THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

INTRODUCTION TO THE MANUAL

For the Web

The first edition of the manual was dedicated to the techniques that were utilised in restoring the rivers Cole and Skerne in the autumn of 1995. It was RRC's intention that the manual would be regularly expanded to include additional techniques drawn from other notable projects, particularly those that feature different types of rivers, e.g. in upland areas.

The first of these 'updates' is included within this web version. These additional 20 techniques, taken from 15 different projects, begin to increase the range of river types covered by the Manual.

The techniques are presented in 11 separate parts of the manual, each part encompassing a significant activity, or objective, that may typically be included in a restoration project brief, e.g. Part 4: Revetting and supporting river banks.

Each Part comprises examples of techniques that may be useful in achieving the specific objectives, e.g. Technique 4.1: Spiling revetment.

Experience has shown that river restoration projects are most successful if a clear set of aims and priorities are established at the outset, and that one of the first outputs is a vision plan for the future prepared without undue regard to constraints of funding, etc. The plan may then be scaled down to suit what is achievable in the short term, in the knowledge that initial works can safely be followed up later to achieve the full potential of the site.

Recognising what the full potential of any site may be is far from straightforward. It demands much practical experience, knowledge and sound judgement which few can rightly claim to possess because river restoration is only recently being practised on a significant scale. In these circumstances, the sharing of knowledge and experience is of particular importance and will remain so for some years to come.

RRC hope that the manual will assist practitioners to gain an understanding of what has gone before them so that each new project benefits from ideas that may be incorporated and improved upon. Inspiration for new ideas may also occur, thereby furthering the practical knowledge available.

The importance of river restoration projects should not overshadow the countless opportunities to incorporate its principles in almost any river management activity. Several techniques featured are equally appropriate to small-scale operations such as creating a ford (Part 8) or creating an outfall to a river (Part 9). Equally, the principles of river restoration may contribute much to major flood defence projects so that environmental benefit compliments improved protection.

Readers are encouraged to register their interest in receiving updated and additional entries to the manual by contacting RRC. Similarly, readers are encouraged to contact RRC if they wish to contribute any new technique to future editions. Full contact details for RRC can be found at www.the RRC.co.uk.

the River Restoration Centre
Working to restore and enhance our rivers
www.therrc.co.uk

Manual of River Restoration Techniques

The manual of River Restoration Techniques is presented in PDF (Adobe Portable Document Format), a FREE viewer can be downloaded from the Adobe website, simply click here

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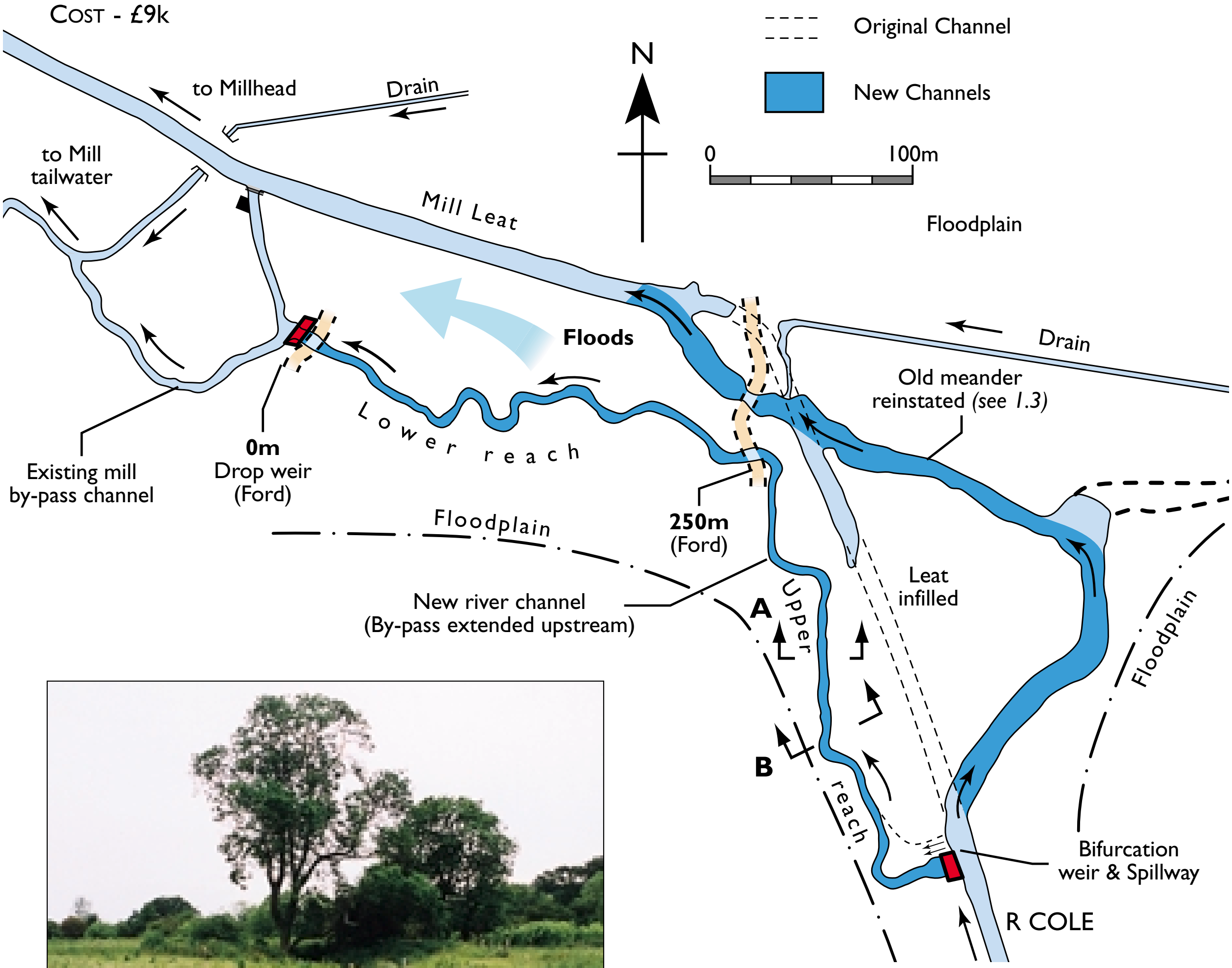
RESTORING MEANDERS TO STRAIGHTENED RIVERS

1.1 New meandering channel through open fields

RIVER COLE

LOCATION - Coleshill, (Oxon/Wilts border) SU 234935
DATE OF CONSTRUCTION - Autumn 1995
LENGTH – 500m
COST - £9k

Figure 1.1.1
PLAN OF UPSTREAM OF MILL



Lower reach in Summer – *August 1997*

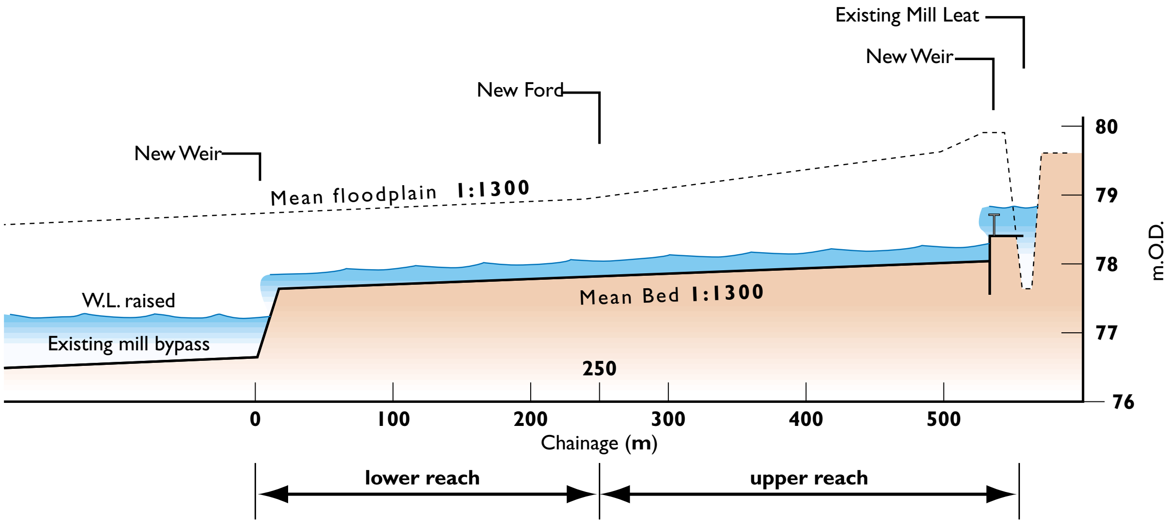
DESCRIPTION

A new river course was created to introduce a reach of free flowing water to a floodplain that hither to featured only a slow flowing mill leat. An exisiting mill by-pass channel remained in operation and was incorporated into the new design by extending it as far upstream as practical to create the additional meandering channel that was required. The River Cole is now diverted from the leat to flow in the new channel, which is small in size, to ensure seasonal inundation of the adjacent floodplain.

DESIGN

Longitudinal profile (fig. 1.1.2)
The new mean bed gradient was set at 1:1300 to match the mean floodplain gradient. The bed elevation was set to give the shallowest channel

Figure 1.1.2
LONGITUDINAL PROFILE



possible whilst having just sufficient depth to contain summer spates. The resultant channel bed is elevated higher than the old mill by-pass, but is lower than the retained water level in the mill leat which feeds it. Drop weirs were therefore required at each end *(see 5.1 and 5.2).*

Whilst weirs are generally undesirable, the alternative of deeper channels was more so at this site. The drop at the downstream end was reduced in height as a consequence of introducing new meanders downstream of the mill; these raised normal water level in the existing mill by-pass to historic levels (*see 1.2*).

