some areas including the loss of fine sediment in sensitive habitats.

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.

3.6.3.1 *Change to flow, velocity and depth*

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.

The increase in flow upstream of Deerhurst, 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 30th June to the 12th of October in the A82 scenario and from 15th June to 2nd November in the M96 scenario. The flow increase during the summer period is around 309 Ml/d.

Habitats in this reach are generally uniform with some change in availability near the Upper Lode weir:

- The most discernible change **at the Upper Lode weir/downstream of the confluence with the river Avon** as a result of the increased flows will be an average daily increase of 4.3- 12.6 % in velocity in the months of June - October in an A82 scenario and an average daily increase in velocity of 3.2 – 15.7 % in the months of June – November in M96 scenario. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.02 m/s in both scenarios. The modelled data shows that depth will not change during operation, although a slight decrease in depth is noted in October (~0.5 cm).
- The most discernible changes **downstream of Upper Lode weir/upstream of Deerhurst** as a result of the increased flows will be an average daily increase of 0.1- 15.1 % in velocity in the months of June - October in an A82 scenario and an average daily increase in velocity of 1.9 – 18.4 % in the months of June – November in M96 scenario. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.02 m/s in both scenarios. The modelled data shows that depth will not change during operation, although a slight decrease in depth is noted in October (~0.5 cm).

As noted above, the overall dominant habitats within the reach will remain present through the operation of the scheme. The results show that the change in flow is not discernible and will not have an impact on aquatic communities assessed within this reach. The changes depth and velocity detailed above will not likely result in a change to the preferred flows of the macroinvertebrate communities within the reach, nor result in the washout of any incubating eggs or young established plants.

The potential changes in velocity and depth are not considered to be of a magnitude to affect habitat availability for the macroinvertebrate, macrophyte, and phytobenthos communities in this reach. This is because the velocity and depths that would be observed under an unsupported and fully supported STT are similar to baseline conditions, and are within the preferred and optimum requirements for the baseline communities associated with the reach.

The associated changes in flow are not considered to be significant enough to result in a noticeable or measurable change in the marginal macrophyte community, as the community's preferred habitats of a generally uniform, slow and deep nature will be retained.

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. Two surveys were completed under flows of 1,926Ml/d measured on 15 and 21 July 2021, and 3,367Ml/d measured on 28 October 2021: a difference of 1,441Ml/d. The results of the analyses are provided in Annex A of the Physical Environment Assessment Report[33]. The hydraulic data indicates that the reach is generally uniform, slow and deep nature, with limited variation in flow habitats. Any changes in 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 impact on habitat availability will be limited.

Overall, no impacts on the macroinvertebrate, macrophyte, and phytobenthos communities are expected as a result of hydrological and hydraulic changes in this reach under the current conditions.

3.6.3.2 *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 and are summarised below:

- In the River Severn upstream of Deerhurst, water temperature is not predicted to change due to STT operation;
- Dissolved oxygen concentrations, nor saturations, are not predicted to change due to STT operation;
- Ammoniacal nitrogen concentrations are also not predicted to change due to STT operation; and
- Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.05 mg/l during the operation of STT.

As there are no changes in the physico-chemical characteristics of the water, no impacts on the macroinvertebrate, macrophyte, and phytobenthos communities are expected. The decreased phosphate concentration would provide a potential benefit to the reach through a reduction in the potential for algal growth.

[33] 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.

The non-discernible change in water quality will not affect any macrophytes that may provide some cover/habitat for fish in this reach.

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 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. 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 *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 UKCIP34 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[35]. 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.

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

3.7.1 Baseline

The macroinvertebrate, macrophyte, and phytobenthos communities in this reach are representative of the local geomorphology. Aerial imagery and extended and repeated walkover hydromorphological surveys undertaken[36] show that the river is characterised by mostly slow flowing deep glides and runs, with the bed

[34] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/summaries/headline-findings

[35] https://check-for-flooding.service.gov.uk/station/2078

[36] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 4 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

likely dominated by coarse material based on the upstream reaches. It is representative of a typical lowland river. The majority of banks appear to range from moderate to steep with occasional shallow banks. Bank erosion is present but not common.

The baseline data suggest that the macroinvertebrate community within the River Severn, from downstream of Deerhurst to the tidal limit, has a moderate to low sensitivity to water quality and flow changes. The community is dominated by taxa with a preference for slow flowing water.

