Advisory Visit

R Wharfe & tributaries, Bolton Abbey Estate, Sept 2019

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Key Findings

- The Wharfe at Bolton Abbey is already a relatively large river and affected by topography and land management in various guises beyond the reach of the Estate, for better *and* for worse.
- In an area of high rainfall, depauperate vegetation on the higher fells and generally steep gradients in the local tributaries combine to increase conveyance of spate flows. This exacerbates erosion and can degrade habitat (especially the substrate) throughout the Estate waters, and beyond.
- However, naturally diverse topography and a lack of management in some of the wooded valley sections, coupled with replanting of riparian areas with trees and exclusion of livestock, has demonstrably resulted in areas of fantastic quality riparian and better quality instream habitat.
- The majority of the main stem Wharfe and mid-lower reaches of Hambleton, Barden, and Kex Becks are lacking gravel (a function of the spate flows, a lack of channel sinuosity and complexity from historical channel 'straightening', and in the case of Barden, the reservoir), and hence even the smallest of tributaries is important for spawning habitat. It is generally easier to improve smaller watercourses than larger ones, and the Estate controls much, if not all, of some of the sub-catchments.
- There is great potential for simple, low-cost, small-scale natural flood management approaches such as leaky dams to be applied. Key will be to prevent the water from gaining momentum by 'slowing the flow' little and often before it reaches the steepest parts of the fells, and thereafter by instigating or maintaining as long a channel as possible (via meandering) as it reaches the flatter valley floors.
- There is sufficient space, and the raw materials on the Estate, to apply these approaches without unduly compromising the current management regimes. Indeed, the benefits are multiple, including reduced loss of land area / soil cover as well as increasing biodiversity and ecological functioning.

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1.0 Introduction

This report is the output of a series of site visits to the Bolton Abbey Estate which encompasses a middle section of the River Wharfe and several key tributaries (Maps 1 & 2 for an overview). The assessment was requested by the Estate Manager, undertaken by Prof J Grey of the Wild Trout Trust, and parts of the walkover were accompanied by the Riverkeeper.

Normal convention is applied with respect to bank identification, i.e. left bank (LB) or right bank (RB) whilst looking downstream. Upstream and downstream references are often abbreviated to u/s and d/s, respectively, for convenience. The Ordnance Survey National Grid Reference (NGR) system is used for identifying locations.

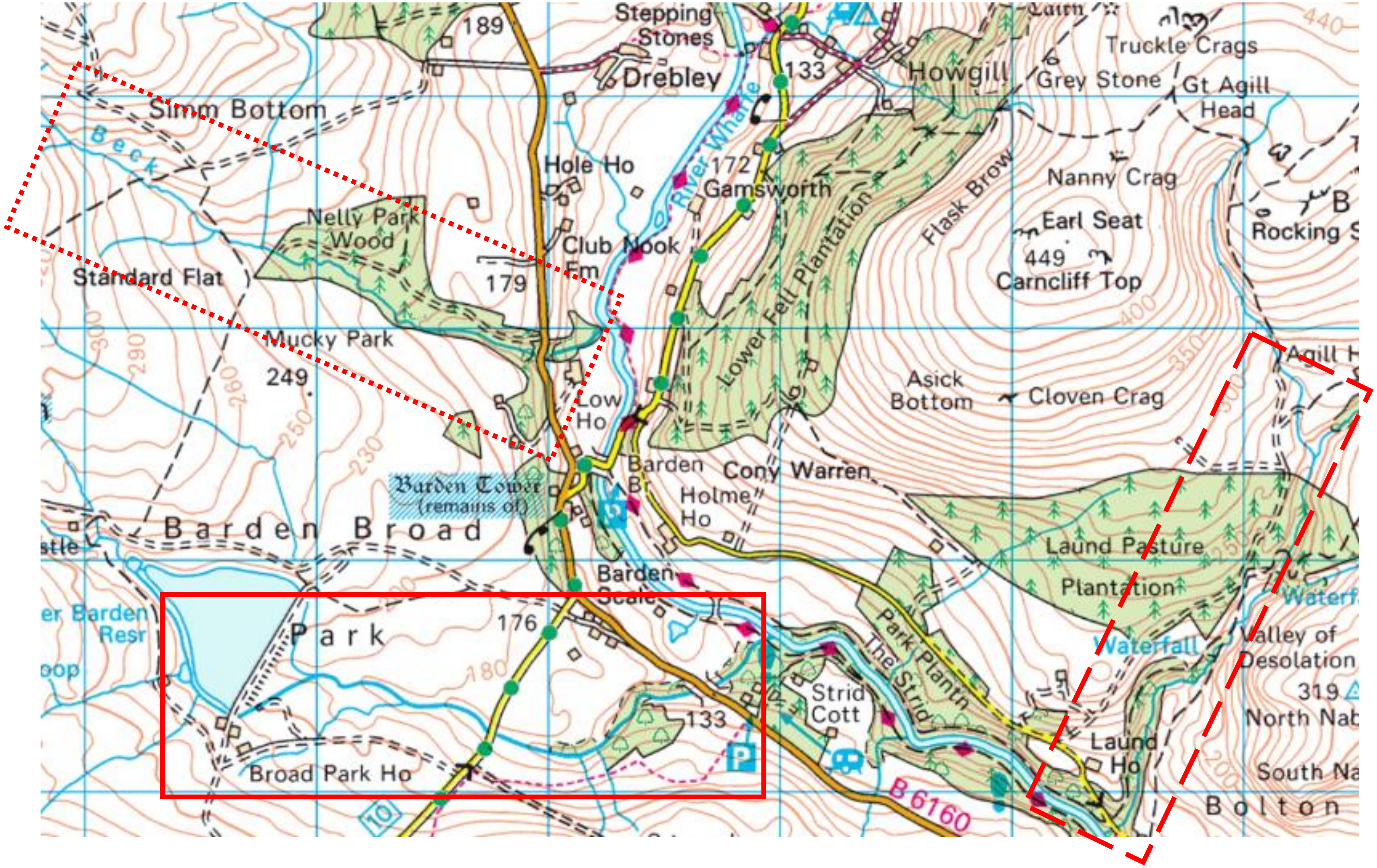
Under the Water Framework Directive (WFD), three of the classified waterbodies examined are considered Heavily Modified Water Bodies (HMWBs); only Kex Beck is considered a natural watercourse (Table 1, overleaf).

It is important to note that five ecological classes are used for WFD Water Bodies: High, Good, Moderate, Poor, and Bad. These are assessed against 'Ecological Status' (or 'Ecological Potential' in the case of HMWBs). The status (or potential) of a waterbody is derived through classification of several parameters: water quality, physical condition and barriers, invasive non-native species, fish, and flows and levels. The overall status is then dictated by the lowest score amongst those parameters. However, it is important to note that, in the case of HMWBs, the status of fish (and benthic invertebrates) are often discounted as the HMWB designation already highlights a potential impact on those biological indicators, but as these are of the greatest immediate importance to angling clubs, they should not be overlooked.

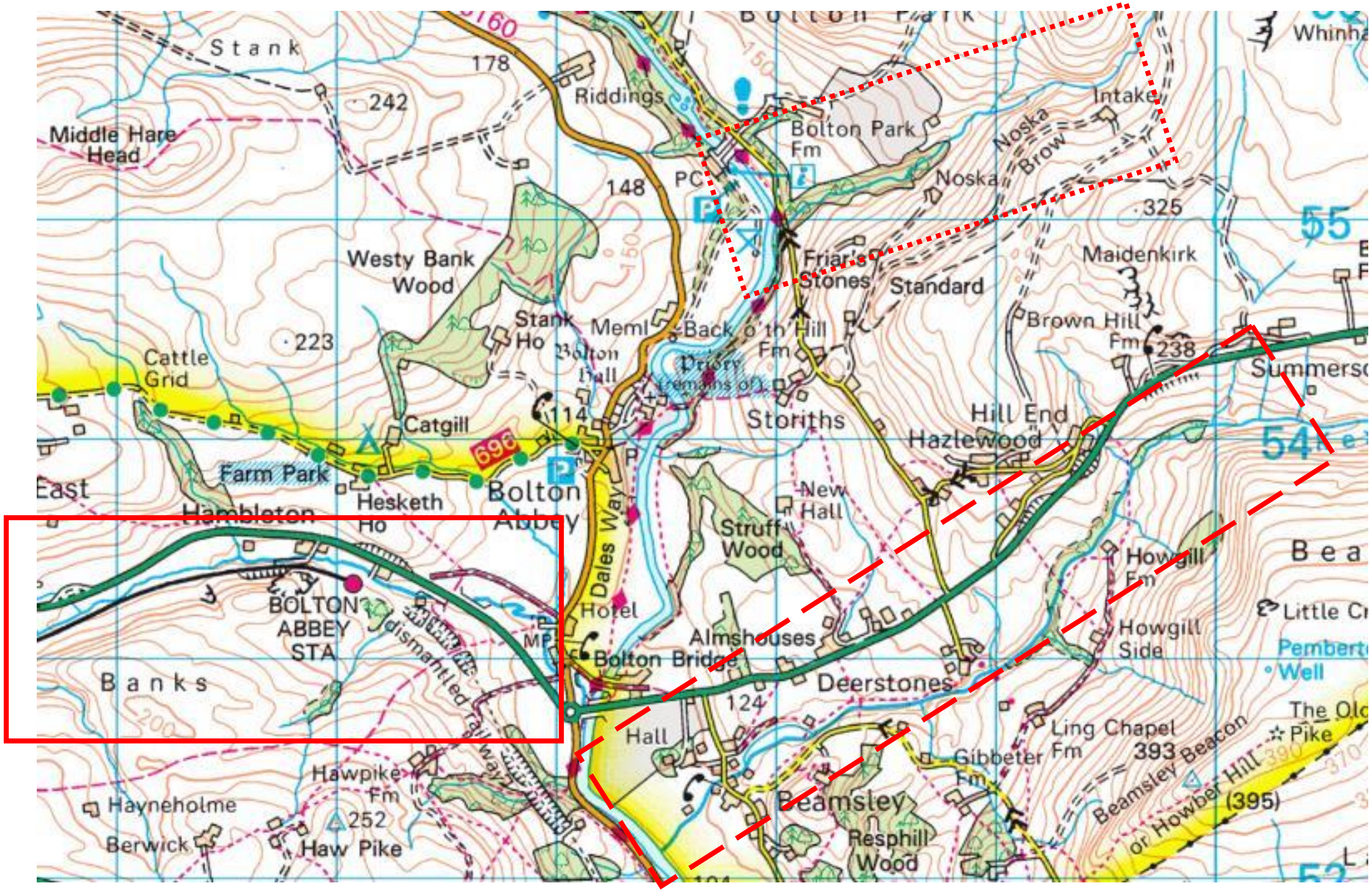
Through the period 2013-2016 assessment, all four waterbodies fail to achieve Good Ecological Status or Potential; indeed, Kex Beck deteriorated over the period from Good to Poor, with the component most affecting the results across all waterbodies designated as Fish.

