WILD TROUT TRUST

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River Axe, Wookey, Somerset

Wild Trout Trust report on a walkover survey carried out on 19 October 2020

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Contents

1. Key findings

1.1. Water quantity, 'slowing the flow' and flood risk

- This area of the River Axe catchment is less confined than the upper reaches at Wookey Hole, but the flatter landscape offers potential for 'slowing the flow' to more flood-prone areas.

- A significant proportion of the river's flow is diverted to the millstream, where flows fluctuate quite dramatically due to activities at Burcott Mill

- Opportunities have been identified to restore the river and millstream, 'slowing the flow' downstream into vulnerable areas. At times of low flow, a more sinuous river channel could also enhance habitat value for many species of birds, fish and insects.

1.2. Water quality and habitat improvement

- Water quality in the upper River Axe appears generally good, although possibly subject to long-term lead pollution from historic mining activities.

- The river has plentiful gravels, with high spawning potential for trout and other fish. Spawning success could be improved by adding woody material to increase complexity and reinvigorate natural processes.

1.3. Barriers to fish passage

- This stretch of the River Axe has historically been heavily modified for milling purposes, and the river is still fragmented by weirs and other structures. Many of these are now redundant and should be removed because of their negative impact.

- Trout were seen in one area of the main river, and two areas of the mill stream. However, these are potentially isolated populations, with recolonisation impeded by a variety of weirs and culverts, which should all be removed if possible (or significantly modified).

1.4. Opportunities for community engagement

- From an ecological perspective, local landowners and residents could be steered towards 'river-friendly gardening', leaving 'shaggy edges' to increase habitat complexity and biodiversity – instead of clearing vegetation and woody material from the channel, which is detrimental to wildlife.

- Local people could take part in river-based citizen science programmes, such as riverfly monitoring and Westcountry CSI, as well as habitat enhancements and eradicating any invasive non-native species.

2. Introduction

This report is the output of visits undertaken by Theo Pike of the Wild Trout Trust on approximately 1 km of the River Axe and its associated mill stream in Wookey, Somerset.

This initial visit was undertaken on 19 October 2020 to provide a baseline habitat assessment of the urban reaches of the River Axe as part of the TWIST (Transforming Waterways In Somerset Towns) pilot project – understanding pressures on the urban water environment, as well as investigating opportunities for physical enhancements and engaging urban dwellers with their local river. Particular attention was paid to:

- identifying opportunities to 'slow the flow' and reduce flood risk
- identifying and prioritising barriers to fish migration
- identifying opportunities to improve water quality and habitat
- identifying opportunities and locations for community engagement

At the time of the walkovers, stream flows were judged to be at moderate autumn / early winter levels, and water clarity was very good.

Comments in this report are based on observations on the days of the visits and brief discussions with local residents. Throughout the report, normal convention is followed with respect to bank identification i.e. banks are designated Left Bank (LB) or Right Bank (RB) whilst looking downstream. The Ordnance Survey National Grid Reference system is used to identify specific locations.

Figure 1: A map showing the location of the River Axe and its mill stream at Wookey, Somerset

3. Catchment and location overview

The River Axe is an urban watercourse in the Somerset village of Wookey.

This small limestone river rises from springs on the heights of the Mendip Hills, running over areas of impermeable shale and other rocks before sinking into swallets and reappearing from the limestone at Wookey Hole caves. From here, the river flows south west to Wookey, and then broadly west and north-west along the southern edge of the Mendips, and eventually joins the Bristol Channel at Weston Super Mare.

River	River Axe
Waterbody Name	Axe – source to Cocklake
Waterbody ID	GB109052021520
Management Catchment	Somerset South and West / Brue and Axe
River Basin District	South West
Current Ecological Quality	Moderate (as at 2019)
U/S Grid Ref inspected	ST 52050 45713 (approx.)
D/S Grid Ref inspected	ST 51581 45651 (approx.)
Length of river inspected	1 km approx.

Table 1: Water Framework Directive (WFD) information for the River Axe

The village of Wookey is located south of the Mendip Hills, approximately 3 km downstream from the spring source of the River Axe at Wookey Hole – the second largest resurgence associated with the Mendips, with an average discharge of 789 litres per second.

This powerful spring is the outflow from a system of underground 'karst' channels and caves, which over time have been dissolved by rainwater percolating through the predominantly limestone geology of the Mendips. The origins of the water which reappears at Wookey Hole have been traced to a number of stream sinks or 'swallets' on the plateau above, including St Cuthbert's Swallet, Eastwater Swallet, Plantation Swallet and Priddy Green Sink (which are also associated with well-known cave systems such as Eastwater Cavern and Swildon's Hole). A second, smaller resurgence also appears in the grounds of Glencot House, c800m downstream.

Owing to the extended residence time of water in their underground aquifers, limestone streams are typically somewhat more stable in temperature and flow regime than rain-fed systems. When combined with calcium-rich and slightly alkaline water chemistry, these conditions can promote highly productive ecosystems, comparable in many ways to chalk streams. However, flows can move surprisingly quickly through subterranean limestone channels dissolved by acid rain.

Despite their reputation for pure, rock-filtered water, karst systems are vulnerable to pollution via sinkholes, swallets and quarrying activities, and such

contamination may also be long-lasting. In the case of the River Axe, this is exemplified by long-term lead pollution, whose impact is still noted in ecological assessments, but became contentious for the first time in the 1860s. When lead miners at Priddy allowed waste-water from 'puddling' to flow away down local swallets, the Wookey Hole paper millers noticed that the resurgence became muddy and contaminated with lead which affected the quality of the paper being made. After early experiments in dye tracing proved the connection between the Priddy swallets and Wookey Hole, the resulting court case eventually led to the abandonment of lead mining in this area.

Thanks to its reliable spring flows, the Axe's water was exploited for milling from an early date. In 1086, Domesday Book recorded the presence of mills at Wookey Hole and Wookey, the latter on the site of Burcott Mill (with buildings now dating from 1864). It is thought that the diverted leat which flows from Wookey to Bleadney, through the other 'mill stream villages' of Worth, Yarley and Henton, may represent Saxon engineering from c 950. The hydrology of the area was also complicated by the gradual medieval diversion of the River Brue, which once joined the Axe near Bleadney, but now flows across the Somerset Levels further south. Subsequently, the mill stream has also been diverted into the southern part of the historic moat which surrounded Wookey's medieval bishop's palace, one of the former properties of the bishops of Bath and Wells.

