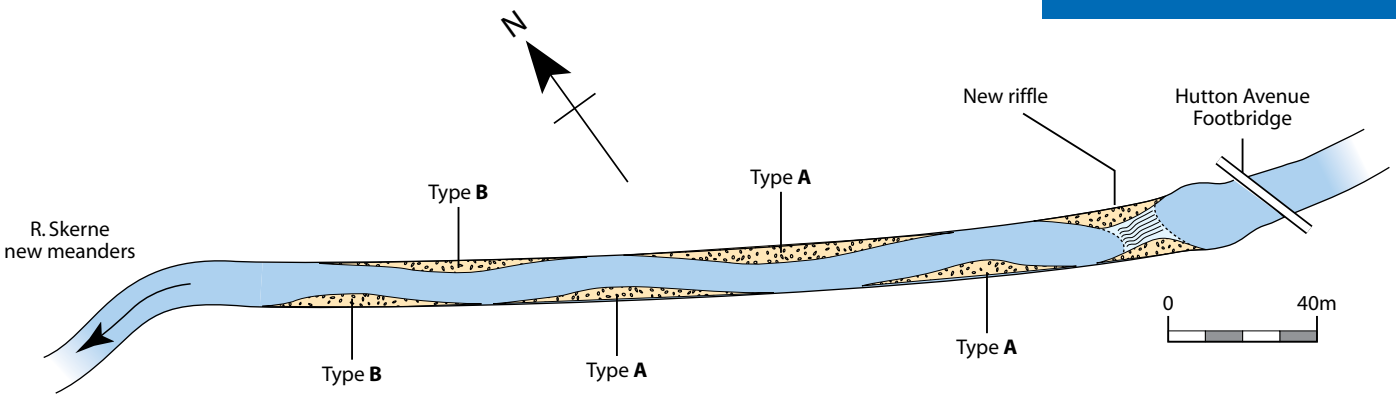
3 Enhancing Straightened River Channels

3.1 Current deflectors

River Skerne

Location - Darlington, Co Durham, NZ301160
Date of construction - August 1995
Cost – Type A - £1,100, Type B - £900

Figure 3.1.1
Plan of location of deflectors



Description

The river had been straightened and enlarged to carry floodwaters safely through an urban area. A gas main runs parallel to one bank and contaminated landfill lies close to the other. The channel was uniformly trapezoidal although bank toes had been eroded. No diversity in the shape of the bed or banks, or of flow currents, existed and the ecological and visual amenity was poor.

View downstream before deflectors constructed

Diversity was introduced by building a series of low level structures in the bed that intermittently narrowed the channel causing variation in flow currents and localised pockets of erosion and deposition (deepening of the bed and accreting at the banks). The structures were necessarily small scale to avoid creating any scour of the river banks or significantly impeding flood flow.

Design

A series of artificial shoals were built, projecting up to one third of the way across the river bed (3m shoals in 9m bed). The shoals were semi-eliptically shaped in plan and elevated above normal water level by only a small amount. Their spacing along the reach varied, but they were placed on alternating sides of the river to encourage a small degree of sinuosity to the normal flow regime.

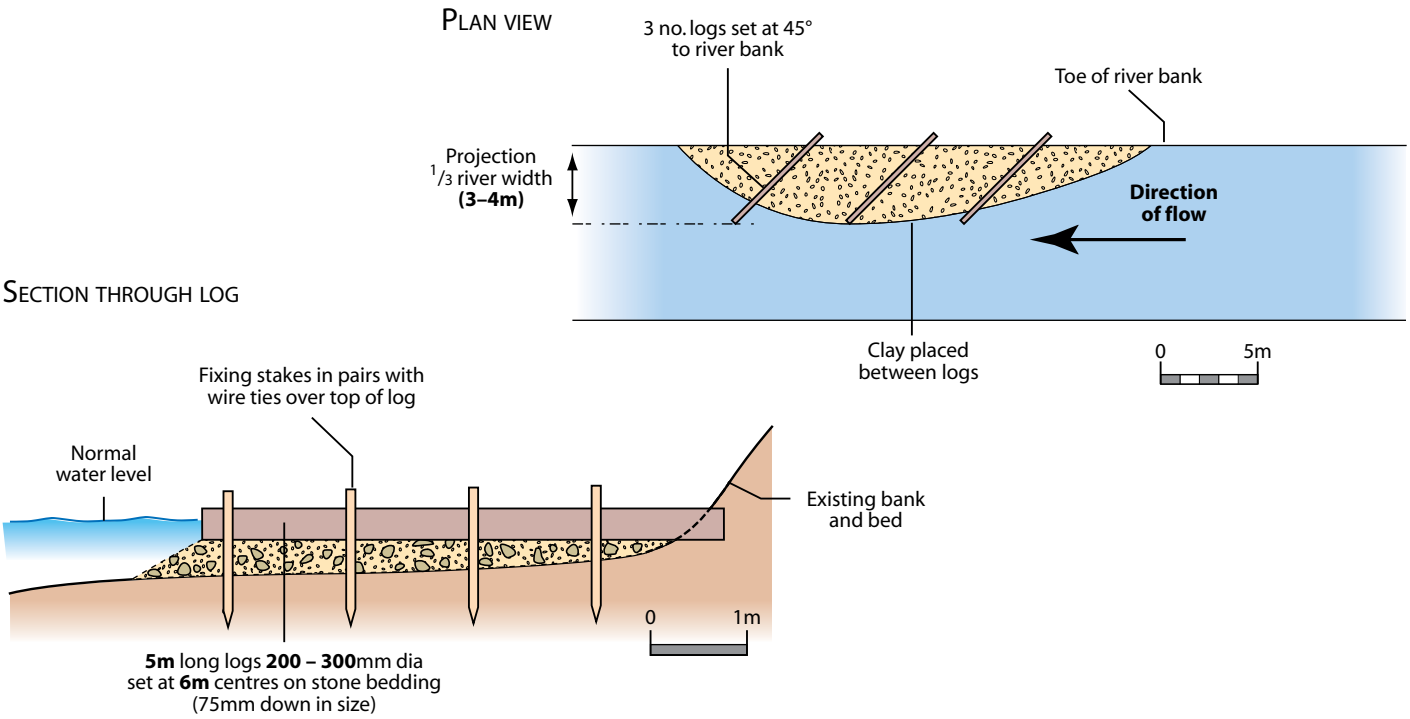
As this form of shoaling was not natural to the straightened reach, the design needed to impose conditions that would generate and sustain both scour and sediment deposition. This was achieved by incorporating a series of current deflectors, of varying length, out from the water's edge. These impede river flows, causing scour at their tips, whilst creating eddy currents within which silt is deposited closer to the bank. The anticipated form of silt deposition was simulated by adding stone and clay between the deflectors to initiate shoal formation.

Tree trunks (logs) of c. 300mm diameter were specified for deflectors as this is the most suitable material generally available near rivers, although all were imported at this urban location. Logs were secured with fence posts and wire after setting to line and level on a bed of stone.

Two variations of the designs were introduced. The deflectors of 'type **A**' point downstream (*Figure 3.1.2*), whereas those of 'type **B**' (*Figure 3.1.3*), point upstream. This was done to help determine the most effective alignment for future application of the technique.

The height of the deflectors above normal water levels was also important. If set too low they would not create enough flow variation or visual benefit but if set too high they would create excessive erosion and would resemble terrestial features.

Figure 3.1.2
TYPE **A** DEFLECTOR



Type **A** deflector
– vegetation established

The type **A** deflectors were specified at about 200mm above water level and type **B** sloped from 300mm above water level at the bank down to water level at the projecting end.

Some planting using marginal species was planned for the end of the first winter's season after the river had adjusted the shape of the 'as built' structures.

Subsequent performance 1995 – 2001

Whilst the deflectors have added a useful degree of diversity to the reach, this was not achieved without post-works modification following reaction by the river to their imposition; particularly those of 'type **A**'.

The primary difficulty was experienced when setting the level of the deflectors in relation to the normal range of low water levels; a critical factor. Deflectors were installed at the start of extensive river restoration works further downstream, when water levels were temporarily raised. Consequently, the 'type **A**' deflectors were set higher than designed and 'type **B**' were set lower. Live willow logs were used in 'type **A**' and inevitably began to grow, threatening to cause obstruction to flood flows.

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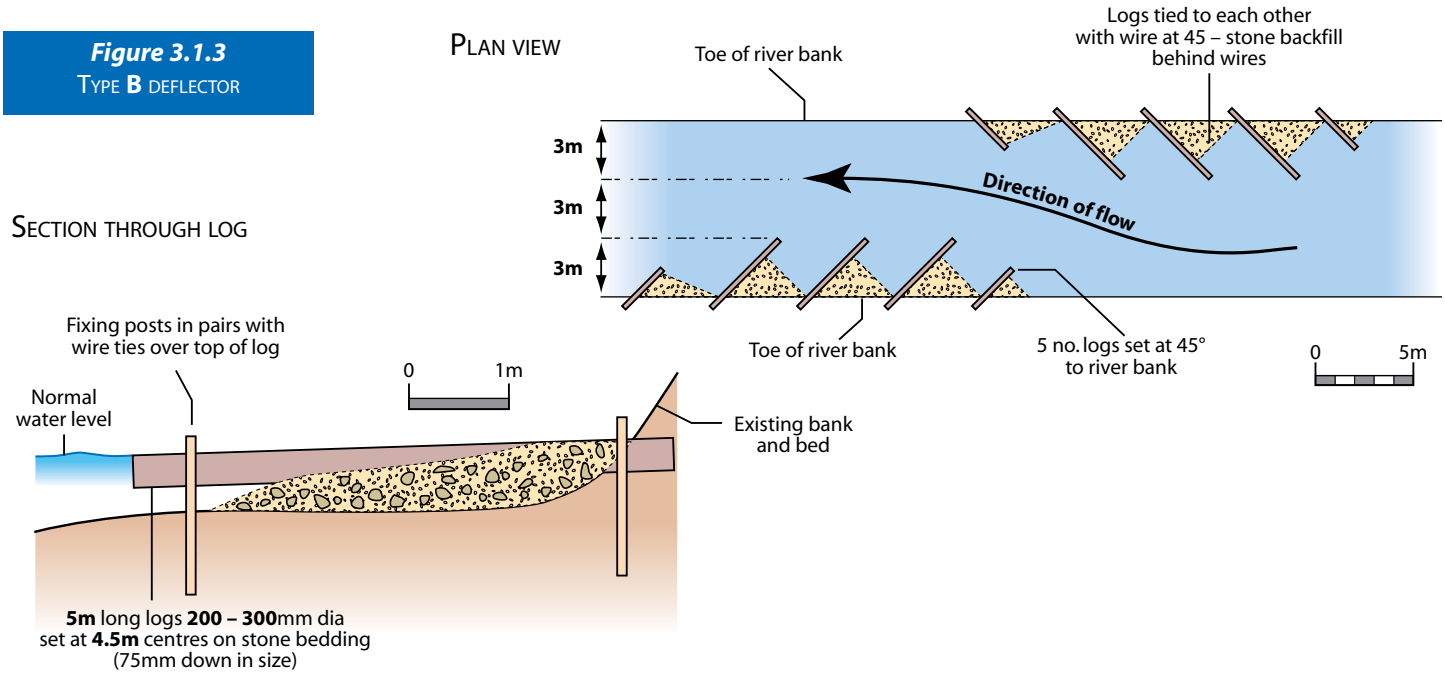
Enhancing Straightened River Channels

Type **B** defelctor before planting

Figure 3.1.3
TYPE **B** DEFLECTOR



As a result of these factors, over winter floods washed out much of the fill from 'type **A**' deflectors, leaving them perched above the water level, and causing erosion of the opposite river bank. Conversely, 'type **B**' deflectors had no discernible effect on the river regime.

Repairs to 'type **A**' deflectors comprised removal of the logs and replacement with pre-planted fibre rolls set at the surviving shoal level, as well as some planting using fibre mattresses. 'Type **B**' were not modified but some plant pallets were introduced near the bankside.

Subsequently 'type **A**' deflectors continued to adjust but show signs of becoming stable at about the levels designed and indicated in the figure. Small pools exist just downstream and currents are discernibly faster through the narrows created. 'Type **B**' deflectors remain less evident and would ideally be raised in level to bring them up to those designed.

The technique appears to be very worthwhile, but success is clearly sensitive to the size and level of the structures introduced. Both types were further enhanced by adjoining marginal planting at a later date (*see Technique 3.2*).

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Enhancing Straightened River Channels

3.2 Narrowing with aquatic ledges

A) River Skerne

Location - Darlington, Co Durham, NZ301160
Date of construction - Type A – Autumn 1997, Type B – Autumn 1998
Cost – Type A – £45 metre, Type B – £40 metre

Attaching coir matting to create Type **A** ledges on River Skerne

Description

The river had been straightened and enlarged to carry floodwater safely through an urban area. A gas main runs parallel to one bank and contaminated landfill lies close to the other. The channel was uniformly trapezoidal although bank toes had been eroded. No diversity in the shape of the bed or banks, or of current flows, existed and the ecological and visual amenity was poor.

Ledges were installed both upstream and downstream of Hutton Avenue footbridge; in the former location along an unmodified channel and at the latter in association with current deflectors. These ledges help control undercutting of the river bank toe as well as introducing desirable habitat and improved visual amenity. They also narrow the normal flow channel encouraging velocity variations in an otherwise sluggish river.

Design

As marginal plants were absent in the reach it was evident that the straight river would not naturally sustain the shallow, silty edges necessary for their growth. The design needed to create these conditions artificially in a manner that would eventually become self sustaining.

Two designs were developed utilising proprietary matting to hold backfilled river silts in place along the waterside (*Figure 3.2.1*). The ledges created were either planted with pre-grown materials or left to colonise from planting introduced nearby.

Type **A** design is suited to wide ledges (up to 2m at this site) but the width can be varied to introduce curvature to the plan alignment.

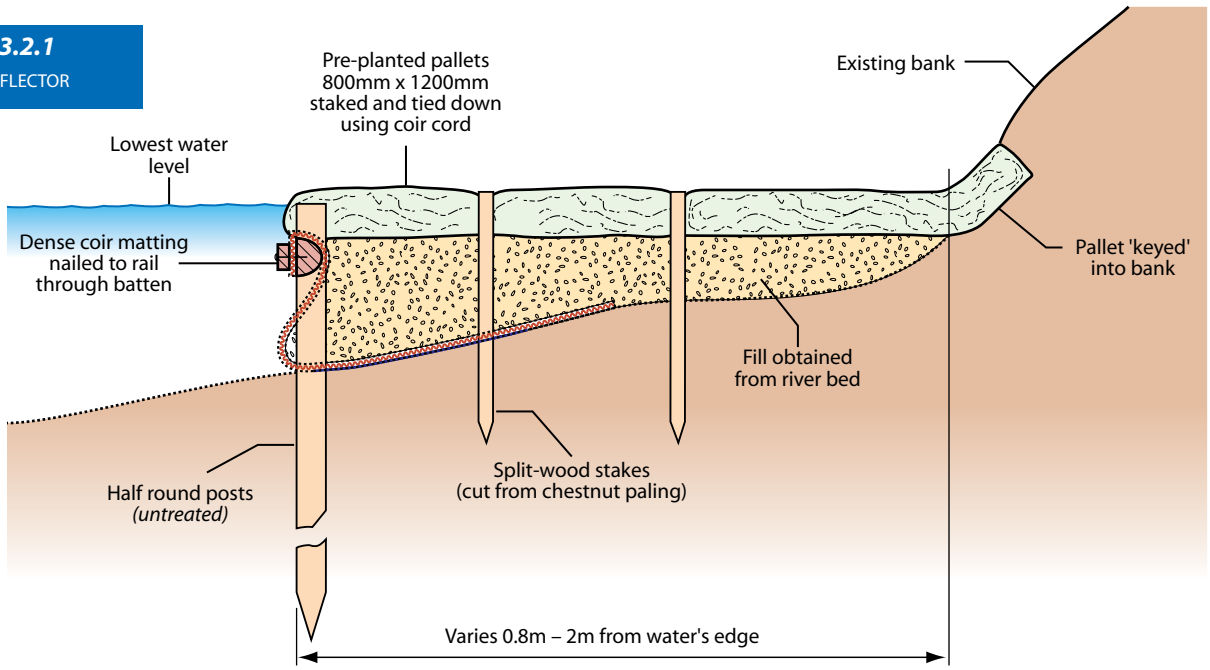
Type **B** design is suited to narrow ledges and is most appropriate where the river bed falls away steeply at waters edge and a small fringe of marginal vegetation is all that can reasonably be sustained.

Both designs rely upon a face of untreated timber posts and rails to hold the matting containing silt backfill. To ease construction, these are firstly assembled with matting in place just above water level and then the posts are pushed below water using an excavator bucket. The use of wire ties at rail joints affords the necessary flexibility.

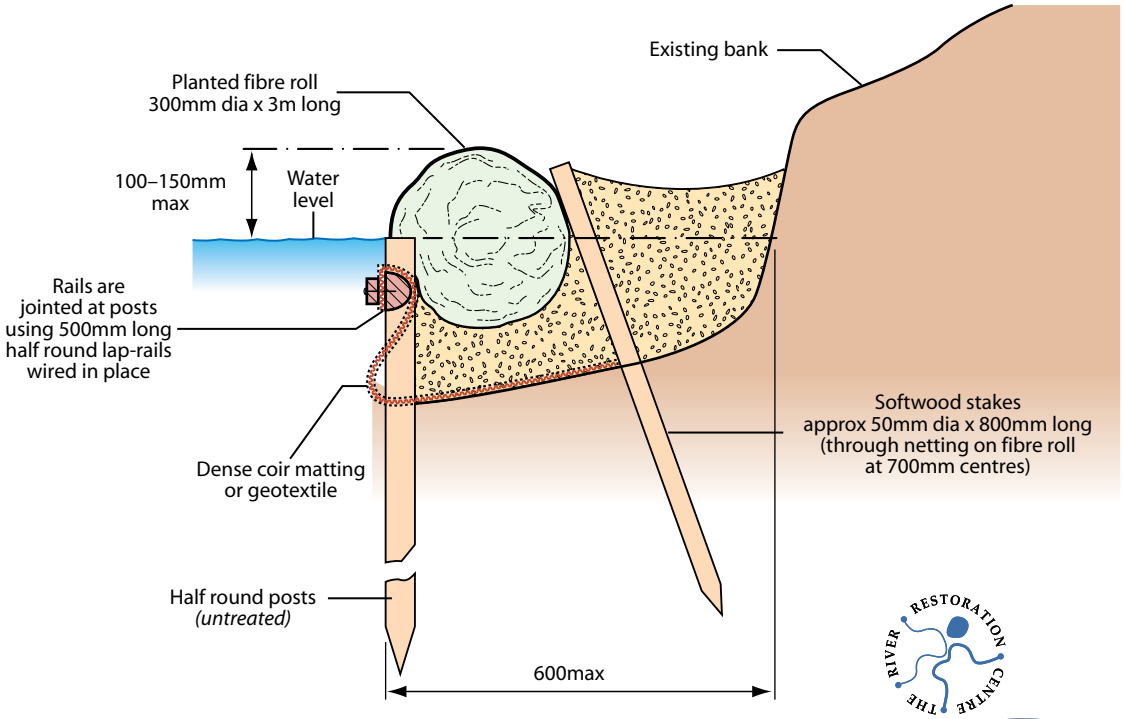
Biodegradable coir matting was favoured, but some nylon matting (Enkamat) was utilised in the type **B** application where hydraulic conditions suggested a long life material was needed. Under most conditions the root growth of the plants introduced is expected to consolidate the underlying silts whilst matting and timber slowly decay, perhaps over a 5-10 year period. Emergent growth was expected to attract silt deposits as plants become established.

Figure 3.2.1
TYPE **A** DEFLECTOR

TYPE **A**



TYPE **B**



3 Enhancing Straightened River Channels

Type **A** Ledge on the Skerne – May 1998

Subsequent performance 1995 – 2001

Type **B** margins utilising plant rolls were installed upstream of the footbridge in August 1996. In 1998 they are attractive features much favoured by resident ducks that have created some bare patches between well established runs of lesser pond-sedge, yellow flag and reed canary-grass. The attraction of silt within the overwinter dormant vegetation along the ledges is significant; ledges have built up by as much as 300mm in places before being assimilated within new spring growth.

Type **A** margins using plant pallets were installed downstream of the footbridge in the autumn of 1997 and overwintered satisfactorily in dormant conditions after several floods. Early summer 1998 growth was patchy with some silt banks smothering pallets. Growth was sufficient to ensure the spread of species to generate the dense cover required. Noteable species that survived include occasional purple loosestrife and meadowsweet.

Type **B** Ledge on the Skerne after 2 years

Enhancing Straightened River Channels

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B) River Cole

Location - Coleshill, Oxon/Wilts border, SU 234935
Date of construction - Autumn 1997
Cost – £56/metre

Type **A** and **B** ledges on the Cole after one winter

Description

Ledges of both type **A** and type **B** designs used on the Skerne were created on a short reach of the river located immediately downstream of the main road bridge at Coleshill. The work followed the installation of a new gas pipe crossing under the river bed and were part of the contractors river bank reinstatement programme.

The river conditions are more fully described in *Technique 1.2*. The reach is part of the original river within which water is impounded by newly created meanders downstream.

Post and rail was driven up to 2m out of from the waters edge, coir matting attached and then backfilled with soil excavated from the same river bank. Excavation from the river bank enabled the width of the ledge to be extended, to more than 2m in places but, more importantly, it afforded a flatter, more varied bank profile than the previous 1:1 batter. Transitions into the existing banks at each end used the type **B** design.

Subsequent performance 1995 – 2001

The ledges overwintered well in dormant conditions with no structural damage by floods although little more than 50% of the plants appeared to have survived to grow on during summer. The ledges are developing very well (1998) and creating both emergent vegetation habitat and landscape enhancement in the short stretch of river that previously had the least habitat and visual amenity value.

Prior to re-profiling and ledge construction – May 1996

3

Enhancing Straightened River Channels

3.3 Stone riffle

RIVER SKERNE
LOCATION - DARLINGTON, CO DURHAM, NZ301160
DATE OF CONSTRUCTION - AUGUST 1996
LENGTH - 60M
COST - £2,000

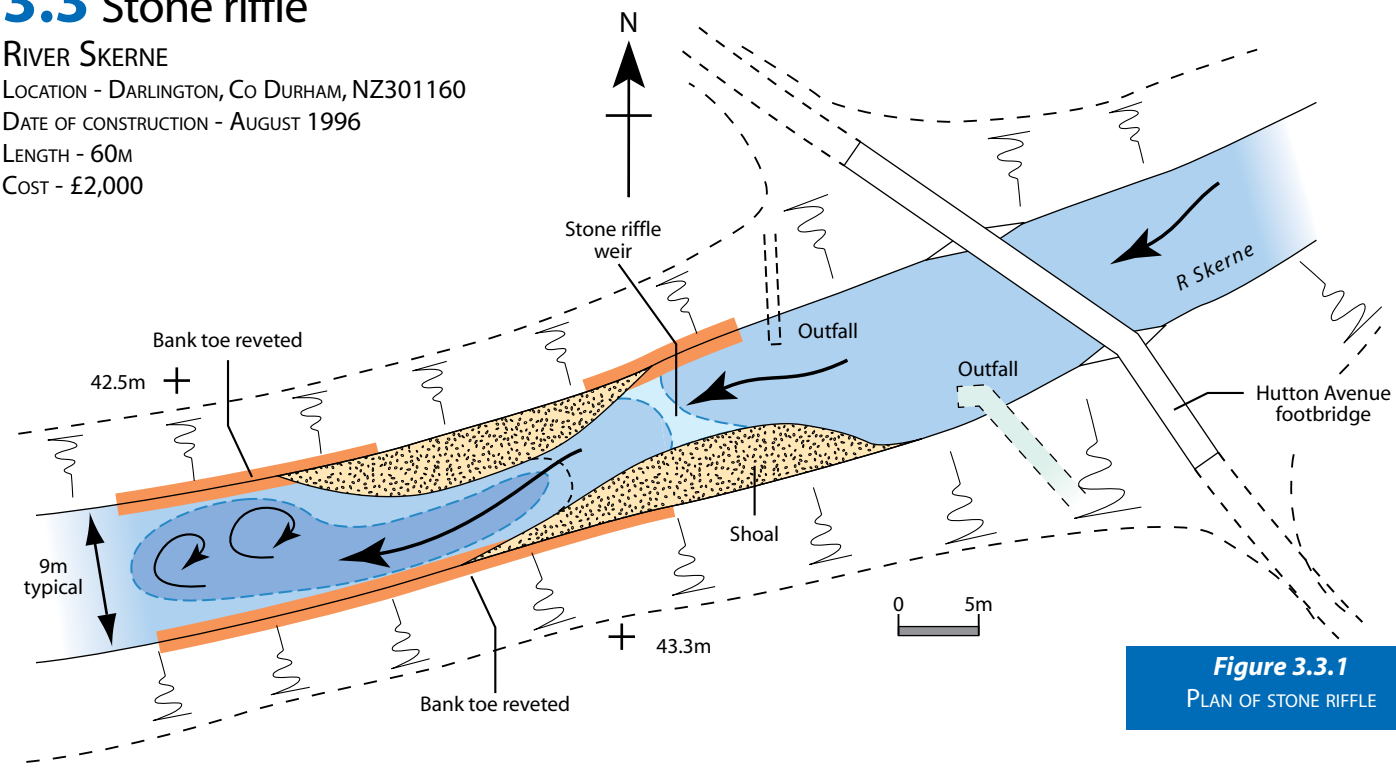

Figure 3.3.1
PLAN OF STONE RIFFLE

Description

The Skerne has no natural gravel sediments in the restoration reach, so the introduction of a stone riffle feature needed to be entirely artificial and self sustaining. A riffle located just downstream of Hutton Avenue footbridge afforded several benefits within what was a featureless, straight reach of river (*see Techniques 3.1 and 3.2)* for other enhancements in the same reach).

Firstly, the sight and sound of water cascading over the riffle is enjoyed by people using the footbridge. Also, the regulation of normal water levels upstream has helped in introducing stable marginal planting ledges wher water birds and mammals can always be seen. Two surface water outfall pipes just upstream (one 900mm diameter) are always submerged because of the riffle (*see Technique 9.1*). Children regularly paddle in the shallow flow over the riffle. In anticipation of this the design needed to be as intrinsically safe as possible.

Design

Although described as a riffle, the structure was designed as a low weir. Scour of the structure, as well as the river bed and banks downstream, were primary considerations.

The riffle is configured as two semi-eliptical shoals, diagonally opposite each other, that are linked by a shallow sloping weir, such that the whole is a single, homogeneous structure. During low flows, only the weir is submerged but the shoals quickly drown as flows increase. The configuration sustains a deep faster flow of water around the downstream shoal that noticeably

Stone Riffle downstream of Hutton Avenue footbridge

Enhancing Straightened River Channels

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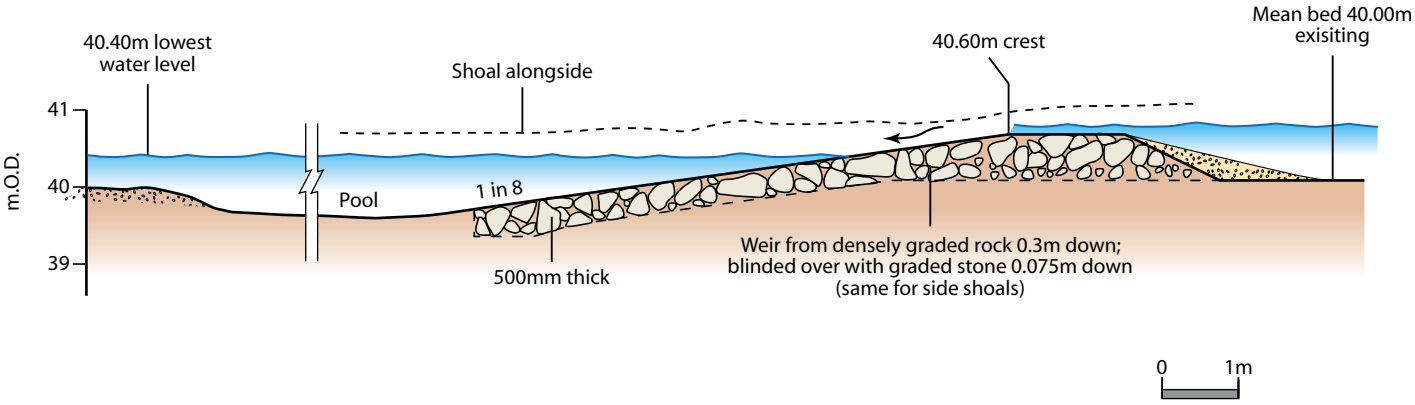


eddies as the currents merge with the lower river. These variations in the speed, depth and direction of flow all sustain habitat diversity. The river banks alongside each shoal are graded as flat as practical to make access to the water's edge easy and safe. The toes of the river banks are reveted with stone where river flows are accelerated during passage over the structure and beyond.