	Bolton Abbey Estate			
River	River Wharfe			
Operational Catchment	Wharfe Middle and Washburn			
River Basin District	Humber			
Waterbody Name	Wharfe from Barben Beck / R Dibb to Hundwith Beck	Hambleton Beck / Ings Beck catchment	Barden Beck catchment	Kex Beck catchment
Waterbody ID	GB104027064257	GB104027064030	GB104027064060	GB104027064050
Current Ecological Quality	Heavily Modified Overall potential of **Moderate** has been sustained from 2013 - 2016	Heavily Modified Overall potential of **Moderate** has been sustained from 2013 - 2016	Heavily Modified Overall potential of **Moderate** has been sustained from 2013 - 2016	Overall status has declined from **Good** to **Poor** ecological status from 2013 - 2016
U/S NGR inspected	SE 05815 59186	SE 05102 53340	SE 03967 56496	SE 11839 54725
D/S NGR inspected	SE 07458 52094	SE 07105 52720	SE 05954 56651	SE 07458 52094
Length of river inspected	~10,700m incl several small trib lower reaches	Spot checks plus ~1200m	~2400m	Spot checks plus ~1500m

Table 1. Overview of the waterbody. Information sourced from:
https://environment.data.gov.uk/catchment-planning/WaterBody/GB104027064257



Map 1. Overview map of upper reaches. Red rectangles are: solid – Barden Beck, Map 7; dotted – Gill Beck, Map 8; & dashed – Posforth Beck, Map 3.



Map 2. Overview map of lower reaches. Red rectangles are: solid – Hambleton Beck, Map 6; dotted – Pickles Gill, Map 4; & dashed – Kex Beck, Map 5.

Catchment / Fishery Overview

The River Wharfe is a gravel bed river in a glacial valley, rising on Camm Fell in the Yorkshire Dales National Park and flowing for ~115km to join the Yorkshire Ouse near Cawood. The physical characteristics of the Wharfe and hence the potential of the fishery, by the time it reaches Bolton Abbey Estate, are influenced strongly by processes and interventions occurring upstream. Most Yorkshire Dales' rivers have been affected by drainage and intensive stock grazing in both the catchments and floodplains, resulting in rapid transit of water and flashy hydrographs with narrow, high peaks and troughs of flow, excessive erosion, and a scarcity of wetland features. There is typically over-supply of cobble and gravel resulting in pools filling in to become uniformly shallow, especially where natural geomorphology is constrained by bank revetment and channel realignment / straightening (see scale of this in Maps 1 & 2).

The mainstem Wharfe is fished for trout and grayling on a day ticket basis. Various electrofishing surveys have been conducted (by Hull International Fisheries Institute and Yorkshire Water; HIFI & YW) on tributaries which tend to point to underperformance and independently corroborate the Environment Agency assessment for the WFD (Table 1). The waters are stocked using hatchery fish reared on site from local broodstock. While this reduces some of the genetic issues of stocking, it does not resolve issues associated with mate choice and rearing environment, or competition with wild counterparts at release sites, and it is generally accepted from a wealth of scientific evidence that stocked fish are less capable in dealing with environmental pressures (competition, predation, spate flow) than wild fish. If the wild population can be promoted via habitat improvements, then the fishery is far more sustainable and resilient in the longer term. Given that the Wharfe produces plenty of fish where catch & release is practised (e.g. waters around Buckden and Burnsall, u/s) and of considerable size (historic specimens in glass cases in various pubs, prior to the recognition that unsustainable harvesting would cause their demise), the potential for a wild fishery on the Estate should be considered. More information is available at:

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

2.0 Habitat Assessment

2.1 Main stem Wharfe

The middle Wharfe has been highly constrained for much of its length, prevented from meandering by rock armour / boulder revetment. Originally for easing the management of agricultural on either side, the 'fixing' of the river course has been accentuated by the formalisation of footpaths, in some cases along both banks, and especially around focal points like Bolton Abbey, Bolton Bridge, and Beamsley Hall. Straightening and hence shortening the course of a river increases the gradient and speeds up the flow, increasing erosion and transport of material through the system. Straighter channels with fixed banks tend to adopt a rather uniform, trapezoidal cross-section and the substrate is deposited rather evenly across the bed instead of being sorted by size or weight where there is flow variation. Instead of a classic pool-riffle-glide repeating sequence, flow characteristics tend to be dominated by almost continuous riffle and glide.

Due to the extra speed within straightened reaches, the substrate is typically dominated primarily by boulders and large cobbles (with some exposed bedrock); there is limited retention of the smaller fractions such as gravel. Indeed, this was common throughout the mainstem Wharfe and highlights the importance of the smaller tributaries for spawning and juvenile habitat which are assessed later. A cursory examination of some of the cobbles at various sites revealed many Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies), indicative of good water quality.

The assessment started at the u/s end at Drebley stepping-stones where the channel has been historically straightened for >1km (Fig 1). Boulder revetment was evident on the LB for much of this length although, because of livestock exclusion fencing to separate the Dales Way footpath from the fields (and hence inadvertently the riverbank), the native riparian vegetation was lush and diverse (Fig 2). The ecosystem benefits provided by such plant cover includes: low, trailing stems over the water for fish to hide under, and for aquatic insects to exit (emerge) or enter the water (to lay eggs); dense stands of vegetation providing feeding and refuge opportunities for aquatic and terrestrial invertebrates and vertebrates, and their predators; imparting 'hydraulic roughness', to slow the flow of water during spates; intercepting overland flow and any fine sediment and other diffuse pollutants from agriculture or road run-off; a diverse root assemblage penetrating and binding the soil, increasing

Fig 1. Looking d/s from the stepping-stones at Drebley, the upper extent of the walkover.

resilience to erosion; and not forgetting aesthetic beauty, especially blooms like cranesbill and burnet spp.

In stark contrast, the RB was open to livestock and grazed to a short sward of grass turf (Fig 2). Where grass is cropped and shoot material removed regularly, photosynthetic energy is invested in regenerating shoot rather than root material. As a consequence, there is no root matrix holding the soil together in grazed pasture. Exposed vertical banks hint at lateral erosion via block failure, as spate flow erodes the base of the 'cliff' and slabs collapse into the channel. These can be seen in Fig 2 (& Fig 3) and might eventually lead to reprofiling of the bank to a more natural gradient if stock were removed. However, with continued access, that stock will maintain the deposition bar free from colonising plants by browsing and trampling, and further maintain the weakened integrity of the bank face by traversing across and rubbing against the soil.

The channel was probably 10-15m wider than it should be (in Fig 2) simply because of straightening and unrestricted livestock access. The exact same situation could be observed for 200m of the LB as soon as the livestock fencing ceased (Fig 3; below Wood Spring).

Fig 2. Compare and contrast the riparian flora and related extent of erosion on the two banks: the LB well vegetated with a diverse native herbage and rich resource for pollinators; the RB overgrazed to a short sward and eroding laterally as a result of block failure and stock accessing the toe of the bank.

Fig 3. Block failure of the LB above Barden Bridge. Overgrazing has created a short sward of grass with no diverse root structure to physically bind the soils together and present greater resilience to spate flows.

At two locations on these upper reaches, the Wharfe had managed to exploit a weak spot in the bank armouring and carved out a small side channel, thereby encapsulating an island at each (Fig 4). Neither appeared to be eroding excessively primarily because of a robust riparian vegetative fringe, where livestock could not reach. These shady channels with lower flow rates than the mainstem offer protection from spates and predators and are especially important for nursery / juvenile areas.

Fig 4. Two examples of where an island has formed, and the resultant side channels provide excellent cover and refugia for juvenile fish from flow and predation pressures in the main channel. Upper: at SE 05456 58472; and lower at SE 05264 57908. The latter is particularly valuable given the highly exposed and uniform characteristics of the main channel caused by the lateral erosion of the overgrazed LB.

Tree cover returned to the riverbank in the run down to Barden Bridge, providing some useful cover along the edges of the straightened channel, which was otherwise relatively featureless and impounded by the bridge footings (Fig 5).

Fig 5. Characteristics around Barden Bridge. Upper: looking u/s from the bridge at the straightened, impounded section – a saving grace being the extensive overhanging tree cover on each bank. Mid & Lower: the pinching effect of the bridge parapets and extensive deposition bars d/s narrow (and speed the flow within) the main channel, and create shallow backwaters against the LB; important nursery areas for fry.

Deposition of cobble and gravel in the lee of the bridge parapets extended the impact of the pinching (narrowing) of the main wetted channel whilst also creating a shallow backwater against the LB (Fig 5: lower). Such areas of relatively warmer water with slacker flow are essential for the weaker swimming fry to develop in.

