South West Water Limited

River Lyd Drought Permit Environmental Assessment Report

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Project reference:	**P00011635**
Date of issue:	**March 2023**

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This is a draft report and should not be cited.

Revision and Amendment Register

Version Number	Date	Section(s)	Page(s)	Summary of Changes	Approved by
1.0	14/03/2023	All	All	Draft for client review	HW
2.0	15/03/2023	All	All	Updated draft after client comments	FE

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1. Introduction

1.1 Background

South West Water (SWW) supplies water to Cornwall, Devon, Bournemouth, Isles of Scilly and parts of Hampshire, Dorset, Somerset and Wiltshire. Water resource planning is based on five water resource zones (WRZ) – Colliford, Roadford, Wimbleball, Bournemouth and Isles of Scilly – with Devon and Cornwall supplied primarily by Colliford, Roadford and Wimbleball.

1.2 Drought permits and drought orders

In periods of exceptionally low rainfall, when water resources become scarce, powers are available to grant ordinary and emergency drought permits and orders under the Water Resources Act 1991 (as amended by the Environment Act 1995 and the Water Act 2003). Drought permits and drought orders are drought management actions that, if granted, can allow more flexibility to manage water resources and the effects of drought on public water supply and the environment (EA & Defra, 2019).

In the case of drought permits, the Environment Agency ('the Agency') must be satisfied that a serious deficiency of supplies of water in any area exists or is threatened and that the reason for the deficiency is an exceptional shortage of rain.

Drought permits can be applied for under the Water Resources Act 1991 (Section 79A) (as amended by the Environment Act 1995) to vary an abstraction licence condition, such as the maximum yearly allocation or a compensation flow or to allow water to be taken from another source. They are authorised by the Agency. If objections are duly made and not withdrawn the Agency will give the objector an opportunity to be heard at a hearing or cause a public inquiry to be held.

Following the severe drought in northern England in 1995/96, the Government set out a wide range of actions to be taken by the water industry, including the need for water companies to demonstrate that they have adequate drought contingency plans. As required under Sections 39B and 39C of the Water Industry Act 1991, as amended by the Water Act 2003 and in accordance with the Drought Plan Regulations 2005 the Drought Plan Direction 2020, water companies have a duty to prepare and maintain a Drought Plan.

Prospective drought permit options may be identified within Drought Plans. Over the last 12 months SWW's Drought Plan has been going through the routine statutory update process with DEFRA. The Drought Plan details the range of actions that SWW will consider implementing during drought conditions to maintain essential water supplies to its customers and minimise environmental impact. The environmental assessment of drought permits is undertaken in recognition of the guidance from the Agency and Defra, as contained in:

- EA Water Company Drought Plan Guideline (April 2020);
- EA and Defra Guidance on Drought Permits and Drought Orders (March 2021); and
- EA environmental assessment for water company drought planning supplementary guidance (July 2020).

The environmental assessment of a drought permit is not a statutory Environmental Impact Assessment (EIA), as recognised, for example, within the Town & Country Planning regime and its enabling regulations. However, this environmental assessment has been undertaken in accordance with best practice guidance wherever applicable.

An Environmental Assessment Report (EAR), which includes a monitoring plan and mitigation measures, is required to support each drought permit/order application. Each EAR should provide details of baseline flow conditions, assess impacts of potential changes to the flow regime due to implementation of the drought permit/order, and provide an environmental monitoring plan (EMP) to support the requirement for baseline, during and post drought permit/order implementation monitoring.

1.3 River Lyd abstraction and drought permit

The option to abstract from the River Lyd to aid refill of Roadford Reservoir has most recently been assessed within the current abstraction licence Environmental Assessment Report (EAR) (APEM, 2022), which appraises the environmental and ecological risks associated with the following Abstraction licence conditions;

- From 1 November – 15 January: No abstraction shall take place unless the rate of flow in the River Lyd is equal to or greater than 1,343 litres per second (1.343 m^3/s) 116.04 Ml/d;
- From 16 January – 31 March: No abstraction shall take place unless the rate of flow in the River Lyd equal to or greater than 537 litres per second (46.36 Ml/d);
- The quantity of water abstracted shall not exceed 50 percent of the available flow in the River Lyd in excess of the hands off flow; and
- Duration: up to five months (November to March).

Due to the exceptionally dry conditions of 2022 and February 2023, and the delays associated with implementing the River Lyd abstraction licence, Roadford Reservoir is currently only approximately 58 percent full. Following discussion with the Agency, SWW is proposing that the current conditions specified within the abstraction licence EAR be applied to a drought permit for the period April 1st to May 31st 2023 to aid the refill of Roadford Reservoir. This would allow for abstraction under the same conditions, but within the April to May period of 2023.

This document is a revised version of the abstraction licence EAR (APEM, 2022). Whilst all other specifications of the abstraction licence abstraction specified above would remain unchanged, there is a requirement for the assessment of potential effects on the environment and ecology, which might result from abstraction within the period April to May. The focus of this updated EAR has been to re-assess the hydrological and ecological receptors associated with the River Lyd within the context of the proposed drought permit abstraction between April 1st to May 31st of 2023, and to make updates to the monitoring and mitigation plans tailored to the single drought permit application. To allow for slippage in drought permit application impacts have been assessed to the 10th June 2023 as a precautionary measure.

1.4 Aims and objectives

This report has been prepared to support a River Lyd drought permit application. It presents baseline data relevant to the affected area and assesses the potential impacts of changes to the river flow regime that could occur due to operation of the proposed drought permit. This report also includes a summary of the EMP and proposed mitigation measures to avoid and reduce the effect of any potential impacts.

1.5 Scope of the assessment

Following a 'source-pathway-receptor' approach, this environmental assessment focuses first on examining how the proposed drought permit (the 'source') will affect the hydrological, hydrogeological, hydromorphological and physicochemical environment (the 'pathways'), and then considers how ecological and other features (the 'receptors') may respond to changes in those pathways.

As a preliminary screening step, the list of pathways and receptors in Table 1-1 was reviewed to identify the environmental features of interest for inclusion in the environmental assessment. Features were excluded only if:

- the pathway or receptor is absent from the area of potential impact;
- there is no pathway by which the receptor could be impacted; or
- the receptor is not sensitive to changes in these pathways.

Table 1-1 Environmental features considered in this environmental assessment

Category	Environmental feature	Included in this assessment
Pathways	Hydrology	Yes
	Hydrogeology	No
	Geomorphology	Yes
	Water quality	Yes
Ecological receptors	WFD status	Yes
	Phytoplankton	Yes
	Macrophytes and Phytobenthos	Yes (Phytobenthos)
	Macroinvertebrates	Yes
	Fish	Yes
	Birds	Yes
	Protected species	Yes
	Invasive non-native species	Yes
Other receptors	Designated sites	Yes
	Socioeconomics, tourism and recreation	Yes
	Other abstractors	Yes
	Aesthetics and landscape	Yes
	Archaeology and heritage	Yes

1.6 Structure of this report

Figure 1-1 shows how the EA's requirements for environmental assessments of drought permits/ orders are satisfied by this report.

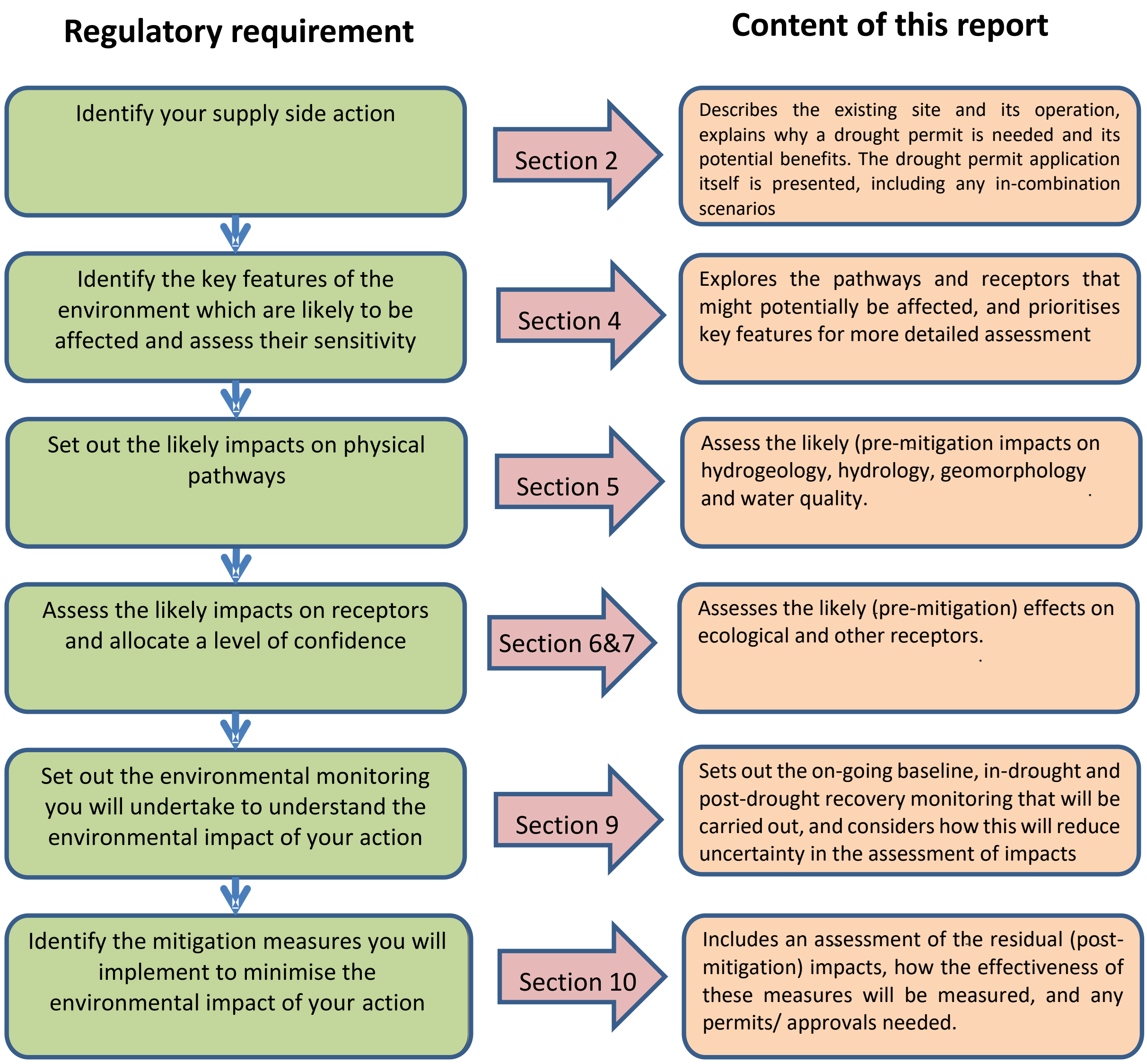


Figure 1-1 Flow chart detailing how the EA's requirements for drought permits/ orders are satisfied by this report

2. Description of proposal

2.1 Drought permit proposal

The proposed drought permit details are as follows:

- abstraction of up to 40 Ml/d from the River Lyd to discharge into Roadford Reservoir;
- abstraction on the Lyd subject to a 50% take above a prescribed flow (which will be referred to as a hands-off flow (HoF) for the purpose of this report) of 46.36 Ml/d (537 L/s); and
- duration: up to two months (April and May) during 2023

Water would be abstracted from the River Lyd via an existing 7.5 km pipeline, which would discharge into Roadford Reservoir at a single location. There are 2 mm eel compliant screens at the Lyd intake.

2.2 Site setting

Roadford Reservoir is a major source of water supply in SWW's Roadford Water Resource Zone (WRZ) in South West England. Construction was completed in 1989. A map of the affected area is presented in Figure 2-1.

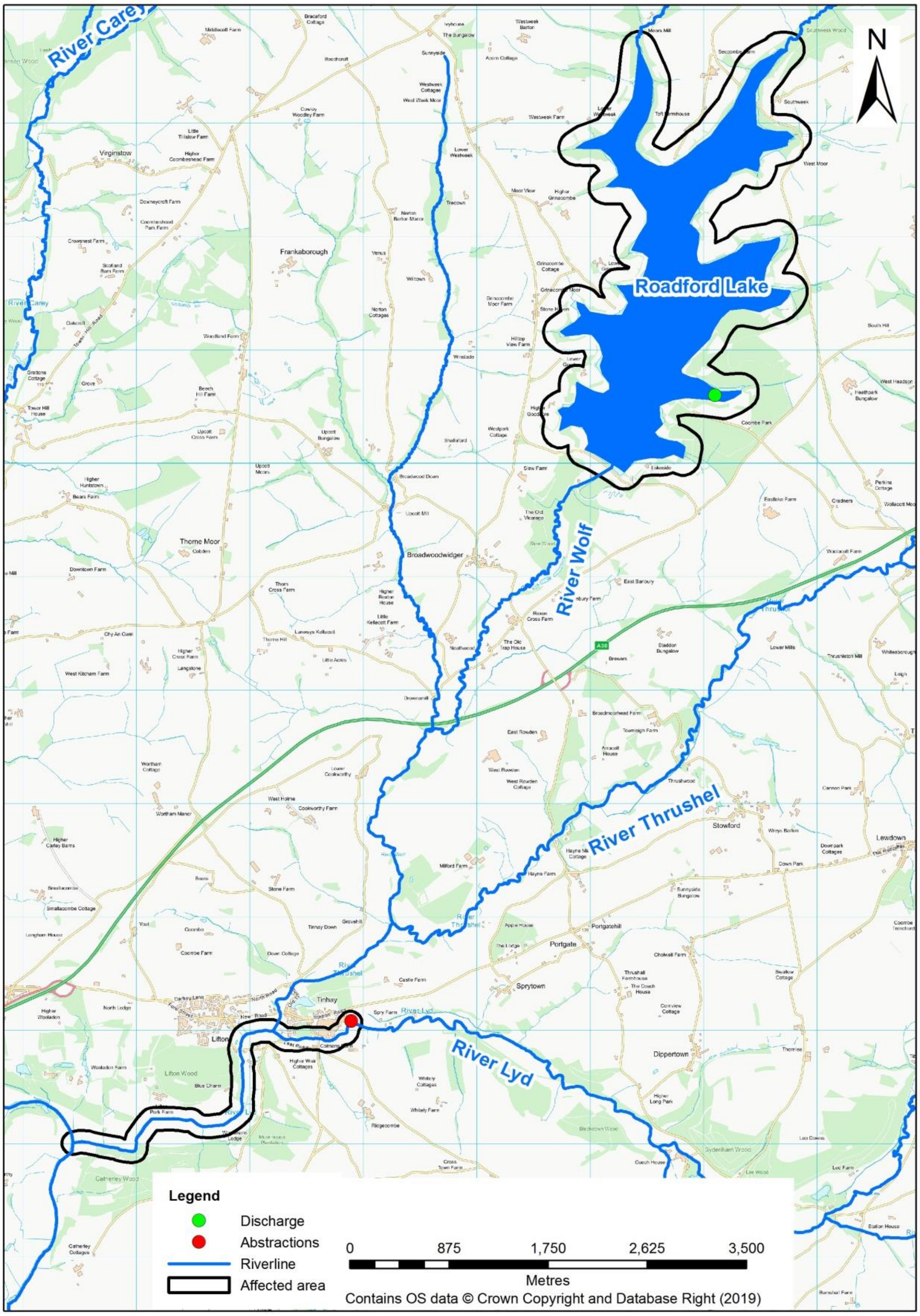


Figure 2-1 Map of the Lyd, Thrushel and Wolf operational catchments, location of South West Water's proposed abstraction point on the River Lyd, proposed discharge point on Roadford Reservoir, and the extent of the affected area

The WFD water bodies of relevance are:

- GB108047007731 (Lower River Lyd)
- GB30847000 (Roadford Lake)

Five additional WFD river water bodies are also located within the wider catchment:

- River Thrushel (GB108047008010);
- Wolf (GB108047008020);
- Broadwood Brook (GB108047007990);
- Upper River Lyd (GB108047007750); and
- Lew (Tamar) (GB108047007770).

Whilst these water bodies will not be affected hydrologically by the proposed drought permit they have been considered with regards to potential effects on migratory fish.

The River Lyd is part of the eastern catchment of the River Tamar, and comprises the main upland area of the Tamar catchment, with Dartmoor dominating much of the headwaters. The River Lyd rises on Dartmoor, flowing over moorland, before reaching Lydford Gorge Site of Special Scientific Interest (SSSI). Downstream of Lydford Gorge, the landscape of the River Lyd becomes agricultural before the river meets the Tamar downstream of Lifton. The overall classification status of the Lower River Lyd (GB108047007731) was Good in 2019 (see Section 4 for a detailed breakdown of WFD status).

Barring consideration of potential effects on migratory fish, water bodies downstream of the Lower River Lyd (Lower River Lyd) were not scoped into the study area. This was based on the modest predicted hydrological effects; maximum predicted change of approximately 7% downstream of the confluence between the Lyd and the Tamar.

2.3 Previous abstraction

A single drought order was previously implemented in 1996 to allow abstraction from the River Lyd to support storage in Roadford Reservoir following a period of prolonged dry weather.

The conditions of the application are detailed in Table 2.1.

Table 2.1 Conditions of the drought order application prepared in January 1996 for the River Lyd

	River Lyd at Lifton
Maximum Daily Quantity (Ml/d)	40
Maximum Instantaneous Rate (m^3/s)	0.463
Prescribed Flow (m^3/s)	0.415

The drought order was successful and came into force on 27 January 1996 and operated between 07/04/1996 - 07/07/1996 inclusive (every day) on the River Lyd. This resulted in the implementation of an agreed schedule of monitoring and mitigation. The requirements of the schedule were delivered in full. Many of the issues identified as part of this process were incorporated into the design of permanent abstraction structures and became the benchmark for subsequent temporary licence applications for the same sites in 1997. A detailed Environmental Statement was prepared and submitted in support of the SWW application proposal.

SWW was granted licences to abstract from the same location on the river, time-limited for the period 30 January 1998 to 31 March 2000. The specified period for the temporary licences was for three months, January to March inclusive in each year. Procedures and working practices were developed during this time to ensure compliance with regulatory conditions and the delivery of a sustainable solution with minimal risk to the environment. During this period the licences permitted:

- Abstraction of up to 40 Ml/d from the River Lyd) for discharge into Roadford Reservoir, with abstraction subject to a 50% take above a prescribed flow of 84.41 Ml/d.

Although the temporary licence was granted, abstraction from the River Lyd was never implemented during the time-limited period. Since the expiry date of the temporary licence, the site has not been in operation. The majority of the infrastructure was de-commissioned and ‘moth-balled’ on site.

A permanent abstraction licence (SW/047/0051/002) was granted for the River Lyd on 8 February 2023. Abstraction occurred from the River Lyd as part of the pipeline recommissioning process during March 2023 however it is unlikely there will be any meaningful refill of Roadford Reservoir once the recommission process is complete, prior to the end of March 2023.

3. Environmental assessment methodology

3.1 Impact and risk pathways

Figure 3-1 summarises the process used to describe and categorise the impact of the Drought permit on each receptor. Although not a drought permit assessment, the process remains consistent with the latest Agency guidance on Environmental Assessment for Water Company Drought Planning (EA, 2019), which is considered to be a robust and thorough framework applicable to an assessment to support a permanent licence application, and draws on industry good practice for undertaking ecological impact assessments (CIEEM, 2018) and on NRW technical guidance for Water Company Drought Plans (NRW, 2017).

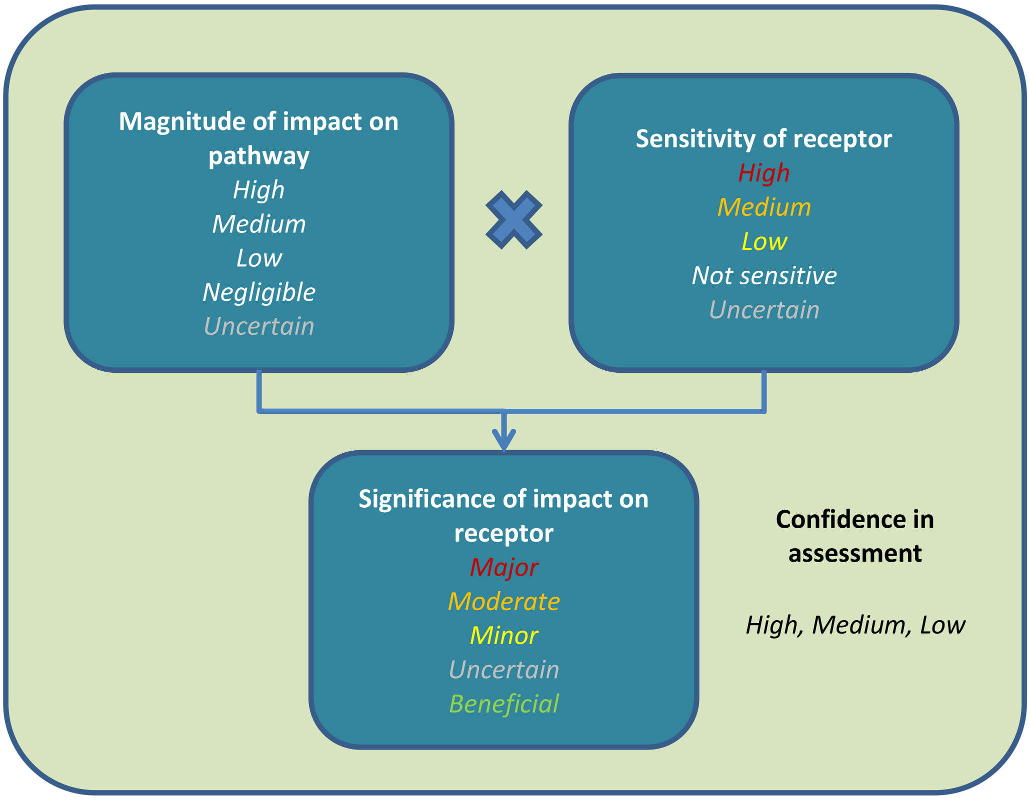


Figure 3-1 Flow chart outlining the environmental assessment process

The first step is to assess **magnitude of impact on each pathway**. We have chosen to categorise these impacts on a five-point scale similar to that advocated by the Agency for assessing the sensitivity of receptors (EA, 2020): High, Medium, Low, Negligible, or Uncertain. These categories and associated definitions are provided in Table 3.1.

Table 3.1 Magnitude categories

Category	Definition
High	A large, extensive, long-term and/or very frequent change.
Medium	A medium-sized, substantial, medium-term and/or frequent change.
Low	A small, localised, short-term and/or infrequent change.
Negligible	A change unlikely to be noticeable / measurable.
Uncertain	Insufficient information is available to judge the magnitude of impact.

Following NRW (2017) and CIEEM (2018) guidance, the assessment of magnitude takes into account some or all of the following factors (as necessary to understand the resulting impact on receptors):

- severity – the degree of change, relative to the baseline (large, medium, small);
- extent – the area over which the impact occurs (extensive, substantial, localised);
- duration – the time for which the impact occurs (short-, medium-, long-term); and
- frequency – how often the impact may occur (very frequent, frequent, infrequent).

Where relevant, the specific location and timing of any impacts is also described. Impacts on pathways may translate into positive or negative impacts on receptors, so whilst the direction of change is important (e.g. increase or decrease), impacts on pathways are not described as being positive or negative.

Next, the **sensitivity of each receptor** is categorised as High, Medium, Low, Not Sensitive, or Uncertain, in accordance with EA guidance (EA, 2020). Definitions are provided in Table 3.2.

Table 3.2 Sensitivity categories

Category	Definition
High	Receptor is highly sensitive to changing environments due to inability to tolerate and recover from changes.
Medium	Receptor is sensitive to changing environments due to limited ability to tolerate and/or recover slowly from the environmental change.
Low	Receptor is relatively insensitive to changing environments due to ability to tolerate and/or recover quickly from the environmental change.
Not sensitive	Receptor is not sensitive due to high tolerance to environmental change and/or ability to recover rapidly.
Uncertain	Insufficient information is available to judge the sensitivity of the receptor.

Sensitivity is a function of the receptor's capacity to accommodate change and its ability to recover if it is affected. A receptor may be more sensitive to changes in certain pathways than others. The assessment of sensitivity takes into account some or all of the following factors (adapted from NRW, 2017):

- adaptability – the degree to which a receptor can avoid or adapt to an impact;
- tolerance/ resistance – the ability of a receptor to accommodate change without a significant adverse impact; and
- recoverability/ resilience – the temporal scale over and extent to which a receptor will recover following an impact.

The magnitude of impact is combined with the sensitivity of receptor to assess the **significance of impact on each receptor**, as shown in Table 3.3 (adapted from NRW, 2017). In accordance with Agency guidance (EA, 2020), impacts on receptors are categorised as:

Major, Moderate, Minor, Negligible[1], or Uncertain. Definitions, adapted from NRW (2017), are provided in Table 3.4.

Table 3.3 Determining the significance of impacts on receptors

Magnitude of impact on pathway	Sensitivity of receptor				
	High	Medium	Low	Not sensitive	Uncertain
High	Major	Major	Moderate	Minor	Uncertain
Medium	Major	Moderate	Minor	Negligible	Uncertain
Low	Moderate	Minor	Negligible	Negligible	Uncertain
Negligible	Minor	Negligible	Negligible	Negligible	Uncertain
Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain

Table 3.4 Significance categories

Category	Definition
Major	Very large or large change in environmental, ecological or socio-economic conditions, which, if lost, cannot be replaced or relocated. The impacts are generally, but not exclusively associated with features and sites of national to regional importance because they contribute to achieving national / regional objectives. The impacts are likely to result in exceedance of statutory objectives and/or breaches of legislation (e.g. Likely Significant Effects or deterioration of WFD status).
Moderate	Intermediate change in environmental, ecological or socio-economic conditions. The impacts are likely to affect important considerations at a regional and local level. The impacts are unlikely to affect key decision-making processes (e.g. statutory objectives). Nevertheless, the cumulative effect of such impacts may lead to an increase of overall effect on a particular area or on particular features.
Minor	Small change in environmental, ecological or socio-economic conditions. These effects may be raised as local issues but are unlikely to be of importance in the decision-making process.
Negligible	Any change in in environmental, ecological or socio-economic conditions that is unlikely to be noticeable.
Uncertain	Insufficient information is available to judge the impact significance.

Impact significance provides a consistent means of expressing impacts which, in turn, informs the need for mitigation measures to offset the impacts. The determination of impact significance, both pre and post mitigation, also provides a transparent means for regulators to understand the impacts of an Drought permit.

In practice, determining the significance of impact carries a degree of subjectivity and requires expert judgement. This may be because of limited evidence/ data on the sensitivity of the receptors and/ or the complexity of interactions that require assessment to determine the

[1] Whilst the Agency guidance does not provide a negligible category one has been used here to differentiate between minor and negligible impacts; the latter being considered unlikely to be noticeable.

magnitude of change. For example, receptors may experience direct impacts as a result of changes in pathways, but also indirect impacts as a secondary response to changes in other receptors. If a receptor is subject to different impacts via different pathways, then the combined effect of the different pathways is integrated to assess the overall significance of impact.

Finally, in accordance with Agency guidance (EA, 2020), the **degree of confidence** in the assessment of impact significance is categorised as High, Medium or Low. Definitions are provided in Table 3.5. Key sources of uncertainty are identified and used to inform the design of the EMP.

Table 3.5 Confidence categories

Category	Definition
High	Judgments based on high-quality, robust information, and/or the nature of the impact makes it possible to render a solid judgement.
Medium	Credibly sourced and plausible information, but not of sufficient quality or corroboration to warrant a higher level of confidence.
Low	The information available is too fragmented or poorly corroborated to make solid analytic inferences, or significant concerns or problems with information sources exist.

The assessment has also considered the legislative requirements of:

- Conservation of Habitats and Species Regulations 2017;
- fisheries legislation: Salmon and Freshwater Fisheries Act 1975 and the Eel (England and Wales) Regulations 2009;
- Water Environment (Water Framework Directive) Regulations 2017 including the objectives set out in river basin management plans;
- Section 40 of the Natural Environment and Rural Communities Act 2006 (NERC);
- legislation covering INNS;
- other non-statutory requirements (local wildlife sites etc.);
- protected areas designated under international agreements (incl. Ramsar & Natura 2000 sites);
- protected areas designated under national legislation (SSSIs), nationally protected species and habitats - Wildlife and Countryside Act 1981 and other locally important sites.

3.2 Qualitative definitions of Water Framework Directive status classes

Potential impacts were also considered in the context of the WFD, which provides qualitative descriptions for each biological quality element in each surface water category (i.e. river, lake, transitional water or coastal water) and for each ecological status class. The different classes represent different degrees of disturbance to the quality elements relevant to the category of water concerned.

The degree of disturbance to each quality element is assessed against a ‘reference value or set of values’ for that element. A reference value for a biological quality element is a value identified from the typical range when the quality element is subject to no or only very minor alteration as a result of human disturbance (i.e. when it is in a reference, or high status, condition). UKTAG (the UK Technical Advisory Group for the WFD) recommends that reference conditions should reflect "a state in the present or in the past corresponding to very low pressure, without the effects of major industrialisation, urbanisation and intensification of agriculture, and with only very minor modification of physico-chemistry, hydromorphology and biology" (UKTAG, 2008).

The qualitative definitions of ecological status are as follows:

- Good: none of the biological quality elements can be more than slightly altered from their reference conditions;
- Moderate: one or more of the biological elements may be moderately altered;
- Poor: the alterations to one or more biological quality elements are major; and
- Bad: there are severe alterations such that a large proportion of the reference biological community is absent.

For the purposes of WFD classification, whether or not a particular element meets these definitions is assessed against various numerical metrics. For the purposes of this study, these metrics have not been re-calculated, rather, potential changes to WFD status have been assessed on a qualitative basis.

4. Water Framework Directive status and designated sites

4.1 Water Framework Directive classification status

Summaries of current WFD classification status for the Lower River Lyd (GB108047007731) and Roadford Lake (GB30847000) water bodies are shown in Table 4.1 (based on the 2016 and 2019 Cycle 2 classification data). Current cycle 3 classifications are based on 2019 cycle 2 classifications only (CDE, 2023).

The Lower River Lyd and Roadford Lake water bodies are currently at Good and Moderate status, respectively. Roadford Lake is classed as Artificial and for all WFD classification items the reason for not achieving Good Potential is ‘disproportionate burdens’ with an objective date of 2027. The only ecological element assessed is phytoplankton (Moderate status in 2016 and 2019) and the phosphorus and nitrogen physicochemical supporting elements also indicated Moderate status. The 2019 Cycle 2 classification data demonstrated High status for all physico-chemical elements within the Lower River Lyd water body. The combined phytobenthos/ macrophyte element was indicative of Good status while fish and invertebrates were indicative of High status.

The WFD requires ‘no deterioration’ in the ecological status of water bodies. When assessing impacts on WFD elements, it is necessary to consider whether any impacts are temporary, whether the water body will recover quickly and without the need for restoration measures, and the extent to which the impact is a result of natural causes versus anthropogenic management practices.

Table 4.1 Summary of the Lower River Lyd (ID GB108047007731) and Roadford Lake (GB30847000) Cycle 2 Water Framework Directive classification status and objectives

Classification	Water Body ID	Water Body Name	Ecological Status	Phytoplankton	Invertebrates	Fish	Phytobenthos Macrophytes	Ammonia	Dissolved Oxygen	pH	Phosphate	Total phosphorus	Total Nitriogen	Salinity	Temperature
2016 (Cycle 2)	GB108047007731	Lower River Lyd	G	G	H	-	G*	H	H	H	H	-	-	-	H
2019 (Cycle 2)	GB108047007731	Lower River Lyd	G	-	H	H	G*	H	H	H	H	-	-	-	H
Objectives	GB108047007731	Lower River Lyd	G (2027)	G (2027)	G (2015)	-	G (2027)	G (2015)	G (2015)	G (2015)	G (2015)	-	-	-	G (2015)
2016 (Cycle 2)	GB30847000	Roadford Lake	M	M	-	-	-	-	-	-	-	M	M	H	-
2019 (Cycle 2)	GB30847000	Roadford Lake	M	M	-	-	-	-	-	-	-	M	M	H	-
Objectives	GB30847000	Roadford Lake	G (2027)	G (2027)	-	-	-	-	-	-	-	G (2027)	G (2027)	G (2015)	-

NB H=High, G=Good, M=Moderate,

*The macrophytes and phytobenthos elements are combined for Cycle 2

4.2 Designated sites

There is only one designated site within the study area: Roadford Lake Local Nature Reserve (LNR), which covers the north east limb of the reservoir, a section of the River Wolf, as it enters the reservoir and Southweek Wood. It consists of 34 hectares of freshwater, swamp, marshy grassland, dense scrub willow carr, broadleaved woodland and coniferous plantations. The mature woodland habitat supports small populations of dormice, which are protected under the Wildlife and Countryside Act 1981.

The most upstream 5km (approximate) of the River Lyd are within Dartmoor SAC. There is no direct hydrological pathway of impact that might affect this reach. Furthermore, whilst salmonids constitute a feature of the 'inland water bodies (standing water, running water)' designation of Dartmoor SAC, salmonids (and other migratory fish and eels) cannot migrate upstream of the natural barrier presented by Lydford Gorge, which prevents them from reaching the SAC. Dartmoor SAC has therefore been screened out of further assessment.

The Plymouth Sound and Estuaries SAC and the Tamar Estuaries Complex SPA are outside the reaches hydrologically affected by the proposed drought permit. Allis shad (*Alosa alosa*) are a qualifying feature of the Plymouth Sound and Estuaries SAC. Currently, Allis shad are unable to migrate into the River Lyd because of downstream barriers at Gunnislake, Duchess and Lamerhooe (Natural England, pers. Comm.). Allis shad have therefore been screened out of further assessment. Whilst work has begun on constructing a fish pass at Gunnislake, which is due for completion by 2025, there are no plans currently in place for the remaining two barriers. Therefore, the situation should be reviewed as part of triannual reporting to confirm whether or not Allis shad require assessment in relation to this proposed drought permit EAR.

5. Assessment of physical effects and identification of geographical extent

5.1 Hydrology

5.1.1 Baseline

Daily mean river flow data, from the Agency (collated from existing gauging stations) and abstraction information from SWW have been used to define the potentially affected reaches. A summary of the available data is provided in Table 5-1.

Table 5-1 Summary of Agency flow gauge data in the River Lyd catchment

Data	Location	Data Source
Reservoir Storage (Ml)	Roadford Reservoir	South West Water
Historic abstraction	Hayne Bridge Colmans intake	South West Water
Naturalised flows (m^3/s)	Inflow to Roadford Reservoir	South West Water
Measured flow (m^3/s)	Roadford compensation (NGR: SX 4190 8980)	Environment Agency
	GS 47018 Thrushel at Hayne Bridge (NGR: SX 4160 8670)	
	GS 47008 Thrushel at Tinhay (NGR: SX 3976 8549)	
	GS 47006 Lyd at Lifton Park (NGR: SX 3888 8424)	
	GS 47019 Tamar at Polson Bridge (SX353848)	

Station details have been referenced against the National River Flow Archive (NRFA, March 2023):

- Station 47025 Wolf at Germansweek (1992 onwards) measures inflows from the small (11.3 km^2) catchment of moderate relief agricultural land to Roadford Reservoir;
- Station 47017 Wolf at Combe Park Farm (1977-86) measured flows immediately downstream of the Roadford Reservoir site but was closed prior to completion of the reservoir in 1989. Since this time, the Roadford compensation has been measured by SW.
- Station 47018 Thrushel at Hayne Bridge (1988 onwards) measures runoff from the Thrushel catchment upstream of the Thrushel's confluence with the Wolf, and as such is not affected by abstraction to, storage in or releases from Roadford Reservoir – and is not materially affected by other influences. As such it provides an estimate of natural runoff from an agricultural catchment of moderate relief draining the western flank of Dartmoor. However, flow measurement may not be reliable, the National River Flow Archive describing the site as a "Low level bed control in poor section on meandering stretch with accretion problems".
- Station 47008 Thrushel at Tinhay (1969 onwards) measures flows in the River Thrushel downstream of the Wolf confluence and hence, for the period 1988 onwards has been affected by construction and operation of Roadford Reservoir. Measurement

via a three bay compound Crump weir appears good at low flows, if potentially prone to drowning during higher spates.

- Station 47006 Lyd at Lifton Park (1962 onwards, excluding the 1981-88 period) measures flows on the River Lyd downstream of the River Thrushel confluence and thus, since reinstatement of the station since 1988, has been affected by Roadford Reservoir. The Lyd abstraction also affects flows to the Lyd at Lifton Park. Measurement arrangements were improved in 1968.
- Station 47019 Tamar at Polson Bridge (1987 onwards) measures flows on the River Tamar upstream of the Thrushel confluence. Flows are considered natural to within 10% of low flows, but affected by Tamar lake operations.

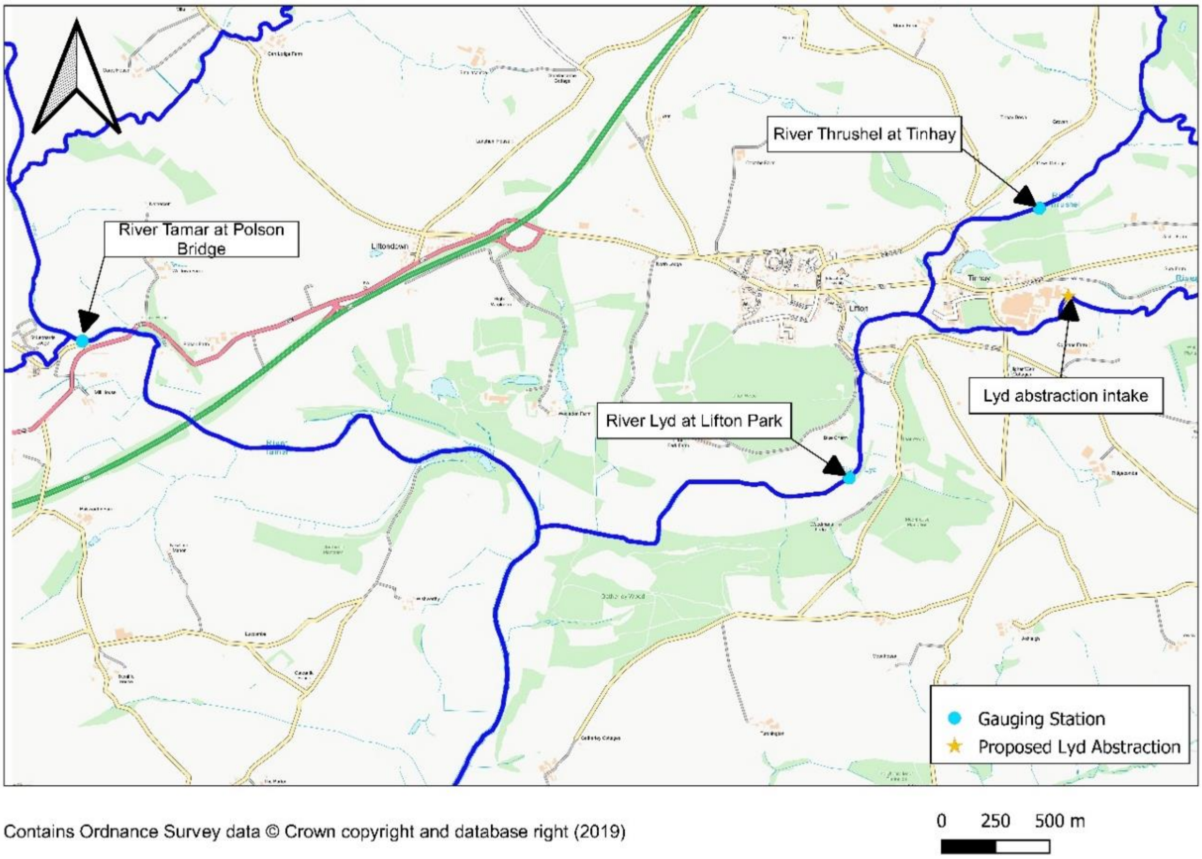


Figure 5-1 Gauging Stations in the River Lyd catchment shown alongside the nearest gauge on the River Tamar

5.1.2 Flow naturalisation

The Agency (James/ Snooke, pers. Comm 25/02/2021) use the following method to estimate natural flow upstream of the Lyd abstraction (no allowance being necessary for intervening accretion).

Natural flow upstream of Colmans intake $= Qn_{Lifton} - Qn_{Tinhay}$

Where:

- Qn_{Lifton} is the daily mean naturalised flow calculated at Lifton Park gauging station
- Qn_{Tinhay} is the daily mean naturalised flow calculated at Tinhay gauging station

Qn_{Lifton} is calculated at a daily timestep by correcting for the effects of Roadford Reservoir since 31/3/1988 by subtracting the Roadford compensation and adding back estimated natural inflows. A correction is also made for the Colmans abstraction during 1996 and abstraction at Hayne Bridge during the 1996-1998 period. i.e.:

$$Qn_{Lifton}^{t} = Qobs_{Lifton}^{t} + (Inflow_{Roadford}^{t} - Comp_{Roadford}^{t}) + Abs_{Colmans}^{t} + Abs_{Hayne\ Bridge}^{t}$$

Qn_{Tinhay} is calculated at a daily timestep by correcting for effects of Roadford Reservoir since 31/3/1988 by subtracting the Roadford compensation and adding back estimated natural inflows. A correction is also made for abstraction at Hayne Bridge during the 1996-1998 period, i.e.:

$$Qn_{Tinhay}^{t} = Qobs_{Tinhay}^{t} + (Inflow_{Roadford}^{t} - Comp_{Roadford}^{t}) + Abs_{Hayne\ Bridge}^{t}$$

Estimated natural inflows to Roadford Reservoir were provided by SWW and have been calculated using a variety of methods, making best use of available data for relevant time periods (Table 5-2). The Roadford natural inflow sequence ends in 31/12/2022, with two periods interpolated due to missing data – 20/6/89-17/7/89 and 30/9/2021 – 14/102021.

Table 5-2 Derivation of Roadford natural inflows

Start date	End date	Method	Equation description
01/01/1957	31/12/1969	1	Roadford naturalised flow = 0.02304 × (Gunnislake naturalised flow - 0.923)$^{1.11279}$
01/01/1970	05/04/1977	2	Roadford naturalised flow = 0.29364 × (Tinhay gauged flow - 0.025)$^{1.02221}$
06/04/1977	23/05/1977	3	Roadford naturalised flow = Combepark Farm gauging station
24/05/1977	30/10/1977	4	Roadford naturalised flow = Roadford upstream gauging station 1
31/10/1977	20/07/1983	5	Roadford naturalised flow = Combepark Farm gauging station
21/07/1983	08/09/1983	6	Roadford naturalised flow = 0.29364 × (Tinhay gauged flow - 0.025)$^{1.02221}$
09/09/1983	16/03/1987	7	Roadford naturalised flow = Combepark Farm gauging station
17/03/1987	30/03/1988	8	Roadford naturalised flow = Roadford upstream gauging station 2
31/03/1988	05/11/1989	9	Roadford naturalised flow = Roadford compensation gauging station, infilled with Roadford upstream gauging station 2 where Roadford compensation gauging station is missing[a]
06/11/1989	26/08/1991	10	Roadford naturalised flow = Change in storage + Roadford abstraction to Northcombe WTW - pumped storage abstraction into Roadford + Roadford comp gauging station flow
27/08/1991	02/04/1992	11	Roadford naturalised flow = Germansweek gauging station * mass balance ratio (3.040)
03/04/1992	31/12/2000	12	Roadford naturalised flow = Moorsmill gauging station * annual mass balance ratios
01/01/2001	31/12/2001	13	Roadford naturalised flow = Change in storage + Roadford abstraction to Northcombe WTW - pumped storage abstraction into Roadford + Roadford comp gauging station flow
01/01/2002	31/12/2009	14	Roadford naturalised flow = Moorsmill gauging station * annual mass balance ratios
01/01/2010	01/04/2021	15	Roadford naturalised flow = Germansweek gauging station * annual mass balance ratios

5.1.3 Years used to illustrate potential drought permit effects

Potential effects of the proposed drought permit on flows in the River Lyd were examined through selection of representative 10th April to 10th June periods in the historical record. Selection was based upon runoff accumulation between these dates and as the drought permit extension into April, May and June is intended to assist refill (and need not in themselves be dry), effects on a range of flow conditions were investigated. All selected years are post reservoir construction, with recent years preferred:

- 2020 and 2022 represent recent dry years, having runoff accumulations over the 10th April to 10th June period in the lowest five since 1989 in both the Lifton Park gauging station record and the simulated natural record at the proposed Lyd abstraction site;
- 2021 represents a very wet year, having one of the highest runoff accumulations over the 10th April to 10th June period in both the Lifton Park gauging station record and the simulated natural record at the proposed Lyd abstraction site;
- 2013 represents an average year, having a runoff accumulation over the 10th April to 10th June period close to the median in both the Lifton Park gauging station record and the simulated natural record at the proposed Lyd abstraction site.

Table 5-3 Post Roadford construction 10th April to 10th June runoff accumulations used to select years to illustrate potential drought permit effects

Blue cells denote wet years in both records, green cells denote average years and orange cells denote dry years

Year	Lifton Park gauged accumulation	Rank	Lyd abstraction naturalised	Rank
1989	8193	16	13690	16
1990	3628	2	5929	1
1991	7799	14	11839	13
1992	9105	18	15253	20
1993	12472	28	20530	28
1994	10295	22	16211	22
1995	6157	11	12318	14
1996	9708	21	14427	18
1997	4636	5	7100	4
1998	15212	30	24511	29
1999	12253	27	20525	27
2000	15756	31	27705	34
2001	10609	23	19364	26
2002	16484	33	26902	33
2003	5568	8	9180	8
2004	6684	12	10403	11
2005	11484	25	18589	25
2006	10795	24	16400	23
2007	8920	17	14401	17
2008	9181	19	15098	19
2009	9421	20	15810	21
2010	5683	9	9950	10
2011	3173	1	6226	2
2012	16658	34	25903	32
2013	8173	15	13529	15
2014	14712	29	24669	30
2015	5178	7	9066	7
2016	5708	10	9677	9
2017	7601	13	11219	12
2018	11595	26	16960	24
2019	5083	6	8545	6
2020	3687	3	7066	3
2021	16245	32	25778	31
2022	3870	4	7333	5
2016	5708	10	9677	9
2017	7601	13	11219	12
2018	11595	26	16960	24
2019	5083	6	8545	6
2020	3687	3	7066	3
2021	16245	32	25778	31
2022	3870	4	7333	5

5.2 Surface water (River Lyd)

5.2.1 Baseline

Flows in the Lyd, Thrushel and Tamar during a dry year are illustrated below in Figure 5-2.

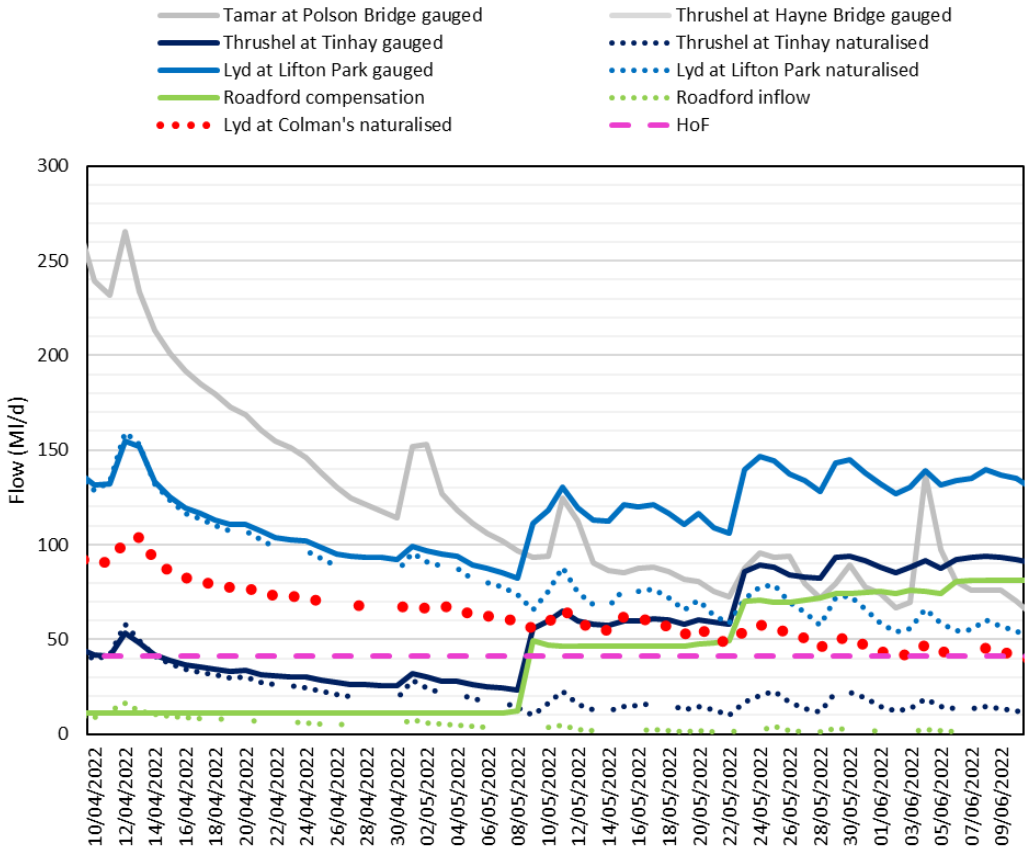


Figure 5-2 2022 dry year flows (Ml/d) - Lyd, Thrushel and Tamar

The naturalised series for the Lyd abstraction presents a plausible flow recession throughout the simulation period. The effect of the compensation flow in supporting dry spring and early summer flows above those naturally expected is evident by comparison of dotted and solid lines at Roadford and Tinhay and, during the driest spells, by the Lyd at Lifton exceeding the more natural flows on the Tamar at Polson Bridge. During these dry years, it is also clear that little water is available for abstraction at the Colman's intake, the naturalised inflows approaching and sometimes reaching the HOF.

Average and wet year flows are illustrated in Figure 5-3. In average and wet years, estimated natural inflows at the Colman's intake remain well above the proposed HOF, meaning substantial water available for abstraction even with the constraint of the proportional take. Substantial spates also mean that flows can be elevated for days or even weeks (except in the gauged Roadford compensation flow, where these are removed by storage) – a consequence of rainfall onto low or mixed permeability catchments.

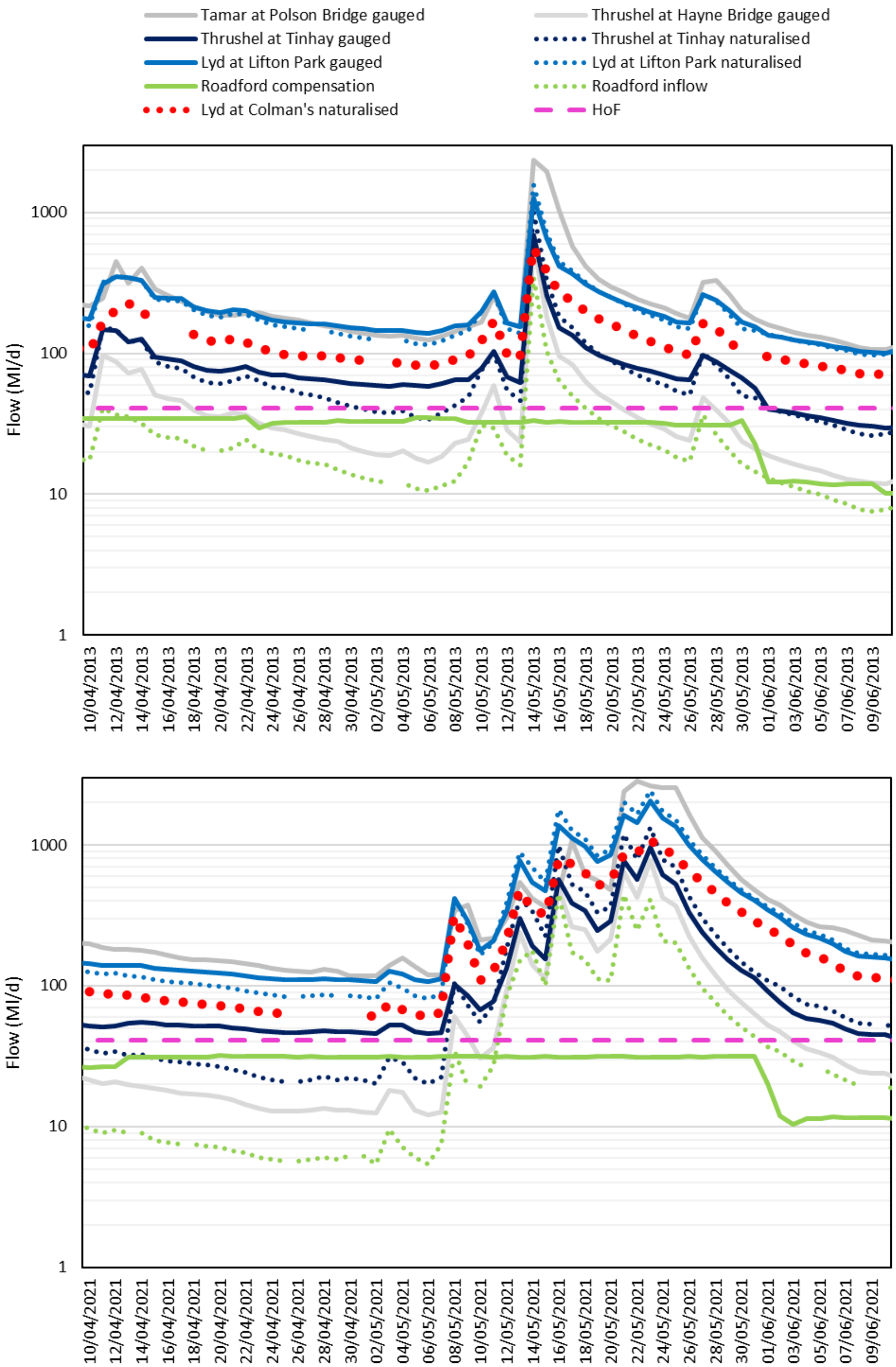


Figure 5-3 2013 (top) and 2021 (bottom) average and wet year flows (Ml/d)

Note log scale used on y-axis

Flow duration curves are presented in Figure 5-4. Again, the simulated flow duration curves for derived series – including the Lyd at Colman's intake, appears consistent with relatively natural flow duration curve. The Lyd at Colman's intake demonstrates that the HOF is likely to be reached only in dry years – and very seldom in the 10th April – 10th June period.