The stone used for construction was a densely graded crushed rock mixture sized 300mm down to 5mm. The dominant size (at least 50%) was in the range 125-300mm to ensure that the structure would not wash away during floods, albeit some adjustment to form would inevitably occur. As a final measure, the entire structure was covered in a layer of smaller crushed stone to simulate gravel. This mixture was sized 75mm down. Its purpose was to smooth out the irregularities in the core rock surfaces improving appearance. Much of this material would be washed away by floods, but was expected to settle out in desirable niches close downstream.

The riffle allows easy access down to the river – November 1996

At normal water levels the new structure is free flowing, but spates of floodwater cause downstream levels to rise more quickly than those upstream such that the structure is 'drowned out' at an early stage; an important flood defence and fishery requirement. Weed growth downstream of the structure also causes seasonal rises in normal water level that partially submerge the structure.

Subsequent performance 1995 – 2001

The new riffle/weir has performed well and adds greatly to the amenity of this well visited location. The river has scoured away much of the smaller sized stone, as anticipated, but a stable structure has evolved in the form required. The slope of the weir has steepened significantly (from 1 in 8 built to perhaps 1 in 4).

It was anticipated that washed out stone would lead to the formation of a smaller, secondary riffle close downstream but this has not occurred. Consideration has been given to building this in order to stabilise normal water levels at the bottom of the main weir, whilst adding an additional element of diversity.

Of particular note is the popularity of this spot with children who can gain safe access to the river and paddle in the shallow water, where the bed is firm and stoney.

3

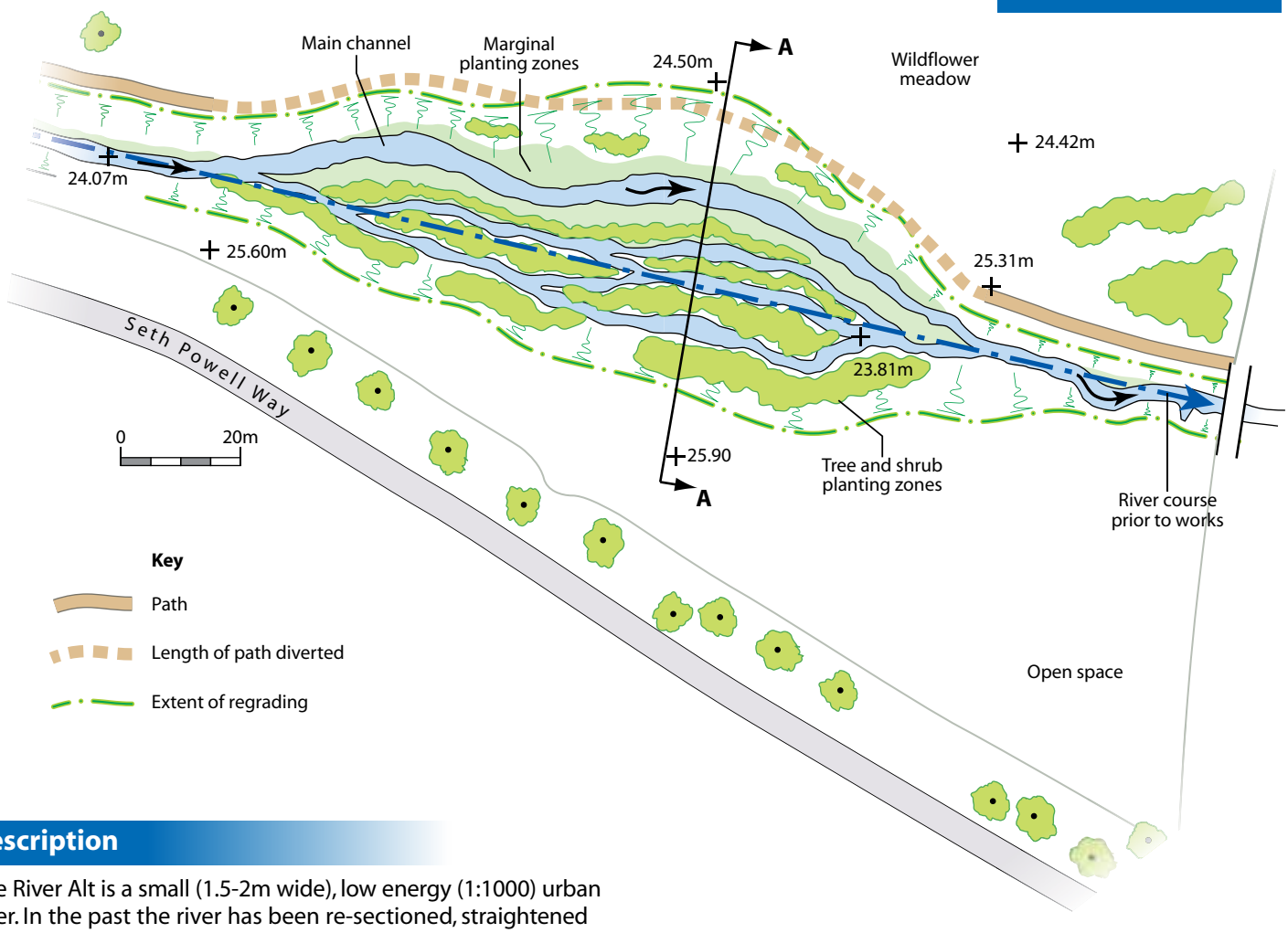
Enhancing Straightened River Channels

3.4 Radical re-design from uniform, straight channel to a sinuous, multi-channel river

River Alt

Location – Knowsley, Liverpool, Merseyside SJ435927
Date of construction – 1996
Length – 140m
Cost – £40,000

Figure 3.4.1
Plan of the widened braided channel



Description

The River Alt is a small (1.5-2m wide), low energy (1:1000) urban river. In the past the river has been re-sectioned, straightened and over-deepened. The rehabilitated section runs through an area of public open space having been previously realigned to follow the road edge, close to a housing estate. Improved water quality has resulted in fish returning to some parts of the system in recent years, but further improvements in wildlife value had been limited by the poor quality of the river habitat.

Consultation with local authorities, community groups and local schools took place during the design and construction phases. Options for rehabilitation were constrained by existing planning permissions on part of the site and the existence of a wildflower meadow. The provision of public access was a very important element in the design.

The river flows beside a road and was constrained within a trapezoidal channel. Dense bankside growth often hid the small watercourse. An existing footpath on the left bank was set back from the river. A result of disposal of excavated material from the original construction of the course, the immediate bank was at a higher level than the surrounding land, effectively shielding the river from view.

As the river course moved away from the roadside, it presented the opportunity to create a wide (up to 30m) floodplain within the confines of the channel. By doing so this could open up the view of the river by removing the existing 'raised' bank.

Trees, shrubs and marginal plant species

Trees at 2m centres	Shrubs at 1m centres	Marginals at ~ 4/m^2
White willow	Common osier	Purple loosestrife
Ash	Goat willow	Yellow flag
Oak	Hawthorn	Water plantain
Alder	Blackthorn	Common club-rush
Gean	Hazel	Common reed
Bird cherry	Dog rose	Water mint
Eating apple varieties	Honeysuckle	Gypsy wort
	Dogwood	Water forget-me-not
	Bramble	Brooklime

Trees and shrubs all 1+1 bare root transplants 0.6m–0.9m, ratio of 2:1 shrubs to trees.
Random species groups of 3–5 trees and 5–7 shrubs.

Before:
The Alt, straight and steep sided

Bed dominated by silt

Design

The 1.5 metre 30 degree banks were excavated back on either side of the existing course, creating up to a 30m width of 'floodplain'. This work was carried out over 140m. The 'floodplain' comprises a 'main' channel and several braided channels separated by marginal berms. In order to achieve a matrix of channels, standing water and damp areas, interspersed by trees and shrubs, ground levels needed to vary. Due to the uncertainties of ground condition and in order to work with the natural conditions as much as possible, this was supervised on-site to avoid over-specification on the design drawings, and to allow for adjustments as necessary.

Bed levels were calculated from existing levels, constrained by a bridge at both ends and an outfall half way along the scheme. Fortuitously the bed level corresponded to a clay layer, making a good guide for the contractors. Working in the wet also provided a good guide to relative levels.

The existing channel was narrowed to form the deeper of the braids. The new 'main' course was about 25% larger and deeper than the braided channels to encourage the majority of low-flows along this route, and was located along the left bank, nearest to the footpath route. It was accepted that high flows would possibly alter this pattern and that such natural changes could take place due to the excess flood capacity within the new 'floodplain'.

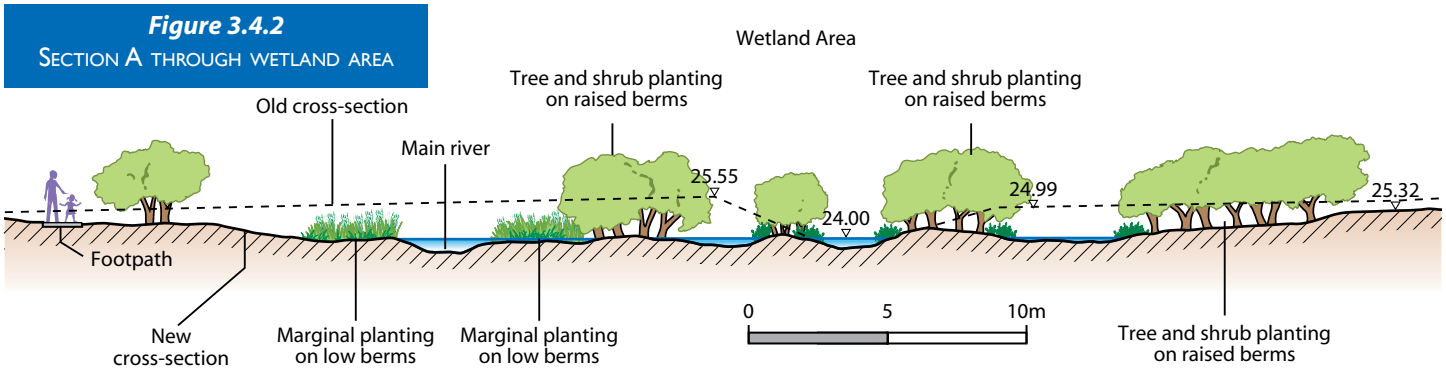
The excavated 'floodplain' area

The final bank profiles were as shallow as 1:25, connecting the low lying adjacent land by removing the existing raised edge. For a length of 50m the redirected footpath now cuts across the shallow bank slope bringing the public closer to the watercourse.

The shallow berms separating the braids and main course were planted with various riparian species rather than relying on natural recolonisation, as there was little natural seed source upstream. In addition on some of the higher berms willow was planted to provide extra cover. A native grass and wildflower mix was used for the banks.

Spoil disposal had to be addressed at an early stage to permit such a large (9000m³) 'floodplain' excavation. The nearby school planned to build an earth bank to prevent illicit vehicle access to its playing fields. By using 6000m³ from the enhancement works to help the school achieve this, the project avoided a potential doubling of costs.

Figure 3.4.2
SECTION A THROUGH WETLAND AREA



Subsequent performance 1996 – 2001

The planting has been successful, with the exception of some of the shrubs on the riverbank which were removed.

Though only indicative at this stage, on at least two occasions there has been a whole water quality class improvement between upstream and downstream on the site. Though not physically well suited to most fish, the number of sticklebacks (*Gasterosteus spp.*) has increased markedly.

Anecdotal evidence suggests that people are happy with the scheme. However, there is also evidence that some people were expecting something different.

When creating a wide, shallow and braided channel it is important to recognise the likely increase in urban rubbish deposited after flood events. If not properly managed this can seriously affect the success of the overall project, particularly from the public's viewpoint.

Original Information Provider:
Neil Guthrie

A good diverse vegetation structure has developed along and between the channel threads

3

Enhancing Straightened River Channels

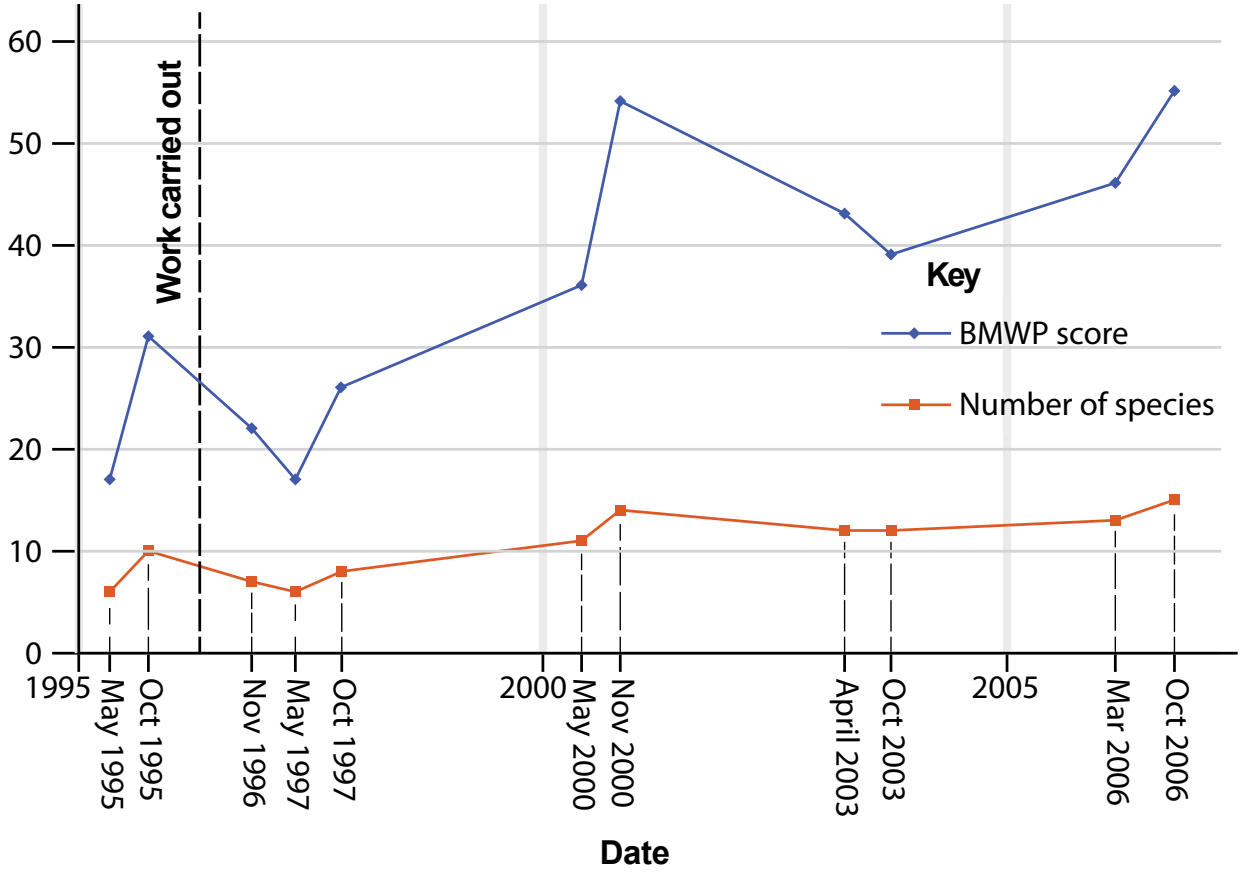
River Alt	Low energy, clay
WFD Mitigation measure	Improve floodplain connectivity Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats Set-back embankments (a type of managed retreat)
Waterbody ID	GB112069060580
Designation	None
Project specific monitoring	Macroinvertebrate

3.4 River Alt 2013 Update

The initial earthworks have led to access and recreation improvements along this stretch of the Alt. Common reed (*Phragmitesaustralis*)hasbeen able to develop reinstating a locally rare habitat and increasing the biodiversity potential of the river at this location. Biodiversity within the braided section of the channel has been limited by reedbed monoculture. The encroachment of the reedbed has reduced velocities thereby increasing siltation and reducing flow variation as a result.

Minimal management has been undertaken since the project works and is limited to debris clearance at the road culvert downstream. As a result the wider area is heavily shaded by willow (*Salixspp.*) and alder (*Alnusspp.*) tree cover. Bramble (*Rubusfruticus*)is also dominant over much of the site. In 2012 Knowsley Metropolitan Borough Council (MBC) carried out improvement works on the riparian corridor and re-opened the choked braided side channels as part of the 'Knowsley 2020' project. Tree works on the over steepened banks immediately upstream of the site were also undertaken. The council has been advised not to plant further willow and alder trees but to use oak (*Quercusspp.*),hawthorn (*Crataegusspp.*) and hazel (*Corylusspp.*)as they are not likely to encroach as far into the reedbed.

The visual appeal of the site and the visibility of the River Alt as a feature at this location has been improved through the scheme. Knowsley MBC is undertaking further work to open up access to the riparian corridor and is currently installing a cycle way. Local residents were consulted through the North Huyton Neighbourhood Network for the 2012 works.



Changesto overall number and diversity of invertebrates at the downstreamend of the site between 1995 and 2006.
(*Stock Bridge Site, SJ43210 92717. EAdata*)

Water quality and invertebrate sampling was undertaken between 1994 and 2006 and indicates that there has been an overall improvement in the number and diversity of macroinvertebrates at the site. Further to the improvements in water quality. noted in 2001, the Biological Monitoring Working Party (BMWP) scores shown below indicate that water quality downstream of the site has improved following the works. The BMWP uses invertebrates as biological indicators of water quality. A high BMWP score is indicative of cleaner water.

The technique used on the River Alt has been a catalyst to encourage similar thinking in the region. The site would have benefited from a tailored long term management plan.

One of the choked braided side channels – March 2012

Contacts

Sue Slamon , Environment Agency (*North West*)
susan.slamon@environment-agency.gov.uk, 08708 506506

Phillip Hurst, Knowsley Metropolitan Borough Council
philip.hurst@knowsley.gov.uk, 0151 4432482

3

Enhancing Straightened River Channels

3.5 Narrowing of an over-widened channel using low cost groynes

RIVER AVON

LOCATION - STRATFORD-SUB-CASTLE, SALISBURY, WILTSHIRE SU127327

DATE OF CONSTRUCTION - OCTOBER 1997

LENGTH - 125M

COST - £2,000 (EXCLUDING FENCING)

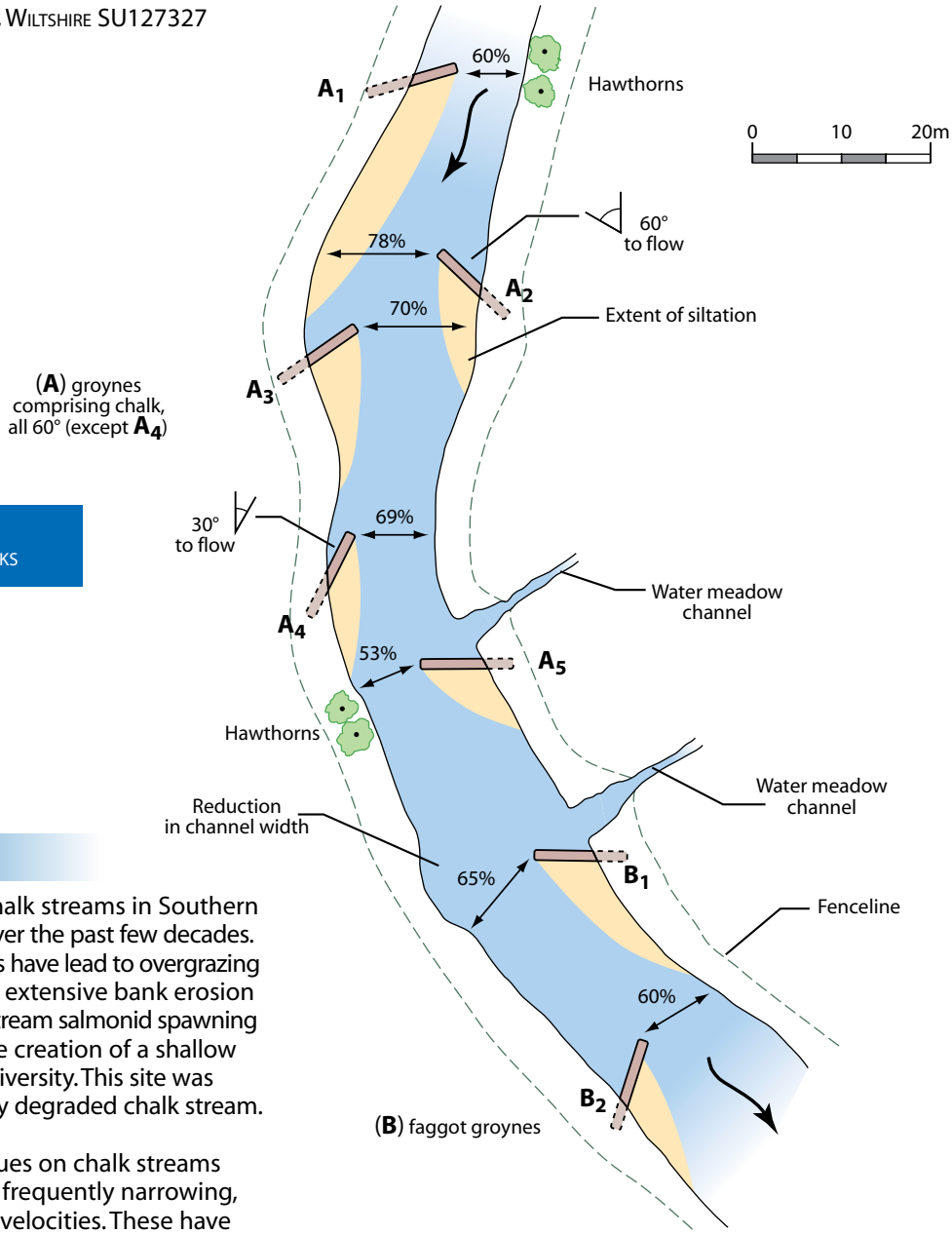


Figure 3.5.1
PLAN OF NARROWING WORKS

Description

The Wiltshire Avon, like many other chalk streams in Southern England has been severely degraded over the past few decades. Excessive stock of cattle in adjacent fields have lead to overgrazing and poaching of its banks resulting in extensive bank erosion and the accretion of sediment in downstream salmonid spawning gravels. The overall result has been the creation of a shallow over-wide channel with poor habitat diversity. This site was chosen because it represents a severely degraded chalk stream.

Recent habitat enhancement techniques on chalk streams have concentrated on modifying, and frequently narrowing, the channel to sustain increased flow velocities. These have involved bio-engineering methods such as the extensive use of willow (*Salix spp.*), loose brushwood and faggots to redefine specific channel characteristics. However, these techniques have proven to be costly, in the order of £30-£55 per metre of river (*see Techniques 3.1 and 3.2*). This project sought to evaluate an alternative technique to establish whether the same level of habitat diversity could be achieved using low-cost groynes comprised of different materials.

Different types of groyne construction were trialed. The expectation was that the groynes would 're-energise' the reach, providing variations in flow characteristics. Sediment being transported downstream would accumulate both upstream and downstream of the groyne and ultimately result in a 'natural' narrowing of the channel due to the settlement and accretion of transported material. Fencing of the river, preventing stock access would allow marginal plants to stabilise this new channel edge and lead to the creation of in–channel sinuosity and flow variation. Habitat diversity would follow as a direct consequence of the physical alterations and stock exclusion.

The total cost of the groynes was less than £2000, equating to a cost over the area of £11 per linear metre.

Enhancing Straightened River Channels

Completed chalk groynes

Design

The design concept incorporated the need to diversify the flow characteristics along the length of the river by installing upstream facing groynes at specific sites on the right and left bank. These were placed according to the on-site observations and an understanding of the flow dynamics of the river.

Construction of the first of the seven groynes in the 125m stretch commenced at the upstream limit of the site. The angle of groyne at the bank was decided by ascertaining the direction of flow (using a floating rope) and constructing at either 60° or 30° to this. The same method was used to construct each of the groynes. Final placement of the groynes was decided on site.

After marking out the area with pegs a JCB dug a trench 0.5m deep and 1-2m wide, with the excavated bed and bank material placed to one side. The trench was cut into the existing bank to anchor the completed groyne. The trench was then filled with either chalk or faggot bundles to provide reinforcement and stability and the excavated material from the original trench replaced on top.

Type **A** deflector
– vegetation established

Figure 3.5.2
SECTION THROUGH CHALK GROYNE

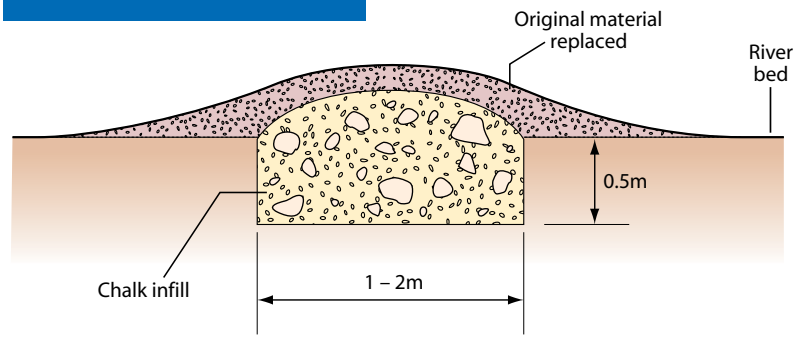
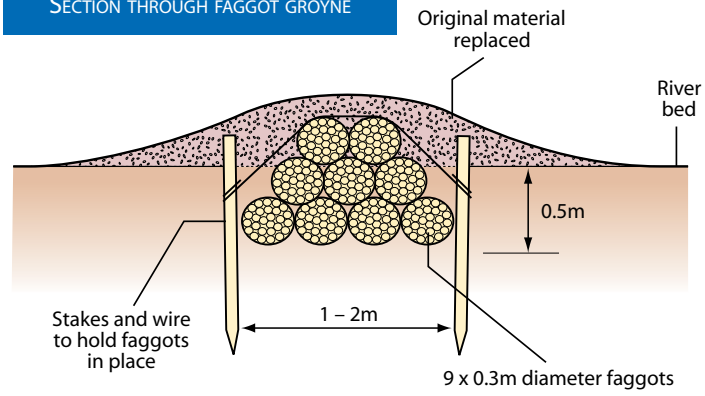


Figure 3.5.3
SECTION THROUGH FAGGOT GROYNE



During construction of the chalk groynes the chalk was rammed down with the JCB bucket. For the faggot groynes the stakes were hammered in by hand, and the JCB bucket was used to hold down the faggots whilst they were wired in place.

By progressing downstream it became apparent that each structure produced a visible 'silt line' marking the extent of slack water created by the groyne. This information was used to determine the positioning of the next groyne, to maximise the likely benefit accrued from each by avoiding overlap.

The finished groynes slope from the bank towards the channel centre so as not to encourage turbulence and erosion of the bank. Also the groynes were positioned facing upstream to ensure that the high flows passing over them were angled towards the centre of the river. This is an effective 'bank protection' and 'pool scouring' measure.

Subsequent performance 1997 – 2001

In narrowing the channel to approximately 60% the groynes have effectively increased velocities. Several structures have had some of the gravel surface eroded by winter flow, the material being deposited immediately downstream of the groyne forming shallow gravel riffles. The ends of the structures are areas of relatively high velocity: these areas have been utilised to great effect by both Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) for spawning.

The desired accretion of material up and downstream of the groynes began soon after installation was completed. Particle sizes indicate a good mix of fine silt and organic material to coarse sand and gravel. This habitat has been colonised by a variety of submerged and emergent vegetation and is providing excellent habitat for lamprey and cyprinid fish fry.

An initial concern, visual intrusion of the groynes, has been negated by the rapid siltation and colonisation by marginal plants naturalising the structures and stabilising the banks. There was no significant difference in the performance and stability of the chalk filled groyne compared with the faggot filled structures: the chalk groynes were however 37% cheaper to construct.

Pre and post-works monitoring was carried out to evaluate the success of the technique. Though the works budget was small it was felt that monitoring was sufficiently important to justify additional expenditure. Monitoring consisted of pre-works, one and three year post-works survey data on physical habitat and flow, fish population, macrophyte observations and macroinvertebrate community sampling.