Alignment of channel (fig. 1.1.1)
The existing mill by-pass follows an ancient course of the River Cole. Remnants of its ancient course were

Upper reach at time of excavation – *October 1995*

Upper reach – *1998*

also evident in the fields between chainage zero and 250m, (lower reach), so the new channel was set to follow these at a fairly uniform depth of c. 1m. Upstream of ch. 250m the new channel deviates from any natural course because it had to be aligned roughly parallel to the mill leat which is unnaturally close to the edge of the floodplain. Land levels along this upper reach rise significantly above the average for the floodplain, hence the new channel is deeper. Meanders were set out to 'mimic' the natural form evident in the lower reach.

Cross-sections (figs. 1.1.3 – 1.1.4)
Section A shows a normal flow channel 2.6m wide by 0.8m deep - the geomorphology of the Cole indicates this to be the ideal size of channel. Because overall channel depth needed to exceed 0.8m *(fig. 1.1.2)*. The upper banks were graded back as flat as practical.

Section B shows a compatible asymmetrical profile introduced at each significant bend. The deepest bed level is cut below the mean bed gradient to introduce pools. The 1:1 batters on the outside of the bend were expected to steepen through natural channel adjustment.

Profiles on inside of meanders
Land levels were lowered to a depth of 0.8m above mean bed as shown on Section B. As all meanders are small in amplitude, no further shaping was undertaken; profiles were simply rounded off to give smooth transitions into Section A either side.
The profile was later modified *(see below)*.

Figure 1.1.3
SECTION A THROUGH SYMMETRICAL CHANNEL

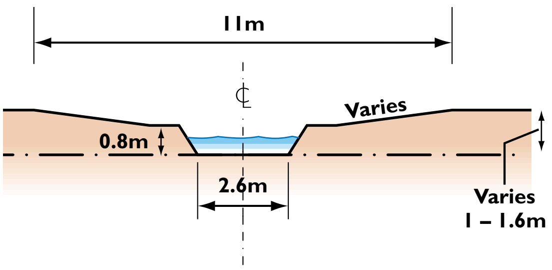
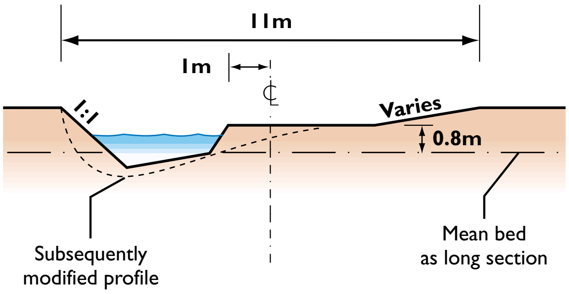


Figure 1.1.4
SECTION B THROUGH ASYMMETRICAL CHANNEL



SUBSEQUENT PERFORMANCE (1995/8)

The upper reach of the channel developed an intermittent bed substrate of gravel as well as small riffles of gravel below each meander. Limited supplies of gravel are derived from the clays exposed towards the bottom of the channel; none are carried down from the upper catchment. Additional gravels were imported to this reach one year after construction and 'seeded' into each pool for distribution by flood currents.

In the lower reach, where the new channel is less deep, gravels are less evident throughout. The drop weir at the lower end draws water noticeable faster as it approaches it. Downstream of this structure, the old by-pass channel has attracted substantial deposits of gravel, sand and silt derived from the new channel. These deposits are well sorted and have partially restored bed levels/profiles in the by-pass to historic levels, recreating variable flow depths.

The stiff clays in the river banks resisted erosion preventing cliffs from forming on the outside of meander bends where 1:1 batters were cut. Conversely, floodwaters were racing across the flat areas formed on the inside of each meander causing scour of the surfaces. The asymmetrical profiles were subsequently re-excavated as indicated on Section B.

Since these modifications the channel has performed satisfactorily in all respects; a good range of flow currents, substrates and bank forms are sustained throughout the year.

No planting, or seeding of the channel was undertaken. Natural colonisation is occurring slowly. The channel is unfenced allowing cattle access at low density under Countryside Stewardship prescriptions. Cattle have effectively grazed a proliferation of willow seedlings. Both aspects are being monitored.

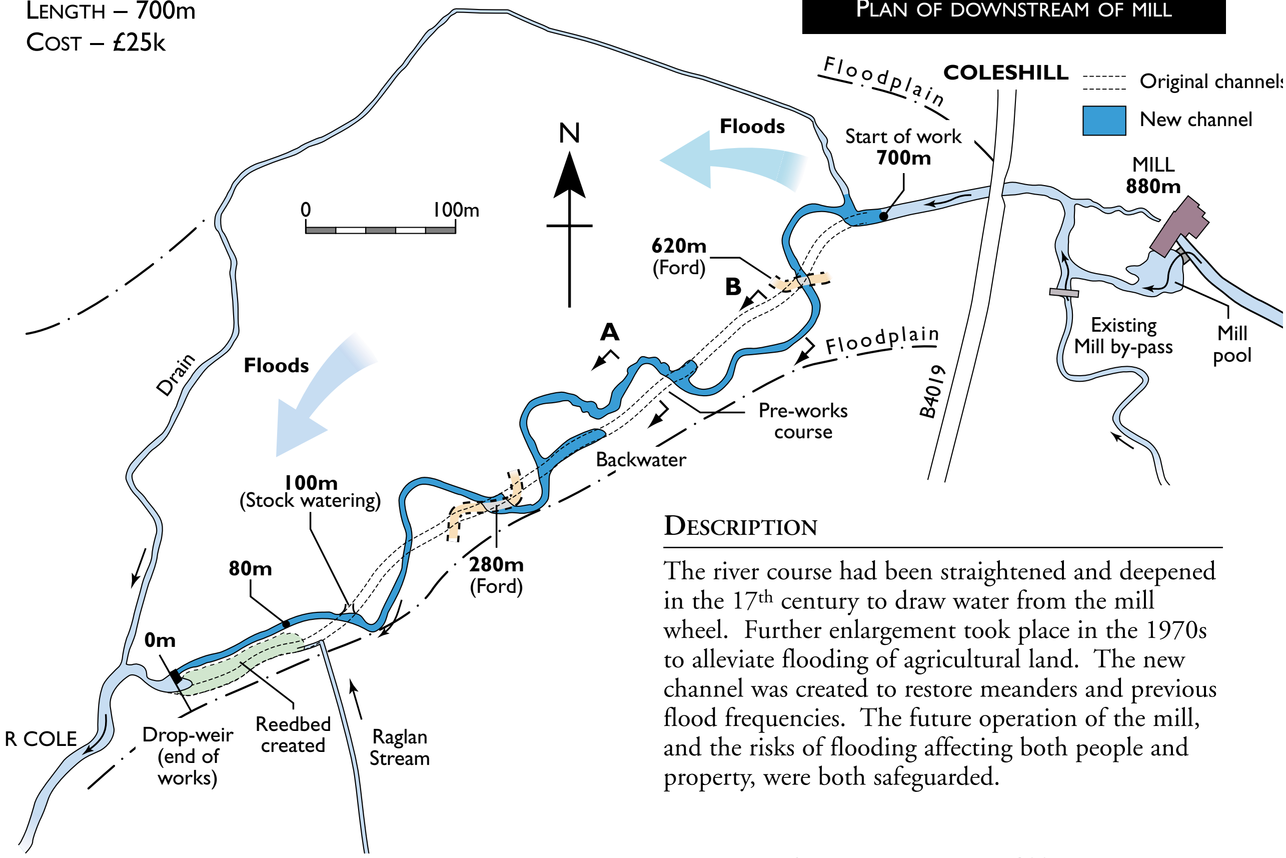
The new meandering river course and the restored meander in the mill leat *(see 1.3) – July 1997*
Photo: Environment Agency

1.2 New channel meandering either side of existing

RIVER COLE

LOCATION - Coleshill, (Oxon/Wilts border) SU 234935
DATE OF CONSTRUCTION - Autumn 1995
LENGTH – 700m
COST – £25k

Figure 1.2.1
PLAN OF DOWNSTREAM OF MILL

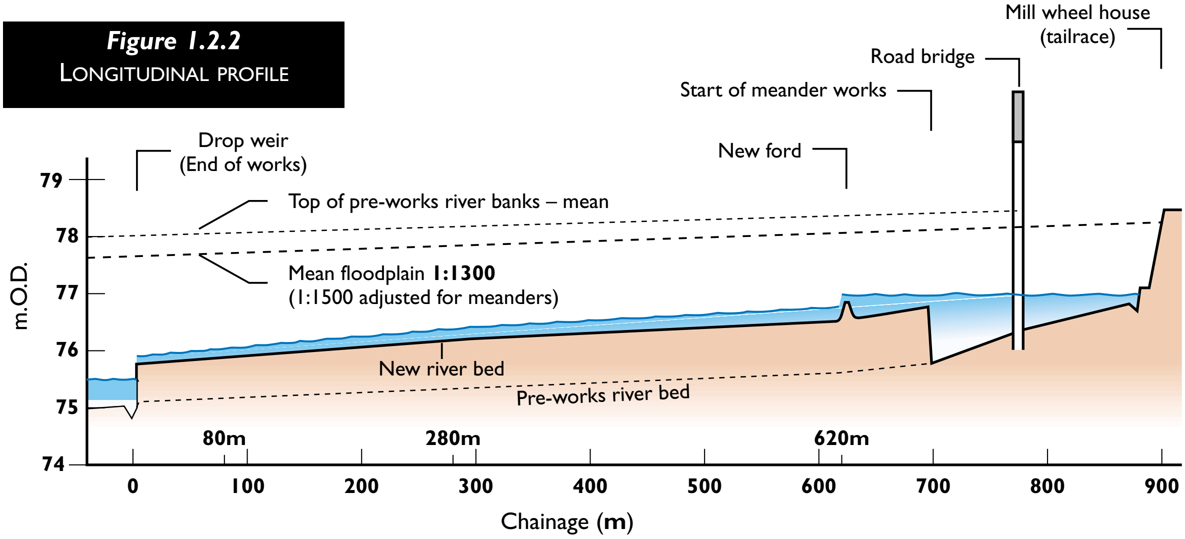


DESCRIPTION

The river course had been straightened and deepened in the 17th century to draw water from the mill wheel. Further enlargement took place in the 1970s to alleviate flooding of agricultural land. The new channel was created to restore meanders and previous flood frequencies. The future operation of the mill, and the risks of flooding affecting both people and property, were both safeguarded.