The flow duration curve for the Thrushel at Tinhay (and less visibly the Lyd at Lifton) again demonstrates the effect of the compensation flow from Roadford Reservoir, with high flows slightly lower in the gauged series and low flows substantially higher than those expected naturally, both in the 10th April – 10th June period and over the course of the year.

10th April – 10th June flows are lower at all locations during high flows, and higher in the low and very low flow range than the annual percentiles, reflecting that it is unusual for the spring/ summer recession to reach the annual minimum before the late summer/ early autumn.

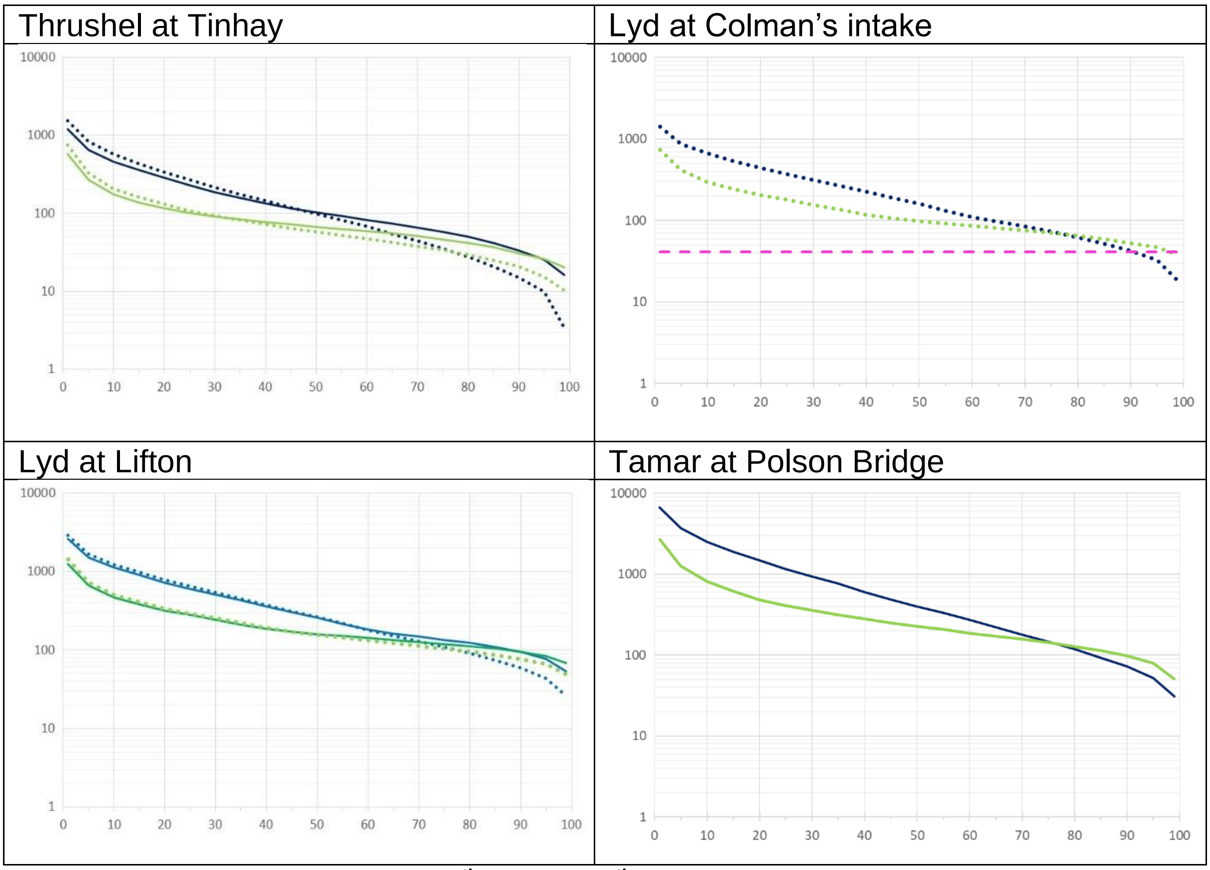


Figure 5-4 Annual and 10th April to 10th June Flow Duration Curves (Ml/d)

Solid blue line = gauged annual. Dotted blue = naturalised annual. Solid green = gauged April – June. Dotted green = natural April – June. Pink dashed line denotes the HOF at Colman's intake. Note log scale used on the Y axis.

5.2.2 Impact assessment

The proposed drought permit is summarised in Section 2.1. Effects of the proposed drought permit were simulated for the Lyd on the reach immediately downstream of the intake, at Lifton Park and downstream of the confluence with the River Tamar were simulated by assuming continuous implementation of the proposed drought permit during the 10th April to 10th June timeframe. These are presented below for 2022 (dry year), 2013 (average year) and 2021 (wet year) in the context of flow variability throughout each of these years (Figure 5-5, Figure

5-6 and Figure 5-7). Effects on the annual flow duration curve for these years are shown in Figure 5-8. Selected flow statistics for baseline and drought permit scenarios are also given for the annual flow duration curve in Table 5-4 and for the seasonal (10th April to 10th June) flow duration curve in Table 5-5 below.

In all cases, simulated flows under drought permit conditions assume maximum take-up of the proposed drought permit conditions (i.e., 50% take above the specified HoF) throughout the 10th April to 10th June timeframe.

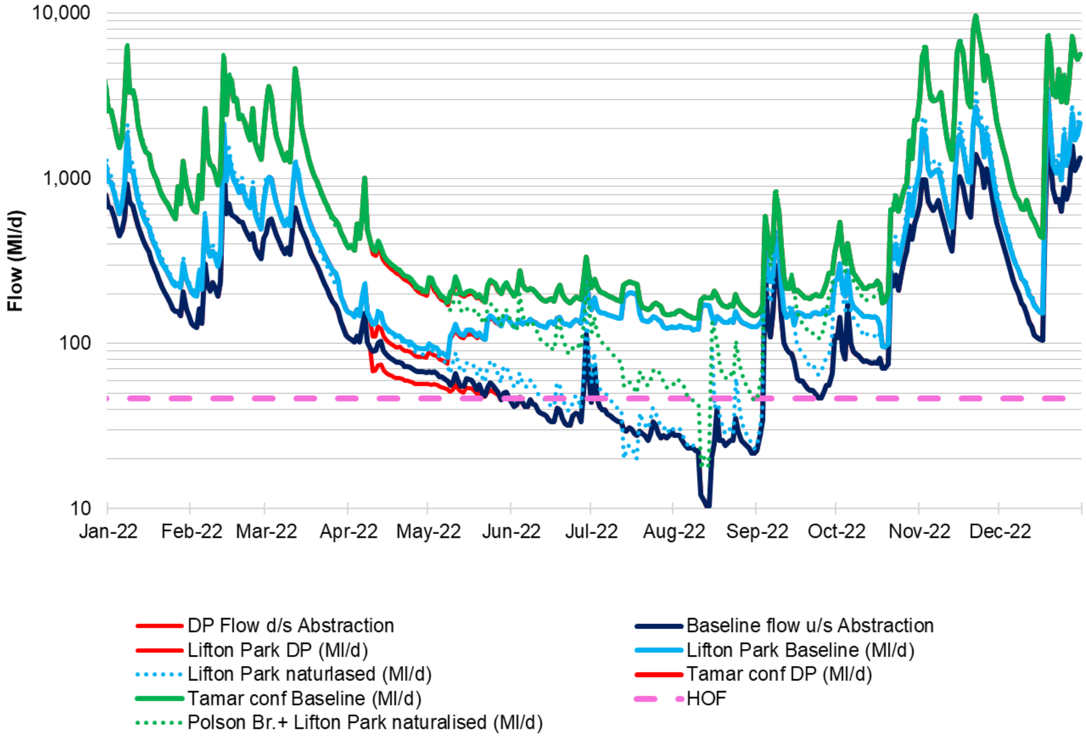


Figure 5-5 2022 (dry year) baseline and simulated drought permit flows at the Lyd abstraction, Lifton Park and downstream of the Tamar confluence.

Note log scale used on Y axis to emphasise low flows.

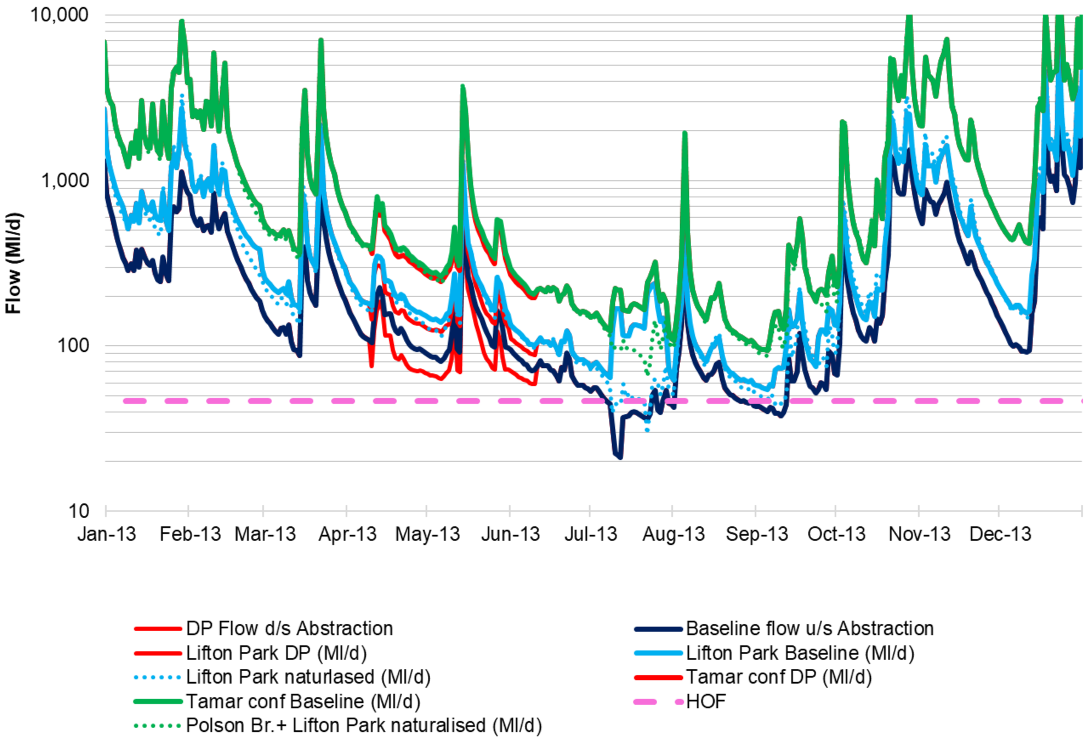


Figure 5-6 2013 (average year) baseline and simulated drought permit flows at the Lyd abstraction, Lifton Park and downstream of the Tamar confluence.

Note log scale used on Y axis to emphasise low flows.

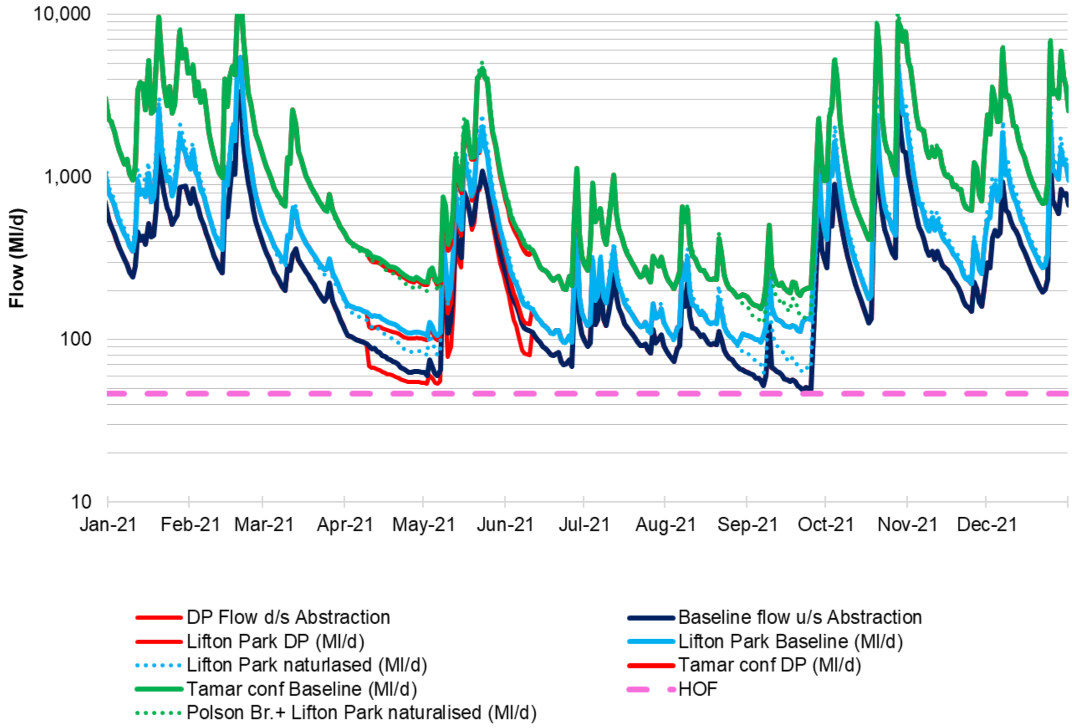


Figure 5-7 2021 (wet year) baseline and simulated drought permit flows at the Lyd abstraction, Lifton Park and downstream of the Tamar confluence

Note log scale used on Y axis to emphasise low flows.

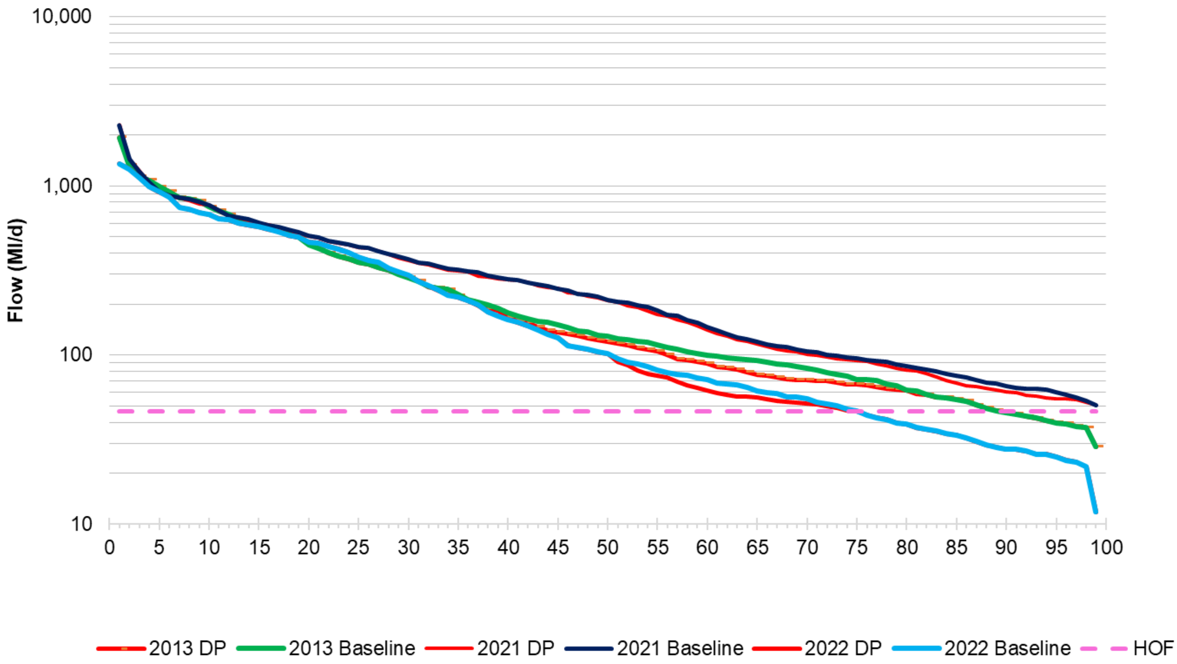


Figure 5-8 2013 (average year), 2021 (wet year) and 2022 (dry year) baseline and simulated drought permit flow duration curves at the Lyd abstraction

Note log scale used on Y axis to emphasise low flows.

Table 5-4 Selected long term annual flow statistics with a drought permit scenario of abstraction when water is available between 10th April and 10th June

Annual flow statistic	Baseline (Ml/d)			With Lyd abstraction (Ml/d)			% Change		
	d/s Lyd Abstraction	Lifton Park GS	d/s Tamar Confluence	d/s Lyd Abstraction	Lifton Park GS	d/s Tamar Confluence	d/s Lyd Abstraction	Lifton Park GS	d/s Tamar Confluence
Q95	32.7	75.9	148.2	32.7	75.4	148.1	0.0	-0.6	-0.1
Q70	85.0	147.7	328.3	76.0	141.3	321.4	-10.5	-4.4	-2.1
Q50	158.5	255.7	661.0	151.2	247.7	654.7	-4.6	-3.1	-1.0
Q30	308.4	499.4	1426.5	304.0	495.9	1419.6	-1.4	-0.7	-0.5
Mean	273.4	466.3	1404.5	269.1	462.1	1400.2	-1.6	-0.9	-0.3

Table 5-5 Selected long term seasonal flow statistics for the 10th April to 10th June period with a drought permit scenario of abstraction when water is available between 10th April and 10th June

Seasonal flow statistic	Baseline (Ml/d)			With Lyd abstraction (Ml/d)			% Change		
	d/s Lyd Abstraction	Lifton Park GS	d/s Tamar Confluence	d/s Lyd Abstraction	Lifton Park GS	d/s Tamar Confluence	d/s Lyd Abstraction	Lifton Park GS	d/s Tamar Confluence
Q95	46.5	83.5	173.2	46.4	78.2	171.3	-0.1	-6.3	-1.1
Q70	75.9	127.0	285.9	61.1	113.1	270.0	-19.4	-10.9	-5.5
Q50	98.5	160.7	395.7	72.4	137.6	366.4	-26.4	-14.4	-7.4
Q30	157.7	247.1	618.8	117.7	207.1	578.8	-25.4	-16.2	-6.5
Mean	**148.7**	**245.3**	**642.2**	**123.7**	**220.3**	**617.2**	**-16.8**	**-10.2**	**-3.9**

Hydrological effects of the proposed DP extension in the period 10th April to 10th June are as below:

Inevitably, effects of abstraction are greatest immediately downstream of Colman's intake. These are modest and progressively reduce relative to the magnitude of flows with inputs from unregulated catchment downstream. With the contribution of the River Thrushel, effects at Lifton Park gauging station are already substantially reduced.

The downstream extent of hydrological effect has been determined as the Lyd/ Tamar confluence, downstream of which changes across the flow regime between baseline and conditions with the abstraction in place are negligible (<10% of 10th April to 10th June flows).

Effects are greatest in average years and in the mid to low flow range (Q50 to Q75). Whilst the maximum permitted abstraction can be taken during wet years, flows are typically larger and therefore, proportionally the abstraction is less important. In dry years, flows are typically receding towards the HOF, which may be reached by the end of the 10th April to 10th June period. Even prior to the HOF being reached, during dry spring recessions, the constraint on the proportional take limits the abstraction to well below the maximum licensed quantity.

The effect of the proposed drought permit even on mid to low flows is well within the range of inter year variability (most easily observed on the flow duration curves) and is certainly within the typical seasonal variation. Because of the Roadford compensation flow, flows would also naturally fall below those downstream of the Lyd abstraction, should it be operated with the proposed constraints.

Spate flows can be reduced by the maximum abstraction volume, but this is a relatively small proportion of the magnitude of spring spates.

Effects of the proposed drought permit over a single year of implementation will average out over the long term and would therefore constitute a negligible change in the long term flow duration curve, even immediately downstream of the Lyd abstraction.

5.2.3 Uncertainties

The naturalised flow estimates are based upon combinations of gauged flows and estimated abstraction volumes. Typically, errors in individual flow series may be between 5-10% even at purpose-designed and well-maintained measurement facilities. Errors in individual flow series are also additive when these are combined (for example, when one flow is subtracted from another to derive another flow estimate).

Some dropouts or short-term declines in the flow series are also evident that are unlikely to represent natural flow recession (e.g. in the baseline flow series at the Lyd abstraction during July/ August 2013 and 2022). These are not atypical of flow series derived from naturalisation by decomposition (addition and subtraction of flow series) and have not been corrected in the above analysis.

Whilst these errors and uncertainties must be acknowledged, they are not considered to cast significant doubt on the broad conclusions of the hydrological impact assessment above.

5.2.4 Summary

- The proposed drought permit is to be implemented between 10th April and 10th June, during the spring flow recession;

- The historical record has been examined for to determine likely effects during dry, wet and average years;
- Effects are greatest at mid to low flows, which are typically most frequent during average years. During dry years, abstraction volumes are limited by a constraint on the proportional take above the HOF. During wet years and during spates, the maximum abstractable volume is a lower proportional of the total available flow.
- The effect of the proposed drought permit even on mid to low flows is well within the range of inter year variability (most easily observed on the flow duration curves) and is certainly within the typical seasonal variation. Because of the Roadford compensation flow, flows would also naturally fall below those downstream of the Lyd abstraction, should it be operated with the proposed constraints.
- Spate flows can be reduced by the maximum abstraction volume, but this is a relatively small proportion of the magnitude of spring spates;
- Effects of the proposed drought permit over a single year of implementation will average out over the long term and would therefore constitute a negligible change in the long-term flow duration curve, even immediately downstream of the Lyd abstraction;
- The predicted magnitude of change on the flow regime of the proposed drought permit is therefore overall deemed **Medium**.
- Flow data for the Lyd catchment is dates back to 1969. Some outages during historical droughts (e.g. 1975 and 1984) are present in the historical dataset, but more recent data are less prone to these losses. Whilst some apparent errors are present in the dataset, these are not considered likely to cast doubt on the broad conclusions of the hydrological assessment. A **Medium** level of certainty has been assigned to this assessment.
- No changes to the status of the WFD Hydrological Regime supporting element are predicted.

5.3 Surface water (Roadford Reservoir level and exposure)

5.3.1 Background

This section assesses potential effects on reservoir water level and exposure as a consequence of the proposed drought permit on the River Lyd and subsequent additional inflows to Roadford Reservoir. This assessment is based on a review of existing data and the results of other areas of the environmental assessment. Long-term measured daily mean level data for Roadford Reservoir were provided by SWW for the period 1995-1997 and 2000-2018.

5.3.2 Baseline

Roadford Reservoir has a storage volume of around 34,500 Ml and reservoir water levels are recorded daily. Figure 5-9 shows the recorded water levels in Roadford Reservoir for the period 1995-2000, inclusive, as well as selected years post 2000. This therefore, includes the effects during and post the 1995-1996 drought.

Roadford is a multi-season refill reservoir with natural refill occurring in 2-3 years. The frequency and timing of reservoir spill at Roadford has been managed by the introduction of the Enhanced Flow Programme (Sambrook and Gilkes, 1994) and releases are also made from the reservoir for the purposes of Hydro-Electric Power (HEP) generation. Details of the framework for reservoir releases for HEP generation and under the Enhanced Flow Programme are included in the Roadford Water Resource Zone Operating Manual (SWW and Environment Agency, 2016).

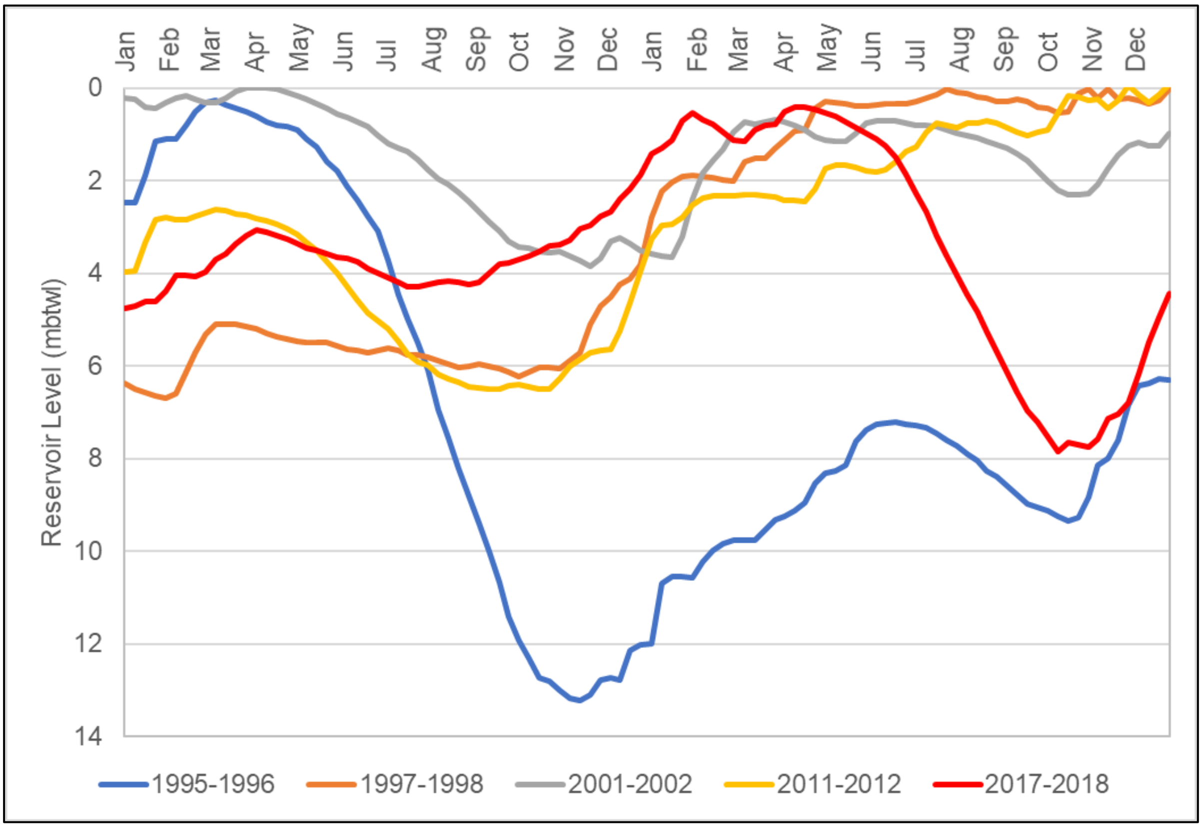


Figure 5-9 Recorded water levels in Roadford Reservoir from 1995- 1998, inclusive, and selected years post 2000

Figure 5-10 shows level percentile curves for Roadford Reservoir and can be used to identify the percentage of time for which a given level is exceeded. The graph was also used to generate a table of level statistics for Roadford Reservoir. The statistics are presented as percentiles (i.e. the 95 percentile equates to the level which is exceeded for 95% of the time, based on the long-term level data). Table 5-6 shows key level percentiles for Roadford Reservoir.

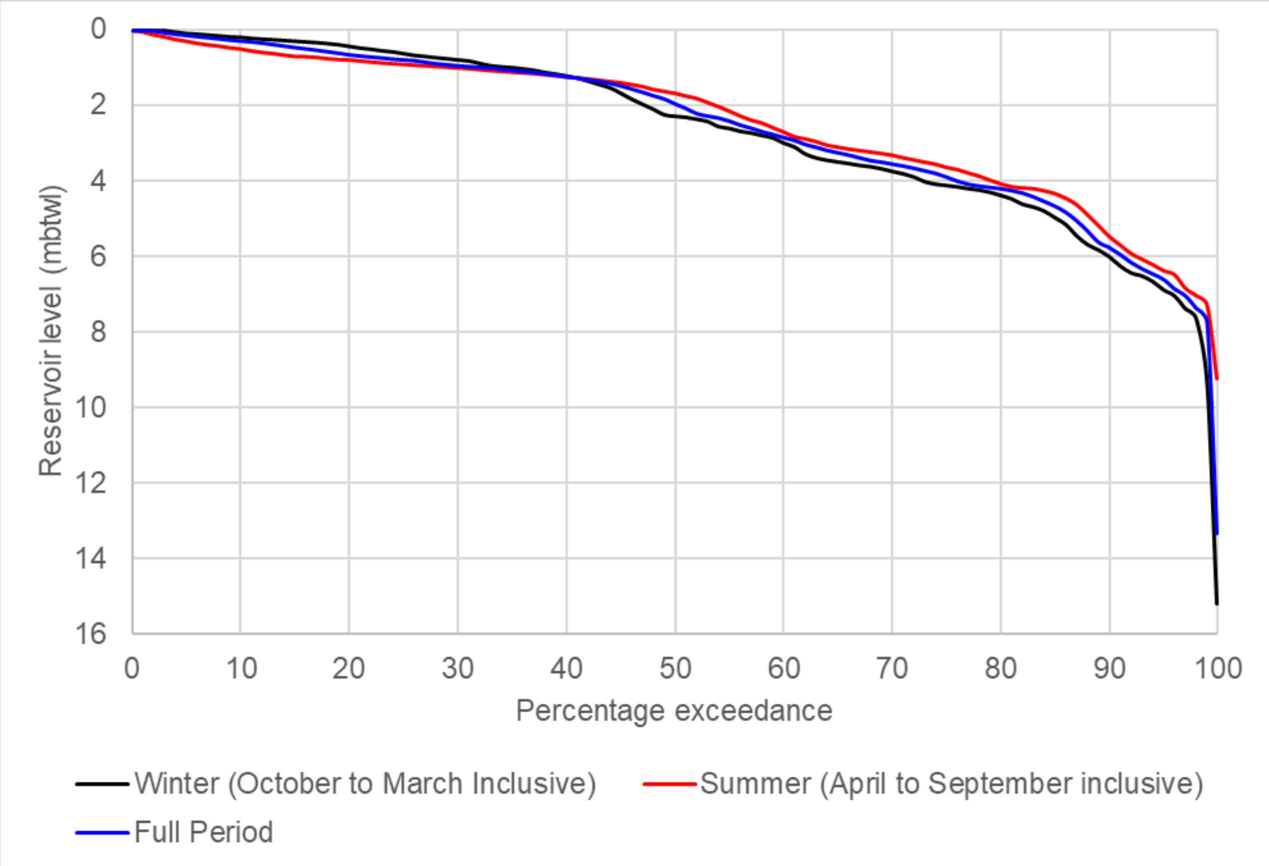


Figure 5-10 Reservoir level duration curve for Roadford Reservoir

Table 5-6 Water level percentiles for Roadford Reservoir

Percentage of time level exceeded	Reservoir level in m below top water level		
	Winter	Summer	Full Period
Maximum reservoir level	0.02	0.02	0.02
10% (high level)	0.19	0.51	0.30
50%	2.28	1.68	1.96
80%	4.37	4.08	4.21
90%	6.00	5.48	5.77
95% (low level)	6.87	6.38	6.61
99% (very low level)	9.33	7.29	7.74
Minimum reservoir level	16.33	11.40	16.33

5.3.3 Impact assessment

From the above data it can be seen that the reservoir water level is subject to considerable inter- and intra-annual fluctuation. This is unavoidable in reservoirs whose primary purpose is public water supply (PWS), as recognised in the UKTAG guidance on classification of artificial water bodies under the WFD. In Roadford Reservoir, the mean water level fluctuation is between 0 and 2.5m per year, with greater drawdowns occurring less frequently.

The proposed drought permit is intended to increase inflows to Roadford Reservoir to delay total drawdown of the reservoir and thereby maintain compensation flow releases and releases for public water supply. With the proposed drought permit in place, the rate of drawdown would be lower than under baseline conditions. This means that, in comparison with the baseline, during the proposed drought permit operation period there would be slower exposure of marginal habitat and a higher proportion of open water habitat available for longer.

For illustrative purposes, analysis of the existing reservoir level data indicates that at Roadford Reservoir, had abstraction from the Lyd been implemented during the November 1996 to March 1997 period (with no changes to reservoir releases), reservoir levels could have been on average 1.07m higher, see Figure 5-11. However, it is not possible to quantify the effect on exposure in the absence of a detailed bathymetric survey data for the reservoir.

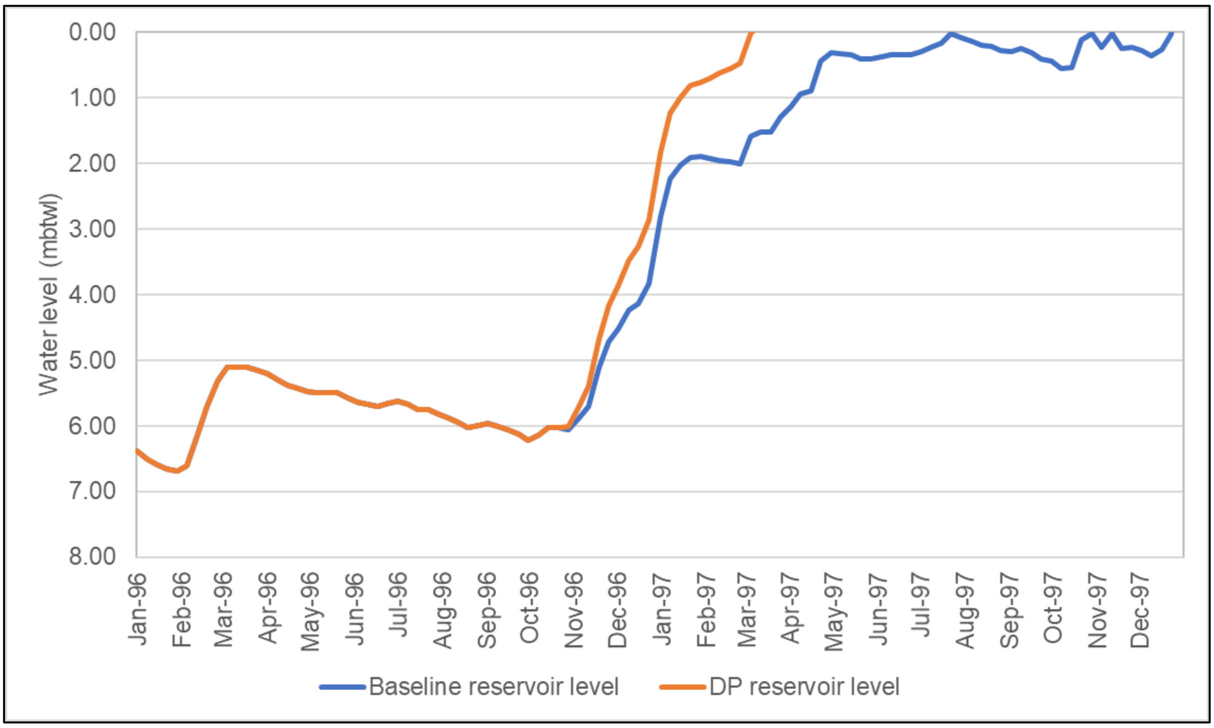


Figure 5-11 Roadford Reservoir baseline water level (January 1996 to December 1997) with estimated water level with additional inflows under simulated drought permit operation (November 1996- March 1997)

5.3.4 Summary

- The north-eastern arm of Roadford Reservoir is designated as a LNR and the reservoir is also used recreationally for walking, canoeing and sailing;
- Operation of the drought permit would be in a period during which refill would be expected to occur (based on historical data). The proposed drought permit would slow the rate of reservoir drawdown and is predicted to have a small effect on reservoir water level and exposure, it is concluded that there will be no subsequent impacts on receptors within Roadford Reservoir (see Section 7). The overall effect during the April to June period would likely be within the range of historical refill. Hence, overall, the magnitude of change on reservoir level of the proposed drought permit is considered **Negligible.**
- Due to the relatively recent construction (1989) of Roadford, in comparison to other UK reservoirs, storage data are temporally limited. Predictions of impact on shoreline exposure are hence considered to have a **Medium** level of certainty.

5.4 River Lyd other abstractors

5.4.1 Background

It is necessary to identify whether the proposed drought permit could affect the ability of third-party surface water drought permit holders to abstract, over and above the effects of natural low flow periods. In addition, it is also intended to identify any river reaches that may be depleted due to a third-party abstraction and whether the drought permit could have an exacerbating effect.

Other abstractors may be affected via:

- reduced river levels that affect their physical ability to abstract water from the river e.g. due to depth of abstraction pipe /inlet; or
- reduced river flows below any HoF specified in their licence that reduce the frequency or duration of periods during which abstraction would be possible under baseline conditions.

These issues are considered in the impact assessment below.

5.4.2 Baseline

Apart from the expired SWW drought permits for the Lyd and Thrushel, associated with Roadford Reservoir, there is only one surface water abstraction within the potentially affected reaches. This is located at Lifton and is operated in support of the Ambrosia Creamery (Licence No. 15/47/051/S/007). Licensed since July 1971, the licence authorises a maximum daily abstraction of 6821.64 m^3 (6.82 Ml/d, although based on abstraction returns, average daily abstraction is much lower than this) and a maximum yearly abstraction of 1,500,210 m^3 (1500.21 Ml/year). Abstraction is permitted throughout the year.

There are no licenced groundwater abstractions downstream of the Lyd abstraction point. The closest groundwater take (<1,000 m^3/d) is located some 4 km upstream of Hayne Bridge at Woolacott.

Further downstream of the reaches potentially affected by the SWW Lyd abstraction there is a small abstraction at Greystone Quarry (SX 367 804) on the River Tamar, of 0.006 m^3/s (0.545 Ml/d), and the SWW Gunnislake abstraction of 1.71 m^3/s (148 Ml/d). However, these would not be affected by the drought permit scenario as they are located too far downstream where the difference between baseline and drought permit scenario flows is less than 10%.

5.4.3 Impact assessment

SWW has obtained abstraction returns for licence no. 15/47/051/S/007 and has used the agreed calculation method described in 5.1.2 to calculate historical naturalised flows upstream of the abstraction and the SWW Lyd intake. Given that licence no. 15/47/051/S/007 was successfully operated during former periods of abstraction with the SWW Lyd intake and the proposed HoF includes a provision for the maximum daily abstraction volume, it is assumed that abstraction under the proposed drought permit would have no effect on downstream abstractors.

5.4.4 Summary

- The proposed drought permit has the potential to reduce the amount of water available within the River Lyd for use by other commercial abstractors. A **Medium** level of sensitivity has therefore been applied.
- Abstraction at the Ambrosia Creamery, the closest site in geographical proximity to the Lyd abstraction intake, continued to be possible during previous SWW abstraction under drought conditions in 1996. Further locations downstream at Greystone Quarry and Gunnislake on the River Tamar are at points where the SWW Lyd drought permit influence is less than 10% in comparison to the baseline scenario. Overall, the impact of the proposed SWW Lyd drought permit on other abstractors is deemed to be **Negligible**.
- Abstraction return data from Ambrosia Creamery are limited to the period 1999-2019 and therefore are outside of most historical dry periods where the potential for an impact would be greater. However, anecdotal evidence suggests that the previous drought permit implementation in 1996 (i.e. under low flow conditions) did not significantly limit abstraction at this location. The overall level of certainty of the assessment is therefore deemed **Medium.**

5.5 Habitat and geomorphology

5.5.1 Background

This part of the assessment reviews the hydromorphological (i.e. the hydrological, hydraulic and geomorphological) effects of the proposed drought permit on the River Lyd.

Hydraulic effects include changes to the physical nature of the water movement: velocity and flow intensity; depth; and wetted width/ wetted perimeter. Geomorphological effects refer to the hydraulic driven effects on erosional and deposition processes occurring within the river and the associated accumulative effects on the physical form of the river. These hydromorphological processes are governed by the river discharge and the physical structure of river channel and can have knock-on effects on riverine and riparian ecology.

5.5.2 Baseline

5.5.2.1 River Habitat Survey

River Habitat Surveys (RHS) provide a standardised method for assessing the quality of physical habitat in rivers based on field observations. The survey method involves recording observations of channel substrate, bank material, flow type, habitat features (e.g. pools, riffles, bars, woody debris, eroding banks), aquatic and riparian vegetation, land use, and artificial modifications at 50 m intervals over a 500 m reach. From this information, two separate indices can be calculated: the habitat quality assessment (HQA) score and the habitat modification score (HMS). Together, these indices provide information regarding channel morphology and constraints on natural functioning.

RHS data are available from the Agency for six monitoring locations on the River Lyd within the potentially affected reaches (Table 5.7; Figure 5-12). These surveys were conducted between September 1996 and July 1999. An additional survey was undertaken by SWW at one monitoring location. Together, these two datasets provide reasonable spatial coverage of the two water bodies of interest, with the exception of the River Lyd upstream of the Thrushel confluence.

Table 5.7 River Habitat Survey monitoring locations on the River Lyd within the potentially affected reaches

River	Survey ID	Monitoring location ID	NGR	Date of survey	Source
Lyd	13232	8085	SX 39000 85000	14/09/1996	Environment Agency
Lyd[a]	13233	8086	SX 40000 85100	14/09/1996	Environment Agency
Lyd	14529	9207	SX 38900 84300	15/10/1997	Environment Agency
Lyd	20604	11659	SX 38800 84300	02/09/1998	Environment Agency
Lyd	20633	11688	SX 38900 84800	02/09/1998	Environment Agency
Lyd	21717	12718	SX 38900 84400	21/07/1999	Environment Agency
Lyd	-	-	SX 38950 84620	2000	SWW

For the HQA scores and sub-scores a colour scale has been applied to indicate how each compares to the average score, derived from expert judgement of RHS. The colour key for the indicative classifications is presented in Table 5.8. For the HMS sub-scores, a colour scale (green to red) has been applied to indicate the relative contribution to the overall HMS that each sub-score makes, with those sub-scores coloured green having a low contribution and those coloured red having a high contribution. The overall HMSs are coloured according to their indicative classifications, as detailed in Table 5.9.

Table 5.8 River Habitat Survey habitat quality assessment scores and sub-scores classification/ description key

Classification	Cell colour
Unusually high scoring / diverse	
Above average quality / diversity	
Average scoring	
Below average scoring / diversity	
Notably low scoring / low diversity	

Table 5.9 River Habitat Survey habitat modification score classification key

Class	Score range	Description	Cell colour
1	0 – 16	Pristine	
2	17 – 199	Predominantly unmodified	
3	200 – 499	Obviously modified	
4	500 – 1399	Significantly modified	
5	1400 +	Severely modified	

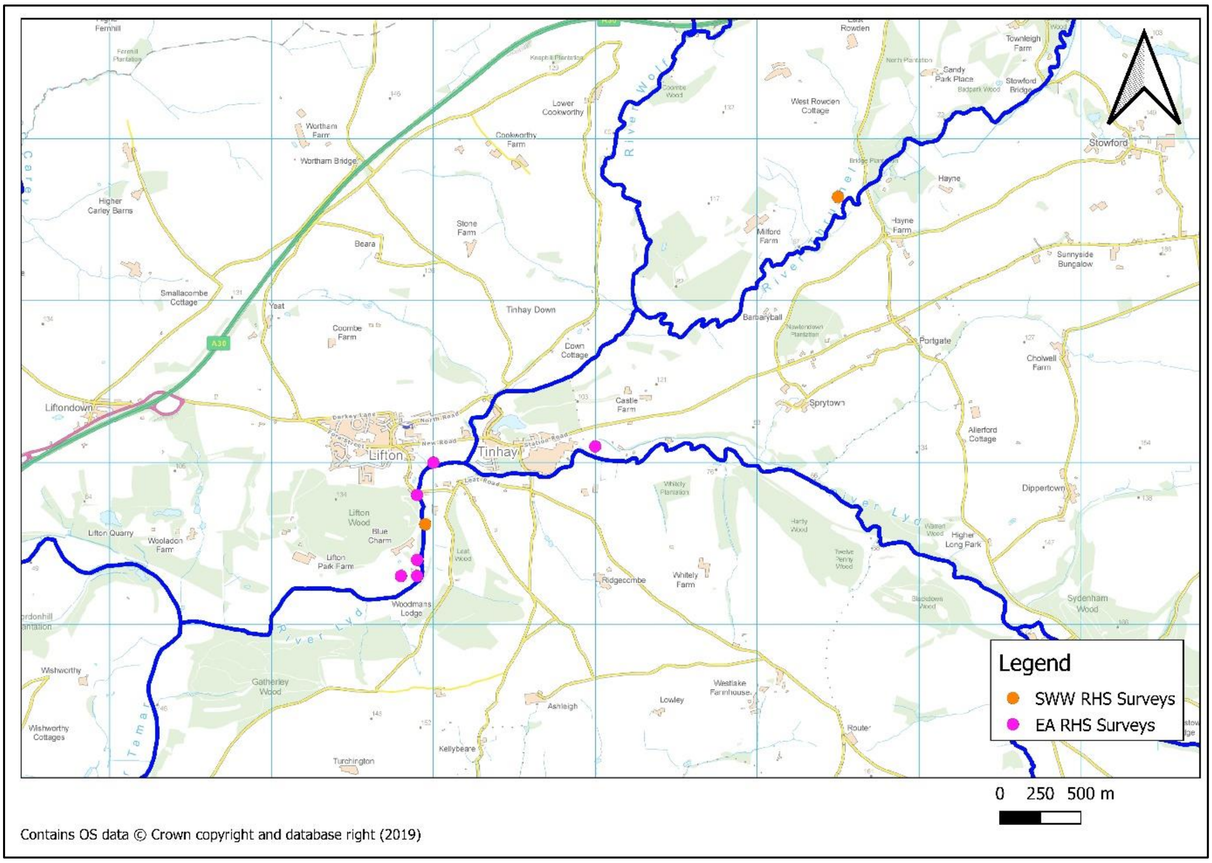


Figure 5-12 River Habitat Survey monitoring locations on the River Lyd within the potentially affected reaches

RHS scores, classifications and sub-scores for the surveys undertaken within the potentially affected reaches of the River Lyd are presented in Table 5.10 to Table 5.11.

The HQA scores (Table 5.10) indicated average and unusually high habitat diversity, with the primary contributor to the diversity being the flow types that were recorded. Instream channel vegetation, bank features, vegetation and trees and associated features were also generally high contributors.

Table 5.10 River Habitat Survey habitat quality assessment scores and sub-scores for the River Lyd

		Channel				Banks and riparian zone				
Survey ID	**HQA score**	**Channel Features**	**Channel Substrates**	**Flow Types**	**In Stream Channel Vegetation**	**Bank Features.**	**Bank Vegetation**	**Trees Assoc. Features**	**Land Use**	**Special Features**
13232	70	5	6	14	11	11	12	11	0	0
13233	68	8	6	18	9	11	7	9	0	0
14529	45	2	2	15	4	1	12	7	2	0
20604	62	4	5	13	10	10	9	11	0	0
20633	76	6	6	19	10	11	12	11	1	0
21717	55	4	6	13	6	1	11	11	2	1

The HMSs (Table 5.11) reveal considerable variation in the level of physical modification on the River Lyd, with scores ranging from 'pristine' to 'significantly modified'. Within the ‘obviously modified’ and ‘significantly modified’ reaches, weirs and bridges were the main identified modifications.

Table 5.11 River Habitat Survey habitat modification scores and sub-scores for the River Lyd

Survey ID	HMS Score	Fords	Poaching	Culverts	Outfall Deflector	Bridges	Reinforced Bed Bank	Resectioned Bank Bed	Berms Embankments	Weirs
13232	69	0	0	0	25	0	40	0	4	0
13233	10	0	10	0	0	0	0	0	0	0
14529	415	0	0	0	0	0	0	40	0	375
20604	0	0	0	0	0	0	0	0	0	0
20633	340	0	20	0	0	300	0	0	20	0
21717	615	0	20	0	0	0	0	0	0	595

5.5.2.2 Bed material composition

In addition, channel bed sediment samples were taken by SWW along the River Lyd between 1987 and 2000. The methodology involved Wolman pebble counts to characterise the armour layer, and freeze-core sampling of the sub-armour material to a depth of between 0.3 and 0.6 m.

5.5.2.3 River structures

Structures posing potential impediment to anadromous fish were reported at three locations on the River Lyd; one downstream of the Lyd abstraction (Figure 5-14) and a further two downstream of the Lyd/ Thrushel confluence (Figure 5-15 and Figure 5-16) locations of which are shown in Figure 5-13. Passability of these structures for migratory fish are considered further in Section 6.3.

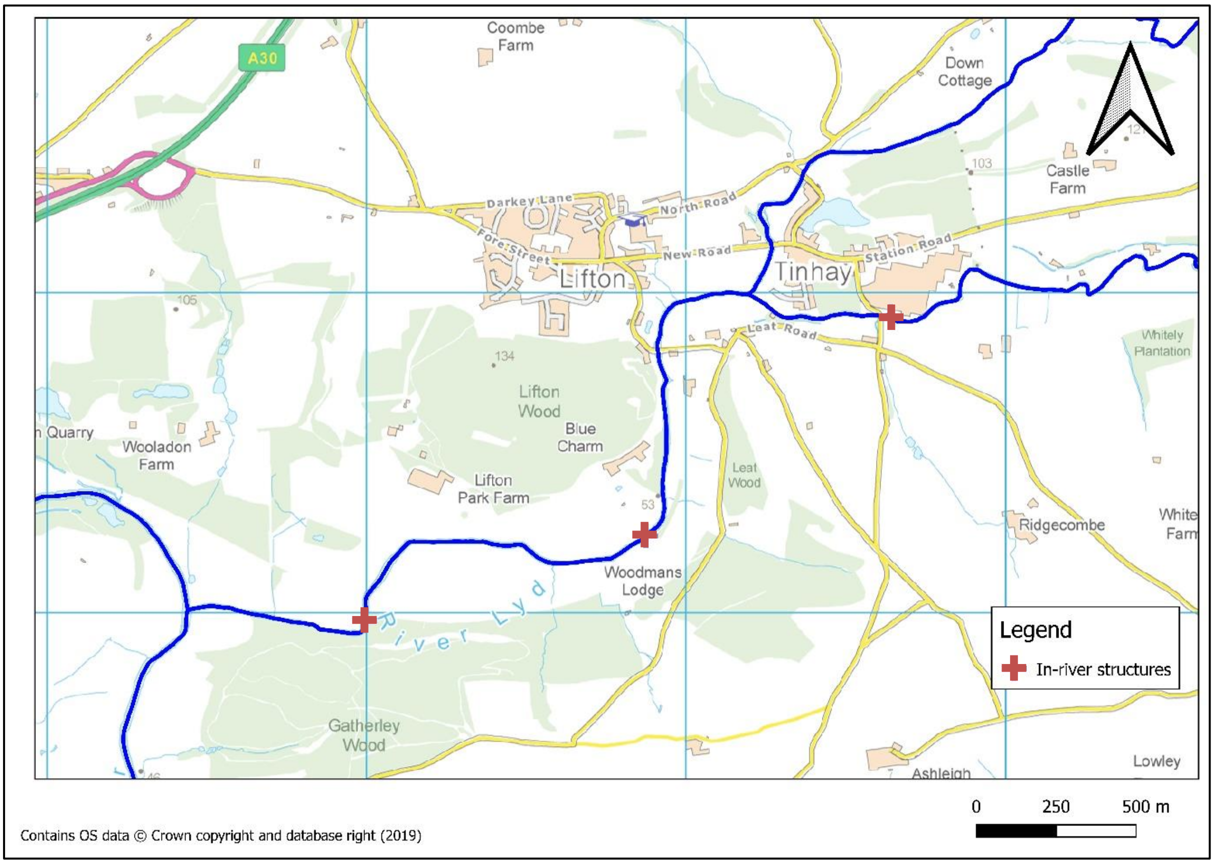


Figure 5-13 Location of in-river structures, River Lyd

Figure 5-14 Rubble weir – River Lyd d/s Ambrosia Creamery discharge point

Figure 5-15 Lifton Park Gauging Station on the River Lyd

Figure 5-16 Impounding structure on the lower reaches of the River Lyd

5.5.2.4 *Geomorphology walkover*

Method

A walkover survey was undertaken to characterise the current geomorphological functioning of the reaches of the River Lyd that may be affected by the proposed drought permit. Accordingly, the River Lyd was surveyed from upstream of the proposed abstraction location (SX 40038 85022) to its confluence with the River Tamar (SX 37449 84009). Surveys were conducted on 7 and 8 August 2019 during low flows (discharge at Lifton Park gauging station on 7 August was 1.79 $m^3 s^{-1}$ (approximately Q65) (NRFA, 2019)).