Type **B** deflector before planting

Enhancing Straightened River Channels

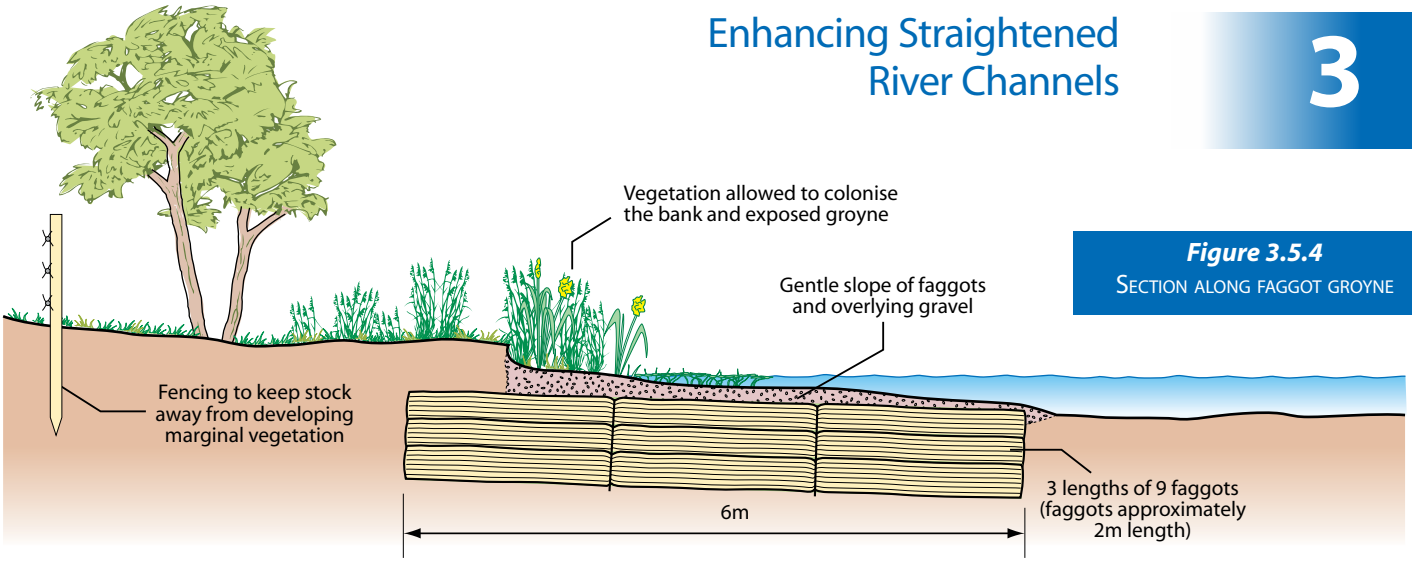


Figure 3.5.4
SECTION ALONG FAGGOT GROYNE

Results from this work indicated that the groynes in combination with the fencing increased marginal emergent and submerged macrophyte diversity, a change in substratum composition (a shift from silt and sand domination to gravel and pebbles), with the finer material being deposited in the slackwater areas. Macroinvertebrate diversity was not influenced by the rehabilitation work, and fish population density and diversity improved.

Original Information Providers:
Lin Davis
Allan Frake

Cattle poached, wide and shallow

Groynes in place already increasing flow diversity

Silt deposits were quickly colonised and the river narrowed

3

Enhancing Straightened River Channels

3.5 River Avon 2013 Update

River Avon	Low energy, chalk
WFD Mitigation measure	Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats
Waterbody ID	GB108043022350
Designation	SAC, SSSI
Project specific monitoring	Vegetation, Fish, Morphology

Initially the chalk and faggot groynes were equally effective. In the medium to longer term the faggot groynes were less effective, disintegrating over time. The chalk groynes remained in place enabling material to accrete up and downstream. In addition the velocities created at the in-stream end of the chalk groynes have been important for attracting salmonids to spawn in the areas just downstream.

The use of faggots was a trial element of scheme but, as they were more costly and less effective in the long term, they would not be recommended for use in future projects of this nature.

Detailed surveys were carried out before the works were undertaken and a long term survey (due to be completed in 2013) has been carried out post works outlining changes to the morphology, hydrology and ecology of the reach. The plant community has changed markedly from pre-restoration and the study aims to determine whether the community has reached a climax structure or is still changing.

Following the works rapid siltation occurred, resulting in channel narrowing. In the 2007 survey an approximately 30% reduction in channel width was observed compared to pre works. The variations in flow characteristics observed in 2002 remain the same.

Catch monitoring undertaken by Salisbury District Angling Club (SDAC) indicates further increases in salmonids and spawning. Fished by wading, the site is a valuable fishery with good stocks of brown trout and grayling (*Thymallusthymallus*).

Most of the reach was fenced to prohibit the entry of cattle into the channel. In addition, there has been the occasional need to trim back willows along the walkways to maintain access for anglers.

©Allan Frake

The narrowed channel – May 2007
(Arrow indicates location of 2012 photograph)

© SDAC

The site after 15 years showing the development of vegetation – November 2012

Contacts

Allan Frake, Wild Trout Trust
allan@afrake.orangehome.co.uk, 07873410219

Peter Shaw, University of Southampton
p.j.shaw@soton.ac.uk, 02380 595867

John Stoddart, Salisbury & District Angling Club
office@salisburydistrictac.co.uk, 01722 321164

3

Enhancing Straightened River Channels

3.6 Creating a sinuous low flow channel in an over-widened river

RIVER DEARNE

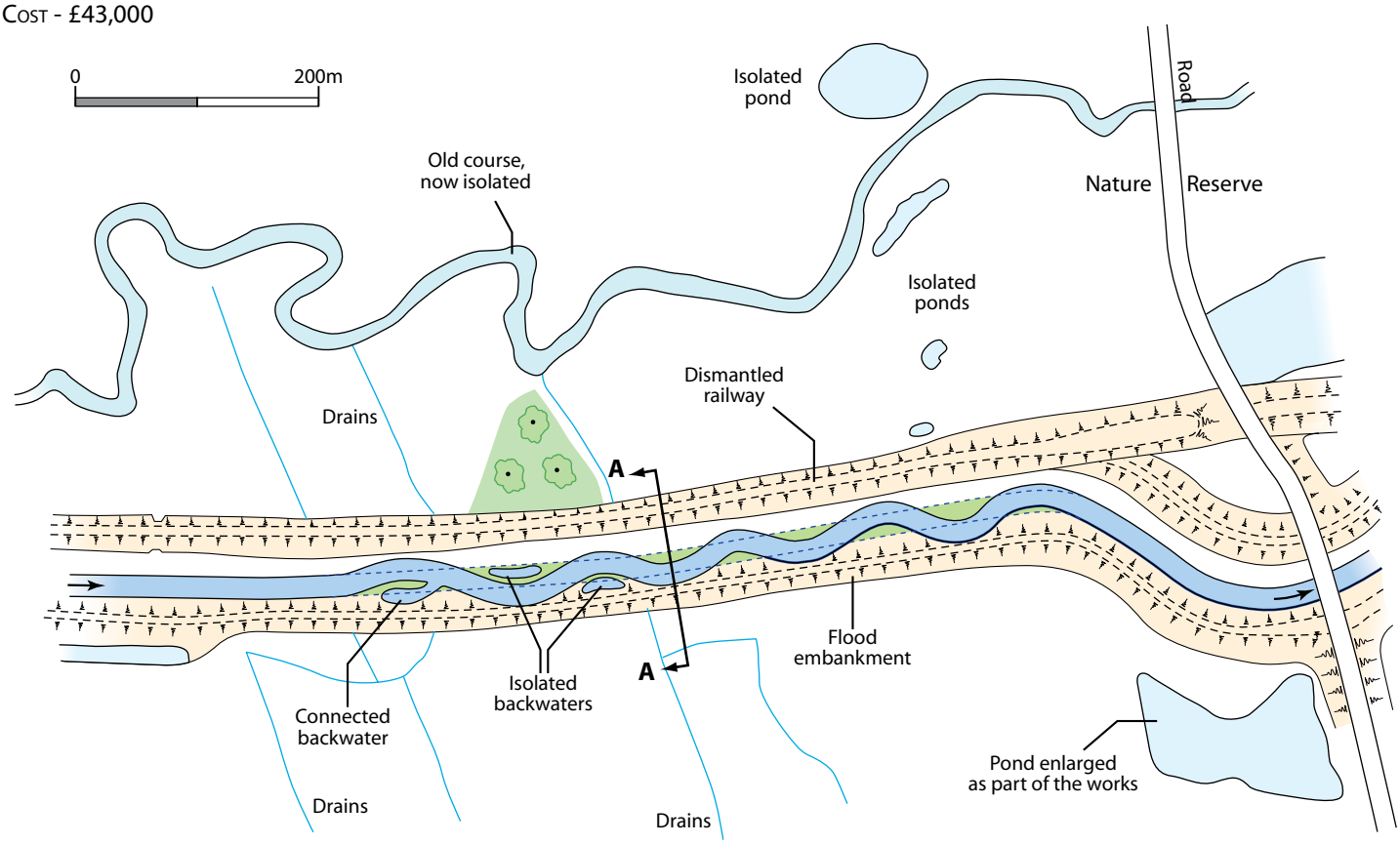
LOCATION - MEXBOROUGH, WEST OF DONCASTER, SOUTH YORKSHIRE SE484012

DATE OF CONSTRUCTION - SUMMER 1995

LENGTH - 500M

COST - £43,000

Figure 3.6.1
PLAN OF SITE



Description

The lower River Dearne had suffered substantial changes to its natural gradient as a result of subsidence problems caused by deep mining operations. To alleviate this problem, a new, straight and featureless river was created in the 1970s to ensure efficient evacuation of floodwater. The design standard for the channel was calculated to be approximately 1 in 150 years (50% greater than required). The lack of physical diversity resulted in excessive emergent vegetation growth which extended across the channel and further impeded flow. Prior to the works, high terrestrial berms rose up to the flood banks. The river bed substrate was composed predominantly of nutrient-rich silt, overlaying some transported gravels.

Some of the subsided land adjacent to the abandoned old channel formed wetland habitat, which has subsequently been designated as a SSSI. However, the wildlife value of the canalised river was very low due to its physical uniformity, poor water quality and low gradient. Water quality began to improve in the 1980s due to mine closures and improved sewage treatment, and the river became valued as a coarse fishery. Its potential was however limited by the lack of in-stream physical habitat diversity, which left few opportunities for fish to spawn.

Meandering was not a viable option, and so the creation of a low-flow channel was deemed beneficial for all interests. A narrow channel would create a self-sustaining coarse substrate with greater water velocity, which in turn should reduce the extent of siltation and reed (*Phragmites spp.*) growth.

A scheme was developed which would maximise the present fishery and the wider spawning potential of the river by introducing sinuosity into the straight, over-widened channel. It would also demonstrate reduced maintenance benefits whilst having no detrimental effect on flood protection.

The proposed scheme was a drastic reduction in width, with a very sinuous course created by constraining the low-flow width by large boulders. The previous over-design of the straight course allowed for such work to be undertaken and still provide the necessary flood protection standards.

Enhancing Straightened River Channels

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River Dearne. Wide and straight, choked in summer

New sinuous reed-fringed course

Design

The sinuous low-flow channel was defined by placing stone in the river to form the 'inside' of each bend. Locally occurring magnesium limestone was chosen. The decision to armour was taken to provide a defined channel and to be removable in the event that flood defence concerns arose.

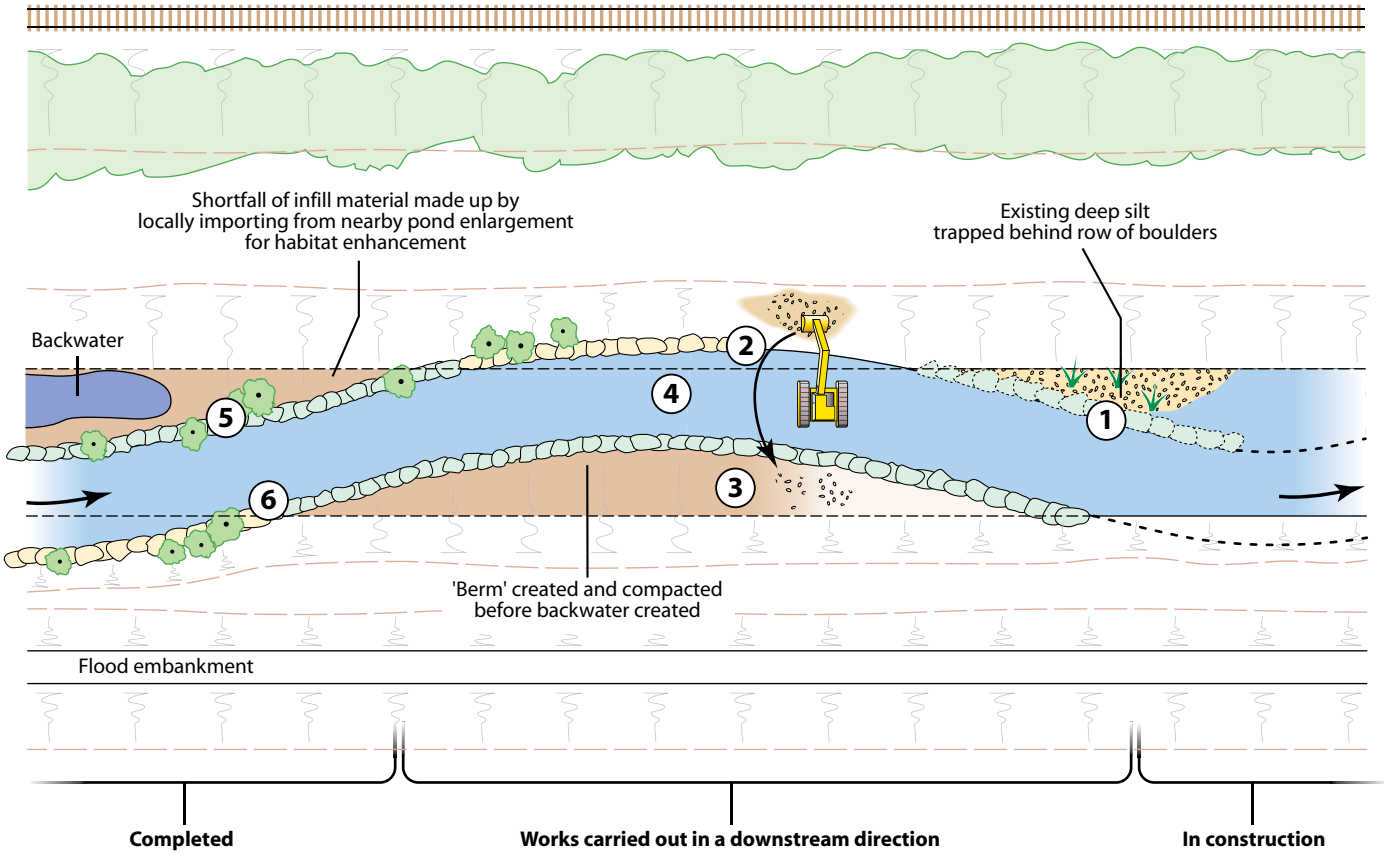
Placement was carried out by an excavator from within the channel as water levels only varied between 0.3m and 0.7m.

Work started upstream and looked initially to increase velocities in the first two bends to 0.5m/s, reducing the increase to near existing flows (approximately 0.2m/s) at the final bend.

In this way the narrowing of the low-flow channel was determined by a combination of estimating the reduction required and measuring the velocity after placement of the boulders.

Placement of limestone boulders and berm back-filling

3 Enhancing Straightened River Channels



Key

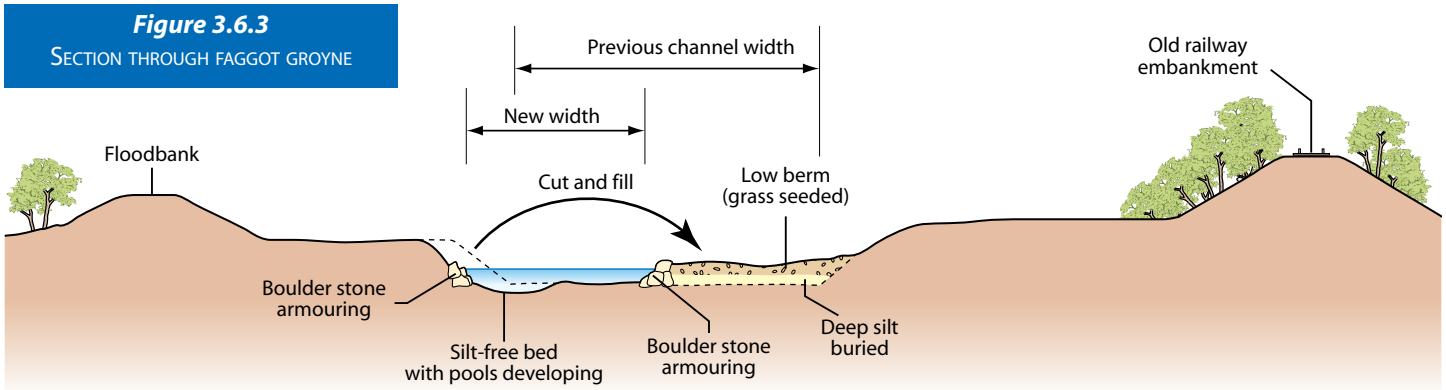
- Stone boulders placed 'in' river
- Stone boulders placed on bank toe
- 1 - 6 Numbers appear in text 'design sequence'

Figure 3.6.2
PLAN OF WORKS

Figure 3.6.2 shows the construction process in six phases:

1. 'Inside' of bend defined by placing limestone boulders into the channel;
2. 'Outside' of bend shaped by excavating material from the opposite steep bank;
3. Material from 2 used to backfill the 'inside' bend forming a low berm;
4. Additional limestone boulder armouring placed on toe of 'outside' bend;
5. Backwaters excavated within the low berms created;
6. Berms and banks seeded with a grass mix and later planted with standard trees.

Figure 3.6.3
SECTION THROUGH FAGGOT GROYNE



Narrowing increased velocities and created riffles used for fish spawning

The low-flow channel included three small backwaters and scrapes, and the low berms were created at a variety of levels to enable the establishment of a range of riparian communities, from swamp to dry grassland.

The former 10m wide channel was narrowed by up to 5.5m in this way, but maintained flood capacity by equating cut and fill and ensuring that the in-channel structures were kept to a low level. The new low-flow berms, were designed to be submerged during floods.

The berms and banks were seeded as soon as the earthworks had been completed so that the root system would consolidate the new earth banks before winter floods. Seeding was completed by late summer and growth was well advanced before the end of the autumn. This also limited potential erosion through heavy rain.

Some transplanting of emergents from the channel was carried out, both in front of and within the rock armouring, to promote vegetation of the berm edge.

The successful completion of the first 500m section prompted a rapid implementation of a similar length in 1996/97.

Subsequent performance 1995 – 2001

By creating a sufficiently narrow low-flow channel the effect on the silty bed was immediate. Within two weeks of completion the majority of the silt had been cleared. Deposition of gravel and silt occurred rapidly on the inside of the bends with pools (up to 2m deep) having since developed at the apex. The silty areas have promoted the colonisation of marginal plant species.

Fisheries surveys since the works were completed show the beneficial effect of the scheme. Numbers of chub (*Squalius cephalus*), dace (*Leuciscus leuciscus*), barbel (*Barbus barbus*), roach (*Rutilus rutilus*) and gudgeon (*Gobio gobio*) have all increased, but more importantly there is now successful spawning and recruitment of juvenile fish.

The limestone was rapidly colonised by algae and lichen once in place and silt deposition between the stones allowed a variety of waterside plants, including reeds and sedges (*Cyperaceae spp.*) to quickly become established. By summer 1996 marginal reeds were beginning to grow and by autumn 1996 the reed growth had masked the armouring.

A small amount of erosion occurred in two areas, which were not protected. In one location rock armouring and willow (*Salix spp.*) planting was used to address this problem, but in the other the river was allowed to widen into a pool.

Live willow stakes were inserted along both banks and on the new berms to provide cover and supplement the self-set trees already establishing at the margins.

The two unconnected backwater pools dried out due to the hydraulic draw of the river through the loosely compacted fill material. To mitigate this effect upstream connections were made using 0.1m diameter plastic pipes.

Two years post-works, an audit of the scheme reported an annual saving of between £2,500 and £3,000 in reduced maintenance costs as a direct result of the work carried out.

Original Information Provider.:
Chris Firth OBE.

Main channel and backwater 5 years on, Summer 2000

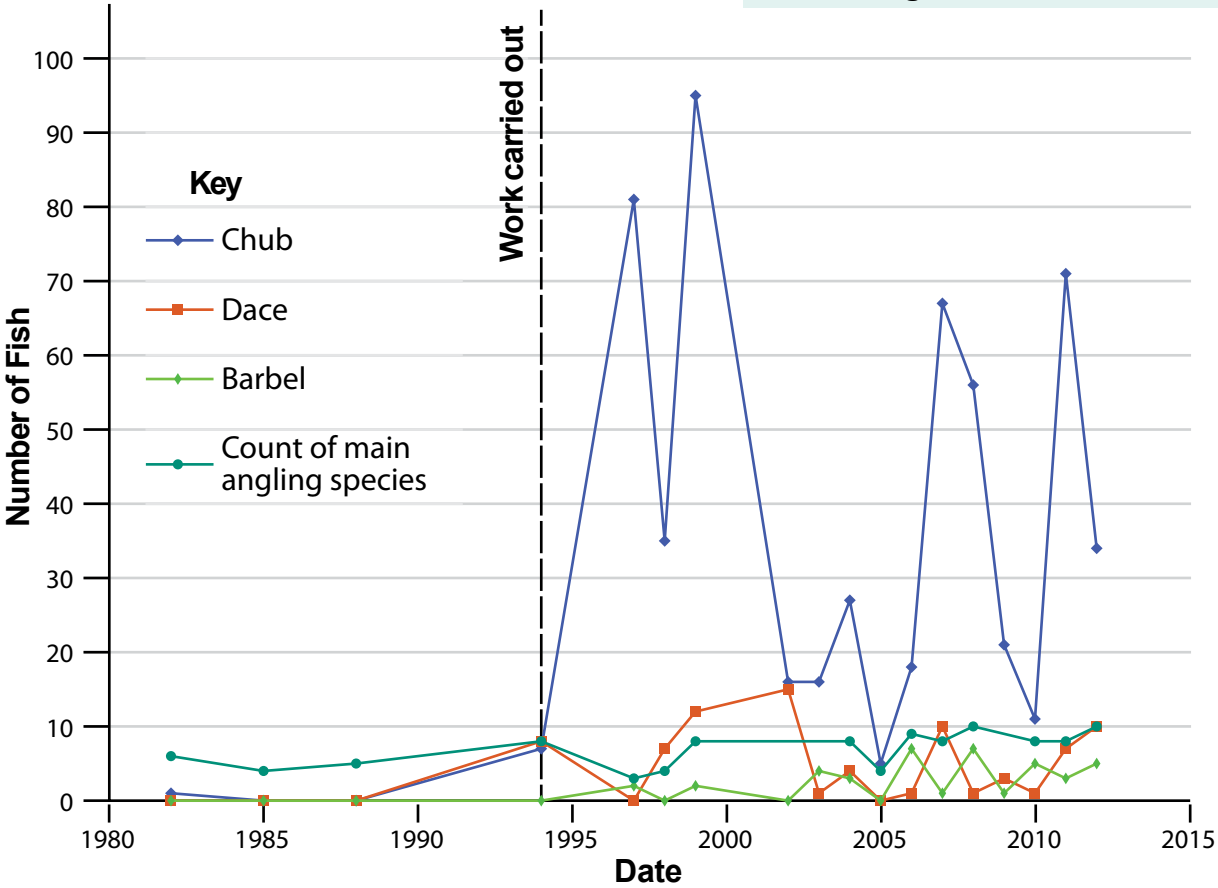
3

Enhancing Straightened River Channels

3.6 River Dearne 2013 Update

The narrowed channel has increased velocities and as a result sediment has been transported downstream, maintaining clean gravel spawning grounds in the restored reach. Anglers are happy with the results of the scheme and have commented on improved fish size in the area. Two particularly successful seasons for recruitment and spawning, 2010 and 2008, are cited as the reason for this. In 2012 a Barbel of over 10lbs was recorded at this site. Fish populations are monitored annually and both the number and diversity of fish species has increased following the works.

River Dearne	Low energy, gravel
WFD Mitigation measure	Preserve and, where possible, restore historic aquatic habitats Appropriate channel maintenance strategies and techniques e.g. minimise disturbance to channel bed and margins Preserve and where possible enhance ecological value of marginal aquatic habitat , banks and riparian zone
Waterbody ID	GB104027063173
Designation	SSSI
Project specific monitoring	Fish



Fisheries data showing changes in the count of species of anglers over time.
The data indicates improvement in the count of the main angling species and significant increases in the numbers of some individual species. (*Pastures Bridge site, EA data*)

Of the three backwaters created along the channel, two have now silted up and only operate in very high flows. The third was breached at its top end and has formed a secondary channel. This provides a relatively sheltered environment that anglers indicate holds fish fry under normal conditions. If the breach had not occurred it is highly likely that this backwater would also have silted up. Whilst the silted backwaters are not functioning as fish habitat as they were intended, they do have wider biodiversity benefits.

© Environment Agency

Main channel and operational backwater – October 2012

Occasional tree management continues to be necessary along the banks and involves pollarding of willows. When one section is cut, the adjacent section is left to ensure that some cover is always available.

The scheme has been successfully replicated at two upstream locations on the same watercourse. The use of similar backwater features located within the low flow berm areas were not included by the Rivers Trust at these sites, due to the risk of rapid siltation. Whilst the backwaters created for this scheme are not functioning as fish habitat, they have wider benefits to biodiversity and as such any Environment Agency schemes would probably still include them. This project has demonstrated the need to design accordingly depending on the desired aim of the backwaters. Building a maintenance plan would also be beneficial to address the likely siltation of backwaters.

Contacts

Chris Firth OBE, Don and Rother Rivers Trust
chris.firth@dcrt.co.uk, 01302 539489

Andrew Virtue, Environment Agency (*North East*)
andrew.virtue@envrionment-agency.gov.uk, 08708 506506

3

Enhancing Straightened River Channels

3.7 Replacing a concrete drain with a 'natural' channel

YARDLEY BROOK

LOCATION - SHARD END, SOUTH-EAST BIRMINGHAM SP118198

DATE OF CONSTRUCTION - MARCH 1995

LENGTH – 100m

COST – £5,000

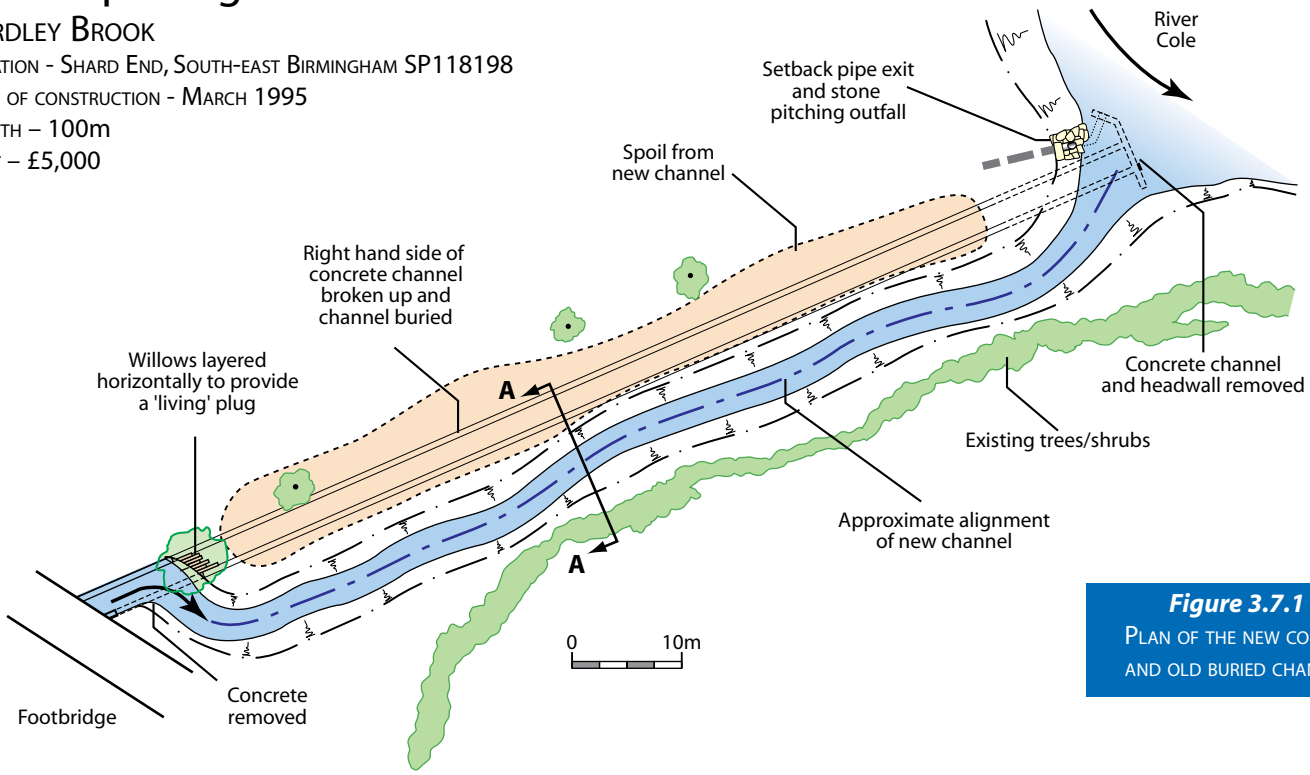


Figure 3.7.1
PLAN OF THE NEW COURSE AND OLD BURIED CHANNEL

Description

Yardley Brook rises in south-east Birmingham and emerges from a culvert onto the floodplain of the River Cole in a concrete channel. The catchment is highly urbanised, with over 150,000 people living within 2km of the river. Urban run-off thus causes periodic poor water quality and significant litter. The brook itself is contained within an area of made-up ground which has been retained as public open space.