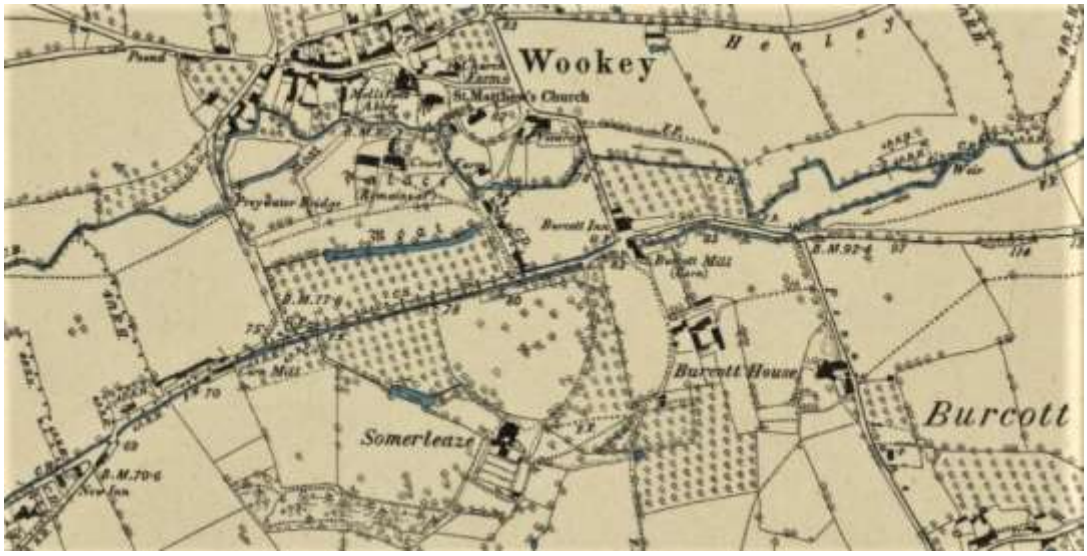

Figure 2: 1884 map of the River Axe, its mill stream and the palace moat at Wookey. (Reproduced with permission of the National Library of Scotland)

As well as karst system related pollution, limestone streams like the Axe can also be impacted by the usual range of spillage events and overland flows, including urban and agricultural runoff. In 2019, Bristol Avon Rivers Trust (BART) secured funding from the Somerset Catchment Partnership to carry out a Diffuse Pollution Sediment Pathways project on the River Axe. Around the same time, BART also undertook a habitat survey of the river. A summary of this work can be found, in the form of a story map funded by the Somerset Catchment Partnership, at: https://arcg.is/1mP1qq

In practice, the surveys for both of these projects seem to have started some distance downstream of Wookey. Thus, it is hoped that this report (also read in

conjunction with a similar report on the Wookey Hole area) will help to complete the picture and identify potential improvement opportunities in the upper catchment.

Classification Item	2013	2014	2015	2016	2019
Overall Water Body	Moderate	Moderate	Moderate	Moderate	Moderate
Ecological	Moderate	Moderate	Moderate	Moderate	Moderate
Supporting elements (Surface Water)	Moderate	Moderate	Moderate	Moderate	Moderate
Biological quality elements	High	High	Poor	Poor	Poor
Hydromorphological Supporting Elements	Supports Good	Supports Good	Supports Good	Supports Good	Supports Good
Physico-chemical quality elements	High	High	Good	Good	High
Specific pollutants	Moderate	Moderate	High	High	High
Chemical	Good	Good	Fail	Fail	Fail
Priority substances	Good	Good	Fail	Fail	Fail
Other Pollutants	Does not require assessment	Does not require assessment	Does not require assessment	Does not require assessment	Does not require assessment
Priority hazardous substances	Good	Good	Good	Good	Fail

Table 2: Water Framework Directive (WFD) details for the River Axe: for full details see https://environment.data.gov.uk/catchment-planning/WaterBody/GB109052021520

According to the Environment Agency's assessment of the River Axe under the Water Framework Directive (WFD: the scheme currently used to assess the Ecological Status or Ecological Potential of our surface waterbodies in Britain), the river is classified as a 'Heavily Modified Water Body' (HMWB).

For HMWBs like the River Axe, the classification of Ecological Potential (rather than Ecological Status) is applied. The Environment Agency (EA) data held for this waterbody indicate that it has an overall classification of 'Moderate Ecological Potential', according to the most recent assessment in 2019. Reasons for failing to reach 'Good Ecological Potential' (GEP) are described as industrial barriers to ecological continuity, urban development, agricultural land drainage, and lead pollution from mining.

Reviewing the EA's ecological data in more detail, it is concerning to note that the river's biological quality elements have declined from 'High' in 2014 to 'Poor' in 2015, and have remained at that level ever since. Within these data, invertebrates have remained 'High', but fish have declined precipitously, apparently for the same physical modifications as those listed for GEP failure as above (with the exception of lead pollution). Encouragingly, however, the river's underlying hydrological regime and hydromorphological supporting elements are still classified as 'High' and 'Supports good' respectively.

Moving on to the EA's chemical data, most chemical elements are classified either as 'Good' or 'Does not require assessment'. The exception is priority hazardous substances, including lead from historic mining (most likely in the Priddy area),

polybrominated diphenyl ethers (PBDE) flame retardant, and mercury and its compounds.

With the exception of lead, this is a situation which applies to a very high proportion of the UK's rivers, following new standards applied to chemical assessments in the 2019 round of WFD classifications. Under the 'one out, all out' rule, the River Axe now fails the EA's tests for chemical quality (whereas it passed them until 2015, when lead became a first reason for failure). Since the newly-measured chemicals are now considered to be chronically present in almost all of the UK's fresh waters, it is not currently known how this situation can be improved. However, since most of the River Axe's other chemical classifications are listed as 'Good' or 'Does not require assessment', this still implies considerable opportunities to enhance fish populations if historic fish passage and habitat issues can be addressed.

One of the major threats to urban rivers is the presence of sewage treatment works (STWs) which are liable to underperform or even fail catastrophically, resulting in fish kills (such as on the Sheppey in August 2019). This means that it is vitally important to optimise habitat and water quality in the 'safe' areas of catchments upstream of STWs – since these areas serve as vital refuges for populations of fish and other species which may be uniquely genetically adapted to the characteristics of their river, and therefore irreplaceable.

In the case of Wookey, the nearest STW discharges some distance downstream of the of areas discussed in this report. This does not preclude the possibility of combined sewer overflows (CSOs) as mapped in Figure 3 below, or misconnections or faulty septic tanks contributing to chronic pollution on the River Axe, but it does fortunately remove the threat of STW pollution from the river, and highlights the importance of improving the upper Axe as a vital reservoir of biodiversity for the whole catchment.

Figure 3: A map of CSOs on the River Axe at Wookey (data from 2019)

According to the Rivers Trust's interactive map of sewage outfalls (available via https://www.theriverstrust.org/what-we-do/is-your-river-fit-to-swim-in/ - most recent data

from 2019, as above) the River Axe at Wookey may be affected by 2 CSOs operated by the sewerage provider Wessex Water:

- ST 53119 46017 (approx.): Haybridge pumping station CSO: spill durations are not currently monitored at this location
- ST 51504 45637: Axe Road: in 2019 this CSO spilled 1 time for less than 1 hour

The following CSOs are also present further upstream at Wookey Hole:

- ST 53129 47321: Kennel Batch CSO: spill durations are not currently monitored at this location
- ST 53147 46927: Glencot Lane (Glen Cottage): in 2019 this CSO spilled 28 times for a total of 14 hours

The Environment Agency carries out routine monitoring of fish, invertebrates, macrophytes and diatoms on all rivers in England and Wales: these results are available in 'explorer' format at:

https://environment.data.gov.uk/ecology-fish/

The monitoring points for the Axe are located some distance up- and downstream of Wookey, as discussed below:

Macroinvertebrates

The EA's data shows two monitoring sites for macroinvertebrates on the River Axe: one of these is in Wookey Hole at ST 53190 47502, but the most recent survey at this location appears to have taken place in 2010. At that time, good counts of freshwater shrimp (200) and stoneflies (140+) were found, suggesting very high water quality.