The survey focused on recording features indicative of geomorphological processes (i.e. sediment erosion, transport and deposition) and the impact of current anthropogenic modifications on these processes. Consequently, the following features were recorded:

- evidence of sediment supply, i.e. bed and bank erosion, tributary inputs;
- evidence of sediment storage, i.e. in-channel bars (point, medial, confluence) and floodplain deposits;
- physical characteristics of the channel, i.e. bed and bank material composition (visual estimates of dominant particle size, classified according to the Wentworth scale);
- engineering modifications and pressures, i.e. bed and bank reinforcement, culverts, bridges, weirs, realignments, simplified riparian vegetation, cattle poaching; evidence of sediment supply (bed and bank erosion, tributary inputs), and evidence of sediment storage (in-channel bars and floodplain deposits); and
- additional physical habitat features of relevance, e.g. woody material, riparian vegetation structure and extent, macrophytes.

These observations were used to divide the surveyed rivers into homogeneous reaches based on the dominant coarse sediment transport processes operating in each. Each reach was assigned to one of the following six categories:

- erosional source (supply);
- erosional exchange;
- balance exchange;
- balance transport;
- depositional exchange; and
- depositional sink.

These classifications are known as ST:REAM types after Parker (2010; 2015) and SEPA (2015). Brief descriptions for each class are provided in Table 5.12. Essentially, distinctions between classes are based on the ratio of sediment transport capacity to the supply of sediment from upstream: reaches in which transport capacity exceeds sediment supply are classified as erosional, while those in which capacity is less than supply are classified as depositional. If capacity and supply are approximately equal, the reach is considered to be in balance. Practically, this is determined in the field based on the balance between sediment production (i.e. erosion) and sediment supply (i.e. deposition).

Table 5.12 ST:REAM reach types and descriptions

ST:REAM type	Description
Erosional source	Erosion dominates and there is no supply of sediment from upstream.
Erosional exchange	Erosion dominates, but there is a supply of sediment from upstream, some of which may be temporarily stored within the reach.
Balance exchange	Rates of erosion and deposition within the reach are approximately equal, and sediment supply to the reach is approximately equal to sediment export.
Balance transport	Sediment supply to the reach is approximately equal to sediment export, but there is no exchange of sediment within the reach (i.e. sediment supplied from upstream passes through the reach with no temporary storage).
Depositional exchange	Deposition dominates but there is some erosion with the reach and, consequently, some sediment export.
Depositional sink	Deposition dominates and although there may be some erosion within the reach, there is little or no sediment export from the reach.

Results

A summary of the reach classifications for the River Lyd is presented in Figure 5-17. The river was divided into six reaches (L1 to L4 upstream of the River Thrushel confluence; L5 and L6 between the River Thrushel confluence and the River Tamar). Descriptions of the geomorphological functioning of each reach are provided in the following sections, and representative photographs of each reach are provided in Table 5.13.

L1: Spry Farm to Leat Road (Erosional Exchange)

The River Lyd through this reach is set within a wide floodplain, but the channel is incised 2-3 m below the floodplain elevation and, consequently, largely disconnected. The channel bed is dominated by coarse sediment in the gravel to cobble range, while the banks are composed of finer alluvial material and mostly well vegetated. Bank protection is present on the right bank for approximately 150 m downstream of the Lyd abstraction (SX 39920 85071). For most of this length, the bank protection takes the form of a brick wall which also acts as an embankment, constraining flow within the river and preventing floodplain inundation during spates. With the exception of the protected sections, bank toe erosion is evident along much of the reach, and exposed tree roots, undercut walls, and trees leaning over the channel providing evidence for incision. The presence of bank protection and local bedrock exposures attest to the erosional nature of this reach. Bank poaching also provides a local source of sediment. Although several small bars are present, sediment storage within the reach is minimal, being restricted by the incised nature of the channel which prevents energy dissipation during high flows. There is a small rubble weir at the downstream end of this reach which, at the time of survey, was impounding the flow for less than 20 m and was not considered to be a significant control on geomorphological processes within the reach.

L2: Leat Road (Depositional Exchange)

This is a short reach of approximately 80 m centred on Leat Road bridge where deposition dominates. The characteristics of this reach are sufficiently different from those upstream and downstream to warrant distinction. There is a tongue of uncompacted alluvial material immediately upstream of the bridge, the constituent particles of which reduce in size with distance downstream. Sand is present in the bed in large quantities downstream of the bridge. The bridge may be acting as a hydraulic control, impounding the flow during spates and reducing flow competence. The channel is also substantially wider in this reach than upstream meaning that stream power per unit width is reduced for all flows and, consequently, sediment deposition is more likely.

L3: Leat Road to Tinhay Mill Industrial Estate (Erosional Exchange)

A short distance downstream of Leat Road bridge the geomorphological characteristics of the River Lyd revert to those observed in reach L1. Specifically, the channel is incised, the bed is predominantly composed of coarse gravel and cobble with occasional bedrock exposures, and bank toe erosion is prevalent throughout. Although a floodplain is present on the left bank for much of this reach, its width reduces with distance downstream. There is no floodplain on the right bank as the land rises abruptly from the channel to a wooded area. Exposed tree roots, undermined walls and leaning trees provide evidence of bed incision. Although small sediment bars are present in places throughout this reach, there is minimal storage (most likely due to the incised and constrained nature of the channel) and erosion is clearly the dominant, operative process.

L4: Tinhay Mill Industrial Estate to River Thrushel (Balance Transport)

Towards its downstream extent, the River Lyd remains confined and incised. However, the channel boundaries become increasingly dominated by bedrock which, despite the presence of small pockets of alluvial material, exerts the principal control on geomorphological processes. There is little evidence of contemporary bed or bank erosion (although it is likely that the channel has historically eroded to bedrock), and no substantial sediment storage. It is therefore assumed that this reach efficiently transports the majority of its coarse sediment supply with minimal local exchange. Due to the nature of this reach, it could not be walked in its entirety and was predominantly viewed from its upstream extent.

L5: River Thrushel to Lifton Park (Depositional Exchange)

Downstream of its confluence with the River Thrushel, the River Lyd becomes dominated by processes of sediment deposition. This is mostly likely due to a combination of high sediment supply from erosional reaches upstream on both the Lyd and Thrushel, and a reduction in unit stream power as the channel becomes wider and less confined. Bank height reduces with distance downstream, particularly on the left bank, and channel-floodplain connectivity is improved relative to upstream reaches. Numerous sediment bars are present within the reach between the confluence and Lifton Park, indicating abundant sediment storage, and the bed is composed of finer material (mostly sand, gravel and fine cobble) than that in upstream reaches, indicating reduced transport competence and a tendency towards deposition. Some minor bank toe erosion is present on the outside of the meander bend, but in general the banks appear stable and the volume of sediment storage far exceeds the volume of sediment generated from erosion.

L6: Lifton Park to River Tamar (Erosional Exchange)

On the River Lyd between Lifton Park and the River Tamar, depositional features are less frequent than immediately upstream, bed material is coarse (coarse gravel and cobble), and bedrock is exposed in the channel bed and banks throughout. The channel is confined by steep valley sides at Lifton Wood (between SX 38915 84722 and SX 38934 84615) and Gatherley Wood (between SX 38000 83990 and SX 37709 83981). Where a floodplain is present, the channel is typically incised 2 – 3m below the floodplain elevation. The planform of the River Lyd through this reach is noticeably straight and it is likely that the channel has been historically realigned. Such an alteration would have increased channel slope and, consequently, unit stream power, which would have increased rates of sediment erosion and transport. Two weirs are present within the reach and, although they create local zones of deposition, they do not exert a dominant control on geomorphological processes operating on the lower River Lyd. Given the frequency of bedrock exposure in the channel bed and banks, contemporary rates of erosion within the reach are not particularly high, but evidence of bank toe erosion is present throughout, including bank overhangs, exposed tree roots, and trees leaning towards the channel. Bank poaching also provides local inputs of sediment, and where this occurs the coarse channel bed is commonly veneered with fine sediment (sand and silt). Given the limited sediment storage within this reach, erosion is the dominant geomorphological process. However, coarse alluvial material is present on the bed indicating that material supplied from upstream is temporarily stored and exchanged during high flows.

Table 5.13 Representative photographs for each reach on the River Lyd


Reach L1: view downstream showing steep, undercut banks and overhanging trees with minimal sediment storage.

Reach L2: Substantial sediment deposition upstream of Leat Road bridge.

Reach L3: view downstream, showing steep, undercut banks and overhanging trees with minimal sediment storage.

Reach L4: view downstream showing channel boundaries dominanted by bedrock.

Reach L5: view upstream showing sediment deposition on the inside of a meander bend and well-vegetated, stable banks.

Reach L6: view upstream showing steep, undercut banks and overhanging trees with minimal sediment storage.

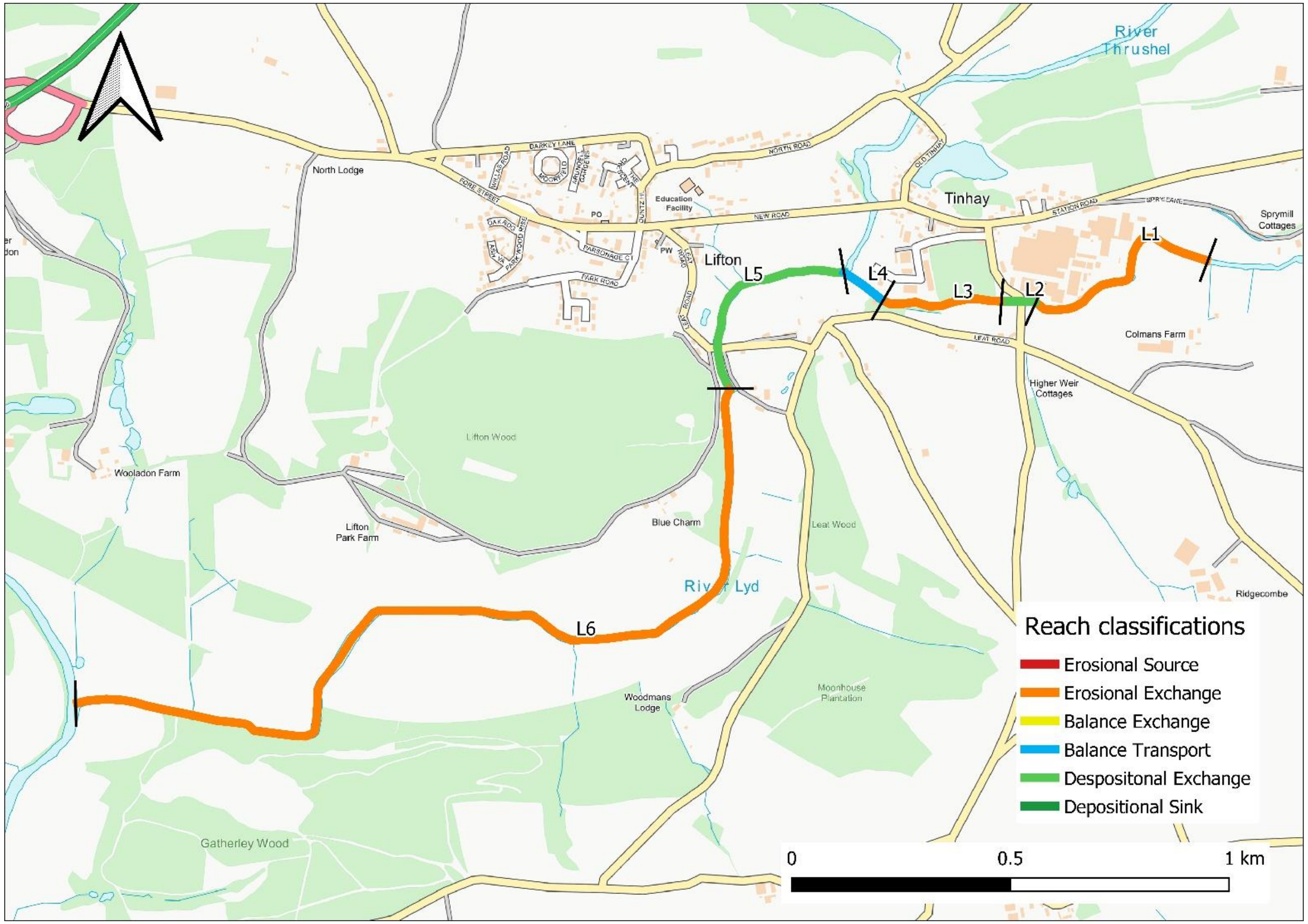


Figure 5-17 ST:REAM reach classifications on the River Lyd

5.5.2.5 *Bathymetry surveys*

To inform the assessment (originally within the context of the proposed drought permit, reported within the drought permit EAR (APEM, 2022)), bathymetric data were collected at two reaches along the 3.5 km length of the River Lyd between the Lyd abstraction and the confluence with the River Tamar. Reaches were selected based upon results from habitat and geomorphological walkover surveys, along with results from historical redd mapping completed by the Arundell Arms with the aim of selecting areas likely to be sensitive to changes in flow under the proposed drought permit; in particular those areas which historically have been suitable for spawning of salmonid species as indicated by redd count data. The extent of the two reaches are illustrated in Figure 5-18 and summarised as follows:

- Reach 1 extends from NGR SX3852384178 adjacent to the Lyd intake downstream of the Ambrosia Creamery discharge at NGR SX3969184912, a length of approximately 315 m. The reach location was chosen because it encompassed areas of known salmonid spawning habitat based on historical redd mapping data and represents the area of greatest potential hydrological change under the proposed drought permit.
- Reach 2 extends from the downstream extent of Home Beat at NGR SX3852384178 to NGR SX3829084223, a length of approximately 250 m. The reach location was chosen because it encompassed a mixture of spawning, juvenile and adult habitat, deemed to be representative of the wider River Lyd downstream of the confluence with the River Thrushel.

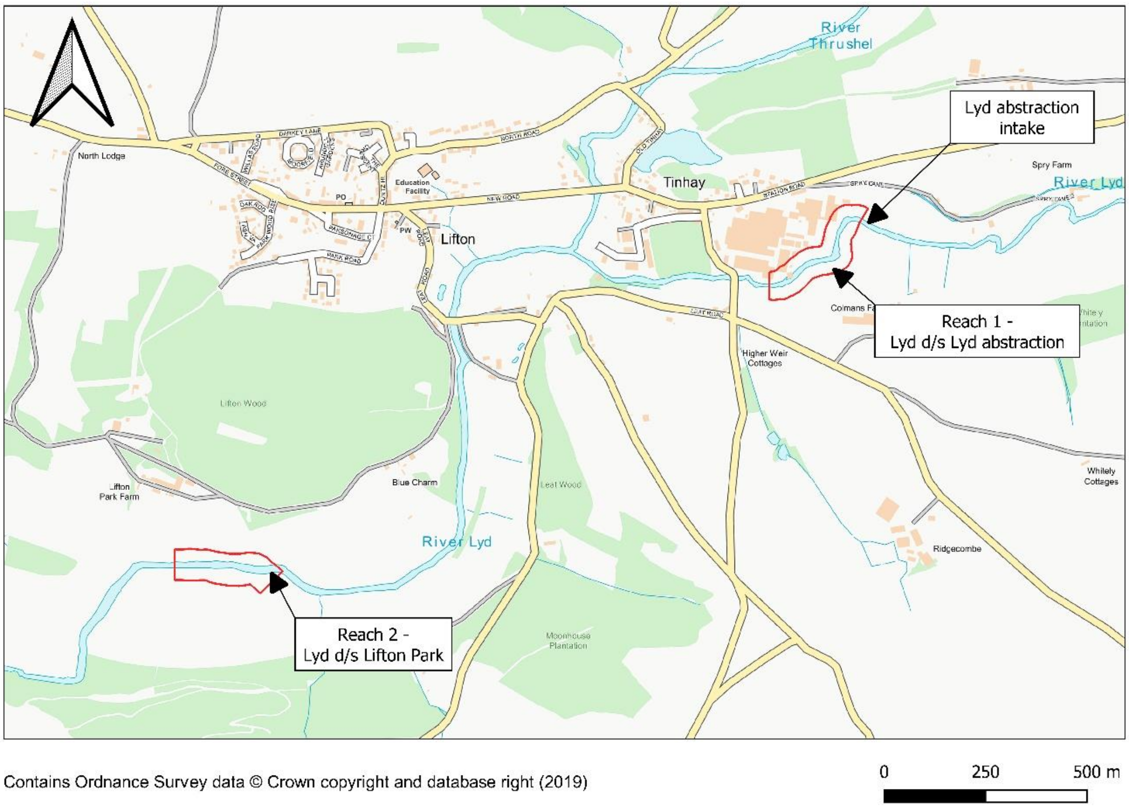


Figure 5-18 Bathymetric survey reaches downstream of the River Lyd abstraction

The bathymetric survey design comprised river channel cross sections (perpendicular to flow) at minimum 5m intervals, together with survey of the top and bottom of bank lines and any changes in bed slope within each survey reach. The coverage was, in part, dictated by the extent of overhanging vegetation, river depth and flow conditions during the survey.

The survey and data acquisition were coordinated and post processed to the following datums:

- Horizontal datum: Ordnance Survey British National Grid (OSGB1936) based on the ETRS89 to OSTN15 transformation;
- Vertical datum: Ordnance Datum Newlyn (ODN) based on the ETRS89 to OSGM15 transformation.

Water levels were recorded relative to Ordnance Datum across multiple locations along each survey reach at the start and end of each survey. LIDAR data of the surrounding land was merged with the bathymetric and topographic datasets to extend survey coverage beyond the immediate river bank. The data were interpolated to generate a continuous grid of depth data to encompass each survey reach at 0.5 m grid cell resolution which was used to produce an accurate digital terrain model (DTM) of the survey reaches (Figure 5-19).

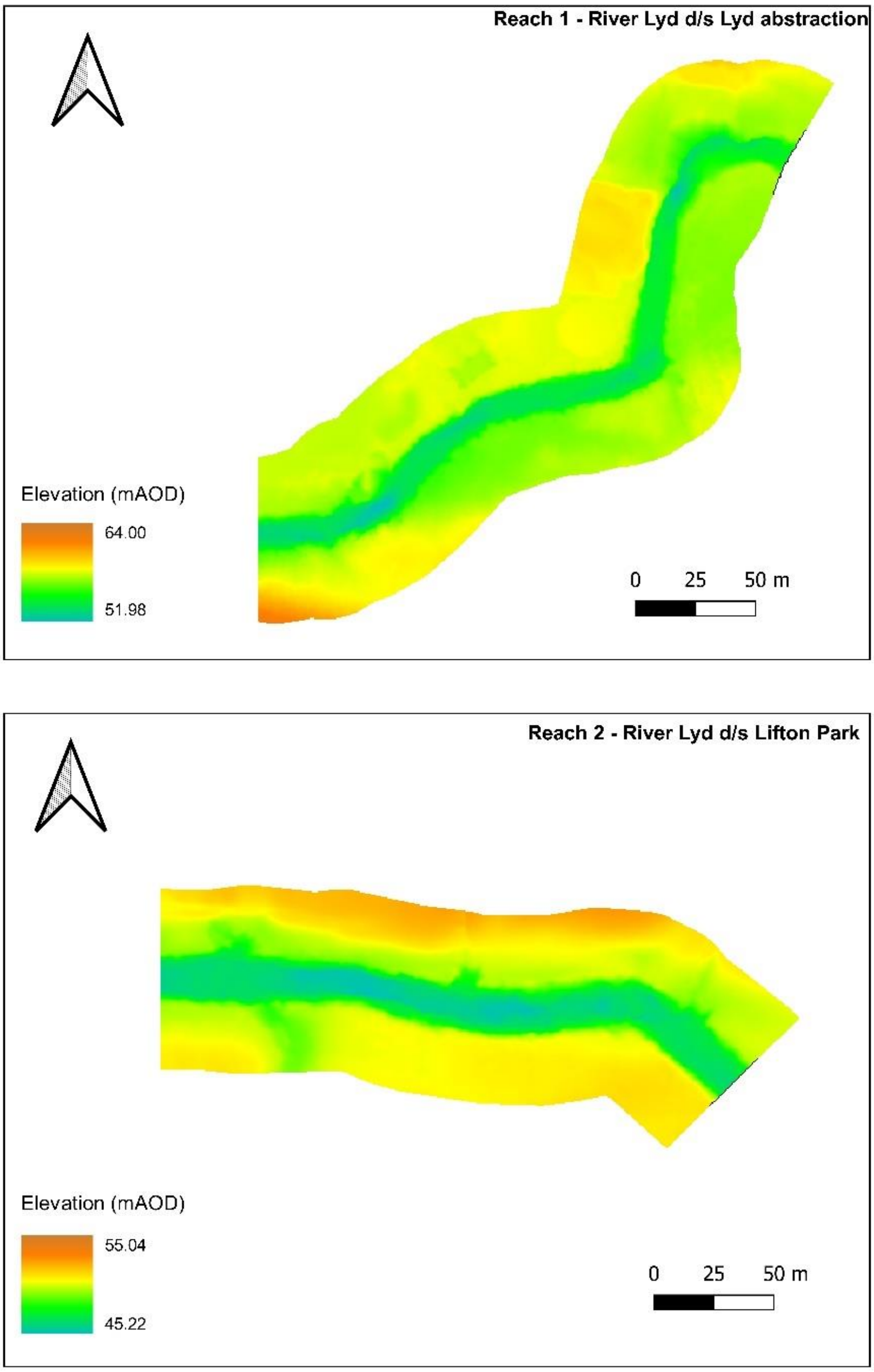


Figure 5-19 Outputs of bathymetric data processing for modelled River Lyd reaches

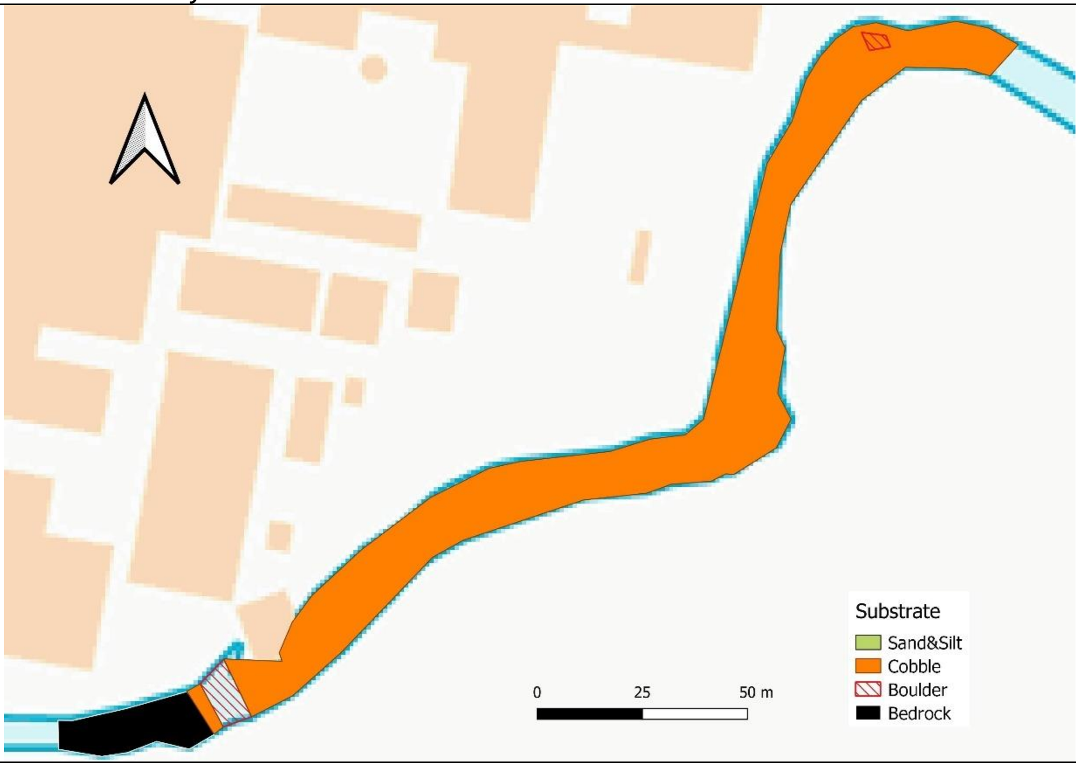
The bed substrate composition of each reach was mapped and classified on site, based on the particle size thresholds provided in Table 5.14.

Table 5.14 Size threshold of substrates recorded during bathymetric surveys

Substrate	Particle size range
Boulder	>256 mm
Cobble	64 – 255 mm
Pebble	16-63 mm
Gravel	2 – 15 mm
Sand	0.06 – 1 mm
Silt	<0.059 mm

A coordinate grid of substrate composition was generated for each reach to inform the subsequent geomorphology and fisheries assessments (Figure 5-20).

Reach 1 – River Lyd d/s abstraction



Reach 2 – River Lyd d/s Lifton Park

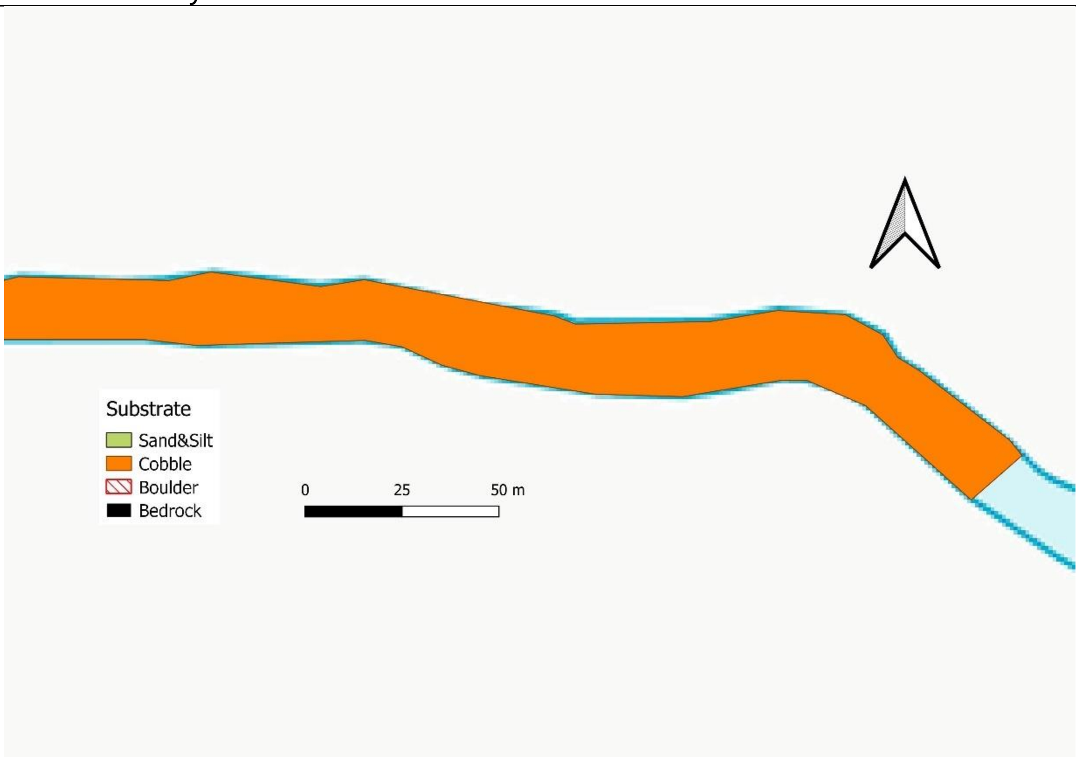


Figure 5-20 River Lyd substrate maps

5.5.3 Impact assessment

5.5.3.1 Hydraulic modelling

Methodology and calibration

Spatially-distributed predictions of flow velocity and depth within both reaches were made using a 2D hydraulic model (CAESAR-Lisflood) under baseline (low flow) and Drought permit scenario conditions. CAESAR-Lisflood is a reduced complexity, cellular model that incorporates the LISFLOOD-FP 2D hydrodynamic flow model of Bates *et al*. (2010) with the CAESAR landscape evolution model (Coulthard *et al.,* 2013). For the purposes of this study, the model was run in reach mode (meaning that a specified discharge was input at the upstream extent of the modelled reach), and sediment dynamics were not explicitly modelled. In each reach, the 0.5 m-resolution DTMs described in Section 5.5.2.5 were used to represent the channel geometry.

Model calibration, i.e. the manipulation of adjustable parameters to ensure optimal agreement between modelled and observed data, was undertaken prior to running the model for the baseline and Drought permit flow scenarios. In this case, and following standard procedures for hydraulic modelling, calibration was completed by adjusting the global value of the roughness coefficient Manning's n and comparing modelled water surface levels with measured water surface levels for a given flow. Manning's n controls flow depth and velocity for a given discharge, making its correct parameterisation essential for the present application. The overall reach energy gradient was reconstructed from continuous (15-minute) stage data recorded at the upstream and downstream reach extents.

Model inflows for calibration for the period of survey were derived utilising Agency 15-minute flow data as follows:

- Reach 1: determined using the naturalisation method described in 5.1.2. Mean flows for the period 04/09/2019 09:45 to 04/09/2019 15:45. Mean flow: 72.08 Ml/d;
- Reach 2: inflows taken as those measured at Lifton Park gauging station, approximately 400 m upstream for the period 03/09/2019 09:30 – 03/09/2019 13:00. Mean flow: 108.17 Ml/d.

Calibration established that a Manning's n of 0.06 provided the best fit between modelled and observed water levels in Reach 1 (Figure 5-21), with a value of 0.08 providing the best fit in Reach 2 (Figure 5-22). The overall energy gradient is determined as a linear extrapolation of stage between two points and does not, therefore, account for local variations forced by channel geometry as picked up by measured water surface levels. Generally, good agreement between measured and modelled water levels was achieved, with all modelled water surface elevations within regulatory guidance tolerances of ± 150 mm[2]. Overall, modelled water surface elevations were moderately below those measured during survey, and are hence a conservative estimate of water depth.

2 Modelled water level accuracy requirements (generally given for peak flow i.e. flood water level modelling) vary by regulatory authority. Environment Agency guidelines (Fluvial Design Guide, Chapter 7) state acceptable broad scale tolerances ±500mm, reducing to ±250mm for flood defences. SEPA guidelines (Flood Modelling Guidance for Responsible Authorities) state ±300 mm reducing to ±150 mm for local scale or detailed studies. The latter guidance (±150mm) by SEPA has been preferred herein.

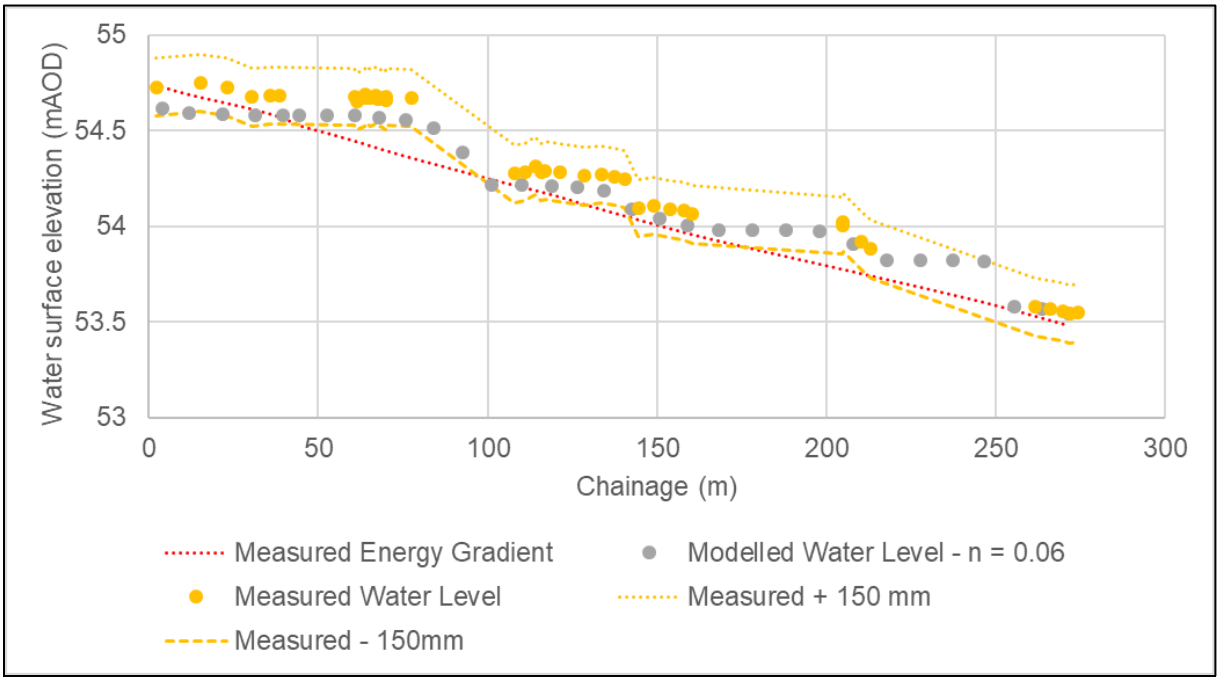


Figure 5-21 Modelled and observed water surface elevations in Reach 1 for the calibration flow of 72.08 Ml/d where Manning's *n* = 0.06

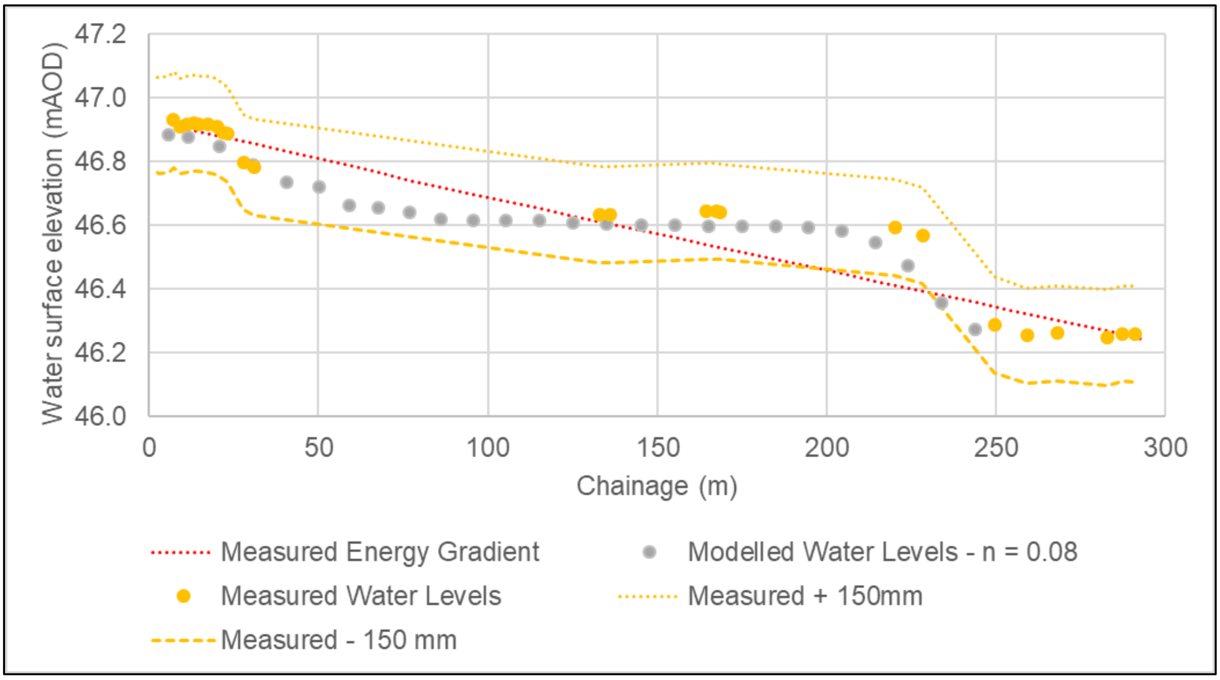


Figure 5-22 Modelled and observed water surface elevations in Reach 2 for the calibration flow of 108.17 Ml/d where Manning's *n* = 0.08

Manning's n values of 0.05 - 0.08 are characteristic of reaches containing weed coverage and/or deep pools (Chow, 1959). Given that this is a good description of the River Lyd between the proposed abstraction location and the reach downstream of Lifton Park, calibrated

Manning's *n* values of 0.06 and 0.08 were considered suitable for predictive modelling for both baseline and Drought permit flow scenarios.

Figure 5-23 Deeper sections of the River Lyd downstream of the Lyd abstraction (04/09/2019)

Figure 5-24 A representative view of the River Lyd downstream of Lifton Park (03/09/2019)

Results

In order to examine the largest potential daily impact the proposed Drought permit could have on in-river hydraulic properties (depth, velocity and wetted area/marginal exposure) on the River Lyd (during the maximum daily abstraction of 40 Ml/d) the following approach to defining inflows to the hydraulic model was adopted, by reach:

- Reach 1 - River Lyd d/s abstraction.
  - Baseline: The lowest flow where maximum abstraction could occur is 126.4 Ml/d (i.e. to take 40 Ml/d, there must be 80 Ml/d of flow available above the HoF of 46.4 Ml/d in the River Lyd).
  - Drought permit: a reduction of 40 Ml/d compared to the baseline i.e. 126.4 – 40 = 86.4 Ml/d.
- Reach 2 - River Lyd d/s Lifton Park.
  - Baseline: Days in the historical record (1969-2022, 10th April to 10th June) where maximum abstraction would have been possible were examined using the naturalised flow record upstream of the abstraction. Of these days, the lowest subsequent flow at Lifton Park gauging station was selected to define the lowest flow during maximum abstraction downstream of the Thrushel confluence. This was 26/01/2017 with a recorded flow of 140.5 Ml/d.
  - Drought permit: 140.5 – 40 = 100.5 Ml/d.

Modelled predictions of flow velocity and depth for the baseline and Drought permit scenarios for Reach 1 and 2 are shown in Figure 5-25 and Figure 5-26 respectively. To aid visualisation of changes in depth and velocity, differences between baseline and Drought permit scenarios for each hydraulic parameter are shown in Figure 5-27 to Figure 5-31.

In both reaches, modelled flow velocity is predominantly moderate (<0.50 m/s) under both baseline and Drought permit scenarios. The highest velocities (> 1.0 m/s) within each reach are modelled to occur at topographic highs, with the maximum modelled velocities (1.9 m/s) recorded over the rubble weir at the downstream extent of Reach 1.

In both reaches and under both flow scenarios, modelled flow depths typically range between 0.25 and 2 m, although variations within and between reaches are evident. Modelled flow depths in Reach 1 are typically deeper than those in Reach 2, with a deep pool (>2.4 m under both flows) present in Reach 1 upstream of the rubble weir. Reach 1 exhibits greater depth variation than Reach 2, with a number of pool riffle sequences evident under both flow scenarios.

Under the Drought permit scenario in Reach 1, depths are predicted to reduce between 0 – 0.1 m with greatest changes predicted downstream of the rubble weir (~ 0.1 m) and at topographic highs such as riffles (0.05-0.07 m). Depths in the vicinity of deeper pools remain largely unchanged (< 0.03 m). Reductions in depth translate to relatively small changes in velocity compared to the baseline scenario and are predominantly less than 0.25 m/s. Greatest changes occur over riffles within the reach, where reductions in depth act to accelerate flow locally. Minor changes in marginal exposure are predicted under the Drought permit scenario, with an increase of 100.5 m^2 (3.7%) compared to the baseline scenario (Figure 5-29).

In Reach 2, reductions in depth are smaller (< 0.07m) in magnitude partly due to accretion in flow downstream of the River Thrushel confluence. Again, reductions in velocity compared to the baseline scenario are predominantly < 0.25 m/s with increases in velocity predicted over riffle features and reductions predicted in deep pools. Minor changes in marginal exposure are predicted under the Drought permit scenario, with an increase of 95.5 m^2 (3.1%) compared to the baseline scenario (Figure 5-32).

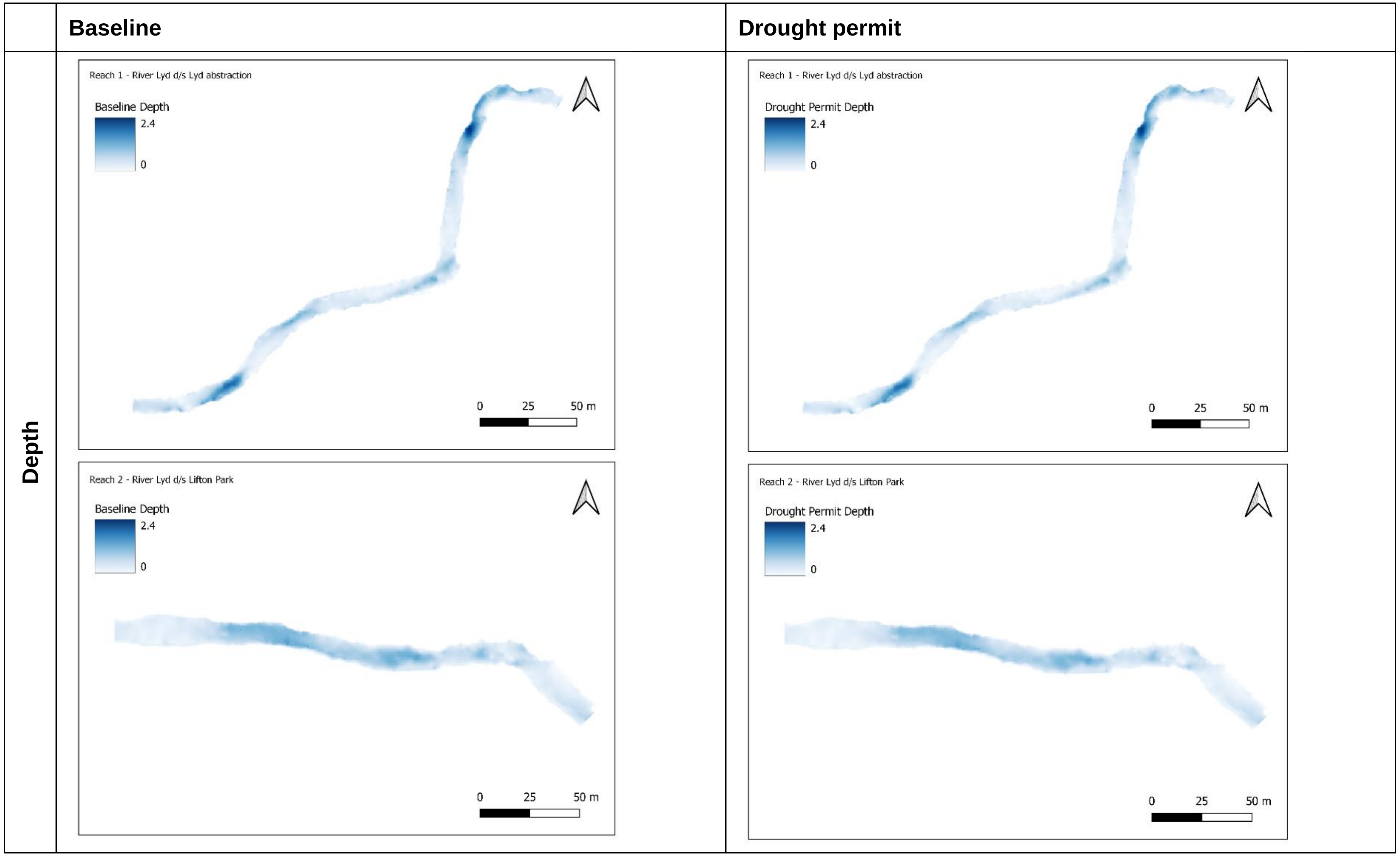
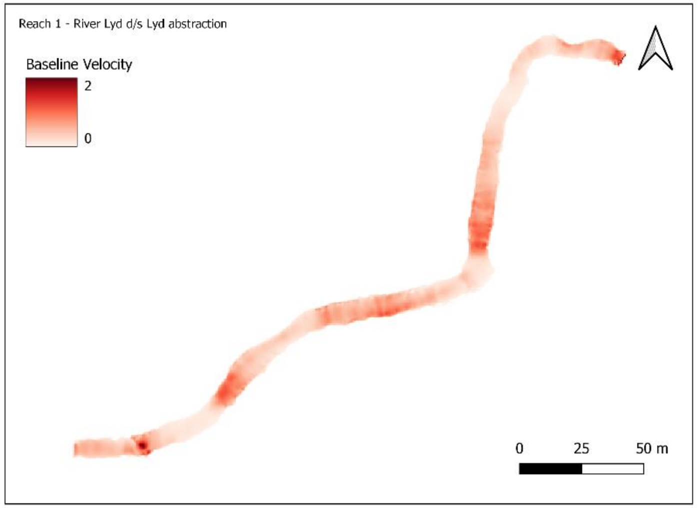
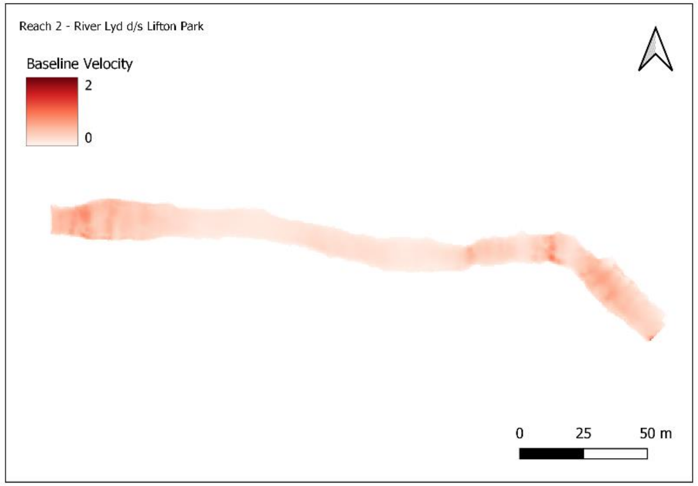


Figure 5-25 Predicted depths in Reach 1 and Reach 2 for the baseline and drought permit scenarios

<table>
<tr><th></th><th>Baseline</th><th>Drought permit</th></tr>
<tr><td>Velocity</td><td>




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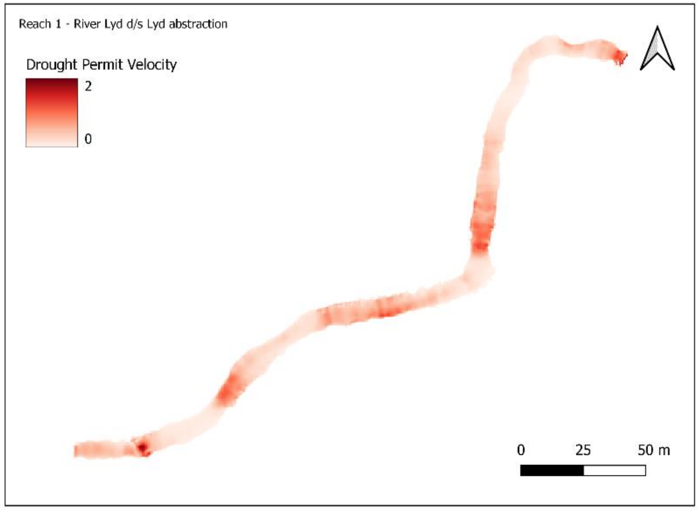

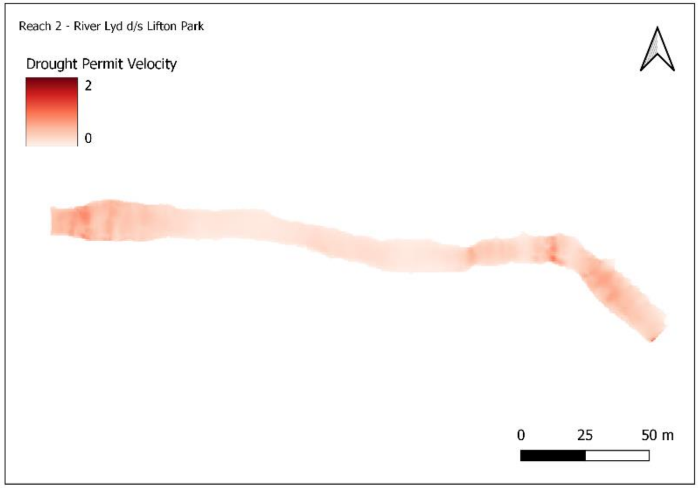

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Figure 5-26 Predicted velocity in Reach 1 and Reach 2 for the baseline and drought permit scenarios

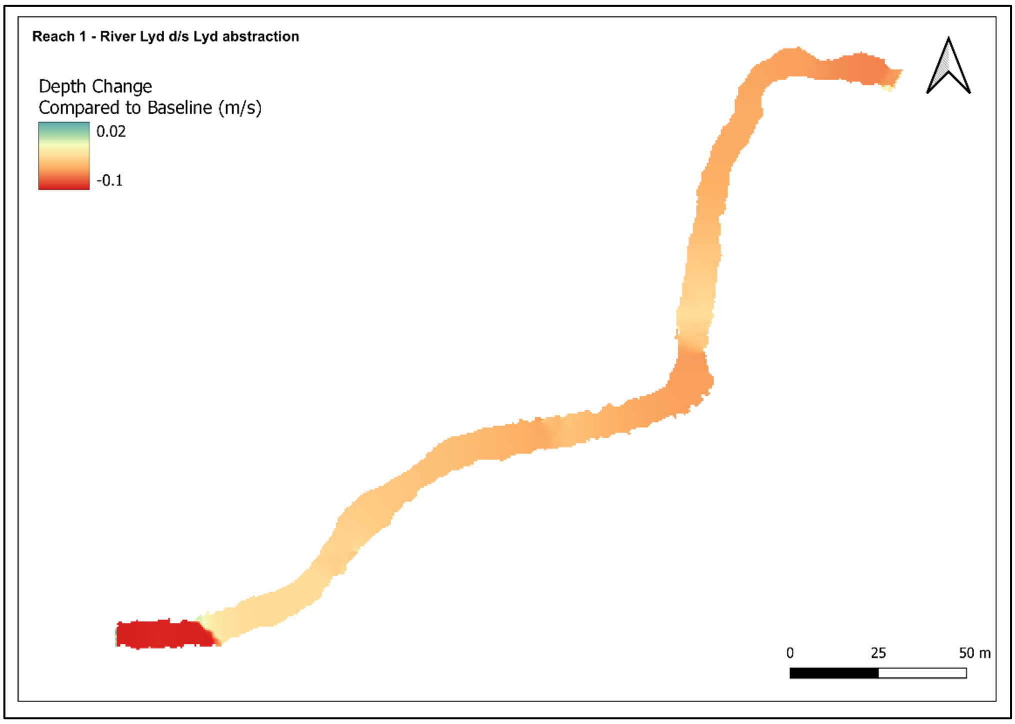


Figure 5-27 Reductions in depth between baseline and drought permit scenario – Reach 1