The macrophyte community is representative of a community with a preference for low energy flow velocities and moderately enriched waters. Similarly, the phytobenthos community is indicative of moderate/high nutrient conditions.

Two species of macroinvertebrate are present within this reach which are listed as Priority Species: the mayflies *Caenis pusilla* and *Potamanthus luteus*.

3.7.2 Relevant impact pathways

In environmental terms, unsupported STT abstraction would be limited by the licenced hands-off flow conditions as set out in **Section 1.3**. Due to these conditions, the greatest impact on pass forward flows would either be at the lowest remaining flow conditions, or highest abstraction rate. The greatest impact of the operation of the STT under the lowest remaining flow conditions would be an abstraction of 172Ml/d when river flows at Deerhurst equates to 2,740Ml/d: this would reduce flow at Deerhurst to 2,568Ml/d. The greatest impact of the operation of the STT under the highest abstraction rates would be an abstraction of 500Ml/d when river flows at Deerhurst are 3,661Ml/d: this would reduce flow at Deerhurst to 3,161Ml/d. These changes in flow due to the operation of the STT scheme occur against a dynamic regime in the River Severn.

Considering the baseline macroinvertebrate, macrophyte, and phytobenthos communities and the operational pattern, the supported and unsupported abstraction could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Decreased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species and macrophytes;
- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa;
- Exposure of marginal habitats where macrophyte species provide cover and spawning habitat for certain fish species; and
- Increased erosion and siltation in some areas including the loss of fine sediment in sensitive habitats.

3.7.3 STT operation – current conditions

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

3.7.3.1 *Change to flows, velocity and depth*

In this reach, the STT solution would abstract flow for transfer in the STT interconnector. The abstraction regime is dependent on the maturity of the STT solution. For the early phase STT, abstraction would be unsupported up to 500Ml/d at selected times, subject to hands-off flow conditions identified by EA. The indicative system operation pattern shows the STT solution abstraction occurring in 24 of the 47 years, and on 11% of days overall.

3.7.3.1.1 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.

3.7.3.1.2 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.

Habitats in this reach are generally uniform with some change in availability near the Maisemore weir:

- The most discernible change in an unsupported abstraction will be an average daily decrease of 4.6 % in velocity in November in an A82 scenario and an average daily increase in velocity of 2.5 % in December in an M96 scenario. As a result, the proportionate change in the average velocities will not be discernible. The change in depth in both scenarios is not expected to exceed 2 % which equates to approximately 2 cm in autumn noting that depths will exceed 3.6 m.
- The most discernible change in a supported abstraction will be an average daily decrease of 2.1- 4.6 % in velocity in the months of September - November in an A82 scenario and an average daily increase in velocity of 0.1 – 4.6 % decrease in velocity in the months of October to January in M96 scenario. Depths are likely to decrease by 0.5 – 1.9 % between September and November in the A82 scenario and 0.1 – 1.9 % in the M96 scenario. As a result, the proportionate change in the average velocities will not be discernible. The change in depth in both scenarios is not expected to exceed 2 % which equates to approximately 2 cm in autumn noting that depths will exceed 3.6 m.
- The impact of the STT scheme near Gloucester is taken from the change at the Deerhurst gauge with an increased flow of 3.87 m^3/s. The flow is increased by 0.7 % in the 50 % AEP (2 year return period) and by 0.4 % in the 2 % AEP (50 year return period). The impact on the frequency at which flooding occurs is therefore minor. The flood levels are increased by around 6 mm in the less frequent AEPs based on the change at the Deerhurst gauge. As data was not available for the frequent floods an increase of around 10 mm was inferred from the Avon at Evesham and Severn at Bewdley[37].

From the results it is evident that the change in flow is not discernible and will not affect the overall dominant habitats within the reach, which will remain present through the operation of the scheme. The potential changes in velocity and depth are not considered to be of a magnitude to affect habitat availability for the macroinvertebrate, macrophyte, and phytobenthos communities in this reach: the velocity and depths observed under an unsupported and fully supported STT operation are similar to baseline conditions, and remain within the preferred and optimum requirements for baseline communities associated with the reach.

This is evident when comparing photographs taken under different flow conditions in 2021. These photographs 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 3.6** shows the River Severn downstream of the Deerhurst on two separate dates in 2021, namely the 21st of July 2021 when the water level (at Deerhurst) was at 0.584m, and the 13th of August 2021 when water level was 0.692m. This represents a difference in level of ~10cm and there is no perceptible change in habitat availability for macroinvertebrate, macrophyte, and phytobenthos communities at this location.