Originally a sewage outfall, the brook no longer needed to be contained in a concrete straight-jacket due to closure of the sewage works upstream in the late1960s. The brook is located within the Project Kingfisher area; a collaboration between local and statutory authorities and volunteer groups to achieve a substantial improvement in the wildlife quality of an 11km section of the Cole and adjacent land in Solihull and Birmingham.

Yardley Brook entering the River Cole before works

The brook was constrained in a concrete sleeve, offering no possibility for small-scale in-channel enhancement. Rehabilitation required removal of the brook from its 100m long concrete surround. Complete relocation, rather than removing the concrete, was the cheaper option.

Design

The lip of the concrete channel was broken up using an excavator, to ensure that once buried the remnant channel would not protrude above ground level. The broken concrete was pushed into the barely flowing channel.

Figure 3.7.1 shows the 100m sinuous channel that was excavated alongside the brook. The new course was excavated at a greater depth than the concrete channel bed. Previously the bed of the River Cole had been approximately 0.7m below the concrete outfall, as a result of deepening of the Cole over the lifetime of the concrete brook. A simple 'V' shaped channel was dug with sloping earth banks as it was decided that the brook could sufficiently shape itself. Over-specifying the design would not be cost-effective.

Concrete channel being broken up

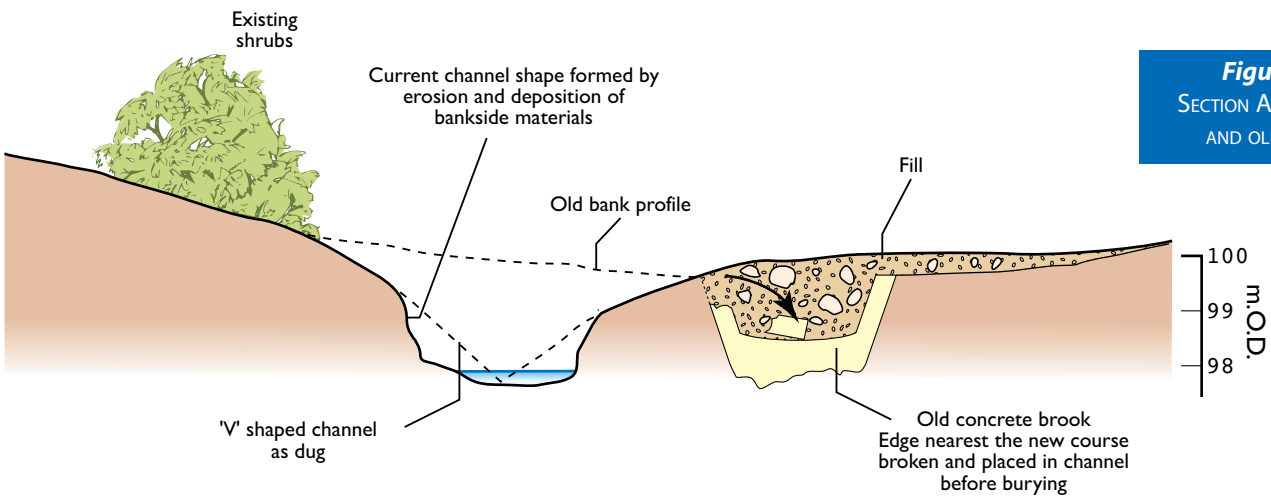


Figure 3.7.2
SECTION A THROUGH NEW AND OLD CHANNELS

3

Enhancing Straightened River Channels

The 'new' brook being excavated adjacent to the old channel. Spoil stockpiled

All spoil was stock-piled between the new and the old channel, and where this became too narrow, on the opposite bank of the old channel. This maintained the flow through the old drain and allowed all work to be carried out in the dry. Once completed, flow was diverted through the new course, and the old channel was filled using the spoil from the new.

At the upstream end of the 'new' brook the old course was blocked with rubble then plugged with live willows (*Salix spp.*) laid in during the in-filling process to form a growing plug.

The new confluence with the River Cole is on the site of the old outfall structure. The large (9m by 2m) concrete eyesore was removed and the mouth reformed to a more natural appearance. A number of large concrete blocks, remnants of failed bank protection works, were also removed. This concrete was broken up and buried nearby.

A drainage pipe that exited at the old outfall structure was given a new stone pitched headwall which is now well hidden by growth and difficult to discern.

The works took two weeks, one of which accounted for concrete removal and breaking-up. The end result is an apparently natural 2-3m wide channel.

Live willow plug

After – the new 'natural' Brook

Subsequent performance 1995 – 2001

Immediately following the diversion to the new channel a dramatic change in the habitat quality of the brook was achieved in terms of landscape, visual amenity and ecology.

After completion winter flows quickly began to 'develop' the kinds of natural channel features one would associate with a small brook. The 'V' shape quickly transformed through erosion of the loose fill material into a much more 'natural' channel 2-3m wide. This process has continued as the site matures.

The live willow plug has grown to secure the breakout point of the new brook. This area now blends in well with the general appearance of the brook and its self-set bankside trees and shrubs.

Six years on, Yardley Brook has developed 'natural' channel features in contrast to the concrete channel previously in place. The brook still suffers from periodic poor water quality due to the dense urban population that surrounds it.

The work was deemed so successful that a further concrete length of the main River Cole was removed in 1996-1997. This type of 'demonstration' site gives added confidence to others and reduces potential risks through valuable experience.

Original Information Provider:
Andrew Crawford

Six years on. Earth cliffs, gravel shoals and a diverse flow regime – April 2001

3

Enhancing Straightened River Channels

3.7 Yardley Brook 2013 Update

Yardley Brook	Medium energy, clay
WFD Mitigation measure	Alteration of channel bed (within culvert) Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats Removal of hard bank reinforcement/ revetment, or replacement with soft engineering solution Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Waterbody ID	GB104028042502
Designation	None
Project specific monitoring	None

Following works a more natural bed profile has been created and natural processes are now able to take place. The more natural channel has created flow variability with areas of fast flowing water and slack water at the margins, where emergent vegetation is now growing. There are still major water quality issues, as a result of misconnections, which may be investigated in the future.

The project would have benefited from following the original plan, i.e. make a shallow V shaped cross section with the excavated material placed away from the bank. Instead the soil was piled up next to the channel making a much steeper V shaped channel. Erosion has removed much of the material which has contributed to raising the bed of the River Cole, at the mouth of the brook, by some 0.4m. In addition, as a result of the new channel having too steep a gradient in some places, a nick point started to move upstream exposing a sewer pipe. To remediate this, a layer of large gravel stones was laid on top to act as a check weir to prevent further erosion.

The live willow plug at the upstream end of the brook has continued to be very successful as a bioengineered bank stabilisation method.

Following this project similar work has been carried out on the main River Cole. Concrete was broken up, and where possible, removed from the channel immediately downstream of the confluence with Yardley Brook.

© Environment Agency

Erosion exposing sewer pipe as nickpoint moves upstream

© Environment Agency

Yardley Brook flowing into Cole

© Environment Agency

Yardley Brook flowing into the Cole. Riparian trees and vegetation have now grown up to stabilise the banks – February 2013

Contacts

Andrew Crawford, Environment Agency (*Midlands*)
andrew.crawford@environment-agency.gov.uk, 08708 506506

3

Enhancing Straightened River Channels

3.8 Creation of on-line bays

RIVER TALL

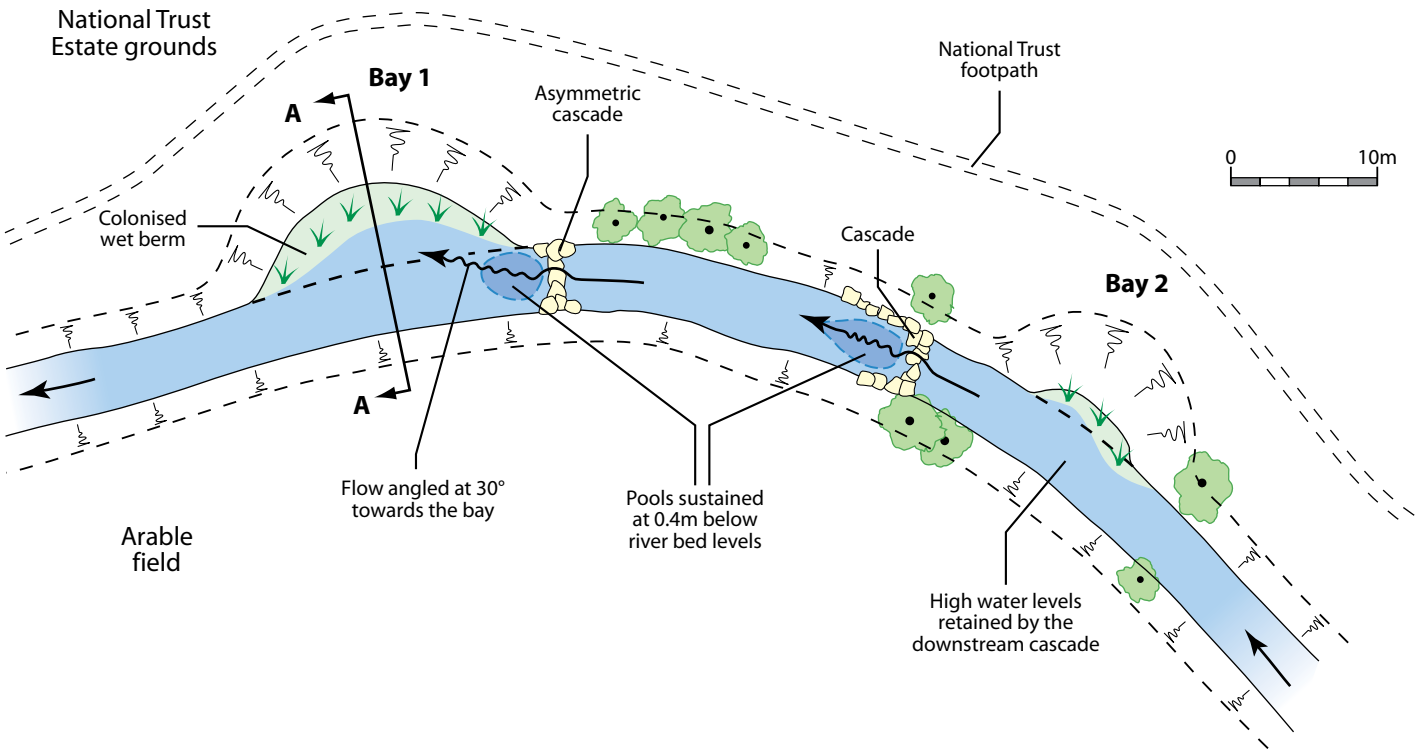
LOCATION - ARDRESS, NR. MOY, CO. ARMAGH, N. IRELAND. OS MAP 19, H916555

DATE OF CONSTRUCTION - JULY 1995 TO DECEMBER 1996

LENGTH - BAYS BETWEEN 10M AND 30M

COST - NOT AVAILABLE

Figure 3.8.1
PLAN OF SITE



Description

The Tall River is a main tributary of the River Blackwater, flowing through Co. Armagh. It is a slow flowing, low energy river within an agricultural catchment. The river had been subject to an arterial drainage scheme in the 1960s, which deepened and widened the river.

The 1.2km Tall River scheme was the first project within Northern Ireland to address the specific need to enhance the riverine environment, rather than being attached to a larger flood prevention scheme. The enhancement works were a part of a larger 'water recreation' scheme, developing footpath access along the river linking with footpaths already developed by the landowner, the National Trust. Due to landowner restrictions works could only be carried out on the National Trust owned right bank and in-channel.

The deepening resulting from the arterial drainage scheme meant that the river had lost its natural connection to the floodplain. It was felt that some kind of shallow slackwater habitat was needed. As creation of large backwaters was unacceptable to the landowner, the option of creating small 'bays' was considered. These bays would provide some shelter in high flows suitable for fish fry and invertebrates, and shallow margins should increase the macrophyte diversity within the reach.

Design

Four bays of differing sizes were excavated within the reach. Three of these were accompanied by upstream stone cascades, to generate turbulence and ensure that the bays remained 'open' rather than quickly silting up. The bays also incorporated a low ledge, just below summer water level to accommodate a variety of macrophyte species. *Figure 3.8.1* shows the two bays located at the downstream end of the enhancement reach.

The roughly semi-circular bays were excavated down to bed level where the bay meets the channel. This level is then followed back, rising to the low ledge level at the bay edge. The width of ledge varies with the size of bay.

Downstream bays after less than a year.
Note: Bay 2 is already becoming choked with vegetation

From the ledge the bank rises at a batter shallower than the existing 1:1 bank (approx. 1:2 to 1:3). The batter angle varies with the difference between bed and bank top from 2 – 4m (*Figure 3.8.2*).

The stone cascades were constructed from 0.5m+ boulders formed into a rough 'loose' arc and dished in the centre. This configuration helps to direct the flow away from the potentially erodable banks. The bankside boulders are securely keyed into the sides. The loose construction allows water to pass through the structures, reducing the backwater effect at low flows whilst providing a good degree of turbulence.

Subsequent performance 1996 – 2001

The bays that had associated upstream boulder cascades have remained 'open' to differing degrees.

Upstream bays 3 and 4 (not illustrated)
These two bays are accessible to cattle and are used as drinking points. There is an element of poaching at the water's edge, but the stocking densities are low enough not to be of concern. Grazing maintains a cropped but diverse macrophyte margin.

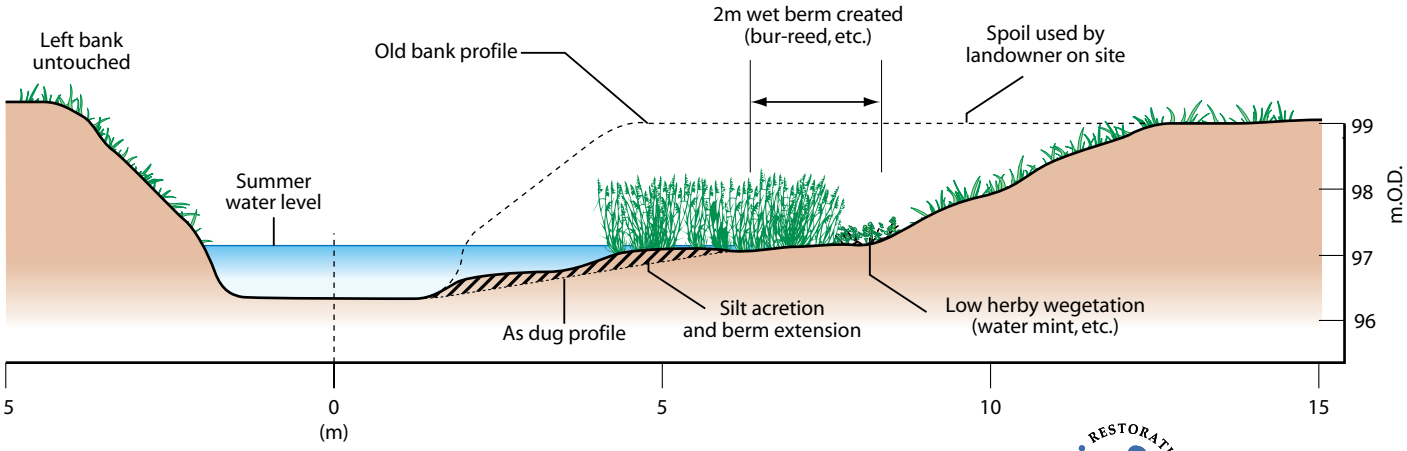


Figure 3.8.2
SECTION A THROUGH BAY 1

Bay 1 showing the angle of flow keeping the bay 'open'

The smaller of the two (bay 3) is sustained by the turbulence generated by its cascade and is cleared of loose silt during high flow events. The larger (bay 4), 30m in length, is too large to remain silt free and has developed shallow margins. Both cascades have excavated deeper pools adjacent to the bays.

Downstream bays 1 and 2 *(Figure 3.8.1)*
Cattle are excluded from the lower reach and, as a result, the more vigorous emergent vegetation, such as bur-reed (*Sparganium spp.*), is dominating.

Bay 1 is similar in size to bay 4 but is able to retain its open nature due to the positioning of its cascade. The flow of water over the boulders is angled into the bay, approximately 30 degrees offset from the main channel. This directional flow is helping to maintain the bay at low and high flows.

Bay 2 rapidly silted up and colonised with emergent vegetation, spreading well into the main channel. The cascade for this bay was placed downstream, resulting in increased water levels from the backwater effect created. This has reduced flow velocity and now acts as a silt trap, promoting silt deposition and vegetation growth.

The success of these bays on the River Tall seems to be determined by:

- adequate velocity, turbulence and direction of flow;
- sizing and shaping of the bay;
- grazing of the colonising vegetation.

Original Information Provider:
Judith Bankhead.

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Enhancing Straightened River Channels

River Tall	Low energy, clay
WFD Mitigation measure	Recreate marginal features by re-narrowing the river course. Soft options should be used rather than concrete to allow the river to move in time. Use a two-stage channel where the floodplain cannot be inundated.
Waterbody ID	10611
Designation	None
Project specific monitoring	Vegetation

3.8 River Tall 2013 Update

A repeat River Corridor Survey (RCS) carried out two years after the works showed an increase in emergent vegetation and macrophyte diversity. The bays are inundated at high flows, acting as a fish refuge, however due to siltation these may be becoming too shallow. Following the creation of stone cascades a greater variation in flow characteristics has been observed.

The success of the bays varied depending on the presence, or otherwise, of a structure deflecting water into them. If the project was to be carried out again, more consideration would need to be given to either the location of the bays within the overall flow regime of the river, or be designed to include a deflection structure that would maintain flows into the bay. Additionally, the site would have benefited from a long term management plan, particularly for tree planting.

The scheme has been used as an early demonstration site within Northern Ireland which effectively communicated the concept of implementing restorative measures on rivers to both senior management and wider stakeholders. The works demonstrated the need to design in harmony with the rivers natural processes and hence some of the measures implemented worked better than others. Similar projects have since been undertaken including the successful creation of vegetated berms on the Ballee Burn and the creation of shallow bays at Ecos Centre, Ballymena.

© DARDNI

Bay 2, looking downstream. Heavily vegetated – May 2012

© DARDNI

Bay 2, looking downstream – March 2006

Contacts

Judith Bankhead, Rivers Agency, Department of Agriculture and Rural Development Nothern Ireland (DARDNI)
judith.bankhead@dardni.gov.uk, 02890 253196

3 Enhancing Straightened River Channels

3.9 Introducing gravel to inaccessible reaches

River Chess

Location – Blackwell Hall, Latimer, Buckinghamshire SU980997
Date of construction – 1994/95
Length – 250m
Cost - Not available

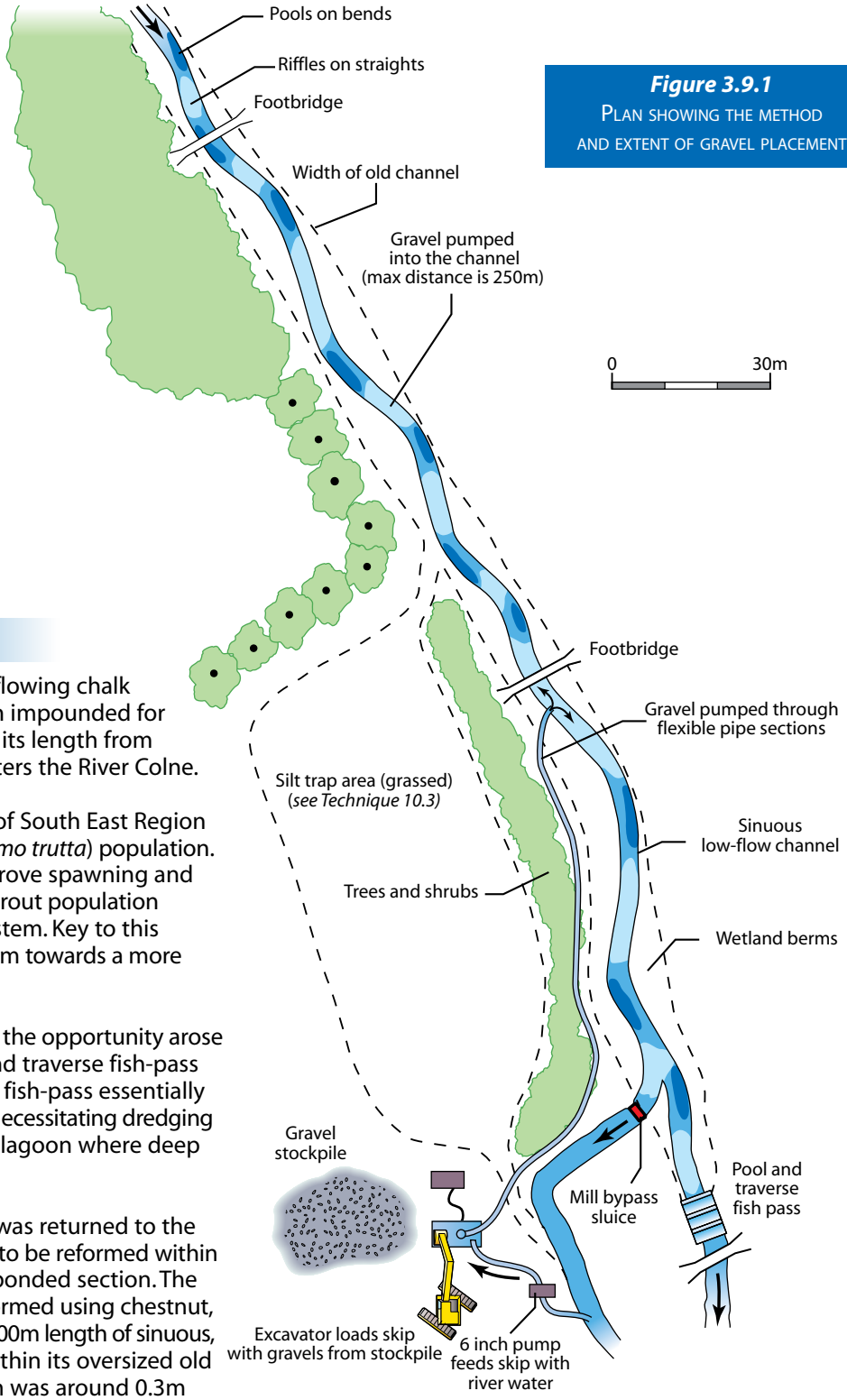


Figure 3.9.1
Plan showing the method and extent of gravel placement

Description

The River Chess, naturally a shallow fast flowing chalk stream with a good gravel bed, had been impounded for milling purposes at various places along its length from Chesham to Rickmansworth where it enters the River Colne.

It is one of the few rivers in the NE Area of South East Region to have a self-sustaining brown trout (*Salmo trutta*) population. A long-term strategic objective is to improve spawning and holding conditions for the native brown trout population and restore free passage through the system. Key to this objective is the rehabilitation of the stream towards a more natural gravel-bed chalk stream habitat.

In 1993, at the request of the landowners, the opportunity arose to replace an old mill weir with a pool and traverse fish-pass to restore fish passage. Building the new fish-pass essentially lowered the upstream water level by 1m, necessitating dredging and re-profiling of the exposed wide silt lagoon where deep silt had accumulated (*see Technique10.3*).

By lowering the weir sufficient gradient was returned to the river to enable a narrow sinuous channel to be reformed within the previously deep, over-widened and ponded section. The narrowed new course of the Chess was formed using chestnut, ash and birch faggoting. This resulted in a 300m length of sinuous, narrow, fast flowing river, meandering within its oversized old channel. The sustainable, desirable depth was around 0.3m with an undulating gravel bed.

View of the wide dredged section, gravel being placed within the low-flow channel

As a result of the previous management of the river, the Chess had been gradually denuded of its gravel bed. Imported gravels were introduced into the stream by pumping. This method of placement overcame the imposed restrictions associated with conventional plant access to privately owned land and disturbance of woodland and bankside vegetation.

Design

The gravel material specified was well-graded 5–25mm gravel, which closely resembled the grading found downstream. The poor accessibility meant a novel approach was used to place the gravel material.

- At the site compound a submersible pump powered by a diesel generator was placed in a skip located near to the river.
- Using a six inch pump the skip was filled with river water.
- An excavator loaded the stockpiled gravel into the skip.
- The gravel was then pumped along a 250m flexible pipe and fed into the new low-flow channel where specified.

Pumping apparatus in operation

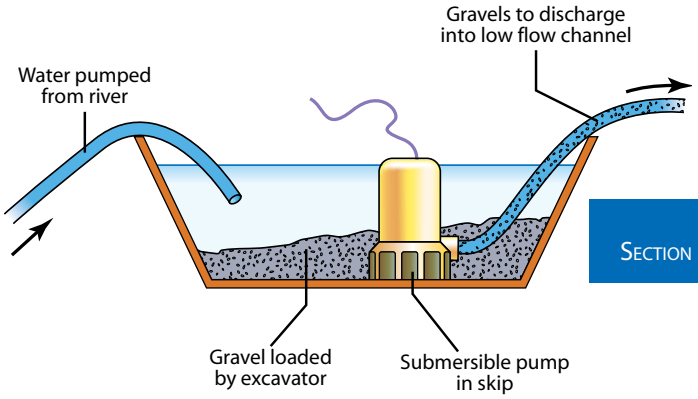


Figure 3.9.2
SECTION THROUGH PUMPING APPARATUS

Gravel pumping in operation

Four years on – gravel shoals and deeper hollows remain

Using this approach the contractor was able to place the gravels economically and without having to remove existing valuable trees and shrubs. By introducing the gravel it was possible to shape the bed, recreating pools on the bends and riffles on the straight sections (*see Technique 5.5* for more detail on bed raising).

Subsequent performance 1995 – 2001

Some redistribution of gravel has occurred locally, forming deeper hollows and bars.

Original Information Providers:
Steven Lavens
Chris Catling

3

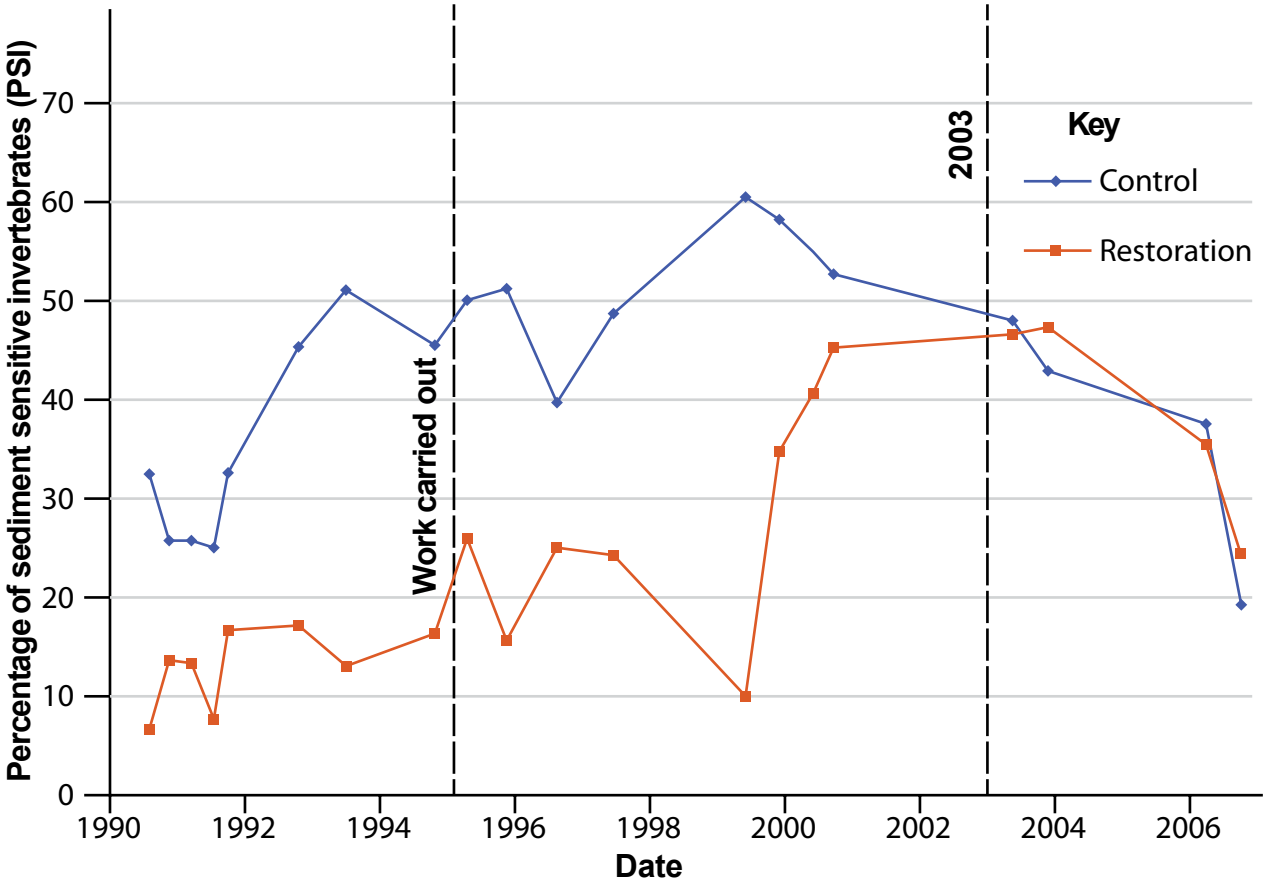
Enhancing Straightened River Channels

3.9 River Chess 2013 Update

River Chess	Low energy, chalk
WFD Mitigation measure	Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitat Sediment management strategies (develop and revise) which could include: substrate reinstatement, sediment traps, allow natural recovery minimising maintenance, riffle construction, reduce all bar necessary management in flood risk areas Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Waterbody ID	GB106039029870
Designation	None
Project specific monitoring	Invertebrates

The works have successfully created diversification of flow, from moderate velocities in deeper glides, to fast flowing water over the gravel riffles. There has been some localised redistribution of gravel but the narrowed channel remains silt free. Very clean gravel is now present where before the substrate was entirely silty. The variety of gravel sizes has provided a range of niche habitats and has encouraged the establishment of submerged macrophytes such as water starwort (*Callitriche heterophylla*).