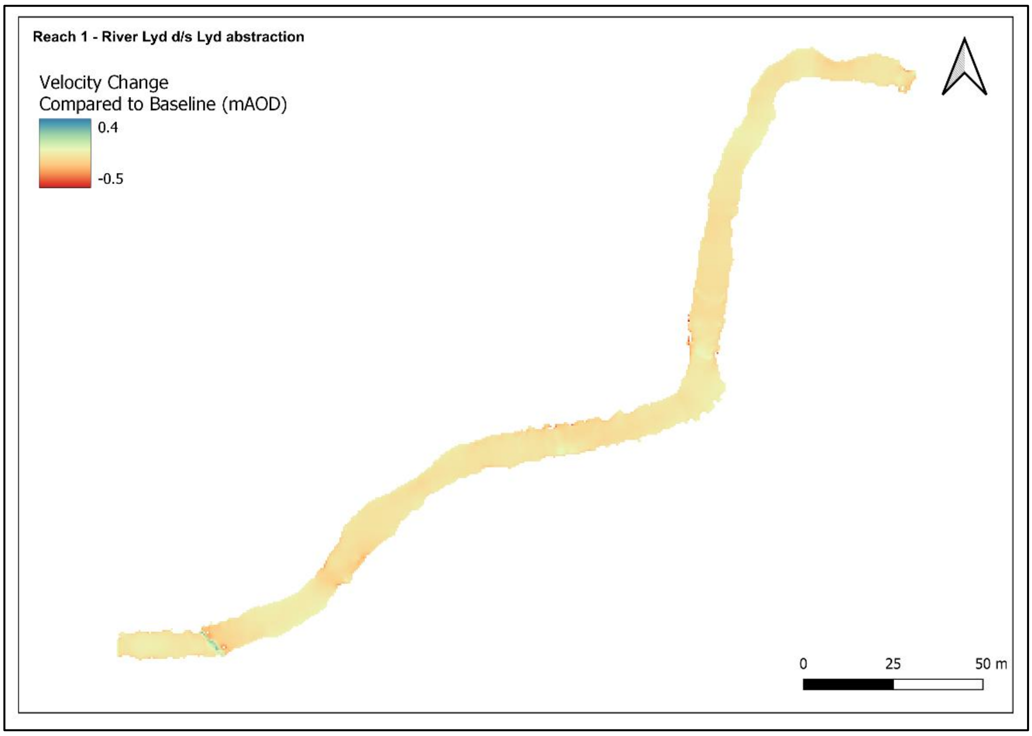


Figure 5-28 Reductions in velocity between baseline and drought permit scenario – Reach 1

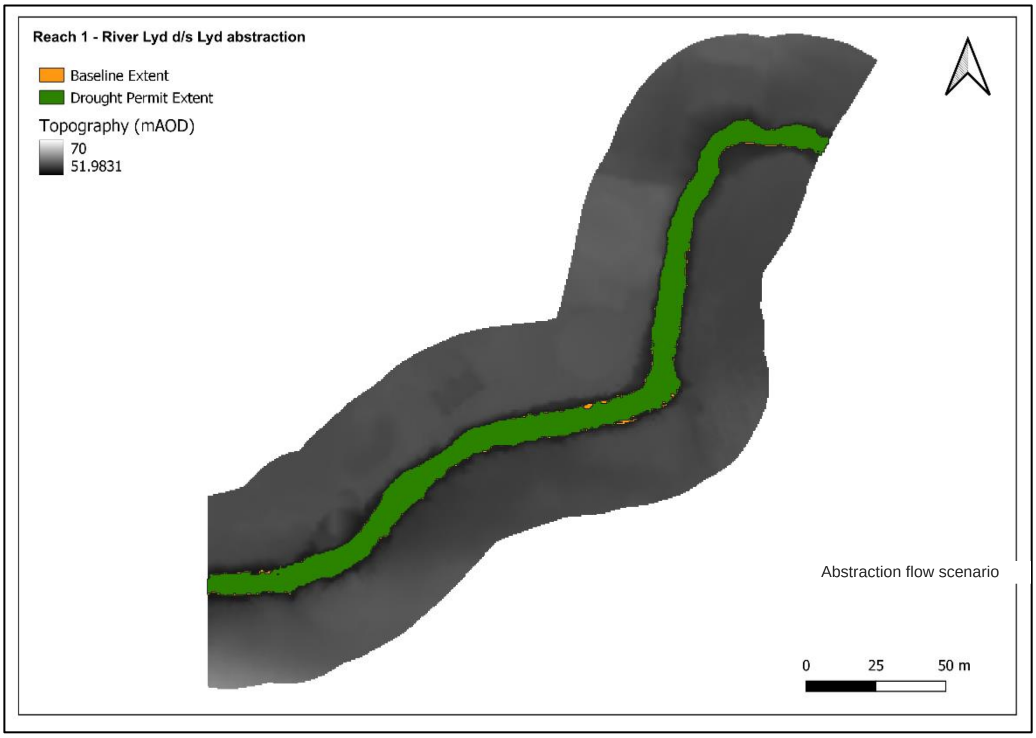


Figure 5-29 Water surface extent under baseline and drought permit scenarios – Reach 1

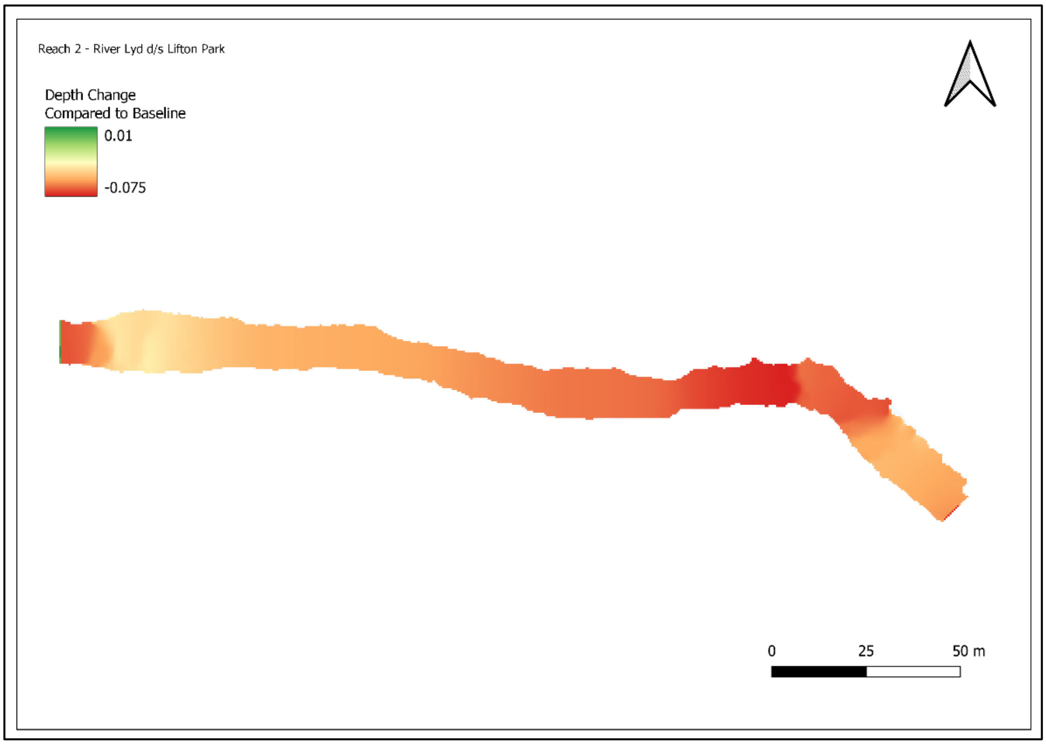


Figure 5-30 Reductions in depth between baseline and drought permit scenario – Reach 2

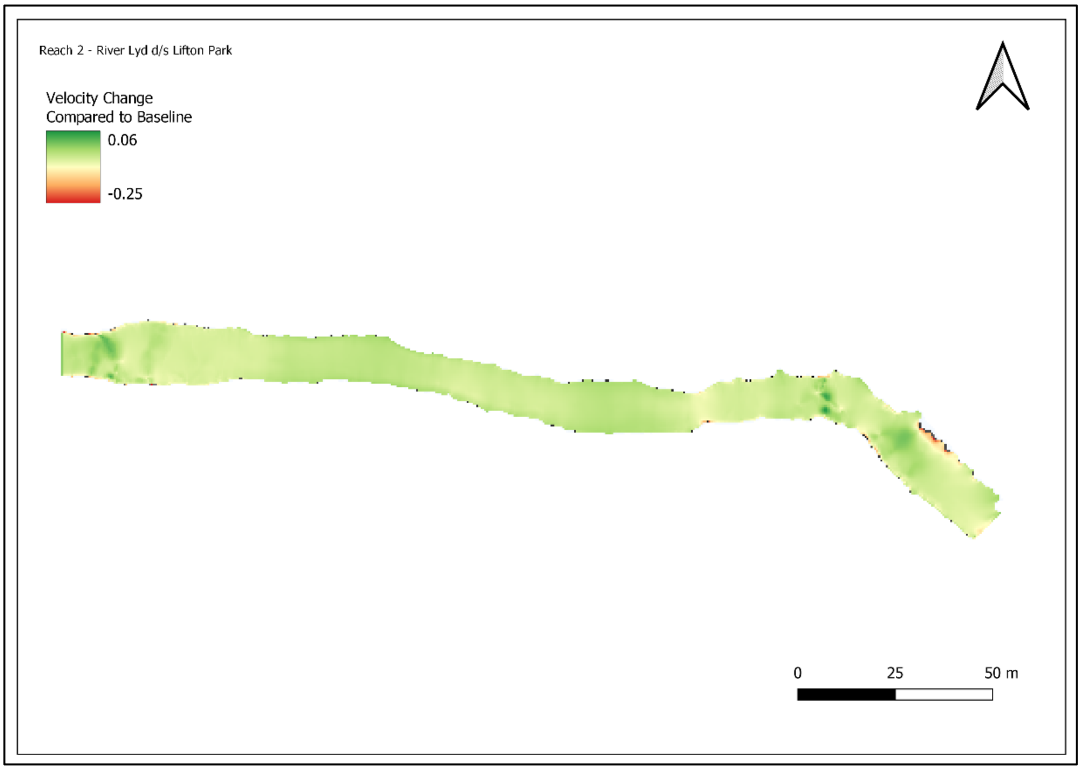


Figure 5-31 Reductions in velocity between baseline and drought permit scenario – Reach 2

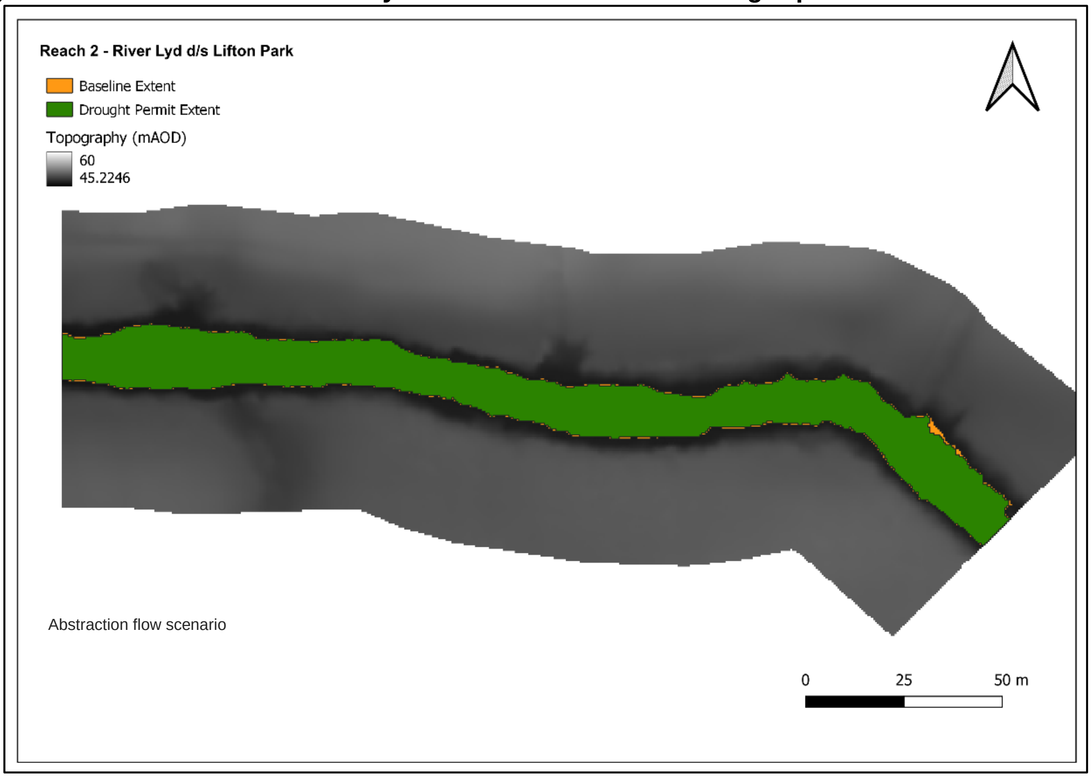


Figure 5-32 Water surface extent under baseline and drought permit scenarios – Reach 2

5.5.3.2 Geomorphology

The reduction in flow caused by implementation of the proposed drought permit is unlikely to have a substantial impact on geomorphological processes given that such processes only operate at significant rates during high flows, when the proposed abstraction would represent a relatively small proportion of the river flow. Consequently, rates of geomorphological processes will be negligible during periods of low flows at which the proposed drought permit is most likely to be in operation. Moreover, the baseline geomorphology walkover confirmed that the River Lyd is likely to be insensitive to moderate changes in flows, given that the channel boundaries are dominated by coarse sediment (coarse gravel and cobble), which will only be mobile during very high flows, and bedrock. Therefore, moderate changes in low flows are not expected to have noticeable impacts on coarse sediment dynamics or resultant river forms; i.e. peak daily abstraction of 40 Ml/d (which would not be in constant use throughout every winter, given Roadford Reservoir naturally fills across periods of two to three years) is not expected to have a noticeable effect within the context of flows downstream of the Lyd abstraction (baseline 5th percentile flows of 867.3 Ml/d and 10th percentile flows of 661.6 Ml/d).

The most likely impact of implementing the proposed drought permit on geomorphological processes is increased deposition of fine sediment delivered from upstream due to reduced flow competence. Fine sediment comprises particles <0.062 mm in diameter which are typically carried in the water column as suspended load. Deposition of sediment of this calibre occurs when the flow velocity falls below the settling velocity of a particle. Based on Stokes' law, the settling velocity of a 0.062 mm diameter particle is 0.0034 m/s. In the absence of an excessive fine sediment load, it can be assumed that deposition of fine sediment carried in suspension will not occur when flow velocities exceed this threshold. Maps showing modelled flow velocities relative to the threshold velocity (0.0034 m/s) are presented in Figure 5-33, and the data have been summarised in Table 5.15.

Table 5.15 Area of channel and percentage of cells above and below the threshold of fine sediment deposition in each reach

Reach	Scenario	Area below deposition threshold (m^2)	Area above deposition threshold (m^2)	% below deposition threshold	% above deposition threshold
Lyd downstream abstraction	Baseline	8.00	2703.75	0.29	99.71
	Drought permit	6.50	2600.25	0.24	99.76
Lyd downstream Lifton Park	Baseline	2.25	3112.00	0.07	99.30
	Drought permit	2.25	3012.75	0.07	99.30

Under baseline conditions, modelled flow velocity exceeds the threshold velocity for fine sediment deposition in >99% of model cells in the upstream reach and downstream reach, implying that the risk of fine sediment deposition is minimal under baseline conditions. Those cells in which modelled flow velocity is below the deposition threshold are typically located in the channel margins in both reaches.

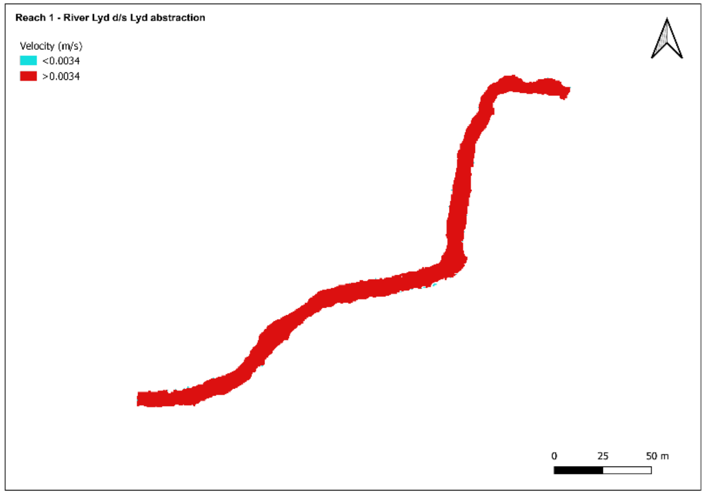
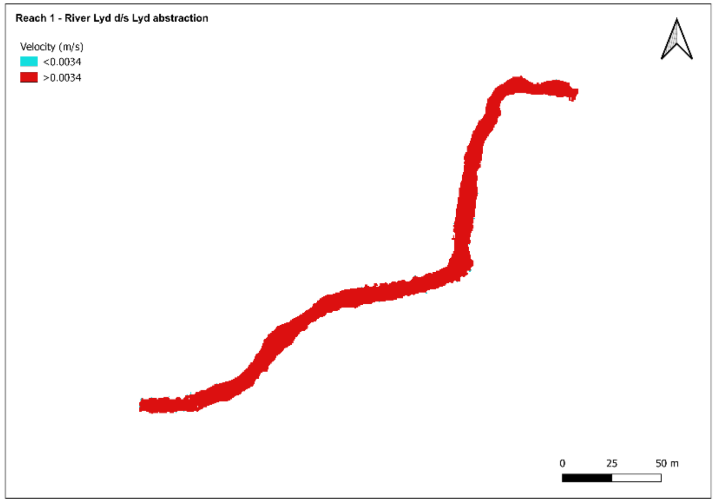
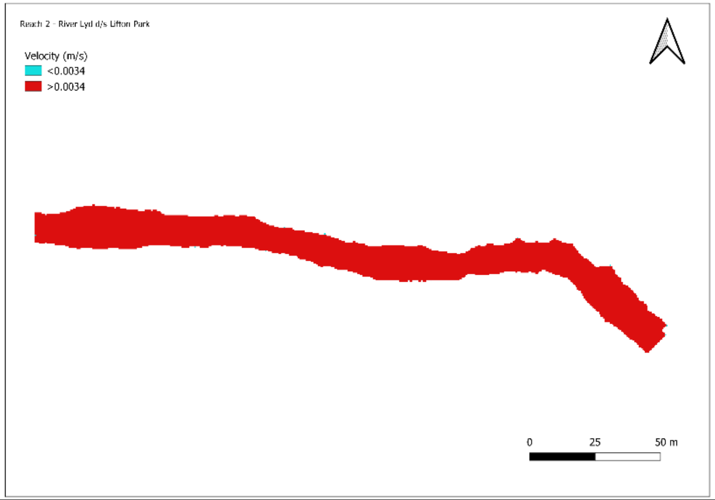
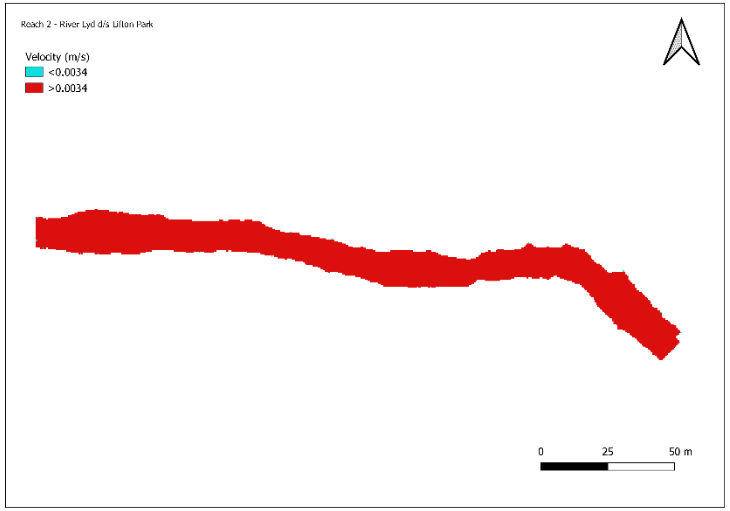
	Baseline	Drought permit
Lyd downstream abstraction		
Lyd downstream Lifton Park		

Figure 5-33 Velocity threshold maps

In the upstream reach, there is a small decrease in the area and percentage of cells in which fine sediment deposition may occur under drought permit operation, reducing from 8 to 6.5 m^2, (0.029% down to 0.024%). The spatial distribution of depositional cells is similar to those under baseline conditions, with most deposition concentrated in the channel margins. In the downstream reach, there is an increase in the percentage of cells in which fine sediment deposition occurs under drought permit operation from 0.076% to 0.078%. This is driven by a reduction in wetted width at the lower flow and a subsequent reduction in the number of marginal cells in which modelled flow velocity is below the threshold for fine sediment transport. Consequently, the extent of marginal deposition may be reduced under drought permit operation compared with the baseline flow.

Overall, the results of the hydraulic modelling indicate that flow velocities are largely sufficient to maintain the transport of any suspended sediment delivered to the study reaches from upstream under both baseline and drought permit scenarios. Consequently, deposition of fine sediment is not considered to be a significant risk of drought permit implementation in either of the modelled reaches, and substantial changes in bed material composition are not expected.

Any surficial deposits of fine sediment formed during drought permit operation will be flushed during the next competent flow. Given that the mobilisation of fine sediment deposited on the surface of the bed will not require significant force, it is considered likely that competent flows will be relatively frequent. As such, the likely duration of any fine sediment impacts will most likely be short. However, if drought permit implementation between April and June were to be followed by drought conditions in spring and summer then the impacts could be more prolonged. In this scenario, an extended period of low flow could lead to increased vegetation encroachment within the channel (although this would only occur during the 'natural' spring and summer drought) and increased fine sediment deposition if cattle poaching and river access provide a local sediment source. The frequency of occurrence of this scenario is likely to be low, and the risk of fine sediment accumulation could be monitored by a during abstraction walkover compared to baseline data collected during 2019 to document potential impacts.

5.5.3.3 Uncertainties

The relationship between hydraulic parameters and flow varies between locations. Reaches were selected due to their perceived sensitivity to flow changes and only represent a proportion of the river from the abstraction to the confluence with the River Tamar. Predictions of depth and velocity have not been verified against empirical data at flows below that at which the bathymetry data were collected.

Although flow velocity exerts a primary control on rates of fine sediment deposition, such rates also depend on the concentration of suspended sediment in the water column. However, information on suspended sediment concentration cannot be reliably predicted, so it is possible that excessive concentrations may induce more deposition than is considered likely based on hydraulic modelling. Conversely, sediment deposition may not occur at all if the suspended sediment concentration is very low. Nonetheless, modelled flow velocities typically exceed the settling velocity of fine sediment by several times, meaning that substantial deposition is unlikely even during events with high sediment loads.

5.5.4 Summary

- Baseline topographical surveys showed the cross-section profile of the River Lyd to be predominantly rectangular with the channel incised relative to the floodplain. Channels of this nature typically exhibit little variation in wetted perimeter with changes in depth, with large increases in marginal exposure only occurring at the lowest flows. The baseline geomorphology survey confirmed that the bed and banks of the River Lyd are generally dominated by coarse sediment (coarse gravel and cobble) and bedrock. Channels with these characteristics are typically considered to have high resilience to changes in flow and sediment supply.
- Hydraulic modelling of the River Lyd indicates small changes in hydraulic parameters of depth and velocity under the drought permit scenario with changes predominately confined to topographic highs, in the vicinity of riffles for example. Changes in marginal exposure are small (Around 3%). Such changes are expected to be within the range of natural variation during April - June, based upon predicted hydrological changes. In the absence of a very high suspended sediment load, rates of fine sediment deposition are unlikely to be substantially elevated above baseline conditions during drought permit implementation. As such, there is unlikely to be a substantial change in substrate composition, and any changes will most likely be temporary as fine sediment deposits will be re-entrained during subsequent high flows. Consequently, the predicted magnitude of change of the proposed drought permit on geomorphological processes and physical habitat is expected to be **Negligible**.
- The assessment of physical habitat and geomorphological sensitivity is unavoidably based on subjective interpretation of channel conditions during a single survey, and hydraulic modelling was only conducted on two discrete reaches. Information on suspended sediment supply from upstream during drought permit implementation are not available and cannot be predicted. A **Medium** level of certainty has therefore been assigned to this assessment.

5.6 Water quality

5.6.1 Background

This section assesses the potential effects of the proposed drought permit on water quality within the study area.

The proposed drought permit will reduce the quantity of water in the River Lyd downstream of the proposed abstraction, which could in turn affect water quality in the river downstream via reduced dilution of point source and diffuse inputs.

5.6.2 Baseline

Agency water quality data are available for the River Lyd and were downloaded via the Defra Data Services Platform (Defra, 2023). The databases are extensive in terms of duration (2000 to January 2023) and include a wide range of determinands. There are however some gaps in the data.

A total of seven sample locations are present on the River Lyd and two locations on upstream tributaries of the Lyd on the River Lew and Quiver Brook. One WFD waterbody is of interest: Lower River Lyd (GB108047007731). Within the potentially affected reaches, a total of seven monitoring locations have been selected (Table 5.16). All are spot sampling locations, the data from which are integrated into the compliance reporting procedures used by the Agency. Details of permitted discharges in the study area were provided by the Agency and SWW.

Table 5.16 Water quality sampling locations on the River Lyd and tributaries

Location	Easting	Northing	Data period	Data included in assessment
River Lyd at A386 roadbridge Lydford	252062	84445	2000-2023	Yes
River Lyd at Greenlanes Bridge	244383	83239	2000-2017	Yes
River Lew u/s River Lyd	244098	83388	2000-2017	Yes
River Lyd at Sydenham Bridge	242880	83880	2001-2002	No
Quither Brook u/s River Lyd	242615	83971	2000-2015	Yes
River Lyd u/s Ambrosia Creamery cooling	239870	85000	2001-2022	Yes
River Lyd at Southern Bridge	239599	84927	2007-2022	Yes
River Lyd d/s Ambrosia Creamery STW	239490	84920	2005-2005	No
River Lyd at Lifton Bridge	238911	84838	2001-2022	Yes

5.6.2.1 Environmental standards

Characterisation of the recent baseline condition for the River Lyd was undertaken via assessment of WFD physico-chemical elements: dissolved oxygen (DO), total ammonia, soluble reactive phosphorus (SRP), water temperature, and pH. Nitrate, biochemical oxygen demand (BOD), un-ionised ammonia (UIA), and suspended solids were also assessed as indicators of general water quality, but these parameters are not included in WFD classification.

Appropriate statistics were calculated and compared against the relevant WFD Environmental Quality Standards (EQS) for each location. To apply EQS under the WFD it is necessary to assign a river type and water hardness (as alkalinity measured by $CaCO_3$ mg/l) to the watercourses (this is known as typology). No typology data were provided for the River Lyd locations however, based on alkalinity data, and the presence of salmon in the Lyd, it was assumed that these are Type 2 Upland and Low Alkalinity (UpLA) for DO, BOD and total ammonia. With regards to SRP, UKTAG guidance (UKTAG, 2014a) requires that site specific phosphate standards be calculated using altitude and long-term alkalinity data.

There are no WFD EQS for UIA and suspended solids and so results have been compared to the (now repealed) EC Freshwater Fish Directive (FFD) (78/659/EEC) guidelines for indicative purposes only. With regards to the FFD the River Lyd was classified as a salmonid water. Nitrate data were compared to the Nitrate Vulnerable Zone (NVZ) standard (again for indicative purposes only) although there are no NVZs in the catchment (CDE, 2019).

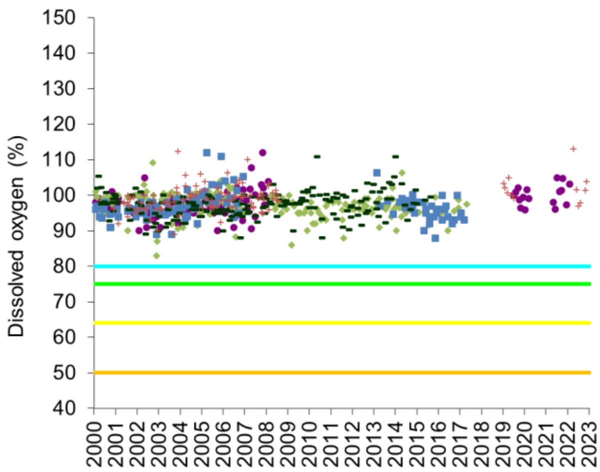
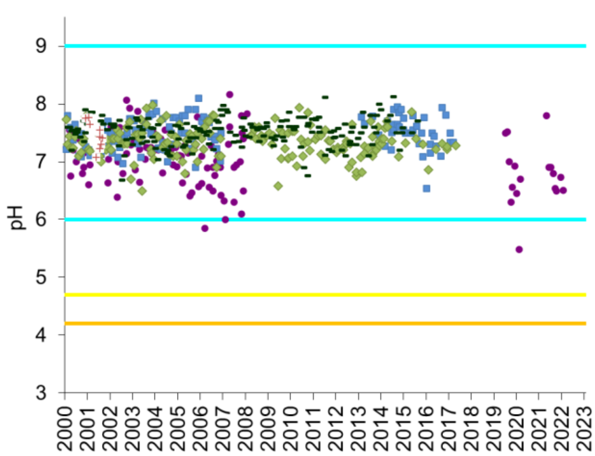
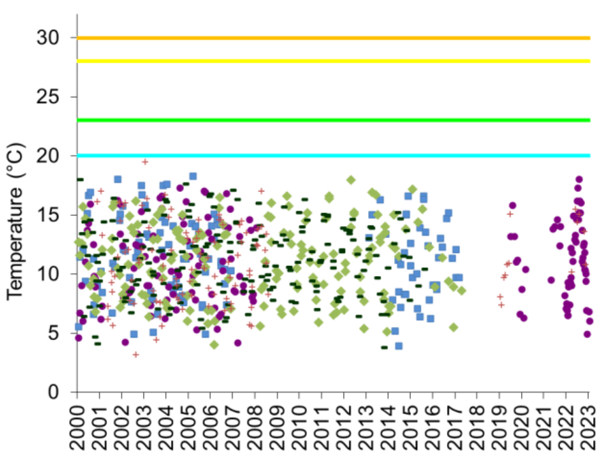
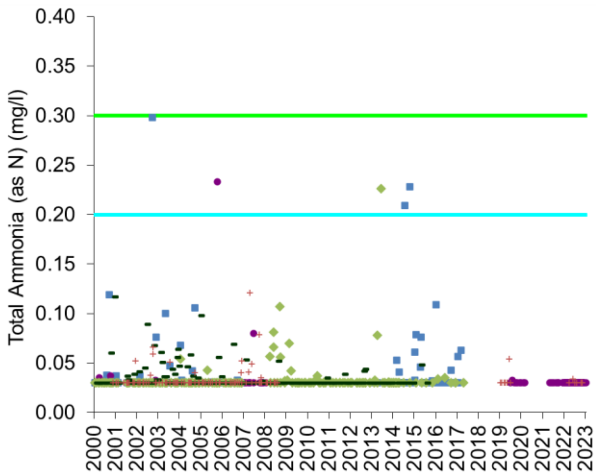
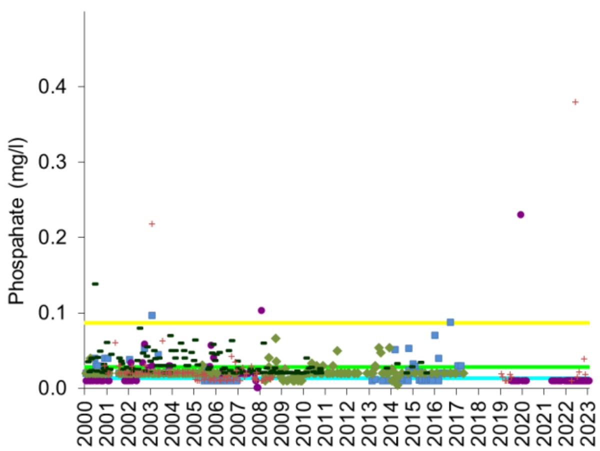
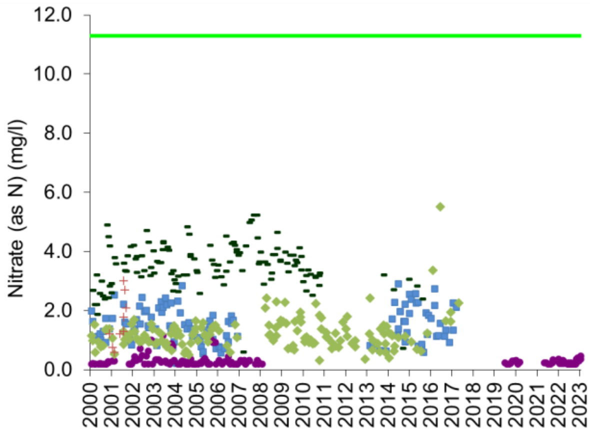
Data are presented either as means or as percentiles derived from a normal probability distribution fitted to the data (or log normal for BOD and ammonia). Where results were below the Limit of Detection (LOD) the average and percentile summary statistics have been calculated using these figures at face value.

5.6.2.2 Baseline water quality data

The most recent WFD classification data (2019) show that the Lower River Lyd (GB108047007731) water body is at High status for physico-chemical parameters, and at Good status overall.

Water quality data received from the Agency are presented in Figure 5-34 and Figure 5-35 for the River Lyd and tributaries.

The data indicate good water quality for all parameters at all locations. Exceptions were one-off low (below the boundary for Good status) DO readings at the Southern Bridge and Lifton Bridge locations in 2015 and 2005 respectively and one-off low pH readings at the A386 Roadbridge location in 2006 and 2020. SRP concentrations were also intermittently elevated above the boundary for Good status at most locations. A one-off elevated (above Good status) ammonia concentration was recorded at the Lifton Bridge location in 2009. One-off elevated BOD concentrations (above the boundary for Good status) were recorded at the River Lew u/s River Lyd, Quither Brook, Ambrosia Creamery, Lifton Bridge and Southern Bridge locations. Occasionally elevated suspended solids concentrations were recorded at the Quither Brook, Greenlanes Bridge, Lifton Bridge and Southern Bridge locations.

Dissolved Oxygen (% saturation)	pH
	
Temperature	**Total Ammonia as N**
	
Phosphate	**Nitrate**
	

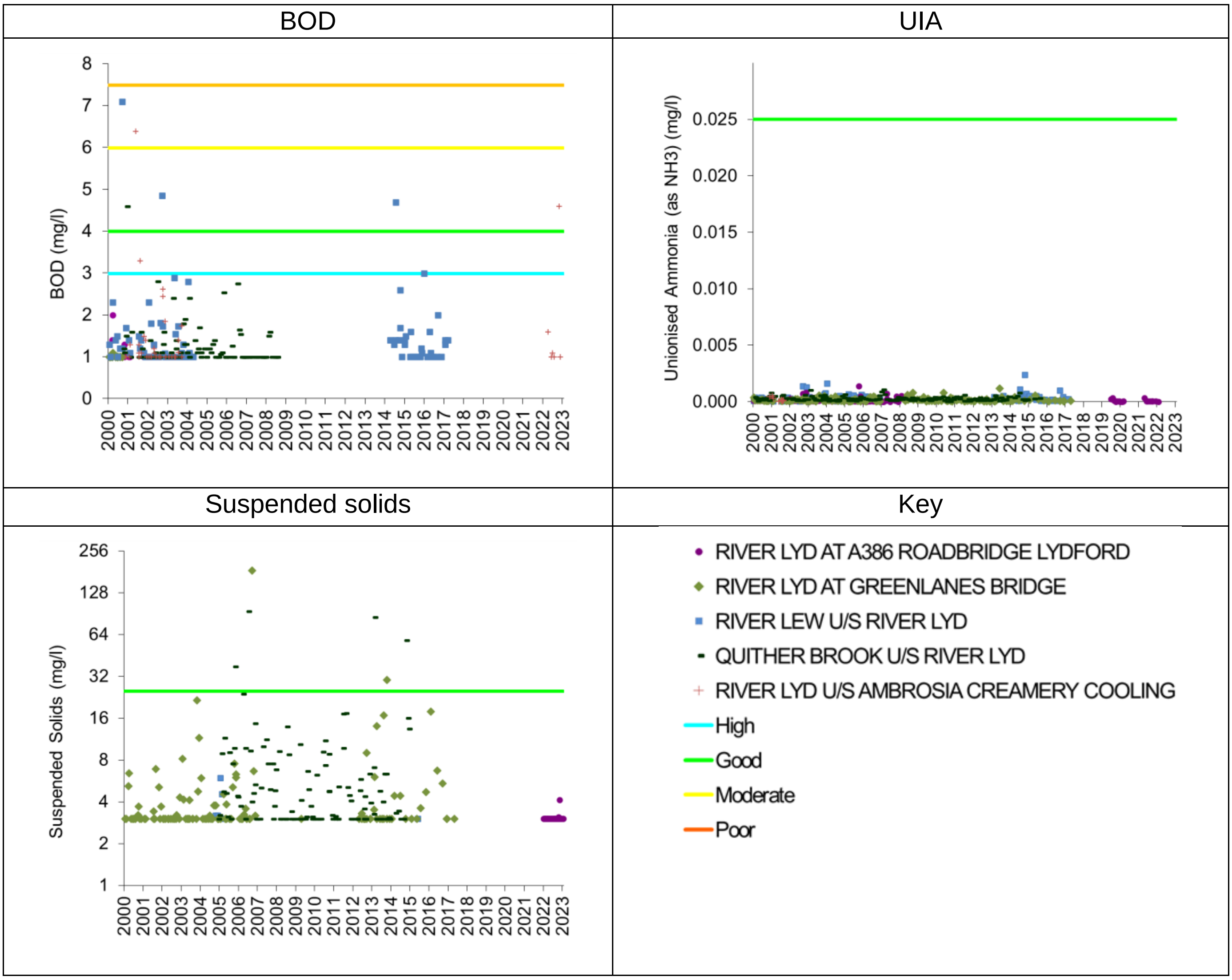
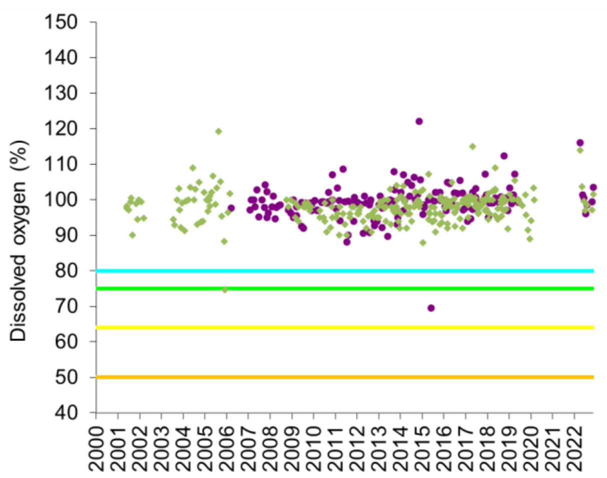
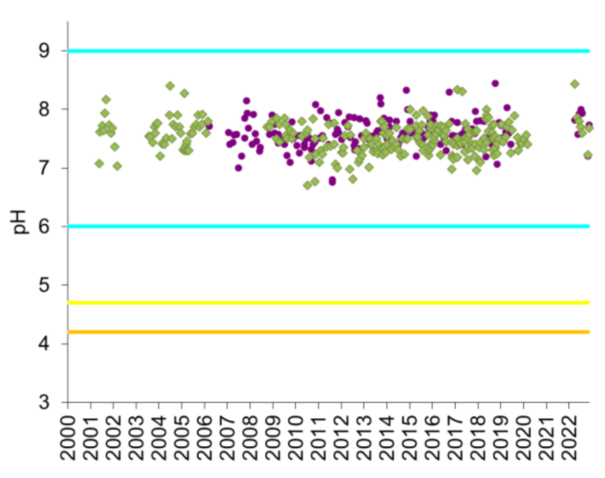


Figure 5-34 Water quality data and indicative WFD status boundaries for the A386 Roadbridge, Greenlanes Bridge and upstream Ambrosia Creamery locations on the River Lyd. Data are also presented for two adjacent tributaries of the River Lyd (River Lew and Quither Brook).

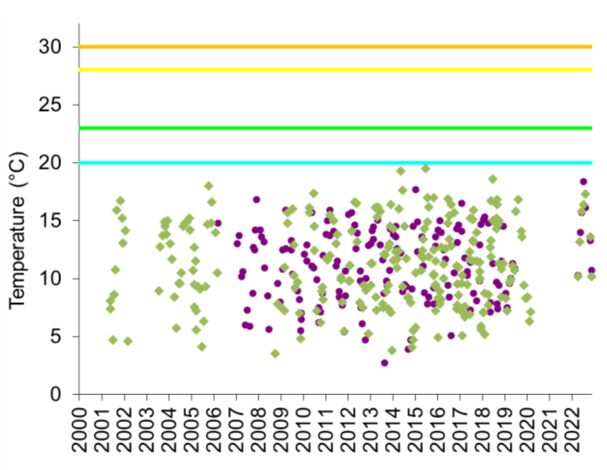
Dissolved Oxygen (% saturation)



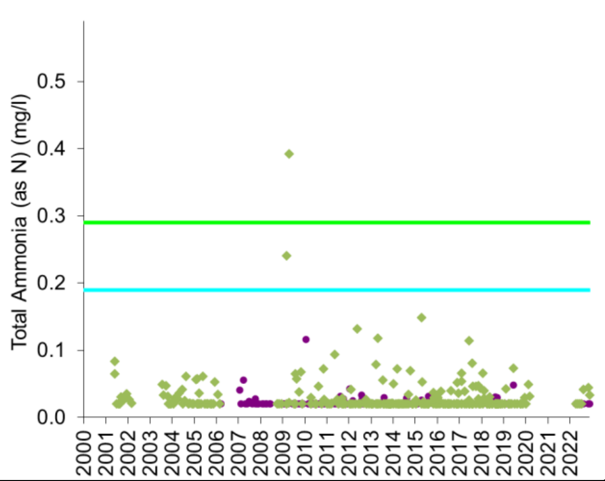
pH



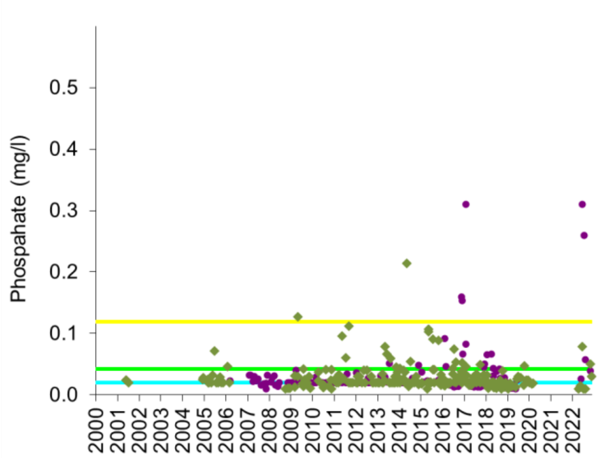
Temperature



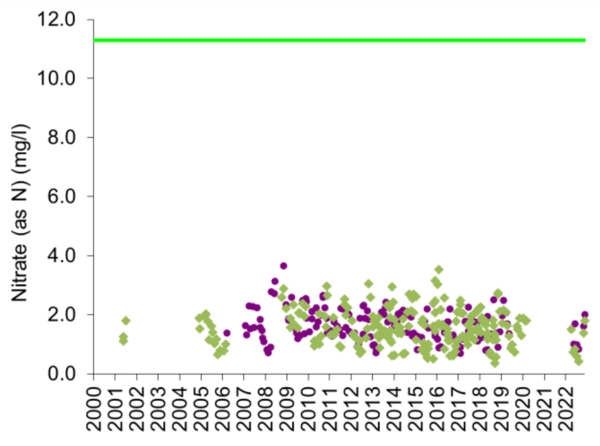
Total Ammonia as N



Phosphate



Nitrate



BOD

UIA

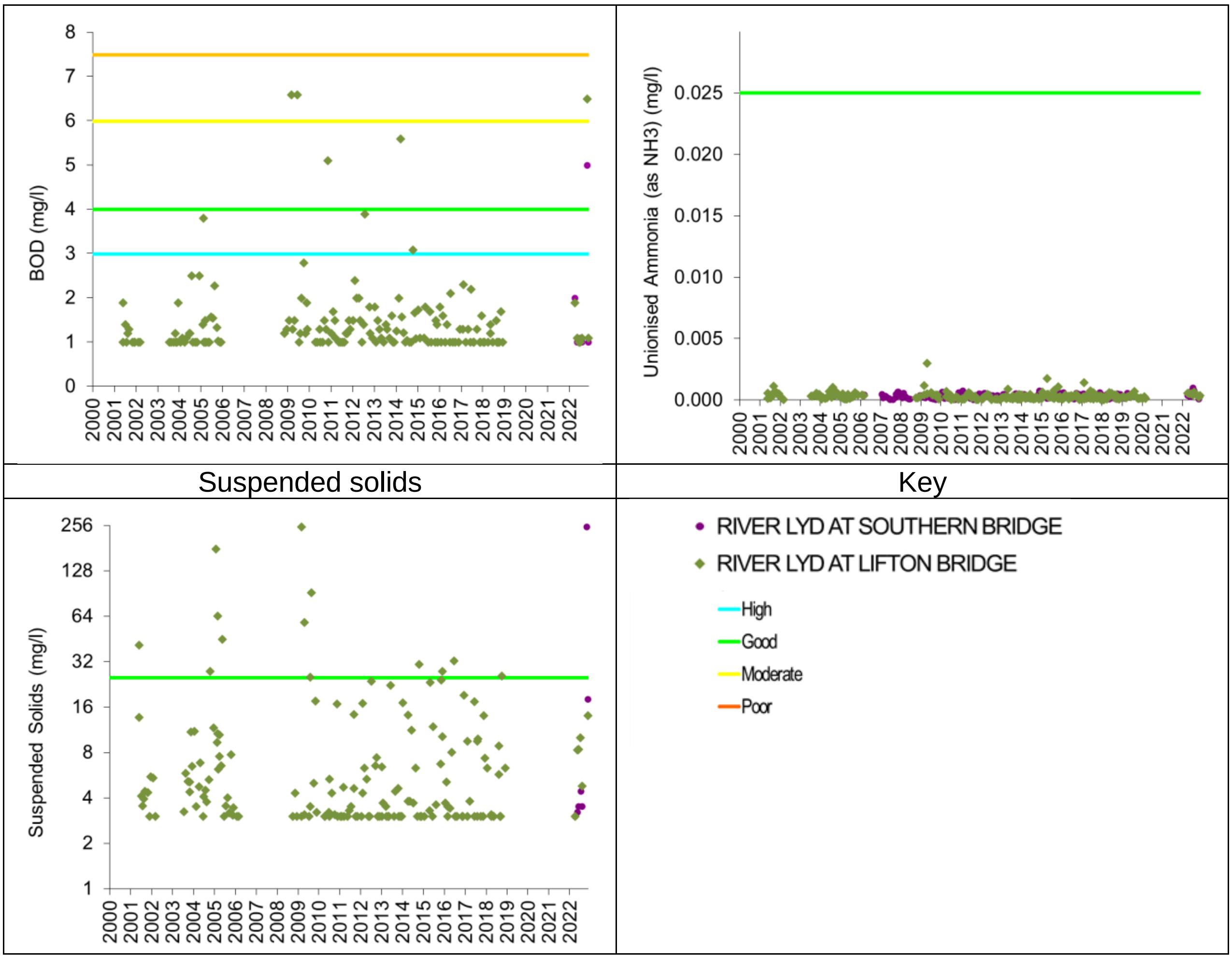


Figure 5-35 Water quality data and indicative Water Framework Directive status boundaries for the Southern Bridge and Lifton Bridge locations on the River Lyd

5.6.2.3 Permitted discharges

Permitted discharges in the potentially affected area were reviewed to identify those with a daily or maximum discharge volume or maximum consented limits (e.g. for BOD, ammonia or suspended solids) that could be large enough to affect water quality as a consequence of reduced dilution. The following discharges were identified:

- Lifton STW;
- Ambrosia (Lifton) creamery.

5.6.3 Impact assessment

For the two consented discharges an impact assessment was undertaken to assess the effect of the reduced flow in the River Lyd. This was carried out using the Agency's River Quality Planning (RQP) software.

The assessment was undertaken as a worst-case scenario. It used discharge permit limits for effluent flow (the dry weather flow was multiplied by 1.25 to represent mean flow at Lifton STW). The assessment was undertaken for orthophosphate, BOD and suspended solids. It should be noted that no allowance for unknown inputs from small, unclassified discharges has been incorporated into the impact assessment.

Upstream flow inputs into the model were based on two scenarios between 10th April and 10th June: a baseline scenario and a scenario using the proposed drought permit flows. The data used for RQP modelling are summarised in Table 5.17.

Table 5.17 Details of data used for RQP modelling

STW	Receiving water body	Flow Data	Chemical Data
Lifton STW	River Thrushel (note: the STW discharges very close to the confluence with the River Lyd)	River Thrushel upstream of Lyd confluence (95.8 Ml/d – mean flow; 25.9 Ml/d – Q95 flow) STW mean flow 0.375 Ml/d	1. Environment Agency sampling location: Tinhay Bridge 2. RQP outputs from Lifton STW final effluent
Ambrosia (Lifton) creamery	River Lyd	River Lyd downstream of abstraction but upstream of Ambrosia creamery (Baseline flow of 148.7 Ml/d – mean flow and 46.5 Ml/d – Q95 flow; Drought permit flows of 124.8 Ml/d – mean flow and 46.4 Ml/d – Q95 flow) Effluent Flow 0.7 Ml/d	1. Environment Agency sampling location: Upstream Ambrosia creamery cooling 2. RQP outputs from Lifton Creamery final effluent assessment.

The results of the impact assessment are presented in Table 5.18 and Table 5.19. The results indicate that only small changes to water quality will occur and there will be no WFD status changes. The RQP calculation spreadsheets are provided alongside the EAR.

Table 5.18 Predicted changes in water quality parameters in the River Lyd upstream of the River Thrushel confluence under drought permit conditions (10th April to 10th June)

Scenario	BOD (mg/l) 90%ile	Suspended Solids (mg/l) 90%ile	Orthophosphate (mg/l) mean values
Baseline	2.59	38.63	0.06
Drought permit	2.60	38.62	0.06
Percentage change under drought permit compared to baseline flow	0.39%	-0.03%	No change

WFD status:
High status
Good status
Moderate status

Table 5.19 P edicted changes in water quality in the River Lyd downstream of the River Thrushel confluence under drought permit conditions (10th April to 10th June)

Scenario	BOD (mg/l) 90%ile	Suspended Solids (mg/l) 90%ile	Orthophosphate (mg/l) mean values
Baseline	3.03	28.43	0.05
Drought permit	3.10	27.66	0.05
Percentage change under Drought permit compared to baseline flow	2.31%	-2.71%	No change

In theory, the effect of the reduction in flow on water quality could include a reduction in dilution of small sewage discharges, such as those from septic tanks and private sewage treatment plants. This could result in an increase in BOD, suspended solids and phosphate concentrations downstream. Due to the rural nature of the catchment it is possible that various small unconsented discharges (i.e. septic tanks) could be present within the study area. However, given the relatively small volumes associated with such discharges the risk to water quality deterioration is generally expected to be small and localised.

Drinking water considerations

This report is an EAR, and, therefore, consideration of drinking water standards are not within the formal scope of the report. However, the Agency has requested additional consideration of the risk to drinking water quality. The normal source of water for Roadford Reservoir is the River Wolf. Therefore, the water quality of the River Wolf and River Lyd have been compared to demonstrate whether an abstraction from the River Lyd presents a risk of causing a water quality deterioration in the reservoir. The Agency's safeguard zone action plan for Roadford Reservoir lists blue-green algae, geosmin and MIB as the at-risk substances. In addition, Roadford Reservoir has been identified as being at risk due to water quality problems associated with nutrients (causing taste and odour issues); therefore, the nutrient data for phosphorus and nitrogen have been compared in both rivers. The safeguard zone action plan for Roadford Reservoir only lists blue-green algae, geosmin and MIB as the at-risk substances. Consideration has therefore been limited to these substances.

Table 5.20 Mean water quality concentrations – River Wolf and River Lyd (2015 to 2023)

Sampling sites	Total oxidised nitrogen (mg/l as N)	Orthophosphate (mg/l as P)
River Wolf at Weeks Mill Bridge (81271593)	1.082	0.021
River Lyd upstream Ambrosia cooling (81261132)	1.524	0.021
Difference	41%	No change

The data show that the River Lyd would contribute additional nutrients to Roadford Reservoir during abstraction. Geosmin and MIB risk is related to blue-green algae. Whilst blue-green algae respond to both nitrogen and phosphorus concentrations, the primary driver of blooms is phosphorus concentrations. Furthermore, the main source of taste and odour problems is phosphorus. The mean concentration of phosphorus in the River Lyd is similar to the mean concentration in the main water supply river for Roadford Reservoir, the River Wolf. Given the small magnitude of difference in P concentration, the abstraction is considered unlikely to cause a significant increase in parameters identified as at-risk in the safeguard zone action plan.