This conclusion is further supported by targeted hydraulic surveys that were completed in July and October 2021 in the River Severn near Deerhurst. Two surveys completed under flows of 1,926Ml/d measured on 15 and 21 July 2021 and 3,367Ml/d measured on 28 October 2021: a difference of 1,441Ml/d. The survey data indicate that the increase in flow of 1,444Ml/d only results in a change in velocity of 0.17m/s with velocities remaining at 0.0325m/s (slow flowing water) and average depths changing by ~10cm. This change results from a significantly higher flow change that would be observed under a supported or unsupported STT. The results of the analyses are provided in full in Annex A of the Physical Environment Assessment Report[38].

Overall, no impacts are expected on the macroinvertebrate, macrophyte, and phytobenthos communities as a result of hydrological and hydraulic changes in this reach under the current conditions.

[37] HR Wallingford (2022). Severn Thames Transfer SRO – Hydraulic and Water Quality Modelling, Flooding Assessment. Report for Ricardo, 1 – 43.

[38] 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 3.6 Photographs showing the River Severn downstream of the Deerhurst on 21st of July 2021 (top) and 13th August 2021 (bottom) when levels were at 0.584m and 0.692m respectively (as measured at Deerhurst)

3.7.3.2 *Changes to water quality*

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT operation and 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%sat);
- 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.

The results of the water quality modelling indicate that changes are expected to be minimal, with a slight increase in ammoniacal nitrogen concentrations expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. Therefore, no significant impacts are anticipated on the macroinvertebrate, macrophyte, and phytobenthos communities.

Dissolved oxygen concentrations in shallow vegetated areas of aquatic systems can be dynamic within a watercourse and is used by all forms of aquatic life in surface water, including macroinvertebrate, macrophyte, and phytobenthos communities. Dissolved oxygen concentrations within a watercourse are influenced by water temperature: warmer water holds less dissolved oxygen, with concentrations generally lowest in summer. As noted above, dissolved oxygen (as % saturation) will remain high, with the reduction in dissolved oxygen (as % saturation) being likely less than 1%.

As such the change is not considered to be of a magnitude to affect the macroinvertebrate, macrophyte, and phytobenthos communities.

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 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).

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 *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.

3.8 THE SEVERN ESTUARY DOWNSTREAM OF THE TIDAL LIMIT AT GLOUCESTER

3.8.1 Baseline

Downstream of the normal tidal limit 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 2.3km seawards.

The habitats within the Severn Estuary support a number of fish and bird communities that are qualifying features of the Severn Estuary European Marine Site. It is well known that many of the fish and most of the wading birds and waterfowl within the assemblage, including the internationally important population of waterfowl, feed on invertebrates within and on the sediments of the intertidal mudflats and sandflats. The shingle and rocky shores section of the estuary where saline and freshwaters meet are also known to provide habitat for Twaite shad, which feed upon a variety of invertebrates including crustacean, mysids and copepods, small fish and fish eggs.

Seagrass beds are one of the most productive habitats of shallow water coastal ecosystems supporting large numbers of algae, invertebrates and fish and are an important food source for several species of ducks and geese including wigeon and European white-fronted geese. The *Zostera* beds in the Severn are unusual in that they occur in an area of mixed cobbles, sand and mud with large boulders; in other parts of Wales they are associated with mudflats.

3.8.2 Relevant impact pathways

In environmental terms, unsupported STT abstraction would be subject to licenced hands-off flow conditions as set out in **Section 1.3**. Under these conditions, the greatest impact on pass forward flows would either be at the lowest remaining flow conditions, or highest abstraction rate. The greatest impact of the STT operation under lowest remaining flow conditions would be an abstraction of 172Ml/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 the highest abstraction rates would be an abstraction of 500Ml/d at river flows at Deerhurst of 3,661 Ml/d, reducing flow at Deerhurst to 3,161 Ml/d. These changes arising from the operation of the STT scheme are set against a dynamic flow regime in the River Severn.

Considering the baseline macroinvertebrate, macrophyte, and phytobenthos communities and the operational pattern, the support releases could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Impacts on the benthic invertebrate communities of the intertidal mudflats and shingle and rocky shores due to change in freshwater inflows and changes in water quality;
- Impacts on phytoplankton and zooplankton abundances due to changes in water quality;
- Impacts on the seagrass beds due to change in freshwater inflows and changes in water quality; and
- Impacts on saltmarsh habitat due to changes in freshwater inflows and 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[39], 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.