Encouragement of people to engage with and enjoy the river is worthy but has introduced an inherent conflict: trying to balance access requirements with retaining the integrity of banks and not disturbing wildlife. This was evident from Barden Bridge to the aqueduct (the LB in particular favoured by walkers / picnickers), and at the main car park (Wooden Bridge to the Abbey), Fig 6 & 11.

Fig 6. The long, sweeping, relatively uniform section between Barden Bridge and the aqueduct (Fig 7), typical of a realigned watercourse with boulder revetment to prevent the channel meandering. Paleo-channels can be seen on either side of the current artificial course from aerial imagery. Desire lines, footfall around focal features like benches and deposition bars ('beaches') create potential weak spots in the bank line via trampling of the soil and vegetation.

Fig 7. A seam of bedrock has been used to facilitate crossing of the aqueduct. This natural pinch diversified the channel characteristics briefly before it returned to the same uniform proportions (as in Fig 6) under the constraint of boulder revetment banks within 50m d/s.

Aside from these 'honey-pots' and focal points around benches, the footfall of walkers did not have much of an apparent effect on any of the banks where the riparian vegetation had been allowed to flourish; a natural, living barrier. The RB with its greater percentage of mature woodland appeared to attract fewer walkers (in the sunshine at least).

The channel was maintained by revetment on a sweeping course from Barden Bridge to the top of The Strid. The consistent proportions of the channel only returned to a more natural and varied state when a seam of bed-rock, exploited to carry the aqueduct, was reached, and all flow was accommodated through a channel width 25% of that u/s & d/s (Fig 7).

A further ~250m d/s, below the confluence with Barden Beck, the valley narrowed and channel morphology consequently diversified throughout the mixed deciduous cover of Strid Wood (Fig 8). Pool-riffle-glide sequences were established within the twists and turns. The footpath on both banks was diverted away from the water's edge because of the gradient, providing greater protection from human disturbance, and the channel exhibited some of the most high-quality habitat mosaic on the main stem. Natural deposition bars from the inside of bends and d/s from fallen trees resulted in pinching of the channel to deeper runs along the opposite bank under overhanging branches; perfect fish feeding lies. Adjacent slackwater habitat, ideal for juveniles, had formed between the bars and the near bank (e.g. Fig 9).

The channel at the d/s end of the Strid Wood was extremely complex and appeared to have been modified at some point in history to form (at least some) of the Lud Stream Islands; these were clearly visible on the first Ordnance Survey maps of the 1850s. Notwithstanding how they evolved, the islands have resulted in a series of smaller channels weaving around large boulders and trapped wood, creating pocket water and retaining plenty of smaller gravel fractions in ramps that could be used for spawning (Fig 10). Ample cover was afforded by the fringing shrubby tree species.

Fig 8. The narrowing of the valley instigated a few natural twists and turns through The Strid, and with no requirement for revetment on either bank, the channel presented very diverse morphology and high quality habitat.

Fig 9. The development of a natural deposition bar within Strid Wood created a run of deeper water to the LB under the cover of overhanging branches (perfect feeding lies for larger fish) whilst also forming an adjacent shallow, slackwater pool to the RB (important for juvenile fish).

Fig 10. Channel diversity amongst the Lud Stream Islands; plenty of pocket water, shade and retention of gravel.

From the Pavilion car park almost down to Bolton Bridge, the RB was heavily impacted, assumed formerly by agriculture and latterly by human access for tourism and leisure (Fig 11). Grazing or mowing affected much of the bank tops although the slope to the water's edge was generally wilder and, in some places, left unkempt. Trees were more notable by their scarcity. The LB was more natural woodland, primarily because of gradient, at least to the Abbey environs. From there, the LB also flattened out and livestock access had caused considerable erosion and lack of floral diversity.

Fig 11. A return to more formalised banking and uniformity of channel characteristics, and footfall pressures d/s of Wooden Bridge at the Pavilion and Sand Holme Brow. Lower: the white arrow depicts the confluence of Pickles Gill Beck on a more secluded stretch of the LB.

One meander spanning the full width of the valley floor near to the Abbey has been 'fixed in time', presumably for aesthetic landscaping reasons (Fig 12). Natural processes of erosion and deposition have still accentuated the channel morphology within the constraints of the bank revetments, especially visible as the gravel bars on the inside of bends and deeper runs on the outside. This was rapidly curtailed at the return of the meander to the LB by the installation of a weir / footings for a footbridge and stepping-stones at the Abbey (Fig 13). The combination of structures was perched and in conjunction with the shallow water and perpetual disturbance, at least during daylight hours, would be an impedance to free fish passage. The angle of the weir focussed flow at the LB and was undoubtedly contributing to the erosion of that steep LB and corresponding deposition to the RB.

Fig 12. One of the few meanders retained although now 'fixed in aspic' via revetment immediately u/s from Bolton Abbey. These bends are tighter than the long sweeping examples u/s & d/s, and impart more natural channel morphology as a consequence.

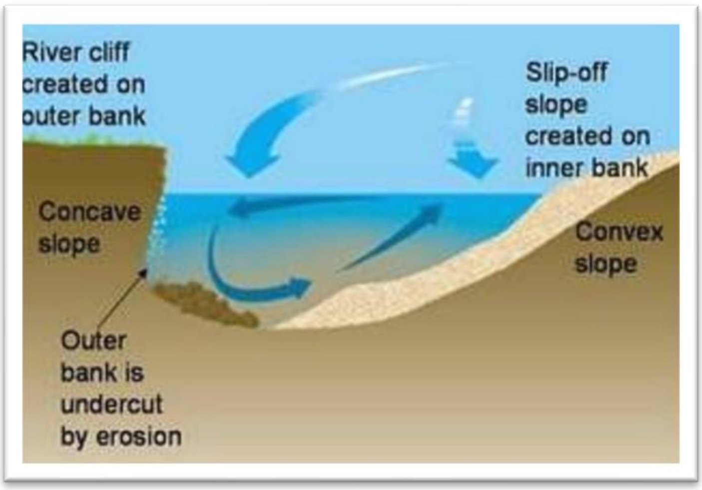


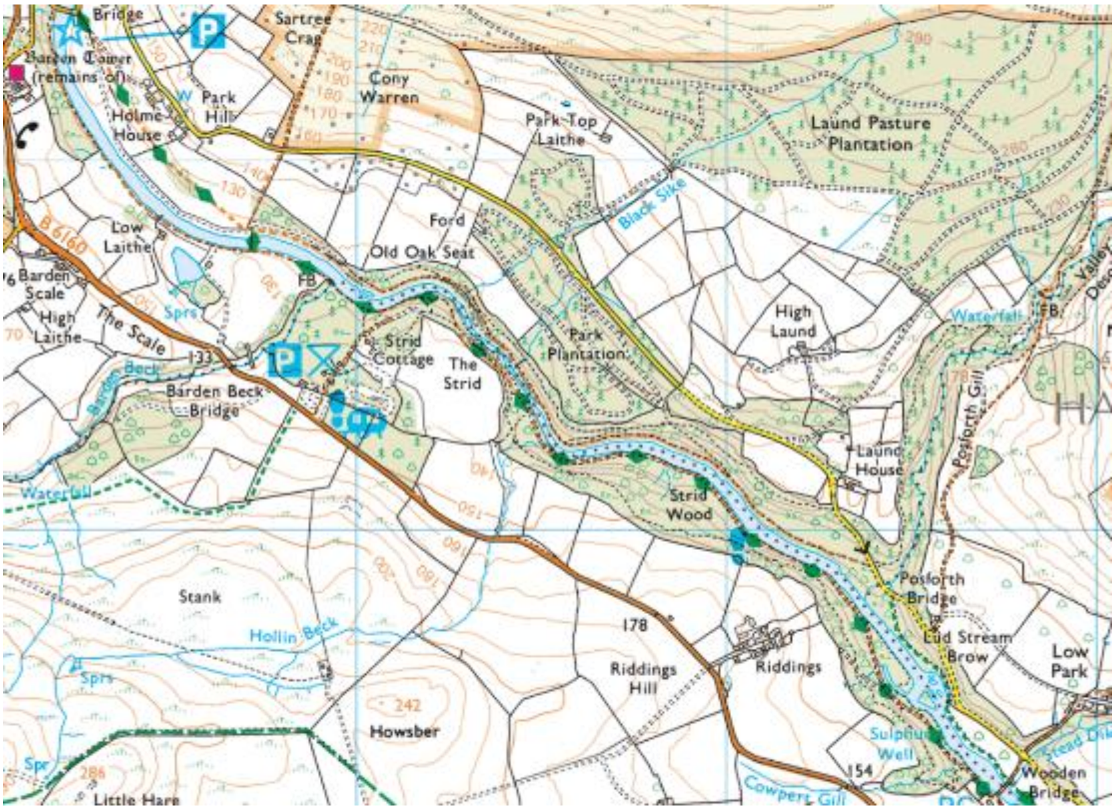
Fig 13. Upper: the weir, wooden footbridge and stepping-stone footings combined to reduce free fish passage at the Abbey. Lower: d/s of the footbridge, the channel was essentially pinned to the left hand side of the valley (in part by the angle of the weir). As a consequence, there was considerable erosion of the exceedingly steep LB (visible in the upper panel) and deposition of substrate to the RB from the helicoidal flow (see schematic).

From the Abbey down to Bolton Bridge (The Strand), the channel was again constrained and virtually straight with only one notable bend where the channel butted up to the left hand side of the valley once more. The RB riparian fringe from below the bank top to water’s edge improved in floral diversity with distance from the Abbey and there was (again, as in Fig 2) a notable contrast between ungrazed and grazed banks (RB and LB, respectively) in terms of erosion.