5.6.4 Summary

The River Lyd achieves Good or High WFD status for all physico-chemical parameters.

No significant impact of the proposed drought permit on water quality in the River Lyd is predicted.

- The baseline dataset demonstrates that water quality on the River Lyd is at Good status or higher and there are few consented discharges within the affected area;
- Impacts of the proposed drought permit on dilution of water quality parameters are predicted to be **Negligible** in magnitude;
- The baseline water quality dataset is spatially robust. The data set is less robust over the proposed drought period due to fewer samples available for statistical analysis. Therefore a **Medium** level of certainty has been assigned to this assessment.

No change in the WFD status of the River Lyd is predicted with respect to water quality (physico-chemical quality elements) based on the assessment described above. No significant increase in taste and odour problems at Roadford reservoir are predicted for the Lyd abstraction.

6. Ecological assessment

6.1 Phytobenthos

6.1.1 Background

This assessment focuses on potential effects of the proposed drought permit on phytobenthos communities associated with the Lower River Lyd (GB108047007731), including consideration of potential effects on WFD status. It is based on the assessment created for the abstraction licence application (APEM 2022).

The standard WFD methodology for the recording and classification of the combined element macrophytes and phytobenthos is targeted specifically at detecting impacts of eutrophication, and not at the detection of possible low flow stress.

Macrophyte data have not been considered due to the low alkalinities throughout the River Lyd catchment (mean alkalinity values of < 50 mg/l $CaCO_3$); at alkalinities of less than 75 mg/l phytobenthos data alone provide a more reliable assessment of changes in nutrient status.

6.1.2 Potential routes of impact

Within the River Lyd phytobenthos communities could theoretically be affected by reduced flows leading to:

- additional deposition of fine sediment, leading to smothering of phytobenthos communities, with resultant changes in phytobenthos community type;
- increases in nutrients leading to modifications of phytobenthos communities; or
- reduced flows can change the phytobenthos community with planktonic communities replacing epilithic communities as flows reduce, although communities will be resilient to single season low flow periods.

6.1.3 Baseline

Phytobenthos data were available from existing Agency monitoring locations. Data were downloaded via the Defra Data Services Platform (Defra, 2023) (Table 6.1). Alkalinity data required for calculation of location-specific TDI4 expected scores were provided by the Agency (UKTAG, 2014b). In addition, phytobenthos data were collected at five locations in the spring and autumn of 2019 by SWW.

Table 6.1 Environment Agency phytobenthos sampling location information

River	BIOSYS ID	Location Name	Easting	Northing	Data period*	Data included in assessment
Lyd	8857	Upstream Ambrosia) Creamery	239760	84940	2016 – 2019	Y
Lyd	183108	Downstream Ambrosia Creamery	239497	84935	2016 – 2019	Y
Lyd	8858	Lifton Bridge	238930	84770	2013 – 2019	Y
Lyd	8883	A386 Bridge	252120	84470	2013 – 2015	N
Lyd	8885	Greenlanes Bridge	244130	83320	2008 – 2019	Y
Lyd	8941	Spry Farm	240220	85020	2006 – 2019	Y

The indices listed below have been used for interpretation of the phytobenthos surveys:

- Trophic Diatom Index (TDI4). This is a measure of which phytobenthos grow in the river and their association with high nutrients and is measured on a scale from 1 (nutrient sensitive) to 5 (nutrient tolerant).
- Ecological Quality Ratio (EQR). This is a measure based on observed data and predicted reference values resulting in an overall EQR that can be used to represent an ecological status class of either High, Good, Moderate, Poor, Bad. The EQR scale ranges are listed in Table 6.2.

Table 6.2 Ecological status boundaries for the biological element phytobenthos

Ecological status	EQR status boundaries
High/ Good status	0.80
Good/ Moderate status	0.60
Moderate/ Poor status	0.40
Poor/ Bad status	0.20

The current WFD status of the macrophytes and phytobenthos combined biological element in the Lower River Lyd waterbody is Good (Table 6.3).

Table 6.3 Agency macrophytes and phytobenthos WFD status WFD status for the Lower River Lyd Waterbody

Location name	Year	HMWB	Water Body Code	Easting	Northing	WFD status
Lower River Lyd	2019	No	GB108047007731	240717	85055	Good

Historical monitoring data for all sampling locations on the River Lyd are presented in Table 6.4. At all locations upstream of the town of Lifton the annual WFD status has been at Good/ High status across the data record. At the location downstream of Lifton (Lifton Bridge) the historical annual WFD status has been at Moderate status across the data record apart from 2019 (spring season only) when the WFD status was Good.

Table 6.4 Agency derived Phytobenthos indices for the River Lyd monitoring locations

Location name	Date	Normalised Observed	Normalised expected	Normalise EQR	WFD Class
Greenlanes Bridge	2008	68.13	65.41	0.83	High
	2010	68.92	65.41	0.84	High
	2012	60.34	65.41	0.74	Good
	2015	61.85	65.41	0.76	Good
	2019*	61.63	65.41	0.75	Good
Spry Farm	2006	50.03	65.41	0.61	Good
	2008	56.57	65.41	0.69	Good
	2010	55.50	65.41	0.68	Good
	2012	50.28	65.41	0.61	Good
	2015	53.98	65.41	0.66	Good
	2019*	55.81	65.41	0.68	Good
US Ambrosia Creamery	2016	57.15	65.41	0.70	Good
	2019*	53.41	65.41	0.65	Good
DS Ambrosia Creamery	2016	56.59	65.41	0.69	Good
	2019*	54.08	65.41	0.66	Good
Lifton Bridge	2013	46.67	65.41	0.57	Moderate
	2015	47.37	65.41	0.58	Moderate
	2016	48.46	65.41	0.59	Moderate
	2019*	50.74	65.41	0.62	Good

* Results presented for spring season only. All other results calculated from a combined EQR for spring and autumn seasons

6.1.4 Impact assessment

The drought permit is not predicted to result in any significant changes to the hydrological regime or the water quality of the River Lyd within the affected area and any changes will be temporary in nature.

The phytobenthos biological element of the Lower River Lyd waterbody is currently at Good WFD status and this has been the case at all locations upstream of the Thrushel confluence since 2006 (whilst data collected from locations downstream of the Thrushel confluence (at Lifton Bridge) have been indicative of Moderate status since 2013).

- The baseline dataset demonstrated a stable phytobenthos community with no change in WFD status across the recent data record. Therefore, a **Low** level of sensitivity has been assigned.
- Normal operation of the abstraction licence conditions from November to March was predicted to have a Negligible impact on phytobenthos (APEM 2022). Although the drought permit extends abstraction into warmer and more productive months of the year, given the negligible and temporary changes predicted to the

flow regime and water quality, the predicted impact significance of the proposed drought permit on phytobenthos is **Negligible**. Likewise, it is considered that there is no potential for cumulative effects year to year.

- Whilst the dataset was spatially and temporally well distributed, the consistency and frequency of sampling was variable between locations. A **Medium** level of certainty has therefore been assigned to this assessment.

No change in the WFD status of the phytobenthos biological element is predicted either at the waterbody or monitoring location level.

6.2 Macroinvertebrates

6.2.1 Background

This assessment focusses on potential effects of the proposed drought permit on macroinvertebrate communities associated with the Lower River Lyd (GB108047007731), including consideration of potential effects on WFD status. It is based on the assessment carried out for the abstraction licence application (APEM 2022)

6.2.2 Potential routes of impact

In riverine habitats, shallow groundwater-fed and upland watercourses are regarded as more ecologically sensitive to low flows than deeper lowland systems. In all riverine situations, however, macroinvertebrate communities are typically resilient to single-season low flow periods (typically occurring in the summer), recovering rapidly from any negative impacts of low flows.

The impact assessment for this study focuses on the WFD status of macroinvertebrate communities present in the River Lyd, and the potential for impacts due to implementation of the proposed drought permit. Ecological assessment has been undertaken based on the predicted magnitude and duration of flow, habitat and water quality alteration, and using expert judgement to inform decisions regarding likely sensitivity of the macroinvertebrate community.

6.2.3 Baseline

6.2.3.1 River Lyd and River Thrushel

The Lower River Lyd (GB108047007731) is currently classed as being at Good Ecological Status (WFD Cycle 2 2016). The macroinvertebrate biological element has been reported as being at High status since 2014.

Table 6.5 WFD status of the River Lyd water body (Cycle 2 2019)

Water Body	Water Body ID	Overall Status	Ecological Status	Invertebrate Status	Overall Objectives
Lower River Lyd	GB108047007731	Good	Good	High	Good

Macroinvertebrate data were available from existing Agency monitoring locations and were downloaded from the Defra Data Services Platform (Defra, 2023). The downloaded database was extensive in terms of duration (1990 to date) and included a wide range of biotic indices.

Environmental data required for the calculation of location-specific expected scores were provided by the Agency.

Macroinvertebrate data and associated environmental data were available for six Agency monitoring locations in the Lower River Lyd water body (GB108047007731) (Table 6.6). Data covered the period 1990-2019 and included locations both upstream and downstream of the former abstraction intake (providing both impact and control locations). Inclusion of data within the assessment was determined by the number of samples available for a given location and the relevance of those locations to the study area. Justification for inclusion of monitoring locations was based on availability of a relatively consistent data record (≥ four years), with an emphasis on data collected post 2000 due to possible upgrades of STWs in the 1990s and also changes in Agency quality control procedures.

Table 6.6 Macroinvertebrate sampling locations on the River Lyd

River	BIOSYS ID	Monitoring location name	Easting	Northing	Data period	Data included in assessment
Lyd	8857	Upstream Ambrosia Creamery	239760	84940	1996 - 2007; 2019	Y
Lyd	8858	Lifton Bridge	238930	84770	1990 - 2019	Y
Lyd	8883	A386 Bridge	252120	84470	1990 - 2009	N
Lyd	8885	Greenlanes Bridge	244130	83320	1990 - 2019	Y
Lyd	8916	Prior to River Thrushel	239220	84970	1991 - 1994; 2019	Y
Lyd	8941	Spry Farm	240220	85020	2002 - 2012; 2019	Y

Macroinvertebrate data were summarised as a suite of biotic indices, calibrated to detect the biological effects of low flows and water pollution:

- Lotic Invertebrate index for Flow Evaluation (LIFE; Extence *et al.*, 1999) is the average of abundance-weighted flow groups that indicate the preferences of each taxon for higher water velocities and clean gravel/cobble substrata or slow/ still water velocities and finer substrata. LIFE is used to index the effect of flow variations on macroinvertebrate communities.
- Whalley Hawkes Paisley Trigg (WHPT) method (UKTAG 2014c) is an index of overall biological quality using macroinvertebrates similar to the BMWP index. WHPT responds to the same environmental pressures as the Biological Monitoring Working Party (BMWP) though, unlike BMWP, it is abundance-sensitive and it can detect moderate changes in water quality that would previously have been undetected. WHPT NTAXA also responds to the same environmental pressures as BMWP NTAXA. WHPT and WHPT NTAXA are the current indices used to determine WFD status during classifications for macroinvertebrates and are useful for distinguishing the direct effects of water abstraction from the effects of water pollution.

Expected scores for unimpacted reference conditions at each sampling location have been calculated using the River Invertebrate Prediction and Classification System (RIVPACS) IV model (Davy Bowker *et al.*, 2008) within the River Invertebrate Classification Tool (RICT). RICT input data were sourced from the Agency. Expected scores were generated separately for each season.

Observed WHPT, ASPT, NTAXA, family LIFE (LIFE F) and PSI were provided for all samples. Species LIFE scores (LIFE S) were provided for most samples, but not all, so have not been presented.

The Lower River Lyd water body dataset is spatially and temporally well distributed. Three monitoring locations are situated upstream of the abstraction point at distances of 300 m (Spry Farm), 7.5 km (Greenlanes Bridge) and 14 km (A386 Roadbridge). Downstream of the abstraction point there are three monitoring locations on the River Lyd; Upstream Ambrosia Creamery, located 200 m downstream of the abstraction point and 400 m upstream of the Thrushel confluence; Prior to River Thrushel, located just upstream of the River Thrushel confluence; and Lifton Bridge, located 300m downstream of the River Thrushel confluence.

The macroinvertebrate community of the River Lyd was found to be diverse and indicative of good water quality, with NTAXA and ASPT Observed:Expected (O:E) ratios found to be consistently high and indicative of Good status or better for all locations included in assessment. LIFE O:E ratios demonstrated that there was no indication of an impact of low flow on the macroinvertebrate community, with LIFE O:E ratios for all locations consistently above the indicative threshold (see Figure 6-1 to Figure 6-6). This trend continued for samples collected in spring and summer of 2019; a consecutive low-flow year (until October 2019) following the dry 2018. Similar trends were seen for PSI O:E ratios, with ratios for all locations consistently above the boundary indicative of potential sediment stress (see Figure 6-1 to Figure 6-6).

There was no observable difference in diversity or quality of the macroinvertebrate community identified from locations sited below the abstraction point compared to those upstream of the abstraction point. The most consistently sampled location from 1990-2019 was Lifton Bridge, located downstream of the confluence with the River Thrushel. The Lifton Bridge location showed no indication of an impact of low flow or of excessive fine sediment pressure in previous low flow years (1990, 1995 & 1996), nor for the 2018/ 2019 samples (see Figure 6-6). At Greenlanes Bridge, located 7.5 km upstream of the abstraction point, LIFE O:E was reduced for all samples collected through low flow years 1990 and 1995, suggesting that low flow stress may have been exerting some pressure on the macroinvertebrate community at this time. PSI was also reduced at Greenlanes Bridge in spring of 1990 and spring & autumn of 1995. However, both LIFE and PSI sustained high values in spring 2019 (see Figure 6-2).

Given that indication of potential low flow stress was absent for a majority of locations, even in notably dry years, it appears that the macroinvertebrate community of the Lower River Lyd is resistant to low flows. However, a review of the most recent species list available (those for 2019) demonstrates a relatively great representation by taxa that are associated with relatively high flow velocities. For this reason, a sensitivity categorisation of **Medium** has been assigned.

Whilst the dataset was spatially and temporally well distributed, the consistency and frequency of sampling was variable between locations.

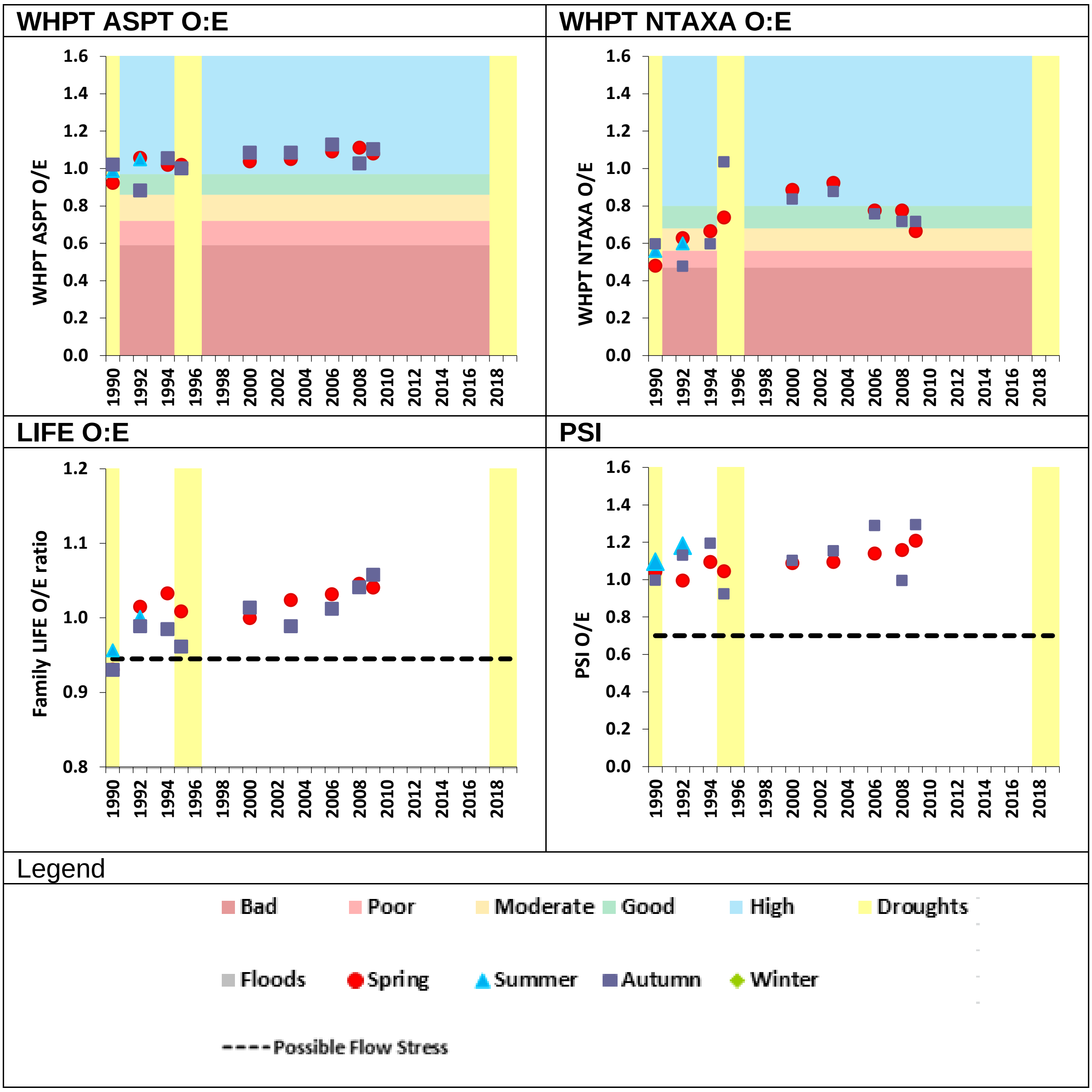


Figure 6-1 WHPT, ASPT, FAMILY LIFE and PSI O:E ratios for A386 Bridge (GB108047007731)

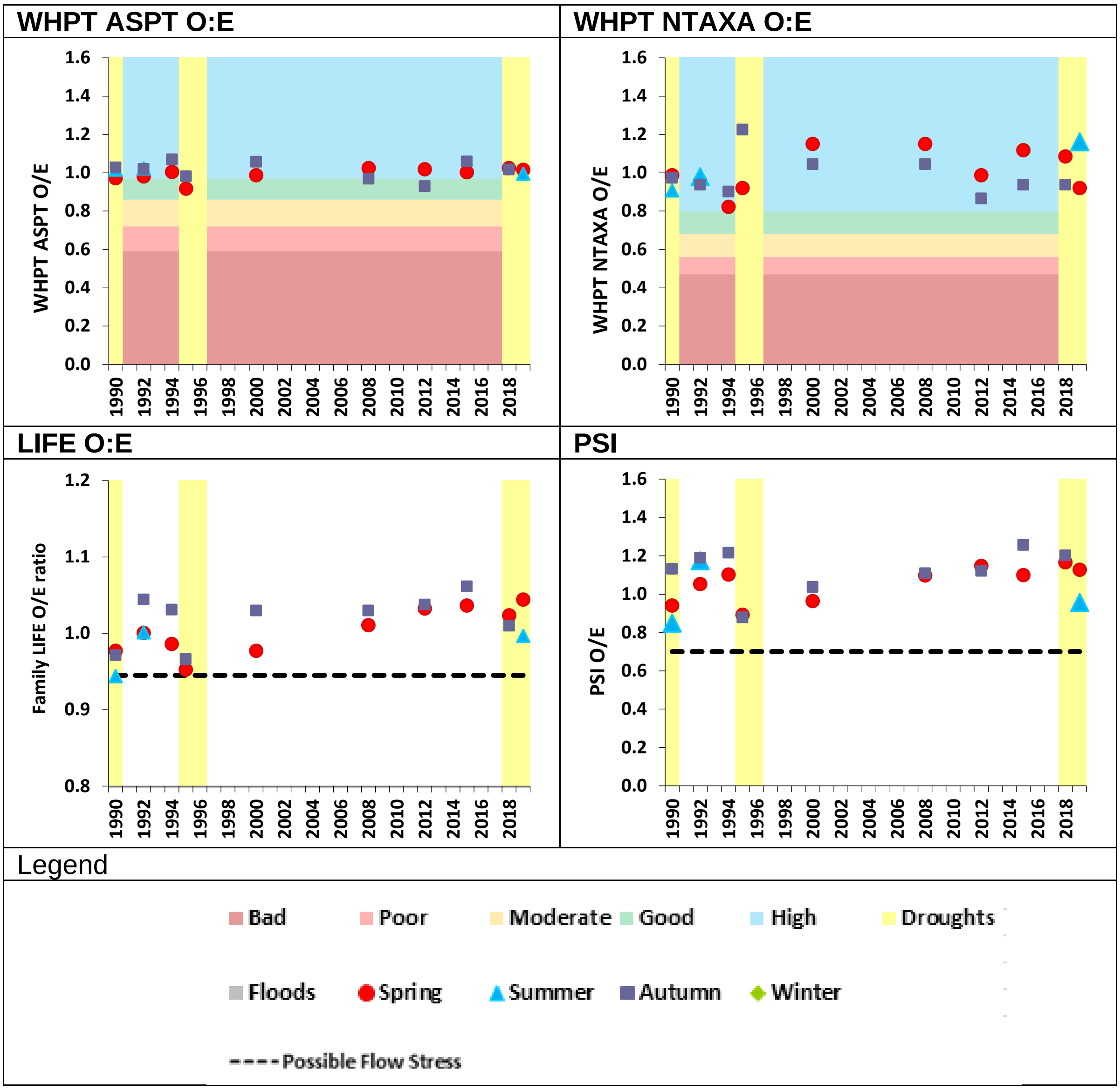


Figure 6-2 WHPT, ASPT, FAMILY LIFE and PSI O:E ratios for Greenlanes Bridge (GB108047007731)

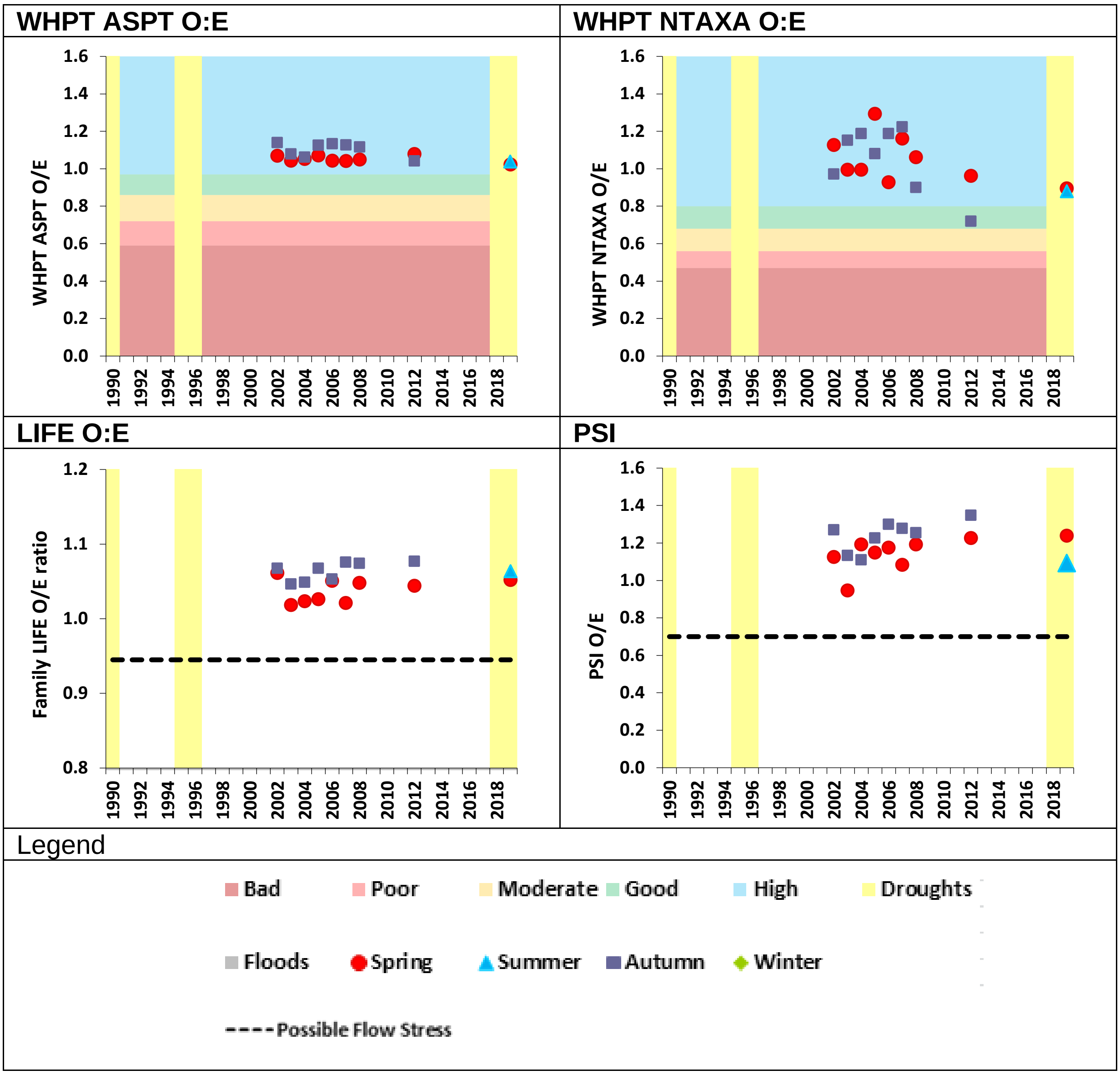


Figure 6-3 WHPT, ASPT, FAMILY LIFE and PSI O:E ratios for Spry Farm (GB108047007731)

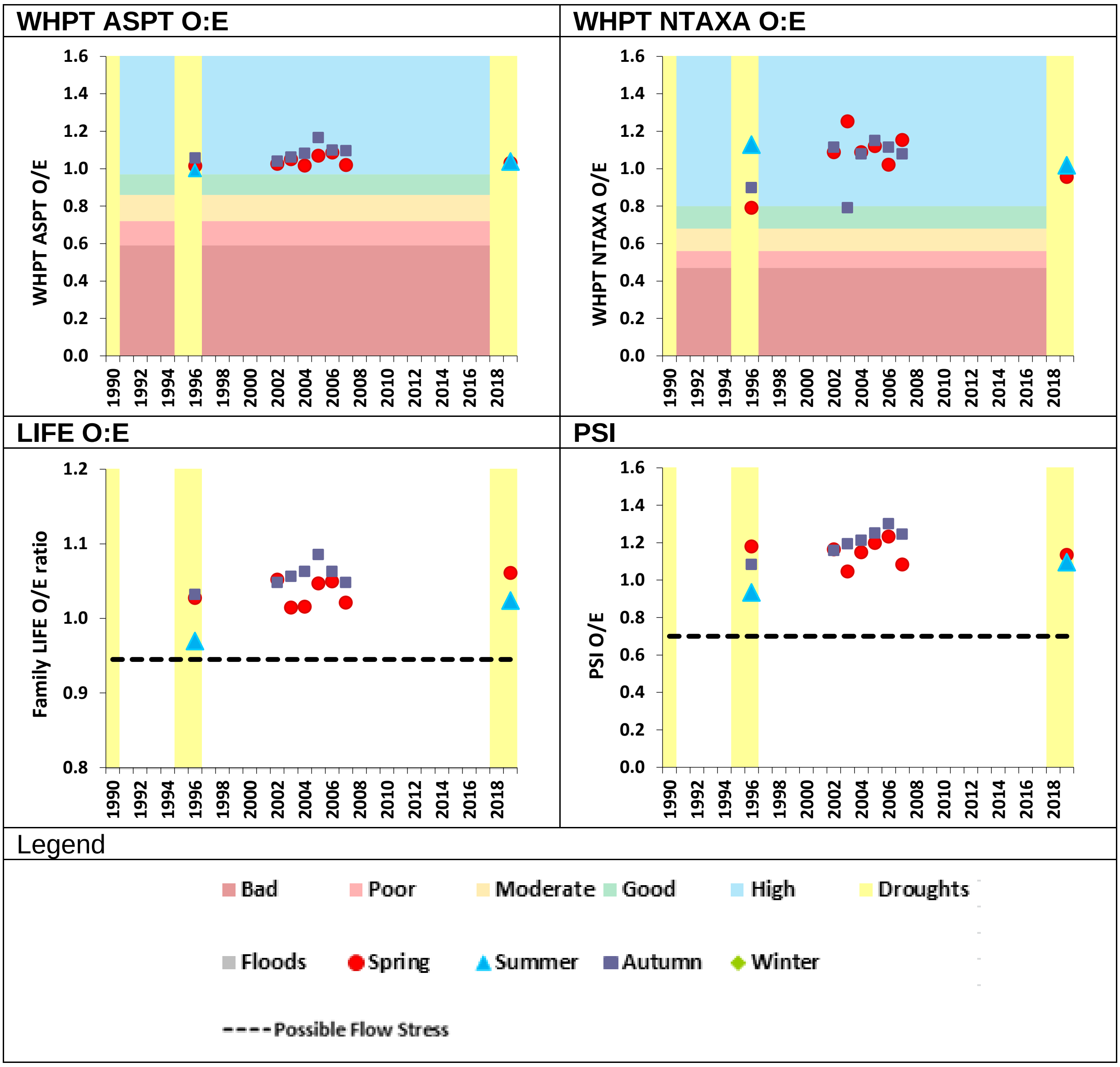


Figure 6-4 WHPT, ASPT, FAMILY LIFE and PSI O:E ratios for US Ambrosia Creamery (GB108047007731)

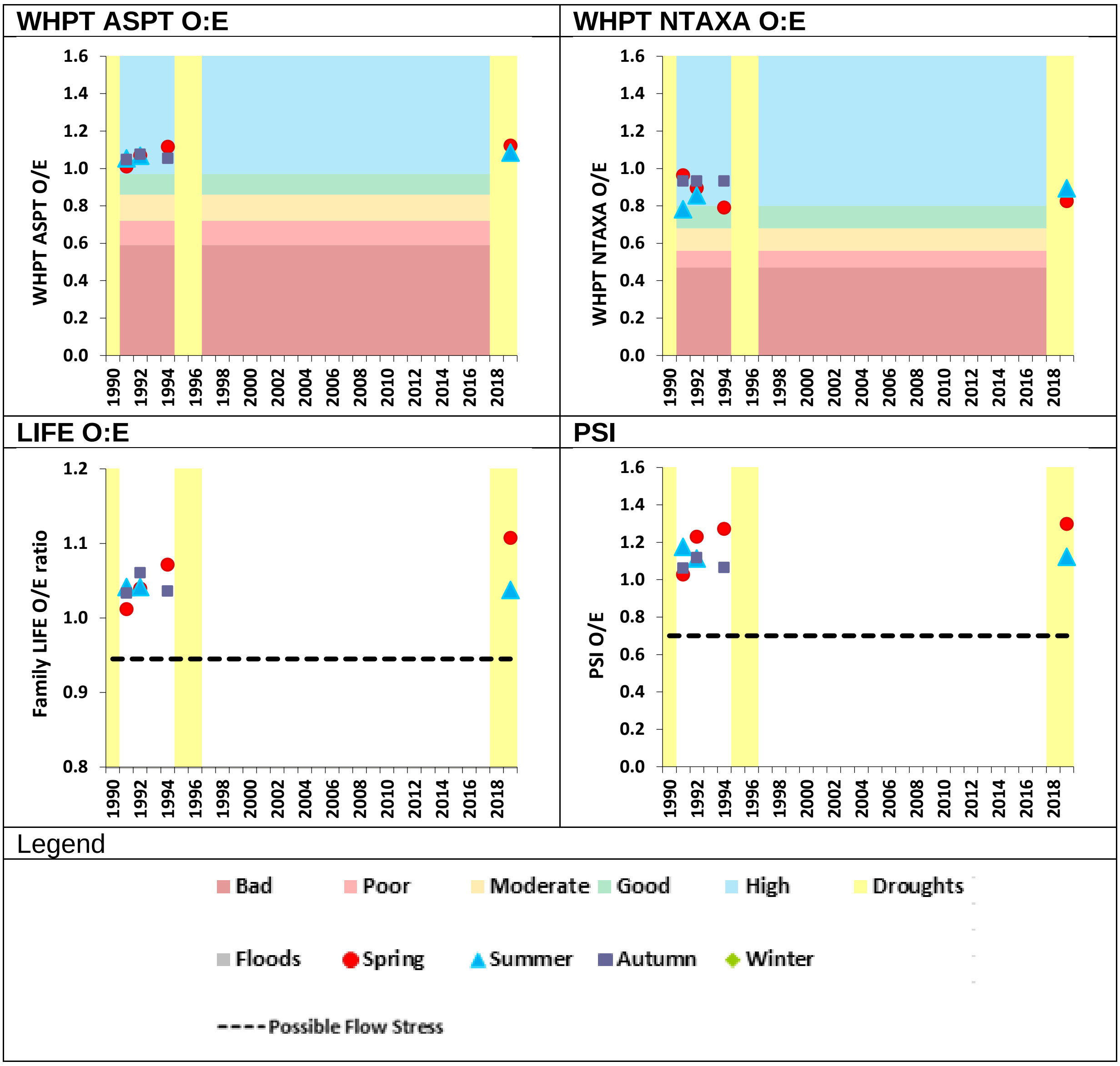


Figure 6-5 WHPT, ASPT, FAMILY LIFE and PSI O:E ratios for Prior to River Thrushel (GB108047007731)

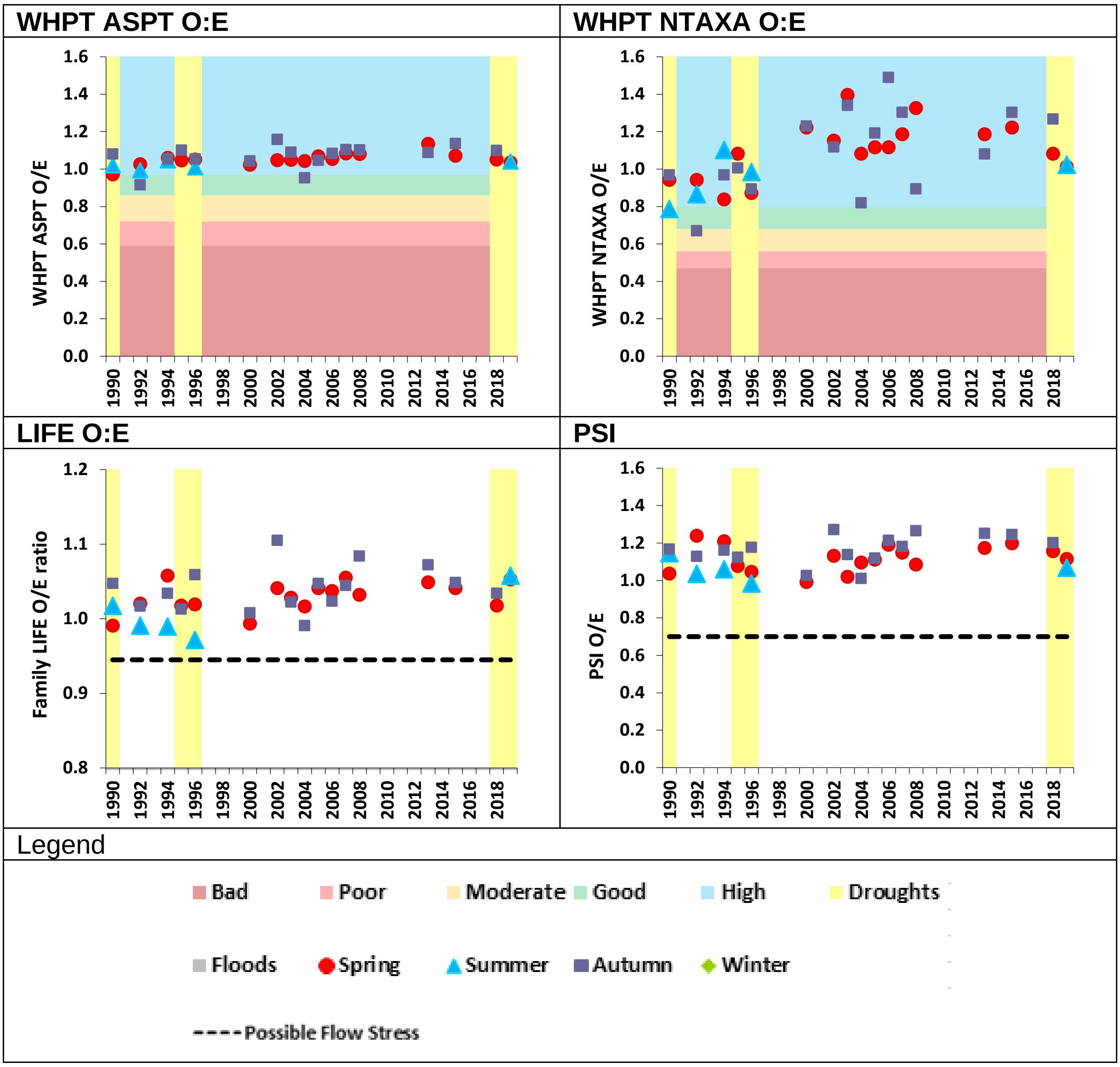


Figure 6-6 WHPT, ASPT, FAMILY LIFE and PSI O:E ratios for Lifton Bridge (GB108047007731)

6.2.4 Impact assessment

Changes in water depth, wetted perimeter and velocity can affect sensitive groups of macroinvertebrates and consequently the overall ecological status of a water body. Assessment of impacts of the proposed drought permit are based on the EAR created for the abstraction licence application (APEM 2022). The assessment of the impacts on the macroinvertebrate community was made in the context of the baseline condition and effect of previous low flow periods, using a suite of diagnostic biotic indices. The following assessment of impacts discusses the predicted hydraulic habitat changes during operation of the proposed drought permit and relates them to expected changes in macroinvertebrate communities. Reference is also made to the predicted effects of the proposed drought permit on water quality.

6.2.4.1 *Lower River Lyd (GB108047007731)*

Baseline data did not indicate significant flow stress on the macroinvertebrate community of the Lower River Lyd water body, based on study of LIFE O:E ratios from six locations sampled from 1990-2019. Modelled flow velocity at baseline conditions for the Lower River Lyd were moderate, and similar flow conditions have been predicted under both abstraction licence conditions and proposed drought permit operation (i.e. abstraction period extended April to June 2023). Depth reductions downstream of the abstraction point were predicted to be minimal. Flow reductions relate to small changes in velocity compared to the baseline scenario (predominantly less than 0.25 m/s), which would be most pronounced at pools and riffles, but still were minimal. As the scale of changes identified were relatively minor, the scale of effect on physical habitat from the abstraction was considered to be negligible (APEM 2022). Based on this information, the likelihood of flow stress impacting the macroinvertebrate community of the Lower River Lyd under the proposed drought permit two-month extension is also considered to be **Negligible**.

Of the macroinvertebrate indices assessed, NTAXA O:E is considered to provide the best indication of habitat diversity – diversity of taxa present will generally correspond with diversity of habitat available. As potential impacts of the proposed drought permit on physical habitat were deemed negligible, and the baseline macroinvertebrate data showed NTAXA O:E to consistently fall within the WFD boundary of Good status or better, it is considered that the proposed drought permit will have a negligible adverse impact on the macroinvertebrate community in terms of diversity. Furthermore, no significant impacts have been predicted on water quality downstream of the proposed abstraction under drought permit conditions. The good water quality of the Lower River Lyd was reflected in the ASPT O:E ratios analysed during the baseline assessment, which were consistently found to fall within the WFD Classification boundary of Good status or better. Based on this information it is considered unlikely that the predicted changes in physical habitat or water quality under proposed drought permit conditions would result in deterioration of the macroinvertebrate element WFD status.

Fine sediment deposition is considered to be one of the primary potential impacts of abstraction (APEM 2022) and thus of the drought permit operation. However, hydraulic modelling confirmed that rates of fine sediment deposition during operation of the abstraction are unlikely to be substantially elevated above baseline conditions, and modelled flow velocities typically exceeded the settling velocity of fine sediment. This assessment also extends to the proposed drought permit scenario of abstracting from April to June. In conjunction with the consistently Good or better PSI scores observed in the baseline dataset, the likelihood of sediment stress impacting the macroinvertebrate community of the Lower River Lyd under drought permit operation is considered **Negligible**.

6.2.4.2 *Summary*

- The Lower River Lyd water body dataset is spatially and temporally well distributed. The baseline dataset (2002 - 2019) is considered sufficient to assess the impacts of the proposed drought permit on the macroinvertebrate community of the River Lyd. Periodic updates (triennially) would be recommended to ensure the baseline remains up to date.
- The baseline dataset demonstrated a macroinvertebrate community resistant to low flows. However, a review of species lists demonstrated a relatively great representation by flow sensitive taxa. Therefore, a **Medium** level of sensitivity has been assigned.

- Given the negligible impacts predicted for the hydrological regime, hydromorphology and water quality and the short duration of the proposed drought permit the predicted impact on macroinvertebrates is **Negligible**. As the predicted impact within a given November to March period (based on the normal abstraction licence conditions) is negligible, following an intervening four-month period no sustained effect is predicted and there is not considered to be potential for cumulative effects year to year.
- Whilst the dataset was spatially and temporally well distributed, the consistency and frequency of sampling was variable between locations. A **Medium** level of certainty has therefore been assigned to this assessment.

6.3 Fish

6.3.1 Background

The River Tamar (of which the River Lyd is a tributary) supports an important fishery for Atlantic salmon (*Salmo salar*) and sea/brown trout (*Salmo trutta*). The Tamar is designated as an Environment Agency Index River, forming part of a network of sites used to monitor long-term national trends in salmonid populations. Consequently, there is a wealth of both historical and recent monitoring data available for the River Lyd and the wider catchment, with an Environment Agency Index River monitoring report published for the Tamar annually. Operation of the Gunnislake fish trap and counter provides information on the total size and seasonality of salmon and sea trout runs entering the Tamar catchment each year, with historical data extending back to the 1980s.

The River Lyd is one of several tributaries of the River Tamar which provide important spawning and nursey habitat for salmonids and is thus responsible for a sizeable proportion of juvenile salmonid recruitment within the Tamar catchment. A number of studies were undertaken on the Lyd sub-catchment as part of the Roadford Fisheries and Environmental Investigations (1985-1992). These studies involved trapping, electric-fishing, radio tracking, tagging and angler logs, interspersed with routine monitoring programmes undertaken by the Environment Agency. In more recent years, the Agency has expanded the monitoring programme on the Tamar and tributaries following its nomination as an Index River. Data on juvenile salmonid recruitment is therefore collected by the Agency through a network of fish monitoring sites, primarily for the purpose of index river monitoring, although additional surveys are completed for other purposes (e.g. for WFD classification and the recently established national drought monitoring network).

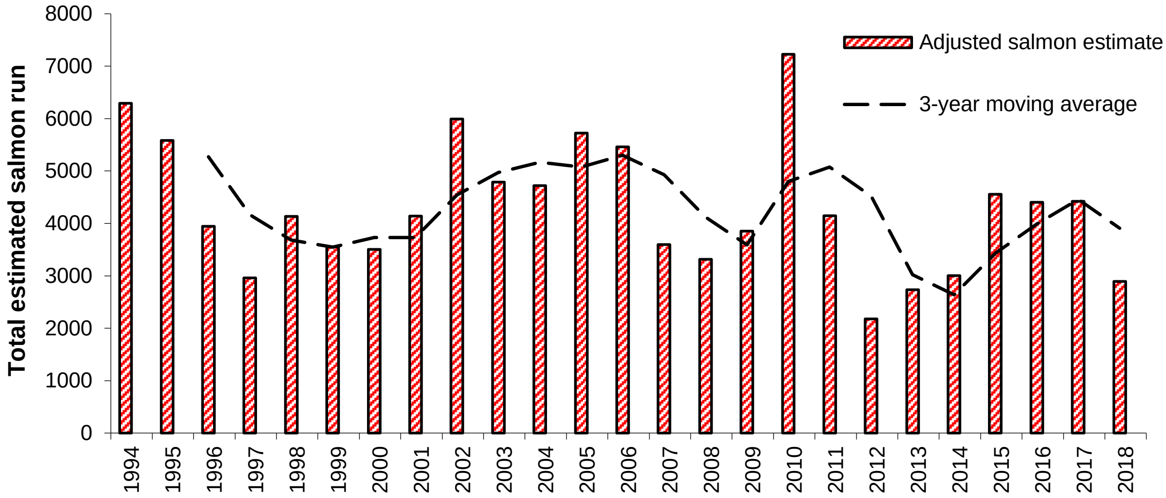
The ongoing status of salmon populations in the Tamar catchment is determined against river-specific Conservation Limits (egg deposition standards, which are biological reference points set by the Environment Agency for each river in England). These data are the best available for assessing long term population trends, but they do not describe seasonal variation. The Conservation Limits for the River Tamar are derived from the total annual run of fish recorded passing Gunnislake weir (covered below), from which a total estimate egg deposition rate is determined. As of 2018 the compliance of the Tamar was assessed as ‘Probably at risk’ of failing to meet the Conservation Limit, with egg deposition at 79 % of the target required (Environment Agency, 2018). The 10-year and 5-year averages for the Conservation Limit on the Tamar are 100.2 % and 91 %, respectively, reflecting a decline in the rates of returning adults and egg deposition in recent years. However, for reasons discussed below the Tamar has seen a minor upturn in egg deposition with %CL being 78%,113% and 124% in 2019, 2020 and 2021 respectively; but it remains classified as Probably at Risk (Cefas/EA/NRW 2022).

The following sections provide more detailed background information on trends in salmonid migration and juvenile recruitment on the River Tamar and River Lyd.

6.3.1.1 Upstream migration

Upstream migration of fish on the Lyd principally concerns the movement of adult salmonids (both anadromous salmon and sea trout and potamodromous brown trout) prior to spawning.

The Agency operates a resistivity fish counter and a manual fish trap at the upstream end of the pool and traverse fish pass on the Cornish bank of Gunnislake weir (NGR SX4368471133), located at the tidal limit of the River Tamar. The Cornish fish pass represents the primary route upstream of the weir (although passage is also possible through a second smaller fish pass adjacent to the Devon bank of the weir) and therefore provides robust data on the numbers and timing of adult salmonids entering the catchment. The estimated total run of salmon and sea trout entering the Tamar catchment is provided in Figure 6-7. The annual run of sea trout is typically 2 – 3 times greater than the salmon run (sea trout 10 year average run of 12,122, compared to 3,984 for salmon). Both species suffered notable declines in run size during 2011 – 2013, declining to approximately half of the 3-year moving average. However, in the following years the run sizes increased and largely stabilised, although a moderate decline in run size is again apparent in the latest 2018 data.



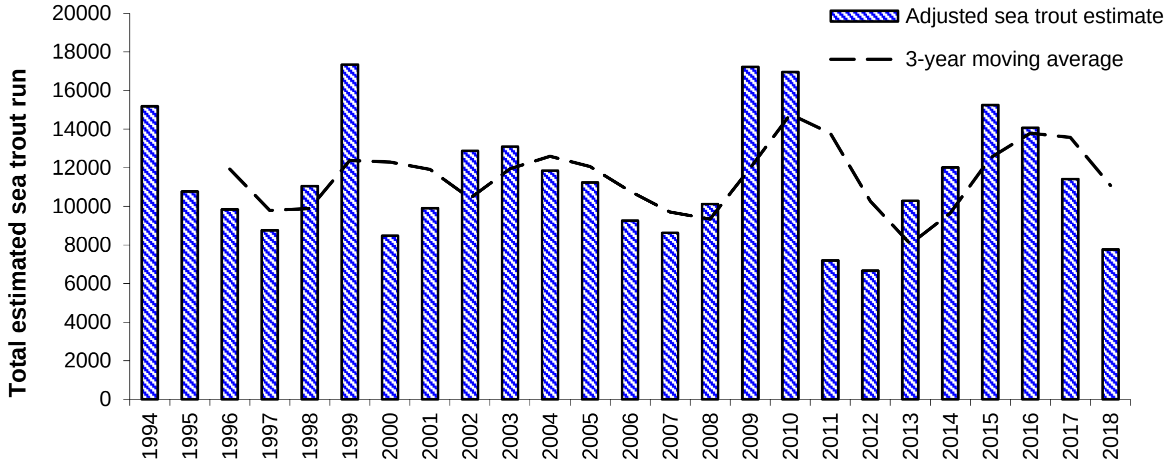


Figure 6-7 Total estimated runs of salmon (top) and sea trout (bottom) in the Tamar catchment, derived from the Gunnislake fish counter and trap data

In recent years there has been an increase in the proportion of the salmon run comprising multi-sea winter (MSW) fish, with a reduction in 1SW fish (grilse) (Figure 6-8).

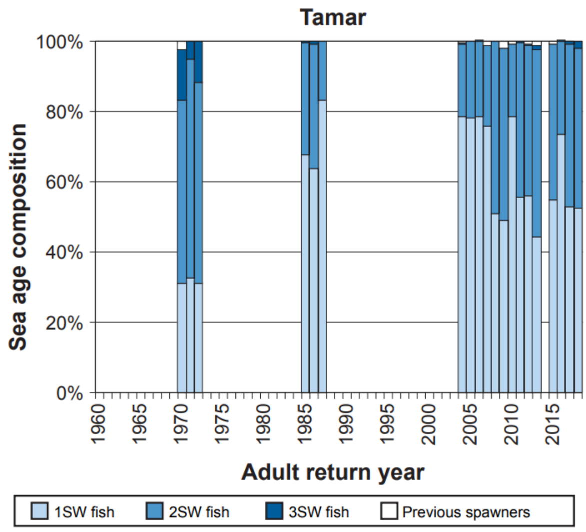


Figure 6-8 The age composition of adult salmon returning to the River Tamar (Environment Agency, 2019)

The effect of the shift in sea age has been to offset somewhat the decline in spawner abundance such that egg deposition has remained comparatively stable and has even increased on the Tamar in comparison with adjacent rivers (Figure 6-9), although other river-specific factors may also be involved. However, informal information about 2022 returns is that the widespread long term decline in salmon continues.

