5.0 Physical Enhancements

The scope for physical intervention in the channel and on the banks of upland streams is more limited than on lowland rivers. The spate discharges and associated high energy found on upland rivers have the capacity to destroy many of the techniques and structures routinely used on chalkstreams and other relatively low energy river systems. Not only can this result in the loss of expensive work, but it can cause excessive erosion, and even increase flood risk, for instance by blocking bridges with debris. These facts are of fundamental importance to understanding the limitations of many techniques. They also highlight once again the necessity to view habitat issues in upland systems on a catchment basis. Land use usually holds the key to restoration of these rivers.

It is vital therefore to careful consider the appropriateness of any planned works to rivers. It may be wise to seek professional advice from the WTT or the river authority to help in this process.

The vital importance of tributary streams and the very upper reaches of main rivers to trout stocks in upland river systems is often underestimated. In many rivers, the majority of spawning and juvenile recruitment takes place here. One of the key difficulties of managing smaller tributary streams is that they have not traditionally been a source of revenue to landowners. Too small to be of interest to salmon and sea trout anglers, they have often been undervalued and neglected. Subject to excessive grazing of their banks, overshading, diffuse run-off, and with no positive management, their fundamental importance to the wellbeing of salmonid fisheries has not been recognised.

The wide scale and damaging flooding experienced throughout the British Isles has added a further pressure to the management of upland streams. In the mistaken belief that ensuring unencumbered passage of water along river channels is a good way to protect property from flooding, landowners and some local authorities have embarked on river clearance exercises. The removal of Large Woody Debris, and the dredging of small streams have been carried out in the name of flood protection.

TRIBUTARY STREAM IN CORNWALL

supported by

Asiantaeth yr Amgylchedd Cymru Environment Agency Wales

The River Restoration Centre — Working to restore & enhance our rivers

Eden Rivers Trust

Noddir gan Lywodraeth Cynulliad Cymru — Sponsored by Welsh Assembly Government

Association of Rivers Trusts

One of the important challenges for angling groups in the future is to highlight the misapprehensions associated with some of this work. In many instances, inundation of low grade agricultural land in the floodplain of tributary streams and upper reaches of main rivers makes a positive contribution to the protection of villages and towns further downstream. By 'attenuating' peak flows, areas of floodplain effectively reduce downstream flows. An interesting example of this approach is the ALFA (Adaptive Land use for Flood Alleviation) project[10]. This is being developed to show how habitat restoration and land use changes can help to reduce peak flood flows in key locations in northern Europe, with the Eden catchment the UK demonstration site.

One challenge therefore is to highlight this importance to landowners, and to promote the benefits of restoration and enhancement. Once the link between the well-being of these small channels and the whole river system has been made, then positive management of these vital resources makes clear ecological and financial sense. The range of potential enhancements to tributary streams and the upper reaches of main rivers are discussed below.

INUNDATION OF FLOOD PLAIN LAND IS AN IMPORTANT PROCESS THAT CAN REDUCE FLOOD RISK FOR DOWN-STREAM PROPERTIES

5.1 Fish passage

If the trout spawning potential of streams is to be realised, then it is vital that adult fish have easy access to key sites. Similarly, free passage must be assured for downstream migrating smolts and parr. Barriers to migrating fish can include mills, sluices, dams, and poorly installed culverts. Draw-off points for abstraction, including those for fish farms, potable supply and irrigation can also significantly affect both upstream and downstream migrating fish. Effective screening can significantly reduce losses of fish at these locations. Recent legislation has enshrined in law the requirement for such screening in England and Wales. Angling groups are advised to contact the relevant river authority with details of where it is not currently in place.

The recent shift towards 'green' electricity generation has increased the number of low head hydroelectric schemes being promulagated. Whilst screening and the use of Archimedes screw technology for generation can reduce losses of fish moving down-stream, there are real concerns that the installation of hydropower schemes may significantly affect upstream migration of salmonid and other fish. Re-opening of redundant leats and millstreams can also divert water away from significant lengths of salmonid habitat in natural channels.

The Water Framework Directive (WFD) emphasises the need for connectivity along river systems, particularly for migrating fish. Rivers Trusts and angling interests have a key role to play in the identification and cataloguing of structures restricting fish access along watercourses. Some obstructions are in remote areas, rarely visited by river authority officers. A methodical walkover survey by fisheries interests can be invaluable in highlighting and overcoming these impediments to migration. A simple recording form can be used to identify and report obstructions (**Fig 5.2**)

Once an initial survey for the presence of obstructions has been undertaken, the scale of the problem should be considered. Large obstructions with significant head differences between upstream and downstream water levels are likely to require substantial financial outlay to create free passage for fish.

5.2 Pro-forma form for identifying and reporting obstructions

A SURVEY SITE DETAILS

Date: ....../...../20.....

Survey Section: ....

River/Stream name: ....

Tributary to: ....

Surveyor name/s: ....

Ownership (if known): ....

GPS co-ordinates: ....

Number of photographs taken: ....

Photo Refs: ....

Field sketch made? Yes ☐ No ☐

Rainfall conditions: 1–5 ☐

Waterway state: Flood ☐ Spate ☐ Moderate ☐ Low ☐ Dry ☐

Are adverse conditions affecting site survey?

If yes, state: ....

Channel width: Upstream .... Downstream ....

Are fish pass facilities present?: Yes ☐ No ☐

Estimated effectiveness of pass facilities: Good ☐ Moderate ☐ Not effective ☐

B ARTIFICIAL STRUCTURES OF CONCERN

Culvert/outfall (Section C)		Weir (Sections D1 and D2)	
Sluice (Section E)		Dam (Section F)	
Ford (Section G)		Natural barrier (Section H)	
Other – state			

Material:

PCC ☐ CPC ☐ CST ☐ SST ☐ CAL ☐ SPS ☐ PVC ☐ TMB ☐ MRY ☐ OTH ☐

Material: PCC=pre-cast concrete, CPC = cast-in-place concrete, CST = corrugated steel, SST = smooth steel
CAL = corrugated aluminium, SPS = structural plate steel, PVC = polyvinylchloride, TMB = timber, MRY = masonry, OTH = other

Field sketch:

They will generally require the installation of a modular fish pass, although the removal of the obstruction should first be considered. The design and build of modular fish passes will generally be beyond angling groups, with the river authority, fisheries consultant, or WTT generally taking the lead in any project. The Environment Agency has published a very useful CD guide to fish pass design[2]. Information on the construction of nature-like fish bypasses is also available.[3]

However, angling interests are potentially able to address smaller scale obstructions on a more 'self-help' basis, with guidance from the WTT or river authority. For example, vertical obstructions of up to 1m in height in small streams may be tackled by the construction of pre-barrages. Large boulders, strategically placed below the obstruction, can cut down the overall water level difference across the structure, allowing fish to pass it with ease.

A MAJOR OBSTRUCTION ON A RIVER. NOTE THE CONSTRUCTED POOL-TRAVERSE FISH PASS ON THE ON THE LEFT OF THE PHOTO.

STRUCTURE RESTRICTING UPSTREAM ACCESS TO MIGRATORY FISH

OBSTRUCTION IMPASSABLE TO MIGRATING FISH

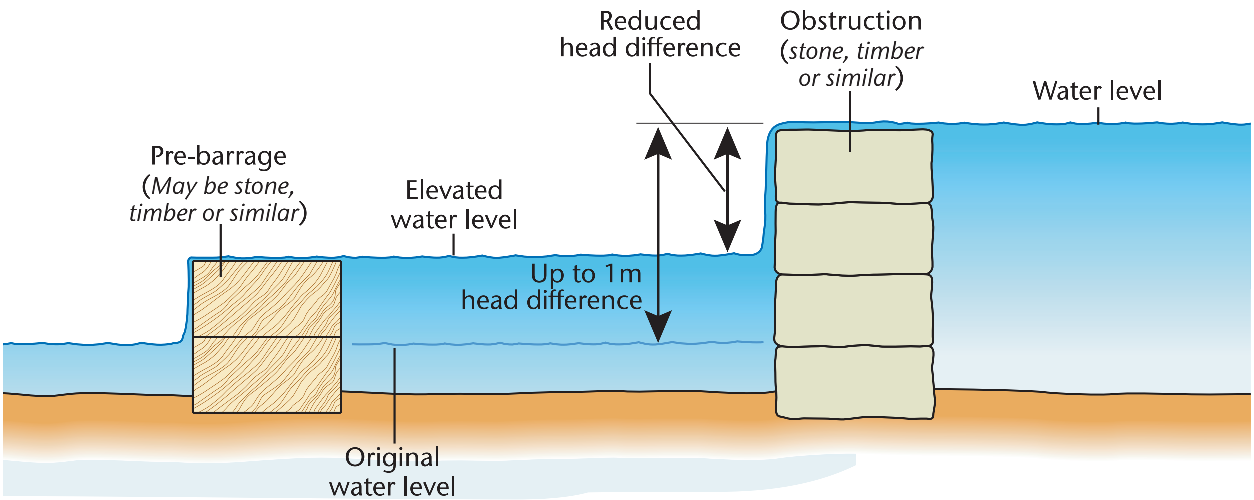
INSTALLATION OF PRE-BARRAGE (BOULDERS) REDUCES HEAD DIFFERENCE ACROSS THE OBSTRUCTION, ALLOWING FISH TO PASS OVER IT