More recent surveys have taken place further downstream, between Wookey Hole and Wookey at ST 52748 46064. In September 2019, the data show a reasonable count of freshwater shrimp (60) indicating good chemical water quality. Among other pollution-sensitive species, small dark olives (90) and stoneflies (10) were present. Good numbers of blue-winged olives (500) had also been counted earlier that year in April 2019, along with larger numbers of freshwater shrimp (250) and stoneflies (19).

Fish

All of the Environment Agency's fish monitoring sites are well downstream of the River Axe's urban areas at Wookey Hole and Wookey. According to available data, the most recent surveys appear to have taken place in 2011. This may suggest that the river's ecological classification as 'Poor' for fish been generated from physical characteristics (ecological discontinuity, urban development and land drainage) rather than from actual electrofishing data.

From observations during this survey, adult trout were certainly present at points high up the system: however, it is likely that fish passage issues such as weirs are currently limiting the population, and would make recolonisation difficult or even

impossible, if isolated upstream populations became extirpated by low flows or pollution incidents.

The UK's native wild brown trout are noted for their genetic variability and potential to produce (over the course of generations) locally-adapted strains which can cope with specific challenges posed by their particular environment. In light of the River Axe's history of lead pollution, it is highly probable that its trout population is uniquely adapted to surviving these elevated levels of lead which might kill trout not similarly selected to survive the river's particular cocktail of heavy metal contamination. The River Axe's trout are therefore potentially irreplaceable, so it would be highly beneficial to help their population to become as successful and resilient as possible.

The upper reaches of many limestone streams in the Mendips support healthy populations of fish, including trout, and it would be reasonable to suggest that a wide range of fish species could thrive in the urban reaches of Wookey Hole if water quality, quantity, fish passage and habitat issues were successfully addressed.

4. Habitat assessment

4.1. River Axe: main river channel (Vicarage Road to Preywater Road)

Figure 4: Looking downstream from Vicarage Road, the River Axe flows through residential gardens

The main stem of the River Axe enters the village of Wookey under the Vicarage Road bridge and immediately disappears from public view into private gardens, from ST 52049 45717 to ST 51935 45680 (approx.).

Within the channel, gravel and cobbles seem abundant, if perhaps unsorted. Although detailed assessment was not possible, experience suggests that river channels in residential areas like these have often been simplified and hardened, as well as overshaded, perhaps by non-native conifers and other evergreens (as shown in Figure 4 above). Ornamental lawns may also be mowed right down to the water's edge, leaving little marginal vegetation as habitat for insects, birds and fish. Runoff from roofs and paved areas is likely, and misconnections are possible.

Throughout this area, it would be worth engaging with local residents to highlight these potential issues and communicate the benefits of 'river-friendly gardening': solving misconnections, and promoting use of water butts, rain gardens, and permeable paving, as well as softening banks and improving in-channel habitat along individual lengths of stream.

Figure 5: The view upstream from Vicarage Lane

At Vicarage Lane, the river becomes visible again from the public highway, as shown in Figure 5 above. Despite a hard stone wall on the LB, the channel is geomorphologically active, with clean gravels and cobbles, and a point bar forming on the inside of the LB bend. Macrophyte growth is good in this unshaded area, with beds of ranunculus and emergent vegetation.

Historic maps suggest that the river was once wider at this point – perhaps the site of an older ford. Since then, the channel has been dramatically narrowed and armoured with gabion baskets near the bridge, and broken concrete and hard core on the RB further upstream. Indeed the adjacent land on the RB is now an unsightly area of very poor habitat value: marked as 'private land' on a makeshift fence, it is dominated by areas of burned concrete and other rubbish, and may be a source of pollution for the river.

It would be worth engaging with the landowner to improve the ecological and aesthetic value of this area, perhaps by replacing the rubble with a soft riparian fringe of native vegetation, for the benefit of insects, birds and fish.

Figure 6: A recently regraded garden bank, where a 'shaggy' trailing marginal fringe should now be allowed to develop

Following the River Axe downstream from Vicarage Lane towards St Matthew's Church, the RB is wooded and the LB is bounded by private gardens. At least one of these garden riverbanks seems to have been recently cleared and regraded (as shown in Figure 6 above), but the presence of young sedge plants at the toe of the bank suggests that a soft margin is already re-establishing itself.

As previously discussed, engaging with the local community to retain and develop such soft, 'shaggy' fringes of native vegetation, and encourage more 'river-friendly' gardening practices, would be highly beneficial.

Figure 7: Looking upstream from the church footbridge, this stretch of the Axe is overshaded and uniform, lacking habitat features

Near St Matthew's church footbridge, as shown in Figure 7 above, the river becomes rather heavily overshaded by trees on the LB (south). The channel is shallow, straightened and uniform, and the banks are armoured with gabion baskets and rock walls, or dominated by ivy (which, however, has been tidied at water level, leaving no trailing cover for insects and fish).

Tree management in this area is recommended, to reduce heavy overshading, allow more light into the river corridor, and create a 'mosaic' of dappled light and shade. Arisings from these tree works should be introduced to the river as flow deflectors and other Large Woody Material (LWM) structures – increasing flow complexity and localised scour and deposition, and creating a wide range of micro-habitats for different species. Increased light levels will also allow a more diverse riparian fringe to become established: this should be left shaggy and trailing to provide as much roughness and habitat complexity as possible.

With landowner permission, ST 51861 45753 (approx.) could also be a suitable site for riverfly monitoring by members of the local community.

Below the church footbridge, the river disappears into private gardens again, including the grounds of Mellifont Abbey, and is not easily accessible for several hundred metres downstream. The Historic England listing for the former bishop's palace in this area suggests that part of the river was 'realigned' for garden landscaping in the 19th century.

Figure 8: The straightened channel and small weir alongside Preywater Road: this weir is likely to be a barrier to small fish, while the shallow, uniform channel just upstream offers little habitat for larger adult trout

The River Axe reappears from the gardens of private properties at ST 51578 45692 (approx.), and flows alongside Preywater Road for about 100 m before turning sharp right, and crossing under the road in a concrete culvert.

Just upstream from the road bridge is a small weir (shown in Figure 8 above), which is not likely to be a significant barrier to most fish: however, removing this structure would facilitate natural passage for all species through the full range of flows. Further upstream, the roadside channel offers limited habitat value, being straight, shallow and overshaded by trees on the south western bank.