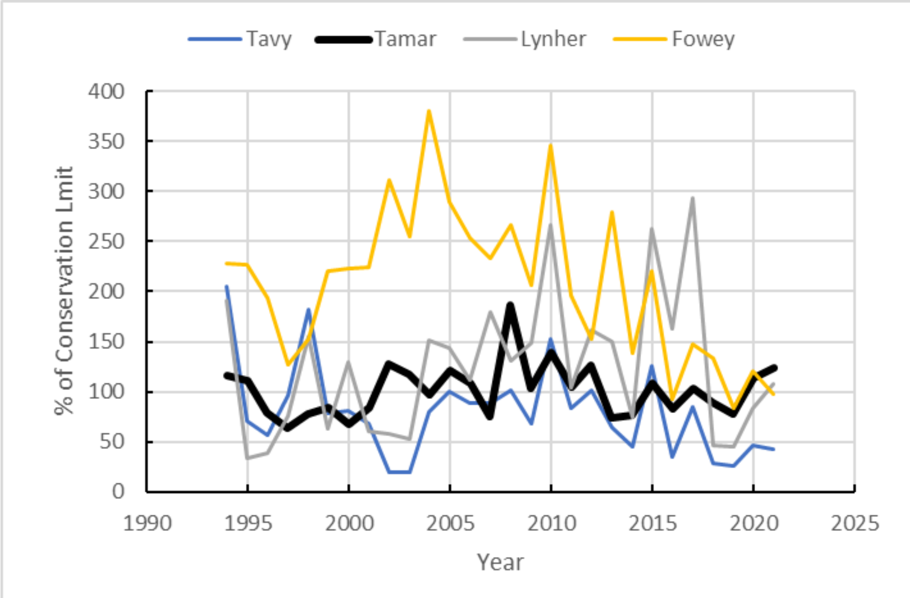
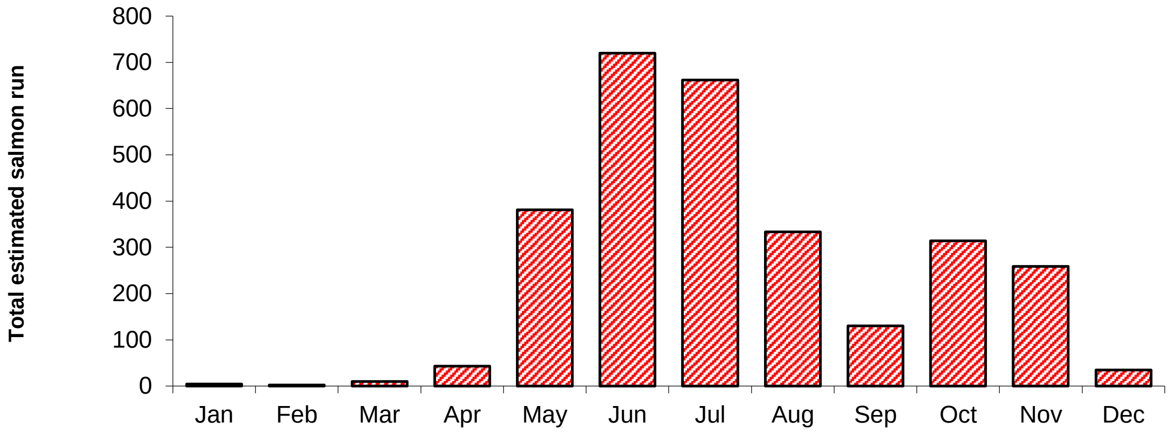


Figure 6-9 Long-term changes in salmon Conservation Limit Compliance in the Tamar and three adjacent rivers (Cefas/ EA/ NRW, 2022)

Breaking the run size down by month over the same period reveals fairly distinct and typical differences in migration trends for the two species (Figure 6.). Salmon migrate over a relatively wide season of May – November, with a primary peak in June and July (accounting for 46 % of fish movements). A secondary peak of autumn migrating salmon is then evident in October and November. All fish must reach spawning grounds at an opportune time to successfully reproduce (broadly November – January for salmon) and therefore salmon entering freshwater earlier in the year are likely to spend a greater period of time resident in freshwater than later migrating fish. Fish entering freshwater during the autumn months are more likely to undertake directed and rapid movements given the proximity to the spawning period (Milner *et al.* 2012). Additionally, there is evidence to suggest that migrants entering freshwater earlier in the year may travel furthest to spawn in the upper reaches of catchments (Laughton 1991; Hawkins & Smith 1986, Gowans 2004). Salmon typically enter the upper reaches of large catchments later in the year to coincide with the higher flows that make access and passage easier in smaller channels (Milner et al 2012). This will be the case in the Lyd and has been noted in tracking studies (Solomon et al 1991). Rod catch data index the seasonal abundance of salmon within rivers and for the Tamar show that on average 26% (range 14% to 35%) of the annual catch occurs in months March to end of June (EA Rod catch statistics). This catch applies to the whole Tamar and most pre-July fish will be taken in the main stem Tamar, well downstream of the impact zone. Rod catch over-estimates the proportion of the total annual run, because angling season closure means that the last part of the run (post-October is not sampled by catch). This coupled with the later arrival of salmon means that any effects of a DP operating March to June could only act on a small fraction of the annual spawning run into the Lyd. An analysis of local rod catches would help to confirm this.

In contrast to salmon, the migration of sea trout is focused into a considerably shorter season, with approximately two thirds of fish moving in June and July, with sharp declines outside of this period (Figure 6.). The entry of sea trout earlier in the year is likely to be at least partially attributable to the earlier spawning window compared to salmon.



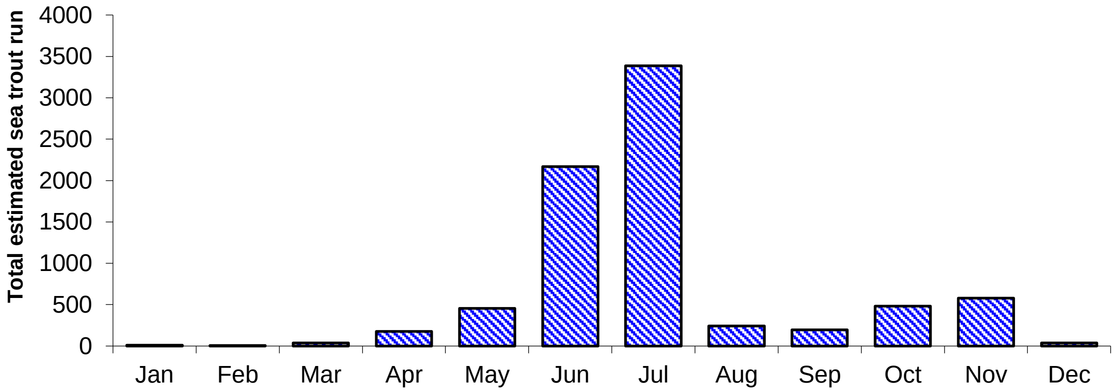


Figure 6.10 Total estimated average monthly runs of salmon (top) and sea trout (bottom) in the Tamar catchment (1994 – 2018), derived from the Gunnislake fish counter and trap data

6.3.1.2 Downstream migration

Downstream migration with respect to the River Lyd primarily relates to the emigration of salmon and sea trout smolts upon maturity, in addition to the movement of kelts (spent adult fish) after spawning.

Smolt migration occurs in the spring over a relatively short period - normally between March and June - but predominantly concentrated in April and May. The timing of emigration is important because there is evidence that smolts need to arrive at the sea at a time that maximises their feeding opportunity, coinciding with the onset of coastal marine spring production (Thorstad *et al.* 2011). Given that the distance and travel times to the sea vary around large catchments, smolts depart at different times from different sub-catchments (e.g. a smolt emigrating from the upper River Lyd is likely to depart earlier than one emigrating from the lower end of the main stem River Tamar to ensure a comparable marine arrival). These timings need to be protected and barriers to migration that lead to delays or to increased predation are recognised as potential hazards to migration. Even small barriers can be important constraints on downstream salmonid passage at times of low flow leading to delays and increased exposure to predation (Gauld *et al* 2013). Passage over existing weirs on the River Lyd is therefore an important aspect within the assessment to ensure that consideration has been given to potential migration delay under reduced flows.

In comparison to patterns of pre-spawning and smolt migration, comparatively less is known about the nature of kelt migration and the role of environmental factors in triggering or sustaining outwards migration after completion of spawning. There is an on-going research project under the Salmonid Management Round the Channel (SAMARCH) programme involving the tagging and tracking of sea trout kelts within the Tamar catchment. However, the research is primarily concerned with the movement of kelts through the lower River Tamar and estuary and is therefore of limited relevance to movement of fish through the lower River Lyd during operation of the proposed Drought permit.

There is evidence to suggest that several different strategies are employed during kelt migration, with some fish overwintering within freshwater after spawning before migrating back downstream to sea the following spring, whilst other fish may forgo the overwintering phase and migrate back downstream soon after spawning (Bendall *et al.* 2005). Findings by Bendall *et al.* (2005) during a tracking study of 45 sea trout kelts on the River Fowey concluded that fish tended to migrate downstream during periods of elevated river flow, although there was no particular threshold flow required to initiate migration.

6.3.1.3 Juvenile populations

Data on densities of juvenile salmonids on the River Lyd and upstream water bodies are available from a number of Environment Agency fish monitoring locations, with data collected primarily for the purposes of index river monitoring and WFD classification. A map of monitoring locations within the water bodies of interest is provided in Figure 6-10 and data from recent surveys are summarised in Table 6.7 to Table 6.10.

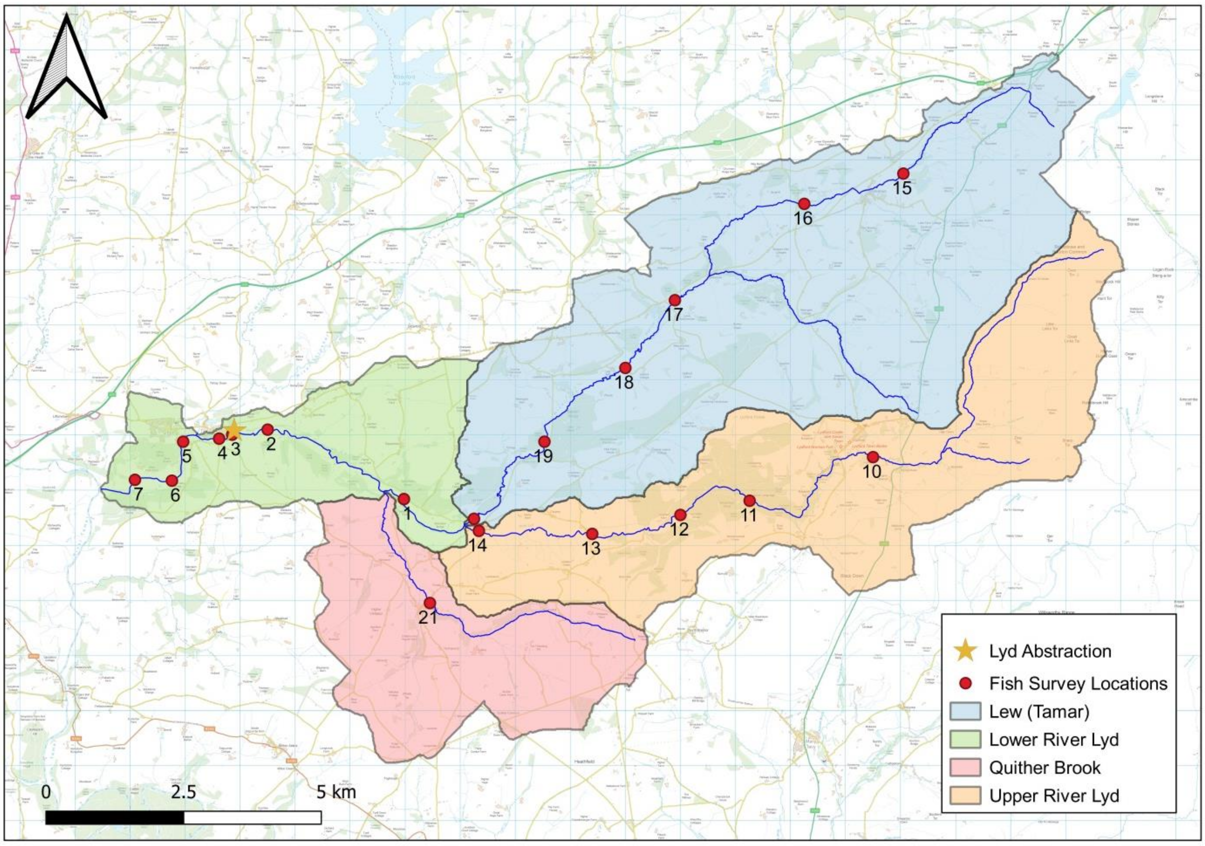


Figure 6-10 Recent Environment Agency fish surveys completed in close proximity to the Lyd intake. Numbers correspond to the Site IDs provided in Table 6.7 to Table 6.10

Density data from the fish surveys have been colour coded according to Fisheries Classification Scheme (FCS) boundaries, which although now superseded, provide a useful visual tool for interpretation. Data from 2000 - 2022 for 0+ and >0+ salmon are presented in Table 6.7 and Table 6.8, respectively, whilst data for 0+ and >0+ trout are presented in Table 6.9 and Table 6.10, respectively.

It is apparent from the data that all four water bodies provide suitable juvenile/rearing habitat for salmonids (and by extension, spawning habitat), demonstrated by moderate to high densities (typically equivalent to FCS grades of A – C across the majority of monitoring locations). Densities of >0+ salmon are generally high throughout the Lower River Lyd WFD water body.

The Upper River Lyd and Lew (Tamar) water bodies each support reasonable grades of 0+ salmon throughout much of the data period, although the grades of >0+ salmon at the same monitoring sites are typically lower. In contrast, both water bodies (and the Quither Brook) historically support high densities of 0+ and >0+ trout, likely reflecting a greater suitability for trout habitat on these smaller tributaries. In contrast, low trout densities are recorded on the Lower River Lyd water body for both 0+ and >0+ age classes, reflecting a dominance of salmon on this water course.

Recruitment of salmon shows a broadly downwards trend across all four water bodies over the last 20 years, with the most marked declines evident in the 0+ age class (Figure 6-11). In comparison, juvenile trout recruitment has been somewhat more stable, although a moderate decline in densities is evident for both 0+ and >0+ age classes in the Lew (Tamar) water body.

The historical fish surveys also provide useful data on the wider fish assemblage of the River Lyd. In addition to populations of salmonids, a range of other species typical of upland water bodies have been recorded. These include stone loach (*Barbatula barbatula*), minnow (*Phoxinus phoxinus*), bullhead (*Cottus gobio*), European eel (*Anguilla anguilla*), grayling (*Thymallus thymallus*) and brook/river lamprey ammocoetes (*Lampetra planeri* or *L. fluviatilis*).

Table 6.7 Summary of 0+ salmon density from historical Environment Agency timed fish surveys in the River Lyd catchment, coloured by FCS thresholds

Site	ID	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	*Mean (all years)*
Lower River Lyd (GB108047007731)																									
Sydenham	1	20.8		50.8	20.9	89.2	57.8	84.1	33.6	19.6	30.2	37.4	31.0	21.2	44.1	35.6	33.4	10.5	27.2	56.2	6.9		12.4	17.4	35.3
Spry Farm	2	16.9	24.5	25.8	43.4	97.9	88.6	99.1		0.9	14.3	31.9	47.7	28.4	96.8		53.4	11.7	34.1	42.2	7.3		2.9	12.1	39.0
Colemans Farm	3						471.5	408.3		21.9															300.6
Ambrosia Bridge	4						78.2																		78.2
Lifton Playing Field	5	51.1		15.6	13.5	55.3	74.0	59.7			132.4	44.5		27.5	97.9		17.9	4.8		24.8	7.2		1.8	1.3	39.3
Lifton Park	6	25.7		3.0	8.6	19.8	25.4	28.5			26.0	18.4		17.8	37.7		5.0						0.9		18.1
u/s Gatherley	7	111.6		6.0	35.3	75.0	74.4	101.1			62.7	110.2		30.5	68.5		12.9	10.5		46.1	4.0		3.8	6.3	47.4
d/s Gatherley	8																								
Upper River Lyd (GB 108047007750)																									
D/S Kit Steps	10			0.0	0.0	0.0	0.0	0.0																	0.0
Lydford	11				30.9	14.0	32.2	23.4	17.5	6.3	9.4	5.5	6.5	2.8	7.3		0.0	0.3	0.0	1.8			2.4	2.1	9.6
Langham	12		33.8																						33.8
Coryton	13				39.1						16.6						18.8						4.3		19.7
Greenlanes	14	41.7	48.9	27.4	66.8	148.6	84.7	79.9			32.5	55.6	38.1	40.6	107.5		75.5	31.0	22.7	69.5	8.5		15.8	17.9	53.3
Lew (Tamar) (GB108047007770)																									
Ebsford	15		79.9																						79.9
Stone	16			64.5	76.7						66.0	20.2	15.5	46.4	57.7		0.9	14.4	27.0	3.0	4.3		26.3	0.0	30.2
Foxcombe	17																								
Lew Mill	18			78.5	71.2	34.3	45.5	99.7	99.9	39.4	81.3	42.6	37.1	58.5	77.8		34.9	16.5	56.5	120.5	10.0				59.1
Lew Wood	19		32.6																						32.6
Lee	20			40.7	60.5						104.9	54.9	104.8	39.5	140.8		56.0	32.2	27.8	79.8	14.6				63.0
Quither Brook (GB108047007710)																									
Chillaton	21		89.7		19.3						21.0						0.0	0.0	0.0	0.0	4.6		0.6	1.9	13.7
Sydenham (Quither)	22		49.9																						49.9

Table 6.8 Summary of >0+ salmon density from historical Environment Agency timed fish surveys in the River Lyd catchment, coloured by FCS thresholds

Site	ID	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	*Mean (all years)*
Lower River Lyd (GB108047007731)																									
Sydenham	1	1.1		3.0	1.3	2.6	2.6	2.2	4.6	4.6	2.1	7.0	1.9	5.3	5.5	9.5	7.6	4.6	2.4	8.4	0.4		1.1	2.5	3.8
Spry Farm	2	6.4	10.6	4.0	18.2	12.1	27.8	9.0		8.9	4.1	7.6	12.0	14.6	14.1		10.2	3.8	3.8	7.8	1.6		2.0	1.1	9.0
Colemans Farm	3						37.2	19.0		18.0															24.7
Ambrosia Bridge	4						16.0																		16.0
Lifton Playing Field	5	10.6		2.6	16.4	5.5	18.7	5.4			16.6	24.1		20.1	13.2		11.3	8.7		9.9	1.9		2.0	1.6	10.5
Lifton Park	6	2.1		0.6	0.5	1.7	1.9	1.4			1.8	2.0		3.4	2.8		4.1						0.0		1.9
u/s Gatherley	7	9.4		6.5	11.6	9.3	9.9	7.3			7.8	15.7		16.9	26.6		9.6	6.8		11.9	0.6		1.6	3.5	9.7
d/s Gatherley	8																								
Upper River Lyd (GB 108047007750)																									
D/S Kit Steps	10			0.0	0.0	0.0	0.0	0.0																	0.0
Lydford	11				2.2	1.5	1.0	2.4	0.9	2.5	0.0	1.7	0.5	0.5	0.0		0.7	0.3	0.0	0.0			0.0	0.0	0.8
Langham	12		1.7																						1.7
Coryton	13				7.8						1.6						2.4						1.6		3.4
Greenlanes	14	3.5	6.7	3.1	5.9	6.9	6.8	6.2			0.9	3.7	1.6	7.5	7.4		10.9	8.7	1.9	10.3	0.4		0.6	1.1	5.0
Lew (Tamar) (GB108047007770)																									
Ebsford	15		6.4																						6.4
Stone	16			7.5	14.1						7.3	9.4	4.2	14.2	4.9		3.1	1.8	1.9	7.3	1.9		1.8	3.2	5.9
Foxcombe	17																								
Lew Mill	18			5.4	2.2	3.8	3.3	1.9	11.0	13.9	7.0	9.8	9.4	12.4	9.9		5.4	4.1	1.9	11.1	2.4				6.8
Lew Wood	19		3.6																						3.6
Lee	20			8.0	16.9						4.5	25.0	11.4	13.8	18.4		16.5	10.9	1.5	11.7	2.4				11.8
Quither Brook (GB108047007710)																									
Chillaton	21		8.0		10.2						9.8						5.2	0.6	0.0	0.8	0.0		1.3	0.0	3.6
Sydenham (Quither)	22		2.9																						2.9

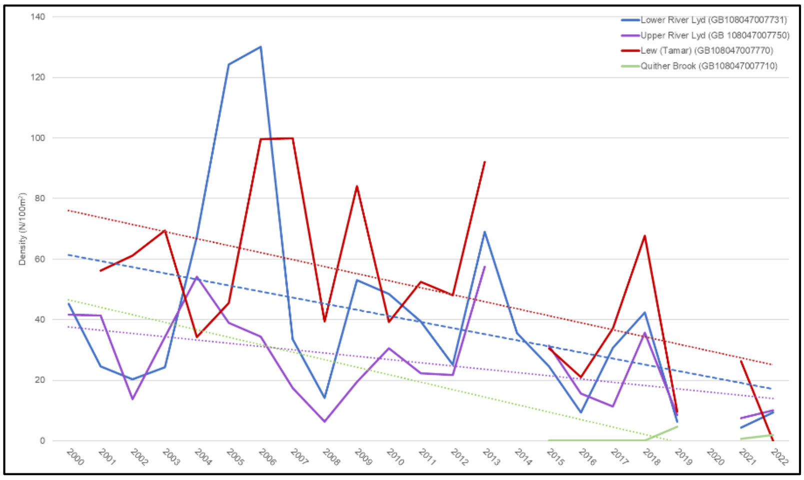
Table 6.9 Summary of 0+ trout density from historical Environment Agency timed fish surveys in the River Lyd catchment, coloured by FCS thresholds

Site	ID	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	*Mean (all years)*
Lower River Lyd (GB108047007731)																									
Sydenham	1	6.9		3.0	0.0	4.2	2.0	1.5	2.3	2.7	3.8	12.7	2.1	2.5	4.6	4.9	6.1	2.5	6.6	9.9	4.2		1.3	2.5	4.1
Spry Farm	2	0.0	0.8	0.0	1.3	0.8	0.5	1.1		0.5	1.6	2.3	0.5	0.0	1.4		2.4	0.5	5.0	1.2	0.2		0.4	2.7	1.2
Colemans Farm	3						1.2	2.7		3.0															2.3
Ambrosia Bridge	4						1.0																		1.0
Lifton Playing Field	5	0.0		0.0	0.3	0.3	0.0	0.4			0.0	2.5		0.3	0.3		0.0	0.0		1.9	0.2		0.0	0.9	0.4
Lifton Park	6	0.0		0.0	0.0	0.0	0.0	0.0			0.4	0.7		0.0	0.0		0.0						0.0		0.1
u/s Gatherley	7	0.0		0.2	0.0	0.0	0.2	0.0			0.0	1.5		0.2	0.0		0.0	0.8		1.5	0.3		0.1	0.6	0.3
d/s Gatherley	8																								
Upper River Lyd (GB 108047007750)																									
D/S Kit Steps	10			11.7	19.8	13.5	44.2	18.5																	21.5
Lydford	11				13.0	14.3	11.0	11.3	7.3	14.6	9.8	16.9	18.9	11.0	16.7		6.3	3.5	4.3	7.6			6.9	5.7	10.5
Langham	12		14.2																						14.2
Coryton	13				9.8						12.6						9.3						4.0		8.9
Greenlanes	14	3.7	6.2	1.4	4.2	14.2	4.2	5.4			4.2	7.0	8.4	3.1	6.4		7.0	4.1	8.2	12.2	1.7		0.9	3.0	5.6
Lew (Tamar) (GB108047007770)																									
Ebsford	15		77.3																						77.3
Stone	16			17.8	39.0						40.0	95.7	25.4	13.2	9.3		54.8	7.7	21.0	12.9	19.3		13.6	11.1	27.2
Foxcombe	17																								
Lew Mill	18			8.6	9.4	10.6	8.5	11.6	10.2	14.2	8.1	20.7	2.5	6.2	5.6		8.0	4.1	9.7	11.1	3.0				8.9
Lew Wood	19		14.2																						14.2
Lee	20			4.3	4.1						8.5	14.6	14.3	4.8	8.5		6.0	1.3	7.1	6.4	4.0				7.0
Quither Brook (GB108047007710)																									
Chillaton	21		34.5		40.9						58.9						55.8	6.3	34.1	48.0	29.8		7.7	26.9	34.3
Sydenham (Quither)	22		9.6																						9.6

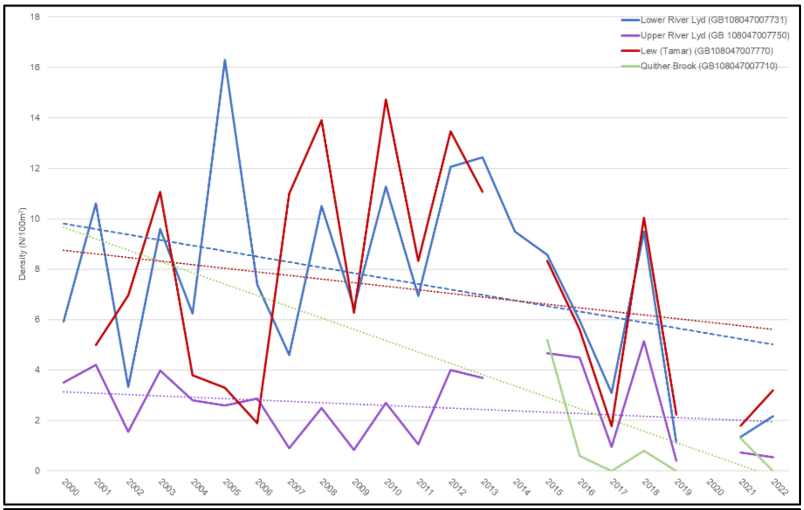
Table 6.10 Summary of >0+ trout density from historical Environment Agency timed fish surveys in the River Lyd catchment, coloured by FCS thresholds

Site	ID	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	*Mean (all years)*
Lower River Lyd (GB108047007731)																									
Sydenham	1	2.2		5.6	0.0	5.9	2.4	2.2	3.1	3.8	2.1	2.5	2.3	3.4	2.8	5.3	9.3	3.9	1.7	7.4	2.3		0.6	2.7	3.4
Spry Farm	2	0.5	1.5	2.0	0.0	0.3	1.6	1.3		1.2	0.5	0.5	0.5	2.1	1.4		1.6	0.0	0.5	2.4	0.5		0.2	0.2	0.9
Colemans Farm	3						1.2	2.7		4.3															2.7
Ambrosia Bridge	4						2.2																		2.2
Lifton Playing Field	5	1.9		1.5	1.7	1.6	2.1	2.5			4.4	6.6		3.1	2.4		5.0	3.5		3.3	1.0		0.6	0.9	2.6
Lifton Park	6	0.0		0.9	0.5	0.3	0.0	0.5			0.0	0.3		1.1	1.0		0.0								0.4
u/s Gatherley	7	0.0		1.1	0.4	0.1	0.8	0.0			1.8	1.6		1.8	1.6		4.6	1.4		2.3	0.5		0.5	0.5	1.2
d/s Gatherley	8					0.1																			
Upper River Lyd (GB 108047007750)																									
D/S Kit Steps	10			39.1	27.8	22.1	24.2	46.6																	32.0
Lydford	11				5.3	11.6	12.0	18.5	5.0	13.8	4.6	25.7	30.8	11.4	19.8		9.3	12.4	12.4	13.1			8.2	4.0	12.8
Langham	12		16.2																						16.2
Coryton	13				12.4						13.4						18.5						7.0		12.8
Greenlanes	14	7.2	16.3	3.3	11.2	5.9	9.9	6.7			4.0	9.1	14.6	7.5	6.8		12.3	10.1	7.3	15.3	5.6		0.9	1.3	8.2
Lew (Tamar) (GB108047007770)																									
Ebsford	15		28.6																						28.6
Stone	16			19.2	14.8						2.2	9.0	6.7	10.6	2.4		3.5	15.1	2.2	5.2	11.2		1.8	0.0	7.4
Foxcombe	17																								
Lew Mill	18			16.3	6.5	11.3	6.4	6.4	24.4	17.1	14.6	19.6	29.1	18.9	15.1		8.6	13.3	8.1	15.0	5.2				13.9
Lew Wood	19		19.5																						19.5
Lee	20			13.3	8.5						7.2	13.8	9.7	5.6	7.2		8.7	8.3	4.1	10.3	4.8				8.5
Quither Brook (GB108047007710)																									
Chillaton	21		10.6		6.6						17.5						8.9	11.5	10.2	19.4	10.6		18.7	10.6	12.5
Sydenham (Quither)	22		7.1																						7.1

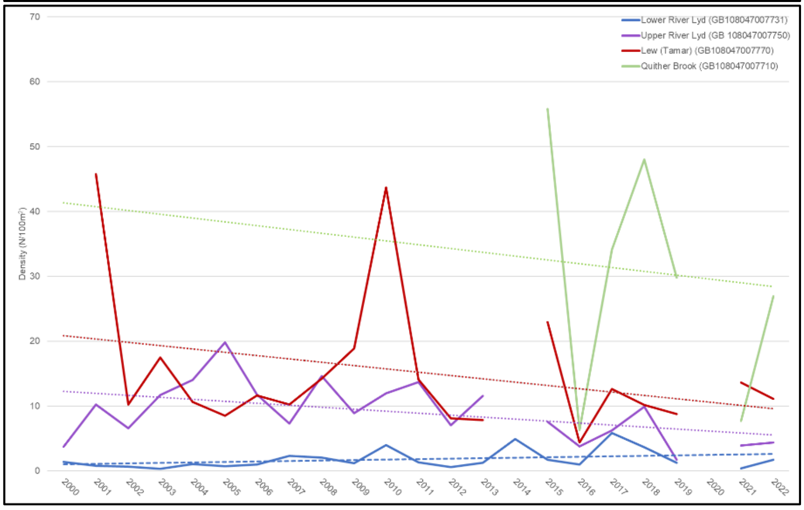
0+ salmon



>0+ salmon



0+ trout



>0+ trout

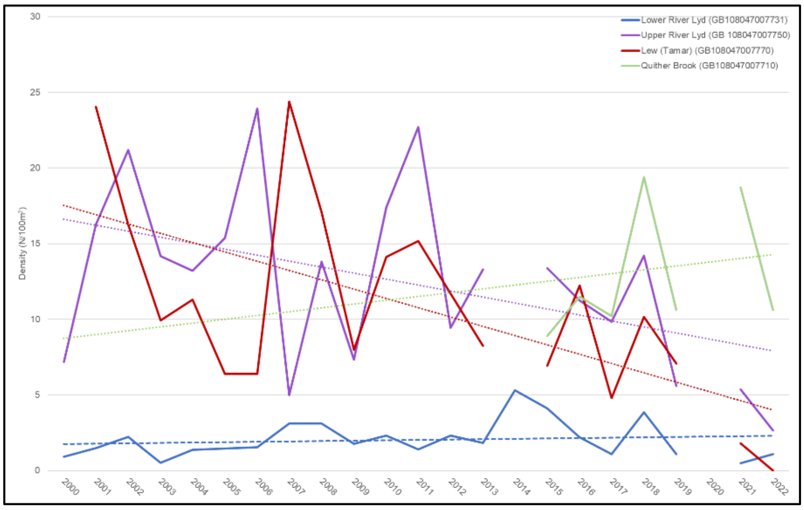


Figure 6-11 Mean density of juvenile salmonids across the four WFD water bodies from Environment Agency surveys (2000 – 2022), fitted with linear trend lines

6.3.2 Potential routes of impact

Fish species vary in their spatial and temporal habitat requirements and sensitivity to altered flow scenarios. In addition, variations in river flow can have different types and magnitude of impact on fish depending upon their timing, duration and magnitude. Key considerations are therefore the changes in the quality or extent of habitat as well as impacts on habitat accessibility; individual species and life stages require access to a variety of habitats (and associated environmental conditions, such as water temperature and dissolved oxygen concentration) at different times of the year for successful recruitment. In addition, predicted impacts to macroinvertebrate populations are also considered in terms of potential changes in availability of food sources.

Section 5 outlines the physical pathways through which the drought permit may potentially impact on ecological receptors (including fish). To consider the likelihood and mechanisms by which these pathways may act upon individual species and life stages of fish it is necessary to understand the seasonality and key sensitivities of life stages in relation to the proposed Drought permit timings. An overview of periods of key sensitivity for each individual species and life stage is presented in Table 6.11 in relation to the proposed drought permit operation period. Based on this information, the potential for impact pathways to act upon each species is discussed below.

Table 6.11 An overview of periods of key seasonal sensitivity for individual species and life stages in relation to the proposed drought permit operation period (April – June inclusive)

Species	Life stage	J	F	M	A	M	J	J	A	S	O	N	D
Atlantic salmon	Spawning & egg incubation	■	■								■	■	■
	Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
	Adults	■	■							■	■	■	■
Brown trout	Spawning & egg incubation	■	■								■	■	■
	Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
	Adults	■	■	■	■	■	■	■	■	■	■	■	■

Bullhead	Spawning & egg incubation												
	Juvenile												
	Adults												
European eel	Elver U/S migration												
	Adult D/S migration												
	Adults												
Brook lamprey	Spawning & egg incubation												
	Ammocoetes												
Grayling	Spawning & egg incubation												
	Juvenile												
	Adults												

6.3.2.1 Salmonids

The proposed drought permit would be in place between April and June (inclusive). Based on the timings outlined in Table 6.11, the drought permit will not coincide with the spawning period for salmon or trout, and is unlikely to coincide with the subsequent egg incubation and alevin life stages (both of which have been encompassed within the 'spawning & egg incubation' life stage given the immobility of individuals within the spawning redds during this phase). Impacts on these life stages may arise through reductions in water level during operation of the abstraction and subsequent exposure/drying out of spawning redds, which can lead to reductions in egg viability and alevin survival (Becker *et al*. 1985). Alternatively, declines in water velocity during the period of operation of the abstraction may increase the settlement of fine sediments that would normally be suspended in the water column. Where fine sediment settles on spawning redds there is the potential for reduced intragravel flow, compromising the exchange of oxygen and waste metabolites between eggs/alevins and the surrounding water (Julien and Bergeron, 2006). However, juvenile life stages of both salmon and trout will be present in the River Lyd year-round, prior to smoltification and downstream migration. Based on the proposed timing of the abstraction, young of year salmon and trout (i.e. 0+ fry) will have emerged from spawning gravels, and consideration of the impacts of abstraction on the availability of habitat for these salmonid life stages is therefore required.

In addition to impacts on recently emerged juvenile salmonid life stages, there are key considerations with regards to the migratory movements of salmonids. Wild salmon and trout smolt data provided by the EA's 2022 Tamar (Endsleigh) RST trapping programme indicates that smolts of both species may begin to migrate downstream as early as the first week of April, with the main run for both species occurring towards the end of April and into May. Additionally, the upstream migration of adult salmon has been observed to occur between March and January on the River Tamar, based on trapping studies at Gunnislake (EA, 2004). The proposed drought permit therefore overlaps with the majority (if not the entirety) of the smolt migration window for both salmon and trout and coincides with upstream movements of 'spring' adult salmon.

There is the potential for any effects on migration of fish during operation of the abstraction to result in adverse impacts on fish populations in water bodies upstream of the Lower River Lyd. For example, if the migration of adult fish through the River Lyd is delayed or prevented, this may affect the opportune arrival of fish in spawning tributaries (e.g. the Lew and Quither Brook) and therefore affect subsequent spawning success and juvenile recruitment. Therefore, if potential impacts to migration are identified for the Lower River Lyd, consideration will also be given to possible impacts on upstream water bodies.

6.3.2.2 Grayling

Grayling are typically found in wider sections of rivers where the water is cool and well-oxygenated, and favour riffles and rapids separated by pools and runs. They are a potamodromous species, migrating solely within freshwater, and are therefore vulnerable to changing river conditions, particularly changes to passability of barriers and longitudinal connectivity. Whilst they display a tolerance for a wider range of environmental conditions than other salmonids, they are thought to succumb quite quickly to pollution and elevated water temperatures (Ingram *et al*, 2000). Juvenile and adult grayling may be present within the River Lyd year-round, and impacts on these life stages must therefore be considered with regard to the proposed drought permit.

6.3.2.3 Eels

The drought permit period may coincide with the beginning of the upstream migration of elvers (typically occurring between April – September on the River Lyd given the distance upstream of the tidal limit at Gunnislake). Yellow eel will be resident in the River Lyd year-round and consideration of potential drought permit impacts through changes in the quality and/or extent of habitat is required. However, the downstream migration of mature silver eels typically occurs between September – November, and therefore will not coincide with the proposed drought permit.

6.3.2.4 Brook lampreys

Based on the timings outlined in Table 6.11, there is the potential for impacts on spawning and juvenile life stages of brook lamprey during operation of the abstraction. Spawning typically commences in early spring (March onwards) once water temperatures exceed 10 – 11°C (Maitland, 2003), which will overlap with the proposed timing of the abstraction. The habitat utilised by lamprey species for spawning shares similarities with trout spawning habitat (Maitland, 2003) and thus the potential impact pathways are similar, warranting assessment.

Juvenile lampreys (ammocoetes) will remain resident in the River Lyd year-round, typically burrowing in silt beds along the channel margins in areas of low water velocity. Juvenile lamprey often display a high sensitivity to reductions in water level due to the likelihood of exposure of marginal habitats during water level reductions and the relatively sessile nature of the ammocoete life stage, thus warranting assessment.

6.3.2.5 Bullheads

Bullhead spawning may commence as early as February (Tomlinson and Perrow, 2003), although there is an element of spatial and temporal variation driven by factors such as altitude and water temperature. Spawning habitat comprises areas of coarse gravel/cobble substrate with a moderate depth and water velocity (Tomlinson and Perrow, 2003). Eggs hatch after 20 – 30 days, with fry dispersing from spawning nests a further 10 days later following full egg absorption (Tomlinson and Perrow, 2003). The proposed drought permit period would therefore coincide with the initial dispersal and early juvenile life stages of bullhead, requiring assessment.

6.3.2.6 Summary

In summary, there is the potential for impact pathways to act on the following species and life stages, which will be considered during the impact assessment:

- salmon and trout spawning habitat (encompassing consideration of egg incubation and alevin survival);
- downstream migration of kelts and smolts;
- upstream migration of adult salmon;
- freshwater migration of grayling;
- upstream migration of elvers; and
- changes in the quality or extent of habitat for salmon (juvenile), trout (juvenile and adult), eels (elvers), lampreys (spawning and juvenile), grayling (juvenile and adult) and bullhead (spawning and juvenile) through hydromorphological or water quality changes.

6.3.3 Baseline

To characterise the nature of the River Lyd under baseline conditions with respect to fish habitat, a walkover survey of the river channel was completed from the location of the abstraction (NGR SX39938506) to the confluence with the River Tamar (NGR SX3745884067), a length of approximately 3.5 km.

6.3.3.1 Methodology

The habitat walkover survey was undertaken by an experienced fisheries scientist on 13th – 14th August 2019. Flows at Lifton Park gauging station were stable during the survey period at 2.24 – 2.40 m^3/s, equivalent to Q55 – Q58 and deemed to be representative of moderate summer flows.

The survey followed the Hendry and Cragg-Hine (1997) methodology and was designed to inform the spatial distribution, quality and quantity of key functional habitats within the potentially affected reaches. Habitats favoured by juvenile and adult salmonids including those areas with gravel composition suitable for spawning were recorded along with optimal juvenile lamprey (ammocoetes) habitats (Table 6.12). In addition, other water flow classifications were recorded including runs and glides which provide suitable migratory passageway for salmonids, and pools which offer suitable resting areas.

Further observations which were noted during the walkover include areas of excessive erosion which could cause siltation of nursery habitat and anthropogenic alterations to the channel which could affect fish migration. Additional prominent features (e.g. woody debris/macrophyte cover/depositional bars) were also recorded with all salient observations throughout the walkover recorded with a unique GPS reference and photographs.

Table 6.12 Walkover habitat classification system

Habitat Type	Description
Spawning gravel	Ideally stable but not compacted, with a mean grain size 25 mm or less for trout, but up to 80 mm for salmon. 'Fines' (< 2 mm grain size) to be less than 20% by weight.
Fry (0+) habitat	Shallow, < 20 cm deep, fast flowing (> 30 cm/s), with surface turbulence and a gravel and cobble substrate.
Parr (≥1+) habitat	20 - 30 cm deep, fast flowing (>30 cm/s), surface turbulent, with gravel / cobble / boulder substrate.
Riffle	Shallow (< 30 cm deep), fast-flowing (> 50 cm/s), surface turbulent, gravel / cobble / boulder substrate.
Glide	= or > 30 cm deep, moderate velocity in range 10-30 cm/sec, surface smooth and unbroken, relatively even substrate of cobbles with finer material
Pool	= or > 40 cm deep, slow-flowing (< 10 cm/s), surface unbroken, substrate with a high proportion of sand and silt.

6.3.3.2 Survey results

The River Lyd offers widespread salmonid nursery habitats with mixed juvenile and parr habitat notably prevalent throughout the 3.5 km survey reach. These nursery grounds were interspersed by deep runs and glides providing excellent transitional water for migratory and resident salmonids. Numerous deep holding pools were also recorded in the survey reach and were often over hung by foliage, offering ideal cover for adult fish during low flows.

The salmonid nursery habitats recorded were well distributed amongst the year classes with mixed juvenile habitat and parr habitats contributing over 80% overall. Fry specific habitats (those favoured exclusively by 0+ fish) were less common (13%) and optimal salmonid spawning grounds covered 4% of the area surveyed (Figure 6-12).

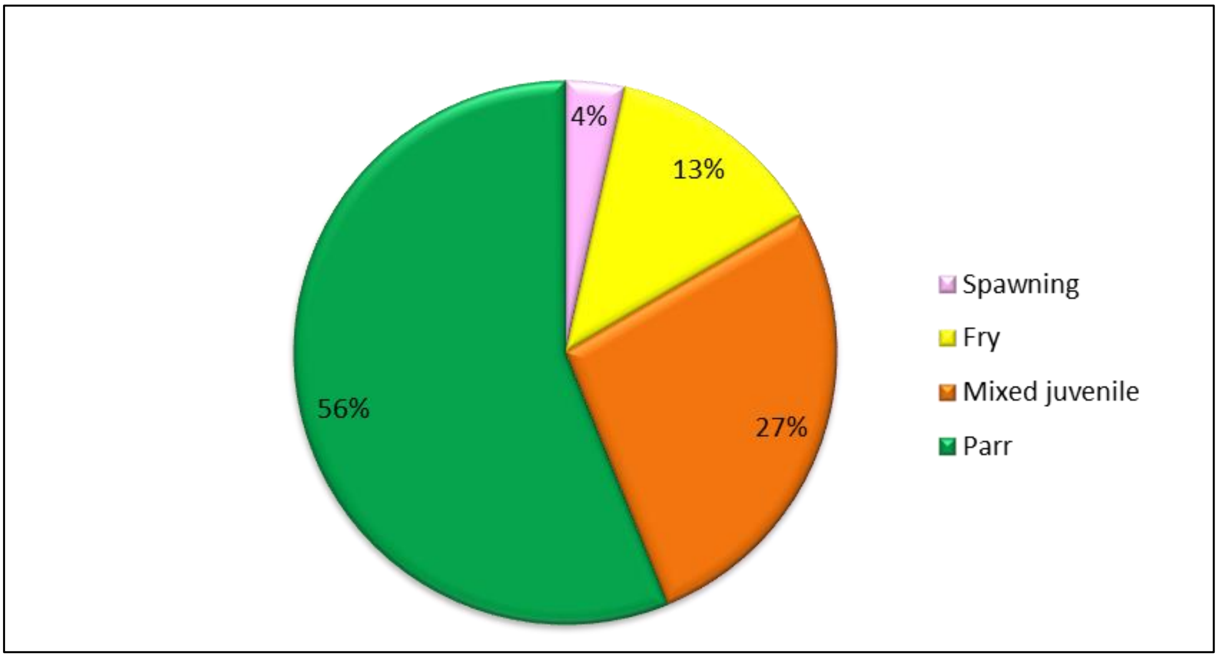


Figure 6-12 Salmonid nursery habitat breakdown by area contribution (%) on the River Lyd

The juxtaposition between spawning habitat and fry/parr habitat was optimal at many locations in the survey reach, offering uninhibited transition between nursery habitats for young fish. These nursery grounds were also well distributed throughout the river reach surveyed, supporting optimal conditions for seasonal recruitment over extended reaches of the River Lyd.

The physical condition of the salmonid nursery grounds on the River Lyd was generally good, however the capability of the gravels to support young fish was compromised in a number of locations by excessive interstitial sediment loads and accreted substrates (Figure 6-13). The condition of this substrate appeared to be notably poor where riparian land had been converted to agricultural pasture and arable land.

Figure 6-13 Salmonid nursery habitat denuded by accreted substrate

Excessive bankside erosion was recorded at numerous locations in the 3.5 km of the survey reach of the River Lyd. This erosion was exacerbated by cattle poaching where stock proofing and fencing (or watering points) were absent (Figure 6-14).

Figure 6-14 Bank erosion exacerbated by cattle poaching

Small patches of optimal juvenile lamprey habitat were reported throughout the survey reach of the River Lyd. This habitat type was generally observed in marginal areas where the river channel was unmodified and follows a meandering footprint within the flood plain (Figure 6-15).

Figure 6-15 Lamprey ammocoete habitat

Structures posing potential impediment to migratory fish were recorded at three locations on the River Lyd. The structures included an informal rock/boulder weir structure a short distance downstream of the Ambrosia abstraction (NGR SX3965484922), Lifton Park gauging station (NGR SX3887984245) – a compound weir comprising of a central concrete flume flanked by two broad crested side weirs - and a small impounding structure on the lower reaches of the River Lyd (NGR SX3799683972). Photographs and further information on each structure are provided in Section 5.5.2.3. Under the flow conditions of the survey none of the structures were deemed likely to pose a significant impediment to migration of salmonids, although there is potential for passability to decline under reduced flows. This is considered further in Section 6.3.4.

6.3.4 Impact assessment

The impact assessment focuses on two primary routes of impact for key species and life stages; potential impacts upon key migration activity (primarily for salmonids), and potential impacts on the quality and availability of habitat for sensitive life stages resident within freshwater. An overview of the assessment methodology used is provided below, followed by the results of the assessment.

6.3.4.1 Methodology

To quantify the magnitude of change in the quality and/or extent of habitat for key fish species, habitat modelling has been undertaken using the outputs from the hydraulic modelling (Section 5.5.3.1).

Habitat suitability values for individual species and life stages of fish have been determined based on the hydraulic modelling and sediment data collected across the two reaches described in Section 5.5, following a physical habitat simulation (PHABSIM) style approach (Dunbar *et al*. 2002). A suitability value ranging from 0 (entirely unsuitable) to 1 (entirely optimal) was assigned to the depth and velocity of individual cells from the hydraulic model of each reach using habitat suitability indices taken from peer reviewed literature. Similarly, the mapped substrate data within each reach (Figure 5-20) was used to assign a substrate suitability value for each model cell. The overall habitat suitability for individual model cells is then calculated as follows:

$$H_S = V_S \times D_S \times S_S$$

Where, H_s = overall habitat suitability;
V_s = velocity suitability;
D_s = Depth suitability; and
S_s = Substrate suitability

For example, a cell with a velocity suitability of 0.8, a depth suitability of 0.7 and a substrate suitability of 1.0 equates to an overall habitat suitability of 0.56.

Given that the area occupied by each model cell is known and remains constant (0.25 m^2), the overall area of suitable habitat for each species and life stage within the modelled reach can be quantified. The final results for each species/life stage have been expressed as a 'suitability weighted habitat area', calculated by multiplying the area of each cell (0.25 m^2) by the overall habitat suitability value. For example, a cell assigned a suitability value of 1.0 (optimal) would have a suitability weighted habitat area of 0.25 m^2, whilst a cell with a suitability value of 0.2 (sub-optimal) would receive a suitability weighted habitat area of 0.05 m^2. The suitability weighted area of all individual cells within the model extent are then summed to arrive at an overall suitability weighted habitat area for each species/life stage under both the baseline scenario and the drought permit scenario. Weighting the habitat area in this way accounts for the increased productivity and higher carrying capacity offered by optimal habitat, compared to sub-optimal habitat.

The species and life stages considered within the assessment are summarised in Table 6.13, alongside the sources used to derive the habitat suitability data.

Table 6.13 Fish species/life stages assessed through habitat modelling

Species	Life stage	Habitat suitability data source
Atlantic salmon (*Salmo salar*)	**Spawning**	**Louhi *et al*. (2008)**
	Juvenile	**Heggenes (1996)**
Brown trout (*Salmo trutta*)	**Spawning**	**Louhi *et al*. (2008)**
	Juvenile	**Heggenes (1996)**
	Adult	**Armstrong *et al*. (2003)**

Whilst optimal juvenile lamprey (ammocoete) habitat was observed across the wider reach of the River Lyd targeted by the walkover survey, there was no suitable habitat observed within the two modelled reaches (substrate within the two reaches comprised of coarse gravel, cobble and bedrock, with an absence of areas or marginal fine sediment). Consequently, habitat modelling has not been undertaken for juvenile lamprey. Instead, potential impacts across the wider reach are discussed in the context of channel marginal exposure predicted by the hydraulic modelling (Section 5.5.3.1). Additionally, impacts on other species/life stages have been assessed by expert judgement and drawing upon the findings of similar life stages presented in Table 6.13. For example, given the established similarities between spawning habitat for lamprey and salmonids, the modelling outputs for salmon and trout spawning have been used to inform potential impacts on lamprey.

6.3.4.2 Habitat assessment

Suitability weighted habitat areas for the two reaches under the baseline and drought permit scenarios are presented in Table 6.14. Results for individual species/life stages are discussed in turn below.

Table 6.14 Suitability weighted habitat area (m^2) for individual species and life stages

Species	Life stage	Upstream reach			Downstream reach		
		Baseline	Drought permit	Change	Baseline	Drought permit	Change
Salmon	Spawning	764	674	-12%	1034	861	-17%
	Juvenile	855	884	+4%	211	200	-5%
Trout	Spawning	805	795	-1%	1181	1123	-5%
	Juvenile	470	565	+20%	136	154	+13%
	Adult	705	656	-7%	948	884	-7%

Salmon spawning

Habitat modelling outputs for salmon spawning in the two modelled reaches under the baseline and drought permit scenario are presented in Figure 6-16. Under baseline conditions there is optimal spawning habitat distributed throughout the upstream reach, including a small area immediately downstream of the SWW abstraction location. The majority of optimal habitat is located in the centre of the reach in fairly distinct clusters, interspersed with areas of deeper pool/glide habitat which are deemed unsuitable due to excessive depth and low velocity. Towards the downstream end of the reach the impoundment associated with the small boulder weir downstream of the Ambrosia abstraction results in an extensive area of unsuitable habitat under baseline conditions. Known historical locations of salmonid spawning redds collated by the Arundell Arms have been overlaid on the modelling outputs (Figure 6-16). These correlate well with predicted areas of optimal spawning habitat, providing a degree of validation for the model outputs.

Under the proposed drought permit scenario a minor reduction in spawning habitat is predicted in the upstream reach, and the suitability weighted habitat area is predicted to decrease from 762 m^2 under baseline conditions to 674 m^2 under the drought permit scenario, equivalent to a decline of 12 %. The proposed timing of the drought permit (April – June) means that it is not likely to coincide with salmon spawning activity, and there should therefore be minimal risk to exposure of redds. However, it is important that areas of suitable salmon spawning habitat remain wetted to ensure egg viability and alevin survival (Becker et al. 1985), with sufficient flow to prevent excessive settlement of find sediments which may compromise the exchange of oxygen and waste metabolites between eggs/alevins and the surrounding water (Julien and Bergeron, 2006). All areas of spawning habitat that are wetted under baseline conditions are predicted to remain wetted under the drought permit scenario. Habitat in the vicinity of known historical locations of salmonid spawning redds also remains of suitably high quality for salmon during the modelled drought permit scenario.

Optimal salmon spawning habitat is present throughout the downstream reach under the baseline scenario, focused primarily towards the upstream and downstream extents. There is an area of pool/glide flow deemed to be entirely unsuitable for spawning through the centre of the reach, driven by excessive water depth. Under the drought permit scenario the overall extent of optimal habitat is predicted to remain largely unchanged, albeit with some spatial shifts in the location of habitat. The fragmented areas of optimal spawning habitat towards the upstream end of the reach under baseline are predicted to remain fragmented under the drought permit scenario, driven by predicted reductions in water velocity. Overall, the suitability weighted habitat area is predicted to change from 1034 m^2 under the baseline scenario to 861 m^2 during the drought permit scenario, equivalent to a reduction of 17 %.

It should be noted that the modelled scenario represents a worst-case scenario for the point at which the maximum abstraction is achieved and thus the point at which the percentage reduction in flow on the River Lyd is greatest. Historical hydrographs for the River Lyd during a wet, dry and average year indicate that river flows are typically elevated above this level for significant periods between April and June. During these periods the reduction in flow as a proportion of total river flow would be lower than the modelled drought permit scenario. If flows remain subdued throughout this period during operation of the abstraction, a negligible impact magnitude is anticipated for salmon spawning based on the results of the habitat modelling, equating to a minor impact significance overall.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted very low to negligible changes in water quality parameters. Therefore, impacts on salmon spawning habitat via these pathways are predicted to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Trout spawning

Habitat modelling outputs for trout spawning in the two modelled reaches under the baseline and drought permit scenarios are presented in Figure 6-17. Under baseline conditions the quality and extent of spawning habitat is largely comparable to that modelled for salmon, although there is a greater proportion of spawning habitat present within marginal areas, reflective of a tendency for trout to spawn closer to channel margins (Carling and McCahon, 1987). Under the drought permit scenario, a moderate increase in the area of available trout spawning habitat is predicted to occur, with additional areas of optimal habitat identified compared to baseline conditions. The proposed timing of the drought permit (April – June) means that there is minimal risk to trout spawning activity, although, similarly to salmon, any impacts that may lead to exposure of redds, reduced survival of eggs and / or alevins, and reductions in localised habitat quality, would merit further consideration. However, as the overall suitability weighted area in the upstream reach is predicted to change from 805 m^2 under baseline to 795 m^2 during the drought permit scenario – a negligible decrease in suitability of 1 %, risk of any impacts on trout spawning habitat or survival of egg / alevin life stages is considered to be negligible. Habitat in the vicinity of known historical locations of salmonid spawning redds also remains of suitably high quality for trout spawning during the modelled drought permit scenario.