Below Bolton Bridge and the confluence of Hambleton / Ings Beck, footfall pressure near to the banks was much less and the riparian zone has been protected from livestock access for a considerable period (Fig 14). The margins were diverse with predominantly herbs and tall grasses on the LB and deciduous trees on the RB. Of note were several large trees that had fallen or were leaning from the RB and providing excellent cover habitat and imparting flow diversity.

Fig 14. Although still straightened, the riparian zone on both banks downstream of the A59 at Bolton Bridge was much more natural and with less evidence of management although trees were sparse on the LB; several leaning and fallen trees from the RB were *in situ* and providing excellent habitat.

2.2 Posforth Gill Beck



Map 3. The lower reaches of Posforth Gill Beck entering from the LB within Strid Wood.

Posforth Gill Beck was examined from its confluence for a distance of ~450m. Natural waterfalls prevent further use of the beck by fish. Boulder revetment of the Wharfe bank had been almost wholly reclaimed by nature at the confluence; the walling had been broken up, and natural regeneration and succession of native trees provided good shade and plentiful leaf litter input. The mouths of small tributaries can become very shallow due to the deposition of sediment when they meet a mainstem river in spate flow. However, larger boulders at the mouth of this beck constrained it and scoured a deeper path, thereby maintaining access for fish even at low flows. Deposits of clean gravel in the lower reaches indicated the potential contribution and supply of quality spawning substrate both within the beck and into the Wharfe (Fig 15).

The valley was naturally narrow and steep with few signs of direct human influence to the channel morphology, aside from where it was constrained to run through two bridges (Fig 16). Both were clear span. The more modern footbridge did not impinge upon channel characteristics. Footings of the older road bridge were formerly protected by an apron of dressed stone, although ~60% of this had been washed away over time which has no doubt improved passage options for fish. Further u/s, the gradient and frequent interfacing with seams of bedrock created typical pool-cascade habitat in between boulder strewn runs, ideal parr habitat (Figs 17 & 18).

Despite the fabulous native wet woodland on both banks, there was very little evidence of woody material in channel. Lodging some large, locally-won trunks across and along the channel would increase cover, help to slow the flow, and improve retention of gravel of a size (10-40mm) suitable for spawning. Given the relatively undisturbed nature of the lower reaches of the beck, a small amount of effort to improve the spawning habitat here by retaining more gravel in channel could result in big wins for the local fish population.

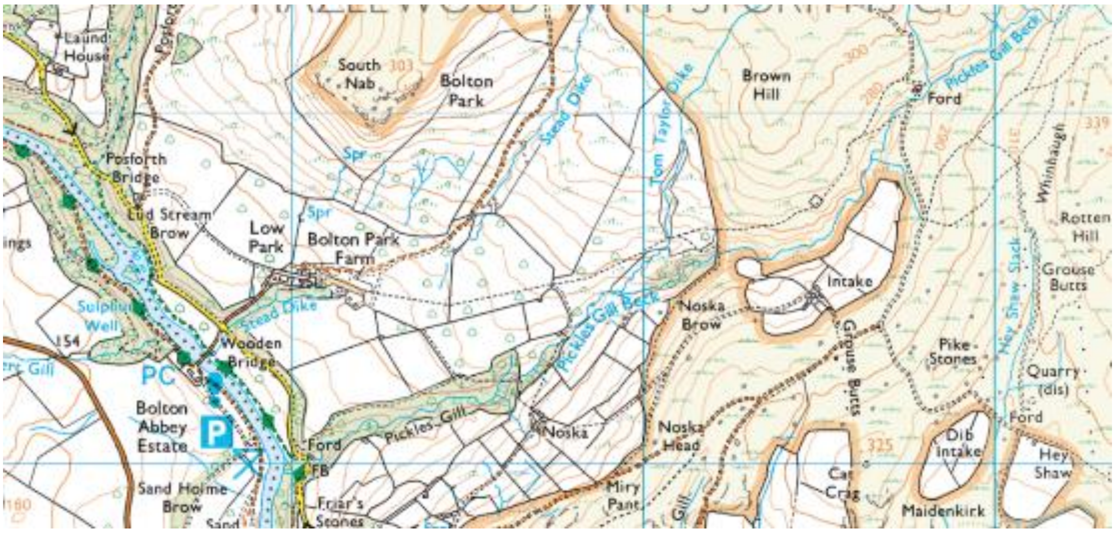
Fig 15. Upper: the confluence of Posforth Gill Beck and the mainstem Wharfe was relatively shallow but boulder strewn thereby focussing flows and maintaining access for fish. Lower: deposits of gravel indicate Posforth is a source of suitable spawning substrate and macroinvertebrate habitat.

Fig 16. Two bridges adjacent to each other carry the road and the footpath over Posforth Gill Beck. Approximately 60% of the dressed stone culvert beneath the road bridge has been washed away, improving fish passage and holding capacity of the beck at the bridge.

Fig 17. U/s of the road bridge, the beck was naturally constrained within a narrow and steep valley and hence habitat was dominated by pool and cascade between bedrock and boulders. The riparian fringe was native wet woodland. Note the ramp of smaller cobble and some gravel at the d/s end of the pool in the lower image – this is where trout will try to create redds.

Fig 18. Typical pool and cascade features, ideal parr habitat, on the approach to a natural waterfall, the barrier to u/s movement on Posforth Gill Beck.

2.3 Pickles Gill Beck



Map 4. The lower reaches of Pickles Gill Beck, highlighting the position of the ford near to the confluence, and the extent of moorland and pasture within the catchment.

Only the very lowest 400m of Pickles Gill Beck were examined because of the considerable issues observed. Within 50m of the confluence was a dressed stone / cobbled and perched ramp of significant gradient which supported the road and ford above (Fig 19 & 20). Anecdotal evidence of fish waiting at the bottom to ascend is clear evidence of the impact such a structure will have on fish passage; it only being passable for very narrow windows of time, potentially not coinciding with fish spawning migrations. Resident fish would have no chance to ascend under the 'normal' flow conditions observed. This was a great pity because the reach through the woodland u/s had great potential.

Fig 19. The confluence of Pickles Gill Beck, entering the Wharfe from the LB at SE 07982 54981.

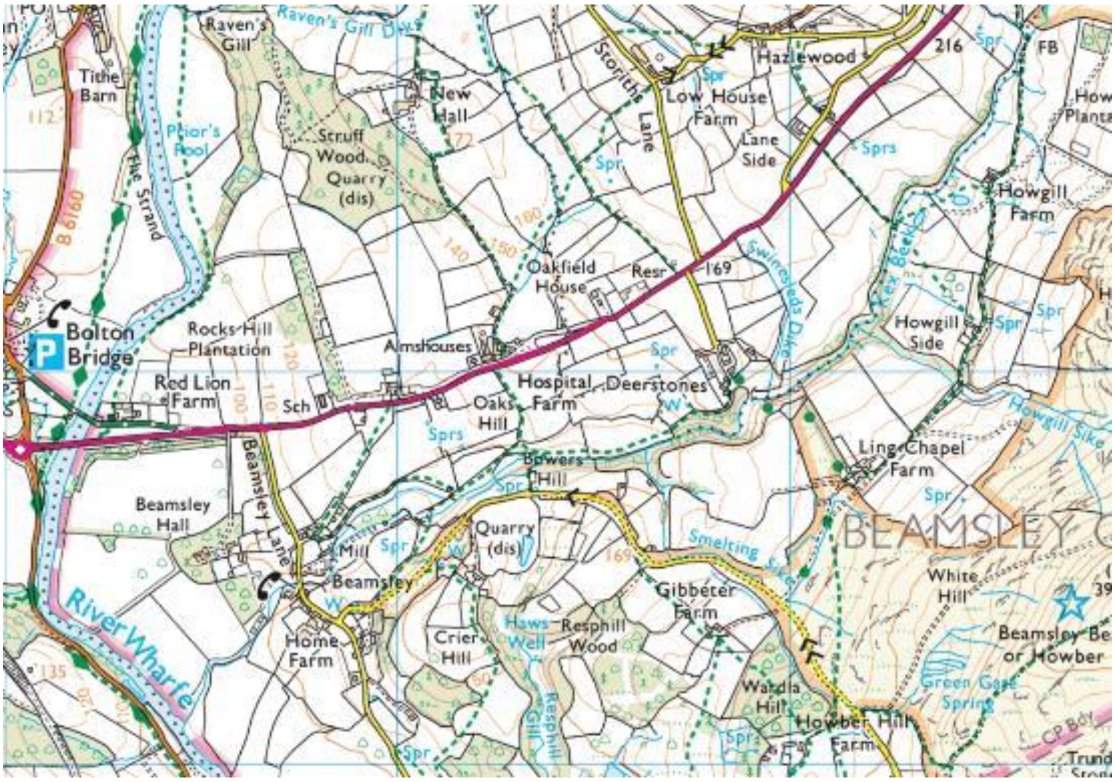
Fig 20. The approach (upper) to the cobbled ford (middle) and the impounded section immediately u/s of the road (lower) presented a series of significant obstacles to fish passage within 50m of the confluence.

Fig 21. There was evidence of meandering across the valley in the lower gradient section above the ford and old paleo-channels or spate flow side channels (e.g. middle panel). The native understory was well developed and some woody material was found in the channel. The cut trunk (lower) was assumed to be for access for gamekeeping / shooting interests, rather than 'tidying up'. There should be more trunks and limbs like this in channel to improve the instream habitat and to help 'slow-the-flow'.

Fig 22. Although the size fractions within gravel deposits were suitable for spawning substrate and demonstrated ample supply (upper), there was also a notable fine fraction smothering and filling the interstices (lower) which points to issues of sediment ingress further u/s.

The channel form was quite natural beyond the impounding influence of the ford and clearly dynamic within the woodland, as evidenced by recent paleo-channels and retention of fallen wood (Fig 21). The substrate was varied in size and there was plenty of gravel but, perhaps more than any other tributary observed, there was a considerable amount of fine silt smothering the bed (Fig 22). Aerial images reveal that the upper reaches of the beck were exposed to livestock access in the relatively long but narrow valley.