As above, tree works are recommended to create a patchwork of dappled light and shade, with enough light to allow new riparian plants to flourish, and arisings recycled as flow deflectors to increase hydrological roughness and habitat complexity. The aim should be to achieve a more sinuous flow within the existing constraints of the channel, restoring processes of localised scour and deposition, and creating varying habitat pockets for a wide range of species.

A foul water sewer pipe also crosses the river just above the bridge: this is not currently thought to threaten the river with pollution, but failure is always a possibility, and it would be worth checking with Wessex Water that regular maintenance checks take place.

Figure 9: Boulders and gravel on the downstream side of the Preywater Road bridge

After crossing under Preywater Road, the River Axe enters private gardens again, but its hydrological complexity seems to increase, with a wider range of substrate sizes including small boulders (and some litter including rubble sacks, probably fly-tipped from the bridge).

A few metres downstream, a flow of water enters the channel from a pipe on the LB: this is believed to be the outfall of the minor channel from the mill stream which is culverted from ST 51632 45572 (see below). Adult trout were observed in this area, moving around the boulders, and in and out of the shadow of the bridge.

4.2. River Axe: mill stream (Burcott Mill to Preywater Road)

Figure 10: An impassable stepped cascade at Burcott Mill

Having been diverted from the main River Axe at ST 52514 45712 (approx.), the mill stream takes a more southerly course to reach Burcott Mill, where water-power is still used to grind flour. At the time of this walkover, it was not possible to assess fish passage possibilities in detail: however, a stepped cascade overspill from the mill pond, at least 1m in height, could be seen from the south verge of the B3139 Wells Road. This overspill is considered to be completely impassable to all fish at any flow of water. Options for fish passage, including eels, on this cascade should be investigated (perhaps with a rock ramp type structure - also taking into account the passability of the culvert just downstream).

The flow from this cascade appears to enter a culvert under the road, and re-emerges in the Glebe Paddock green space to the north of the B3139. On the south side of the road, at ST 52065 45592 a small non-flowing channel could also be seen, possibly the tailwater of the mill, but its reconnection to the main mill stream was not evident.

Figure 11: Fluming of flow through the culvert under the B3139 Wells Road

Flow from the mill pond overspill reappears from an ornamental stone double pipe culvert, and enters a pool whose banks are reinforced with stone gabion baskets, and a very low stilling weir at the tail. Perhaps related to intermittent activity at the mill, the flow from the culvert seemed to be highly variable, with water levels in the pool fluctuating by as much as 4 – 6 inches in just a few minutes. At times of low flow, several adult trout could be seen in the pool, clearly showing signs of panic when water levels dropped enough to remove the security of deeper water and a broken water surface. (Figure 11 above shows high flow, Figure 12 below shows low flow for comparison).

At either flow, the culvert pipes are a barrier to fish passage, and consideration should be given to replacing them with a single-span, partially sunken box culvert.

Figure 12: Low flows from the same culvert

Figure 13: A deeply scoured pool, with slight undercutting by erosion on the LB

Downstream from the stilling weir, the mill stream has scoured another deeper pool, where trout were also observed. The LB is no longer reinforced with stone gabion baskets, so the energy of the stream has been released in this area, and some undercutting by a back eddy was noted, potentially starting to undermine the private garden above. (The properties on the LB, between the mill stream and the B3139, may in fact be built on a previous course of the mill stream, as shown in the 1884 map in Figure 2).

Erosion is a natural river process which creates variations of flow and habitat in every river: however, under some circumstances, it can threaten human infrastructure. In this case, it would be wise to reinforce the eroding bank with soft, energy-absorbing materials such as brush bundles or recycled Christmas trees, possibly interspersed with whips of live willow which will root and add further structural strength. Some tree management in this area would also allow more light into the stream channel, and help reinforced areas to vegetate quickly and sustainably. Pinning the arisings into the channel as LWM, in this pool and the one above, would help to provide refugia for fish, especially if fluctuating flows from the mill cannot be 'smoothed' (although this should also be investigated with the proprietors).

Along the top of the vertical RB, piles of grass clippings had been dumped, possibly after mowing the Glebe Paddock green space. These are likely to leach high levels of nutrients into the stream as they decompose, potentially also raising Biological Oxygen Demand (BOD) in the water which can result in the death of fish and invertebrates. They will also suppress the growth of natural bankside vegetation, leaving areas susceptible to erosion. Disposal and / or composting of green garden waste should always take place as far from a waterway as possible.

Figure 14: Straight and shallow, this stretch of channel offers very little habitat value, but could be transformed through the addition of in-channel structure

Proceeding downstream, the straight channel now becomes extremely shallow and featureless, with a flat bed of unsorted sediment and individual cobbles (possibly eroded and deposited from the deeper pools upstream), and overshading from a non-native conifer hedge on the LB. Some very small 'humps' of fine sediment seem to have formed around stands of starwort, but these are periodically exposed to the air as the water levels rise and fall. By contrast to the pools above, no fish were observed in this area.

Improvements to this stretch could include creating a sinuous inset low flow channel to focus available flows, with alternating flow deflectors to create and maintain deeper areas of scour and sediment sortation, and vegetated berms for 'shaggy', soft edges. Such measures would provide aesthetic benefits for local residents, as well as vastly improved habitat for insects, birds and fish (including trout at all life stages).

Figure 15: A redundant stepped gabion weir in the former moat

The mill stream now flows under a private property and Vicarage Lane in a long double pipe culvert (shown on page 1 of this report). This constitutes a fish passage issue in its own right, but could be addressed with a rock ramp at its downstream end, plus a partially sunken box culvert as discussed previously). Downstream of the culvert, the stream emerges into a further green space: the former grounds of the medieval bishop's palace.

According to Historic England's listing for this site, the southern part of the palace moat 'has been reworked to form a later water leat'. Some of the most recent modifications are clearly visible in the form of gabion baskets used to reinforce the banks. There is also a stepped gabion weir (as shown in Figure 15 above), which appears to perform no useful function, but interrupts the longitudinal connectivity of habitat about halfway along the reach, and is thereby damaging to the health of the river ecosystem (as discussed in *Appendix 3: Weirs and their impacts*).

As a result of past channelisation, exacerbated by the effect of the weir, this whole 200 m length of river is straight, shallow and overwide, even at higher flows from Burcott Mill, and almost devoid of complex habitat, except where small branches have hinged themselves into the water from the LB. It is also overshaded by trees on the LB (south), and most of the RB had been closely strimmed down to the waterline - including an area which had become invaded by horsetail (Equisetum arvense), a native but invasive species which is poisonous to livestock, particularly horses. Ivy on the LB has also been trimmed back, negating any benefit as trailing cover. However, a small number of trout were seen in the culvert pool at the top at the top of this stretch, and in the gabion weir's plunge pool, and it is reasonable to suggest that their numbers could increase in line with more complex, connected habitat.