Aerial view of new meanders – *July 1996*
Photo: Environment Agency

Figure 1.2.2
LONGITUDINAL PROFILE



DESIGN

Longitudinal profile (fig. 1.2.2)
The elevation of the new river bed was raised by up to 1.0m, the maximum possible that still enabled water to flow freely from the old mill wheel tailrace. The bed gradient would ideally have paralleled that of the mean floodplain gradient (1:1300 straight; 1:1500 meandered) but was steepened to reduce the height of the drop structure needed at the downstream end of the reach. The actual bed gradients constructed are: chainage 0-280m at 1:740; 280-620m at 1:1000; 620-700m at 1:460; these equate to a mean of 1:700.

The raised bed enabled impoundment of water upstream of the works, restoring historic levels in the mill pool and the mill by-pass. A stone ford was built at ch. 620m to safeguard water levels against any downward scour of the new bed.

Channel before works – *1994*

New channel flowing into existing channel during construction – *September 1995*

Meanders during construction – *1995*

Alignment of channel (fig. 1.2.1)
Practical influences on the meander layout were the desire to retain several mature willows on the new river banks, and to maintain a sensible balance of land areas lost/gained either side of the old straight course. A geomorphological audit of the river, including a study of meander form evident in the downstream reach, finalised the layout. The relatively straight reach between ch. 0 and 80m avoided disturbing a fritillary meadow alongside and facilitated a riverside reedbed downstream of the Raglan Stream junction *(see Part 9)*. At ch. 280m the meander deliberately cut into rising ground just off the floodplain to provide a local cliff face c. 2.5m high.

Cross-section (figs. 1.2.3 – 1.2.4)
Section A shows a normal flow channel 2.6m wide by 0.8m deep. The geomorphological audit of the Cole indicates this to be the ideal size of channel. Because actual channel depths were greater than 0.8m, the upper banks were graded back at shallow profiles.

Section B shows a compatible asymmetrical section introduced at each bend. The deepest bed level is below the mean bed gradient to ensure that pools are sustained.

Land profiles between meanders
These were all lowered by c. 0.4m to levels that approximated to the mean floodplain levels (*fig. 1.2.2)*.

Figure 1.2.3
SECTION A THROUGH SYMMETRICAL CHANNEL

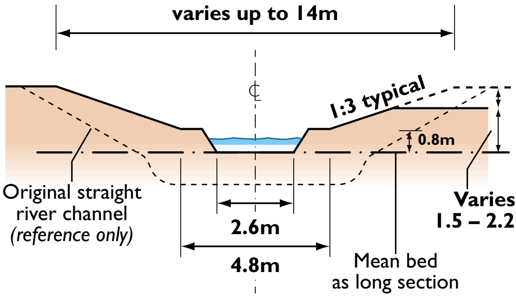
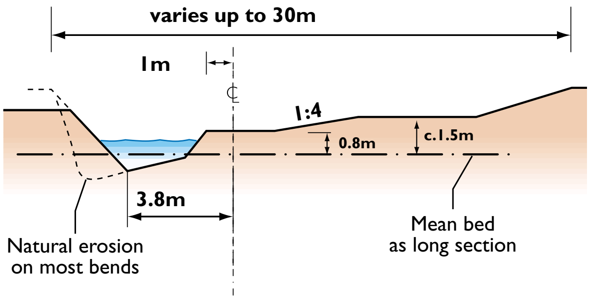


Figure 1.2.4
SECTION B THROUGH ASYMMETRICAL CHANNEL



This necessitated the removal of spoil deposited on the old river banks from the 1970s deepening works. The conveyance of flood flows across the meanders proved to be important in achieving the necessary hydraulic safeguards during 1 in 100 year flood conditions.

The old straight channel located within these areas was largely backfilled, although not completely (*see Parts 2 and 8* for details of backwaters, fords, stock watering points, etc that were incorporated).

SUBSEQUENT PERFORMANCE 1995/8

Spates of floodwater immediately following completion of the new channel led to rapid and extensive reshaping of the channel. Cliffs were eroded, pools were scoured and gravel riffles and sandy shoals deposited, all creating desirable natural features within the reach. Excess sediments built up immediately downstream of the works, helping to restore a further reach of the original over-deep channel. Since these initial adjustments, subsequent spates have satisfactorily sustained the regime described but at a much lower rate of change. Intervention has been limited to further flattening of the profile of the inside of the south side bend at ch. 280m. The river is largely unvegetated after two summers, although marginal vegetation is becoming established. A wide range of soil types are exposed in the channel and these account for the diversity of features that are now evident.

Diverse new channel – Two years after construction. – *March 1997*

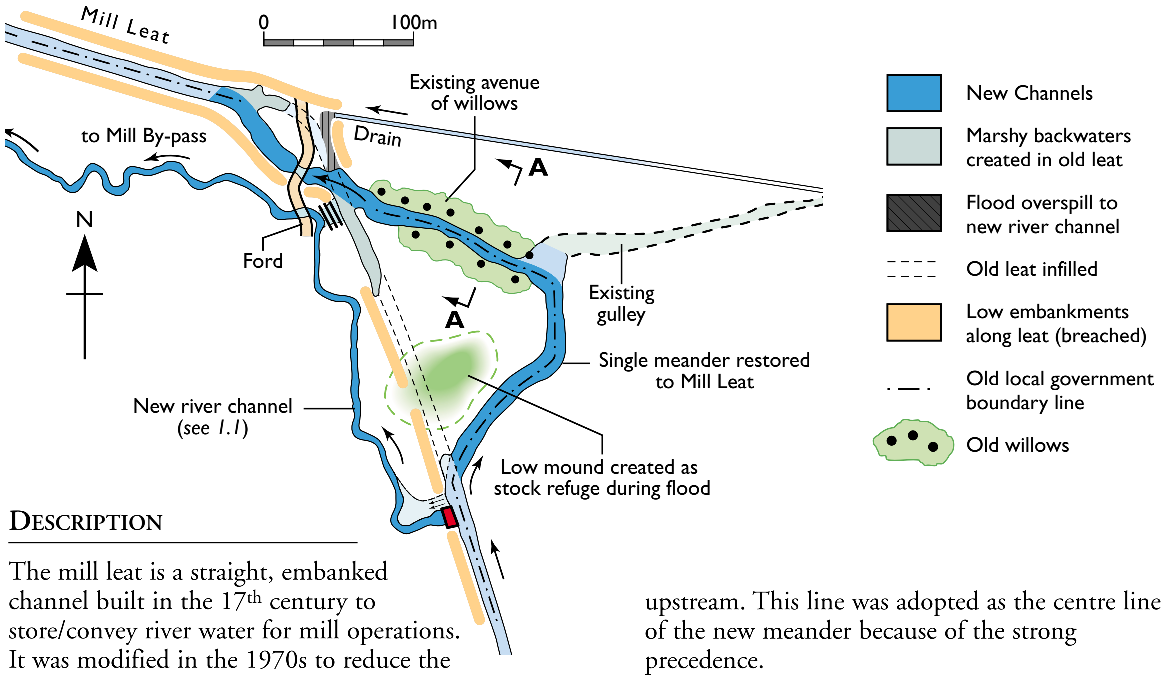
Natural cliff formation post works – *March 1997*

1.3 New meander in an impounded river channel

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1996
LENGTH – 300m
COST – £9k

Figure 1.3.1
PLAN OF MILL LEAT AND NEW MEANDER



DESCRIPTION

The mill leat is a straight, embanked channel built in the 17th century to store/convey river water for mill operations. It was modified in the 1970s to reduce the risk of flooding adjacent land. As part of the River Cole restoration project most of the river flow now by-passes the mill (and the leat) in a new meandering channel *(see 1.1)*. The leat was subsequently enhanced by restoring a single meander to its course.

DESIGN

Longitudinal profile
The existing river bed levels were retained throughout the new meander in order to maintain the historic depths of impounded water. Normal water levels were raised by c. 300mm to achieve this, involving replacing/repairing sluices at the mill in accordance with archived drawings retained by the owner, the National Trust. No embankments were reinstated on the new meander; water is free to spill into adjacent fields consistent with the overall river restoration objectives for this site.

Alignment (fig. 1.3.1)
The pre-existence of the meander was evident in two ways. A shallow, muddy depression between a short avenue of old willow pollards, branching off the leat, delineated part of an old river channel. A study of old maps indicated that an historic local government boundary line passes between the willows, continuing in a clear meander line that rejoined the leat further upstream. This line was adopted as the centre line of the new meander because of the strong precedence.