2.4 Kex Beck



Map 5. The majority of Kex Beck and various tributaries.

The Kex Beck catchment effectively forms part of the lower boundary of the Estate, flowing from Beamsley Moor and entering the Wharfe ~750m d/s of Bolton Bridge (Map 5). The confluence was within a dynamic deposition zone on the mainstem Wharfe. Several low deposit bars of boulder cobble and gravel had been colonised by herbs, grasses and goat willow which helped to 'pinch' the mouth of Kex Beck and retain some water depth in an otherwise shallow deltaic system (Fig 23).

The lowest reaches below Beamsley village had clearly been straightened and consequently the channel form was trapezoidal, uniform in proportions, and with unsorted substrate (Fig 24). There was a considerable amount of Himalayan balsam on the banks but otherwise a reasonably wide buffer strip for ~180m that could be improved with some locally won woody material. At SE 07650 52359, there was an outfall pipe from a wastewater treatment plant that has been reported previously to the Environment Agency for polluting discharges. Within the village, the bridge footings were perched and there was clear evidence of fluming flow across the shallow culvert that would be challenging for fish to pass under a range of conditions (Fig 25).

Fig 23. The confluence of Kex Beck entering the mainstem Wharfe from the LB (white arrow). A boulder, cobble and gravel deposit bar along the LB has been partly colonised and stabilised by emergent vegetation such as butterbur and scrubby goat willow which help to retain depth at the mouth and provide important low cover for fish moving in either direction (lower panel).

Fig 24. The lowest reach of ~180m has been straightened and dredged so the channel has taken on a trapezoidal shape with little sorting of substrate and hence uniformity of habitat. Himalayan balsam was prevalent on both banks.

Fig 25. The bridge footings at Beamsley were perched; the combination of a weir and a shallow fluming flow across the culvert presented an obstruction to free fish passage and sediment transport.

At SE 08119 52654, u/s from the bridge in the village, later consultation of a map indicated an old mill and goit which would imply the presence of a weir as well, but this could not be viewed. If present, it would likely impact upon fish passage and should be assessed for such. The hamlet of Deerstones was spot-checked and the channel and riparian zone appeared to be relatively natural, within a very narrow but mostly wooded valley (Fig 26).

Fig 26. The valley of Kex Beck is naturally narrow and steep and with a reasonably well protected riparian fringe in the mid-lower reaches which comprised native deciduous woodland.

A further spot check and short walk u/s from SE 09739 53988 revealed a narrower riparian fringe of alder and ash but a channel benefitting from large boulders, contact with bed-rock and extensive root masses from mature alders (Figs 27-29). Despite the presence of mature trees, there was perhaps surprisingly little evidence of wood in the channel.

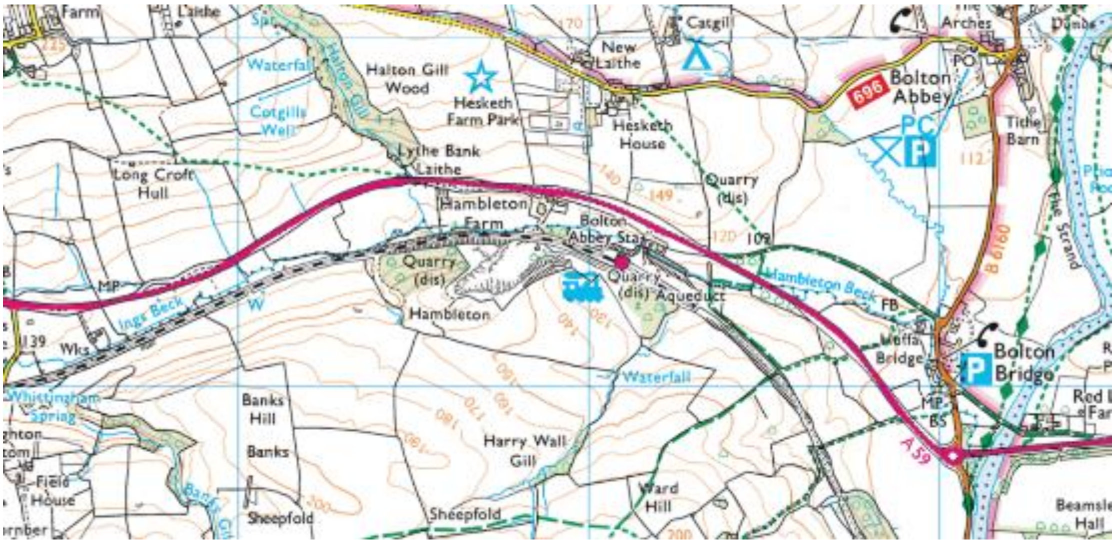
Although the woodland was petering out, a considerable amount of planting had been undertaken with a variety of native species to extend its reach and some of this was well established. Lengths of fencing and walling were in place, but it was not clear that these were entirely effective at removing all grazing pressure on the banks and should be reviewed for repair / replacement. Superficially then, the habitat looked in very good condition for trout and their macroinvertebrate prey but there was still a considerable amount of fine silt infiltrating and impacting the gravel beds, pointing to issues of ingress further u/s from the open, grazed pasture and moorland (Fig 28).

Fig 27. Numerous large boulders, bed rock seams and mature alder growing from the bank toe provided physical structure to richly diversify the channel morphology. Further planting with other species was evident and had clearly been carried out some time ago.

Fig 28. Clearly there have been moves to extend the woodland fringe further up the valley. Beyond that (lower panel), riparian cover was restricted to rough grass and rushes. Note the steep gradient, especially on the LB.

Fig 29. Plastic tubes should have been long removed from this site and recycled or reused.

2.5 *Hambleton / Ings Beck*



Map 6. The influence of infrastructure on the modified course of Hambleton / Ings Beck.

The lower reaches of Hambleton / Ings Beck were walked and a few specific points spot-checked further u/s. The confluence with the Wharfe was surrounded by relatively natural riparian vegetation, benefitting by being effectively 'cut off' from nearby agricultural land by the A59 roundabout complex (Map 5). Clearly the area is heavily influenced by deposition when the mainstem Wharfe is in flood, the habitat dominated by wet willow woodland (Fig 30).

The confluence was well protected by willow, and the boggy ground probably restricted the impacts of footfall from the Dales Way footpath. There was scope for further improving cover along the banks of the lowest 100m by introducing willow whips or diversifying the tree cover with alder or other wet ground specialists.

Some of the worst impacts of exposure to livestock resulting in heavily degraded habitat were observed close to the Devonshire Arms complex (eg Fig 31). In combination with straightening, the channel was much wider and uniform than it should be and bereft of any bankside vegetation to provide cover or shade. Deposition and subsequent colonisation of sediment within the channel hinted at the beck trying to re-establish a natural dynamic equilibrium. This is one of the first parts of the Estate to be viewed by visitors arriving from the south, and it would be relatively simple to achieve some improvements.

Formalisation and realignment of the channel to accommodate the B6160 and the Devonshire Arms complex created a much straighter and consequently steeper channel which was then forced in a 90^{o} turn to the left to pass under the road (Fig 31, lower panel).

Fig 30. Upper: the confluence with the Wharfe was sufficiently deep and with adequate cover, allowing for safe fish passage in both directions, even at summer low flow. Lower: within 100m of the confluence, the beck passed under the A59 bridge which was clear span and presented no issues. The riparian flora was dominated by willow wet woodland.

It is thus unsurprising that there has been excessive erosion and lateral movement of the channel into the RB which appeared incised as a result (Fig 32). Rich gravel seams were evident in the eroding bank and contributing valuable sediment to the channel. Efforts to slow-the-flow u/s in conjunction with removing the cropping or grazing of the RB to the channel edge would help this section of bank to stabilise.

Considerable landscaping via formal walling and impoundment of the beck with log-pole weirs has resulted in the conversion of the beck into a wide featureless 'moat' with a silt smothered bed (Fig 33).

Fig 31. Upper: Looking d/s from the B6160 bridge at Hambleton Beck flowing through the penultimate field before its confluence with the Wharfe. The channel was over-capacity, of relatively uniform dimensions, and almost devoid of instream habitat diversity and bankside cover. Compare the channel dimensions u/s & d/s (lower panel) where the channel was better protected from livestock; white ellipse depicts the reach in the upper panel. Note the three small trees in the aerial image have since disappeared.

Fig 32. U/s of the B6160 bridge, the channel appeared heavily incised (see text) and a field drain in the RB indicated how the channel has migrated laterally in recent years.

Fig 33. The formalised channel within the Devonshire Arms complex was maintained by walling and a series of log weirs ~5x wider than the beck would naturally be. These structures have negatively impacted upon habitat and fish passage.

Ideally, these weirs should be removed, and a narrower sinuous course reinstated between the walls using low berms which would be readily overtopped during spate events. If the aesthetic of a moat must be retained, then simple notching of the weirs would provide some much-needed focal flow to improve fish passage prospects.

Between the Devonshire Arms and the A59 was a stark contrast of protected and unprotected banks. The lower section was open to sheep grazing and the erosion and lack of cover was evident, especially in a tight meander as the beck tried to re-establish a sinuous path rather than a straightened one along a contour (Fig 34).

Fig 34. In the field above the Devonshire Arms complex (at SE 06818 53233), the beck was trying to return to a natural meandering path. The short, grazed grass offered little resistance to lateral erosion, and the reach would benefit from livestock fencing being extended from the exemplary reach u/s (Fig 35).

The upper section, ~250m to the A59 bridge, has been protected by recent fencing and supplementary tree planting (Fig 35). This is to be applauded, and an especially important area to conserve as it has clearly been a very dynamic area; there were many paleo-channels evident on the ground and from scrutiny of aerial imagery. At the time of the visit, the channel was relatively straight but with some simple management interventions such as the addition of large woody debris, could be encouraged to re-meander or at least reconnect better with the floodplain to slow-the-flow during spate events. Diverse emergent and riparian herbage was beginning to narrow the channel and provide hydraulic roughness so important for fry habitat in the margins. The plants here were quite literally buzzing with life compared to the grazed sward on the outside of the fence.