Post project invertebrate monitoring demonstrates an increase in the Percentage of Sediment sensitive Invertebrates (PSI) at the restoration site. This gradual increase to levels similar to the control reach by 2003, indicates a cleaner substrate.



Increases in the number of silt sensitive species.
By 2003 the restored reach had achieved a similar invertebrate community to the upstream control site.
(*Blackwell Hall site, EAdata*)

Enhancing Straightened River Channels

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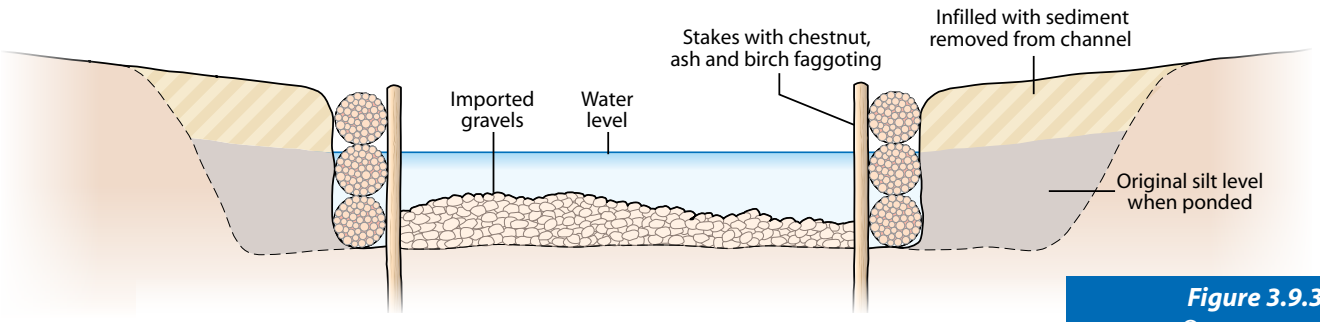

Figure 3.9.3
ORIGINAL DESIGN

Figure 3.9.4
CHANNEL IN 2013 IN SHADED REACHES

© RRC

Looking downstream the lines of posts visible with no vegetation behind them – 2013

© RRC

Silt accumulation behind the posts – 2013

Channel narrowing on the River Chess was successful where the channel is not shaded by trees – 2013

© RRC

The mechanism by which the channel was narrowed has had mixed success.

The use of faggots to define a channel edge relies on a strong growth of marginal vegetation to bind the decaying faggot deadwood, any silt they accrete and the earth/silt bank held behind them.

The works to the 300m dredged section was carried out sympathetically to minimise the need for disturbance to the woodland. However, by not having to carrying out any tree works to these densely shaded parts of the reach, the over-shading has restricted vegetation colonisation and stabilisation of the retained-silt edge. In these reaches the faggots have decayed and in some places the bank edge has eroded (highlighted by the remaining line of posts).

The reduced velocities, resulting from the influence of the banks and the posts, are still acting to attract silt towards the stream's edges. Even now, tree work to open up the canopy to allow sufficient light penetration to aid vegetation colonisation of these silty margins, also helping to protect the eroded edge.

This highlights the need for a clearly defined approach to using biodegradable material (faggots, coir, jute, etc.). They are generally a short term solution that rely on planted or colonising vegetation to take over the stabilizing role that they initially provide. It is therefore critical that the intended vegetation is locally available (in situ or close by) and has sufficient light and growing seasons to establish strongly.

Contacts

Sarah Scott, Envrionment Agency (South East)
sarah.jane.scott@environment-agency.gov.uk, 08708 506506

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Enhancing Straightened River Channels

3.10 Sinuous low-flow course in an over-wide urban channel

RIVER SOMER
LOCATION - MIDSOMER NORTON, SOMERSET ST66495420
DATE OF CONSTRUCTION - MAY 2011
LENGTH – 167m
COST – £40,000

© Woodland Water & Gardens and D.Longley

Measuring existing channel dimensions prior to works – 2011

River Somer	Low energy, clay
WFD Mitigation measure	Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats Remove obsolete structure Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Waterbody ID	GB109053022250
Designation	None
Project specific monitoring	Habitat survey, fish, invertebrates

Description

The overall aim of this project was to improve an over-wide and heavily silted reach of the River Somer running through Midsomer Norton High Street. This involved removal of three small weirs and constructing a new sinuous channel that had sufficient morphological dynamics to remove the need for regular de-silting, reducing maintenance costs and disturbance.

Project objectives included: constructing a sinuous channel using local materials (including accumulated silt); providing diverse habitat features for fish (especially wild brown trout (*Salmotrutta*), plants and invertebrates native to the River Somer; improving the aesthetics of the reach within the town centre; increasing the opportunity for local people to encounter a range of river wildlife; and involving the local community in construction and long term maintenance.

The existing Midsomer Norton Flood Alleviation Scheme and flood relief channel was exacerbating the build-up of sediment by diverting higher "flushing" flows around the town centre reach. However, this also presented an opportunity to create a design which was not heavily constrained by flood risk concerns, since the High Street typically only received local surface floodwaters.

Several on-site factors limited the extent of the works. The channel is culverted at either end of the High Street. Vertical stone walls line the reach, with various surface water drainage pipes discharging into the channel. Two small footbridges cross the channel, along with three low weirs. The bed comprised mostly natural bedrock with some concrete screed to provide a level surface at the time of construction of the bridge piers and weirs.

The pre-restoration reach had a mean water depth of 0.5m and a mean channel width of 4.5m.

Design

The new sinuous channel design was constructed by forming berms to create a low flow channel, with higher flows able to over-top these features. This enabled the required capacity to be provided. The flood relief channel maintained the current level of flood defence to the High Street and allowed flows to be temporarily diverted away from the reach during construction.

The low flow channel width and spacing of the pool riffle sequence was informed by a suitable reference reach from the Somer catchment.

Accumulations of silt were removed from the channel and retained on site for use as backfill in the new design. Three weirs were removed, retaining only the two sides of each structure which were incorporated into the channel berms. This was at the request of the council who wanted to be able to install temporary boards across the channel to retain water depth, should severe drought conditions occur.

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The berms were constructed from "white lias" limestone blocks from a nearby quarry. These were hand placed to mark the edge of the new low flow channel, allowing gaps for existing drainage pipes. The blocks varied in size to a maximum of approximately 0.40mx0.3mx0.15m. Planting bays along the edges of the new channel were lined with a heavy coir blanket and filled with the retained silt.

A carefully selected range of native riparian plants, such as brooklime (*Veronicabeccabunga*), water forget-me-not (*Myosotis scorpioides*) and water mint (*Mentha aquatic*) were procured from a professional supplier as plugs. This was primarily informed by a survey undertaken within a reference reach. Consideration was given to plants whose flowers would be attractive in the urban setting and species which would encroach into the channel to adjust the width, but flatten during flood flows to ensure they would not reduce conveyance capacity. Plants which would increase the physical integrity of the berms were also chosen.

A 40mm–60mm angular gravel mix from a local supplier was used to dress the top of the berms and create the riffles.

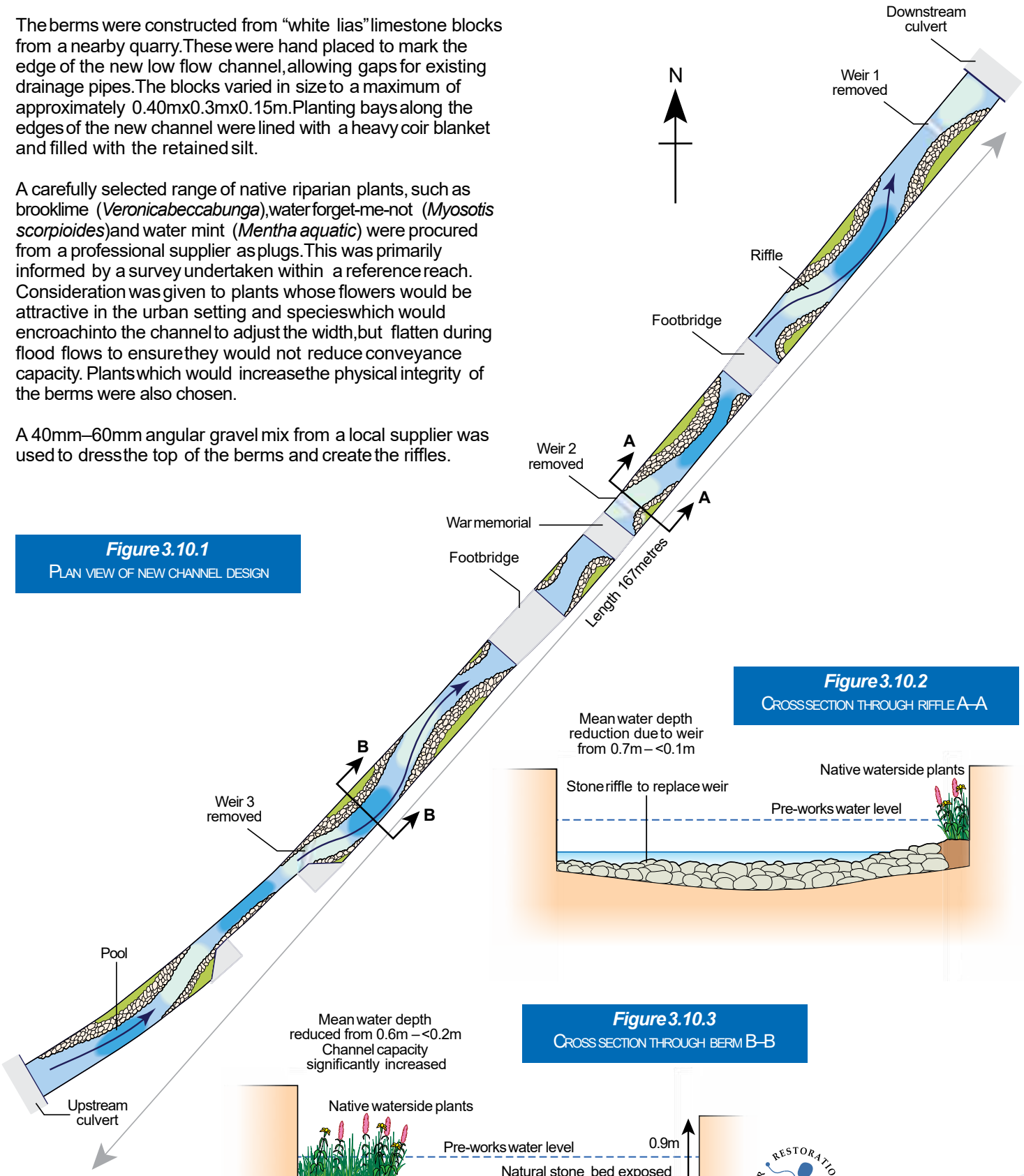

Figure 3.10.1
PLAN VIEW OF NEW CHANNEL DESIGN

Figure 3.10.2
CROSS SECTION THROUGH RIFFLE A–A

Figure 3.10.3
CROSS SECTION THROUGH BERM B–B

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Limestone blocks laid out to delineate berm structure edges – 2011

© Woodland Water & Gardens

Silt is used to fill the marginal berms ready for planting – 2011

© Woodland Water & Gardens

Two sides of the weir have been retained and incorporated into the berms – 2011

© Woodland Water & Gardens and D.Longley

Local volunteers help to complete the planting phase – 2011

Subsequent performance

In June 2012 the first formal post project assessment and maintenance visit was carried out. This was to assess the condition of the channel against the original project design and aspirations in terms of ecology, aesthetics, resistance to flood flows, flow patterns, siltation and routine maintenance by volunteers.

This assessment indicated that the berms were intact and in good condition despite several high flow events. Plant communities had matured well, providing a diverse marginal habitat.

Kick samples revealed that aquatic organism diversity has increased since completion of the scheme. Whilst kick samples were being taken three-spined stickle-back (*Gasterosteus aculeatus*) and bullhead (*Cottus gobio*) were captured. Many more stickleback were also observed in the slower channel sections. Freshwater shrimp (*Gammarus pulex*) were extremely abundant in the kick samples, indicating an improvement in aquatic conditions due to it's pollution intolerance and requirement for figh levels of dissolved oxygen. Some small silt deposits have formed in low flow areas, but the channel is generally self-cleansing. The project has been awarded a civic "Pride of Place" award for environmental enhancement from Midsomer Norton Town Council.

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Maintenance, carried out by volunteers from the Friends of the River Somer group, has helped to keep the channel free of litter and nuisance species such as buddleia (*Buddlejadavidii*), dock (*Rumexhydrolapathum*) and nettles (*Urtica dioica*).

Time spent discussing and explaining the principles and objectives of the scheme with stakeholders such as contractors, labourers and locals was well-spent. In this case it has facilitated the formation of the Midsomer Norton River Management Team who will help to ensure the continued success of the scheme.

The involvement of the local community from the outset has provided an opportunity to build a long term maintenance strategy, and has been an important legacy of the project.

In the right location and with a well considered design, this has proved an extremely cost-effective, adaptable and effective technique.

Section of the reach before, showing significant sediment accumulation – 2011

© Woodland Water & Gardens and D.Longley

During construction, just before the planting phase is due to commence – 2011

© Woodland Water & Gardens and D.Longley

One year after restoration showing development of diverse bankside vegetation – 2012

© Woodland Water & Gardens and D.Longley

Contacts

Luke Kozak, Woodland Water & Gardens
lukekozak@gmail.com, 07791 607969

Dominic Longley, Principal designer
dominiclongley@hotmail.co.uk, 07770803512

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

3

Enhancing Straightened River Channels

3.11 Sinuous low-flow course in an over-wide urban channel

River Wandle

Location - Carshalton, Sutton, South London TQ 28166504
Date of construction - November 2014
Length - 120m bed re-profiling and chanel narrowing
Cost - £45,000 (Plus £31,000 for the weir lowering and fishpass adjustment)

Type	Low energy, chalk
Status	Failing for fish (driver physical habitat modification). HMWB
Waterbody ID	GB106039017640
Designation	Site of Metropolitan Importance for nature Conservation (SMI)
Monitoring	Fixed-point photos, fish habitat survey, EA WFD Electrofishing, redd counts

Description

The 1km Carshalton arm of the River Wandle is a chalk stream flowing through a heavily urbanised area. Butter Hill Mill weir is approximately half way along the waterbody with 500m of river upstream to the source at Carshalton ponds and 500m of channel downstream to the confluence with the main Wandle. The weir created a total barrier to fish and impounded ~15% of the river length. The impounded reach, featured here, was straight, over-wide, shallow and possessed a very poor habitat structure and had a bed consisting of deep silty sediments. The site has a housing estate on one side and a road on the other, well-used footpaths on both sides of the river and a brick wall on the left bank for the whole reach.

South East Rivers Trust (SERT) aimed to rehabilitate the Carshalton waterbody by improving fish passage, habitat diversity and quality, hydromorphology and water quality, with wild trout used as the indicator species for the river's recovery.

This project was part of the wider multi-year ambition of SERT (carried out between 2011-2015) to obtain GEP and establish a population of brown trout in the upper Wandle.

Fine sediment fills the impounded river - Feb 2013 © SERT

Design

© SERT

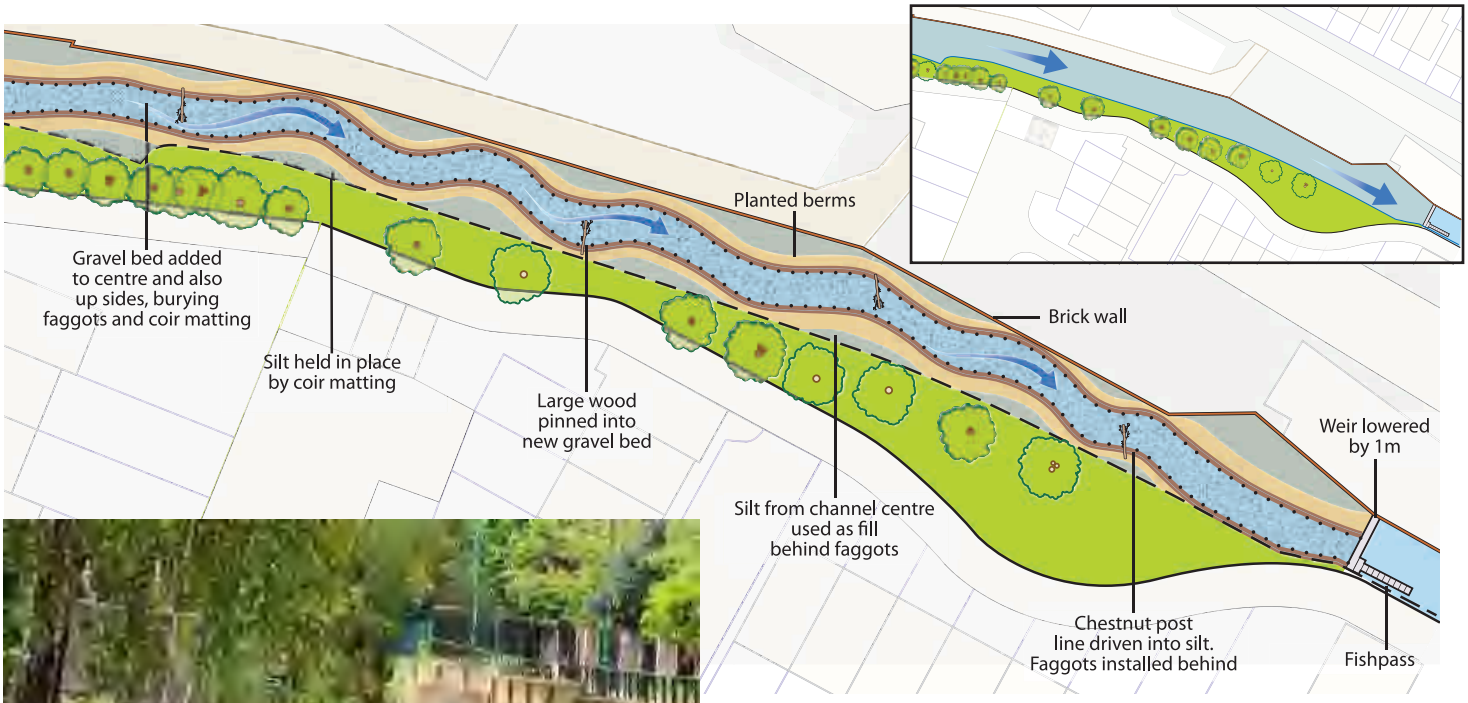
Inset – Weir lowered by 1m and fishpass modified and refitted at 15° gradient. The newly restored channel is visible beyond – 2014

Larinier fishpass originally installed. Too steep to be effective – 2012

Weir and Fishpass

Butter Hill Mill weir was part of an old mill structure, and a Larinier fishpass had previously been installed but had never worked due to its length and steep angle. The weir was not designated and surveys showed the structural integrity of the adjacent building was not dependent on the weir. The weir was lowered by 1m enabling the upstream impoundment to be removed and the fish pass to be modified (shortened and shallowed to a 15 degree gradient) over the remaining head drop to allow fish to pass upstream. Further work was needed throughout the previously impounded reach to address the excessive fine sediment build up and recreate the missing low-flow gravel channel.

Figure 3.12.1 Planform of the new layout



© SERT

Desilted central channel. Spoil placed behind the faggot rows and coir matting – Sept 2014

Channel

The channel design was led by spreadsheet-based hydraulic modelling (this was sufficient for Environment Agency flood defense consent (FDC)) to determine a width of channel that would give an average depth of 30cm along the reach (an EA gauging station was 300m upstream). Then geomorphological calculations were carried out (in-house by SERT but checked with Malcolm Newson at Tyne Rivers Trust) to identify the gravel size to be installed, such that it would be stable and would not result in mass movement of gravel downstream causing blockage of the fishpass.

The objective was to create a sinuous channel within the straight confines of the original channel. This involved narrowing the previous wetted width from 5m to 2-3m, but giving some freedom for the stream to adjust its low flow course; e.g. responding to vegetation growth, etc. An indicative meander spacing of 10-14 channel widths was applied.

Once the channel had dewatered and the old silty bed was exposed, the delivery process followed these stages.

1. Sinuous new bank lines were created with double height green chestnut faggots pushed into the exposed silt. The faggots were held in place using 1.5m chestnut posts which were driven down on either side of the faggots through the rubble strewn bed. The faggots were compressed and secured in position with fencing wire. Coir geotextile lined the back of the faggots with a short skirt laid on the exposed silt and the remaining width sat on the faggots whilst the central channel was excavated. The silt in the central channel was excavated by machine and placed behind the faggots (trapping the skirt of the coir matting).The coir geotextile was then rolled back from the faggots over the silt to prevent it from being mobilised under high flow events.

Enhancing Straightened River Channels

Filling the channel with gravel and pushing down the posts and faggots – Oct 2014

© SERT

In this constrained urban location, the above was done in very short sections, by a machine standing on bogmats on the exposed silt. [At less constrained sites, it would be simpler to work along the entire length of the reach: – lay out the entire run of faggots, – secure them with posts, – lay out the coir, – excavate the
central channel and backkfill, – pull over the coir to trap the silt].

2. 110 tonnes of Thames catchment 40mm+ flint reject gravel was placed into the desilted central channel and sculpted to include pools and point bars.

3. The faggots and posts were pushed down further into the silt to follow the dished profile of the new bed. The gravel was raked up to cover all of the faggots to form a seamless transition between the bed and bank.

4. A number of tree limbs were pinned into the bed to add flow diversity and encourage scour to retain pool habitat.

5. Volunteers planted 2000 plugs of marginal plants on the new berms to help stabilise them further and kick-start colonisation of these wet edges. This was deemed necessary as there was no good upstream source of plants for natural colonisation.

The shaped sinuous gravel bed and berms being planted – Oct 2014

© SERT

The native marginal plant list was agreed with the EA and London Borough of Sutton's ecologist. A variety of plants included reed canary grass (*Phalaris arundinacea*), greater pond sedge (*Carex riparia*), lesser pond sedge (*Carex acutiformis*), purple loosestrife (*Lythrum salicaria*), yellow flag (*Iris pseudacorus*), hemp agrimony (*Eupatorium cannabinum*), soft rush (*Juncus effusus*), water forget-me-not (*Myosotis palustris*) and water mint (*Mentha aquatica*).

Figure 3.12.2
The initial indicative two-stage design. Main channel and marginal ledge, with a defined faggot edge.

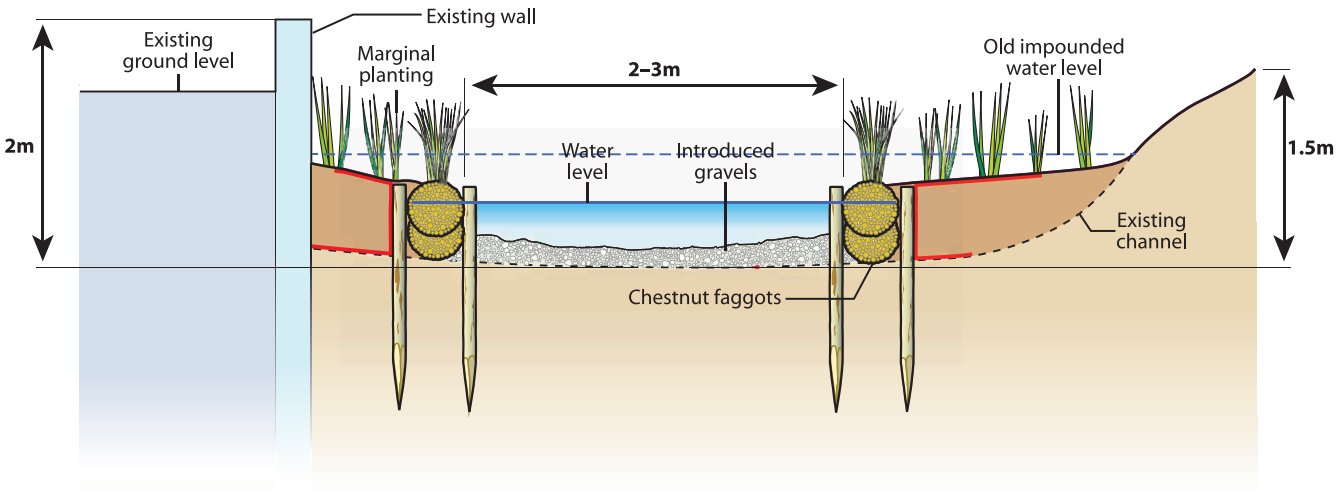
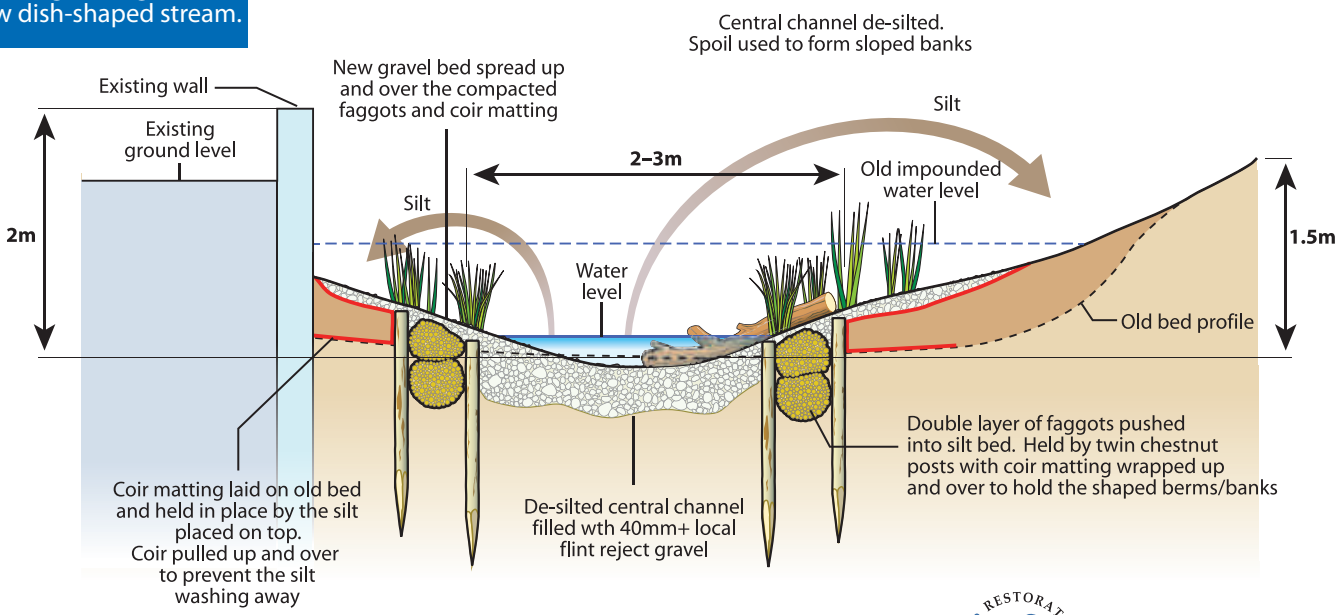


Figure 3.12.3
Indicative as built. By squashing the faggots and posts into the silt bed and adding more gravel. A shallow dish-shaped stream.



Enhancing Straightened River Channels

Subsequent performance – 2014 to 2019

A shallow fast flowing gravel bed chalkstream again – Oct 2014 © SERT

Established well-vegetated stream - 2019

© SERT

From observation, the hydromorphology of the restored reach has worked as predicted in terms of water depth, flow diversity and movement within the gravel but not excessive mobilisation in a downstream direction.