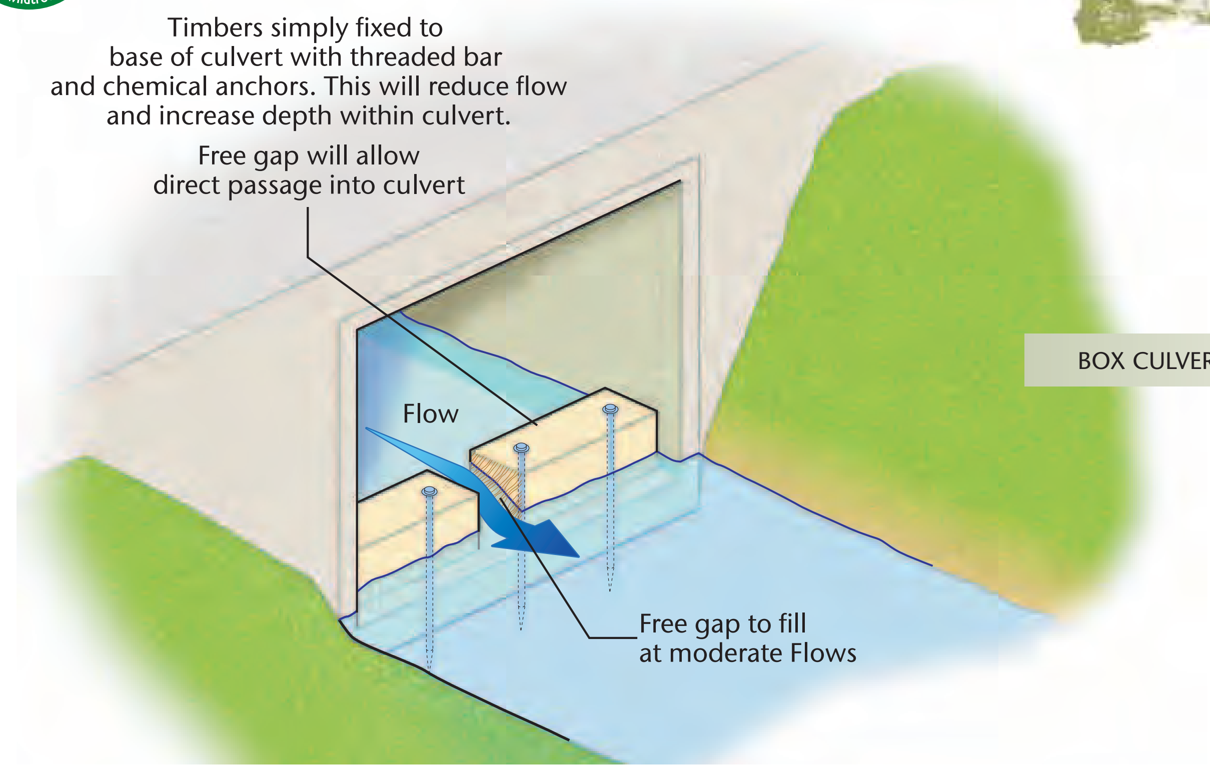
Other obstructions can be addressed by the removal of undersized culverts, by the construction of bypass channels, and by cutting low flow notches through structures.

All of these options could potentially be undertaken by angling groups, provided that the correct advice is obtained and the necessary consents granted from the river authority. Detailed advice on tackling obstructions caused by culverts can be found at http://www.scotland.gov.uk/consultations/transport/rcmf-01.asp

CULVERT PIPES UNDER A RURAL PATH PREVENTING MIGRATION ALONG AN IMPORTANT TRIBUTARY STREAM. REMOVAL OF SUCH OBSTRUCTIONS CAN OPEN UP MANY KILOMETRES OF POTENTIAL SPAWNING HABITAT FOR TROUT.

X-SECTION SHOWING TYPICAL CONSTRUCTION OF A PRE-BARRAGE FISH PASSAGE





BOX CULVERT EASEMENT[10]

5.3 Gravel management

Trout spawning takes place in sections of fast flowing, shallow water, with a gravel substrate. Typically, brown trout will select gravel of between 5mm-75mm diameter, with larger sea trout able to utilise larger diameter gravel. The physical act of spawning cleans the gravel by 'winnowing' fine sediment from its interstices. Subsequent deposition can cause re-siltation of the gravel, with a consequent reduction in hatch rate of the deposited eggs. Practical enhancement of spawning areas should therefore concentrate on both optimising the amount of available spawning gravel, and improving its quality, particularly with reference to its silt burden.

After an assessment of habitat present in the stream has been undertaken (**see Section 3.0**), it should be possible to make a judgement regarding the availability of spawning habitat. Some streams clearly have a deficit of suitable gravel shallows, creating a habitat bottleneck at this lifestage that will limit overall numbers of trout. This may be a natural phenomenon, with the stream more suited to spawning salmon.

SPAWNING HABITAT IN CORNWALL

However, in some cases, the lack of suitably sized trout spawning gravel is caused by man-made factors. These can include the construction of a reservoir that will not only result in direct loss of spawning due to flooding of the stream, but will also cut off previously important habitat from migrating fish and may also restrict the downstream movement of gravel, vital to replenish spawning areas below the reservoir. In other cases, the reasons for a lack of spawning areas may be less clear cut. Past dredging for land drainage, flood defence or for the extraction of gravel for roads or building, may be responsible.

Changes in the flow regime of the river, for instance increased flood peaks as a result of gripping or forestry operations, can wash out suitable spawning gravel, leaving areas dominated by bed-rock and boulders. It is of fundamental importance to fully understand the reasons for any loss of gravel spawning sites. Without this understanding, it is likely that any remedial works to the river will fail to achieve their aims.

Increasing the length of spawning habitat available generally involves importing additional gravel to the site. The diameter of the gravel should be in the range 5mm-75mm, with the bulk between 10mm-50mm. Design of riffles should take into account the energetics of the river. This will generally require professional input from the river authority, WTT or independent consultants. Calculation of the tonnage required should be based on the formula: W (channel width in metres) x L (length of new riffle in metres) x D (depth of gravel, generally between 0.3m-0.5m) x 1.8 (approximate weight of $1m^3$ of gravel). On rare occasions, piles of material previously excavated from the river may remain close by. Consideration should be given to reintroducing the cobble and gravel elements to the river to re-establish riffles.

Ideally, riffles should be a minimum of 10m in length to ensure initial stability. Given the high energy of many upland streams, migration of the gravel downstream may be an issue. In the absence of replenishment from natural upstream sources, the longevity of constructed riffles may be limited. The provision of gravel 'checks' (boulders) across the channel at the downstream limit of each riffle may increase its life span.

Riffles should generally be located downstream of pools. On meandering rivers, pools are often found on the outside of bends, whilst in artificially straightened channels, pools may occur less predictably[4]. The incorporation of large woody debris (LWD) deflectors and individual boulders should be considered (**see below**). These act to create areas of local scour, creating variation in depth and profile, whilst providing additional cover, and helping to sort the gravel into different sizes. Increasing depth variation and cover is vital for spawning adult trout. In the absence of these features, fish are more vulnerable to predation, and may be reluctant to use otherwise suitable spawning sites.

GOOD SPAWNING HABITAT

Enhancing the quality of existing trout spawning areas can be an important and effective mechanism to improve recruitment. As discussed previously, entrapment of fine silt particles in the gravel is the main cause of poor egg hatch rate. Reducing the amount of sediment washed into the river, both from poor land use (**see Section 4.0**) and from bank erosion (**see below**) is the most effective way to improve hatch rate. More localised methods can however, also be of benefit. Large woody debris (LWD) is perhaps the best way of maintaining clean spawning gravels. Retaining LWD or even

LWD CREATING SCOUR AND SORTING THE GRAVEL SUBSTRATE

felling it in shallow, gravel dominated sections can markedly improve the spawning potential of a stream. Scour resulting from LWD not only removes silt but also sorts gravel into size categories, creating ideal spawning conditions and deeper pool areas. The advantage of sections of stable LWD are many, with perhaps the most important being its longevity; the timber continues to work long after its introduction to the river, often for years. Details of fixing LWD *in situ* can be found in **Section 5.4.2**.