Fig 35. A relatively recently fenced-off reach of 250m up to the A59 bridge (SE 06510 53291) with some supplementary tree planting. The biodiversity benefits were clear to see with tall herbage and grasses to the bank toe providing shading and cover, and the channel width regaining more natural proportions.

The next location observed was a culverted section near to Bolton Abbey Railway Station which introduced various issues for fish passage: perching at the d/s end requiring a leap onto a long, shallow culvert subject to fluming flow, and then a water gate at the u/s end which will be prone to blockages and damage during spate events (Fig 36).

Fig 36. At SE 06154 53396, the beck was culverted for ~25m through a dressed stone tunnel. Various issues impacting upon fish passage were identified with this structure: perching at the d/s end; shallow depth throughout; and a water-gate at the u/s end.

At SE 05861 53461, behind the Route 59 Café and various small businesses, the LB was being used as a dumping ground for various materials and a considerable amount had slumped and sloughed into the beck. This fly-tipping should be reported to the Environment Agency and / or local authority.

Above Hambleton Farm, the channel was in better condition although had been historically realigned to run parallel to the railway line (to the RB; Fig 37). The straighter sections were relatively featureless and of constant proportions, but several delightful meanders were encountered and more were evident from aerial imagery (Fig 38). Unfettered livestock access in the fields immediately adjacent to the farm was clearly leading to erosion of the banks and the riparian zone of the LB was like a bowling green. The RB was generally more natural, although still relatively few self-set trees indicating that even a reduced grazing regime was impacting upon the regeneration of the riparian flora.

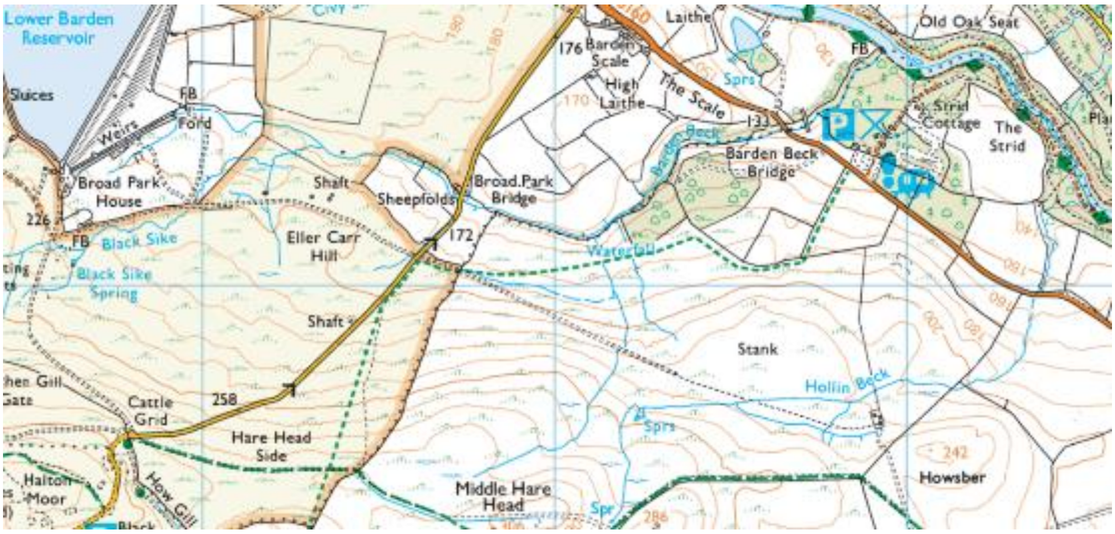
Fig 37. Looking u/s & d/s (upper & lower, respectively) from SE 05306 53380 at a realigned section to pin the beck parallel to the railway line and maintain a coherent parcel of flatter land for improved grazing. As a consequence, the channel was straight and of relatively uniform dimensions. The riparian flora of the RB was in better condition (less livestock impacts) although under low flow conditions, sheep had still crossed in the lower field.

Fig 38. In several locations, the beck had been allowed to meander and there were deeper pools, here with beneficial cover, for larger fish as a result.

The most u/s point visited (SE 05066 53340; Fig 39), was in a marshy area dominated by sedges and perhaps grazed very occasionally. Shaggy vegetation trailing into the water provided good overhead cover to fish, but the sediments were clearly impacted by infiltration of fine silts pointing to ingress upstream. Consultation of aerial imagery indicated that although the beck meandered naturally in the fields u/s, sheep have access to both banks and there was no tree cover. A wastewater treatment site was observed ~600m u/s.

Fig 39. Numerous springs made both banks extremely wet at the highest location examined (SE 05066 53340) where some sort of pipe crossing caused a small interruption to fish passage and sediment transport. The trailing shaggy vegetation provided good cover. A lack of self-set trees in this area suggested occasional grazing use.

2.6 Barden Beck



Map 7. Barden beck from the lower Barden Reservoir outflow to its confluence with the Wharfe u/s of the Strid.

The Dales Way footpath crosses Barden Beck within 15m of the confluence with the Wharfe (Fig 40), and hence the beck banks suffer from excessive footfall and dog access. A delta of fine sediment and debris was evident, a common feature where a smaller watercourse hits a much larger one and backs up under spate flow, causing material in suspension to settle out. In doing so, the normal flow of the beck was better constrained into a narrow, deeper channel (currently to the LB) and hence provided reasonable access to and from the beck into the tail end of a deep glide in the Wharfe. However, human / dog disturbance is likely to be an ongoing issue, limiting fish movement to within the hours of darkness.

Upstream from the footbridge until Barden Beck Bridge (B6160), the channel was relatively natural within a narrow steep valley and the riparian zone comprised mixed deciduous woodland of varied age structure, perfect for shading and providing leaf litter. There was some evidence of wood fall contributing to diversifying the channel morphology (Fig 41), but not as much as might be expected. The naturally steep gradient resulted in pool and cascade character with substrate dominated by larger cobbles and boulders although a few small pockets of gravel were evident (Fig 42). Hence, there was holding water (pools) for larger resident and potadromous (river migrating) spawning fish, and plenty of parr habitat amongst the boulders. At the flow height observed, the wetted perimeter was ~20-25% of channel capacity indicating that spate flow must be substantial and thus likely to be stripping out much of the potential spawning gravel habitat and smaller woody debris structure.

Fig 40. The confluence of Barden Beck and the Wharfe is clearly a focal point for footfall from walkers and dogs, and the banks are degraded as a result. Upper: looking d/s from the footbridge. Lower: looking u/s from the confluence to the footbridge. Note the delta of fines and debris caused by deposition when the spate flow from Barden Beck meets the considerably larger volume of spate flow in the Wharfe.

Fig 41. The lower reaches of Barden Beck flow through mixed deciduous woodland and where natural wood fall has been allowed to accumulate, it has diversified the channel morphology.

Fig 42. The naturally steeper and narrower part of Barden Beck approaching Barden Beck Bridge (B6160) was characterised by pools and cascades with larger boulders dominant within channel.

Barden Beck Bridge unfortunately receives run-off from the approach road on either side of the valley and that clearly guttered down the RB on the u/s side of the bridge (Fig 43). In doing so, it also joined a livestock track (desire line) to a popular drinking spot which was already poached. The combination is a point source of pollution by fine sediments and road run-off. It would be relatively simple to divert road run-off to into a short swale angled away from the beck, or fence off the steep bank to the road so that it is not trampled and grazed by livestock.

Fig 43. Evidence of road run-off guttering from Barden Beck Bridge and discharging into the beck. The route of the overland flow (highlighted by the white arrow) also joins a desire line for stock accessing the water and thus further contributes to introducing fine sediment into the beck from the poached and trampled bank (lower panel).

Upstream of the bridge, there was fabulous channel diversity, to a large extent underpinned by the proximity of the bedrock but further accentuated by the addition of natural and numerous wood fall (Fig 44). Recent improvement and extension to a livestock exclusion fence on the RB will only make this reach even better. The bedrock seams introduced some naturally challenging cascades but the presence of pools on either side, and focal flows in between, mean that such obstructions do not pose such an impedence to fish passage as man-made structures (Fig 45).

Fig 44. Immediately u/s from Barden Beck bridge were some excellent natural examples of large woody material lodged in the channel and providing multiple benefits.

Fig 45. Fish passage is not without its natural challenges on Barden Beck but uneven fissures through the bedrock seams generally provide focal flow channels for fish.

Fig 46. Images taken from Broad Park Bridge (SE 04737 56244). The narrow riparian fringe of mostly mature alders in stark contrast to the improved pasture surrounding, and indeed, beneath the trees. There was a distinct paucity of self-set trees to resupply the riparian zone once the mature alders are eventually lost.

Spot checks from Broad Park Bridge revealed that, while the channel course was still relatively natural within the narrow valley, the riparian fringe was restricted to a corridor of mature alders (Fig 46). Improved pasture on either side with no buffer fencing meant that the understory was reduced to a short sward of grass, and there were no self-set trees evident. Channel character was dominated by pool and riffle or cascade, typical for an upland environment.

Fig 47. The alder fringe began to thin out by SE 04390 56310 and only those trees growing from the bank toe had managed to escape browsing pressure. There was an old ford and/or pipe crossing associated with reservoir infrastructure, highlighted in the white ellipse.

Approximately 500m u/s from Broad Park Bridge, the beck was accessed again and the remaining ~500m to the reservoir infrastructure was walked. Initially, the riparian zone was dominated by rough grassland, heather and bracken, and the alder tree fringe was much sparser (Fig 47). Deeper pools typically had a few alders shading them, and there was plenty of shaggy trailing vegetation roughening up the edges and providing refugia for fry.