Very shortly after the work was finished, trout were seen upstream of the pass for the first time in living memory. During the first spawning season, five trout redds were observed in the restored section. The following year, EA fish survey data recorded 67 trout of 0+ age class from immediately downstream of this restored site (but within a section also restored in the same phase of work) demonstrating the first successful recruitment of trout in the Carshalton Arm of the Wandle in over 80 years. Subsequent fish surveys have evidenced up to 12 trout of multiple year classes within a 25m section of the restored channel.

Rapid plant colonisation – Jun 2015 © SERT

Informal redd counts have shown spawning activity every year since the work was carried out.

However, for three of the years there have been water utility flow augmentation infrastructure infrastructure failures, significantly reducing water quantity, which have coincided with the spawning season and impacted spawning results.

Lessons

Greater variability in bed depth could have been built into the gravel channel which would have provided greater diversity of fish habitat. There is not enough energy in this groundwater fed chalk system to create large/deep pools. Site constraints dictating that larger gravel sizes needed to be used in order to minimiseed a mass mobilisation of gravel which would have blocked the fish pass.

Some of the pinned wood temporarily collected debris which created deeper fish holding areas. The subsequent fish surveys also suggest that more juvenile trout habitat could also have been incorporated.

In confined and constrained sites such as this, carefully adding further wood can often help to trigger this type of beneficial and localised bed (pool) scour.

The highly modified river is dependent on a completely artificial recirculation/augmentation system during low river levels to mitigate for groundwater abstraction by the local water company. Despite significant investment to restore the river, which builds in features to provide greater resilience, the whole system is still extremely vulnerable to infrastructure failures which could cause the river to dry up.

Contacts

Tim Longstaff - now River Thame Conservation Trust (RTCT), Project Supervisor. enquiries@riverthame.org

Toby Hull/Bella Davies - South East Rivers Trust, Main Project Partner. Tel. 0845 092 0110

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Enhancing Straightened River Channels

3.12 Establishing marginal habitat along a hard engineered bank

River Nene

Location - Thorpe Lea, Peterborough TL18749817
Date of construction - March 2015
Length - 400m of bank edge over a 640m reach
Cost - £65,300

Type	Low energy, clay
Status	Failing for fish (driver physical habitat modification). HMWB. Moderate (2015)
Waterbody ID	GB105032050381
Designation	None
Monitoring	Fixed-point photos, invertebrates

© RNRP

Sheet pile and concrete bank – Feb 2015

Colourful marginal edge habitat – September 2015 © Salix

Description

The River Nene is a lowland river which begins in Northamptonshire, and flows to the Wash. It is an important navigable waterway as well as a popular coarse fishing river. The Nene has been extensively modified to allow navigation, extract gravels from the floodplain and prevent urban areas from flooding.

At Peterborough, the river is around 50m wide and has been modified to protect the nearby city centre and residential properties. It has been over-deepened, over-widened, impounded and constrained by hard bank protection. The north bank is reinforced with vertical sheet-piled concrete and brick walls, with a footpath alongside top. This looked unsightly and provided no marginal habitat for invertebrates and fish.

The aim of the project was to create a wetland ledge as habitat for fish and invertebrates, as well as provide a more pleasant view for residents walking, cycling or travelling along by boat. River Nene Regional Park worked with Peterborough City Council to identify a 639m reach where improvements could be made to the river margin. The project reach could not extend any further downstream because of boat moorings, and the upstream limit was defined by the end of the bank protection,

The impacts on flood risk and the width of navigable channel were the key limitations on design. As a result, improvements could not extend more than 800mm into the channel. The project reach contains two railway bridges and two footbridges

Enhancing Straightened River Channels

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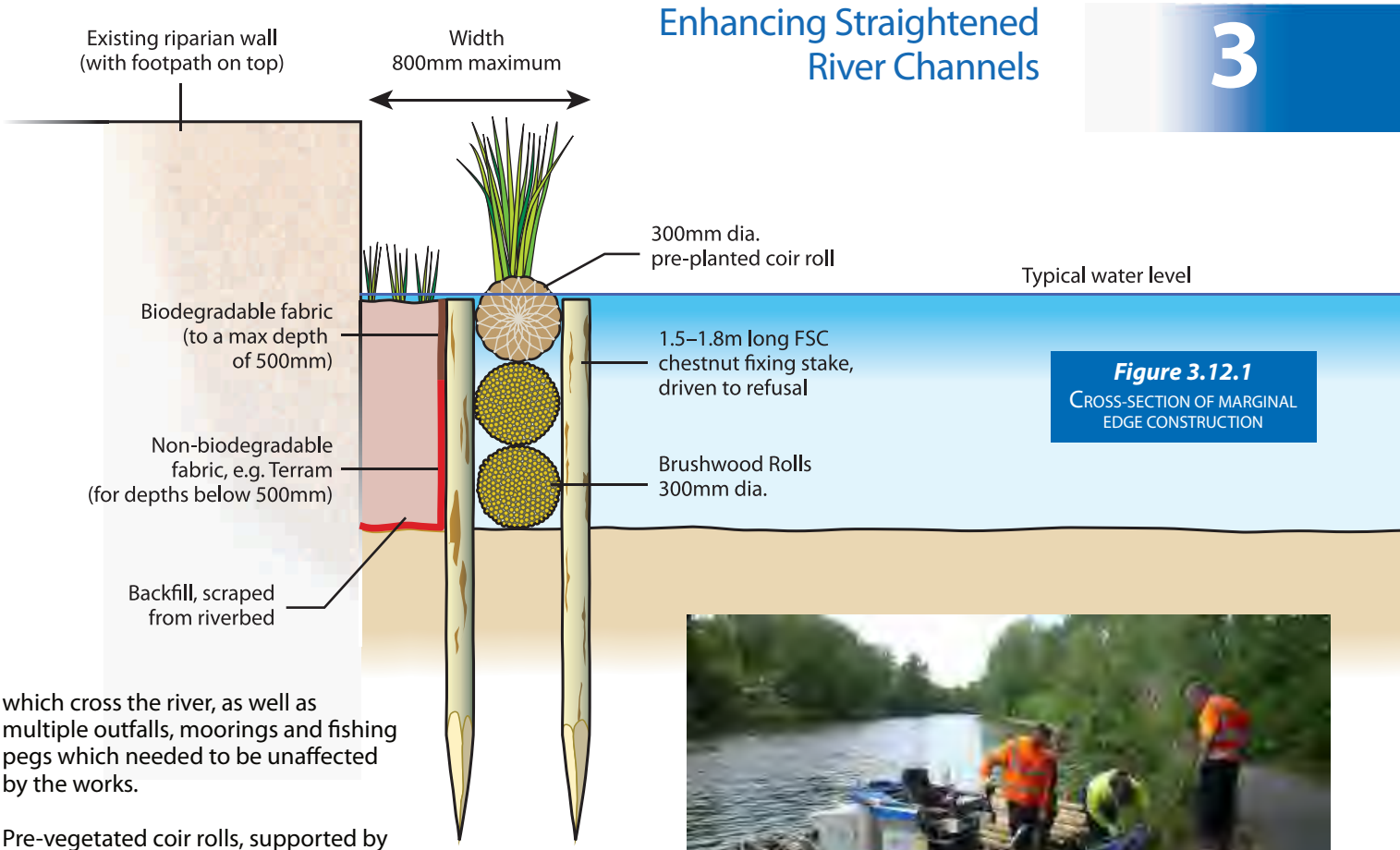


Figure 3.12.1
CROSS-SECTION OF MARGINAL EDGE CONSTRUCTION

which cross the river, as well as multiple outfalls, moorings and fishing pegs which needed to be unaffected by the works.

Pre-vegetated coir rolls, supported by brushwood faggots, were selected as the most suitable technique for this site. This was because they would immediately create amenity value along the reach. The brushwood faggots would ensure longevity by trapping silt and providing the future growing medium for the riparian plants.

Floating vegetated pontoons were considered as an option. However, there were concerns about the pontoons rising above the relatively low bank top in high flows and being 'beached' on the path.

© RNRP

A Truxor provided access from the river – May 2015

A narrow path made access difficult for large sections of the bank. To get around this problem, a Truxor amphibious machine was used to provide access from the river itself.

The work comprised the following:

1. The Truxor and float units were used to transport materials to the work area. Once the Truxor was anchored in place, a hand held hydraulic rammer was used from the Truxor to drive FSC timber stakes into the bed.

2. The 100mm diameter and 1.5m - 3m long stakes (depending on the river depth) were positioned approximately 300mm into the channel and were driven into the bed at a depth of approximately 50% of the stake. Stakes were positioned 300mm apart in two rows, with 1m centres on the back row and 0.5m centres on the front row. At 2m - 3m centres, the front row was tied to the anchoring back row to provide additional support.

3. The required number (between 1 and 3 depending on depth) of hardwood brushwood faggots (2m x 300mm) were then placed between the two rows of stakes.

© RNRP

A 'tried and tested' method using simple components – May 2015

Enhancing Straightened River Channels

4. Finally a single planted coir roll was placed on top so that 60% would sit below the dry weather water line. The pre-established coir rolls contained local native species such as Yellow Flag Iris (*Iris pseudacorus*), Purple Loosestrife (*Lythrum salicaria*) and Lesser Pond Sedge (*Carex acutiformis*). Once in place, the coir rolls (3m x 300mm) were tied together end to end, laced across the top with polypropylene twine and fixed to the stakes with fencing tacks.

5. Before back-filling, a filter fabric was tacked to the back row of stakes, this was to prevent the escape of the backfill sediment. For deep sections and depths below 500mm an non bio-degradable membrane was used, as this would be permanently hidden and would retain its integrity longer. Above this level, either in combination or, in shallow areas, on its own, a bio-degradable fabric was used up to the top of the stakes.

6. The Truxor was then used to suction dredge material from the bed and back-fill the coir rolls. The backfilled area was narrower in the areas where the concrete bed restricted stake placement (as outlined above). Finally, temporary Tenax netting was fixed to the front of the structure with fencing tacks to prevent early damage from wildfowl.

Pre-grown, the plants survive well and quickly thrive (*see timeline below*) – March 2015

7. As the riverside pathway was heavily used, interpretation boards were made up to let the public know what had been done, why, and what the expected benefits were going to be.

On site adjustments

In some sections, a concrete bed was found during construction, located just out from the bank. This prevented stakes from being driven into the bed. The stakes then had to be driven in closer to the bank, where there was no concrete present. This reduced the size of the ledge, and the amount of backfill in these locations.

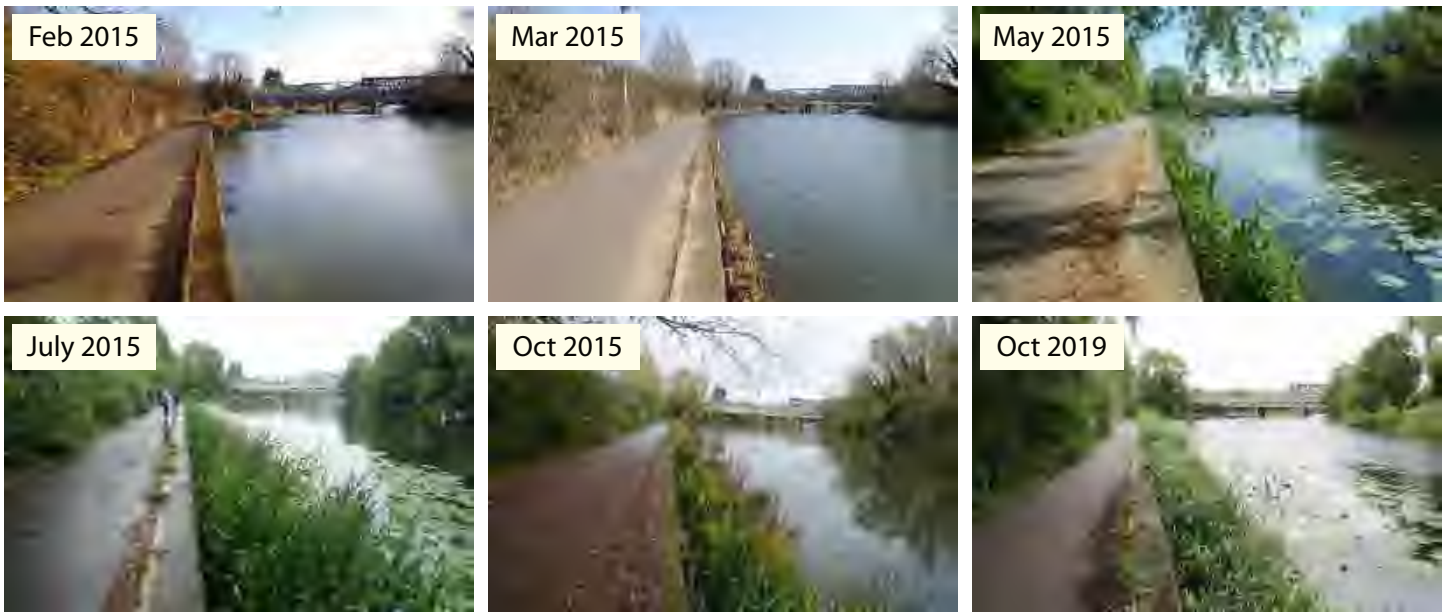
Subsequent performance – 2014 to 2019

Vegetation establishment and visual impact

The transformation of the bleak concrete edge was very quick. Within two months of the pre-grown coil rolls being installed, the rolls had successfully vegetated. By the summer, the entire concrete and sheetpile wall was hidden behind a dense green border and the tall marginal vegetation was up to knee height, acting as a visual safety barrier to the drop off into the river.

After four and a half years, the edge is still as well vegetated, showing that the initial silt backfill and subsequent ongoing deposition is sustaining these marginal plants

Timeline showing the development and visual impact of the new planted edge



Ecological assessment 13/8/15

An assessment of the macroinvertebrates inhabiting the River Nene at Thorpe Lea, Peterborough, was undertaken by the Environment Agency to determine the effect of a marginal enhancement project.

Two macroinvertebrate samples were taken on the 14th July 2015, one within the enhancement area and one in an unenhanced control section, using a standard FBA-pattern pond net.

Even within four months the habitat enhancement had clearly resulted in an increase in the number of supported taxa (23 taxa in the unenhanced control, rising to 37 in the enhanced section). ASPT and BWPM scores rose from 3.93 to 4.24 and 59 to 89 respectively. At this early stage, this did not result in an increase in Community Conservation Index (CCI), as all supported species in both sections are known to be common and widespread. CCI classified both control and enhanced sections as of low conservation value.

© EA

Close-up of the edge, sampled after only 5 months – July 2015

Particularly noteworthy is the buffering effect against invasion by a vigorous non-native predator. The invading amphipod, *Dikerogammarus haemobaphes*, was a dominant component of the fauna in the unenhanced section. A much less vigorous species, *Crangonyx pseudogracilis*, absent from the unenhanced section because of competitive exclusion, was not only present in the enhanced section, but in substantially greater abundance than *D.haemobaphes*.

Environment Agency Macroinvertebrate assessment

Macroinvertebrate species	Control Estimated + Number found	Coir rolls Estimated + Number found
Anisus vortex	1	10
Asellus aquaticus	8	20
Bithynia tentaculata	8	20
Chelicorophium curvispinum	2	1
Chironomi	10	10
Cladocera		2
Cloen dipterum	1	2
Coenagrildae		1
Crangonyx pseudogracilis	1	20
Dikerogrammarus haemobaphes	10	5
Erpodella octoculata		3
Erythromma najas		1
Gyraulus crista		3
Halipus lineatocollis		1
Hippeustis comlanatus	1	
Hydracarina	3	2
Lymnaea stagnalis		1
Micronecta		1
Notonecta	1	1
Notonecta viridis		1
Oligochaeta	4	20
Orthocladiinae	10	
Ostracoda	1	3
Physa fontinalis	5	8
Pisidium amnicum		8
Pisidium nitidum		1
Planorbarius corneus	1	1
Polyclis tenuis		3
Potamopyrgus antipodarum	2	5
Prodiamesa olivacea	2	2
Radix auricularia	2	

This provides superficial evidence that the raised habitat complexity provided by the enhancement acted as a refuge for the less vigorous species and is likely to have provided similar refugia against this and other predatory species for other invertebrate taxa.

In summary, there is clear evidence that the enhancement has been beneficial in raising the local richness of the aquatic macroinvertebrate fauna. Due to the success of this work, RNRP was confident enough to replicate the approach at two other nearby sites.

Management and Maintenance

At this location the River Nene is low energy with comparatively low levels of boat traffic. This technique would be less suitable for banks subject to heavy river traffic and/or high velocities and turbulence.

No work has been carried out or is expected to be carried out in the near future.

The assumption is that the faggots are now a matrix of silt and decomposing brushwood held together by a dense macrophyte root system. Longer-term, there remains a question as to how stable to edge will be once the structural timber posts begin to break down. With a soft earth bank edge, this is not an issue as the plant roots will anchor into the bank, but with a hard engineered edge, any anchoring will depend on the wall. This process could be helped, for example, by bolting a long-lasting (steel, etc.) bar along the face of sheet piling for plant roots to bind around.

Contacts

Simon Whitton, River Nene Regional Park (now Apem) - Project Supervisor
01443 239205

Viktor Tzikas, River Nene Regional Park – Project Lead Partner
01536 526438

Chris Mackintosh-Smith, Salix - Contractor
0370 350 1851

4

Revetting and Supporting River Banks

4.1 Willow spiling

River Skerne

Location – Darlington, Co Durham, NZ301160
Date installed – November 1995 and May 1996
Length – 75 metres
Cost – £115/metre

Willow spiling 2 years after construction

Description

This revetment technique utilises willow poles woven around vertically driven stakes and is particularly suited to steep river banks that need both support and erosion protection.

Spiling was installed at both the entry and exit of a reach of river that was re-meandered. These locations were selected for spiling because the existing banks of the straight channels within which the revetment starts were near vertical due to erosion of the bank toe.

The technique often utilises osier willow because of its prolific production of long, slender, pliable poles suitable for weaving. Other species are less suited to weaving so the availability of indigenous river bank willow for spiling may be limited and other techniques might be more appropriate (*see Techniques 4.2 – 4.3*). The introduction of non-indigenous species, through revetment works, is rarely justified; osiers thrive in withy beds or plantations but less so in many river bank situations.

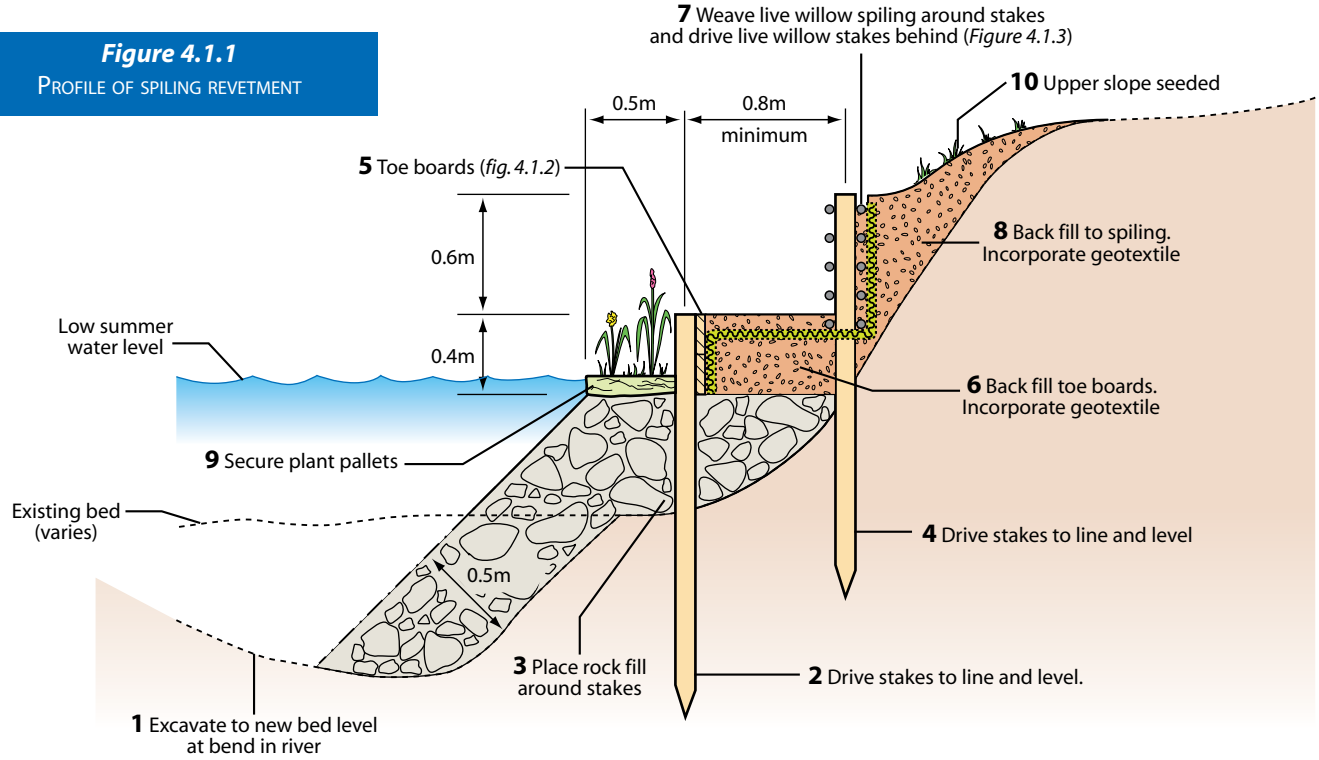
The technique is demonstrated at the Skerne because it is popular with construction teams and relatively easy to install. It is not necessarily best suited to the overall environment at this site, although it is otherwise adequate to protect the banks.

Design

- Below water a densely graded rock matrix is used to line the bank having first excavated down to a designed bed level and to provide room for the rock without it protruding beyond the adjoining natural bank profile (*see Tchnique 4.2 for the rock details*);
- At the water's edge the rock is incorporated into a shelf formed behind toe-boarding;
- Spiling behind and above this shelf is formed from wooden stakes driven to line and level around which the osiers are densely woven. Vertical live willow posts can then be independently placed behind the spiling and can be of a different species. A nylon geotextile was utilised behind the spiling and the toe boarding to help stabilise the soil back filling which follows;
- The upper bank is then graded back to a safe slope that is un-revetted and either seeded with grass or turfed in extreme circumstances.

Revetting and Supporting River Banks

Figure 4.1.1
PROFILE OF SPILING REVETMENT



The basis of this design is to provide a stable underwater environment as a foundation for the spiling which is located just above water level where willows thrive best. The rooted osiers that develop from the woven poles will gradually occupy the underwater rock, and the marginal shelf, as the toe boarding rots away. Pre-planted pallets were placed in front of the toe boards to add to visual amenity and habitat diversity. Over time, the osiers will become dominant and will secure the river bank against further erosion whilst providing valuable habitat. Coppicing of the osiers is planned in line with normal procedure for maintaining the security and integrity of this species.

Commercially available woven willow hurdles can effectively replace the in-situ weaving, but more support posts will be needed. Live willow posts introduced behind the spiling can be allowed to mature into trees (if the osiers are coppiced sufficiently often) and these may be of an indigenous species intended to succeed the osier over time.

This technique does not have the intrinsic flexibility to accommodate bank settlement that is a feature of *Techniques 4.2* and *4.3* because it is, in essence, a vertical retaining wall. It is, however, less demanding of space which is sometimes advantageous.

Subsequent performance 1995 – 2001

The river banks at both entry and exit sites are stable and silts are accumulating around a dense line of willow shoots up to 2.5m tall. The planted ledges are equally densely covered with marginal aquatic species that are similarly accumulating silts. Exceptionally, growth over one short length has been limited to the willow posts introduced behind the spiling. This is because the spiling poles, installed in the autumn, had been stored for too long in dry conditions.

Figure 4.1.2
PLAN OF TOE BOARDS

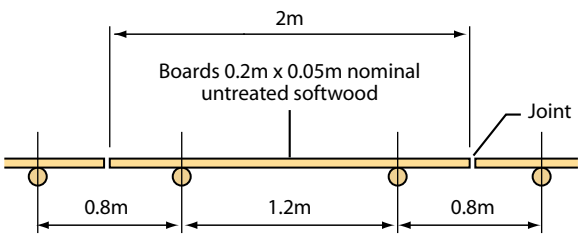
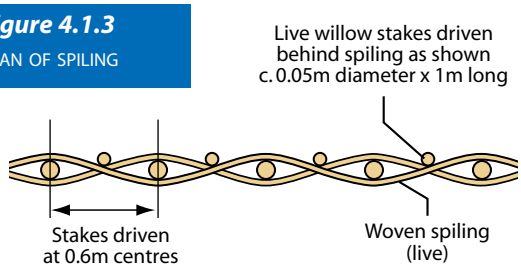


Figure 4.1.3
PLAN OF SPILING



4

Revetting and Supporting River Banks

4.2 Willow mattress revetment

River Skerne

Location – Darlington, Co Durham, NZ301160

Date installed – October 95

Length – 59 metres

Cost – £164/metre

Note: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Mattress revetment under construction – October 1995

Note: Additional poles inserted to close up spacing after photo taken

Description

This technique demonstrates revetment using willow branches that may be readily to hand in riverine situations through routine maintenance or pollarding of trees. They are laid along the reformed river bank and secured with sheep netting such that rapid growth of willow shoots will initiate a long term ecologically sustainable revetment.

Enhancements to the basic concept include the use of underwater rock, plant pallets at water's edge, and standard trees along the upper bank.

Revetment was needed to protect a gas main in the bank and loose backfill closing off a length of redundant channel.

Design

Below water

Crushed rock was used to line the newly excavated channel around a sharp bend, as well as the initial infill of the redundant channel (fill 1). Few alternatives to rock were practical in this urban situation, but rock does form a flexible revetment which tree roots and aquatic flora/fauna will colonise. Most importantly, the rock used was mixed at the quarry to provide a densely graded '0.3m down' matrix to the following specification:

General Rock Revetment Specification (used throughout)

Hard, dense, homogeneous, frost resistant, local rock free from foreign matter

% passing	Sieve size (mm)
100	300
40 – 50	125
30 – 45	75
20 – 40	37.5
10 – 30	10
5 – 20	5
0 – 10	0.6

Revetting and Supporting River Banks

Mattress revetment after 2 years

As an alternative to rock, tree branches may be secured underwater by stapling to sheep netting to form a floating mattress which is then loaded with soil fill to sink it in to place. (Ward *et al.* 1994)

Water's edge and lower bank
The newly aligned and graded river bank was formed to about two thirds height by filling on top of the underwater zone described above. Rolls of sheep netting, cut to length, were incorporated under the fill as shown.

Selected live crack and white willow poles, 0.05m – 0.1m diameter, were then laid horizontally all along the face of the fill and pressed into it. Finally the free ends of the netting were drawn tightly over the poles and secured to stakes driven well back in the fill. Due to the shortage of willow locally, up to 30% non-regenerative sycamore was incorporated intermittently. The netting was stapled to the poles to create a structurally integral unit.

Upper bank
This was made up with fill, leaving a ledge, and seeded with grass.

As a final measure, pre-planted coir pallets were fixed along the water's edge to provide visual amenity and variety of habitat. The following year, standard trees were planted along the upper ledge. These may outgrow the revetment willow as they mature, provided the latter is regularly coppiced.