To restore habitat complexity, it would be well worth investigating removal of the weir and breaking the stream out of its current channel completely - reconnecting it to its floodplain with a new, meandering and much more naturalistic course across part of the green space. This would greatly enhance the habitat potential and aesthetic interest of the whole area, as well as helping to 'slow the flow' of flood waters into residential areas downstream.

Less ambitiously, the redundant weir should still be removed, while the channel could be allowed to regrade through the reach with the assistance of in-channel LWM – with the aim of creating a pool and riffle sequence with soft edges and a sinuous low flow channel. The invasion of horsetail could be removed by careful digging out, if it looks likely to suppress less vigorous native species. Shading from the LB should also be reduced, and the arisings introduced into the resculpted channel as LWM: this will also promote natural processes of scour and deposition, and create complex habitat niches for different species. Trees could also be hinged into the channel.

With landowner permission, ST 51822 45599 (approx.) could be a suitable site for riverfly monitoring by members of the local community.

Figure 16: A small impoundment at the western end of the former moat

At ST 51717 45586 the mill stream appears to be impounded by a small sluice structure, which directs most of the flow in a south westerly direction under a culvert bridge (as shown in Figure 16 above).

The remainder of the flow drops into a minor channel, very incised and overshaded, which flows towards Preywater Road: here it becomes culverted at ST 51632 45572 and joins the main River Axe at ST 51583 45652. Plenty of gravels were visible just above the Preywater Road culvert, suggesting that this very small channel might still provide useful trout spawning habitat if fish passage issues at the upper and lower ends could be addressed (there may also be a small weir about halfway down this reach). However, it is accepted that the long culvert under Preywater Road could make this difficult to achieve.

Figure 17: Looking upstream from the B3139

From the culvert bridge, the main channel of the mill stream flows alongside an orchard in a deeply incised channel, and crosses under the B3139. As shown in Figure 17 above, the flow appears silty and sluggish, and is possibly impounded by the road bridge footings, or another structure on the south side of the road (which may also constitute a fish passage issue). A small tributary also appears to enter from the LB, south of the road, flowing from a pond at ST 51833 45407.

Habitat value in this stretch could be improved by adding LWM to increase roughness and add habitat complexity. Small trees could also be hinged down from the LB hedge. Instead of strimming down to the waterline on the RB, a more relaxed mowing regime would allow a beneficial 'shaggy', trailing marginal fringe to become established.

Figure 18: A source of sediment as a result of poaching by livestock

After flowing under the road, the mill stream takes a sharp right turn, and flows west along the south side of the B3139, past the western end of Wookey, in the direction of Worth, Yarley and Bleadney.

At least one small boulder weir could be glimpsed, and this should be removed for fish passage and sediment transport. The gravels in this area appear mainly clean and scoured, but one part of the LB has been poached by livestock (possibly exploiting a point where a toppled tree's root ball has provided easier access down the steep bank). As shown in Figure 18 above, this is likely to be a small but persistent sediment pathway into the river, and it would be beneficial to fence off this access point, and water livestock with a pasture pump instead.

5. Recommended projects and improvements

5.1. Citizen science: Riverfly monitoring

Riverfly monitoring is a tried and tested methodology which enables local volunteers to support the statutory agencies by checking the health of their neighbourhood river. Such citizen science activities also have a track record of enhancing community cohesion and sense of place – all of which will be particularly important as Somerset emerges from Covid-19.

Subject to landowner permission, easy-access potential locations for riverfly monitoring, and other citizen science projects like Westcountry CSI, have been identified at:

- ST 51861 45753 (approx.): channel near St Matthew's Church
- ST 51822 45599 (approx.): channel alongside former bishop's palace green space

5.2. Habitat improvements

Flow deflector

Figure 19: A flow deflector log pinned at an angle, using rebar stakes, partially across the stream (split chestnut stakes can also be used). In order to create scour in the centre of the channel, the log is angled upstream, with flows coming off it at 90 degrees. At lower flows, the stream width is reduced, keeping the gravels clean and helping to move mobile sediment downstream. Higher flows can run over the top with little impediment.

Hinged trees

Figure 20: To reduce overshading and increase habitat, bankside trees can be hinged into the edge of a river so that they can continue to grow (depending on species) and provide low-level cover for fish, insects and birds. For extra security, the branches can be staked, or the trunk can be cabled back to the stump.

Soft vegetated margins

Figure 21: Millais's 'Ophelia' was painted from life on the banks of the Hogsmill chalkstream, and is widely regarded as a portrait of a perfect, diverse assemblage of native riparian plant species

6. Making it happen

The creation of any structures within 'Main Rivers' or within 8m of the channel boundary (which may be the top of the flood-plain in some cases) normally requires a formal Environmental Permit from the Environment Agency. This enables the EA to assess possible flood risk, and also any possible ecological impacts. Many watercourses perceived to be lower flood risk are not designated as 'Main River', in which case they are classed as 'Ordinary Watercourse' and the body responsible for issuing consent will be the Local Authority. In any case, contacting the EA early and informally discussing any proposed works is recommended as a means of efficiently processing an application.

The WTT website library has a wide range of free materials in video and PDF format on habitat management and improvement:

http://www.wildtrout.org/content/index

A focused Trout in the Town Urban River Toolkit is available at:

https://www.wildtrout.org/content/trout-town

There is also the possibility that the WTT could help via a Practical Visit (PV). PV's typically comprise a 1-3 day visit where WTT Conservation Officers will complete a demonstration plot on the site to be restored.

This enables recipients to obtain on the ground training regarding the appropriate use of conservation techniques and materials, including Health & Safety, equipment and requirements. This will then give projects the strongest possible start leading to successful completion of aims and objectives.

Recipients will be expected to cover travel and accommodation (if required) expenses of the WTT attendees.

There is currently a big demand for practical assistance and the WTT has to prioritise exactly where it can deploy its limited resources. The Trust is always available to provide free advice and help to organisations and landowners through guidance and linking them up with others that have had experience in improving river habitat.

7. Acknowledgement

The Wild Trout Trust would like to thank the Environment Agency and Somerset Catchment Partnership for funding this walkover survey.

8. Disclaimer

This report is produced for guidance; no liability or responsibility for any loss or damage can be accepted by the Wild Trout Trust as a result of any other person, company or organisation acting, or refraining from acting upon guidance made in this report.