Nearer to the reservoir and the associated farmstead, the pasture had been improved again, and the impact of a more intense grazing regime was evident: no trees, a wider more uniform channel, and erosion scars on the steepest slopes caused by sheep traversing, rubbing and laying up in the lee of the overhang for protection from the elements (Fig 48). The spillway was impassable and hence marked the u/s extent of the survey (Fig 49).

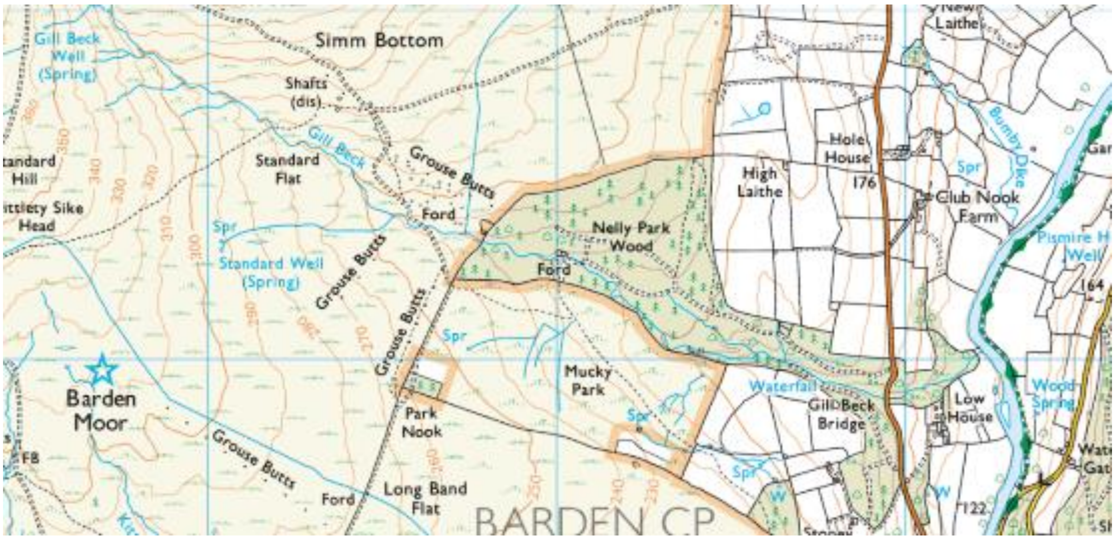
Fig 48. The upper reaches of Barden Beck were essentially devoid of any tree cover and, with unlimited livestock access, there was clear evidence of erosion of the fragile soils.

Fig 49. The impassable spillway and infrastructure below Lower Barden Reservoir marked the u/s extent of the survey.

The Lower Barden Reservoir dam probably has some ameliorating effect on the flow regime of the catchment, even when full, but it would be interesting to discuss with Yorkshire Water how the level is regulated and whether there is scope for it to be lowered overwinter to offer extra buffering capacity as they are trialling elsewhere. Fine sediments from the exposed moorland u/s would be trapped in the dam – a good thing. However, the dam also prevents the natural transport of gravel from the upper catchment and hence the beck below is starved of such substrate, leading to greater incision of the channel and paucity of material of appropriate size for spawning. The exposed character of the surrounding catchment is encapsulated in Fig 50.

Fig 50. An overview of the 'upper' sub-catchment of Barden Beck available to trout (i.e. that below Lower Barden Reservoir).

2.7 Gill Beck



Map 8. The extent of Gill Beck. Note there is a natural barrier d/s of Gill Beck Bridge, limiting the use of the beck to ~350m from the confluence.

Gill Beck was only examined on the d/s side of Gill Beck Bridge as several impassable cascades over bedrock shelves were noted. Despite only ~350m of beck being accessible to trout from the Wharfe, the quality of habitat and protected nature of the lower reaches warrant further investigation of this watercourse. The upper catchment, a narrow relatively short valley, was dominated by heather moorland relatively. Nelly Park Wood was part plantation and part mixed deciduous. If efforts can be made to slow the flow of water through the 1km of woodland u/s of the bridge, then the lowest reach could be very high-quality spawning and juvenile habitat indeed. The confluence appeared perched, presenting a cascade entrance / exit into the Wharfe and should be addressed (Fig 51).

Fig 51. The confluence of Gill Beck with the Wharfe at SE 05225 58020 was perched and probably of limited access under low flow conditions.

The short reach from the Wharfe into the walled wood (~25m) was the only length exposed to sheep grazing. A stand of tall but whippy beech trees also shaded the ground but did little to provide any cover for fish in the shallow waters of the beck. As the LB of the beck is already walled, it should be relatively easy to extend a line of fence to the RB as well and hence counter the issues of perching (Fig 51) and lack of cover with some simple management interventions.

The lower reaches of the beck within the walled wood were also subject to an extremely high canopy and hence understory was sparse except for where trees had been felled for the path of powerlines (Fig 52). The overabundance of tall whippy trunks could be used to improve habitat; felling several in clumps to introduce

Fig 52. The lower reaches of Gill Beck flowed through very tall mixed deciduous trees; only where powerlines passed through the wood was any low cover notable (top left of the upper image).

gaps and thereby encouraging new low understory growth near to the channel while leaving the felled trunks strewn around the channel to mimic natural wood fall and introduce channel diversity (Figs 52 & 53). Keeping more wood in the channel helps to retain and sort the smaller gravel fractions required for spawning, and also further retain leaf litter which underpins much of the macroinvertebrate production. Gill Beck would thus appear a low risk / high reward site for some management interventions (see Recommendations).

Fig 52. As the valley narrowed and steepened, the character changed to boulders, pools and cascades. Retention of leaf packs and small gravel pockets was notable (upper & lower panels, respectively).

Fig 52. Some natural wood fall was noted but much more could be introduced in this low-risk area. The cascade just visible toward the top left of the image is a ~15m near vertical natural barrier to fish movement, ~350m from the confluence.

3.0 Recommendations

The character of the Middle Wharfe (including the tributaries) throughout the Estate has been shaped strongly by the natural topography of the catchment and land management practices, both historic and ongoing. Water falling on the relatively barren fells is transported rapidly to the valley floors and into the mainstem Wharfe. The channel forms of every watercourse bear evidence to extremely high spate flows and rapid conveyance leading to excessive erosion on those sections of bank inadequately protected (from livestock) or to eddying scour at the outflows of culverts / bridges leaving them 'perched' (further accentuated by the interruption to sediment transport). Some channels have been realigned and straightened, hence exacerbating the erosive elements. Sections which butt up against bedrock, or flow through mature woodland clearly were much more resilient and exhibited potential for good quality habitat, both instream and on the riparian strip. However, transport of fine sediments (silt / soil) from upstream still impacted these better areas.

3.1 Slowing the flow

The most beneficial action across the whole estate will be to 'slow the flow' in the tributaries, including the small feeder streams, to reduce the conveyance speed during and following rainfall events. Valuable land is being lost because of excessive erosion so there are benefits to both land practice and habitat quality. The Estate is in an 'enviable' position in this respect by having considerable control of how the tributary catchments are managed. There are several approaches using natural flood management that could be employed, especially as there is the space and the majority of raw materials available on site already. Interventions from the very top of each system, and a little and often approach, are key for reducing conveyance from the tributary headwaters.

3.1.1 Moorland

It is appreciated that the land is managed as a working estate, that vehicular access is required to certain points, and that some drainage is necessary for the tracks to be maintained. However, it is easier to slow the flow at the top of the system before it gathers momentum on the steep fell sides. If heather burning is practised, then a buffer zone of at least 5m should be left unburnt along watercourses to maintain the best possible riparian root structure and above-ground roughness to slow overland flow. Installation of 'leaky dams' in series will greatly reduce the conveyance of water from the fell tops and prevent too much momentum building up in the first instance. The principle behind leaky dams is to mimic natural log jams found in wooded sections and there are good examples across the Estate, particularly just u/s of Barden Beck Bridge (Fig 44). Thus, at low flows, the water just passes under or through the material, but at higher flows, each dam in series creates resistance to the flow. Leaky dams should not trap sediments *per se* and hence should not require too much maintenance, especially as there is little riparian vegetative material (e.g. tree branches etc) to block the interstices of the dam. Leaky dams can either be constructed in a log-jam style, tree limbs or trunks interlocked and secured into position by tethering / posts, or by interweaving substantial brash through braced posts on either side of the low-flow channel, essentially leaving a gap in the middle; see leaky bunds, section 4.2 in the final report available at: https://northyorkmoorsnationalpark.wordpress.com/tag/sinnington/

Fascines are long bunds of brashy, twiggy material that are semi-buried and staked in lines along contours in areas subject to high overland flow, or on exposed slippage sites. They trap material over time, essentially becoming a series of terraces that slowly consolidate and help to protect eroded areas as well as slow the flow to the nearest watercourse. They have been used to good effect in areas of similar topography (and rainfall) such as on Hebden Water (see: http://www.treesponsibility.com/wp-content/uploads/2013/09/Understanding-the-Hebden-Water-Catchment-LOW-RES.pdf).

Leaky dams should ideally be used in conjunction with some judicious planting of hardy, low-growing scrub like willow. The dense shoots of willow will introduce resistance to water flow during spates and the roots will introduce physical resistance to erosion of the banks. As the majority of feeder streams are gullied even at the tops of the fells, they are: (a) not so useful for shooting / grazing interests; (b) better protected from the elements for tree establishment; and (c) potentially easier to prevent livestock / deer gaining access. Willow is ideal as it will tolerate the saturated soils, and can be introduced as whips or stakes cut from established trees elsewhere on the estate. To maintain, dense low growth, some occasional coppicing may be required.

Some specific becks noted earlier in the report had substantially higher silt deposits smothering the bed. These should be targeted to identify particular problem areas and address using the naturally sensitive methods outlined above.