A number of more labour intensive methods for improving spawning in rivers are available. Whilst they can be effective, their benefits tend to be short lived, often lasting no more than one or two spawning seasons.

High volocity water jets produced by pumps and trained onto silted areas of gravel can effectively clean spawning areas. A similar beneficial impact can be obtained using mechanical leaf blowers.[5,6].

Although gravel cleaning is a useful technique, it is very labour intensive, and requires undertaking on a regular basis to maintain gravel quality. Tackling sediment entry to rivers at source is a more sustainable option.

Inadequate or poor quality juvenile habitat may also restrict juvenile trout numbers. In rivers with good quality spawning habitat, density dependent mortality following the swim-up fry stage is one of the key factors regulating the overall number of trout. Increasing the diversity, complexity and abundance of suitable juvenile habitat reduces mortality at this stage, resulting in more parr and ultimately, adult trout. The prescriptions for improving juvenile habitat are relatively straightforward; create more micro-habitat, primarily using stone and timber. Visual isolation of each microhabitat from its neighbour will reduce conflicts between fry and parr occupying the areas, and hence increase trout abundance.

Introducing large cobbles and boulders, retaining and introducing LWD, protecting tree root systems and undercut banks, and promoting the development of a strong growth of fringing vegetation, are all mechanisms for increasing juvenile habitat.

USING A BACKPACK LEAF BLOWER TO CLEAN GRAVEL RIFFLES

5.4 Tree management

5.4.1 Coppicing
There has been much recent focus on over-shading of river channels. Research has shown that overshaded streams hold fewer trout, probably as a result of the reduction in valuable fringing vegetation that fails to thrive in the darker conditions pertaining. Reducing the degree of shading of the channel by rotational coppicing has been shown to increase marginal vegetation growth, which in turn reduces the overall channel width, speeding up water velocity and helping to scour away sediment from gravel riffles. The vegetation also increases cover for juvenile stages of trout.

Careful consideration should be given to the need for coppicing before embarking on any significant felling projects. Concerns have been raised that in some large scale projects, coppicing has failed to realise the expected increases in trout numbers. The reasons for this may be complex but probably relate to poor initial identification of factors limiting trout populations. There is for instance, no logical reason why coppicing should produce a dramatic rise in juvenile trout numbers if poor water quality is the limiting factor.

Other factors to consider before embarking on a coppicing programme include a consideration of water temperature. As climate change becomes an increasing reality, summer water temperatures can, at times, approach the lethal limit for trout. An excessive reduction in shade can exacerbate this trend to the detriment of trout at the individual and population level. The oft-quoted 'ideal' of 60% shaded to 40% open water is a reasonable target for most streams, with the idea of 'dappled shade' expressing the same proportions in perhaps a more poetic manner! Given this, there may actually be a need for increased tree cover in some streams with limited tree shading. A planting programme using native trees of local provenance may prove to be of great benefit in open river reaches, providing not only shade, but cover and erosion protection in the form of root systems. Organisations such as the Woodland Trust, Scottish Native Woods, FWAG and Coed Cymru can advise on species, techniques and the availability of grant aid.

Timber arising from coppicing can be sold, probably as firewood in most instances, providing a small income stream that can be recycled into future projects, not only helping to reduce reliance on fossil fuels, but also increasing carbon capture, and mitigating the impact of climate change. There are great opportunities for community involvement with the sustainable management of riparian trees, that can help to raise interest in the value of river systems.

5.4.2 Large Woody Debris
Some of the timber from coppicing should be retained on site however, and used to create LWD groynes. These are of particular benefit when installed onto existing or newly constructed spawning riffles, where they help create scour and improve diversity.

IMPASSABLE LWD OBSTRUCTION ON A SPAWNING TRIBUTARY

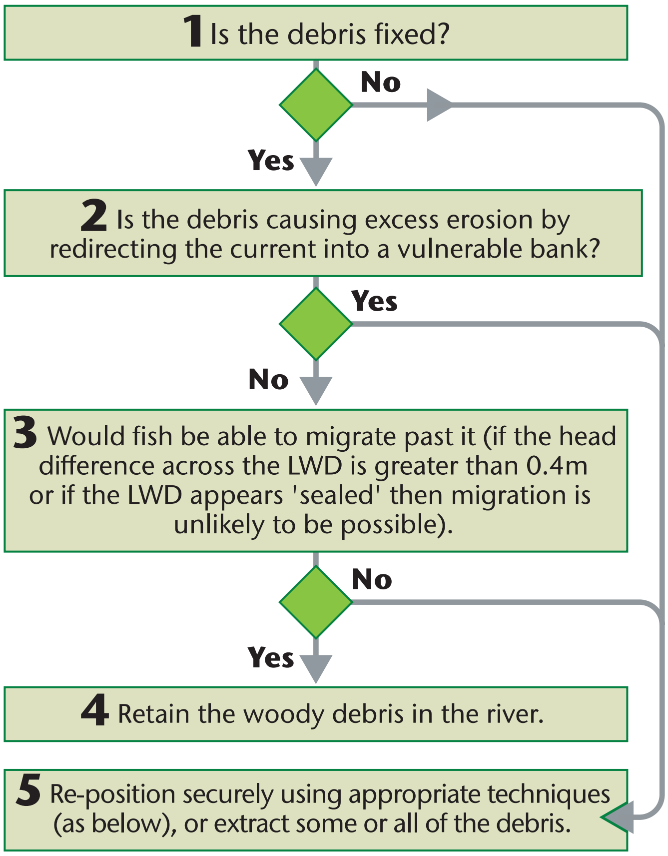
THE SAME SECTION AFTER REMOVAL OF THE OBSTRUCTION

DRILLING LARGE WOODY DEBRIS PRIOR TO INSERTING REBAR

STAGES IN THE INSTALLATION OF LWD

DETAIL OF WIRE RETENTION SYSTEM FOR LWD

'HINGING' LWD FOR INTRODUCTION INTO AN UPLAND STREAM



LWD can also be introduced into rivers by partially cutting through a bankside trunk and 'hinging' it into the water. Careful use of a chain saw will allow the trunk to remain attached to its stump, increasing the stability of timber in the channel, whilst allowing it to continue growing. Stands of ash *Fraxinus excelsior*, alder *Alnus glutinosa*, willow *Salix spp* and hazel *Corylus avellana* are particularly useful for this type of management.

The retention of naturally occurring LWD in river channels is also of great importance. It is valuable both as cover for a wide range of species, and as a key element for increasing channel diversity. LWD encourages differential scouring of the bed and banks, and the useful retention of fine sediment. In high energy systems it can help retain gravels suitable for spawning that would otherwise be washed out of the system.

It also raises water levels locally, promoting increased hydrological connectivity between the river and its flood plain. This is of huge importance for the attenuation of peak flood flows, and the deposition of silt onto the flood plain. There are also direct benefits from the increased percolation of water into permeable strata, and the development of wetland habitats, including wet grassland, bog, and wet woodland. These are all priority habitats under the UK Biodiversity Action Plan (BAP).

The most valuable LWD is stable, often spanning the whole width of the river, and forming 'dams' that can evolve and develop over a period of some years. There should be a general presumption that LWD should be retained within the river channel. However, there are occasions when other concerns, for instance the risk of blocking a bridge arch, or where it is preventing migration of fish, dictate that this is not possible. The West Country Rivers Trust provides a useful guide to the management and retention of naturally occurring LWD. Note that the assessment of LWD should include consideration over the range of flows generally experienced in the river (**above**):

EXTENSIVE BUT STABLE LWD, EASILY PASSABLE BY MIGRATING FISH

There are a variety of methods for safely anchoring LWD in place within the channel. The most important factor to be considered with any of these fixings is that they must provide a reliable way of preventing all reasonable risks of the LWD washing downstream, where it could cause damage and flooding by blocking bridge arches, sluices or similar structures. The most effective way to ensure a a failsafe system is to attach cable laid wire to the LWD, either using staples driven across the wire and into the wood, or by drilling through the trunk, threading wire through and fixing it to itself using proprietary crimps. In either case, the end of the wire should then be fixed to a tree trunk on the bank. This 'failsafe' system allows a number of other fixings to be used to locate the LWD in the channel, normally in an upstream facing direction to avoid excessive bank erosion.