Overall, the changes in freshwater inflows into the Severn Estuary is not discernible.

As such, the changes in pass forward flow are not expected to affect the resident benthic macroinvertebrate and aquatic plant communities of the Severn Estuary. This is because the changes in the freshwater inflows will not be of a magnitude to impact the habitats that support these communities, 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 scenario reference condition.

Overall, no impacts on the macroinvertebrate and aquatic plant communities are expected as a result of hydrological and hydraulic changes in this reach under the current conditions.

3.8.3.2 *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 and are summarised below (see the Water Quality Assessment Report for more information):

- 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; and
- Oxidised nitrogen is increased by about 0.8 mg/l during the scheme (~10% increase on baseline). 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[40] for the 10 year period spanning 2013 to 2022. The 117 data points identify average 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 SRO's advanced treatment processes for the Minworth Transfer, the concentration of DIN in the discharge to the Avon could be 16.9 mg-N/l. Allowing for the expected removal rates of the Severn Trent Sources SRO's advanced treatment processes for the Netheridge Transfer, the concentration of DIN in the discharge to the Severn at Haw Bridge could be 15.8 mg-N/l. The assessment of the modelled output identifies the following points:

- For the full year of the A82 moderate-low flow year scenario, and including abstraction rates for full STT, the scheme 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; and
- 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

[39] 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.

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

Severn Estuary, of 112 tonnes from a baseline of 14,804 tonnes – a reduction of approximately 0.8%. 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 a small overall reduction in DIN input from the freshwater River Severn and Netheridge WwTW combined into the Severn Estuary as result of STT SRO. No impacts on supporting habitats within the Severn Estuary are expected.

Nitrogen (N) is an essential element for aquatic environments. Dissolved inorganic nitrogen (DIN) is the sum of nitrite, nitrate and ammonium, and DIN input can accelerate primary production and eutrophication, resulting in many negative responses, such as increased frequency of harmful algal blooms, hypoxic and anoxic bottom waters, loss of emergent plants, and reduced fish stocks in estuarine and coastal ecosystems. Estuaries receive continuous inputs of nutrients from human activities in the drainage basin, with different behavioural processes in clear and turbid waters. In turbid estuaries such as the Severn, phytoplankton production is often light limited year-round, and growth is low despite the high levels of nutrient input, including DIN. The estuarine nitrogen biogeochemical processes vary spatially and temporarily, and are also highly dependent on system-specific features. DIN is less particle active than other nutrients such as phosphate/ silicate, but may be removed by biological activities such as denitrification.

The dominant process adding nitrogen to the ocean, di-nitrogen (N2) fixation, is mediated by prokaryotes (diazotrophs) sensitive to a variety of environmental factors. Phytoplankton growth in the euphotic zone is commonly limited by the availability of nutrients such as nitrogen: it is often assumed that consequential increased rates of marine N2 fixation do not occur where concentrations of nitrate (NO−3) and/or ammonium (NH+4) exceed 1μM because of the additional energetic cost associated with assimilating N2 gas relative to NO−3 or NH+4[41].

Overall, there are no impacts expected on the macroinvertebrate and aquatic plant communities as a result of water quality changes in this reach under the current conditions. Decreased DIN concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not affect any supporting habitats for the designated communities of the Severn Estuary.

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 in which is longer than in the current climate, and this later seasonal trend may 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 in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters.

[41] Knapp AN. The sensitivity of marine N(2) fixation to dissolved inorganic nitrogen. Front Microbiol. 2012;3:374. Published 2012 Oct 19. doi:10.3389/fmicb.2012.00374

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.

Overall, there are no impacts expected on the macroinvertebrate and aquatic plant communities as a result of water quality changes in this reach under the current conditions. Decreased DIN concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not affect any supporting habitats for the designated communities of the Severn Estuary.

3.9 THE RIVER THAMES D/S CULHAM TO TIDAL LIMIT AT TEDDINGTON

3.9.1 Baseline

The reach is characterised by a mixture of deep glides and runs, with occasional rapids over weirs. No sediment bars are visible, although there are multiple islands scattered throughout the reach with the channel bifurcating around these, e.g. Penton Hook and Platt's Eyot. There is no information to classify the sediment size composing the bed substrate. Riverbanks outside of urban areas range from moderate to steep with occasional shallow banks; bank erosion is not common. Within urban areas aerial imagery indicates dominant reinforcement and re-sectioning of banks.