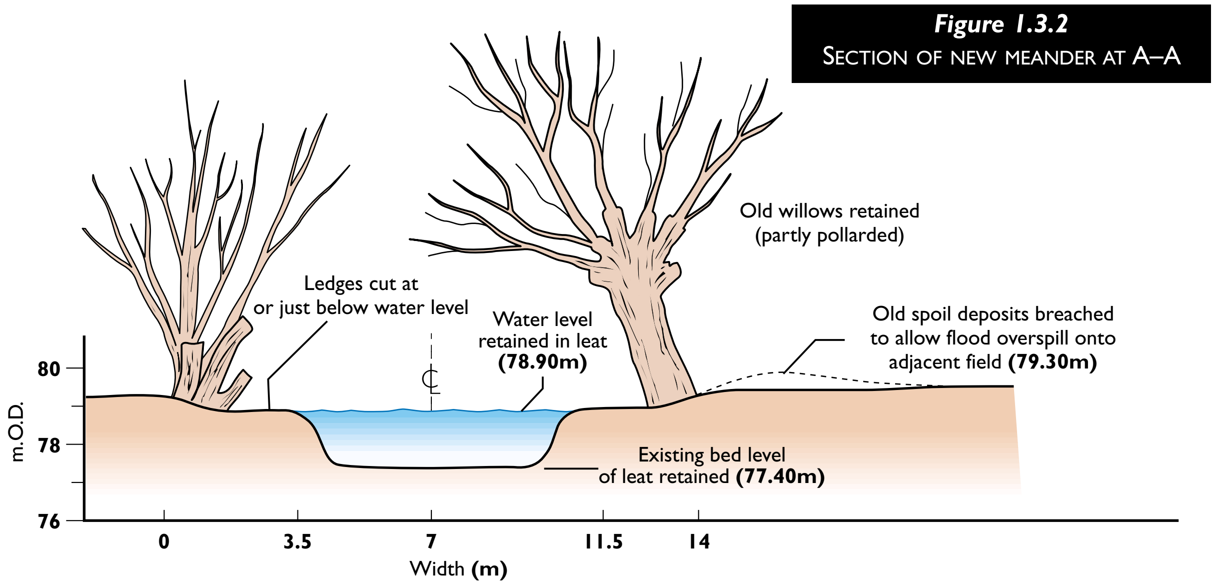
Cross-section (fig. 1.3.2)
The width of channel between bank tops was selected to retain the willows. The resulting dimensions closely matched the top width of the remaining mill leat, so was confirmed as suitable. The existing leat cross-section displayed wide ledges at, or about, normal water level that were cattle trodden either side of a deep, relatively clear, central channel. The new cross-section mirrors this configuration.

Profiles within the meander
The way in which flooding of surrounding land had been designed to occur makes livestock escape or rescue difficult. In mitigation, land levels within the new meander were raised locally in a gentle mound creating a refuge in times of flood.

SUBSEQUENT PERFORMANCE 1996/98

The new meander is visually striking between the willows; swans nested on the spit of land between the new and old channel where a quiet backwater has been created. Sheep are seen to favour the mound, being the 'highest and driest' ground in the area regardless of flooding. Marginal plants are satisfactorily establishing on the ledges each side of the newly created channel.

Figure 1.3.2
SECTION OF NEW MEANDER AT A–A



Remnant of meander – pre-works – January *1996*
(shallow water held temporarily after heavy rain/flooding).

Re-excavated meander – Autumn *1997*

1.4 New meanders to one side of existing channel

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – Autumn 1995 to Spring 1996
LENGTH – 500 m
COST – £40k

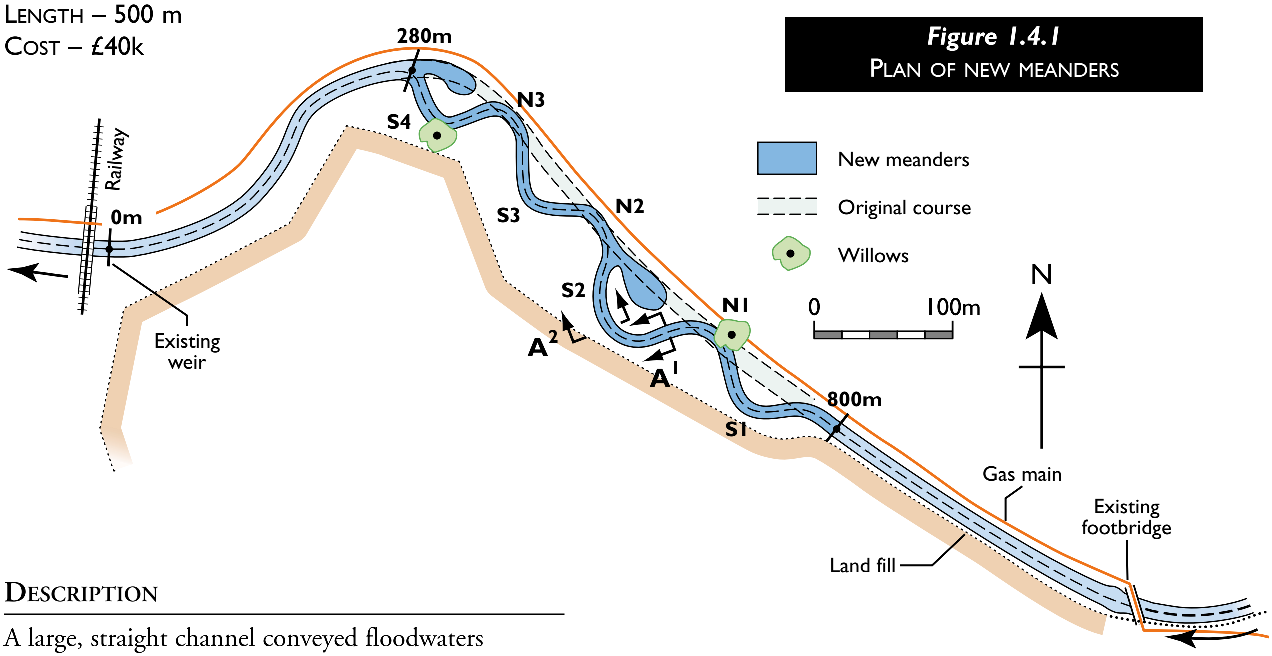


Figure 1.4.1
PLAN OF NEW MEANDERS

DESCRIPTION

A large, straight channel conveyed floodwaters through a reach of grassed public open space that was bordered by housing and old industrial landfill. A new meandering river that partially incorporated the existing channel was created to the south side. The risk of flooding, affecting people and property, was safeguarded.

DESIGN

Longitudinal profile (fig. 1.4.2)
The original mean bed gradient of 1:1300 paralleled the mean bank gradient at a depth of c. 2.4m.

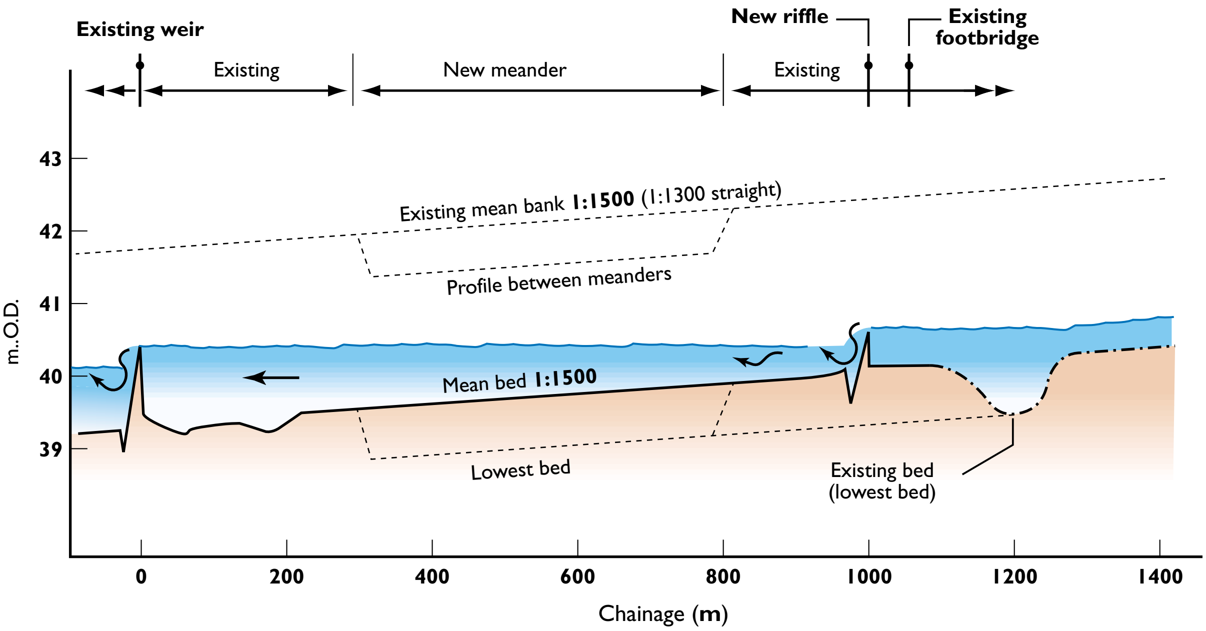
Meander excavation – Autumn *1995*
Photo: Northumbrian Water/AirFotos

The new mean bed gradient and level matches the existing but flattens to 1:1500 because of the increased length created. Bed scour around each meander was expected to reach c.1m depth as observed at an exisiting bend at ch. 1200m. This is shown as 'lowest bed' on the long section 1m below mean bed. Conveyance of floodwaters across the new meanders was facilitated by a general lowering of inter-meander land levels by c. 0.6m. This also enhanced water storage aspects of the 1 in 100 year flood hydrograph, attenuating the peak flow downstream.

Normal water levels in the reach are controlled by an existing weir at ch. 0m, but the effect of this diminished at ch. 900m where the original straight channel was retained and enhanced. Enhancements included an artificial rock/gravel riffle at ch. 1050m shown on the long section (see *Part 3).*

Alignment of channel (fig. 1.4.1)
The lateral extent of meandering is constrained between a gas main, running closely alongside the north bank of the old course, and landfill tipped to within 10 to 50m of the south bank. Bends S4 and N1 were located to retain two mature willows on the banks. The remaining meanders are set out between and checked against geomorphological criteria to finalise the layout. High flows in this channel and

Figure 1.4.2
LONGITUDINAL PROFILE



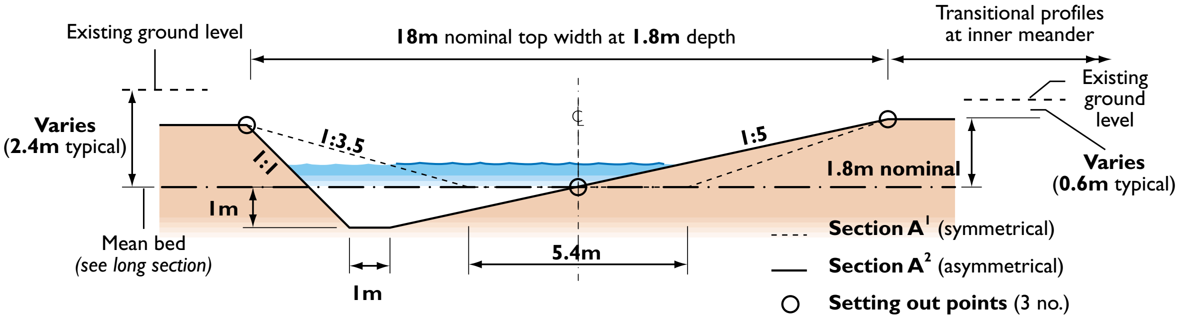
other constraints precluded any possibility of 'mirroring' historic meander patterns that were sustained by entirely different hydraulic criteria.