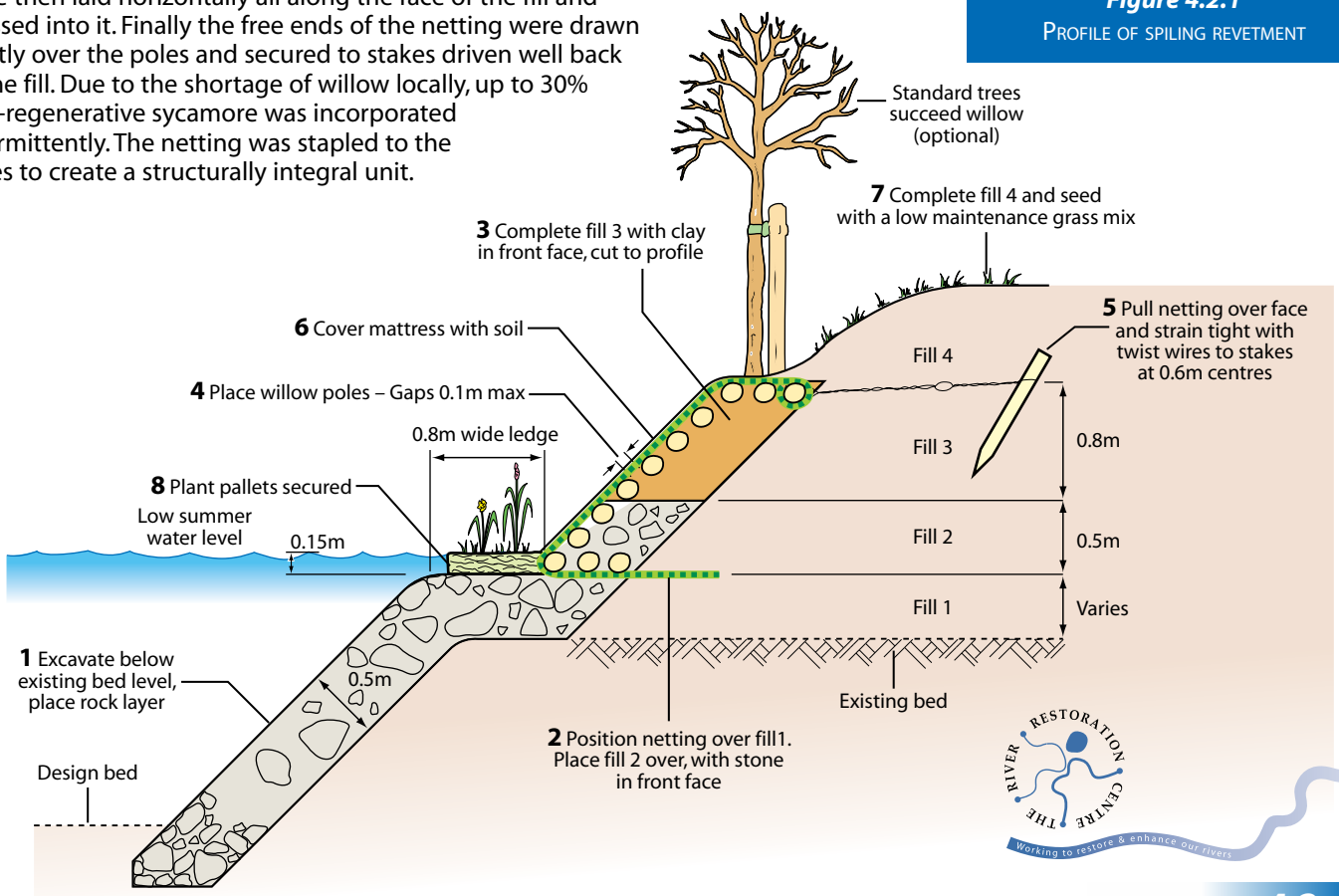
Subsequent performance 1995 – 2001

The revetment has remained stable, and dense willow growth up to 3m high covers the bank. Marginal sedge and iris complete what is a most desirable habitat niche favoured by water voles and birds.

Due to autumnal installation, no growth of willow occurred for the first 6 months, when winter floods washed out some soil. Since then the situation has reversed and silts are accumulating within the willow whilst roots extend into underlying soils and rock.

Rotational coppicing is planned, cutting around one third of the willow annually, as part of a river bank maintenance programme. On the Clwyd (Ward *et al.* 1994) no maintenance has been undertaken for 20 years and large trees have developed without hindrance by the netting which is now subsumed within the trunks.

Figure 4.2.1
PROFILE OF SPILING REVETMENT



4

Revetting and Supporting River Banks

4.3 Log toe and geotextile revetment with willow slips

RIVER SKERNE

LOCATION – DARLINGTON, CO DURHAM, NZ301160

DATE INSTALLED – OCTOBER 1995 (STANDARDS PLANTED MARCH 1996)

LENGTH – 91 METRES

COST – £146/METRE

NOTE: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Log toe revetment three years after construction

Description

This technique demonstrates revetment using tree trunks or large boughs along the water's edge to stabilise the toe of reformed banks. Proprietary nylon geotextile is used to revet the bank above the logs so that willow plants can safely be established within it.

Revetment was needed to protect a gas main in the bank and loose backfill closing off a length of redundant channel.

Design

Three vertical zones within the river bank were considered as follows:

Below water
Crushed rock was used to line the newly excavated channel around a sharp bend, as well as the initial infill of the redundant channel. Details of the rock, and the rationale behind its use, are as explained in *Technique 4.2*. The rock was incorporated around fencing posts driven to mark the line of the new bank toe.

Water's edge and lower bank
Logs were laid out along the top of the rock and lightly wired to the fencing posts to prevent flotation. Logs were then strained tight against the posts using twist wires anchored to stakes set well back into the fill. These ensure that the logs can never float away even if major settlement or scour of the river bank arises.

The logs selected were of oak, sized up to 0.5m diameter, but virtually any timber is suitable because they need not be durable if willow is to be planted above. The use of live willow logs that will rapidly regenerate along the toe may be appropriate in some situations.

Backfill was then extended to about two thirds bank height and profiled as shown. Geotextile (Enkamat 7220) was fixed to the log under nailed wooden boards, pinned down over the bank and covered with soil.

Upper bank
Infilling was completed leaving a ledge as shown. All of the above represents no more than a secure but flexible matrix within which plants can be introduced to become established as the long term revetment medium. Coir pallets pre-planted with marginal aquatic species were fixed along the front of the logs and reed canary-grass planted in the damp zone above. Grey and goat willow plants, as well as some un-rooted slips, were set within the geotextile and standard trees planted along the upper ledge.

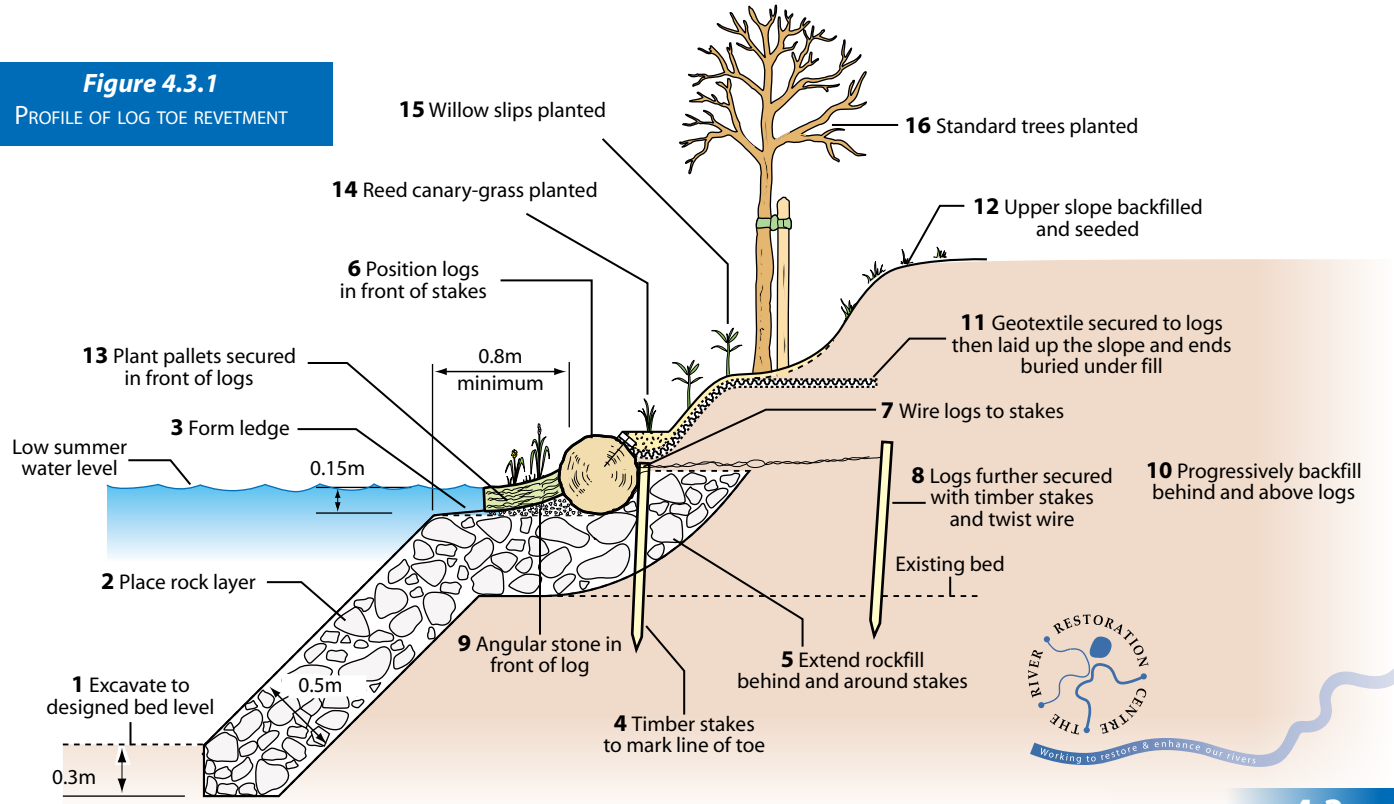
This mixture of plants is intended to be successional. Whilst the willow will quickly dominate the lower banks, as roots penetrate the underwater rock, the standard trees may eventually dominate the willow, particularly if this is regularly coppiced.

Subsequent performance 1995 – 2001

This technique was used in two locations and both have performed well with dense willow growth up to 2m high along the bank and a thick margin of plants along the water's edge, all of which are acreting river silts in successive floods. Rooted willow plants established much more strongly than unrooted slips, but this is not uncommon with the grey/goat species selected. Other willow varieties are known to strike readily from slips. Species that are indigenous to the site are always preferable. Brushwood containing willow cut locally can be built into the lower banks as an alternative to the geotextile utilised at the Darlington site which was virtually barren of trees.

Log toe revetment during construction

Figure 4.3.1
PROFILE OF LOG TOE REVETMENT



4

Revetting and Supporting River Banks

4.4 Plant roll revetment

River Skerne

Location – Darlington, Co Durham, NZ301160
Date installed – Oct 1995 to June 1996
Length – 119 metres
Cost – £130/metre

Note: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Transitonal revetment at installation (*water level artificially low in photo*)

Description

This technique demonstrates the use of proprietary revetment materials in a situation where the potential for erosion is not severe. A flexible revetment is provided within the water's edge zone at the toe of the bank utilising rock rolls and plant rolls to resist undercutting. At this site, it is used to form a smooth transition between the un-reveted river banks and the fully reveted banks described in *Techniques 4.1* to *4.3*.

Design

Rock rolls are flexible 'sausages' of crushed rock contained within nylon netting, whereas plant rolls are of dense coir within which selected marginal aquatic species can be pre-grown. Plant rolls fixed over rock rolls will become homogeneous as roots penetrate downwards into the rock and the adjacent soil. The design provides inbuilt flexibility whilst allowing the plants to develop in stable conditions.

Rock rolls are set out below water on ledges cut to suit and secured by driving posts through the netting. Long term stability and flexibility is achieved by pulling the rolls tight against the posts using twist wires anchored to stakes set well back.

Plant rolls are set out at low water level and wedged tight up against the rock rolls by driving stakes at a suitable angle along the rear of these.

Pre-planted flat pallets of coir were added above the plant rolls to increase the extent of marginal vegetation although this is largely an aesthetic measure.

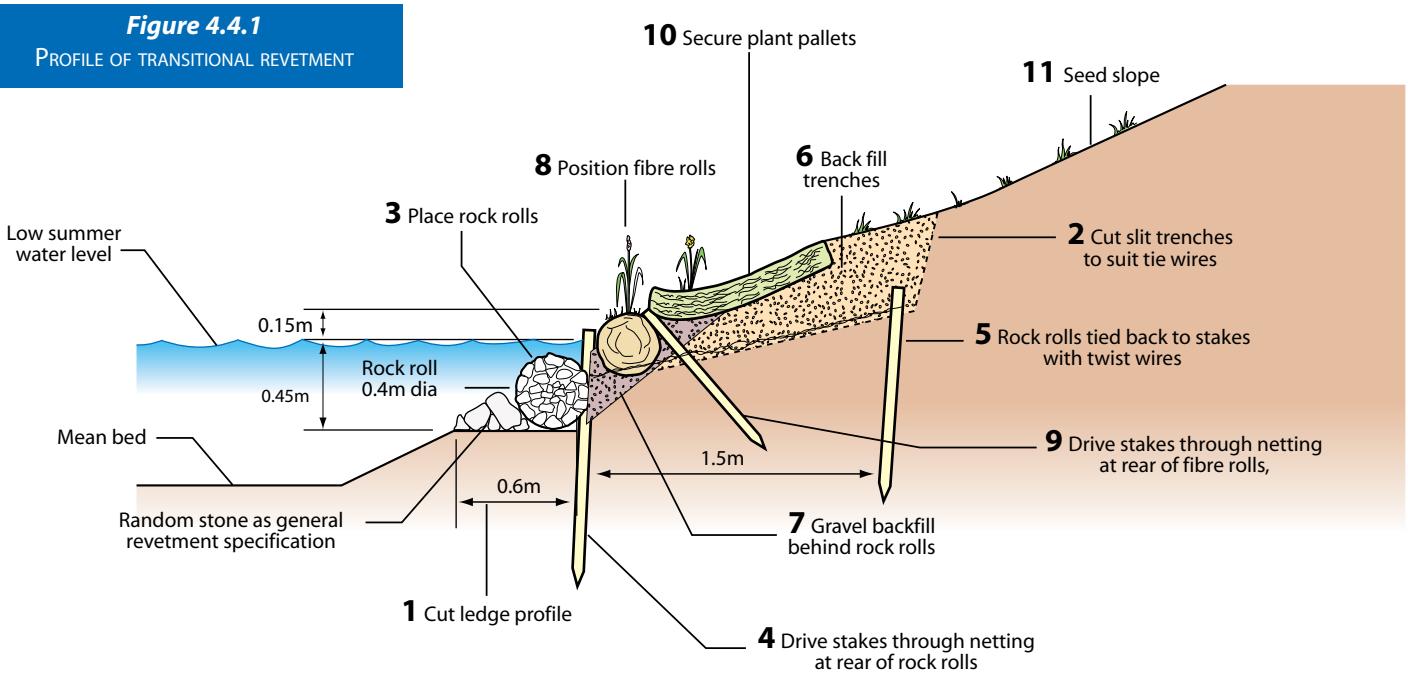
The toe of the bank needs to be permanently damp for this to be worthwhile, which is most likely in situations where undercutting has already occurred and the bank toe is being reinstated, e.g. through boat wash.

Subsequent performance 1995 – 2001

Several lengths of this revetment were installed in various alignments, e.g. entry and exit of bends and in backwaters. All have established well with reed canary-grass proving to be the most dominant plant best suited to the habitat niche created. Growth is generally limited to within 500mm of river level where the bank is damp. Above this the pallets have been colonised by ruderial plants such as himalayan balsam, which is being controlled by mowing before seed heads form.

Children walking along the bank toe, behind the plant rolls, have created ledged paths, which are stable, and are accreting significant amounts of silt due to eddy currents set up as floods pass over the stands of reed grass. This desirable situation contrasts with the erosion of river bank toes that typified pre-works conditions in the straight trapezoidal river.

Figure 4.4.1
PROFILE OF TRANSITIONAL REVETMENT



4.6 Hurdle and coir matting revetments

River Cole

Location – Coleshill, Oxon/Wilts border, SU234935

Date installed – Autumn 1995

Length – Hurdles – 15 metres. Matting 3 lengths of 20 metres

Cost – Approx £40/metre

Construction of coir matting revetment – river being released

Description

The revetments were installed where an old, straight channel is crossed tangentially by a new, smaller, meandering channel at three separate locations. At each crossing point, the old channel was partially infilled and compacted and the new channel then excavated within this fill. As the new river flowed straight across the old, the risk of scour was not great, which suggested that only light revetments were needed, sufficient to protect the bank and bed until soils consolidated and vegetated over. Two bio-degradable materials were selected to line the newly formed banks, coir matting and dead willow hurdles. Stone lines the new bed in both examples.

Coir was installed on both banks at the crossing located mid way between the ford (ch. 280m) and the stock bay (ch. 100m), as well as opposite the large backwater. Hurdles were installed opposite the small backwater. A plan of the reach can be found in *Technique 1.2*.

Design

A primary consideration was achieving a satisfactory method of infilling and compacting the old channel such that the new channel could then be excavated within reasonably stable soils. The complicating factor was the need to work around a flowing river. Failure to achieve sufficient compaction would have required more robust and costly revetments.

Two methods of managing the river flows were combined; pumping round the works and blocking off the flow creating a temporary lake upstream. This put great pressure on the contractors to quickly complete the work, but adequate compaction was achieved. Construction details are similar for both types of revetment (*Figures 4.6.1 – 4.6.2*).

Once the new river channel had been roughly formed (steps 1 and 2) it was relatively straightforward to complete the revetments as indicated by steps 3 to 5.

Points of note are that all joints between individual hurdles or matting were overlapped downstream to avoid lifting in high flows and each run of revetment was securely fixed within undisturbed soils at each end. A single willow hurdle was pegged down over each end of the coir matting for additional security, but some have washed away (without damage to the coir) suggesting they were not necessary. The stone bed was sized 0.1m – 0.15mm and spread up to 0.3m deep.

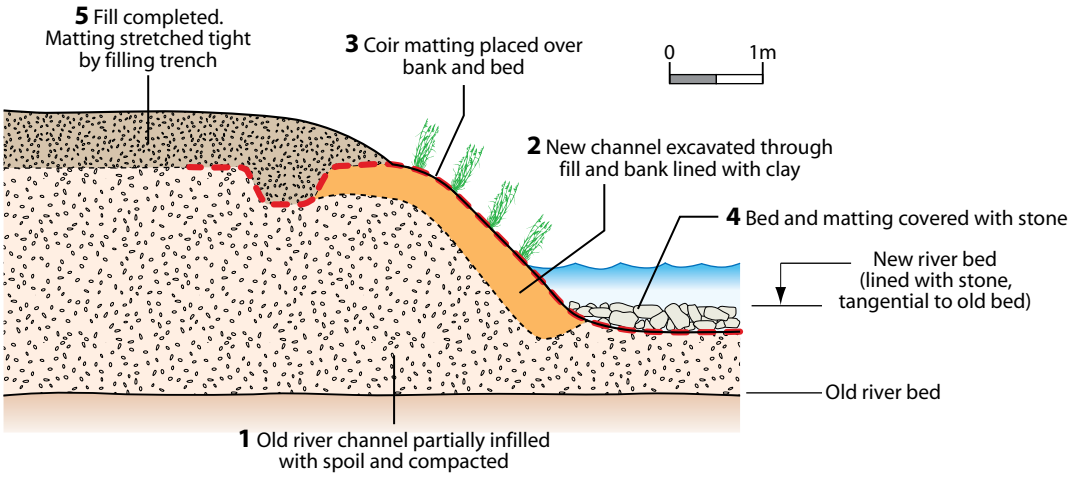


Figure 4.6.1
PROFILE OF COIR REVETMENT

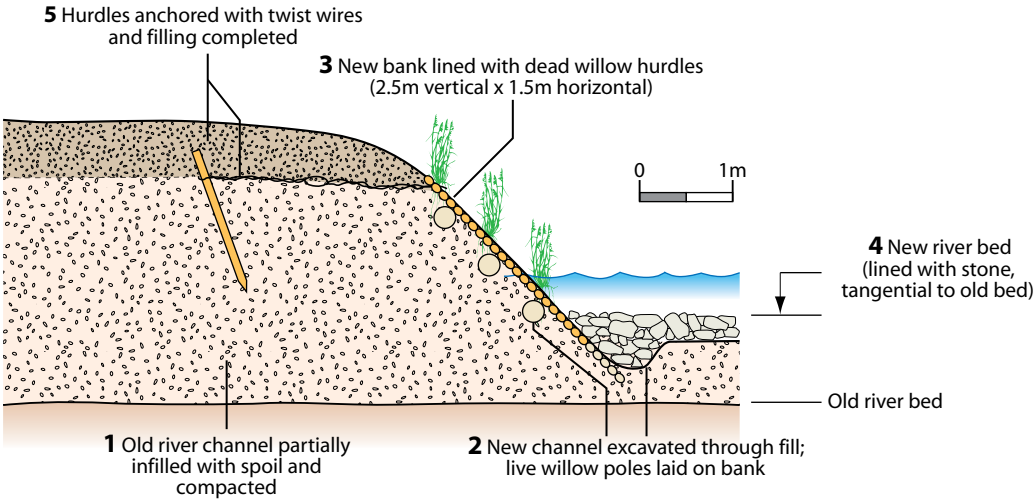


Figure 4.6.2
PROFILE OF HURDLE REVETMENT

Subsequent performance 1995 – 2001

The revetments are all secure with no instability and are vegetated, particularly where turfy backfill was incorporated under the coir. Crack willow has successfully established from the live poles incor-porated underneath the hurdles. None of the materials have seriously deteriorated in the three years since installation but will do so eventually.

In some places, the revetments have proved to be more secure than the adjacent undisturbed soil resulting in a hard 'engineered' line that contrasts with the subtle sculpting of the unprotected banks by river flows.

Alternative techniques for securing infilled river banks elsewhere on the same reach include bays, and backwaters (*see Technique 2.2*), and fords and stock drinks (*see Technique 8.1*). These alternatives have created much greater amenity/habitat value than the revetments and might, therefore, be regarded as preferable if circumstances permit.

4

Revetting and Supporting River Banks

4.7 Bank revetment using low steel sheet piling and coir rolls

RIVER THAMES
LOCATION - CLIFTON LOCK CUT, OXFORDSHIRE SU 544944
DATE OF CONSTRUCTION - SEPTEMBER 1996
LENGTH – 140m
COST – £45,000

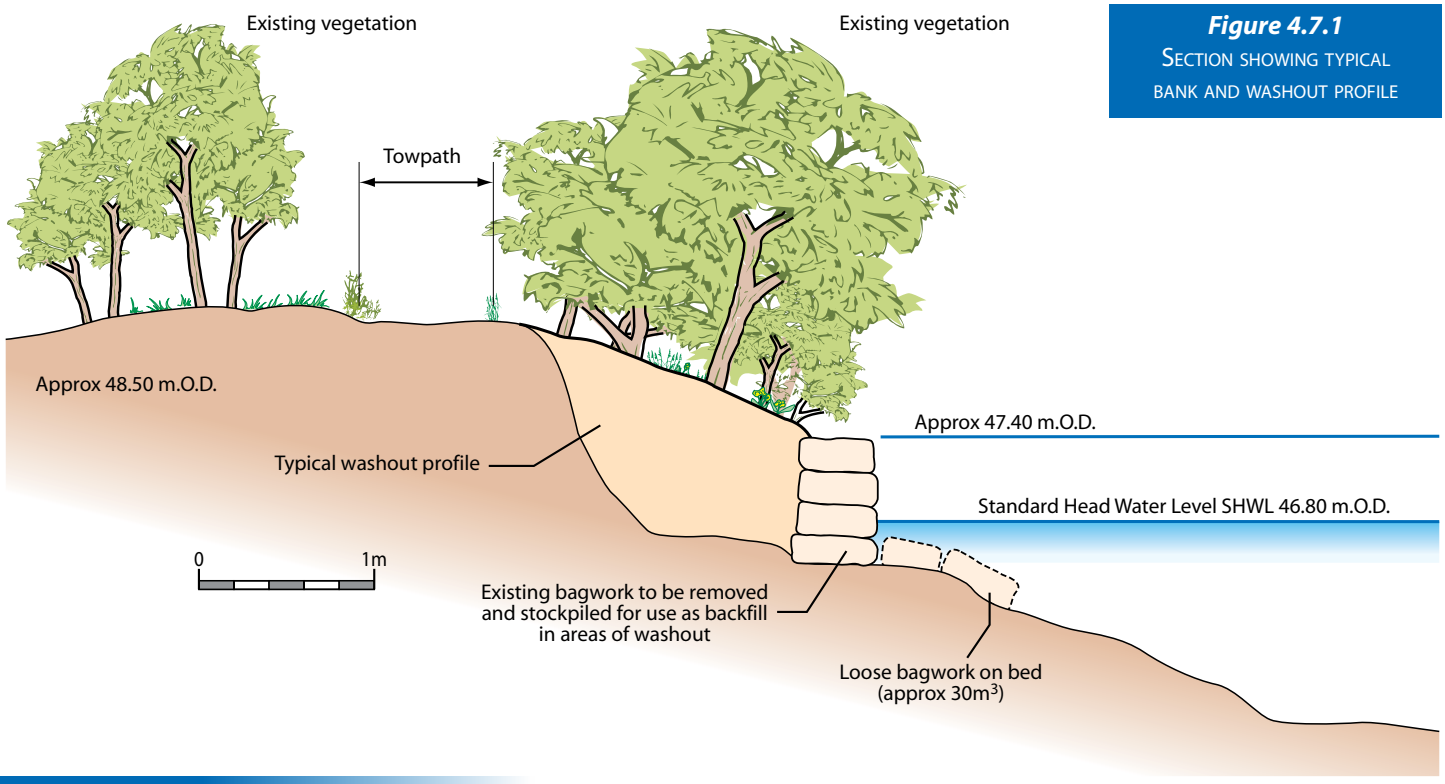


Figure 4.7.1
SECTION SHOWING TYPICAL BANK AND WASHOUT PROFILE

Description

For centuries the River Thames has been heavily managed for the purposes of flood defence and navigation. In its lower reaches the river is restricted and controlled by weirs and locks. Various techniques of bank revetment are used along its banks including steel sheet piling and/or concrete bagwork. Boatwash is a major concern where more natural softer engineered banks exist. In addition, sections surrounding locks and 'artificial' lock cuts experience a degree of rapid drawdown and changes in velocity in association with lock usage.

Sheet piling has the benefit of good structural integrity with a proven lifespan and can retain vertical banks. Concrete bagwork, similarly, has a proven lifespan and can be used in conjunction with near vertical bank faces. However, both these offer little benefit to wildlife in terms of habitat value and do not address landscape or aesthetic issues.

At Clifton lock cut the old concrete bagwork revetment was beginning to disintegrate and allow wash-out of the unprotected bank back towards the towpath. The reinstatement was initially to be sheet piling which would be visible above water level, continuing the existing run of high sheet piling and bagwork that protects the lock.

As an alternative, a more visually acceptable solution was proposed which would add habitat value to the reach. This design incorporated the structural integrity of sheet piling (to

Failed section of bagwork at Clifton Lock Cut

Initial sheet piling after bagwork removal, over existing trees

allow continued maintenance dredging) with an above-water 'soft' approach promoting vegetation growth. The sheet piling was carried out using a land based crane with floating pontoon to support the piling frame, thus reducing the degree of trimming and removal of existing bankside vegetation.

Design

The three vertical zones referred to in previous revetment techniques are considered below:

Below water
The old bagwork was removed to be used as backfill. To ensure stability at the toe of the bank, short sections of sheet piling were driven to below water level. The piling was capped with an inverted steel channel section with mesh welded to the top to prevent movement of the above two courses of new bagwork, ending just below 'standard head' water level (*see Figure 4.7.3*).

Water's edge
The sheet piling and bagwork was backfilled with the old bagwork and dredgings from the channel, then capped with a pre-planted (pond sedge, reed canary-grass and iris) coir fibre roll. The dredgings were stockpiled and allowed to de-water before being used as backfill.