Most of the reach is navigable with numerous weirs and locks. In total there are 41 weirs located along the reach. More than half of these weirs are on bifurcations and have associated bypass locks for navigation purposes on the opposite bifurcation arm. Features of note are Days Weir, Benson Lock and Weir, Goring Lock, Pangbourne Lock, Mapledurham Lock, Sonning Lock, Hambleden Lock, Hurley Lock, Taplow Lock, Romney Lock, Windsor Cut and Old Windsor Lock, Bell Weir Lock, Penton Hook Lock, Chertsey, Shepperton Lock, Sunbury Lock, 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 km downstream.

The macroinvertebrate, macrophyte, and phytobenthos communities are representative of the habitats in this reach. The baseline data suggest that the macroinvertebrate community within the River Thames from Windsor to Teddington has a moderate to high sensitivity to water quality and flow changes. It is noted that the community has a preference for moderate to slow flowing water and increased flows may result in changes to the community structure. It is noted that the data are reflective of where sampling is usually undertaken as sampling occurs in shallower areas such as riffles. The majority of the reach is characterised by deeper, slow flowing areas.

The macrophyte community is indicative of a low energy flow velocity community susceptible to increasing flow velocities, dominated by taxa that are indicative of some moderately enriched waters. The phytobenthos community is also indicative of moderate nutrient conditions.

Several species of mayflies and caddis are present within this reach which are listed as Priority Species (e.g. *Ephemera lineata, Stenelmis canaliculate, Macronychus quadrituberculatus Kageronia fuscogrisea*, *Ceraclea albimacula, C. senilis, Leptocerus lusitanicus, Oecetis notata, Potamophylax rotundipennis* and *Limnephilus binotatus*.) This also includes the Riffle beetles *Oulimnius troglodytes* and *Riolus subviolaceus* which are included in the UK list of Priority Habitats and Species.

Two mollusc species are present within the reach, including Depressed River Mussel *Pseudanodonta complanate* and Fine-lined Pea Mussel *Pisidium tenuilineatum*.

3.9.2 Relevant impact pathways

Considering the baseline macroinvertebrate, macrophyte, and phytobenthos communities and the operational pattern of STT, the supported and unsupported abstraction could affect water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased velocities resulting in a direct loss of preferred flows and habitat for macroinvertebrate species, macrophytes and phytobenthos;
- Direct washout of macroinvertebrate eggs and macrophyte seeds and plant fragments;
- Direct washout/loss of species with a preference for slow/moderate flows;

- Changes in water quality (in particular orthophosphate concentrations, suspended solids, salinity and pH) could impact on the distribution of sensitive taxa macrophyte taxa; and
- Increased erosion and siltation in some areas including the loss of fine sediment in sensitive habitats.

3.9.3 STT operation – current conditions

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

3.9.3.1 *Change to flow, velocity and depth*

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 500Ml/d at selected times, subject to hands-off flow conditions in the River Severn at Deerhurst identified by EA. The indicative system operation pattern of the STT solution augments flow in 24 of the 47 years, and on 11% of days overall.

3.9.3.1.1 Early phase (Unsupported)

Flow augmentation at Culham in the early phase STT scheme occurs 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 $30^{th\ of}$ September to the $30^{th\ of}$ November, and in Scenario M96 from the $31^{st\ of}$ October to the $9^{th\ of}$ 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. 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 modelled long profile for A82 on the $23^{rd\ of}$ 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 ~100km downstream and then re-abstracted. The long profile for M96 on the $5^{th\ of}$ 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 ~100km downstream and then re-abstracted.

3.9.3.1.2 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 the $30^{th\ of}$ June to the $30^{th\ of}$ November, and in Scenario M96 from the $15^{th\ of}$ June to the $9^{th\ of}$ 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 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 ~100km downstream and then re-abstracted.

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 1 m. 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 1 m 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; and upstream of the River Pang and upstream of the Datchet intake average velocity would not fall below 0.25 m/s at times of operation of the STT solution. Impact assessment

Based on the modelling results above, during early phase STT it is evident that the change in flow is not discernible and will not impact on the macroinvertebrate, macrophyte, and phytobenthos communities as a result of hydrological and hydraulic changes in this reach under the current conditions. In addition, as the River Thames channel is managed for navigation, limited impacts on water depth as a result of the STT SRO are anticipated.