Cross-sections (fig. 1.4.3)
Because of continuously varying vertical depths described for the longitudinal profile, the design needed to be simplified. Two sections (symmetrical and asymmetrical) were developed based on mean depth (1.8m) and mean top width (18m). These applied to two points only on each meander - intermediate profiles required a continuous transition between them. The asymmetrical section allows for 1m of scour at each bend described above.

A variation of the pair of sections shown was developed for bends **S1** and **S4**. A horizontal ledge at normal water level was incorporated around the inside of each to simulate the effects of natural shoaling.

Profiles within meanders (see 6.2 and 2.1)
As well as the general lowering of land levels described above, considerable profiling was specified to ensure inundation in time of flood was progressive from the downstream leg back towards the start of each meander. Similarly, special consideration was needed to ensure the safe 'submergence' of backwater features prior to general overbank flow. The safety of

Figure 1.4.3
SECTION THROUGH NEW MEANDERS



people during rising floods is of particular importance at this urban location. Exceptionally, land within bend **N1** could not be significantly re-profiled as a high voltage cable passes underneath.

SUBSEQUENT PERFORMANCE 1995/8

The newly meandered channel has proved to be stable under frequently occurring flood conditions. The most vulnerable banks, located where bends are incorporated into the backfilled course, are supported by revetments (*see Part 4*), but elsewhere the indigenous clays have resisted erosion. Sands, silts and mud have deposited as shoals where eddy currents arise around the inner margins of bends and the deeper pools created around the outside appear self-sustaining. Diverse flora and fauna have rapidly colonised the many different features of the new course and local people enjoy relatively safe access to the waters edge.

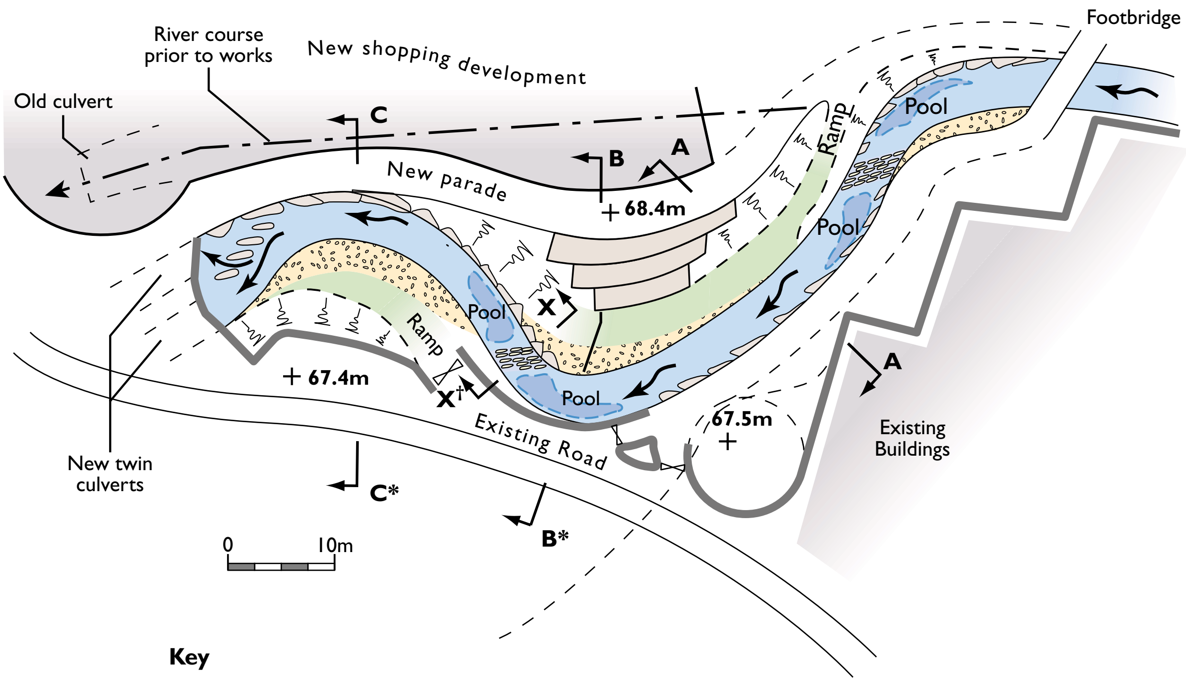
Completed meanders – Summer 1997

Looking downstream
towards large backwater
– February 1997

1.5 New meandering channel replacing concrete weirs

RIVER MARDEN

LOCATION - Town centre at Calne, Wiltshire ST 998710
DATE OF CONSTRUCTION - 1999
LENGTH – 100m
COST - not available



Key

- Flood wall **1m** high
- Gravel Shoals on inner bends
- Stone Riffles in riverbed 2 No. (*see 5.4*)
- Vanes at culvert entry
- Stone foundations to river walls or stone revetment of bank
- Hinged flood gates 3 No.
- Stepped platforms (stone) give access to shoal – (*see 8.5*)
- Grassed areas at waterside
- * *For sections '**B-B**' and '**C-C**' see 8.5*
- † *For section '**X-X**' see 5.4*

Figure 1.5.1
PLAN OF NEW MEANDERS

DESCRIPTION

A town centre factory had been demolished leaving a reach of river flowing through the site in a straight, concrete channel. The channel bed dropped vertically in two places forming weirs that barred the passage of fish and were unsightly.

Redevelopment of the site required that the river be diverted south of its existing course and that its character be improved to create an attractive public amenity. The site is prominently located in the heart of an ancient market town.

The diversion was undertaken in the form of a double meander such that natural geomorphological features including shoals, riffles and pools could be incorporated, as well as good public access to the waterside and a variety of sustainable attractive habitats for flora and fauna.

Earlier proposals to create an impounded, canal-like waterway were dropped in favour of the relatively free flowing river regime described.

DESIGN

The diversion necessitated the re-siting of the upstream part of twin box culverts that carry the river under the main road. Figure 1.5.1 shows the location of old and new culverts. The double meander route between the existing channel and the new culverts was optimised within the constraints of the existing and new buildings shown.

The gradient of the new river bed became 'fixed' between the culvert invert and the existing upstream level. Figure 1.5.2 shows the resultant longitudinal profile with a mean bed gradient of 1 in 140. This gradient is much steeper than arises naturally on this part of the river with consequent high water velocities when the river is in flood.

Hydraulic modelling indicated velocities of up to 2 metres per second and flood levels up to 80cm above adjoining roads and property. These hydraulic parameters meant that flood walls would be needed to contain the river and that erosion of the river bed and banks would need to be rigidly controlled.

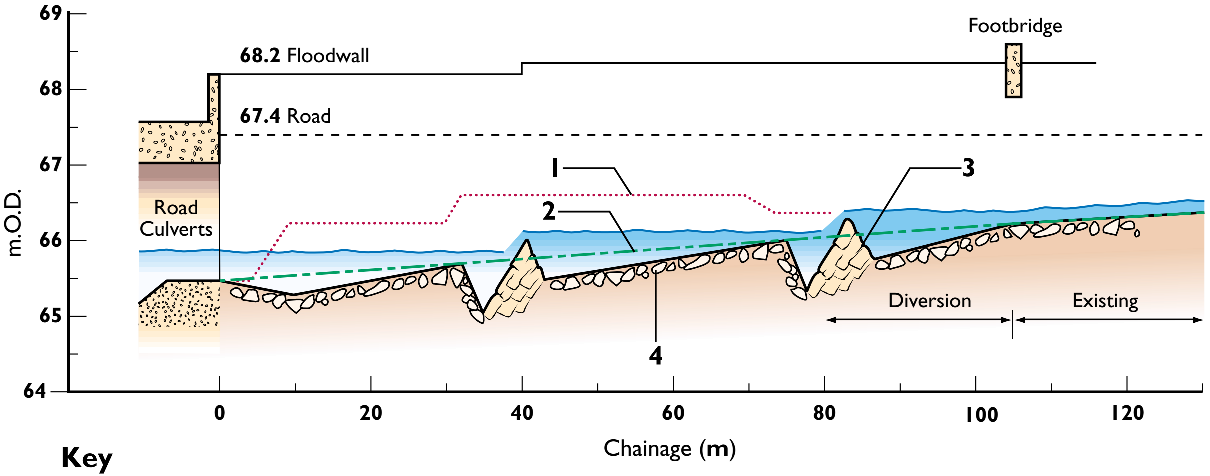
A design concept was needed that was sufficiently robust to meet these demanding hydraulic conditions but equally to meet the need for an attractive and sustainable environment.

The concept adopted was based on the premise that the gradient and alignment of the river were more typical of upland river locations where rock outcrops and gravel and cobble river bed substrates might be expected. Design of the many elements of the project began by developing a method of simulating stratified bedrock underneath the whole river diversion that would 'outcrop' to form river bank revetments, retaining wall foundations and river bed control cills.

Research was undertaken to select quarried rock that could be re-constructed on-site to simulate its natural characteristics. Purbeck Limestone from quarries at Swanage was chosen because it occurred in large, flat slabs of thickness between 10cm and 90cm. Slabs of rock could be laid securely, one above another, at consistent angles to recreate the 'dip and strike' of natural outcrops. The stone was sufficiently durable to withstand frost and could also be provided in cut building blocks for use in walls. Its colour and texture is similar to locally available Cotswold stone but its durability was much greater, an important factor in riverside locations.