9. Appendix: Summary tables of recommendations

9.1. River Axe: main river channel

Location	**Photo** (If required)	**Priority (1-3)**	**Grid reference**	**Proposed action**
Properties below Vicarage Lane (and throughout Wookey)		1	**ST 52049 45717 to ST 51935 45680 (approx.)**	Habitat: Engage with residents to promote river-friendly gardening
Riverside land at Vicarage Lane		1	**ST 51935 45680 (approx.)**	Habitat: engage with landowner to improve aesthetic and habitat value of riverside land
Channel near St Matthew's Church		1	**ST 51861 45753 (approx.)**:	Habitat: tree management to reduce overshading from trees on LB; introduce arisings to river as beneficial LWM

Channel along Preywater Road		1	**ST 51578 45692 to ST 51590 45654 (approx.):**	Habitat and fish passage: remove weir, reduce overshading, introduce LWM, and soften hard channel edges

9.2. River Axe: mill stream

Observation	**Photo** (If required)	**Priority (1-3)**	**Location**	**Proposed action**
Burcott Mill		2	**ST 52111 45601 (approx.)**	Fish passage: investigate options for making overspill passable (including eel passage easement) – both could be achieved with a rock ramp type structure
Low / variable flows from Burcott Mill		1	**ST 52072 45614**	Water quantity and habitat: investigate and smooth variable flows from Burcott Mill if possible; introduce LWM as cover for fish in low flows. Also investigate replacing pipes with passable box culvert, or install embedded rock ramp

Grass cuttings dumped beside mill stream		1	**ST 52072 45614**	Compost grass cuttings further from river to avoid leachate pollution
Erosion on LB		1	**ST 52039 45610**	Habitat: reinforce LB with brash bundles to prevent undercutting of private garden
Channel near Glebe Paddock green space		1	**ST 52005 45611 (approx.)**	Habitat: create sinuous low flow channel with LWM and soft margins for roughness and diversity
Pipe culvert under Vicarage Lane		2	**ST 51927 45610**	Fish passage: address lower end of culvert with rock ramp, and investigate replacing pipes with passable box culvert

Channel alongside former bishop's palace green space		2	**ST 51927 45610 to ST 51717 45586**	Habitat and fish passage: remove weir and regrade stream with sinuous low flow channel and LWM / hinged trees to reduce shade from LB. More ambitiously, break out channel into adjacent green space
Preywater Road culvert		3	**ST 51627 45573**	Fish passage: address fish passage issues to allow spawning access to minor channel (possibly difficult due to length of culvert)
Channel alongside orchard		2	**ST 51717 45586 to ST 51707 45504**	Habitat: introduce LWM for more complex habitat and fish refugia, perhaps hinging small trees from LB hedge; also allow shaggy trailing fringe to develop on RB
Channel on south side of B3139		1	**ST 51683 45485 (approx.)**	Habitat and fish passage: address any fish passage issues; fence off poached area and provide pasture pump for livestock

10. Appendix 2: Trout habitat

Due to their need for clean, well-oxygenated water, structurally-varied habitat, and free movement between different types of habitat at different life stages, the UK's native wild brown trout makes an ideal indicator species for healthy rivers. These characteristics mean that a simple and effective assessment for overall river health can be based around the life cycle requirements of brown trout.

As a result, identifying and noting the presence or absence of habitat features that allow trout to complete their full life cycle is a very practical way to assess overall habitat quality (Figure 22). By identifying the gaps (i.e. where crucial habitat is lacking: Figure 23 to Figure 25), it is often possible to design actions to solve those habitat bottlenecks.

To put all this into context, there are three main habitat types required for wild trout to complete each of their three key life cycle stages. This creates a demand for varied habitat, which is vital for supporting a wide diversity of other species too.

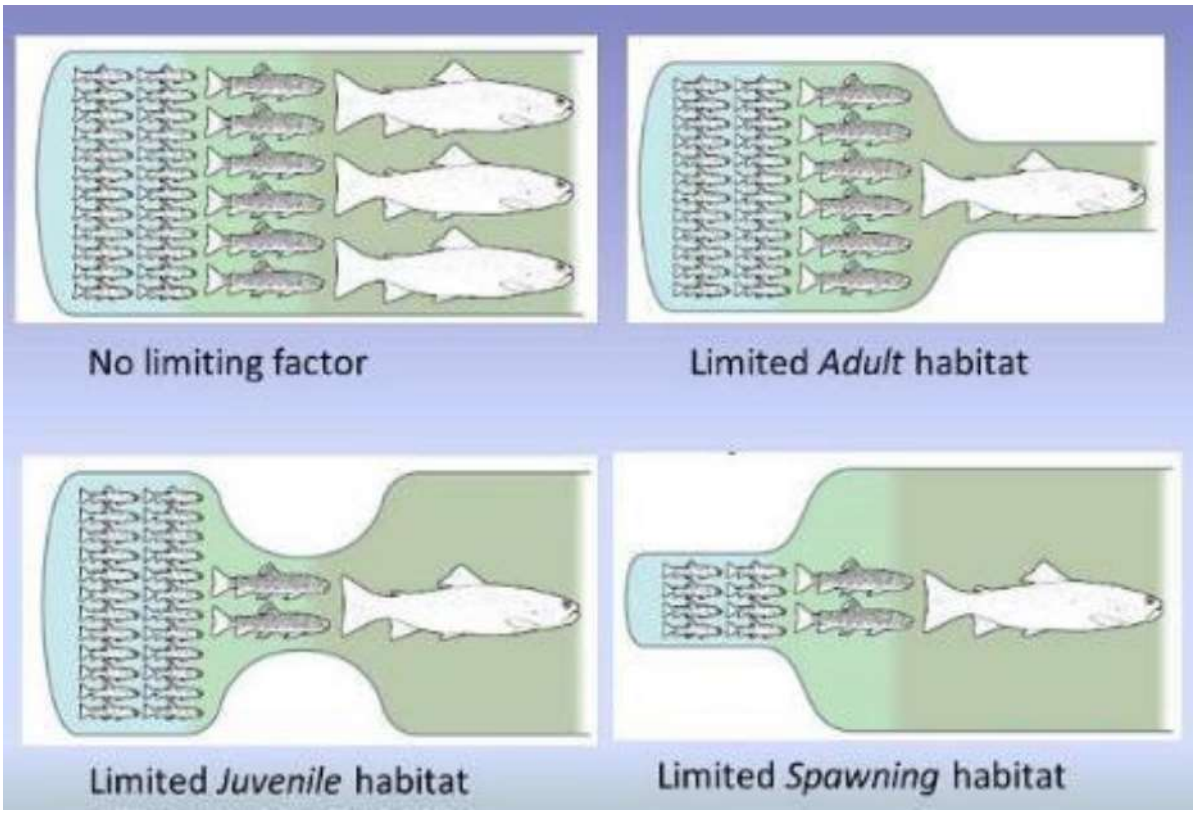

Figure 22: The impacts on trout populations lacking adequate habitat for key life cycle stages. Spawning trout require loose gravel with a good flow-through of oxygenated water. Juvenile trout need shallow water with plenty of diverse structure for protection against predators and wash-out during spates. Adult trout need deeper pools (usually > 30cm depth) with nearby structural cover such as undercut boulders, sunken trees/tree limbs and/or low overhanging cover (ideally trailing on, or at least within 30cm of, the water's surface). Excellent quality in one or two out of the three crucial habitats may not mitigate a 'weak link' in the remaining critical habitat.