USING REBAR TO FIX LWD IN THE CHANNEL

Other 'tried and tested' systems include:

- Wooden stakes driven into the bed on alternate sides of the LWD at a spacing of 0.6m
- Reinforcing bar ('Rebar') driven into the riverbed through holes drilled into the LWD. Diameter of the rebar can be varied depending on the size of the LWD. Generally, 15mm-25mm bar diameter should prove adequate
- 'Failsafe' anchors made by attaching the LWD by strong wire trenched into the bank to a piece of timber buried some metres back from the bank edge

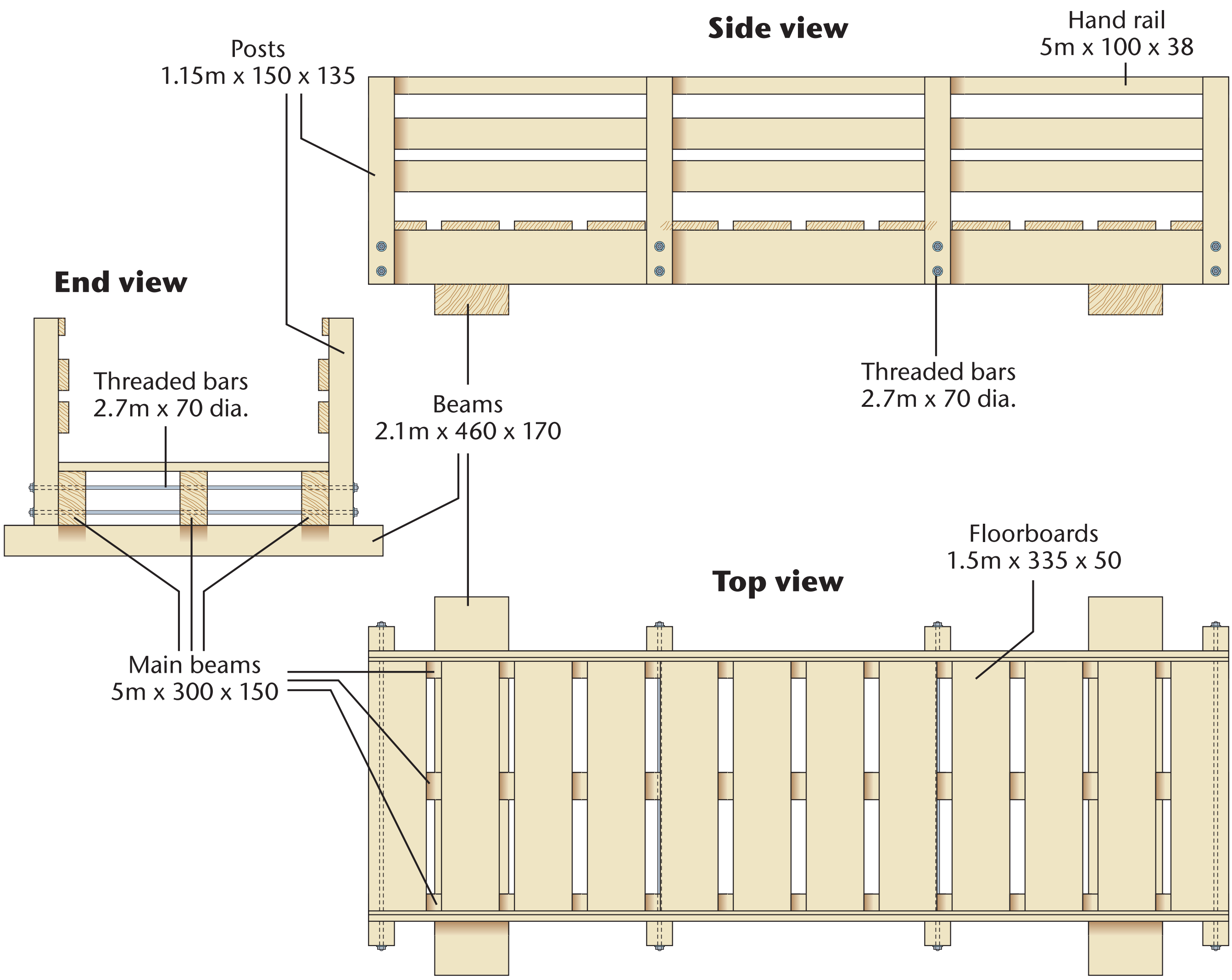
5.5 Stock management

Recent studies using sediment fingerprinting techniques have shown clearly that in many cases, much of the fine sediment in rivers comes from excessive erosion of banks near to the site of sampling. Armed with this information, it is easy to make a strong case for protecting banks from excessive erosion, most often caused by overgrazing by agricultural stock. Ideally, stock numbers can be reduced and farmers compensated for any consequent losses under an appropriate agri-environment scheme (**see Section 4.0**).

A WELL SITED STOCK ACCESS BRIDGE

This approach is however often not possible, leaving fencing to exclude stock as the only practical option. If agricultural interests allow, a wide (10m) buffer of ungrazed grassland should be created between the new fence line and the river. This will allow the development of a zone of rough grass, which will both protect the bank from excessive erosion, and also provide a degree

SPECIFICATION FOR A TYPICAL
5 METRE LONG STOCK BRIDGE

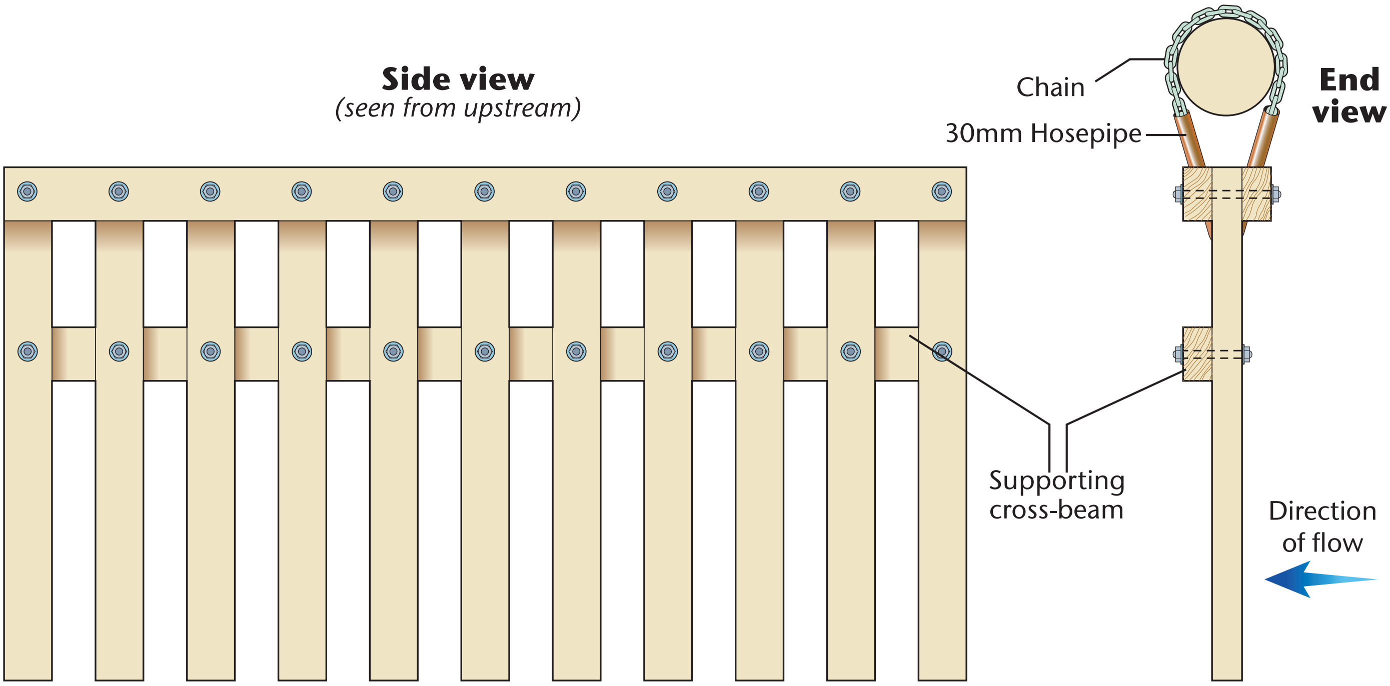


of attenuation of sediment rich overland flow. If a 10m buffer is not possible, then narrower strips of land can still be effective. Make sure that they are wide enough to provide access, both for fishing and for maintenance. Posts and three strands of barbed wire will be adequate to exclude cattle, although stock fencing (more expensive) will be required for sheep. Stock fencing is more vulnerable to 'rip out' during floods, due to debris accumulating on the fence. There may be a case for installing sacrificial panels of fencing at vulnerable locations. By fixing these more loosely (part driven staples, etc) they will be torn out before posts are uprooted, allowing a considerable saving in time and money during the repair phase. Well sited stiles and gates/lift out panels for machinery access will be of great benefit.