2 layer capping bagwork and tie-in to existing sheet piling

Revetting and Supporting River Banks

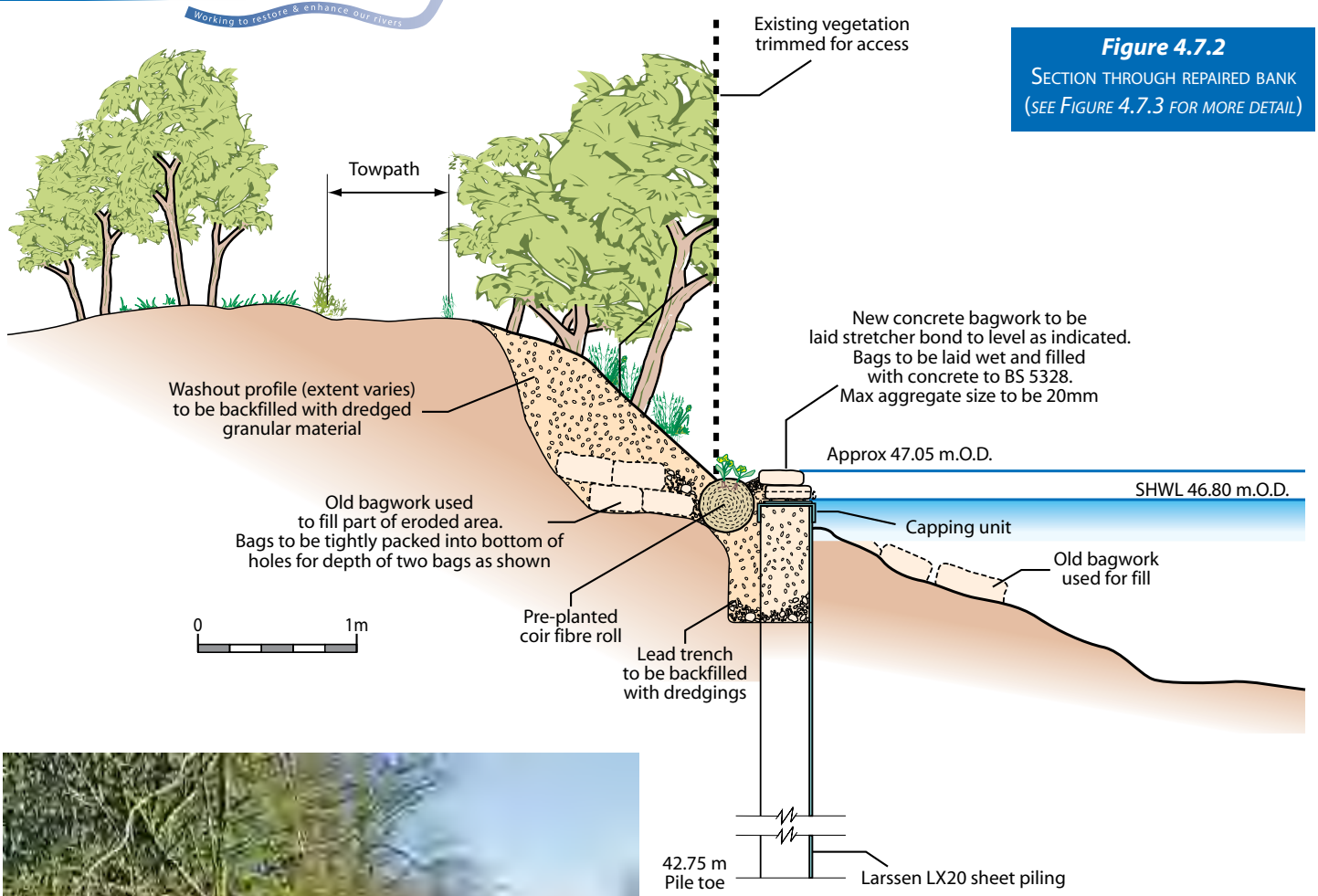


Figure 4.7.2
SECTION THROUGH REPAIRED BANK
(*SEE FIGURE 4.7.3 FOR MORE DETAIL*)

Flax mat secured, planted coir rolls installed and voids backfilled

The roll provides both retention of the backfill, preventing wash-out, and a medium for reedy marginal vegetation establishment. The vegetation, when established, provides an effective natural defence against boatwash, habitat for bankside wildlife and is visually more pleasing.

In addition, 0.05m diameter UPVC 'mammal' pipes were incorporated between the lower level bagwork at 1.5m intervals.

Upper bank
The upper slope was formed from imported topsoil and covered with a biodegradable fibre mat to protect and retain the sloping surface. The mat was used along most of the reach, a necessity due to the timing of the works with little opportunity of vegetation establishment before high winter flows. The matting was pinned to the slope using wooden pegs, rising to the retained shrubline. The bank was not seeded to allow natural re-vegetation.

Transition from the existing high sheet piling and bagwork wall is achieved by stepping down the bagwork to tie into the new 2 layer system. At the upstream end the return piling runs 1.2m into the bank.

Revetting and Supporting River Banks

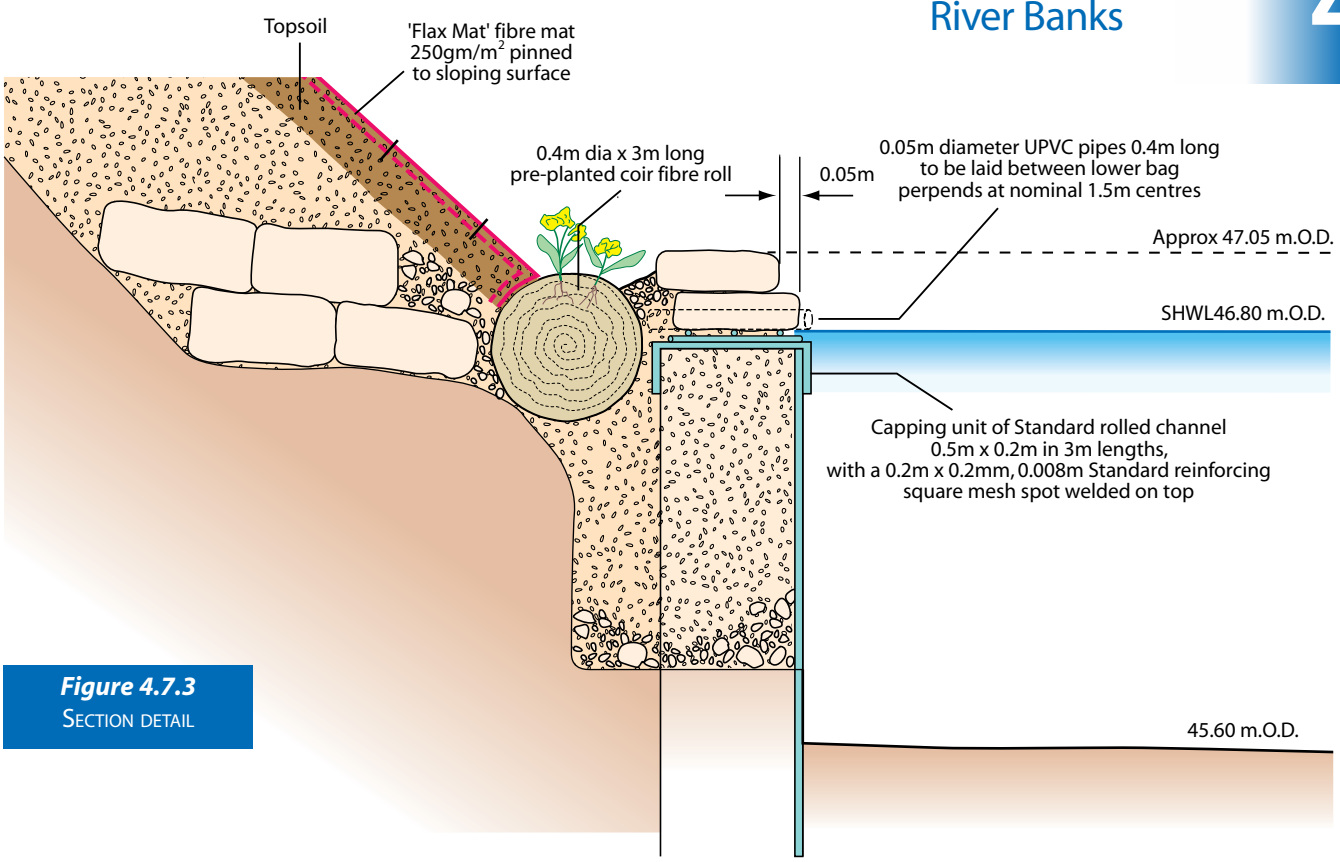


Figure 4.7.3
SECTION DETAIL

Vegetation establishment after 18 months

Subsequent performance 1995 – 2001

The revetted bank showed no signs of erosion and appears quite 'natural'. The emergent species planted in the reed rolls have established well, forming a dense marginal fringe.

The fibre matting protected the slope well and has since almost completely degraded allowing re-vegetation of the upper slope. In areas this has taken a number of years, possibly due to the steepness of some sections and a dry summer after completion. The growing root system of the retained shrubby vegetation helped to bind the backfilled bank and provide extra stability.

Some minor tree maintenance has been carried out along the towpath where it has begun to restrict access to, and views of, the river. In-channel dredging work (removal of displaced material) has also been undertaken since completion, with no adverse impact to the bank.

Original Information Providers:
Lesley Sproat,
Martin Luker.

4

Revetting and Supporting River Banks

4.7 River Thames 2013 Update

The introduced bagwork has settled (soil and silt has solidified) and is standing up well to wash caused by passing boats. Where there is sufficient light there is good vegetation growth and numerous plant species have successfully established. However, in some areas lack of maintenance means riparian vegetation has overgrown, restricting some views of the river from the towpath. The minor tree work carried out along the towpath has since ceased and it is suggested that the scheme may have benefited from a tailored tree maintenance schedule.

This technique has been recommended by the Environment Agency for use along the River Thames and similar managed navigation systems.

River Thames	Medium energy, clay
WFD Mitigation measure	Preserve and, where possible, restore historic aquatic habitats
Waterbody ID	GB106039030334
Designation	None
Project specific monitoring	None

Vegetation growth has established and the bagwork has remained intact – August 2013

Contacts

Lesley Sproat, Environment Agency
lesley.sproat@environment-agency.gov.uk, 08708 506506

4

Revetting and Supporting River Banks

4.8 Bankprotection using root wads

RIVER DULAIS

LOCATION – RHOSMAEN, LLANDEILO, CARMARTHENSHIRE SN645243

DATE OF CONSTRUCTION – MARCH 2004

LENGTH – 80m

COST – £18,000

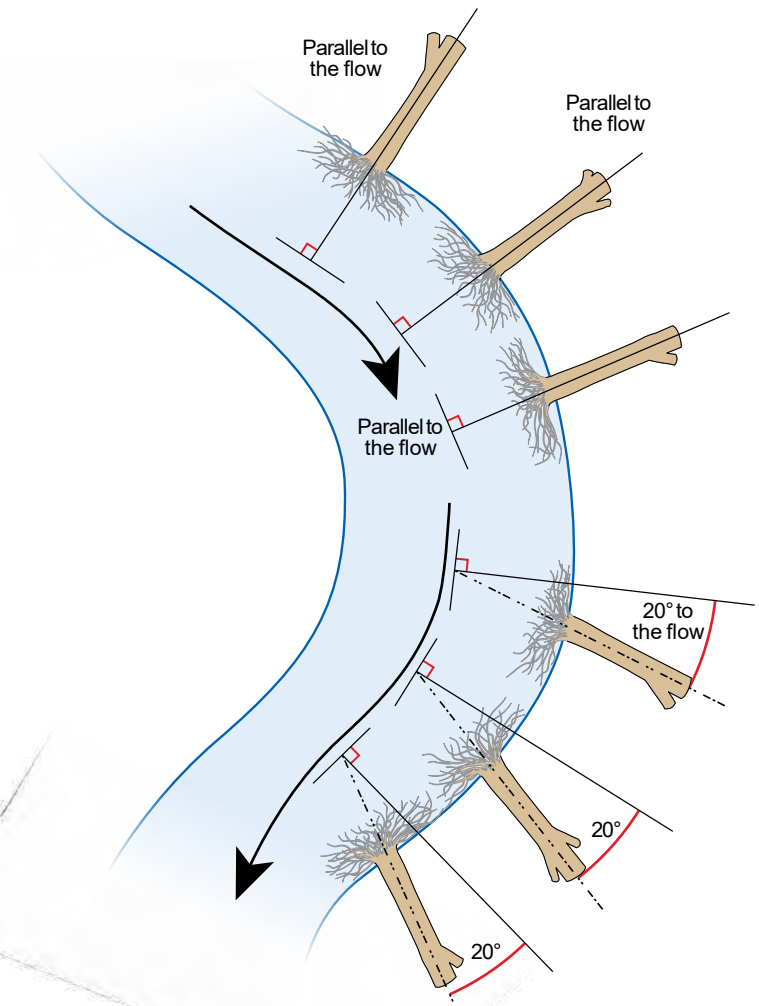
River Dulais	High energy, gravel
WFD Mitigation measure	Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Waterbody ID	GB110060036250
Designation	SAC, SSSI
Project specific monitoring	Fish

Description

The River Dulais (Afon Dulais) is a tributary of the River Towy, and is an important spawning habitat for migratory fish. The river had a history of instability and planform adjustment, with a channel crosssection up to fifty per cent wider at this location than upstream reaches. Unrestricted grazing, by sheep and cattle, had resulted in a loss of bankside vegetation. This had reduced cover for fish and increased erosion, causing bank and bed instability. Coarse gravels were covered with a layer of fine silt deposits. For a period of three years the Environment Agency Wales (now Natural Resources Wales) worked with local landowners to fence off 4.9 km of the River Dulais to combat erosion. However, some sections were in need of more extensive bank protection in order to prevent further bank failure and allow vegetation to recover naturally.

This technique was designed to stabilise a highly mobile reach on the River Dulais using root wad revetment. It intended to demonstrate that soft engineering methods can be used as an alternative to blockstone, whilst also restoring physical habitat to degraded channels and maintaining geomorphological processes.

Figure 4.8.1
PLAN SHOWING POSITION OF ROOT WADS



© Salix

Growth of root wads along bank two years after installation. Brushwood protection can just be seen between root wad growth – 2006

These techniques were developed to suit site specific criteria and may not apply to other locations

Design

1

© Salix Trench excavated in bank – 2004

2

© Salix Excavator moving root wad into position – 2004

3

© Salix Installing root wad in bank – 2004

Forty root wads were installed over eighty metres of bank, with two to three metres of trunk left attached to the root wad. Crack willow (*Salix fragilis*), grey willow (*Salix cinerea*) and white willow (*Salix alba*) with an average trunk diameter of between 0.3m and 0.6m were used. Live willow was chosen as each tree should root and shoot to quickly bind the surrounding bank. All trees were sourced from within the Dulais catchment and two adjacent river valleys.

In some areas additional brushwood protection was needed in between the root wads. Careful thought was given to creating a smooth profile along the bank to reduce the risk of erosion. The riverbank above each root wad was protected by erosion control matting.

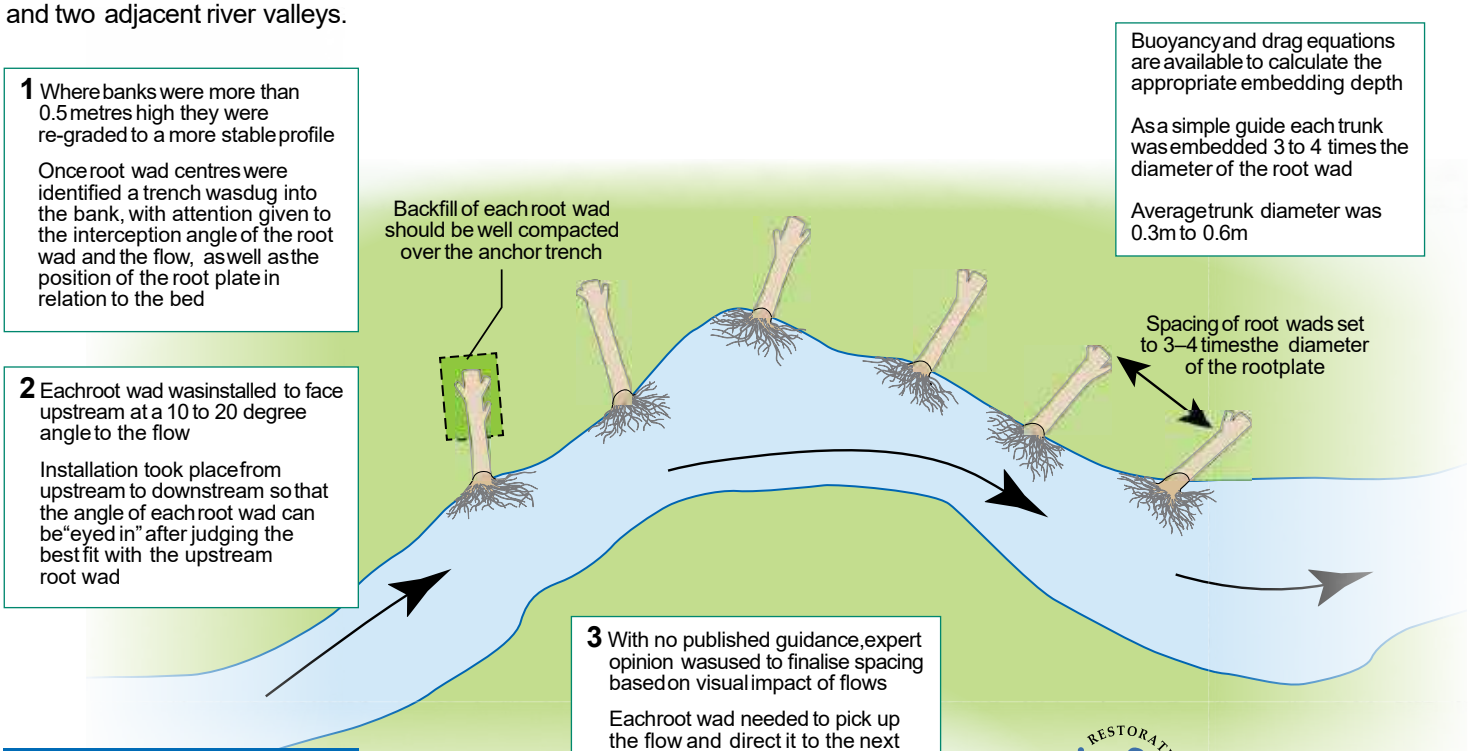


Figure 4.8.2
PLANFORM SHOWING INSTALLATION METHOD FOR ROOT WADS

Revetting and Supporting River Banks

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Rootwads immediately after installation looking downstream – March 2004

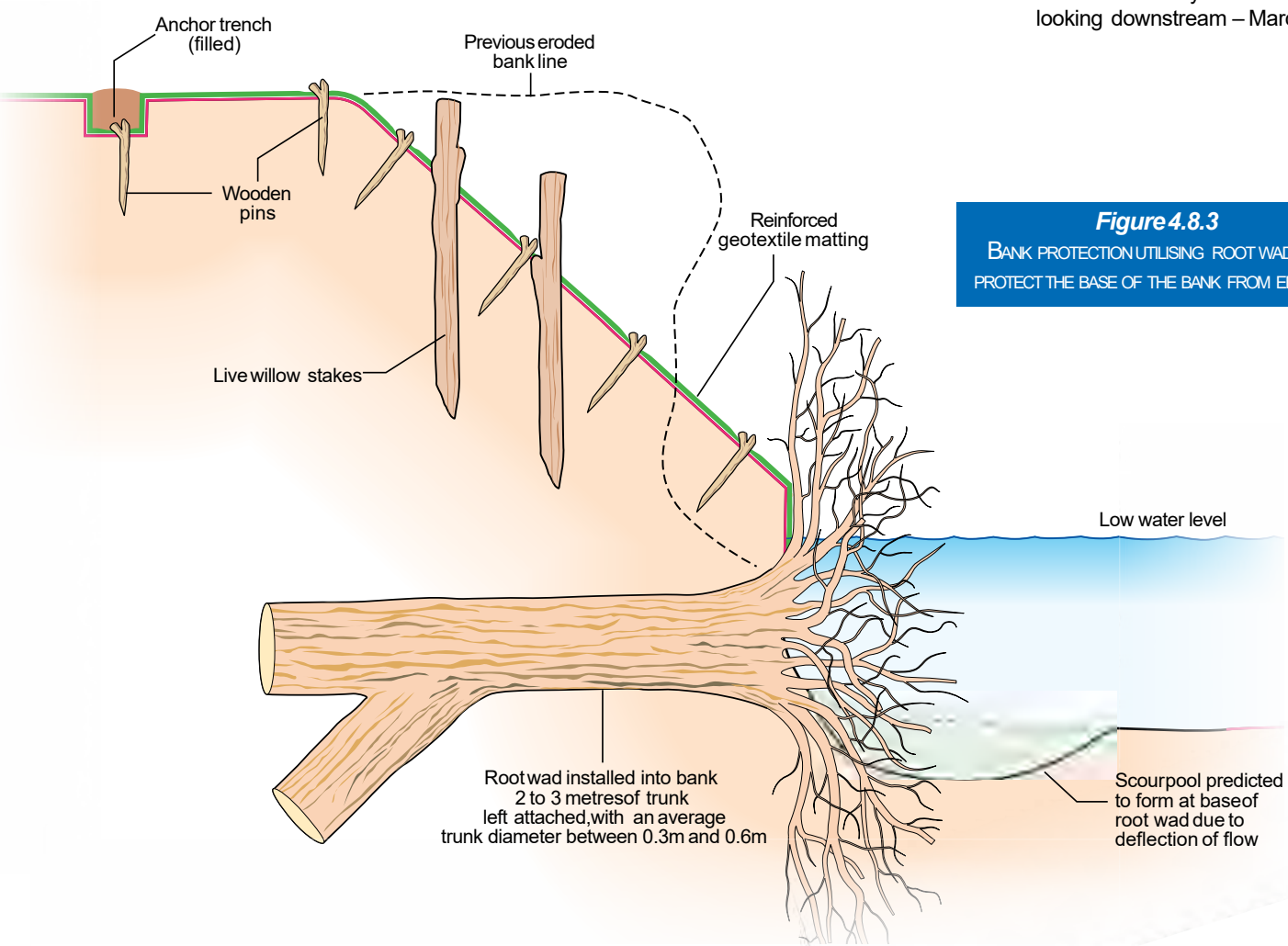

Figure 4.8.3
BANK PROTECTION UTILISING ROOT WADS TO PROTECT THE BASE OF THE BANK FROM EROSION

Subsequent performance

Stabilisation of a complex outer meander bend has been achieved and each of the root wads installed has grown well.

Monitoring encompassed HABSCORE and electro-fishing surveys, which were undertaken by the Environment Agency Wales just after construction in 2004 and again in 2006. Three sites were surveyed within the project reach, and a further three upstream to act as controls. At each site two semi-quantitative and one quantitative electro fishing surveys were carried out to determine population estimates for Atlantic salmon (*Salmo salar*) and brown trout (*Salmotrutta*) fry and parr.

No marked differences were observed in fish densities between the two survey occasions, with some sites showing a reduction in fish numbers. However, it should be noted that the post-scheme surveys were undertaken just one year after the works and the full benefits are not likely to be realised until several years after implementation.

Where flow is focussed directly at the root wads, an area of localised scour has formed under the base of the exposed root ball. This provides an overhanging vegetated bank, which is a valuable new habitat feature.

Diverse bankside cover has established and cleaner gravels are present, with visibly less fine sediment. Overall the channel geometry is now similar to more well vegetated reaches of the river.

Due to its rural and over-wide location, maintenance of flow conveyance was not deemed to be an issue. Even with the very fast growth rate of willow no post-project maintenance (coppicing) was required.

© Salix

Over-wide eroding channel before restoration – 2003

© Salix

Root wads have become established, stabilising the bank and reducing erosion – August 2013

Contacts

David Holland, Salix River & Wetland Services Ltd
david@salixrw.com, 0870 3501851

Revetting and Supporting River Banks

4.9 Brushwood mattress bank stabilisation on a tidal river

RIVER ROTHER
LOCATION – SCOTSFLOAT TQ92302213
DATE OF CONSTRUCTION – 2005
LENGTH – 200m
COST – £170,000

River Rother	Low energy, clay
WFD Mitigation measure	Preserve and, where possible, restore historic aquatic habitats Removal of hard bank reinforcement/ revetment, or replacement with soft engineering solution
Waterbody ID	GB107040013670
Designation	SSSI
Project specific monitoring	Fixed point photography

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Rother embankment erosion threatening to cause a breach, prior to restoration works – 2004

Description

This tidal section of the River Rother has undergone many centuries of river management for land drainage and navigation. The channel is characterised by long stretches of deposited littoral sediments. These preferentially deposit on the inside of meander bends with resultant erosion through rotational slips on the opposite (outer) banks. In some places breaching of the flood embankment is a concern.

The aim of this project was to prevent further erosion and a subsequent breach of the flood embankment by working with natural processes to encourage deposition on the eroding bank.

Design

A traditional brushwood mattress technique more commonly used on chalk streams was specified, to trap suspended sediment during tidal exchange and so stabilize the bank.

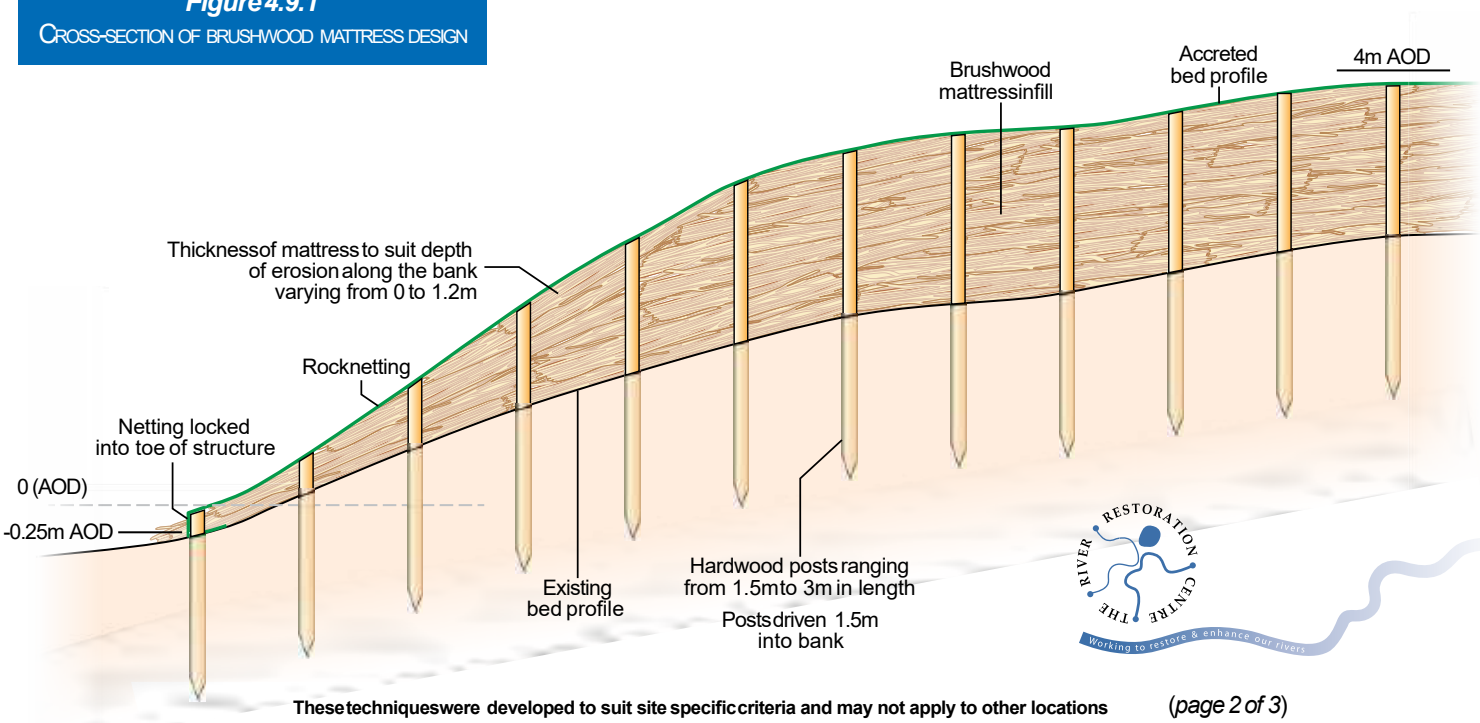
This technique can be used in estuarine environments with high sediment loads where the area is within the normal tidal range. The process of sediment deposition infills the mattress structure. Anaerobic conditions then develop which suspends decomposition of the internal woody skeleton, providing long-term integrity. There is nearby historic evidence from earlier stabilized areas that natural wood has remained intact for some 100 years.

Hardwood sweet chestnut (*Castanea sativa*) posts were used (minimum diameter of 0.125m). These ranged from 2.1m up to 4.5m in length to allow for the variation of the eroded bank profile and to ensure that at least 1.5m of each post was driven into the bank. The posts were installed in a 1m grid along a 200m section of bank, with an average width of 11m (*see Figure 4.9.1*) by a long-reach excavator. A hazel (*Corylus avellana*) brushwood mattress was then laid between the posts, using 3m to 4m long brush. Brush was installed to extend slightly beyond the last posts at the toe of the structure, to encourage sedimentation in this critical area by increasing roughness.

© Cain Bio-Engineering

Installation of a matrix of sweet chestnut posts to secure the brushwood mattress – 2005

Figure 4.9.1
CROSS-SECTION OF BRUSHWOOD MATTRESS DESIGN



These techniques were developed to suit site specific criteria and may not apply to other locations

Brushwood laid between posts to form a matrix to trap suspended sediment – 2005

© Cain Bio-Engineering

The brushwood created walkways and safe access across the site. Hexagonal galvanised rock netting (generally used on rock and chalk escarpments to prevent rock falls) was stapled to the posts across the whole surface of the structure to prevent any brushwood being lost whilst silt was depositing. Completing this as soon as possible was essential to minimise the risk of the structure failing during construction in the event of an extreme tidal event occurring before the whole structure was stabilised. The final slope of the repaired bank had a design angle averaging 40°.

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Once brushwood mattress installation is complete, rock netting is secured to the posts to prevent wash out – 2005

Subsequent performance

Fixed point photography has shown that after seven years this technique is continuing to prevent erosion, with vegetation developing well, especially at the top of the bank.

Some of the brushwood became compressed by the weight of accreted sediment, leaving the netting standing proud above the brushwood. Cutting holes in the netting around the posts would enable it to settle with the compressed brushwood.

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Section of bank post-restoration showing successful accretion of sediments across most of the structure, with some netting still exposed – 2005

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Seven years post-restoration the structure has continued to retain sediments and has been stabilised further by vegetation on the upper bank – June 2012

Contacts

Simon Cain, Cain Bio-Engineering
info@cainbioengineering.co.uk, 01725 467003