3.1.2 Woodland

There is substantial scope to introduce simple log jams within the wooded sections of the tributaries especially where bedrock, very large boulders or other trees can be used to anchor / wedge limbs or trunks across the becks. The majority of these are low flood risk areas, but if need be, the wood that is felled can be effectively secured, often to the base from which it was felled or to a neighbouring trunk via a suitably rated steel cable and clamps; see the WTT 'How to…' video on tree kicker installation, here:

https://www.wildtrout.org/content/how-videos

Wooded sections of the lower gradient watercourses were generally in reasonable condition, primarily through 'benign neglect' – allowing for the natural shaping of the channel (for example, natural tree falls introducing flow diversion and scour and performing natural flood management function), and development of diverse, native, shady riparian cover. Neglect should not be seen as a bad thing as wildlife tends to benefit from it! All of the watercourses d/s will benefit from actions taken to slow the flow from u/s.

One site that would benefit from some coppicing of existing mature trees is Gill Beck where the mature canopy is effectively tunnelling the watercourse, excluding light and preventing development of an understory. The banks are almost bare in places and hence more susceptible to erosion from spate flows despite being well protected from livestock. A strategic rotational coppicing of some of the more mature trees which have bare banks underneath will generate low regrowth at their bases and allow light for new self-set trees to develop. Diversifying the age of the canopy also benefits wildlife. Brash from all coppicing activities can be used *in situ* for leaky dam creation.

Planting is recommended wherever there has been loss of former tree cover and where there is a lack of low cover and structure along the river margins to break up long expanses of exposed bank. It would be beneficial to include a range of native deciduous species but willow is by far the easiest to transplant and manipulate. Note that adequate fencing or some means of stock exclusion is vital to protect such measures, as without it, any planting is likely to be browsed by livestock.

The quickest and easiest way of planting willow is by pushing short sections of willow whip or sections of stake into the ground, using locally sourced material. This can be undertaken at any time of the year, but will have the greatest success if undertaken within the dormant season, shortly before spring growth begins (ideally late Jan-March). Whips should be planted into soft, wet earth/sediment so that there is a greater length within the ground than out of it, and at a low angle, to minimise the distance that water has to be transported up the stem; ~30cm of whip protruding from the ground is sufficient, providing that it receives light past the other bankside vegetation. Live willow stakes can be hammered deep into the bank and may provide greater structural stability under spate conditions. Further advice and support could be sought from The Woodland Trust. See their guidance for 'Keeping rivers cool':

http://www.woodlandtrust.org.uk/publications/2016/02/keeping-rivers-cool/

Further information & case studies on slowing the flow from similar environments (Pickering & Sinnington):

http://www.forestry.gov.uk/fr/infd-7yml5r

https://northyorkmoorsnationalpark.wordpress.com/tag/sinnington/

3.2 **Livestock & fencing**

The second most beneficial action across the estate will be to limit livestock access directly to the water's edge. This has already been achieved to great effect for reaches of the mainstem Wharfe and along the tributaries, and the benefits were clear to see where grazed and ungrazed banks were co-located (e.g. Fig 2, or Fig 34 *v.* 35).

Riparian habitats will function better to slow the flow because of increased hydraulic roughness and be of higher quality to a wide range of wildlife. As noted throughout the report, unfettered livestock access impacts heavily upon bank habitat quality, diversity, stability (loss of land), as well as water quality and community diversity via trampling, grazing, browsing and defecating at focal points such as gateways or feeding troughs placed too close to a waterway. Such degradation of banks by livestock causing excess fine soil to wash into a watercourse is an offence under the Farming Rules for Water, updated in 2018.

Existing fencing or walling should be maintained in a state fit-for-purpose. To maximise the benefits of tree planting (above) and minimise the ingress of fine silt and soil, it will be necessary to exclude livestock. Key sites to consider are: any that can be set aside for planting to slow the flow as high up the tributaries as possible; banks that have already succumbed or are susceptible to further land slip; and around established vegetation that is in immediate danger of succumbing to further erosion from stock trampling. Examples of all of these are noted earlier in the report.

3.3 Fish passage issues

Numerous small weirs and perched culverts were noted either during visits or from maps. While salmonids were present above almost all of them, it does not mean they are passable, and population resilience is reduced by fragmentation and inhibiting juvenile distribution (both u/s and d/s). Many of the perching issues are caused by excessive spate flow (conveyance) scouring around the exits of hard culverts, associated with an interruption of sediment conveyance that prevents replenishment of the eroded material.

Many of the older bridges had aprons of concrete or stone which introduce shallow, fluming flow that the majority of fish cannot navigate, even at burst speeds. Installation of low-cost baffles to increase depth and provide refugia during transit, or increasing the depth of the pool immediately d/s to drown out the apron can be effective in easing fish passage. Design solutions tend to be site-specific but can be achieved surprisingly cheaply.

3.4 Tributaries and spawning habitat

Suitable spawning habitat in the main stem Wharfe was typically rare and even within the lower reaches of tributaries such as Hambleton and Kex Beck, the substrate comprised gravels, cobbles and boulders in an unsorted matrix because of channel realignments or erosion caused by livestock. Hence, to maximise the potential of the wild fish populations, maintaining the quality of spawning habitat in the tributaries is of paramount importance. Recent survey work on the Estate over several years by HIFI & YW has demonstrated that all sites were generally under-performing (reports available), and this would seem to be borne out by observations during the walkovers. Small tributaries contribute disproportionate benefits to main river systems (partly because their length contributes enormously to the total of the whole network) and because the ratio of marginal habitat to open water is greater.

NB: It is equally important to ensure good access from the mainstem into the tributaries for the ascending adult fish, as well as dispersal of any juveniles, and making sure there is plenty of complex habitat on the edges for the fry and parr to evade predation.

Interventions already mentioned will all improve spawning potential: slowing the flow, introduction and retention of large wood, planting of low cover, and reduction of fine sediment ingress from livestock activities. One further point to consider is potential mitigation from Yorkshire Water for the operation of Lower Barden Reservoir which has effectively robbed Barden Beck of a gravel supply. If there are gravel traps at the heads of the various reservoirs to reduce their infilling rate, then they will require periodic maintenance at which point it should be possible to (re)introduce that gravel from above to below the reservoir. There are various projects around the UK involving resupply of gravels below reservoirs such as:

https://www.wyeuskfoundation.org/gravelling-the-elan-ges-project

3.5 **Pollution**

Diffuse pollution sources from silt and soil ingress were the most apparent across the estate. These may be addressed 'internally' i.e. between the estate and tenants, or immediately reported via the Environment Agency hotline (**0800 80 70 60**).

3.6 **Invasive species**

Himalayan balsam was observed at specific sites and is extensive throughout the Wharfe including u/s reaches beyond the influence of the Estate. All estate workers should be encouraged to follow simple biosecurity protocols to ensure they are not transporting propagules.

Yorkshire Wildlife Trust and Yorkshire Dales Rivers Trust have produced detailed information on controlling invasive plants in various publications and should be contacted for their advice.

4.0 Site Specific Action Priorities

4.1 Mainstem Wharfe

- High priority - Livestock exclusion fencing along the remaining open sections – this may need to be flood specification unless set sufficiently back (~8m) from the bank top.
- Resisting clearing any fallen trees; rather, try to secure *in situ* by winching and tethering.
- Improve tree cover along open banks by creation of copses rather than blanket coverage.

4.2 Posforth Gill Beck

- High priority - Introduce more wood into the beck to try and retain / sort more gravel for spawning.
- Although a relatively short reach available to fish from the Wharfe, explore opportunities to slow flow and reduce inputs of fines from the very top.

4.3 Pickles Gill Beck

- Fish passage issues near to the confluence will be expensive to overcome but should be investigated.
- Notable silt issues u/s so there is a need to explore opportunities to slow flow and reduce inputs of fines from the very top.
- Even without improvement in fish passage, habitat for a resident population could be improved and excess trout production would drop d/s to the Wharfe.

4.4 Kex Beck

- High priority – Continue extension of tree planting and stock exclusion from the watercourse as high up the system as possible.
- High priority – Natural flood management techniques to slow the flow, little and often.

4.5 Hambleton / Ings Beck

- High priority – Livestock exclusion wherever possible.
- High priority – Natural flood management techniques to slow the flow, little and often.

4.6 Barden Beck

- High priority – Continue extension of tree planting and stock exclusion from the watercourse as high as possible.
- High priority – Natural flood management techniques to slow the flow, little and often.
- Explore possibilities for gravel resupply.

4.7 Gill Beck

- Assess current use of beck by trout.
- Extend protection from livestock to the confluence, and once completed, plant scrubby willow / modify Wharfe bank to address perching issues.
- Diversify canopy structure and use felled material instream.

5.0 Making it Happen

The WTT may be able to offer further assistance:

- WTT Project Proposal
    - Further to this report, the WTT can devise a more detailed project proposal report. This would usually detail the next steps to take and highlight specific areas for work, with the report forming part of a flood defence consent application.
- WTT Practical Visit
    - Where recipients are in need of assistance to carry out the kind of improvements highlighted in an advisory visit report, there is the possibility of WTT staff conducting a practical visit. This would consist of 1-3 days' work, with a WTT Conservation Officer teaming up with interested parties to demonstrate the habitat enhancement methods described above. The recipient would be asked to contribute reasonable travel and subsistence costs of the WTT Officer. This service is in high demand and so may not always be possible.
- WTT Fundraising advice
    - Help and advice on how to raise funds for habitat improvement work can be found on the WTT website - www.wildtrout.org/content/project-funding

In addition, 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

6.0 Acknowledgement

The WTT would like to thank the Environment Agency for supporting the advisory and practical visit programme in England, through a partnership funded using rod licence income.

7.0 Disclaimer

This report is produced for guidance only; 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.