Where access is required for stock to cross the river, the ideal solution is a well sited and constructed stock bridge. These prevent any need for stock to access water, eliminating the risks associated with faecal contamination, and possible losses of stock through drowning. Bridges can be relatively easy to construct, with grant funding often available to help with costs. Drawbacks to bridges include the risk of blockage by river-born debris, necessitating regular clearance. In extreme flood events, there is a risk of wash-out and loss of bridges. It is therefore prudent to arrange a strong tethering system to prevent the total loss of the main structure.

Where the installation of a stock bridge is not practicable, a water gate should be constructed. This comprises a high tensile wire or timber pole stretched from bank to bank across the river at the upstream and downstream limits of the crossing. Free swinging vertical slats are then hung from the wire, deterring stock from moving upstream or downstream. Gates can be made from treated timber, or sections of drilled pipe.

SWING GATE FABRICATION



A SELECTION OF WATERGATES

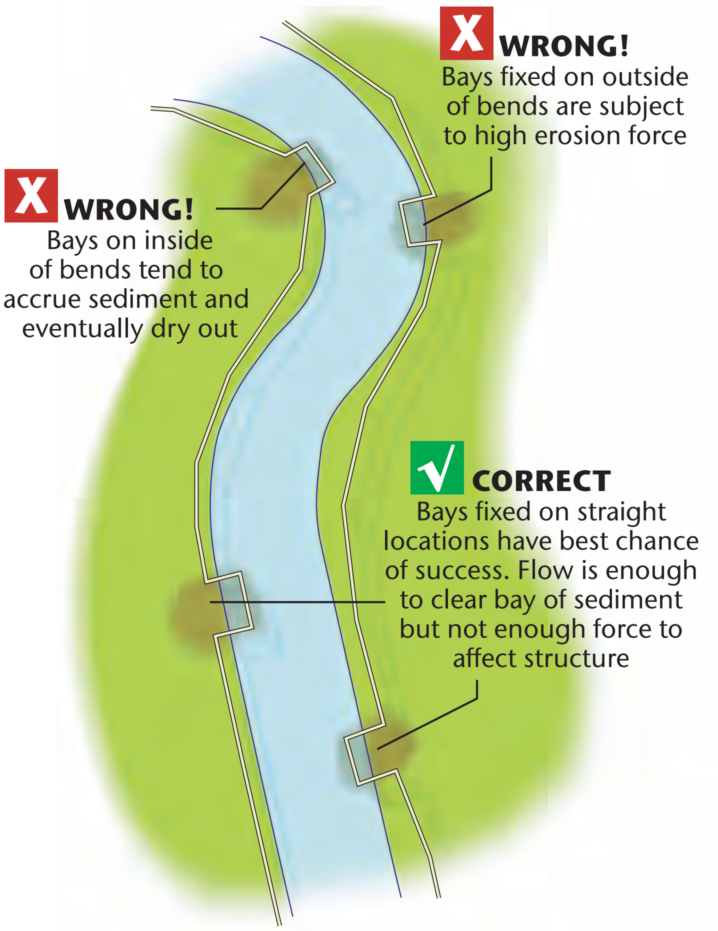
PASTURE PUMP

The welfare of the stock must also be considered in any fencing scheme. Ideally, water would be provided from troughs filled from a mains supply. Although this is an expensive option particularly if there are any leaks on a metered supply, it has the advantage that, in conjunction with stock bridges, it removes cattle totally from the river environment.

If mains water supply is not a practical option, one or more pasture pumps can be provided. These are simple pumps that supply water from the river to cattle on demand. These options remove the necessity for any access for stock to the river, preventing faecal contamination, reducing the risk of diseases such as black leg and foot rot, and the loss of stock through drowning.

As a last resort, one or more cattle drinking areas must be installed. These can be constructed by cutting a shallow access ramp in the bank into the river, covering this with a layer of Terram geotextile, overlain by at least 250mm of 10-15cm stone and erecting post and rail fencing around the whole area. Correct location of cattle drinks is vital to their functioning and longevity. Generally, they should be located on straight sections of channel in order to avoid excessive erosion or deposition of silt.

DRINKING BAY LOCATIONS



CORRECTLY DESIGNED CATTLE DRINKING AREA

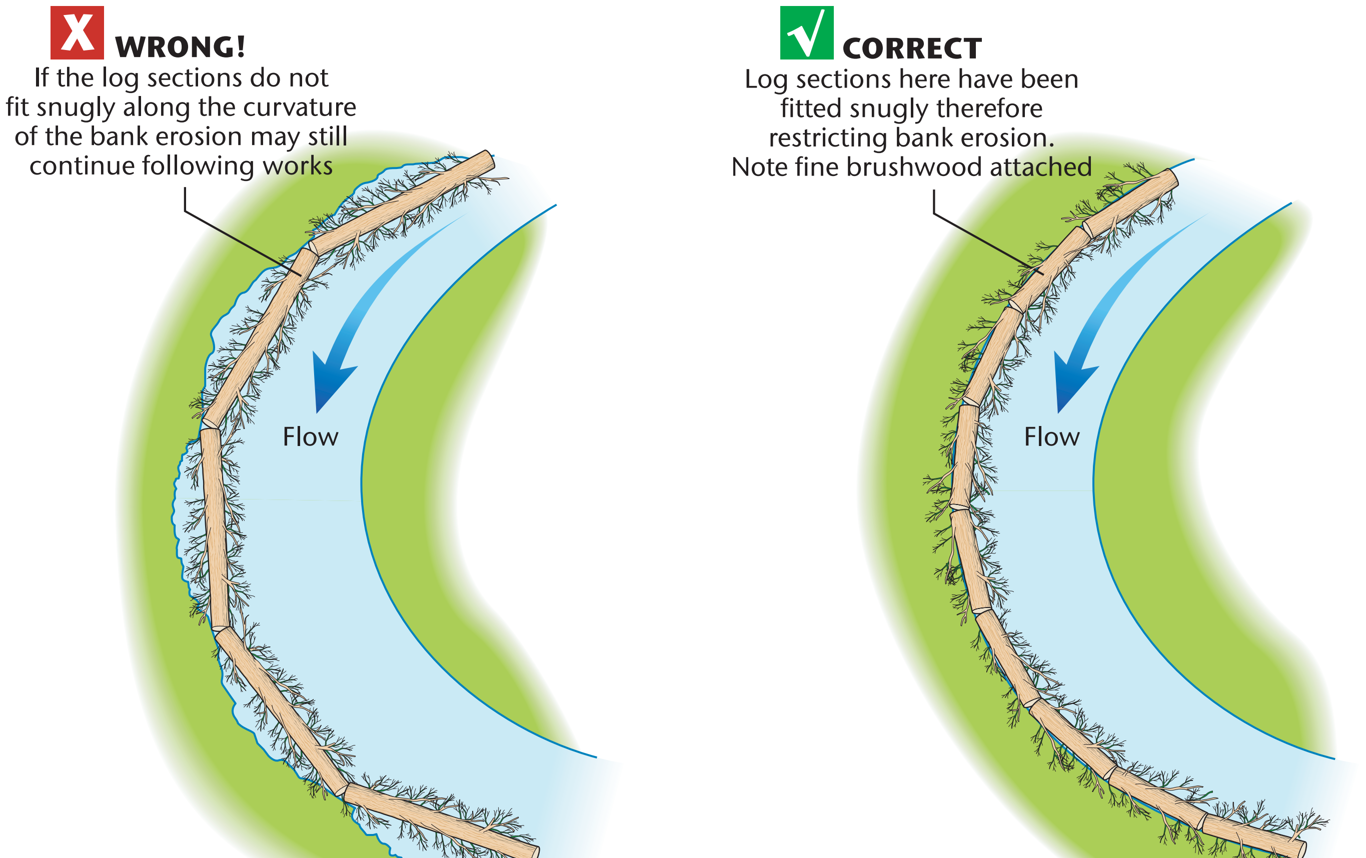
5.6 Controlling excessive erosion

Erosion, of both the bed and banks of rivers, is a natural process. Without it and its mirror, deposition, changes to the form of river channels would not occur. Erosion provides for replenishment of gravel washed downstream, and also helps to keep spawning gravel clean of silt. However, man's activities can increase the rate of erosion to unacceptable levels. Overgrazing, cultivation of arable fields too close to the bank top, removal of protective tree roots, and even excessive angler usage can also help to de-stabilise banks and increase the rate of erosion.