The following lists the key locations where stone slabs were incorporated:

Within the foundations of all vertical riverside retaining walls
Slabs were laid at a consistent angle to project into and above the water creating the appearance of the walls being built on natural rock. Contrasting faces on opposite sides of the river were achieved by



Key

1 Original bed level – concrete channel with two drop weirs

2 New mean bed gradient at **1 in 140**

3 2 stone riffles built to stabilise river bed; pools upstream and downstream of each

4 Actual bed profile of gravel and cobble susbstrates

Figure 1.5.2
LONGITUDINAL PROFILE

Before:
View downstream
towards culvert

Completion:
View of the new
river course

maintaining the ‘dip’ in the same direction i.e. smooth dip slopes one side and jagged escarpment faces on the other. As the river alignment approaches the culverts in the same direction as the selected dip-slopes, slabs were laid with the dip parallel to the retaining wall. This enabled a series of ‘craggy’ current deflectors to be incorporated into the foot of the wall.

At the bottom of earth slopes on outer bends liable to erosion
Slabs were laid exactly as above with consistent direction of dip and strike to revet these banks with varying faces depending upon the channel alignment of each location. See section A–A, figure 1.5.3 for aspects of both wall foundations and bank revetments.

Outcrops in the riverbed to create low cills
The steepness of the river bed gradient needed to be checked by introducing two low barriers of rock to resist any tendency of the bed to scour downwards. These are shown as feature 3 on figure 1.5.2. They are located just downstream of each meander bend where underwater bars of river bed substrate e.g. gravels would naturally accumulate in the form of riffles. The stonework on adjacent walls and river

bank was linked across the bed with stone laid at the same dip slope. Technique 5.4 shows details of these. They incorporate a gently sloping downstream face, much like a riffle. This enables the easy passage of migratory fish to be achieved and creates a 'tumbling' water feature rather than a sharp fall.

Building stone in walls and for amenity surfaces
Dressed stone was used to face and cap all retaining walls and flood walls as well as the head walls on the new road culvert. These head walls were designed with curving arched soffits to give the appearance of an older stone bridge, hiding the unsightly concrete boxes that carry the water under the road. On the inner bend fronting the new development, large stone slabs were laid to create stepped platforms down to the waterside shoal (*see 8.5 for details*).

Vertical vanes in the river upstream of the new road culverts
The twin culverts create an artificially wide river channel at entry with the consequential risk of the culvert on the inside of the bend attracting excessive silt accumulations. Four upright slabs of stone were concreted into the river bed to induce a sustained flow of water towards the inner culvert without barring the natural tendency of flow towards the outer culvert. The slabs project a nominal 15cm above normal water levels and serve as 'vanes' that effectively modify the water currents at all stages of river flow, including flood flows.

All of the stone features described, effectively define a precise and stable course to the river which was essential in this tightly developed urban location. The creation of the river bed and waterside shoals was an equally important aspect of design since both had to be similarly stable as well as being able to sustain flora and fauna.

Geomorphological calculations were undertaken to determine size, shape and distribution of the river bed substrates that were to be introduced in the differing hydraulic conditions generated by the double meander channel configuration. Two sources of material were selected for use either singly or in combination.

Stone rejects from nearby limestone gravel pits were used on the river bed upstream of chainage 40m (the lower riffle) where water velocities were highest. Sizes ranged from 40mm to 200mm and shape varied between rounded gravels and cobbles to flat pieces of stone. Elsewhere 40mm graded and washed gravels were used where water velocities were less severe. This included the inner bend shoals where the public would have easy access. A mixture of both was used in intermediate locations simulating the natural 'grading' of bed substrates that would arise had they been carried and deposited by the river.

The design was completed to accommodate floodwalls and floodgates and a range of public access and amenity features as well as a comprehensive landscape planting scheme sympathetic to the riverine environment. The introduction of marginal aquatic plants, etc. along soft edges and within the numerous interstices of the rock outcrops was deferred until floodwaters has passed through the newly created reach of the river. This enables the river to modify and soften the engineered work thereby revealing the most appropriate plant species for the multitude of different habitat niches expected.

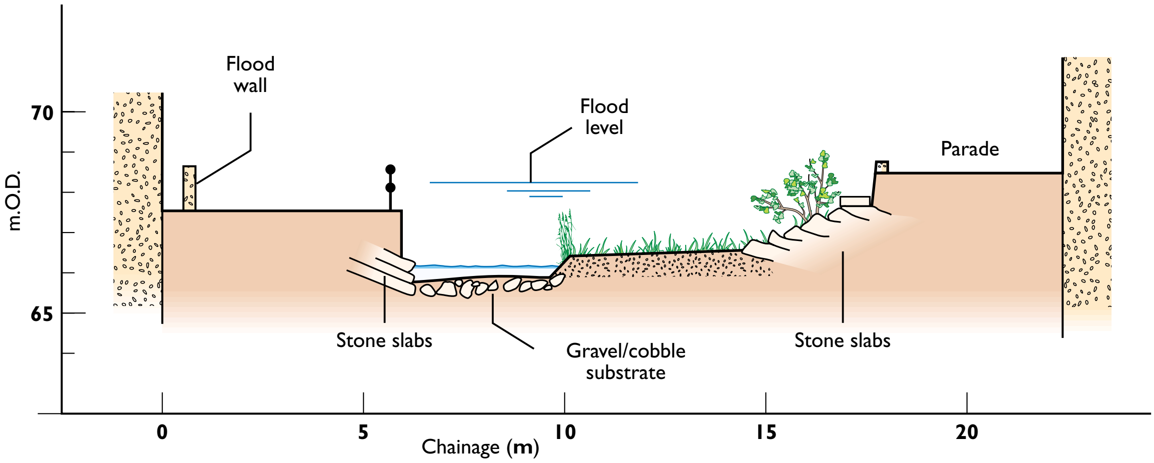


Figure 1.5.3
SECTION A THROUGH RIVER AND STONE SLABS

View of Section A (*fig 1.5.3*) on completion

View of Section A in November 2001

After: The new town centre in November 2001

SUBSEQUENT PERFORMANCE 1999 – SPRING 2001

Landscaping and planting have yet to be completed but the new riverworks have meanwhile been subjected to several flood events.

The works have all remained remarkably stable bearing in mind that river bed substrates and shoal materials were all kept to minimum sizes, rather than 'over-sizing' to ensure stability.

The river has re-distributed some of the stone placed between the two riffles. This has created an additional riffle within the reach and the shoal at the front of the stepped platform has built up into an attractive, accessible beach.

The edge of the river channel between the two stone 'riffles' has slightly eroded along the un-revetted side. The latter can be easily controlled using pre-planted fibre rolls as part of the landscaping work and the former simply requires some gravel reject stone to be introduced into the soil that will then be grassed.

The four vanes at the culvert entry appear to be working well and sustain interesting current variations at low flows although some flood debris is attached to them. This debris is easily removed and is less problematic than it would be if it had entered the culverts.

The overall appearance of the riverworks is excellent and once the contractor finally clears the site and landscaping is completed it should naturalise well. Wildlife has occupied the site despite the intense building work with wagtails, duck and fish being most obvious. The underwater rock and the sustained pools and faster flowing runs of water all promise to develop into valuable habitats.

Local comments are of young people enjoying 'messing about in the river' with no serious vandalism, partly due to the robustness of the design concept.

Contacts:

RRC, Silsoe, Beds. MK45 4DT, Tel: 01525 863341.

1.6 Opening up a culverted stream

RIVER RAVENSBOURNE

LOCATION - Norman Park, Bromley TQ 412674
DATE OF CONSTRUCTION - March to June 2000
LENGTH – 300m
COST - £127,000