3.9.3.2 *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 %sat 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 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.

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.

Based on modelled outputs, no discernible impacts from changes in water quality are anticipated on protected species as the increases in ammoniacal nitrogen, phosphorus and dissolved oxygen saturation are minor and will not impact on the WFD status of the watercourse.

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 by 16% to 132% depending on the 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 assessment of effects on river level and velocity in the reach has not been completed for this draft of the report. It will be completed for the Gate 2 submission.

3.9.4.3 *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.

Based on modelled outputs, no discernible impacts from changes in water quality are anticipated on protected species as the increases in ammoniacal nitrogen, phosphorus and dissolved oxygen saturation are minor and will not impact on the WFD status of the watercourse.

4. CONCLUSIONS

4.1 SUMMARY OF THE EFFECTS UNDER CURRENT CONDITIONS

The results show that the potential changes in flow (as associated with either a supported or unsupported STT operation) are not considered discernible and will likely be within the inter-annual variations that would be observed under reference 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 in the River Vyrnwy, River Severn/ Severn Estuary, River Avon and River Thames and will likely be within the inter annual variations that would be observed under reference conditions.

The baseline data suggest that the communities within the River Vyrnwy there is a wide range of suitable habitats and flow types present in the reach for macrophyte and macroinvertebrate 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. The increased flows could impact on the biofilm community, a composition of phytobenthos.

The baseline data suggest that the macrophyte communities within the River Severn and River Thames are a primary component in terms of the productivity, however potential changes in flow will likely be within the inter annual variations that would be observed under reference conditions. Therefore, the implementation of the STT solution is not likely to result in consequential impacts on other communities supported by macrophyte productivity, community diversity and abundance, such as invertebrate and bird species which utilise macrophyte communities as refuge and feeding habitats.

The diatom community forms the basis of a food web or provides a source of food for protected species (e.g. lamprey ammocoetes). Though there remains limited information or available baseline data on the sensitivity of the diatom/phytobenthos communities, the baseline data suggest the potential changes in flow (as associated with either a supported or unsupported STT operation) are not considered discernible and will likely be within the inter annual variations that would be observed under reference conditions.

The results give evidence that the potential change in flow is not considered discernible, with the dominant flow types and preferred habitats for the macroinvertebrate communities within the River Severn and River Thames likely to be retained. As a result, the potential changes in flow (as associated with either a supported or unsupported STT operation) will not impact on availability, quantity and quality of habitat within the reaches.

In conclusion, the potential changes in velocity and depth (as associated with either a supported or unsupported STT operation) are also not considered to be of a magnitude to result in impacts on habitat availability for the macroinvertebrate, macrophyte, and phytobenthos communities as 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 is the reaches of the River Avon upstream of Alveston. From the modelled and observed data, it is evident that the increased flows would result in an increased in wetted width which will reduce habitat availability/suitability for macrophytes and macroinvertebrates with a preference for marginal habitats (slow flowing water).

Overall, changes in freshwater flow into the Severn Estuary will be minimal and the supporting habitats for the estuarine 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 solution.

The results of the water quality modelling show that water quality changes are 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, there are no changes in the physic-chemical characteristics of the water. The small decrease in DIN concentration would provide a potential benefit through a reduction in algal growth. The non-discernible change in water quality will not affect the supporting habitats for the designated fish community of the Severn Estuary.

4.2 SUMMARY OF THE EFFECTS UNDER FUTURE CONDITIONS

Under Future scenarios, the STT SRO would have a longer period of flow augmentation. As future baseline conditions typically have longer periods where low flow years occur, it is anticipated that the operation of STT SRO will have limited impacts on the macroinvertebrate, macrophyte, and phytobenthos communities and their supporting habitat. Limited changes to water quality were identified under future conditions.

4.3 UNCERTAINTY AND CONFIDENCE DATA GAPS

The available evidence and data are considered sufficient to inform the ecological requirements of the macroinvertebrate, macrophyte, and phytobenthos communities of the waterbodies associated with the STT solution for Gate 2. The additional evidence collected by the STT group has helped to reduce the uncertainty in the conclusion of the Gate 1 assessments.

It is recommended that the baseline monitoring programme for macroinvertebrate, macrophyte, and phytobenthos continues beyond Gate 2 to provide a minimum 3-year baseline.

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

- There is currently no measured data to inform the risk to weir pool habitats in the River Avon.

4.4 RECOMMENDATIONS FOR GATE 3

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

- 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.

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