It is a truism that the best way to address excessive erosion is at source; fencing to exclude stock, the cessation of cultivation adjacent to the channel and re-routing of bankside paths are simple mechanisms that will reduce the rate of erosion. There will however be occasions when this approach is not feasible. If this is the case, there are a number of practical mitigation methodologies that can be used.

Great care must be taken when selecting bank protection techniques. Upland rivers can transfer phenomenal energy during spates, destroying apparently robust installations in a single flood event. Generally, solid blocks of bank protection such as concrete, steel and gabions should be avoided. They are unacceptable environmentally and often transfer erosion to points immediately upstream or downstream. Far better to use techniques that aim to reduce water energy locally and trap sediment, helping to build up the bankline. Protecting banks from erosion may also result in increased bed scouring. This can be beneficial, helping to sort substrate and increasing channel heterogeneity. In more extreme cases, it can lead to over-deepening of the channel and undercutting of banks. For all these reasons, it is vital that professional advice is sought before embarking on any major erosion protection.

Generally, erosion of banks by rivers is caused by damage to the base or 'toe' of the bank. At all water flows, but particularly in moderate spates, scouring of the toe occurs, leading to undercutting and eventually failure of the bank above the toe. It is therefore logical that many erosion reduction techniques seek to protect the bank toe from the full force of the river's flow.



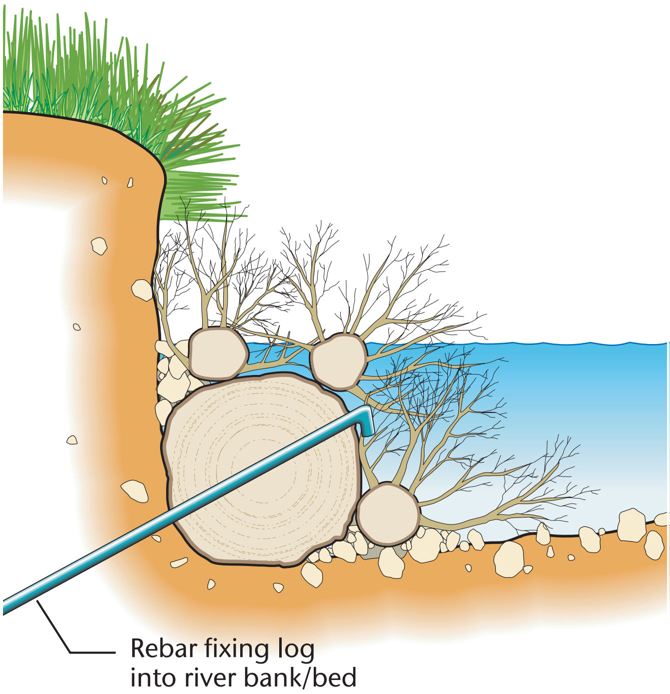
PLAN OF LOG & BRUSHWOOD REVETMENT

Perhaps the most successful technique developed in recent years is the use of logs in conjunction with 'xmas tree' tops. Where there has been a significant bank failure, a single line of logs is fixed in place along the river bed. Each log should be around 3 metres in length, with a diameter of 25cm-30cm, and should be secured using lengths of rebar driven through them.

'Top and lop' from conifers are then nailed to the logs, with their butts facing upstream and overlapping each other by 50% of their length. This forms a dense mattress of fine branches, that not only protect the bank form erosion, but also act to collect sediment during flood events. The accumulated sediment promotes the growth of vegetation whose roots act to bind the bank together. Willow slips planted behind the revetment reinforce this process. Stock proof fencing will be required for the protected section to allow vegetation to develop without grazing.

Willow faggots can be used in a similar fashion, with bundles of live willow wands laid alternately in layers parallel and perpendicular to the flow, and fixed in place with wooden stakes. The willow subsequently roots and grows, forming a dense, living protective mattress for the eroded area. The choice of xmas tree and log, or willow faggot protection will in most cases be guided by the local abundance of the materials required, with both techniques very effective.

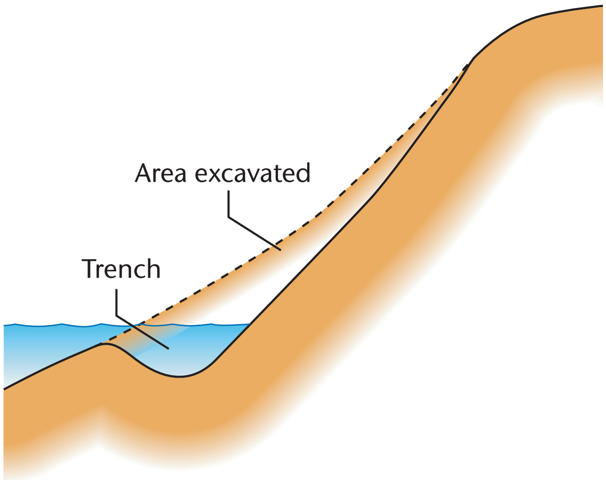
CROSS-SECTION OF LOG REVETMENT



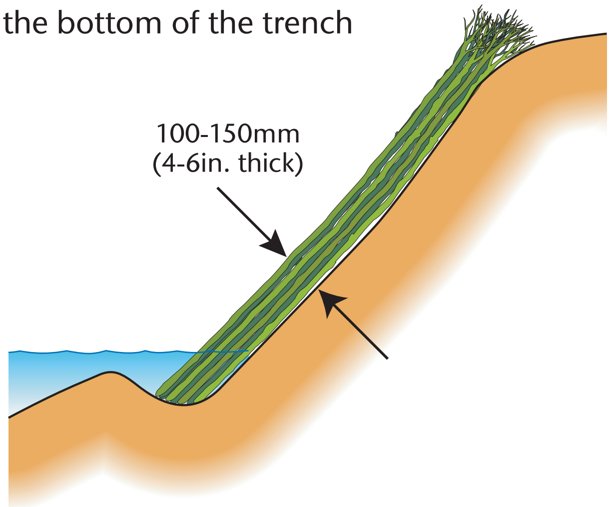
LIVE WILLOW BUNDLES BEING INSTALLED TO REDUCE EROSION ON OUTSIDE OF BEND

INSTALLING WILLOW BRUSHWOOD MATTRESSES

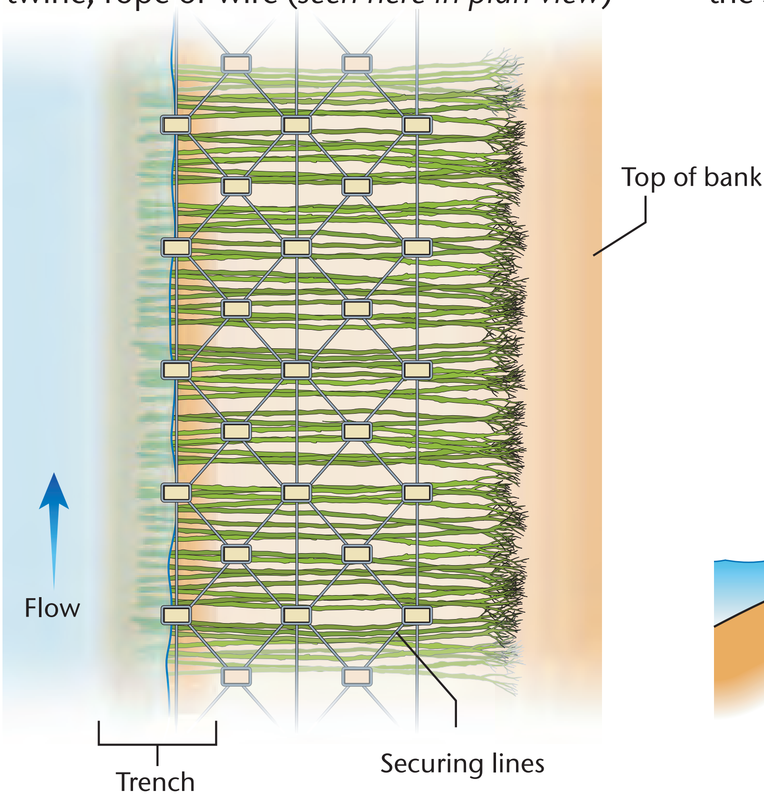
Step 1:
Excavate trench and grade bank



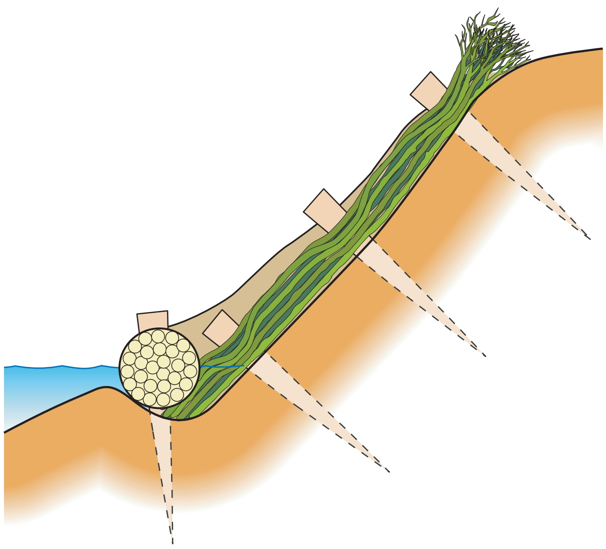
Step 2:
Place willow branches making sure that the butt ends reach the bottom of the trench



Step 3:
Place stakes (*notched*) on 1.0m (*3ft*) centres and secure the mattress with twine, rope or wire (*seen here in plan view*)



Step 4:
Drive the stakes deeply into the bank to tightly compress the branches against the soil.