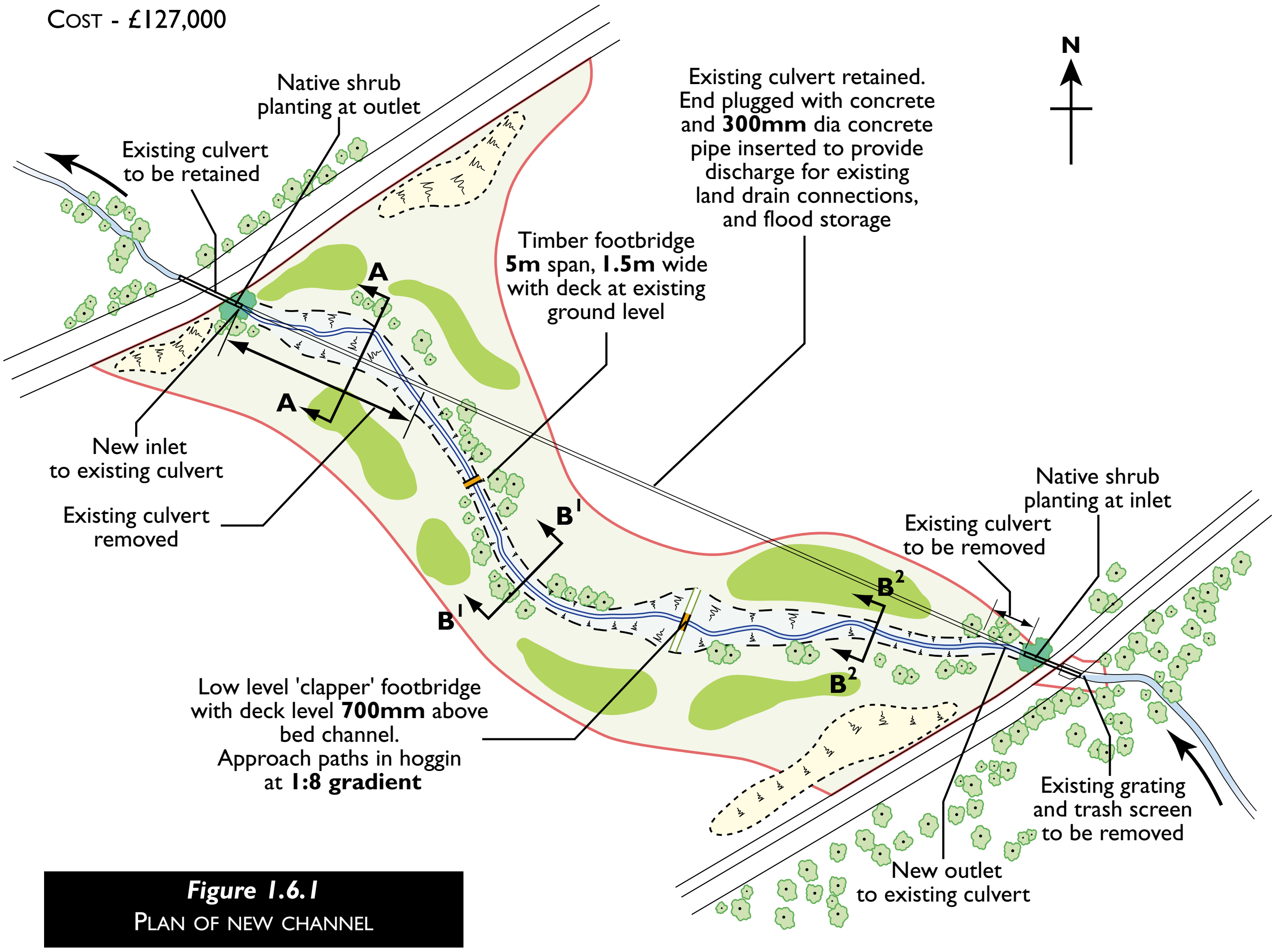


Figure 1.6.1
PLAN OF NEW CHANNEL

DESCRIPTION

The Ravensbourne is a spring-fed stream flowing from its source near Keston, on the north slope of the North Downs, northwards through Bromley, Catford and Lewisham to join the Thames at Deptford Creek. In many areas such as Norman Park the stream was confined within a culvert.

Culverting of small watercourses in urban and parkland areas has been common in the recent past. Burying the river was felt to reduce the flooding potential, minimise safety issues associated with open water and maximise land available for development or use as open space/playing fields. Little consideration was given to habitat loss, aesthetic and landscape appeal of rivers or the potential benefits of surface water storage.

The Ravensbourne flowed for 300m through a 1m diameter concrete-lined steel culvert. Smaller land drains, which had been ditches before the area was levelled to form the park, flowed into the culvert at intervals along its length.

Park access tracks and major services, with a gas pipeline and electric supply cables crossed the culvert at the north end and a water pipe and local electrical supply cables at the southern end.

Deculverting (daylighting) this section of the Ravensbourne provided an exciting opportunity to restore a more ‘natural’ stream with diverse in-channel and bankside habitats that link with Scrogginhall Woods just upstream. It also provides an interesting recreational facility for the local public.

View of headscreen prior to removal

'Daylighting' of the Ravensbourne

DESIGN

Financial justification for the scheme was threefold: reduction in costly maintenance for a culvert, the removal of a trash screen that also required regular clearing and was a health and safety issue, and an increase in flood storage. There was also a positive environmental gain.

The culvert was severed and approximately 70m of the 300m long culvert was removed, isolating 180m of the remaining section. Two short lengths were left to maintain the existing access track and service crossings. As the culvert was ruler straight, simply excavating the watercourse and removing the concrete would produce a far from natural channel. In addition, culvert removal, backfilling and reshaping is considerably more expensive than plugging and digging an alternative, though longer, course.

The design of the river channel was based on the historical layout, fluvio-geomorphology, flooding considerations and present day use of the park (cricket pitches). To avoid being overly prescriptive, the design drawings were kept relatively simple. The conditions encountered on site meant the final course is slightly different from the design plan shown in figure 1.6.1. Indicative cross sections were provided at key locations with the main objective always a shallow, safe, accessible bank (*figs 1.6.2 and 1.6.3*).

The new channel varied in bank slope and bed width, but followed a smooth longitudinal bed profile. By then infilling with an excess of gravel, the stream was allowed to shape its new bed, rather than 'constructing' pools and riffles.

The new course is 12.5% longer than the culvert, sinuous, with varying bed and top-of-bank widths.

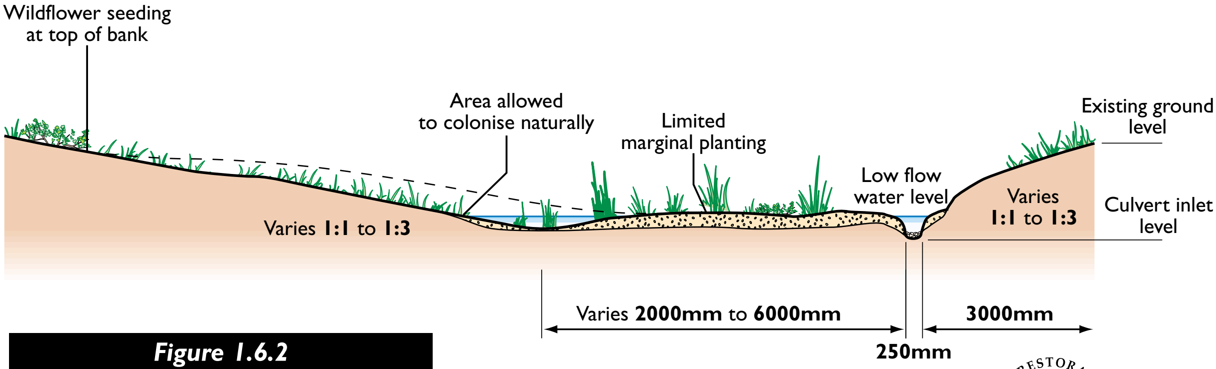
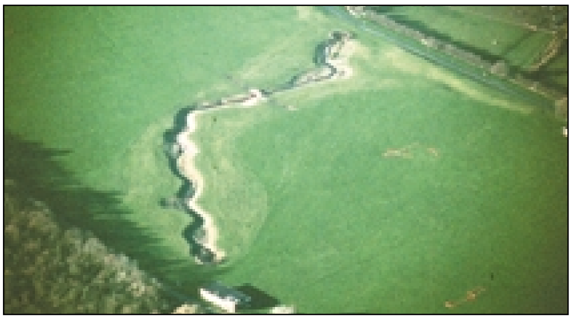


Figure 1.6.2
SECTION A
THROUGH WET BERM AREA

Looking downstream at the shallow bank slopes. The severed culvert still visible



The new sinuous course and extent of wildflower seeding

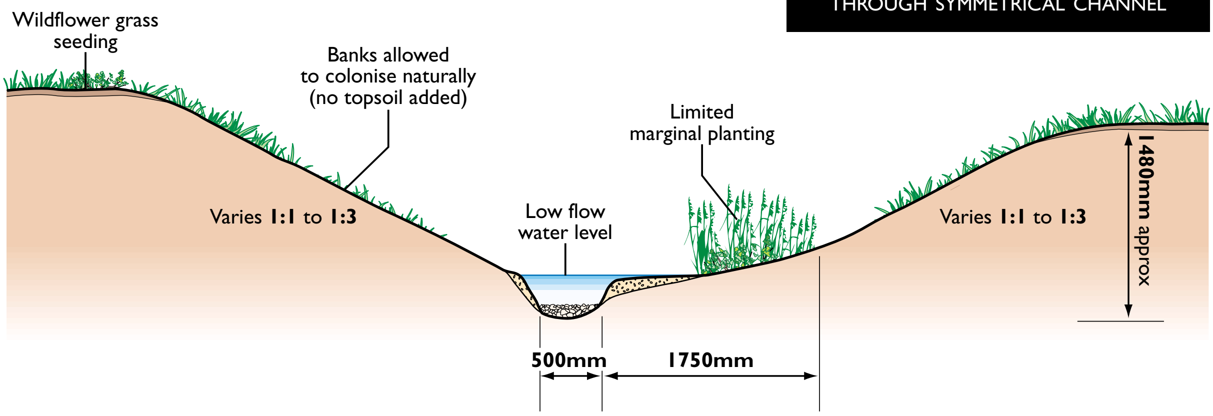
A shallow (1:8 batter) 'beach' area, as a result of an exposed gravel lens, and new meanders (1:5 inside batters) form the focal points for access to the stream.

When considering this type of scheme, where the stream emerges and then re-enters a culvert, it is good practice to build in 'sediment traps'. These can take many forms and do not have to resemble deep holes or even be maintained once the site has stabilised. At Norman Park the channel was greatly widened at the downstream end of the works forming a damp gravely area which would act as a silt trap. This also allows the stream to find its own natural path within the confines of the overall channel width.

Spoil from the excavation remained on site, and the landscape architect located the mounds at either end of the new course, to ensure that they were subtle and blended into the park.

Two crossings have been constructed over the new channel, one a 'clapper' type bridge constructed of concrete (but looking like stone) and the other a timber structure. Both provide easy access across the stream and access to the water's edge is made possible along most of the course by shallow bank slopes.

Figure 1.6.3
SECTION B^1 AND B^2
THROUGH SYMMETRICAL CHANNEL



Planting up the 'wet berm' area and shielding the culvert entrance with shrub planting

Topsoil was not replaced on the riverbanks in order to attain a low fertility substrate suitable for the natural colonisation of wildflowers and plants from upstream. A 'buffer zone' between the amenity grassland and the top of the bank was seeded with a low-density wildflower mix from an approved source. This creates a visually pleasing edge to the playing fields and provides a suitable seed source for the banks. On the river's edge native provenance marginal plants were specified from a carefully sourced local nursery. School children were involved in some of the marginal planting. Wildflower plugs were also planted. The culvert entry and exit were both screened using a variety of native shrub species.

SUBSEQUENT PERFORMANCE 2000 – 2001

The park users, particularly dog walkers, now see the open Ravensbourne as a focal point, circling the area and making use of the crossing points. Children and dogs play along the banks even though the site has still to mature.

The gravel bed has been redistributed by the flow creating riffles and pools (down to the clay bed in places).

The marginal planting is suffering disturbance from early use and may take longer than expected to establish a good cover, though this should eventually produce a good diversity of edge habitats. The wildflower plugs have been decimated by crows in search of worms. About a third were removed from the ground and died.