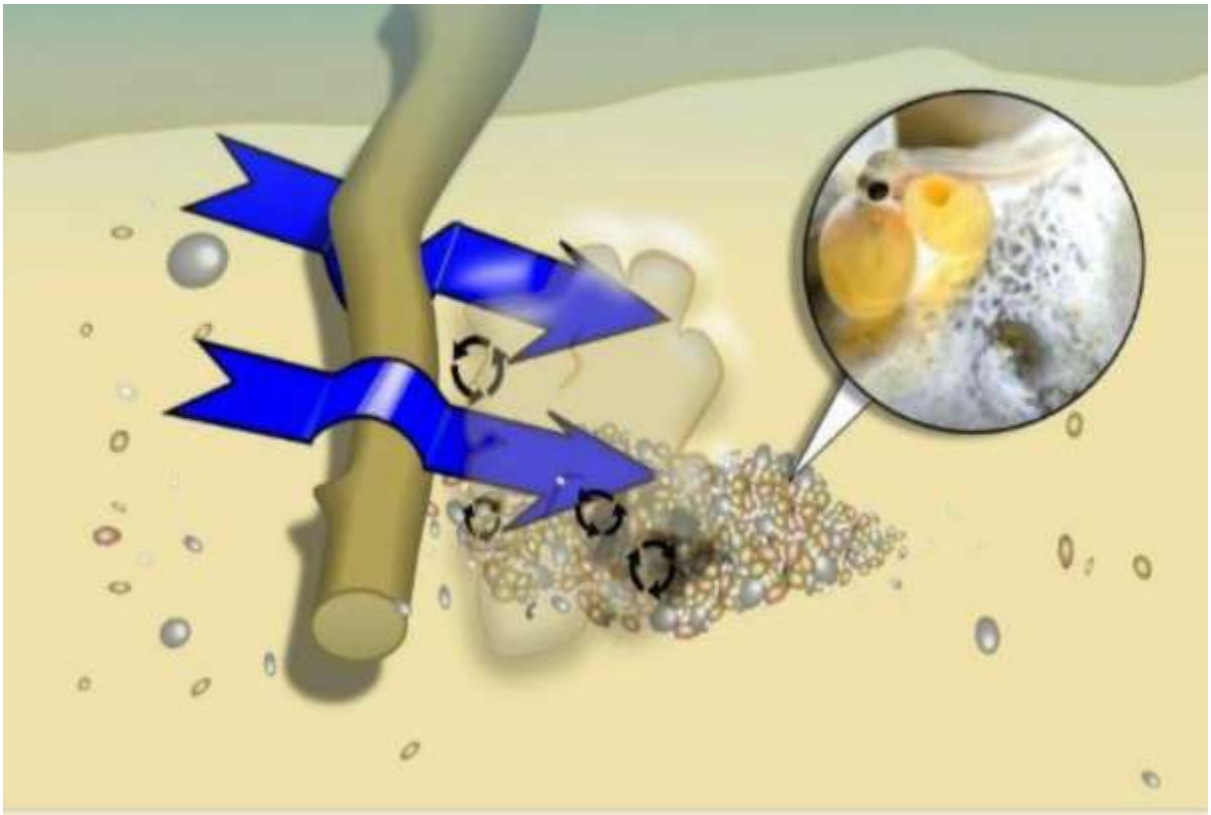

Figure 23: Successful trout spawning habitat requires relatively silt-free gravels. Here, the action of a fallen tree limb is focusing the flows (both under and over the limb as indicated by the blue arrows) on a small area of riverbed that results in silt being washed out from between gravel grains. A small mound of gravel is deposited just below the hollow scoured out by focused flows: this mound will be selected by trout to dig a 'redd' for spawning. In the silt-free gaps between the grains of gravel it is possible for sufficient oxygen-rich water to flow over the developing eggs and newly-hatched 'alevins' to keep them alive as they hide within the gravel mound (inset) until emerging in spring.

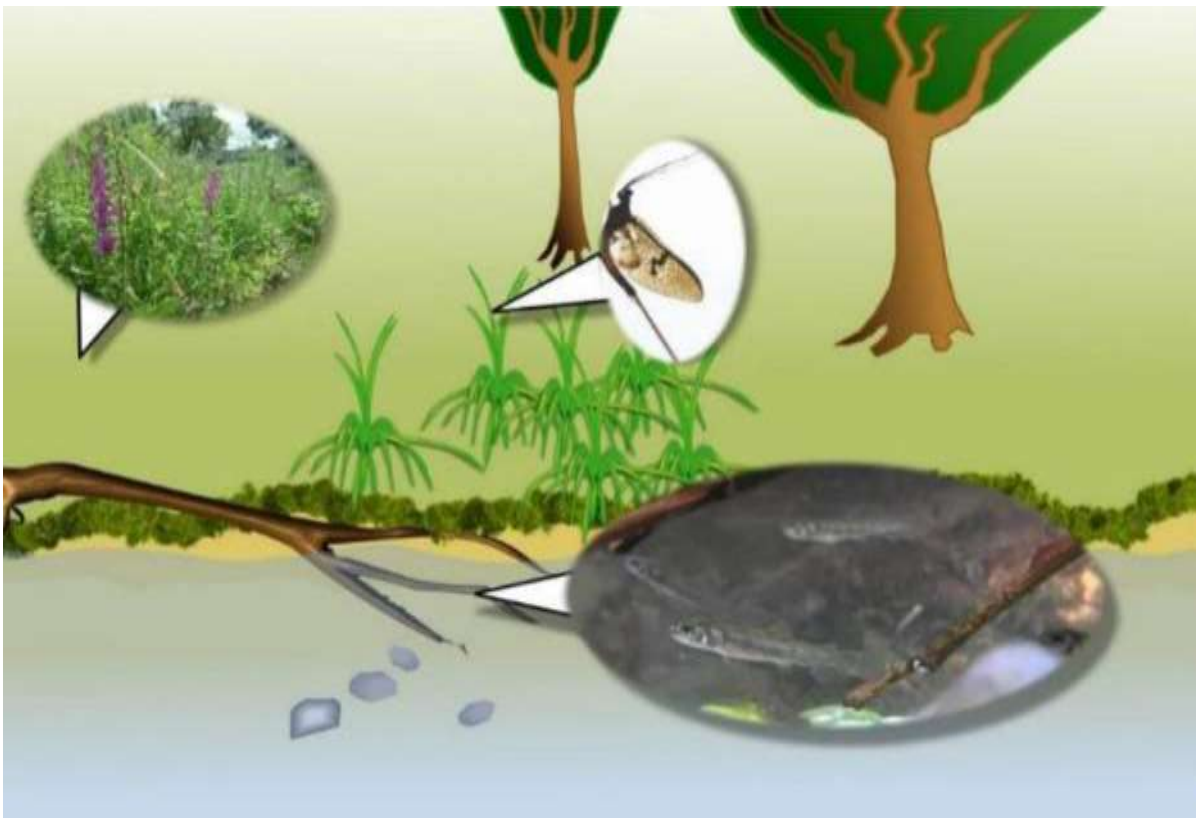

Figure 24: Larger cobbles and submerged 'brashy' cover and/or exposed fronds of tree roots provide vital cover from predation and spate flows for tiny juvenile fish in shallower water (<30cm deep). Trailing, overhanging vegetation also provides a similar function, and has many benefits for invertebrate populations (some of which will provide a ready food supply for the juvenile fish).