ROOT WADS DELIVERED TO SITE...............


.. AND INSTALLED WITH LIVE WILLOW TO PROTECT BANK

Installing roots wads into sections of vulnerable bank is another very simple and effective way to reduce erosion. Initial site preparation involves pinning a line of logs along the toe of the eroding bank (as for the xmas tree and log revetment described above). Root wads from felled or wind-blown trees should then be trimmed to leave approximately 2m of trunk attached. The trunk should be pointed with a chain saw, and then pushed into the vertical bank using a hydraulic excavator. The lower edge of each root wad should overlap the line of pinned horizontal logs, with adjacent wads overlapping each other. Insert enough wads to cover the length of vulnerable bank. Coniferous tree tops should then be nailed both to the horizontal logs and the root wads, with the void space behind the wads filled in with cobbles, small rocks or brushwood. Planting the bank behind the wads with willow slips and fencing to protect it from stock will increase the chances of successful establishment.

'Cut and hinged' LWD (**see below**), can also be effectively utilised to protect vulnerable sections of eroding bank. Generally, angling and fixing felled timber to face upstream will help to deflect flow into the centre of the channel, away from the damaged bank, with natural accretion of gravel upstream of the LWD increasing both its stability and the degree of protection offered to the bank. This may prove to be sufficient to allow the bank to naturally regenerate, or there may be an additional need to utilise one of the techniques described above.

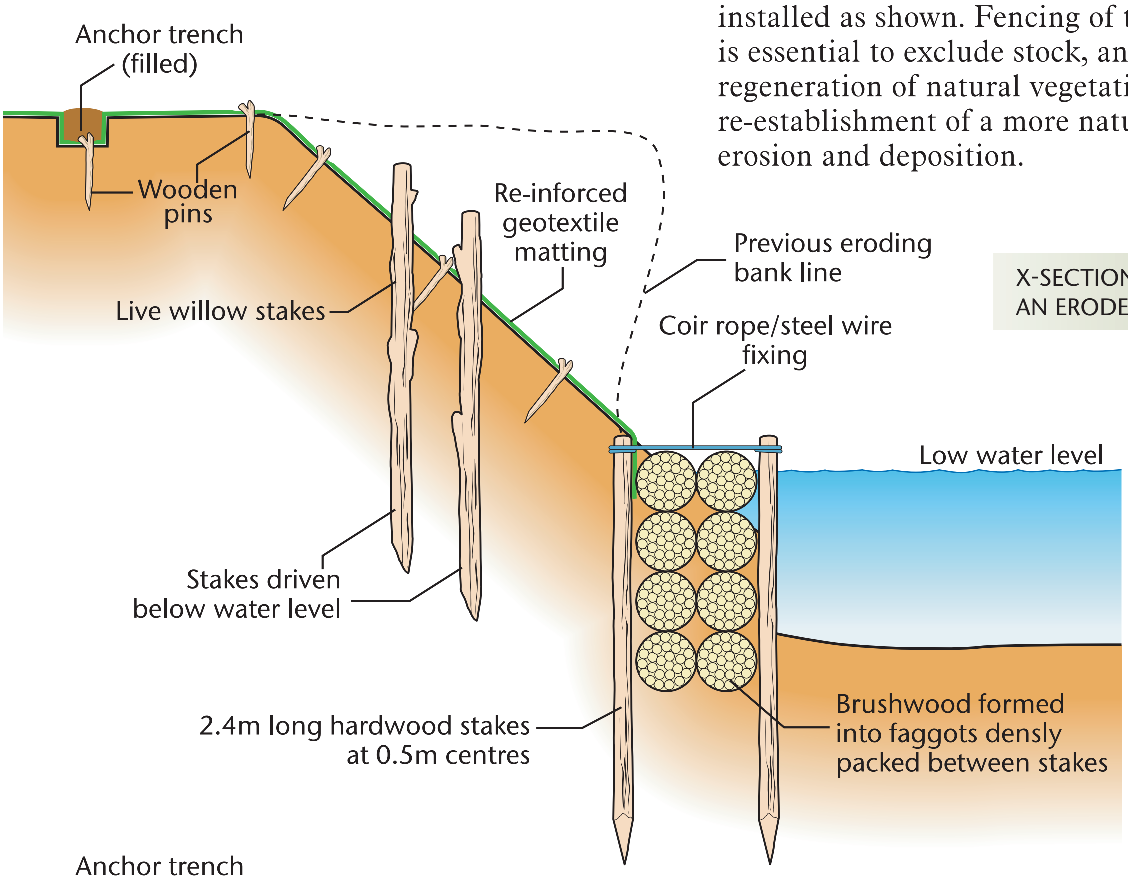
CUT AND HINGED LWD

A more specific technique is the use of so-called 'tree-kickers' to protect the outside of a bend from further erosion. By carefully locating and anchoring a tree trunk, it can be used to deflect the current away from the outside of the bend. The unusual and important aspect of tree kickers is that they are not fixed to the river bed, allowing them to rise up when flows are high, thus offering continued protection to the bank at all stages of discharge.

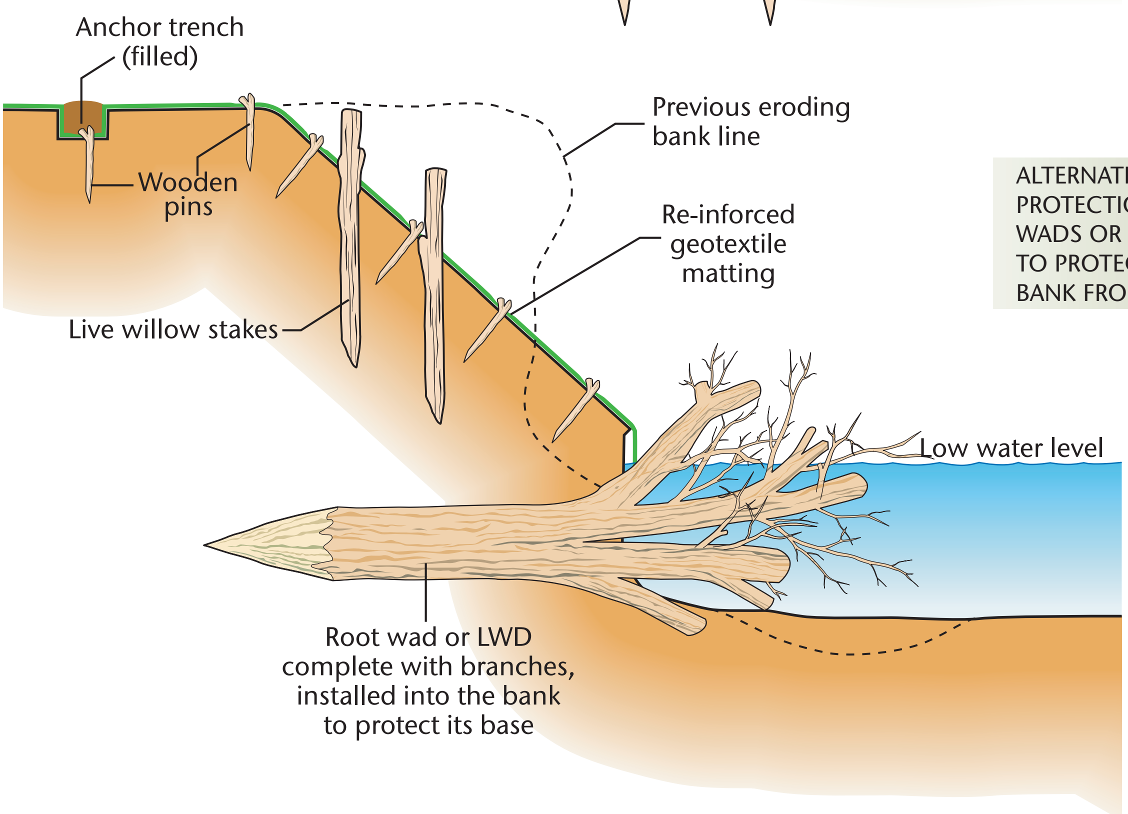
Other techniques utilising live and dead wood that have been successfully used on upland rivers include:

- Brushpacking

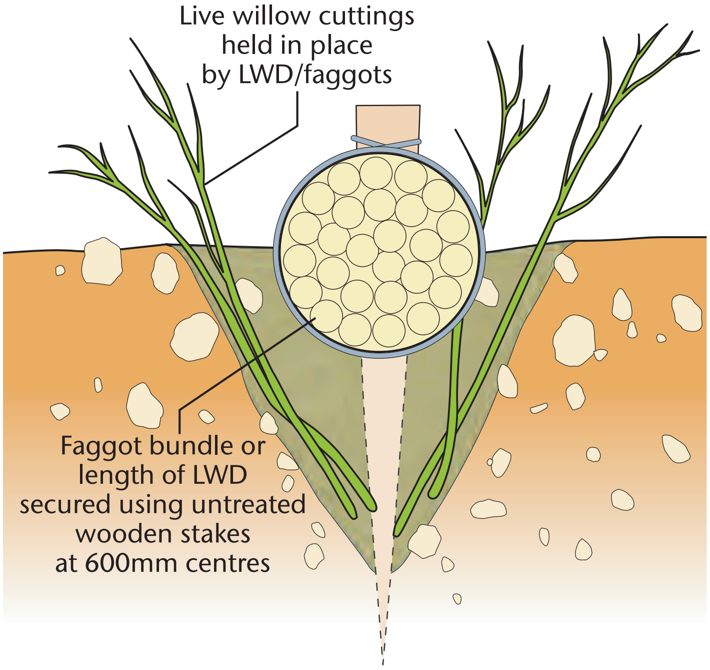
These techniques utilise LWD and live brushwood to provide protection and stability to sections of eroding bank. The eroding bank is initially re-graded to a more shallow, stable profile. The brushwood, willow and LWD protection is then installed as shown. Fencing of the restored area is essential to exclude stock, and promote the regeneration of natural vegetation, and the re-establishment of a more natural regime of erosion and deposition.



X-SECTION OF BRUSHPACKING AN ERODED BANK



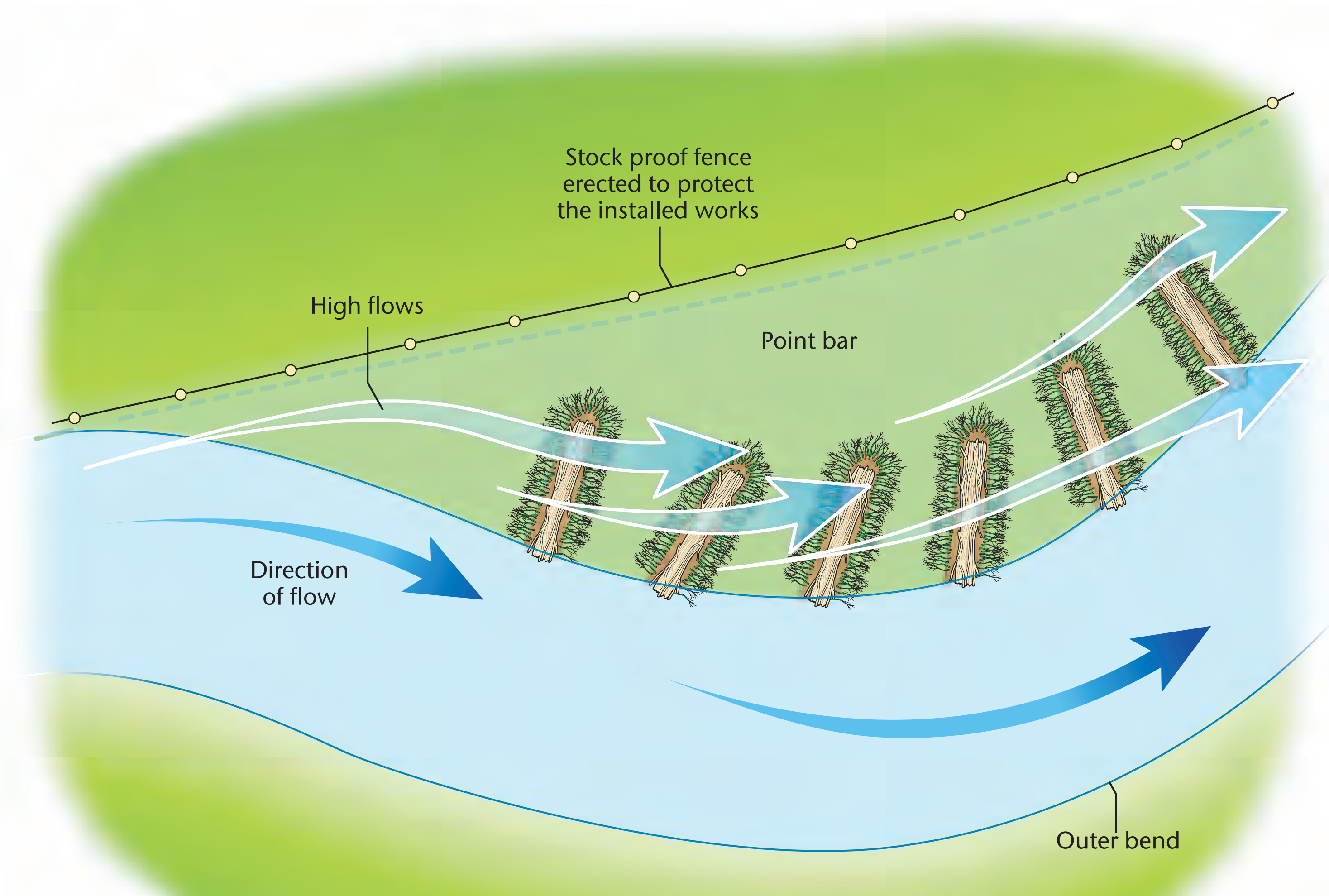
ALTERNATIVE SYSTEM OF BANK PROTECTION UTILISING ROOT WADS OR SECTIONS OF LWD TO PROTECT THE BASE OF THE BANK FROM EROSION



LWD and live willow can also be used to create simple deflectors, that can assist in the stabilisation of the inside of bends, and hence the narrowing of river channels.

Section 3, of The Wild Trout Survival Guide provides further information on all topics covered in this section.

CROSS-SECTION OF WOODY DEBRIS GROYNE.



PLAN VIEW: LWD/BRUSHWOOD GROYNES WITH LIVE WILLOW CUTTINGS PLACED TO DIRECT FLOW AWAY FROM THE INSIDE OF A BEND. THIS TECHNIQUE PROMOTES DEPOSITION OF SEDIMENT, STABILISATION OF THE BANK AND NARROWING OF THE CHANNEL

5.7 Case Study: River Fowey

The upper River Fowey in Cornwall has an interesting recent history. Running from Bodmin Moor to the impressive Golitha Falls, this reach is the traditional spawning ground for many of the river's sea trout, brown trout and the very occasional salmon.

Poor management practices on Bodmin Moor Site of Special Scientific Interest, including overgrazing and damaging illegal ditching operations, released large volumes of sand into the system. This migrated downstream at an alarming rate, covering spawning gravel, often to a depth in excess of 20cm. In addition, there were further releases of fine sediment from inadequately stabilised china clay spoil heaps, that added fine sediment to an already overloaded system

In the face of these threats to the wellbeing of the key recruitment and nursery area of the Fowey, the Fowey Rivers Association (FRA) initiated a number of projects aimed at reversing these declines.

Engaging the services of the Anglers' Conservation Association (now Fish Legal), the FRA worked with the Environment Agency to resolve the issue of illegal dredging activity. They also lobbied the statutory authorities, with only limited success, to address the issue of run-off from china clay spoil heaps.

More positively, they have leased the Draynes Valley, a reach of the upper Fowey, solely as a nursery area. No fishing is permitted, effectively protecting early year classes of sea trout and brown trout from disturbance by anglers. In addition, the association has used money obtained from members and from compensation in a number of legal cases, to construct spawning areas in the upper river and its tributaries. Sea trout have been observed spawning on these features, with the value of the project recognised by an award in the 2007 WTT Conservation Awards.

FINE SAND ACCUMULATED ON SEA TROUT SPAWNING GRAVELS IN THE UPPER FOWEY CATCHMENT

RECENTLY COMPLETED SPAWNING RIFFLE ON AN UPPER FOWEY TRIBUTARY STREAM.

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