Through the downstream reach, optimal trout spawning habitat is again present, in similar quantities but in subtly different locations compared to salmon spawning habitat. In common with the upstream reach, there is a shift towards areas of suitable habitat being located towards more marginal channel areas. A negligible change in suitable trout spawning habitat is anticipated under the drought permit scenario compared to baseline. Areas of habitat towards the upstream end of the reach increase in suitability due to reductions in water velocity associated with the abstraction. The overall suitability weighted area is predicted to change from 1181 m^2 under baseline to 1123 m^2 under the drought permit scenario, equivalent to a minor decrease in suitability of 5 %. Similarly to the upstream reach, risk of any impacts on trout spawning habitat or survival of egg / alevin life stages is considered to be negligible.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted very low to negligible changes in water quality parameters. Therefore, impacts on trout spawning habitat via these pathways are predicted to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Juvenile salmon

Habitat modelling outputs for juvenile salmon in the two modelled reaches under the baseline and drought permit scenario are presented in Figure 6-18. Optimal juvenile habitat is widespread throughout the upstream reach under baseline conditions, reflecting the high densities of juvenile salmon in this reach during historical Environment Agency monitoring (Table 6.7, Table 6.8). The distribution and extent of juvenile habitat under the baseline scenario is broadly comparable to the modelled drought permit scenario. Under the drought permit scenario the predicted change in the quality and extent of habitat in the upstream reach is negligible, notwithstanding some minor shifts in the distribution of optimal habitat. The suitability weighted habitat area is predicted to increase from 855 m^2 under baseline to 884 m^2 under the drought permit scenario, equivalent to a negligible increase of 4 %.

There is a paucity of suitable juvenile salmon habitat within the downstream reach, driven by increased water depth and reduced flow velocity throughout the reach. During the drought permit scenario, suitability weighted habitat area is predicted to decrease from 211 m^2 at baseline to 200 m^2 under the drought permit scenario, equivalent to a negligible decrease of 5 %.

It should be noted that although the modelling predicts an increase in availability of suitable habitat within the downstream reach, the results are unlikely to translate through to an increase in overall juvenile recruitment given that juvenile salmon densities from recent Environment Agency surveys are typically below carrying capacity and the point at which density dependent mortality would be expected to occur (see Table 6.7 and Table 6.8). However, the results serve to demonstrate that adverse impacts on juvenile salmon life stages during operation of the abstraction are unlikely to occur.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted very low to negligible changes in water quality parameters and impacts on macroinvertebrate populations were deemed to be negligible (Section 6.2.4.2).

Therefore, impacts on juvenile salmon habitat via the predicted changes in physical and ecological pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Juvenile trout

Habitat modelling outputs for juvenile trout in the two modelled reaches under the baseline and drought permit scenarios are presented in Figure 6-19**Error! Reference source not found.**. Optimal juvenile trout habitat is relatively restricted in the upstream reach under baseline conditions, being limited to a few discrete areas. The majority of the reach is deemed to comprise either sub-optimal or entirely unsuitable habitat, primarily attributable to velocities exceeding the preference range for the species, with trout typically occupying areas of lower velocity water compared to salmon (Jensen and Johnsen, 2002). Such a finding is reaffirmed by historical Agency fish survey data, which demonstrate consistently low densities of juvenile trout throughout monitoring sites on the Lower River Lyd. Similarly to juvenile salmon, the majority of the downstream reach is also considered to be unsuitable for juvenile trout. The suitability weighted habitat area in the upstream reach is predicted to increase from 470 m^2 at baseline to 565 m^2 under the drought permit scenario, equivalent to an increase of 20 %, whilst the suitability weighted habitat area in the downstream reach is predicted to increase from 136 m^2 at baseline to 154 m^2 under the drought permit scenario, equivalent to an increase of 13 %.

In common with findings for other life stages, it should be noted that an increase in the overall suitability of habitat for juvenile trout may not confer direct benefits to recruitment given that densities are historically well below the carrying capacity at which point density dependent mortality would begin to apply. However, the findings do demonstrate that adverse impacts are unlikely to occur.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted very low to negligible changes in water quality parameters and impacts on macroinvertebrate populations were deemed to be negligible (Section 6.2.4.2).

Therefore, impacts on juvenile trout habitat via the predicted changes in physical and ecological pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given June to April period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Adult trout

Habitat modelling outputs for Adult trout in the two modelled reaches under the baseline and drought permit scenarios are presented in Figure 6-20. Optimal habitat is present throughout both the upstream and downstream reach under baseline conditions, coinciding with areas of deeper pool and glide flow. The suitability weighted habitat area in the upstream reach is predicted to decrease from 705 m^2 at baseline to 656 m^2 under the drought permit scenario, equivalent to a decrease of 7 %, whilst the suitability weighted habitat area in the downstream reach is predicted to decrease from 948 m^2 at baseline to 884 m^2 under the drought permit scenario, equivalent to a decrease of 7 %. The minor magnitude of impact reflects the reduced sensitivity of adult habitat to changes in flow, with the character of relatively deep, slow flowing areas of river channel remaining largely unchanged by the abstraction.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted negligible changes in water quality parameters and impacts on macroinvertebrate populations were deemed to be negligible (Section 6.2.4.2).

Therefore, impacts on adult trout habitat via the predicted changes in physical and ecological pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

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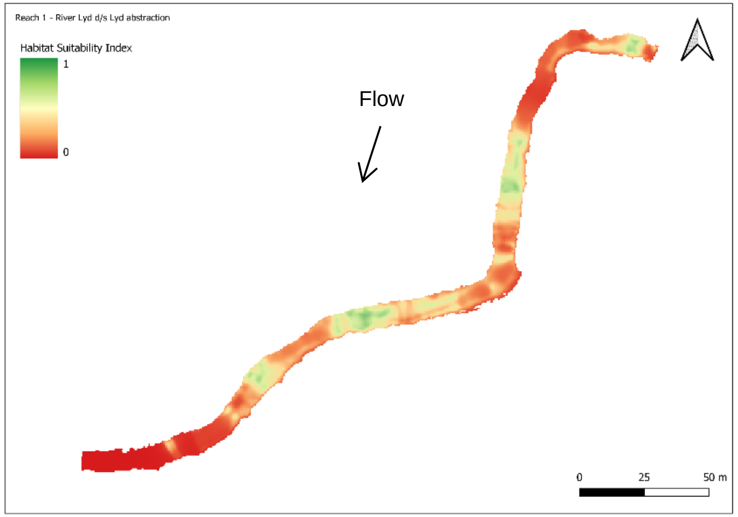
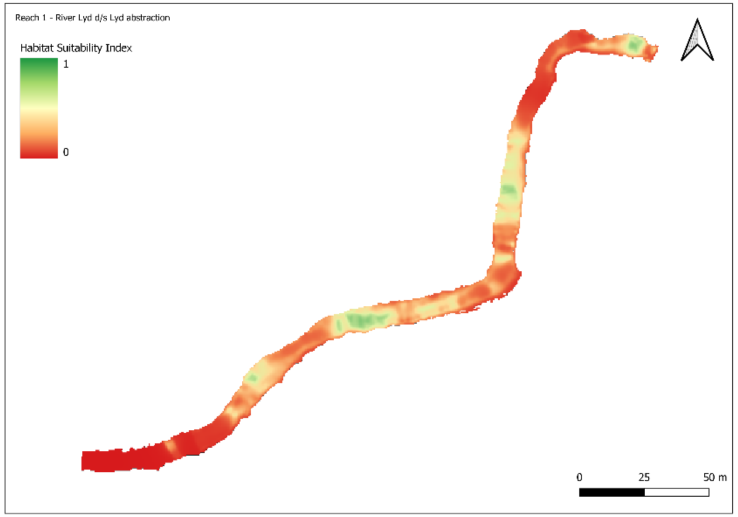
<tr><th>Baseline</th><th>Drought permit</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">River Lyd d/s Lifton Park</th></tr>
<tr><th>Baseline</th><th>Drought permit</th></tr>
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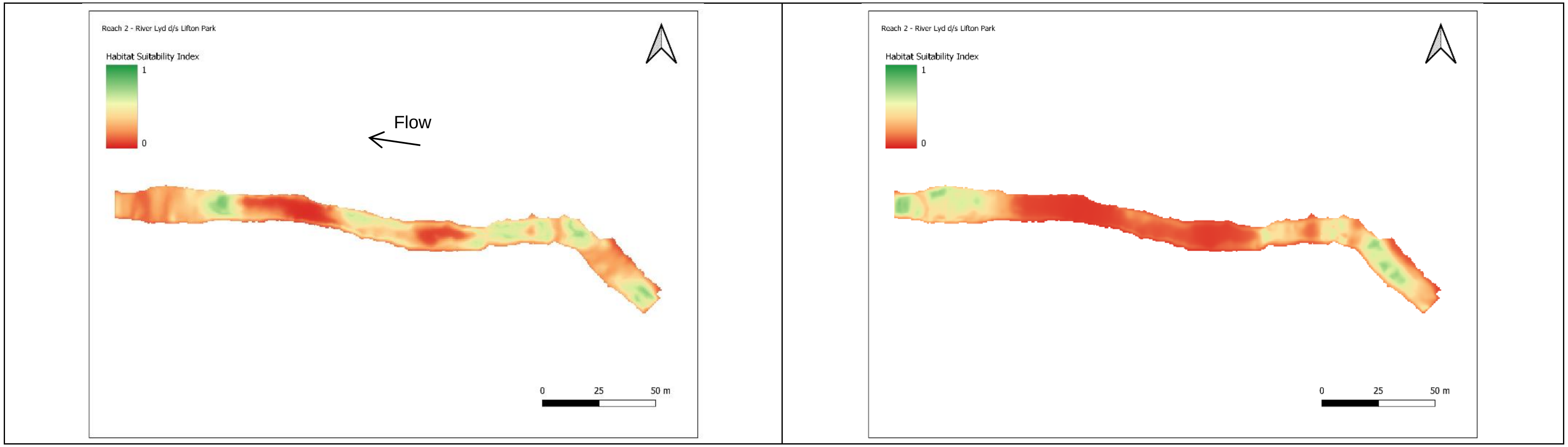
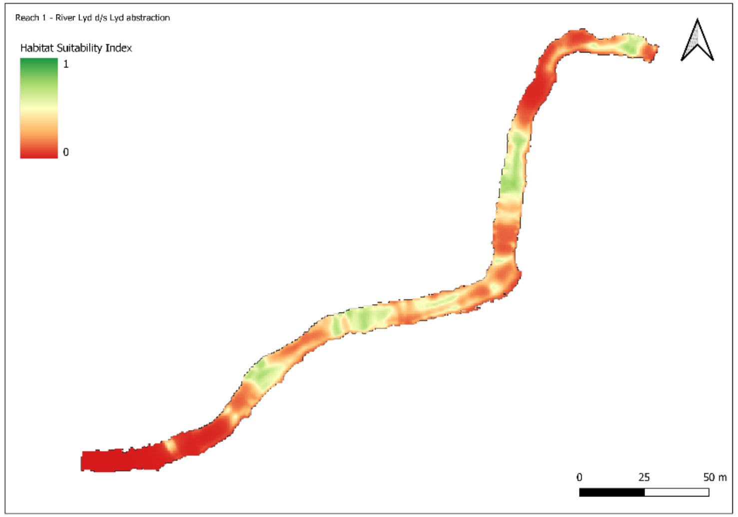


Figure 6-16 Habitat modelling outputs for salmon spawning under baseline and drought permit scenarios on the two modelled reaches. Approximate locations of historical redds identified by the Arundell Arms in the upstream reach are shown for context, denoted by purple circles

River Lyd d/s abstraction	
Baseline	**Drought permit**
	
River Lyd d/s Lifton Park	
Baseline	**Drought permit**

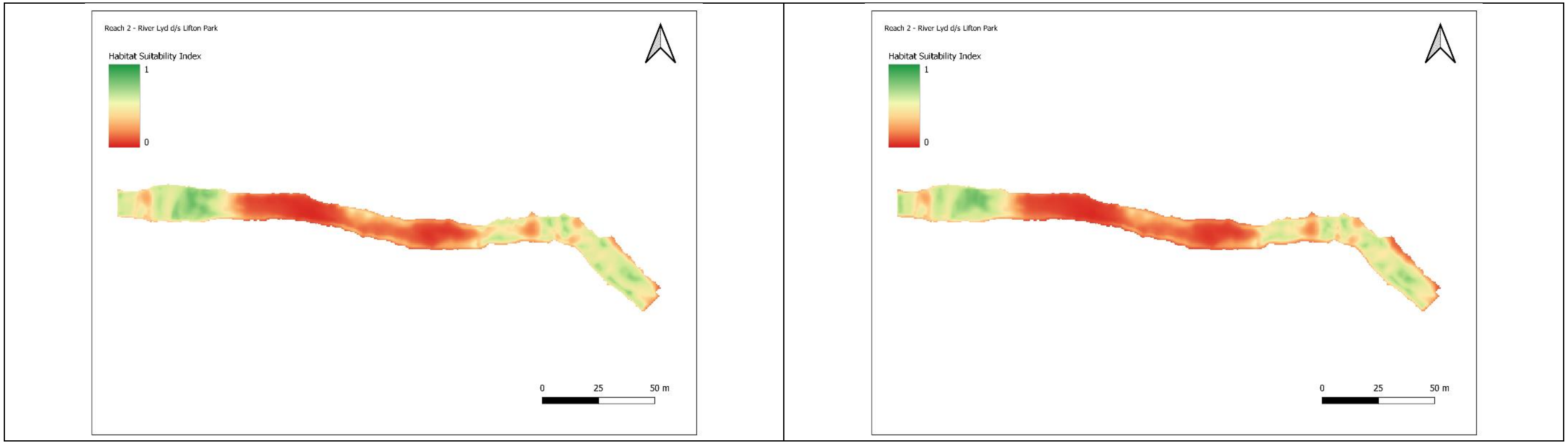
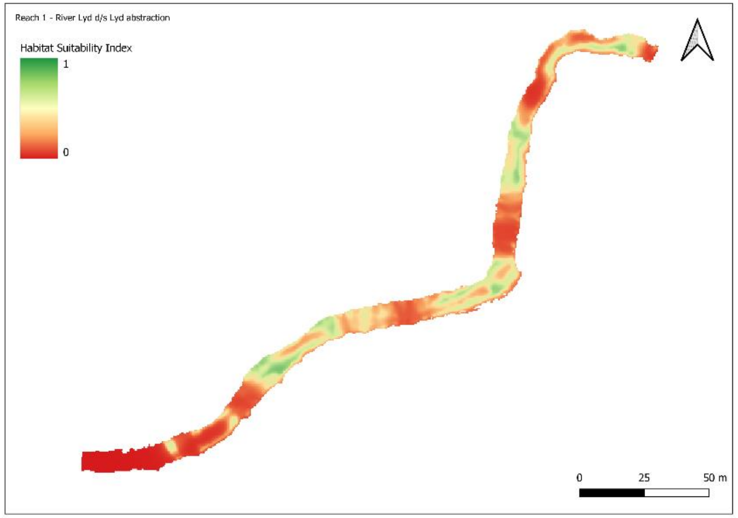
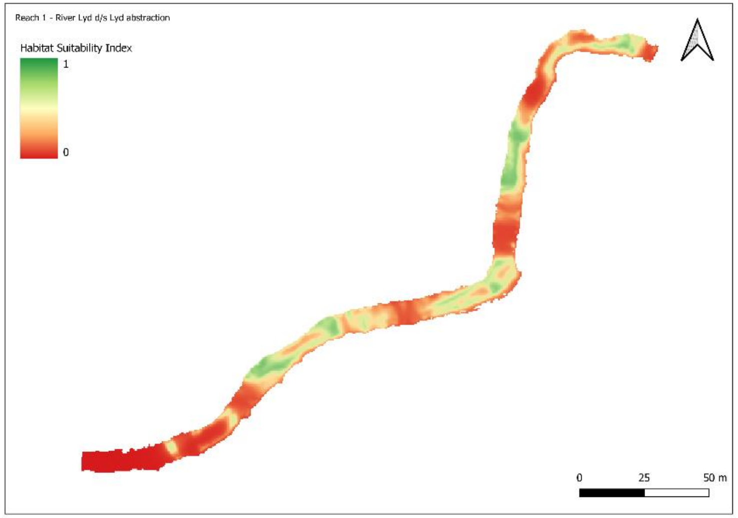


Figure 6-17 Habitat modelling outputs for trout spawning under baseline and drought permit scenarios on the two modelled reaches. Approximate locations of historical redds identified by the Arundell Arms in the upstream reach are shown for context, denoted by purple circle

River Lyd d/s abstraction	
Baseline	**Drought permit**
	
River Lyd d/s Lifton Park	
Baseline	**Drought permit**

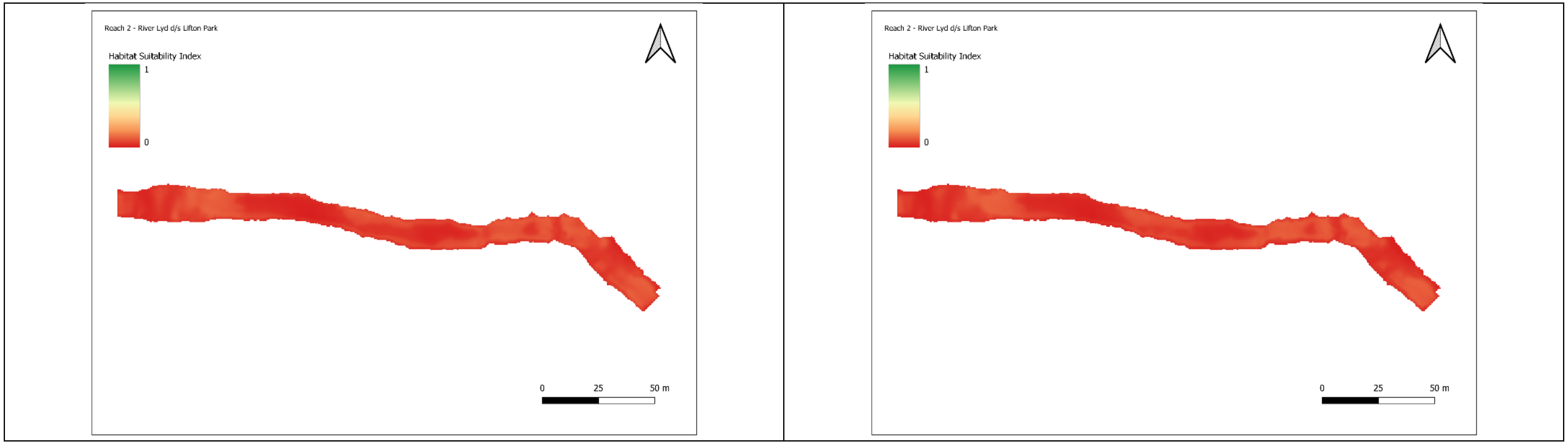
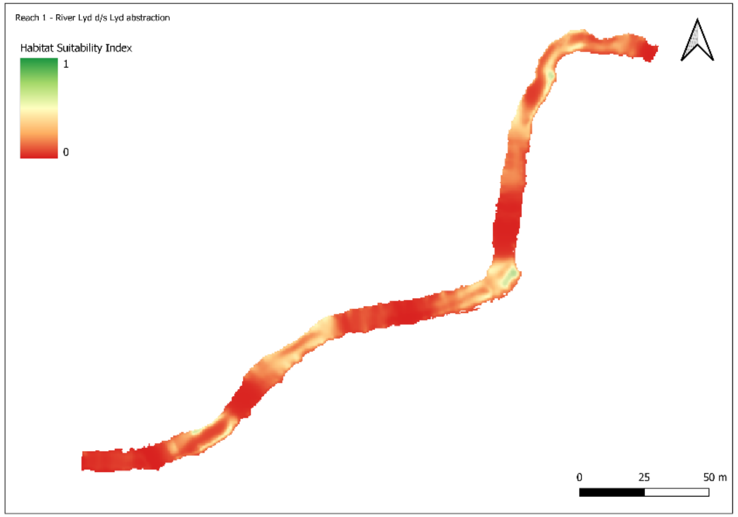
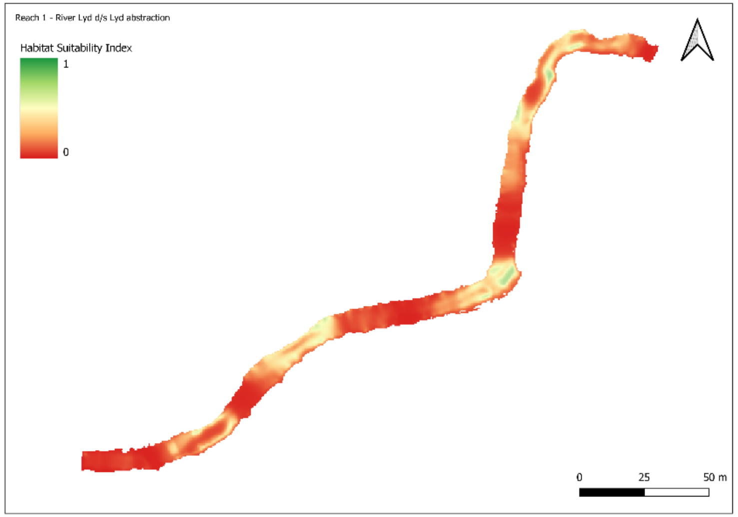


Figure 6-18 Habitat modelling outputs for juvenile salmon under baseline and Drought permit scenarios on the two modelled reaches

River Lyd d/s abstraction	
Baseline	**Drought permit**
	
River Lyd d/s Lifton Park	
Baseline	**Drought permit**

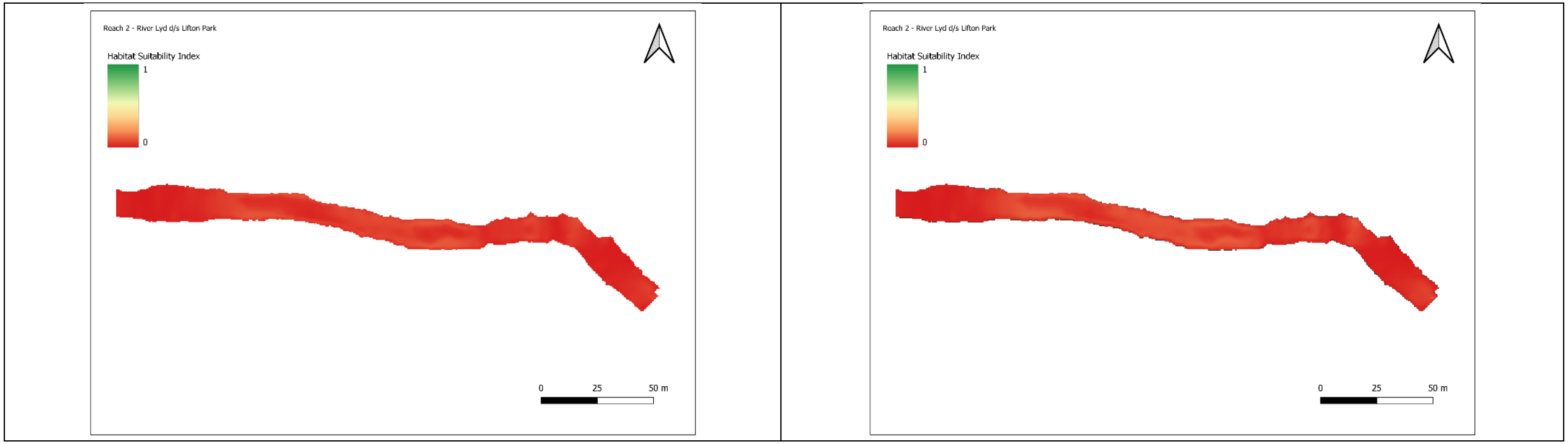
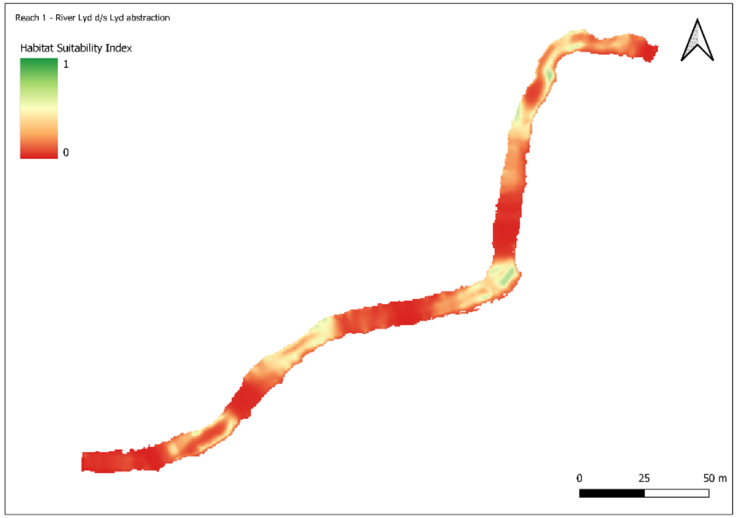
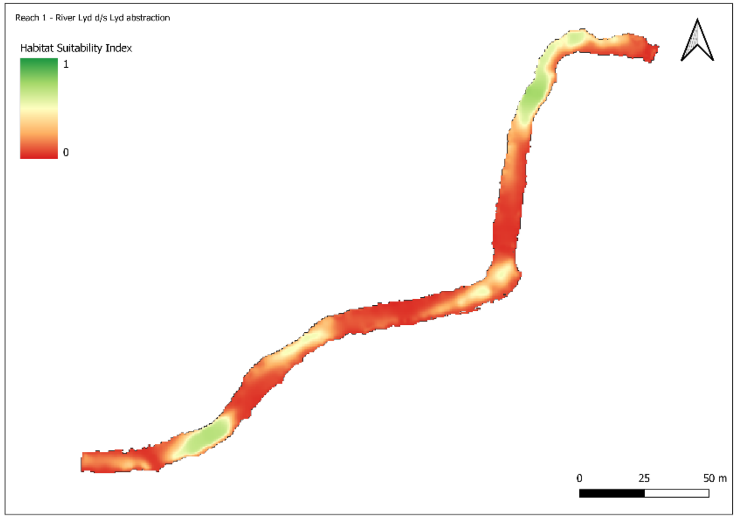


Figure 6-19 Habitat modelling outputs for juvenile trout under baseline and drought permit scenarios on the two modelled reaches

River Lyd d/s abstraction	
Baseline	**Drought permit**
	
River Lyd d/s Lifton Park	
Baseline	**Drought permit**

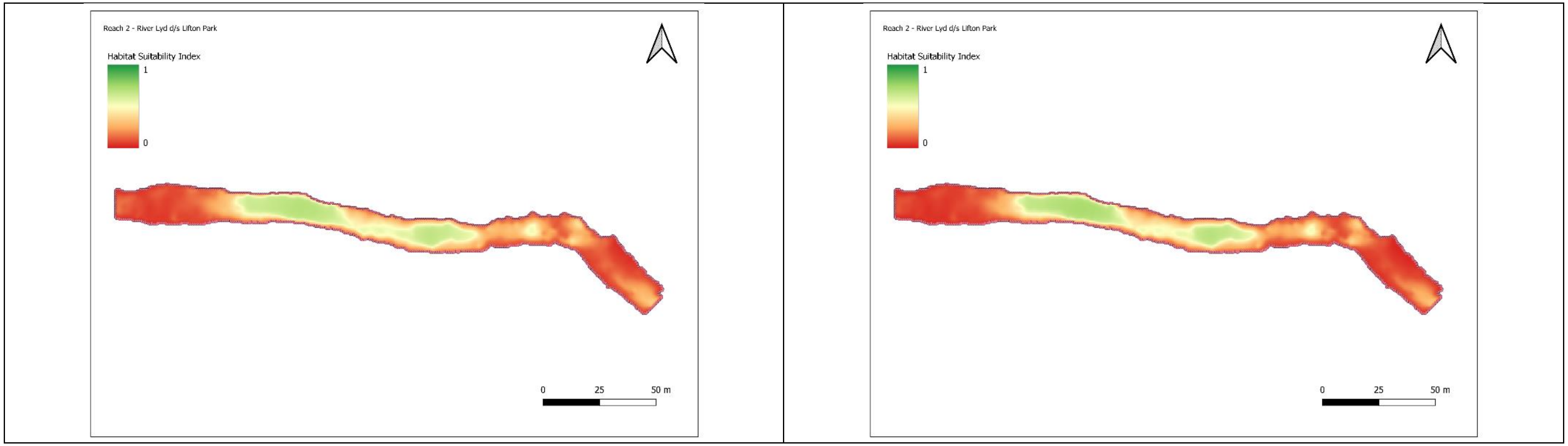


Figure 6-20 Habitat modelling outputs for adult trout under baseline and drought permit scenarios on the two modelled reaches

Brook lamprey

Consideration of potential impacts on brook lamprey relate to changes in the quality or extent of spawning habitat and juvenile habitat. As outlined in Section 6.3.4.1, there are similarities between habitat utilised for spawning in salmonid and lamprey species. The results of the modelling for salmon and trout spawning are therefore considered an appropriate proxy for this species. The results of the spawning modelling ranged from a decline of 17 % (salmon spawning in the downstream reach) to decline of 1 % (trout spawning in the upstream reach). Changes in spawning habitat availability for brook lampreys under the drought permit scenario are therefore likely to fall somewhere between this range. It should, however, be noted that these figures represent a worst-case scenario for the point where maximum abstraction is reached, and thus the point at which reduction in river flow is greatest. Furthermore, given the April to June window of implementation for the proposed drought permit, it is considered unlikely that any impacts on brook lamprey spawning would be observed.

No optimal juvenile lamprey habitat is present through the two modelled extents under baseline conditions due to the coarse substrate composition throughout both reaches. However, optimal juvenile habitat was observed during the walkover survey elsewhere on the River Lyd and thus there is the potential for impacts during operation of the abstraction.

The hydraulic modelling results indicate that there would be limited exposure of marginal habitat in both reaches under the drought permit scenario (Figure 5-29 and Figure 5-32), and that any marginal exposure would be within the range of natural variation during April to June. The extent of marginal exposure would also decline at higher flows when the Lyd abstraction represents a smaller proportion of total river flow. Therefore, any impacts are anticipated to extend over a small spatial scale for a short-term duration within a given year, equivalent to a negligible magnitude of impact.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted negligible changes in water quality parameters.

Therefore, impacts on brook lamprey spawning and juvenile habitat via the predicted changes in physical pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Bullheads

The habitat used by bullheads during spawning is not markedly different to that which would be expected to be utilised for salmonid spawning. The salmonid spawning assessment predicts changes in spawning suitability under the drought permit scenario of -17 % to -1 % compared to baseline. It should, however, be noted that these figures represent a worst-case scenario for the point where maximum abstraction is reached, and thus the point at which reduction in river flow is greatest. Furthermore, the proposed April to June period of implementation of the drought permit should not coincide with the February to March bullhead spawning window, and therefore impacts on spawning habitat are unlikely to occur. Any impacts on habitat for bullhead are therefore likely to manifest over a small spatial scale and extend for a short duration only within a given year, equating to a negligible magnitude of impact and a negligible impact significance overall.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted negligible changes in water quality parameters and impacts on macroinvertebrate populations were also deemed to be negligible (Section 6.2.4.2).

Therefore, impacts on bullhead spawning and juvenile habitat via the predicted changes in physical and ecological pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening seven-month period, it is unlikely that any cumulative effects would occur year-to-year.

Eels

Eels are relatively flexible in terms of their habitat requirements in freshwater, occupying a wide range of habitats from productive deep lowland rivers through to steeper upland streams. Evidence suggests that juvenile eel tend to utilise shallower habitats characterised by a greater proportion of fine sediments, with a trend towards colonisation of deeper habitats with coarser substrate (cobble and boulder) with increasing age and body size (Degerman *et al*. 2019).

Based on the relatively minor predicted changes in hydraulic parameters in both modelled reaches under the drought permit scenario compared to baseline, in addition to the plasticity of habitat preferences for eel, it is considered that there would be a negligible impact on this species.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted negligible changes in water quality parameters and impacts on macroinvertebrate populations were deemed to be negligible (Section 6.2.4.2).

Therefore, impacts on eel habitat via the predicted changes in physical and ecological pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given June to April period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Grayling

Grayling generally display a tolerance for a wider range of environmental conditions compared to other salmonids (Ingram *et al*, 2000), though they may display increased sensitivity to pollution and increasing water temperatures. Grayling also display slightly different spawning habitat requirements to other salmonids, choosing to site redds towards the upstream end of pools, with eggs buried in shallower substrate (Ingram *et al*, 2000). However, as hydraulic modelling indicates that reductions in water depth are likely to be minimal across both modelled reaches, and reductions in salmonid spawning habitat range from -17% to -1%, impacts on grayling spawning are likely to be minor during the April to June Drought permit period.

Both juvenile and adult life stages of grayling may be present year-round, and are likely to be comparably affected by the proposed drought permit to salmon and trout. Changes in suitable juvenile and adult salmonid habitat during the April to June drought permit window range from a 7% decrease to a 20% increase, and impacts on juvenile and adult grayling are therefore likely to fall within this range. It should, however, be noted that these figures represent a worst-case scenario for the point where maximum abstraction is reached, and thus the point at which reduction in river flow is greatest. Impacts on both juvenile and adult grayling are, therefore, anticipated to be minor during the proposed drought permit.

The geomorphology assessment (Section 5.5.3.2) identified a low risk of fine sediment deposition under the drought permit scenario, with any additional deposition expected to be constrained to the channel margins. Similarly, the water quality assessment (Section 5.6.3) predicted negligible changes in water quality parameters and impacts on macroinvertebrate populations were deemed to be negligible (Section 6.2.4.2).

Therefore, impacts on grayling habitat via the predicted changes in physical and ecological pathways are concluded to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given June to April period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

6.3.4.3 Migration assessment

Upstream migration – adult salmonids

The migration of adult salmonids in rivers can be strongly influenced by river flow, although the relationship is highly variable, site- and season-specific and confounded by co-related factors (Banks, 1969; Thorstad *et al.* 2008; Milner *et al.* 2012). Sensitivity to flow changes appears to be lowest in large rivers with deep unobstructed passage and greatest in small tributaries or at any partial barriers where passage is flow-limited (Thorstad *et al.* 2011). Moreover, salmonids are not believed to respond directly to flow (discharge volume) *per se*, but to its hydraulic attributes such as velocity, depth, shear, turbulence, or to variables associated with flow such as temperature, chemical cues, turbidity, and noise.

The volume of flow in isolation does not capture all the features of the hydrograph relevant to fish migration and spawning behaviour. Thus, additional metrics (ecological flow components, EFC) are used that describe the hydrograph in ways more relevant to fish, such as spate size, frequency, flow variability and antecedent flows (e.g. Olden and Poff, 2003; Tetzlaff *et al.* 2005, 2008). Finer time scale changes are also significant; salmonids tend to move at night except in spates or turbid water and can respond to very short term (< one hour) flow changes. Flow response during salmonid migration can vary markedly depending on the location of individual fish between the sea and spawning grounds. Three broad behavioural phases cover much of this range (Milner *et al.* 2012), as follows:

- <u>Phase 1</u>: fish move from the estuary to the river.
- <u>Phase 2:</u> the longest and most variable phase in which fish may move almost continuously upstream, holding for short periods or long periods (days or weeks) at key holding locations.

- Phase 3: when mature fish make rapid movement upstream at or just before spawning time onto main stem spawning areas or into tributaries, usually in response to spates, and remain there for the short duration (hours or days) when spawning takes place, before dropping back downstream.

Salmon and sea trout migrating through the River Lyd are most likely to be in Phase 2 and 3 of migration, depending upon factors such as prevailing river flow and seasonality. Details of rod catches local to the DP impact zone were not available to this study, but if they are suitable, their analysis would be helpful to establish timing of salmon and sea trout presence. Solomon et al (1991) found that tracked salmon arrived at Lifton from the end of April to the end of November during 1988. The eight fish reported were uniformly spread over that period, although they could not be retrospectively allocated to the time and location of tagging in the lower river. The dominant migration window for salmon and to a lesser extent, sea trout, is likely to be later in the year than lower in the Tamar system, probably in the period of August – December, prior to, and encompassing, the spawning period and pre-spawning migrations. Nevertheless, as Solomon's study showed some fish will be present from end of April, with number accumulating through the season depending on seasonal flow patterns, but as argued in Section 6.3.1.1, the proportion of the Lyd run present in the impact zone during the April 10th – June 10th Drought Permit window is anticipated to be very small.

A number of tracking studies have shown the response of salmon to flow variation patterns. The study conducted by Solomon *et al*. (1999) involved the tracking of 1,830 adult salmon into and through six rivers in the southwest of England over a 10-year period, including specific consideration of the River Tamar and River Lyd.

Across a 10-year period, a total of 330 fish were captured and tagged in the Tamar Estuary, supplemented by a further 316 fish that were trapped and tagged at Gunnislake Weir. A series of automatic listening stations (ALS) were positioned along the River Tamar and tributaries to record the movement of salmon through the catchment. One of the two most upstream ALS was located on the River Lyd at Lifton Park, a short distance from the downstream reach subject to hydraulic and habitat modelling in this assessment.

Solomon *et al*. (1999) established that a minimum flow threshold (expressed as a percentage of local Q95 flow) was required to trigger movement of fish from the lower reaches of the Tamar during the summer and autumn months, with the relative flow elevation increasing with distance from the tidal limit. The threshold on the main River Tamar in proximity to Gunnislake weir was equivalent to ca. 130 % of Q95, rising to 230 – 270 % of local Q95 with increasing distance up the river towards Lamerhooe and Leigh Wood. Upon entry into the River Lyd, a flow threshold of 539 % of the local Q95 was required at Lifton Park, representing a sizeable increase in the migratory flow threshold (Figure 6-21), but it should be noted that the number of tracked salmon in the Lyd was small, introducing more uncertainty into the threshold estimate.

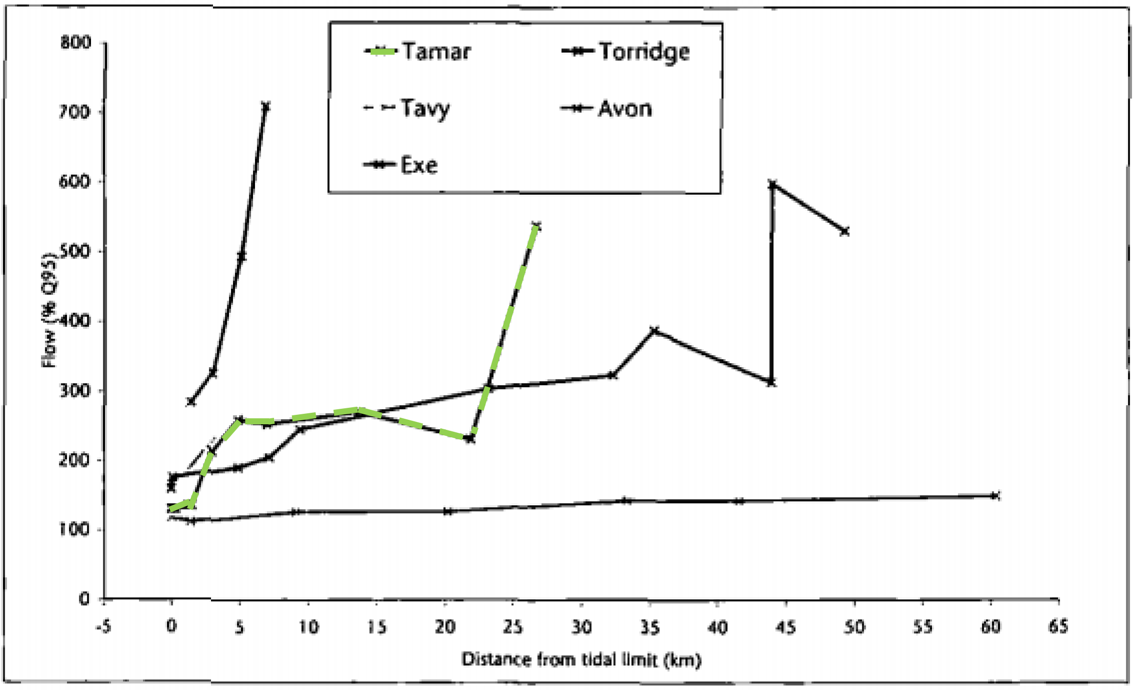


Figure 6-21 Data from Solomon *et al*. (1999), showing the relative increase in flow (as a percentage of Q95) required to stimulate upstream migration of adult salmon through the studied rivers. The results from the River Tamar and Lyd are highlighted for clarity. The Hampshire Avon (bottom line) displays a differing trend, attributed to a considerably higher baseflow than the other rivers

Applying this observed threshold (539 % of local Q95) to the River Lyd equates to a migratory flow threshold of 293.4 Ml/d at Lifton Park gauging station that would be necessary to stimulate upstream migration, equivalent to approximately Q44.

Solomon's data in the Southwest rivers were used to derive generic migration thresholds for salmon in upper river sections of surface water fed rivers (Sniffer 2012; TAG 2013). These were expressed as minimum and maximum values of thresholds, likely to encompass the true value (Table 6.15).

Table 6.15 Derivation of salmon migration flow thresholds for upper sections of surface water fed rivers for Lifton (Sniffer, 2012). Two options are shown based on local Qn95 and ADF (Qnmean)

			Multiplier for "upper" rivers (Sniffer, 2012)			
Location	**Qn95**	**Qnmean (ADF)**	**UKTAG.Q95 min**	**UKTAG.Q95 max**	**UKTAG.ADF min**	**UKTAG.ADF max**
Lifton GS	57.2	448.5	2.5	6	0.26	0.63
Estimated migration threshold flow (Ml/d)			143.0	343.2	116.6	282.6

Following UKTAG, two options for the flow derivation are available based on (i) local Q95 and (ii) ADF (both are shown in Table 6.15, for completeness). Those derived from the Q95 (min = 143 Ml/d and max = 343.2 Ml/d) are used here, to be directly comparable with the observed value of 293.4 Ml/d, giving three threshold estimates. Arguably, the 293.4Ml/d value is the most directly appropriate, because it was local to Lifton, but the uncertainty due to the small sample size of tagged fish warrants reference to the UKTAG values, giving a range of assessment.

Applying these to the historical hydrograph for Lifton GS (47006) for the period 1/1/1991 to 31/12/2020 allowed calculation of the mean number of days per month that the thresholds were exceeded (Figure 6.23).

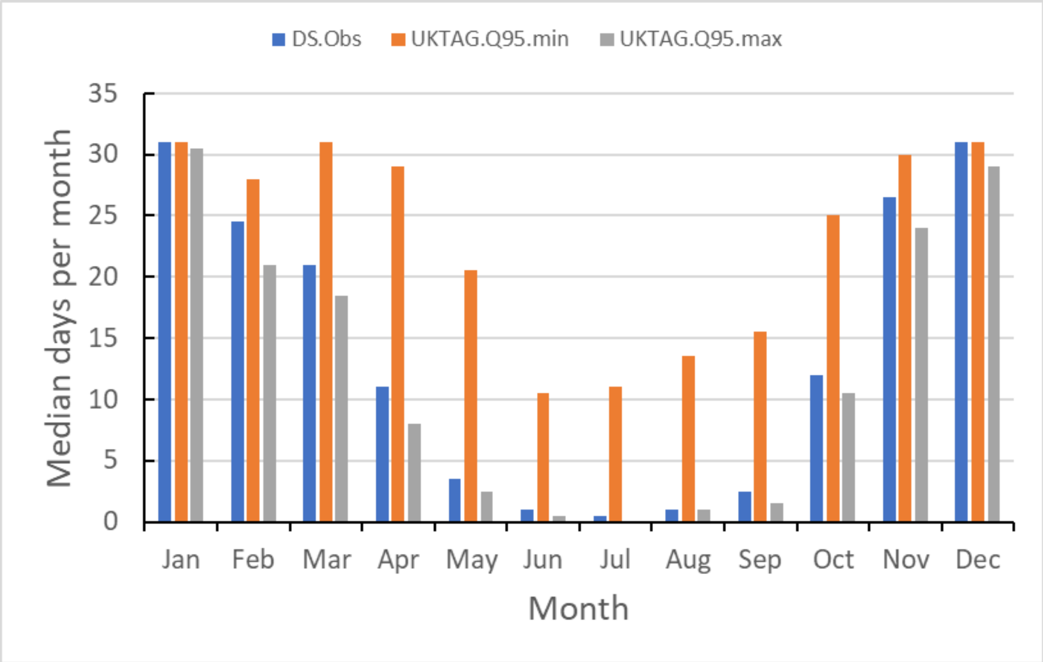


Figure 6-22 Monthly exceedance of three salmon migration flow thresholds, given as medians of 30 years, 1991 to 2020

Considering the observed Lifton threshold (293.4Ml/d), exceedance was lowest in July, with the threshold being exceeded for 0.5 days compared with the min-max range of 11 to 0 days for the UKTAG thresholds. The low incidence of threshold flows in summer months is consistent with low abundance of adult fish at that time, reflecting time to migrate upstream and the potential for flow constraints to apply. As Solomon *et al* (1999) note, migration thresholds increase as a proportion of the local flow-duration curve moving upstream.

Following the principle of using time (in days) exceedance of flow thresholds to index the influence of flow on migration potential, the DP impact on salmon migration was approximated by estimating exceedance under baseline (historic, actual) flows and with the DP in place for April 10th to June 10th (Table 6.16). This demonstrated that across the three thresholds used, the time lost under drought permit operation ranged from 0 to 1.2 days, which would have a negligible effect on salmon migration.

Table 6.16 Estimation of exceedance in days of three salmon migration thresholds using FDC for April 10th to June 10th for baseline flows and with the drought permit operational

Threshold	Flow (Ml/d)	Baseline		DP in place		Diff. days
		%ile	Days exceeded	%ile	Days exceeded	
DS.Obs	293.4	46	28.5	45	27.9	0.6
UKTAG.Q95 min	144	71	44.0	69	42.8	1.2
UKTAG.Q05 max	343.2	41	25.4	41	25.4	0.0

Downstream migration – smolts

Smolt emigration depends on two stages: (a) priming, in which prior growth experience, photoperiod and temperature raise the disposition to smoltify; and (b) triggering by which water temperature and flow increase stimulate behavioural changes that cause the downstream active migration (e.g. McCormick *et al.* 1998). However, the relative importance of the flow effect is not clear because spring flows tend to be correlated with water temperature, directional changes in photoperiod and other related factors such as turbidity, or with conditions that precede flow increase, e.g. rainfall (Carlsen *et al*. 2004). Several studies have reported a more important role of temperature than flow (e.g. Lefèvre *et al.* 2013). The relative importance of these factors appears to vary between locations; but as the eventual desired outcome appears to be for the smolts to reach the sea at a time of optimum marine productivity (Thorstad *et al.* 2012) a link to strong seasonal drivers would make temperature a key factor in initiating the onset of migration.

Based on the minor changes to depth and velocity predicted through the modelled reaches under the drought permit scenario, it is considered unlikely that the downstream migration of smolts would be materially affected. Is it possible that some minor delay may be incurred at existing weir structures on the River Lyd (see Section 5.5.2.3). However, consideration of historical flows during the April to June window indicates that whilst Medium impacts are anticipated on flow regime, these impacts are greatest at mid to low flows, and the high flows under which smolts are likely to emigrate are anticipated to be comparatively less affected. It is therefore anticipated that downstream migration is likely to occur relatively unimpeded.

Accordingly, impacts on smolt migration in water bodies located downstream of the Lower River Lyd (the Upper River Tamar and the Lower River Tamar) are also deemed to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

Downstream migration – kelts

Downstream migration of kelts (spent adult salmon and sea trout migrating back downstream to sea after spawning) may occur during operation of the abstraction. Although kelts are in a somewhat depleted physical condition after spawning, the hydraulic modelling results do not indicate the presence of any areas where migration would be impeded. In common with smolts, there is the potential for some limited delay at in-river structures, although the frequency of flow elevations during the abstraction operation period is likely to provide conditions conducive for downstream migration.

Accordingly, impacts on kelt migration in water bodies located downstream of the Lower River Lyd (the Upper River Tamar and the Lower River Tamar) are also deemed to be of negligible magnitude, equating to a negligible impact significance overall. Given that the predicted impact within a given April to June period is considered to be negligible and interspersed with an intervening nine-month period, it is unlikely that any cumulative effects would occur year-to-year.

6.3.5 Summary

- The baseline dataset demonstrated a fish community on the River Lyd dominated by salmon and trout, which are typically viewed to be flow sensitive species. Therefore, a **High** level of sensitivity was assigned to spawning and egg incubation life stages of these species, whilst a **Medium** level of sensitivity was assigned to juvenile and adult life stages.
- Despite the potential for an impact on the basis of flow sensitivity of the fish community, given the negligible short term impacts predicted for the hydrological regime, hydromorphology and water quality, the predicted impact of the proposed drought permit on fish is **Negligible** for all species and life stages, with the exception of salmon spawning where the predicted impact is **Minor** for the Lower River Lyd water body.
- The fish data are spatially and temporally well distributed given the presence of the extensive Agency index monitoring programme within the catchment. Whilst the fish assemblage of the water bodies are well understood from historical data and key species-specific habitat requirements are documented in literature, there are inherently some difficulties in confidently predicting how changes in hydromorphology or water quality will translate through to impacts at the population level, due to the complexity of biotic and abiotic interactions. A **Medium** level of certainty has therefore been assigned to this assessment.
- Based on the short duration (within a given year) and minor magnitude of any impacts, the risk of deterioration of the WFD Fish element is considered to be very low. Given **Negligible** impacts for all species and life stages (with the exception of **Minor** impacts for salmon spawning on the Lower River Lyd water body), and a minimum intervening seven-month period between abstraction periods, there is not considered to be potential for cumulative effects year to year.

6.3.6 Uncertainties

Three barriers have been identified on the main River Lyd (Figure 5-13 to Figure 5-16). Of these, only the barrier at Woodman's Lodge is recognised on the AMBER Barrier Tracker[3], though no physical information (e.g. barrier height) is available. No other information appears to be available for the remaining two barriers. As described in Section 6.3.4.3, downstream migration on the River Lyd relates primarily to emigration of salmonids, and therefore any reduction in passability of these barriers under the abstraction has the potential to delay emigration and poses risks to migrating fish (e.g. predation). Given the lack of available information regarding these barriers, a full passability assessment has not been possible within the scope of this report and therefore during abstraction monitoring has been recommended to monitor passability at structures.

[3] https://amber.international/european-barrier-atlas/

6.4 Birds, otters, water voles and great crested newts

6.4.1 *Background*

Data relating to protected species within the potentially affected reaches of the River Lyd were downloaded from the NBN Gateway website (NBN Gateway [Accessed 11/03/2019]: Environment Agency –England Protected Species records 1965 to 2017).

A review of the bird species likely to reside on or rely on the River Lyd was undertaken using the following sources:

- The Birds of Devon (Tyler, M. 2010);
- Devon bird atlas 2007-2013 (Beavan, S. & Lock, M., 2016);
- The national breeding and wintering bird atlas (Balmer et al., 2013); and
- The NBN Atlas (https://nbnatlas.org/ - search conducted in October 2019).

6.4.2 *Potential routes of impact*

The main potential effects of the proposed drought permit abstraction scenario on birds, otter and water vole would be potential changes to the availability of suitable habitats for breeding or refuge and potential changes to the availability (access to and quantity of) food sources. At a receptor specific level these potential routes of impact are:

- For piscivorous waterbirds and otter, predation of fish may be more effective under low water level and/or flow conditions as both juvenile and adult fish may become more visible in shallower water and more concentrated as the wetted perimeter decreases.
- For herbivorous waterbirds, lowered water levels could make aquatic macrophytes more accessible initially but as the water level fell below the zone of macrophyte growth those plants could desiccate and die and there would not be further plant food sources at lower levels.
- For otters, falling water levels could distance otter holts from the shoreline increasing the potential for human access and disturbance.
- For nesting waterbirds, falling water levels could strand floating nests or make nests held above the water accessible to terrestrial predators.
- For water voles, changes to water levels or flow could affect marginal plant distribution/extent on the river and therefore that could have subsequent effects on the water vole food resources.
- For water voles, falling water levels could make their burrows more accessible to terrestrial predators.

6.4.3 *Baseline*

Baseline data were analysed for the abstraction licence application EAR (APEM 2022)

Data on protected species in the River Lyd water body document the presence of two species listed under the Wildlife and Countryside Act 1981: Eurasian water vole (*Arvicola amphibius*) and kingfisher (*Alcedo atthis*); and one International Union for Conservation of Nature Redlist (Near Threatened) species otter (*Lutra lutra*), (NBN Gateway [Accessed 22/03/2019]: Environment Agency – Protected Species records 1965 to 2017). The South West Crayfish partnership were also consulted and confirmed that no records of native crayfish are present.