Figure 25: The availability of deeper water bolt holes (>30cm), low overhanging cover and/or larger submerged structures such as boulders, fallen trees, large root-wads etc. close to a good food supply (e.g. below a riffle in this case) are all strong components of adult trout habitat requirements.

11. Appendix 3: Weirs and their impacts

Urban rivers usually exhibit a typical mixture of challenges, including weirs, hard/revetted banks, culverts, impoundments, and straightened/modified channels.

Among these modifications, weirs are perhaps the most damaging. Many of these are likely to have been constructed to provide a head of water for milling purposes: more recently, others may have been installed with the aim of 'keeping more water in the river' – in reality, an intervention which always does more harm than good.

Weirs tend to create extended stretches of slowly-moving water, where sediment carried in suspension drops out of the water column uniformly across the stream bed, and habitat quality and diversity are severely degraded (Figure 26). Such conditions can sometimes temporarily provide sufficient deep water habitat for small numbers of adult trout and other species (until the deep water inevitably fills with sediment) but are generally unsuitable for many beneficial invertebrates, and gravel spawning fish, fry and juveniles.

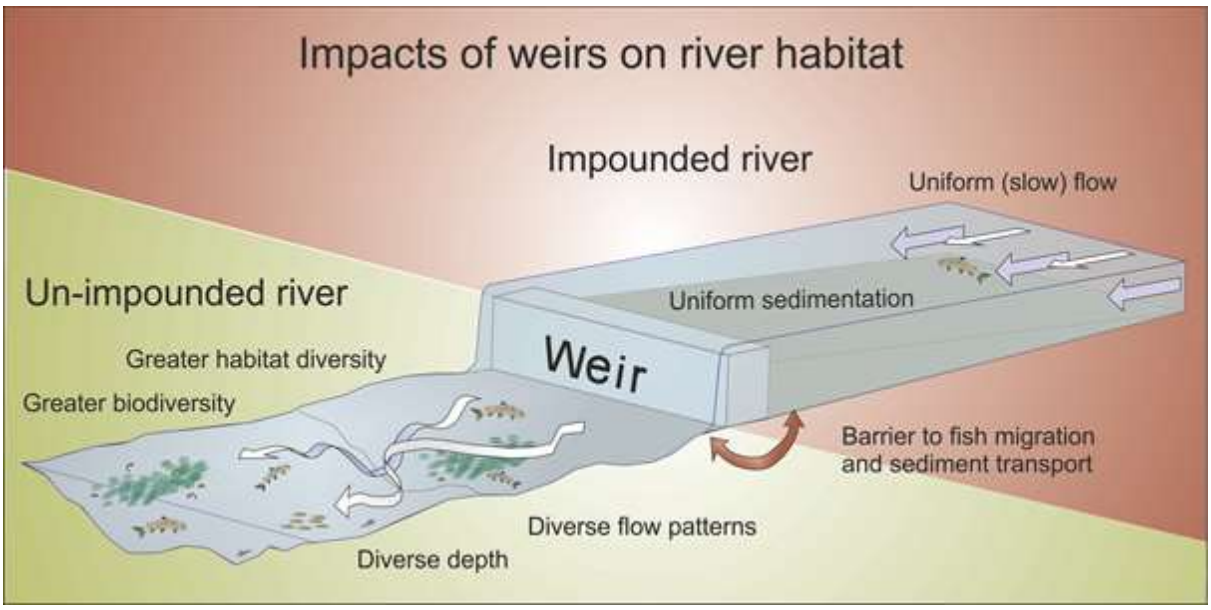

Figure 26: An illustration showing the impacts of weirs on habitat quality

Weirs of all sizes are often significant obstacles – or even complete barriers – to fish passage, preventing many species from moving up and down rivers freely to fulfil the different stages of their life cycles. Weirs also interrupt the natural transport of river sediment (Figure 27). This can cause the river downstream to become depleted of coarse sediment, and increase rates of bed and bank erosion as a result of the interrupted supply of suitable gravel and cobbles from upstream.

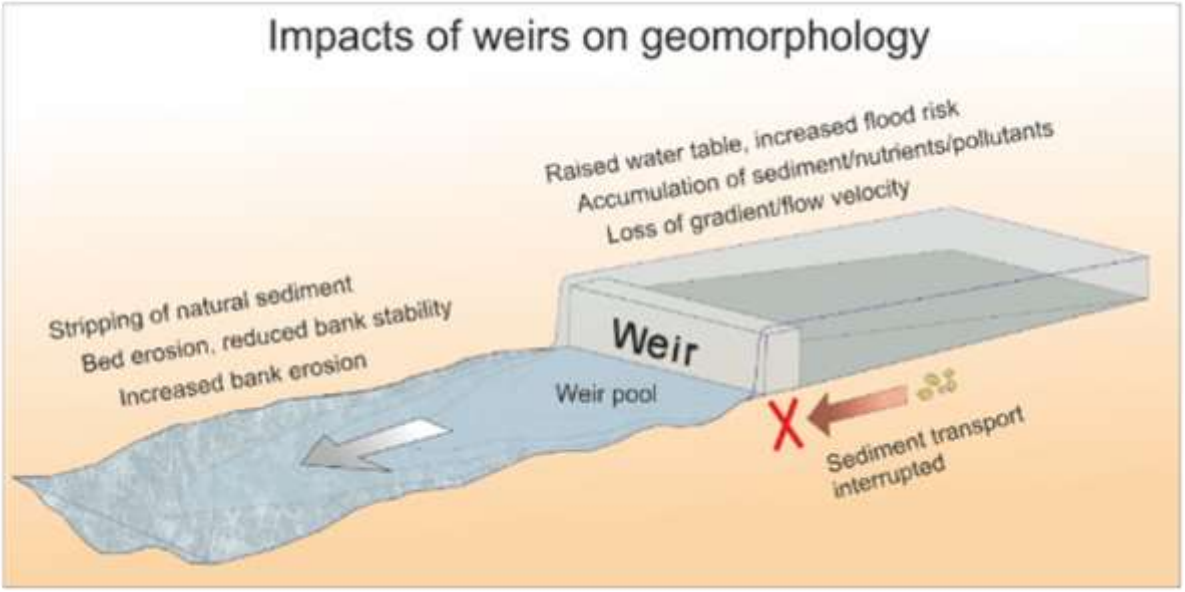

Figure 27: An illustration showing the impacts of weirs on river geomorphology

Weirs and other modifications also produce cumulative effects in terms of their impact. More information about weirs, and the benefits of removing them, can be found on the following links:

https://www.wildtrout.org/content/weirs-culverts-and-barriers

http://urbantrout.blogspot.com/2018/02/why-presume-to-remove-weirs-with-river.html

https://www.americanrivers.org/threats-solutions/restoring-damaged-rivers/how-dams-damage-rivers