The absence of regular overwintering waterbird counts from the River Lyd in the long-term monitoring series of the British trust for Ornithology's (BTOs) Wetland Bird Survey (WeBS) (http://www.bto.org/volunteer-surveys/webs) strongly suggests an absence of significant populations of overwintering waterbirds. A number of species were identified as being present during the non-breeding period (Sept-March) (Beavan, S. and Lock, M., 2016 and Balmer *et al*. 2013) including goosander (*Mergus merganser*), cormorant (*Phalacrocorax carbo*), grey heron (*Ardea cinereal*), dipper (*Cinclus cinclus*) and grey wagtail (*Motacilla cinereal*). Kingfisher are also likely to be present along the River Lyd during both the non-breeding period (NBN, 2019), and the breeding period. The River Lyd was not noted in association with any of these species within the County avifauna (Tyler, 2010).

In addition to the bird species likely to reside on the River Lyd itself, a number of other waterbirds were identified to reside within close proximity to the river (Beavan, S. & Lock, M., 2016 and Balmer *et al*. 2013). These species were water rail (*Rallas aquaticus*), moorhen (*Gallinula chloropus*), Coot (*Fulica atra*) and snipe (*Gallinago gallinago*) during the non-breeding period. However, these species favour open/ still water and/ or wetland habitats over fast-flowing river systems, so are unlikely to regularly reside on or rely on the River Lyd itself and therefore were scoped out of the impact assessment.

None of the bird species identified are known to be present in numbers of regional importance. This is further supported from the County avifauna, The Birds of Devon (Tyler, 2010), not describing the River Lyd as being of importance to any of the species listed in Section 6.4.1 or naming the river itself to be of importance in general during the breeding and non-breeding seasons. Dipper (*Cinclus cinclus*) would be most sensitive to changes in water levels and flows due to their diet dominated by aquatic invertebrates.

The conditions of the drought permit that extend abstraction from April to June provide negligible changes in wetted habitat and water quality however it does extend abstraction into the breeding season for Dipper and Kingfisher.

6.4.4 Impact assessment

The operation of the current abstraction licence and of the proposed drought permit are predicted to result in negligible changes to in-river habitat, and, furthermore, only negligible effects were predicted for macroinvertebrates (Section 6.2.4.2) and fish (Section 6.3.2.6, barring minor effects on salmonid spawning). Macroinvertebrates and fish are important food sources to the protected species identified. The negligible scale and short-term duration of effects on these groups is expected to result in a negligible effect on protected species. There is the potential for changes in flow and water level to affect feeding opportunities for dipper; however, the negligible changes would not affect access for dipper to their prey of small aquatic invertebrates.

6.4.4.1 Summary

- The baseline dataset demonstrated a number of designated species present within the catchment. However, no flow sensitive species were recorded on the River Lyd. Therefore, a **Low** level of sensitivity was assigned.
- Given the negligible impacts predicted regarding hydromorphology, the predicted impact of the proposed drought permit on designated species is **Negligible**.
- As is usual when assessing protected species, the dataset was reliant on local records comprised of disparate sources. A **Low** level of certainty has therefore

been assigned to this assessment (this is considered acceptable, given the negligible magnitude of predicted impact).

6.5 Non-Native Species

6.5.1 Background

Non-native species are organisms introduced by human activities to a geographical area in which they would not normally be found. In many cases these species do not establish a viable population or have minimal impact on the ecological functioning of the habitat. However, in some instances, non-native species can have detrimental impacts to the ecosystem, economy or human health – thereby becoming 'invasive' non-native species (INNS). Impacts can be wide-reaching but some examples are: resource competition with native species; transmission of disease to native species, livestock, etc.; altering the abiotic conditions of the habitat; damage to industrial (including water company) infrastructure or operations from biofouling; or erosion of riverbanks and flood defence.

It has been previously estimated that INNS cost the UK economy nearly £2 billion/yr (Williams et al 2010) although this is likely to have been a considerable underestimate. The report produced by UK Water Industry Research (Aldous et al 2016) updated this estimate with an increased understanding of the water industry's INNS management activities, particularly regarding the costs levied against water-supply operations. For example, Aldous et al (2016) gave the yearly management costs of signal crayfish and zebra mussel as £150k/eradication programme and £800k/yr/company in maintenance cost, respectively. The estimated management costs to an individual water company for INNS plant control (aquatic and terrestrial) ranged from £4k-75k/species/yr. In the absence of effective biosecurity measures to reduce the INNS introductions, these figures clearly represent a potentially significant and ongoing cost to the industry. There are also legislative drivers for the water industry to effectively mitigate the transfer of INNS within their networks. Non-adherence to the legislation carries a potential for liability and reputational damage to the industry.

Defra, Natural England, the Agency and Water Companies have identified raw water transfers (RWT) as a significant pathway for the spread of INNS (EA Position Statement, April 2022). RWTs are a common practice by water companies, whereby bulk untreated water is transferred between source and storage assets in order to manage the demand for water resource in the UK. The nature of some of these connections presents a risk for viable INNS or their propagules to be transferred over long distances and potentially between catchments. The commitments of the current Water Industry National Environment Programme (WINEP) Asset Management Period (AMP) have prioritised the understanding of pathway risk created and possible options for risk reduction of INNS translocation via the RWT pathway. The EA have adopted this position to reduce the risk to water catchments from further spread of INNS over the longer-term. The EA's position to reduce the risk of spreading INNS via RWTs is dependent on the level of connectivity. Where new schemes create a hydrological connection between locations not already connected, mitigation measures are required so that INNS cannot spread. In the case of already connected catchments, proponents are required to undertake an assessment of the increased risk that the scheme presents, and a decision will be made on whether mitigation is required on a case-by-case basis to ensure they do not increase the risk or speed of INNS transfer. In the case of existing transfers, priority should be given to those of the greater risk first.

The impact of the proposed change to the abstraction use under drought conditions on the risk of spreading INNS is considered in light of guidance provided by the EA on the risk assessment of RWT. This assessment should be treated as an extension of the previous assessment conducted by APEM on the River Lyd to Roadford Reservoir transfer, utilising the same data, while considering how the extension of the use will affect the risk of INNS transfer.

6.5.2 Approach

6.5.2.1 INNS baseline review

As per the previous assessment conducted by APEM on the River Lyd to Roadford Reservoir transfer, the following data sources have been used:

- Data were downloaded from the NBN Atlas website (NBN Atlas [Accessed 19/01/2021]) using open access data only. The data gathered from the NBN used in this report is Open Source *Open Creative Commons with Attribution to creator (CC-BY)* as well as containing public sector information licensed under the Open Government Licence v3.0. Data was sourced from the following lists: Wildlife and Countryside Act 1981 - Schedule 9 (GB), Invasive Alien Species of Union Concern, WFD UKTAG aquatic alien species impact. These were downloaded from the National Biodiversity Atlas (nbnatlas.org) in January 2021. Data contributors and attribution parties have been outlined in Section 5, as have datasets used. The use of this data abides by the legal restrictions outlined by Creative Commons (creativecommons.org);
- Data has also been provided by The Environmental Records Centre for Cornwall and the Isles of Scilly (ECRRIS) and their associated contributors. Data were provided from an area within a 100m distance from relevant water bodies. Data were then sorted to remove terrestrial INNS whose dispersal capacity would not be directly impacted by the presence of the RWT or which have other distribution mechanism which would facilitate its spread in the absence of the RWT (e.g. can fly). The UKTAG WFD list was used as the primary selection criteria for those included in the data set;
- Data from invertebrate surveys undertaken in 2019 by APEM;
- Data from riparian macrophyte surveys undertaken in 2019 by APEM; and
- Multi habitat assessment (MHA) and eDNA sampling data collected in 2021 and 2022 by Ricardo.

Further details of how the data was gathered can be found in the assessment report of the River Lyd to Roadford Reservoir transfer produced by APEM. As the proposed changes will not affect the physical nature of the transfer, the transfer has not been reassessed using the SRO Aquatic INNS Risk Assessment Tool (SAI-RAT) as part of this assessment. Here a qualitative assessment of the INNS currently identified as present at the River Lyd and Roadford Reservoir has been made and a consideration of how extending the use of the transfer to include the months of April to June may affect the availability of INNS. The presence of the 2mm slot screen at the River Lyd abstraction has also been taken into consideration as per the previous assessment of the transfer.

6.5.3 Results

6.5.3.1 Species data

Data gathered on INNS distribution have been compiled and are presented in Table 6.17. Information is provided on the absence or presence of the species and the source of the information, either via survey (conducted by APEM or Ricardo), NBN data, ERCCIS data or eDNA (conducted by Ricardo). Maps showing the distribution of the recorded species for the River Lyd (Figure 6-23) and Roadford Reservoir (Figure 6-24) are also presented. Least duckweed is not present in Table 6.17 but has been recorded in ponds in the vicinity of the river system, and therefore included elsewhere for that purpose. The impact category of each species has been indicated in Table 6.17 and was taken from either the UKTAG list or the GB NNSS. The classifications are either H= High, M= Medium, L=Low or U= Unknown. Unknown has been used for species which are listed as unknown on the UKTAG list or for which the GB NNSS have not provided a risk assessment.

Table 6.17 Table listing all INNS detected and in which waterbodies (X= present). Data sources for each species provided along with impact (H=high, M=Medium, L= Low, U=unknown).

Species	Impact?	River Lyd Catchment	Source data	Roadford Reservoir	Source data
American Skunk-cabbage (*Lysichiton americanus*)	H	x	survey, NBN		
Bladder Snail (*Physella acuta/gyrina agg.*)	U			x	survey
Bohemian knotweed (*Fallopia × bohemica*)	H	x	survey		
Giant Hogweed (*Heracleum mantegazzianum*)	H	x	NBN		
Giant Knotweed (*Fallopia sachalinensis*)	H	x	ERCCIS		
Himalayan Balsam (*Impatiens glandulifera*)	H	x	survey, NBN, ERCCIS		
Hybrid Monkeyflower (*Mimulus guttatus x luteus = M. x robertsii Silverside*)	M	x	NBN		
Japanese Knotweed (*Fallopia japonica*)	H	x	survey, NBN		
Montbretia (*Crocosmia x crocosmiiflora*)	L	x	Survey		
New Zealand Mud Snail (*Potamopyrgus antipodarum*)	M	x	survey, eDNA	x	Survey, NBN
New Zealand Pigmyweed (*Crassula helmsii*)	H			x	Survey, ERCCIS
Northern River Amphipod (*Crangonyx pseudogracilis/floridanus sens. lat.*)	L			x	survey
Nuttall's Waterweed (*Elodea nuttallii*)*	H			x	survey
Pink Purslane (*Claytonia sibirica L.*)	L	x	NBN		
Planarian Flatworm (*Girardia tigrina*)	U			x	survey
Rhododendron (*Rhododendron ponticum*)	H	x	Survey		
Signal Crayfish (*Pacifastacus leniusculus*)	H	x	eDNA, NBN	x	eDNA
South American mollusc (*Pisidium dorbignyi*)	U	x	eDNA		

*Recorded here as *Elodea nuttallii* but potentially *Elodea canadensis.*

APEM

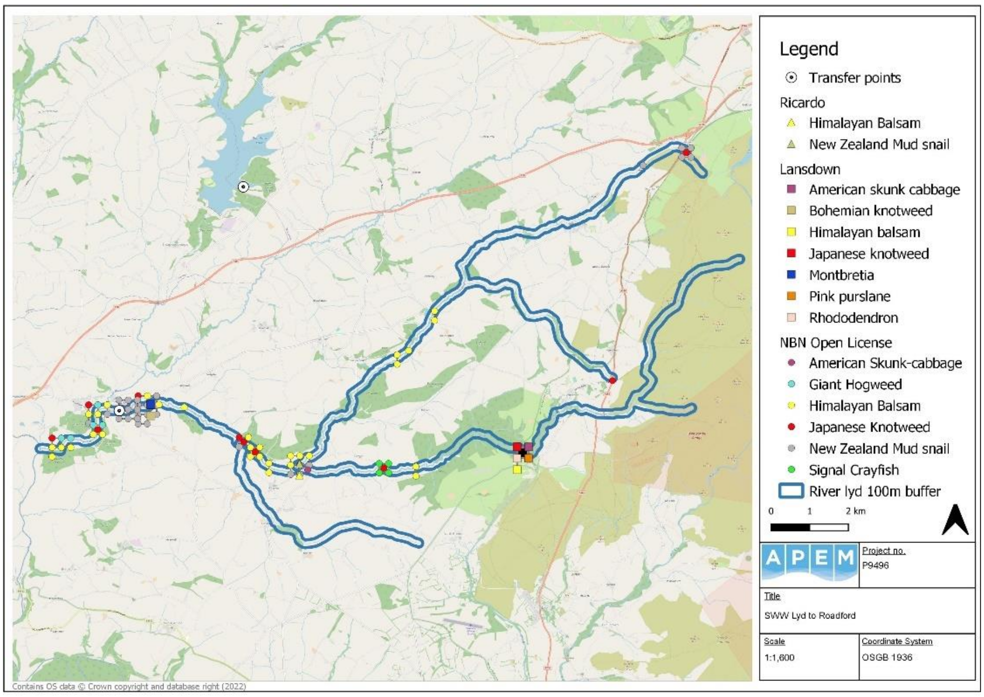


Figure 6-23 Distribution of INNS along the River Lyd, data sources also identified.

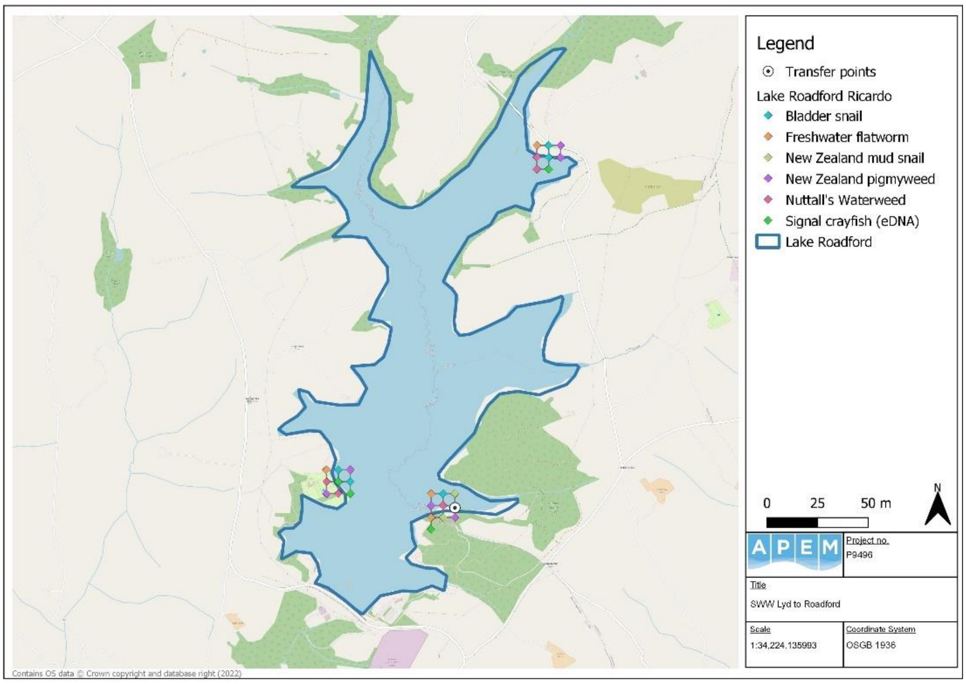


Figure 6-24 Distribution of INNS along the River Lyd, data sources also identified.

From the information gathered it is evident that there are several INNS categorised as High Impact that are present within the River Lyd that are not considered to be present at Roadford Reservoir. These include Himalayan balsam, giant hogweed (although found downstream of the reservoir according to NBN), Bohemian knotweed, Japanese knotweed (and therefore giant knotweed), rhododendron and American skunk cabbage. Several species of Medium, Low and Unknown risk (3 in total, 2 of which are plants) have also been recorded in the River Lyd but have not been recorded at Roadford Reservoir. One species of particular note, *Pisidium dorbignyi* (a pea mussel) has been detected by eDNA analysis in the River Lyd, in spring 2021, and, to the best of our knowledge, is the first record of this species in the UK. This might represent a new introduction; however, it was not subsequently recorded in summer 2022 or in any other surveys, which may suggest its detection was an anomaly of the eDNA process. Further investigation with confirmatory sampling to determine the actual presence/ absence status of the species would help to clarify. It should be noted that montbretia is considered to be present near to Roadford Reservoir but is not within the 100m radius for detecting species from the water course. It is also unclear whether survey effort regarding riparian INNS at Roadford Reservoir has been sufficient to characterise the baseline. As surveys conducted at the site focused on three locations it is possible that key species may have been missed. Although signal crayfish have been detected in both the River Lyd and Roadford Reservoir according to the NBN and eDNA results, no physical animals were detected either in the 2019, 2021 or 2022 surveys. According to local records centre data, an adult claw had been recorded in 2015. While the presence of the species in Roadford Reservoir is established, It may be that signal crayfish are not currently established within the River Lyd itself, but a small residual population may exist within the River Lyd catchment, outside of the main river, resulting in eDNA detection due to discharge of water containing signal crayfish DNA into the water course. Again, to determine the presence/absence of this species further surveys would be required.

6.5.4 Impact assessment

From the previous assessment of the River Lyd to Roadford transfer, the existing 2mm (passive wedge wire) eel screen recently installed on the transfer was concluded to present a valuable and proportional (at this time) step in reducing the risk of INNS movement between the River Lyd and Roadford Reservoir in the absence of further information, guidance, or efficacy assurance. The nominal size of different life stages of INNS identified as potentially present within the River Lyd system were found through a systematic literature review (see Table 6.18). For animal species nominal size of egg, juvenile and adult life stages are presented (where relevant), while of plant species nominal size of seed and minimum viable fragments, including rhizomes, (where relevant) are provided. It should be noted there is sometimes little evidence in the literature of exact measurements of some life stages and the level of detail varies, for example, some studies presenting a maximum size for a life stage and others providing a range. Although the information presented does not provide a systematic review of the nominal sizes of all high impact and horizon INNS, it provides an indication of the net gain to biosecurity that the 2mm screens presents. *Pisidium dorbignyi* has not been included in this table as a possible anomaly.

Table 6.18 Size of different life stages of INNS present in the River Lyd and Roadford Reservoir. The catchment(s) the species are found in is also provided along with impact (H=high, M=Medium, L= Low, U=unknown).

Species	Impact?	Catchment	Egg/seed size (mm)	Juvenile size (mm)	minimum viable fragment (mm)	Adult size (mm)	Comments
American Skunk-cabbage (*Lysichiton americanus*)	H	Lyd only	5-11	-	-	-	Can also grow from rhizomes.
Bladder Snail (*Physella acuta/gyrina agg.*)	U	Roadford only	<1	1	-	7-12	
Bohemian knotweed (*Fallopia × bohemica*)	H	Lyd only	5	-	40	-	Can produce seeds but main method of reproduction is through vegetative propagation.
Giant Hogweed (*Heracleum mantegazzianum*)	H	Lyd only	10x5x2	-	-	-	
Giant Knotweed (*Fallopia sachalinensis*)	H	Lyd only	5	-	40	-	Also reproduces sexually and both male and hermaphrodite plants are present in the UK. However, no single location known where both sexes are present. Has propagules than can remain viable for >1 year.
Himalayan Balsam (*Impatiens glandulifera*)	H	Lyd only	4-7x2-4	-	-	-	
Hybrid Monkeyflower (*Mimulus guttatus x luteus = M. x robertsii Silverside*)	M	Lyd only	0.5-1	-	-	-	
Japanese Knotweed (*Fallopia japonica*)	H	Lyd only	5	-	40	-	
Montbretia (*Crocosmia x crocosmiiflora*)	L	Lyd only	3-5				Can produce seeds but also via vegetative means via a corm (bulb like root).
New Zealand Mud Snail (*Potamopyrgus antipodarum*)	M	Lyd and Roadford	N/A	0.4	-	4 - 12	Eggs carried by female and not present in the water column.
New Zealand Pigmyweed (*Crassula helmsii*)	H	Roadford only	0.5	-	5	-	
Northern River Amphipod (*Crangonyx pseudogracilis/floridanus sens. lat.*)	L	Roadford only	N/A	<2	-	6	Eggs carried by female and not present in the water column.
Nuttall's Waterweed (*Elodea nuttallii*)	H	Roadford only	1-7	-	-	-	Can propagate through fragments but at least 7 nodes without apical bud required.

Species	Impact?	Catchment	Egg/seed size (mm)	Juvenile size (mm)	minimum viable fragment (mm)	Adult size (mm)	Comments
Pink Purslane (*Claytonia sibirica L.*)	L	Lyd and Roadford	0.5	-	-	-	Based on similar purslane species, can self-pollinate,
Planarian Flatworm (*Girardia tigrina*)	U	Roadford only	1.3	2-4.5	-	9-15	Cocoons formed, hatch between 1-4 new-borns.
Rhododendron (*Rhododendron ponticum*)	H	Lyd only	2-4	-	-	-	
Signal Crayfish (*Pacifastacus leniusculus*)	H	Lyd and Roadford	2.58-2.72	12	-	160 - 180	

Of the INNS currently recognised as only present within the River Lyd, the seeds of monkey flower are most likely to pass through the 2mm screen based on the evidence presented. The seeds/fragments of other plants considered present in the River Lyd corridor and not at Roadford Reservoir are likely to not be able to pass through the screen. When considering the seasonality of the transfer in addition to the current biosecurity, monkey flower flowers from June to September, therefore is unlikely to present an increased risk of being translocated with the proposed changes.

Of those INNS considered to be present in both the River Lyd and Roadford Reservoir, juveniles of the New Zealand mud snails could potentially pass through the screen, but their potential to survive the process (given how delicate their shells are) is questionable. New Zealand mud snails do start to reproduce in spring-summer, so propagule pressure may increase between April and June, and therefore may present a slight increase in risk. The small end of the size range of seeds of Nuttall's waterweed would also be able to pass through a 2mm screen along with pink purslane. While pink purslane flowers between June and September, presenting a minimal risk of increasing propagule pressure, Nuttall's waterweed, would present a risk all year.

6.5.5 Summary

- Considering the baseline data in combination with the estimated efficacy of biosecurity already present on the transfer, given the low impact of those species that may present a risk of translocation with the proposed drought permit, the magnitude of impact is considered to be **low** as is the sensitivity.
- The proposed drought permit will, therefore, have a **minor** impact on the risk of transferring INNS that are recognised as already present within the River Lyd.
- The data set used in this assessment is from a combination of sources, so can be considered to be relative robust, but the efficacy of screening still requires extensive testing before clearer conclusions can be drawn. Furthermore, there are significant gaps in the literature in relation to the three-dimensional measurements of INNS, especially juvenile life stages. Additionally, only INNS currently recognised as present within the River Lyd and Roadford have been considered, with no consideration of potential horizon species. Therefore, a **low** level of certainty has been assigned to this assessment.

7. Assessment of other receptors

The following sections are based on the assessment presented in the abstraction licence application EAR (APEM, 2022). Where relevant, considerations have been added for the proposed drought permit

7.1 Socio-economics, tourism and recreation

Super Output Area data were analysed for this report (GDS, 2019). The communities of the Roadford study area are largely rural, with urban communities located in Launceston to the south west and Okehampton to the east. There are no large hospitals or care homes located in the study area (the nearest are in Launceston). Recreational activities (e.g. canoeing, sailing, walking etc.), particularly around Roadford Reservoir, contribute to the local economy.

The rivers Lyd and Thrushel within the study area are popular among visiting game anglers. The Arundell Arms Hotel in Lifton has been one of England’s premier fishing hotels for more than half a century and was voted the UK’s Best Fishing School in the UK by The Field Magazine.

The River Tamar is a nationally recognised salmonid fishery and supports Atlantic salmon, sea trout and brown trout from the upper reaches of the estuary to its headwaters and those of its tributaries. Even so, public access along most of the rivers of the study area is limited.

The South West Lakes Trust manage Roadford Reservoir and the site has been developed for recreation and wildlife, with an onsite visitor centre, café and function suite, and campsite. The reservoir provides 730 acres of open water, some of which are used for sailing, canoeing, kayaking and windsurfing. More than half of the shoreline is used for fly-fishing, together with boat fishing. There is also a network of footpaths and bridleways and the reservoir is used by birdwatchers.

The proposed drought permit is very unlikely to have any adverse impact the Roadford study area and the local visitor economy. This is supported by modelling of river levels (Section 5) which shows that abstraction is not predicted to have a significant effect on river levels in comparison with the baseline scenario. As such, the economic impact of the proposed drought permit is deemed to be negligible.

The proposed drought permit is not anticipated to impact on River Lyd users as abstraction will be restricted by the 40Ml/d HoF, and significant impacts on river habitats are not predicted (Section 5.5). As such, no negative economic impact is anticipated.

7.1.1 Summary

The proposed drought permit scenario is very unlikely to have any adverse impact upon the Roadford study area and the local visitor economy. This is supported by modelling of river levels which shows that abstraction under the abstraction licence is not predicted to have a significant effect on river levels in comparison with the baseline. As such, the local economic impact of the extended April to June abstraction proposed by the drought permit is deemed to be negligible.

- The River Lyd is an important fishery and attracts are a large number of visitors to the area. Therefore, a **Medium** level of sensitivity was assigned.

- Given the negligible impacts predicted regarding hydromorphology, water quality and fish (barring minor effects on salmonid spawning), the predicted impact of the proposed drought permit on socio-economics and tourism is **Negligible**.
- A **Medium** level of certainty has been assigned to this assessment.

7.2 Aesthetics and landscape

Water has been fundamental in shaping the landform and dictating natural vegetation patterns in the Tamar catchment. Agricultural land covers major parts of the Lyd sub-catchment. The semi-natural and managed land combines to create a landscape which is essentially pastoral in nature with little urbanisation. There is no heavy industry in the area, although historic mining activity has had an impact on the landscape, more so in the Lyd Valley.

All the rivers within this study area are visible at many points through a combination of roads, bridges, public footpaths and cycle ways, country parks, privately owned residential and industrial premises. There are many channel modifications along its course, which take the shape of bridges and weirs. These structures affect the characteristics of flow in the parts of the channel they occupy.

The potential impacts on landscape and visual amenity, attributable to the proposed drought permit, relate to annual abstraction of up to 40 Ml/d from the River Lyd to discharge into Roadford Reservoir, during the April to June 2023 period. The outputs from the hydrology assessment (see Section 5.4.3) indicate that changes resulting from the operation of the proposed abstraction would be unlikely to significantly detract from the aesthetic value of the watercourses. Whilst temporary deterioration may be noticeable on the River Lyd just downstream of the abstraction, this diminishes with increased distance from the abstraction point to less than 10% at the confluence with the River Tamar. Moreover, the proposed drought permit will only be operated during the April to June period i.e. any effects will be temporary in nature.

The net result of the proposed drought permit would be a reduction in drawdown of the Roadford Reservoir, meaning that more water would be retained in the reservoir. This will minimise the reduction of the wetted perimeter of the reservoir and will facilitate recovery of water levels following a low flow period. The increased retention of water within the reservoir could be anticipated to have a negligible positive aesthetic impact.

Assuming the implementation of legislation developed by the council, it is unlikely that the proposed drought permit will impact significantly on planning activities in the area. Planning and development in the area is evidently a considered and logical process, and the proposed drought permit is unlikely to alter the council's approach. The character of the landscape may be slightly impacted by a reduction in wetted perimeter, but this impact has been deemed to be insignificant.

Given that the magnitude of the changes in the wetted perimeter is likely to be negligible, it is anticipated that the proposed drought permit operation will have a negligible impact on the aesthetics and landscape of the River Lyd – d/s Lyd abstraction and River Lyd – d/s Lifton.

7.2.1 *Summary*

Predicted impacts on landscape and visual amenity are summarised below.

- The aesthetics and landscape of the watercourses and the reservoir in the Roadford study area were assigned a **Low** level of sensitivity in relation to the proposed drought permit.
- Given the negligible impacts predicted regarding hydromorphology, the predicted impact of the proposed drought permit on aesthetics and landscape of the River Lyd is **Negligible**.
- A **Medium** level of certainty has therefore been assigned to this assessment.

7.3 Archaeology and cultural heritage

A search for statutory and non-statutory historical features was conducted using MAGIC (2023), an interactive mapping website providing authoritative geographic information about the natural environment from across government.

The following layers were interrogated:

- Scheduled monuments (historic statutory land-based designations);
- World heritage sites (historic statutory land-based designations);
- Listed buildings (historic statutory land-based designations);
- Registered battlefields (historic non-statutory land-based designations); and
- Registered parks and gardens (historic non-statutory land-based designations).

National Trust properties were assessed using National Trust Open Data available from the National Trust website (www.nationaltrust.org.uk).

Scheduled monuments and listed buildings are considered to be of National Importance, whilst World Heritage Sites are considered to be of International Importance. The 'historic non-statutory' features and National Trust property are considered to be of Local or Regional Importance.

No records were found to indicate that anaerobic/ organic remains are located within or immediately adjacent to the watercourses. There are no scheduled monuments, World Heritage Sites, registered battlefields or registered parks and gardens located in the area. As such, the integrity of historic and/or heritage features will not be affected by changes to lake levels and therefore, there will be no impact on recreational or visual amenity value.

Given that no archaeological or heritage features have been identified as occurring within or immediately adjacent to the study area, any such features are unlikely to be directly or indirectly impacted by any reduction in flow rate, velocity or wetted perimeter. Therefore, as the magnitude of any potential effect is considered to be negligible, the overall impact on archaeology or cultural heritage is also considered to be negligible.

7.3.1 *Summary*

A summary of the impact assessment is presented below.

- The baseline dataset demonstrated that no sites of archaeological and cultural heritage are located within the drought permit study area. Therefore, a **Low** level of sensitivity was assigned.
- Given the negligible impacts predicted regarding hydromorphology, the predicted impact of the proposed drought permit on archaeological and cultural heritage sites is **Negligible**.
- A **Medium** level of certainty has been assigned to this assessment.

7.4 Designated sites

A search for statutory environmental designations within the study area was conducted using MAGIC (2023). The search was restricted to features located on the banks of the watercourses within the area potentially affected by the proposed drought permit.

The following layers were interrogated:

- Areas of Outstanding Natural Beauty (AONB);
- Local nature reserves (LNR);
- National nature reserves;
- National parks;
- Ramsar sites;
- Sites of Special Scientific Interest (SSSI);
- Special Areas of Conservation (SAC); and
- Special Protection Areas (SPA).

These statutory designations are considered to be of National (domestic UK legislation) or International (European and international legislation) Importance.

Only one designated site was identified in the study area: Roadford Lake LNR, which covers the north east limb of the reservoir, a section of the River Wolf, as it enters the reservoir and Southweek Wood. It consists of 34 hectares of freshwater, swamp, marshy grassland, dense scrub willow carr, broadleaved woodland and coniferous plantations. The mature woodland habitat supports small populations of dormice, which are protected under the Wildlife and Countryside Act 1981.

The most upstream 5km (approximate) of the River Lyd are within Dartmoor SAC. There is no direct hydrological pathway of impact that might affect this reach. Furthermore, whilst salmonids constitute a feature of the ‘inland water bodies (standing water, running water)’ designation of Dartmoor SAC, salmonids cannot migrate upstream of the natural barrier presented by Lydford Gorge, which prevents them from reaching the SAC. Dartmoor SAC has therefore been screened out of further assessment.

The Plymouth Sound and Estuaries SAC and the Tamar Estuaries Complex SPA are outside the areas potentially hydrologically affected by the proposed drought permit. Allis shad (*Alosa alosa*) is a qualifying feature of the Plymouth Sound and Estuaries SAC. Currently, Allis shad are unable to migrate into the River Lyd because of downstream barriers at Gunnislake, Duchess and Lamerhooe (Natural England, pers. Comm.). Allis shad have therefore been screened out of further assessment. Whilst work has begun on constructing a fish pass at Gunnislake, which is due for completion by 2025, there are no plans currently in place for the remaining two barriers. Therefore, the situation should periodically be reviewed, to confirm whether or not Allis shad require assessment in relation to normal operation of the abstraction, however the proposed drought permit does not affect Allis shad.

Designated areas identified are presented within Table 7.1.

Table 7.1 Designated landscape features identified (http://www.magic.gov.uk/)

Feature type	Name	Location
LNR	Roadford Lake Local Nature Reserve	North east part of Roadford reservoir
SSSI	Dartmoor SAC	Upstream of affected reaches
SAC	Plymouth Sound and Estuaries	Downstream of affected reaches

Sites designated under UK, European and international legislation are considered where sites may be designated for their wildlife or geological interest. Designated sites may be impacted vis a change in river/reservoir level leading to exposure of sediments. This has the potential to impact the integrity of the substrate itself and the utilisation of the shoreline by flora and fauna that may be protected under the designation.

Under the proposed drought permit, it is anticipated that the changes in water level, average velocity, depth, wetted width and wetted area of the downstream reaches of the River Lyd will not be significantly impacted (Sections 5.2.4 and 5.5.4) and the Roadford Lake LNR will not be directly impacted by changes in flow or level (Section 5.5.4) as a result of this proposal.

7.4.1 Summary

The predicted hydrological changes are not expected to impact upon the designated sites associated with the study area. There are no designated features associated with the study area which require impact assessment.

A summary of the impact assessment is presented in the table below.

- The baseline dataset demonstrated no designated sites of National importance within the study area. Roadford Lake LNR will not be impacted as water quality from the River Lyd is Good and only negligible (positive) change in lake levels will occur as a result of the proposed drought permit. Therefore, a **Low** level of sensitivity was assigned.
- Given the negligible impacts predicted regarding hydromorphology and water quality, the predicted impact of the proposed drought permit on designated sites is **Negligible**.
- A **Medium** level of certainty has been assigned to this assessment.

8. Summary

This report measured and modelled lake level and river flow data together with walkover and bathymetric survey data to predict hydrological impacts under the proposed drought permit. The results of the hydrological modelling and other analyses have been used to assess baseline data and predict potential impacts for the following features:

- River flow and level;
- Other abstractors;
- Habitat and geomorphology;
- Water quality;
- Phytobenthos;
- Macroinvertebrates;
- Fish;
- Birds;
- Protected species;
- Socio-economics, tourism and recreation;
- Aesthetics and landscape;
- Archaeology and cultural heritage;
- Designated sites; and
- The risk of spread of INNS.

The predicted impacts (arranged by season and receptor) are summarised in Table 8.1. The table indicates, for completeness, impacts predicted under normal abstraction licence operation (November to March) (APEM, 2022) as well as those impacts predicted for the proposed drought permit.

For all receptors under the drought permit scenario only minor or negligible impacts were predicted in comparison with the baseline. Despite the lack of predicted impacts under the drought permit scenario, an environmental monitoring plan and precautionary mitigation measures have been developed (Sections 9 and 10).

Table 8.1 Summary of predicted impacts. The table includes impacts predicted in the abstraction licence application (November to March) as well as those predicted for the proposed drought permit implementation (April to June).

		Sensitivity of receptor	J	F	M	A	M	J	J	A	S	O	N	D	Level of Confidence
Pathways	**Hydrology**														
	Lower River Lyd	NA	**M**	**M**	**M**	**M**	**M**	**M**	NA	NA	NA	NA	**M**	**M**	Medium
	Roadford Reservoir	NA	**N**	**N**	**N**	**N**	**N**	**N**	NA	NA	NA	NA	**N**	**N**	Medium
	Habitat and geomorphology														
	Lower River Lyd	NA	**N**	**N**	**N**	**N**	**N**	**N**	NA	NA	NA	NA	**N**	**N**	Medium
	Water Quality														
	Lower River Lyd	NA	**N**	**N**	**N**	**N**	**N**	**N**	NA	NA	NA	NA	**N**	**N**	Medium
Receptors	**Phytobenthos**														
	Lower River Lyd	Low							NA	NA	NA	NA			Medium
	Macroinvertebrates														
	Lower River Lyd	Medium							NA	NA	NA	NA			Medium
	Fish														
	Lower River Lyd:														
	Atlantic salmon (spawning and egg incubation)	High							NA	NA	NA	NA			Medium
	Atlantic salmon (juvenile and adults)	Medium							NA	NA	NA	NA			Medium
	Brown trout (spawning and egg incubation)	High							NA	NA	NA	NA			Medium
	Brown trout (juvenile and adults)	Medium							NA	NA	NA	NA			Medium
	Bullhead (spawning and egg incubation)	High							NA	NA	NA	NA			Medium
	Bullhead (juvenile and adults)	Medium							NA	NA	NA	NA			Medium
	Eel (Elver U/S migration and adult D/S migration)	Medium							NA	NA	NA	NA			Medium
	Eel (adults)	Low							NA	NA	NA	NA			Medium
	Brook lamprey (spawning and ammocoetes)	High							NA	NA	NA	NA			Medium
	Protected species (birds, otters, water voles and great crested newts)														
	Lower River Lyd	Low							NA	NA	NA	NA			Low
	Non-native species														
	Lower River Lyd	Low							NA	NA	NA	NA			Low
	Socio-economics, tourism and recreation														
	Roadford study area	Medium							NA	NA	NA	NA			Medium
	Other abstractors														
	Lower River Lyd	Medium							NA	NA	NA	NA			Medium
	Aesthetics and landscape														

		Sensitivity of receptor	J	F	M	A	M	J	J	A	S	O	N	D	Level of Confidence
	Roadford study area	Low							NA	NA	NA	NA			Medium
	Archaeology and cultural heritage														
	Roadford study area	Low							NA	NA	NA	NA			Medium
	Designated sites														
	All water bodies	Low							NA	NA	NA	NA			Medium

Key

Magnitude of impact on pathway		Significance of impact on receptor	
H	High		Major
M	Medium		Moderate
L	Low		Minor
N	Negligible		Negligible
NA	Not assessed	NA	Not assessed

9. Monitoring plan

9.1 Introduction

There is an ongoing baseline drought monitoring programme for the River Lyd which is carried out jointly by the Environment Agency and SWW. It is part of the current EMP, within the abstraction licence application EAR, which also includes proposed 'during- abstraction' and 'post-abstraction' monitoring (APEM, 2022). It is proposed that this EMP be modified as necessary for the purposes of monitoring associated with the proposed drought permit.

The receptors to be monitored are those stated on the abstraction licence conditions detailed in Table 9.1, together with the agreed monitoring locations.

It is important to note that the level of monitoring is risk-based. The environmental assessment indicates that the proposed drought permit presents a low risk to the environment (only negligible or minor negative impacts are predicted for all receptors within a low flow period for April to June inclusive). Nevertheless, given the uncertainties inherent in some of the assessments undertaken, monitoring has been recommended, to check the predicted degree of impact, and identify any unexpected impacts in order to trigger mitigation measures, if needed.

Baseline monitoring

Baseline monitoring is required to formulate a description of the existing ecological conditions, from which the impacts of drought permit operations over and above the effects of other pressures, such as natural drought, can be identified. The existing baseline dataset is considered sufficient for the current assessment, given the low risk of the proposed drought permit. It is recommended that the macroinvertebrate baseline dataset is updated in 2023 and should then be periodically updated every three years (i.e. triennially post 2023).

During Drought Permit monitoring

During abstraction monitoring is required to assess any impacts (which are not expected) from the implementation of the proposed drought permit and for the management of mitigation measures

Post Drought Permit monitoring

Post- permit monitoring would aim to assess a site's recovery and to check that there are no long-term effects on any environmental features. This is important as results are needed to assess the success of mitigation measures. It can also feed back into the assessment of sensitivity and likely impact and inform the management of future drought permits.

The need for post drought permit monitoring will depend upon the severity of the natural drought, but will cover the period of recovery and will be carried out in consultation with the regulator.

9.2 River Lyd

Weekly visual monitoring walkovers are recommended upon implementation of the drought permit, reducing to fortnightly after one month in consultation with the Agency. Walkovers would look for signs of distressed/ trapped fish (particularly emigrating smolts) in the vicinity of in-stream structures that may represent barriers to migration.

A pre-implementation baseline walkover, as close to the drought permit operation as possible, is also recommended in order to establish baseline conditions and to understand to what degree any change is attributable to the drought permit itself. Walkover surveys in subsequent drought permit periods would be dependent on flow conditions and the outcomes of previous walkover surveys.

Table 9.1 River Lyd Environmental Monitoring Plan

Parameter	Location	By whom	Brief scope	Baseline/ ongoing timing/ frequency	During abstraction timing/ frequency	Post abstraction timing/ frequency	Notes
Visual monitoring walkover	Former intake (SX 39895 85082) to Tamar confluence (SX 37459 84076)	SWW	Walkover of the whole reach where access permits, looking for signs of fish distress in sensitive areas	A pre-implementation baseline walkover, as close to the Drought permit operation as possible, is also recommended in order to establish baseline conditions.	Weekly during drought permit operation, reducing to fortnightly after a month, in consultation with EA	-	-
Habitat walkover	Former intake (SX 39895 85082) to Tamar confluence (SX 37459 84076)	SWW	Walkover of the whole reach where access permits, following the method outlined in Hendry and Cragg-Hine (1997)	Once during low flow conditions (complete). A pre-implementation baseline walkover, as close to the Drought permit operation as possible, is also recommended in order to establish baseline conditions.	fortnightly surveys for the duration of abstraction. Data to IEP inbox within one week of each survey and final report within six weeks of abstraction ceasing for 2023 assessing the impacts of the abstraction.	-	Baseline surveys completed in March 2023
Geomorphological walkover	Former intake (SX 39895 85082) to Tamar confluence (SX 37459 84076)	SWW	Walkover of the whole reach where access permits to characterise the baseline geomorphological functioning of the potentially	A pre-implementation baseline walkover, as close to the Drought permit operation as possible, is also recommended in order to establish baseline conditions.		-	Baseline surveys completed in Jan 2023

Parameter	Location	By whom	Brief scope	Baseline/ ongoing timing/ frequency	During abstraction timing/ frequency	Post abstraction timing/ frequency	Notes
			affected reaches				
Fish	The following surveys should be undertaken annually, with reasonable gaps in the EA index river monitoring programme filled in by SWW. Nearly all are undertaken annually as part of the EA's index river monitoring, however, SWW will need to confirm this each year. Surveys in bold are NOT undertaken by the EA annually and will need to be delivered by SWW annually. SWW will deliver up to a maximum of 10 electric fishing surveys per annum <u>Lyd:</u> Lydford Gorge 10662 - NGR: SX4925783808; **Coryton Bridge 10463 – NGR: SX4639883205;** Greenlanes 10462 - NGR: SX4433983260; Sydenham 10663 - NGR: SX4297783838; Spry Farm 10664 - NGR: SX4050285099;	SWW/EA	Semi-quantitative surveys	Annually, as a condition of the abstraction licence	-	-	Baseline surveys undertaken by Environment Agency during summer 2019

Parameter	Location	By whom	Brief scope	Baseline/ ongoing timing/ frequency	During abstraction timing/ frequency	Post abstraction timing/ frequency	Notes
	Colmans Farm 16799 – NGR: SX3985785008 OR **Ambrosia Bridge 16030 – NGR: SX396208493;** Lifton Plying Fields 10460 - NGR: SX3896784880; **Lifton Park 10665 – NGR: SX3876284172;** U/S Gatherley 10666 - NGR: SX3809184188 River Lew: Stone 8246 – NGR: SX5025089200; Comebow 10500 – NGR: SX4882287984 Lew Mill 8247 – NGR: SX4700086220 River Thrushel: Beaver 44721 - NGR: SX4464989099 Townleigh 10668 - NGR: SX4255387179 **New site immediately downstream of the Thrushel pipeline washout discharge location between SX4165186716 and SX4118486257**						

Parameter	Location	By whom	Brief scope	Baseline/ ongoing timing/ frequency	During abstraction timing/ frequency	Post abstraction timing/ frequency	Notes
	Tinhay Bridge 10633 - NGR: SX3937285380 River Wolf: Rexon 10651 - NGR: SX4088188334 Cookworthy Trap 10655 - NGR: SX4030086300 Wolf Confluence 10657 - NGR: SX4022086090 **New site upstream of the Wolf tributary pipeline washout discharge location at SX4177488334** **New site immediately downstream of the Wolf tributary pipeline washout discharge location between SX4177488334 and and SX4150088350**						
Fish – SNIFFER weir passability assessments	Lifton Park Gauging Station (SX3889784258) and Impounding structure at SX3799883977	SWW	Fish passage assessments (i.e. SNIFFER) completed during mid-range flows (~Q60) to assess whether the two structures form flow sensitive barriers to fish passage.	Year 1 only	-	-	-
Macroinvertebrates	US Ambrosia Creamery - NGR: SX3976084940; Lifton Bridge - NGR: SX3893084770;	SWW/EA	Sampling at all locations. Samples analysed to species level. Measurement of physico-chemical	Surveys to be undertaken triennially with samples collected three times a year (spring/summer/autumn)	-	-	Baseline surveys completed in 2019, scheduled for 2023

Parameter	Location	By whom	Brief scope	Baseline/ ongoing timing/ frequency	During abstraction timing/ frequency	Post abstraction timing/ frequency	Notes
	Greenlanes Bridge - NGR: SX4413083320; Spry Farm - NGR: SX4022085020		variables (average water depth, average wetted width, substratum composition and electrical conductivity) at all locations and on all occasions				
Phytobenthos	US Ambrosia Creamery - NGR: SX3976084940; DS Ambrosia Creamery - NGR: SX3949784935; Lifton Bridge - NGR: SX3893084770; Greenlanes Bridge - NGR: SX4413083320; Spry Farm - NGR: SX4022085020	SWW/EA	Surveys to follow EA sampling methodology for WFD	Spring/autumn only, optional as required to maintain baseline dataset	-	-	Baseline surveys completed in 2019
INNS (invertebrate surveys)	Invertebrate surveys along a 200m reach at each macro invertebrate location. Specific effort should be made to confirm the presence of signal crayfish and *Pisidium dorbignyi* in the River Lyd.	SWW	Targeted NNS surveys	Summer, once annually after the transfer has been in use	-	-	Baseline surveys completed in summer 2019, scheduled for 2023
INNS (plant survey)	Plant surveys at Roadford reservoir and River Lyd Corridor.	SWW	Targeted NNS surveys	Spring/summer, once annually	-	-	Baseline surveys completed in summer 2019, scheduled for 2023

9.3 Compliance with abstraction licence flow conditions

Should the drought permit be implemented, for live monitoring and compliance purposes flow at the Lyd abstraction point will be calculated by SWW as follows (as agreed with the Environment Agency on 25/02/2021):

Flow at Lyd abstraction point = Lifton gauged flow minus Tinhay gauged flow plus 10% of the Ambrosia daily drought permit limit[4].

Therefore, available SWW abstraction = ((Lifton gauged flow - Tinhay gauged flow + 0.008) – HOF) * 0.5

This is considered a pragmatic approach given that the actual Ambrosia abstraction is not known in real time and given that the Agency method normally used to calculate Tinhay and Lifton natural flows[4] is better suited to retrospective rather than instantaneous assessment of naturalised flow data.

Control and monitoring of the abstraction would be managed by SWW Water Treatment Technicians using the same processes and systems as all other SWW abstractions in the Devon and Cornwall area. All abstractions are monitored on SCADA (supervisory control and data acquisition) using a licence monitoring software package. River level and flow data can be entered into SCADA automatically from suitable gauging systems, or manually entered by Water Treatment staff, and SCADA will calculate the available abstraction in line with the agreed equation above. Restrictions would be implemented within the system that prevent abstraction from exceeding, or generates an alarm if the abstraction is close to exceeding, the allowable volume.

The SWW Water Resources team will collate the abstraction data and report the daily abstraction totals to the Environment Agency after the end of each month as part of the abstractions returns process which is carried out for all SWW Drought permits.

9.4 Ongoing assessment and reporting of environmental and ecological data

To ensure a timely response to any impacts observed during walkover surveys it is anticipated surveyors would flag any concerns to SWW and the Agency informally, within 24 hours. If unexpected impacts are found to be occurring, potential mitigation measures (see Section 10) should be discussed and agreed with the Agency.

Longer-term data would be presented and analysed in triennial reports, assessing all measured parameters for any potential longer-term impacts of the increased abstraction. Walkover data would be included and assessed for any trends seen over time. These reports would also provide the opportunity to account for any future activity on the waterbody that may affect the ecology e.g. downstream barrier removals.

[4] The Agency approach is based on Roadford naturalised flows and includes a mass balance/ Germansweek gauged flow ratio which is updated annually.

10. Mitigation measures

Where significant negative impacts (defined for this report as those of moderate significance or greater) are identified, mitigation measures can be developed in order to avoid, reduce or remedy any impacts.

In this case, no significant negative impacts have been identified as a consequence of the proposed drought permit; its effects are predicted to be minor or negligible on all receptors in comparison with the baseline (a worst-case scenario, based on a drought year). Nevertheless, given the uncertainties inherent in some of the assessments undertaken, a range of precautionary mitigation measures have been developed, in the event that environmental monitoring during the drought permit operation identifies that unexpected impacts are occurring.

Monitoring has been recommended to capture any changes either in the long-term, or during, initial operation of the drought permit (see Section 9). This includes checking for signs of ecological stress including: potential effects on flow; inhibition of movement of fish past river structures or other barriers; habitat availability for adult and juvenile life stages (including spawning/ nursery areas); and concentration of fish in restricted areas/pools which could increase susceptibility to predation.

It should be noted that not all of the mitigation measures described may be required or appropriate. If unexpected impacts are found to be occurring, potential mitigation measures should be discussed and agreed with the Agency.

A number of additional mitigation measures could be implemented depending on feasibility, should monitoring during drought permit operation indicate that significant impacts are occurring (which is not anticpated):

- Fish rescue and relocation should fish become trapped below river structures on the River Lyd during abstraction;
- For localised areas where increased predation is a potential issue, consider requirements for installation of fish refugia within the watercourse in consultation with the Agency;
- Funding of appropriate reasonable measures (e.g. habitat restoration) could be considered to remedy any impacts that are observed to have occurred.

It may not be necessary to implement any of these mitigation measures if (in line with the assessment in this report) significant negative impacts are not observed to be occurring. Implementation of the mitigation measures will take place should monitoring during the drought permit operation indicate that significant impacts are being experienced.

11. Conclusions and recommendations

The proposed drought permit is predicted to have only minor or negligible impacts on all environmental features in comparison with the baseline scenario.

The potential impacts are summarised as follows:

Scenario	Impact Significance	Receptors
Lyd drought permit	Negligible or minor negative impacts	All receptors associated with the River Lyd.

Where significant negative impacts are identified during the environmental assessment process, mitigation measures can be identified to avoid, reduce or remedy any impacts. However, in this case, no significant negative impacts have been identified as a consequence of the proposed drought permit .

Nevertheless, given the uncertainties inherent in some of the assessments undertaken, a range of precautionary mitigation measures have been developed, in the event that environmental monitoring during drought permit operation identifies that unexpected impacts are occurring (Section 10).

Monitoring has been recommended to capture any changes either in the long-term, or during initial drought permit operation (see Section 9). This includes checking for signs of ecological stress including: potential effects on flow; inhibition of movement of fish past river structures or other barriers (including at Woodman's Lodge); habitat availability for adult and juvenile life stages (including spawning/ nursery areas); and concentration of fish in restricted areas/pools which could increase susceptibility to predation, as well as evidence of establishment or expansion of NNS.

In support of and further to the specific monitoring requirements for INNS (Table 10.1) the following recommendations are made concerning the management of risk in the River Lyd:

- The identification of potential sources of plant INNS.
- Depending on sources identified, actions should be made to prevent further introduction/spread of plant INNS:
    - This could include increased biosecurity messaging and/or advice to users and land holders along the River Lyd, with particular focus on those locations where plant introduction may occur.
    - Management plans to remove and/or control plant INNS along this stretch of river should also be considered to reduce propagule pressure.

Additionally, in taking a holistic approach to biosecurity and INNS management the following recommendations are made:

- Surveillance should be increased at Roadford Reservoir, especially around the discharge point and times of use to facilitate early detection and rapid response (as part of the SWW rapid response plan) to new arrivals.

- Biosecurity at Roadford Reservoir should be reviewed and enhanced were possible to take into consideration the potential and measures to prevent the spread of INNS from the site.
- The use of the River Lyd to Roadford Reservoir transfer should also be limited, where operationally possible, to use during winter months, avoiding times when INNS are most abundant, motile and reproducing.

If unexpected impacts are found to be occurring, potential mitigation measures should be discussed and agreed with the Agency.

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