The planting scheme was designed as a balance between creating an instant impact for the local users and allowing the natural processes of colonisation to occur. Even so the local users have stated that they would have liked more immediate impact from the planting.

Intial invertebrate and fish surveys have shown little change, but this should improve with time as the site matures and the marginal and emergent vegetation develops.

The early success of the project can be attributed to the multi-disciplinary project team and the Partnership between the Borough Council and the Environment Agency.

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Tel: 01189 535000.

Completion was celebrated at a launch ceremony in June 2000

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

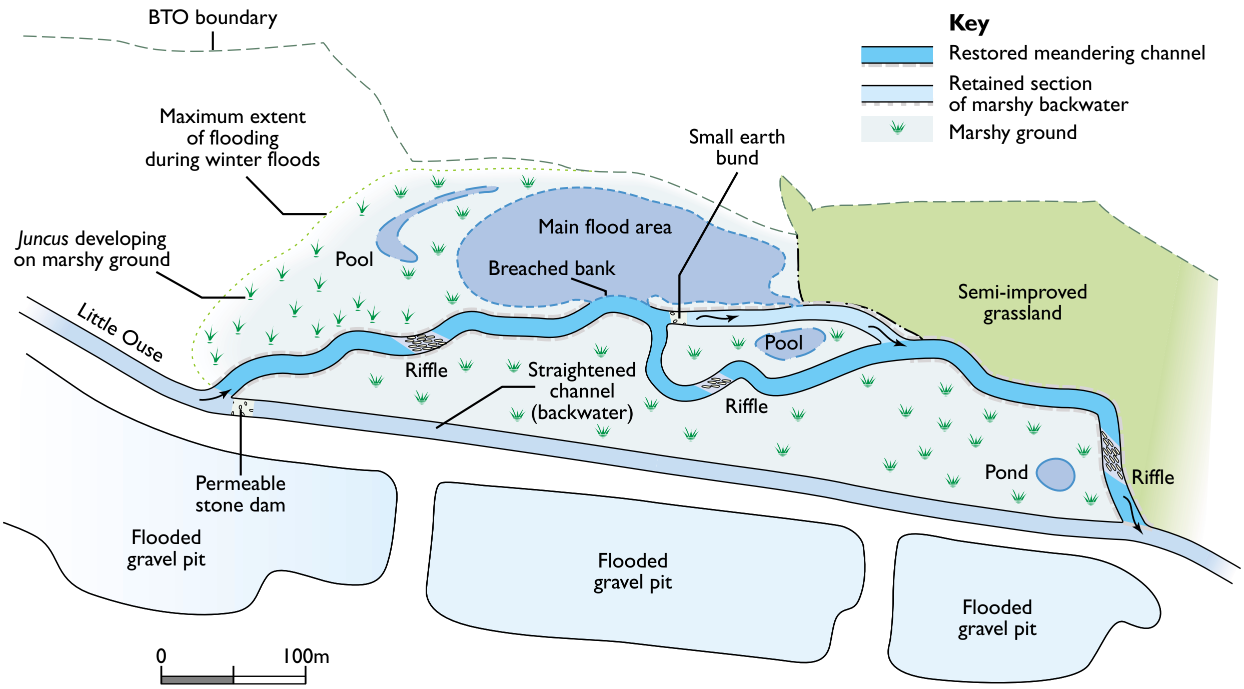
RESTORING MEANDERS TO STRAIGHTENED RIVERS

1.7 Reconnecting remnant meanders

RIVER LITTLE OUSE

LOCATION - Thetford, Norfolk TL 870812 – TL 874816
DATE OF CONSTRUCTION - 1994
LENGTH – 900m
COST - £15, 000

Figure 1.7.1
PLAN OF MEANDERS



DESCRIPTION

The Little Ouse is a low gradient river draining an area of mixed land use (forestry, dry grassland and arable). Sand and gravel extraction has taken place as part of a 30 year programme within the valley. This had lead to 900m of the river being bypassed by a new canalised channel.

Canalised course of the Little Ouse

In 1991, the site and adjacent land was purchased by the British Trust for Ornithology (BTO) to create a wetland bird reserve. BTO approached the Environment Agency to assist with restoring flows to the meandering course. The grassland on either side of the old course was beginning to dry out due to the lower water levels within the new channel, and resultant lack of connectivity between river and floodplain.

The new canalised course was straight, trapezoidal, c.6m wide and 1-2m deep, with 3m dry, steep banks dominated by tall ruderals and grass. In-stream habitat was poor, macrophytes were confined mainly to the shallow margins, and the substrate was dominated by sand with some silt and gravel.

The old meandering channel remained as a damp depression, merely infilled at each end during the excavation of the new cut. By restoring flows to the old channel 900m of diverse river habitat incorporating deep pools, runs and riffles would be regained, in contrast to the uniform, slack and deep water of the canalised section. Additionally, the landowner was keen to see the land adjacent to the meanders flood, restoring the lost hydrological connection between river and floodplain.

Looking downstream along the old meanders

The marshy habitat that the isolated meanders provided would be lost through reconnection, so it was decided to retain and bypass a short 120m section of the old course. This would provide a refuge for plants and animals and a source for colonisation of the proposed wetland reserve.

DESIGN

Assessment and design of the restoration scheme was kept simple and carried out 'by eye', since the old channel was still intact as a reedy, damp depression meandering through the valley bottom.

The old course was reopened by excavating the 'plug' material from the upstream and downstream ends of the meanders. Some tree work and minor regrading was carried out along the remaining length of the original course where necessary. The very small amount of spoil was spread within the immediate reach of the excavator. The restored Little Ouse now has an average channel depth and width of 1m and 8m, respectively.

Using a 50 foot reach dragline, a boulder and stone structure was placed into the river at the upstream end of the canalised reach (permeable stone dam on figure 1.7.1), to raise the river level by 0.6m. This would ensure that approximately 90% of flow would be routed through the re-opened course.

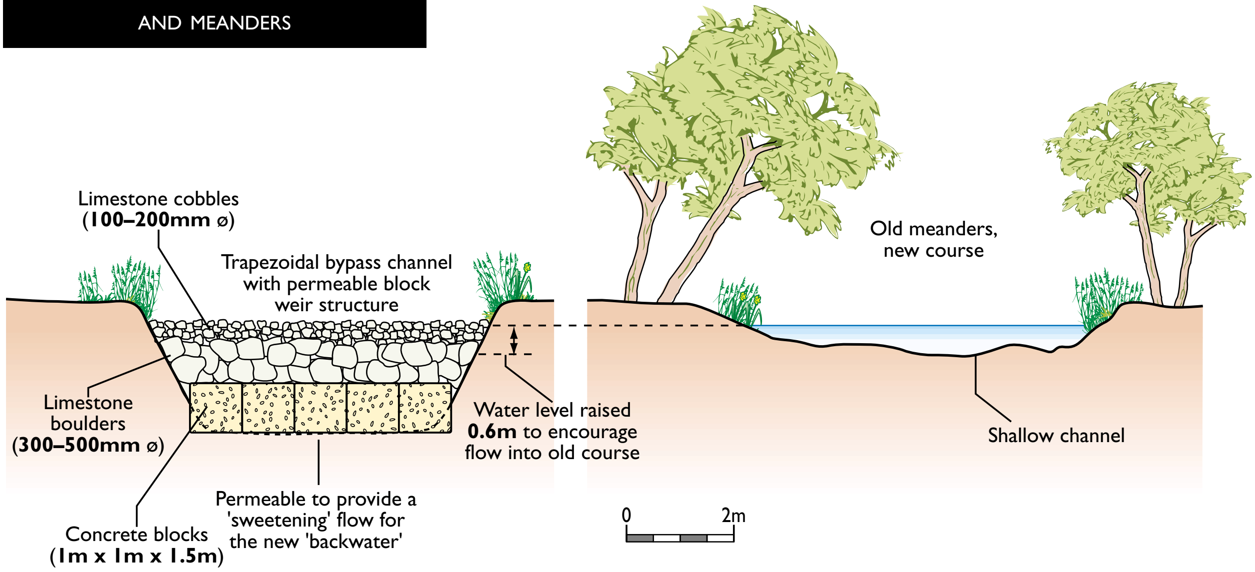
The structure, 6m wide by 10m long by 2m high, was constructed using 1.5 by 1m prefabricated concrete blocks below a 0.75m depth of boulder sized limestone, surfaced with 0.25m of cobble sized limestone. The 'weir' was designed to be permeable to provide a sweetening flow to the canalised channel. Flows, where levels exceed the 2m crest, will overtop and discharge through the retained canalised 'flood relief' backwater channel.

In the middle of the meandering reach a marshy backwater section was isolated with a bund at the upstream end to protect the habitat from high velocity flood flows.

The meanders needed to be 'unplugged' at both ends

Sluice, bund and upstream flooding area

Figure 1.7.2
SECTION THROUGH STONE DAM AND MEANDERS



SUBSEQUENT PERFORMANCE 1994 – 2000

Surveys show that the meandering channel is sustaining a diverse aquatic invertebrate community, with stonefly, mayfly and snail species which are not present in the canalised section. Fish species such as chub and dace, also not found in the straight section, are using the reconnected reach as spawning and nursery habitat.

The re-establishment of marshland plants on this site has taken longer than originally anticipated. This may be due to a combination of factors, including an inadequate seed-bank, build-up of silt deposits, and prolonged inundation. However, wildfowl and waders have not been slow to use the greater areas of shallow standing water, including nesting pairs of lapwing.

After reconnection to the river

The restored Little Ouse

Sections of fencing have been erected along the meanders to restrict grazing and poaching by cattle, and to allow marginal plant establishment.

Some scour around the weir was discovered, due to overtopping in high flows. The length of the dam and a section immediately upstream has since been revetted to minimise further scour.

Contacts:

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Chris Gregory. BTO, The Nunnery, Thetford,
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Flooding along meanders, Spring 1999

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

10

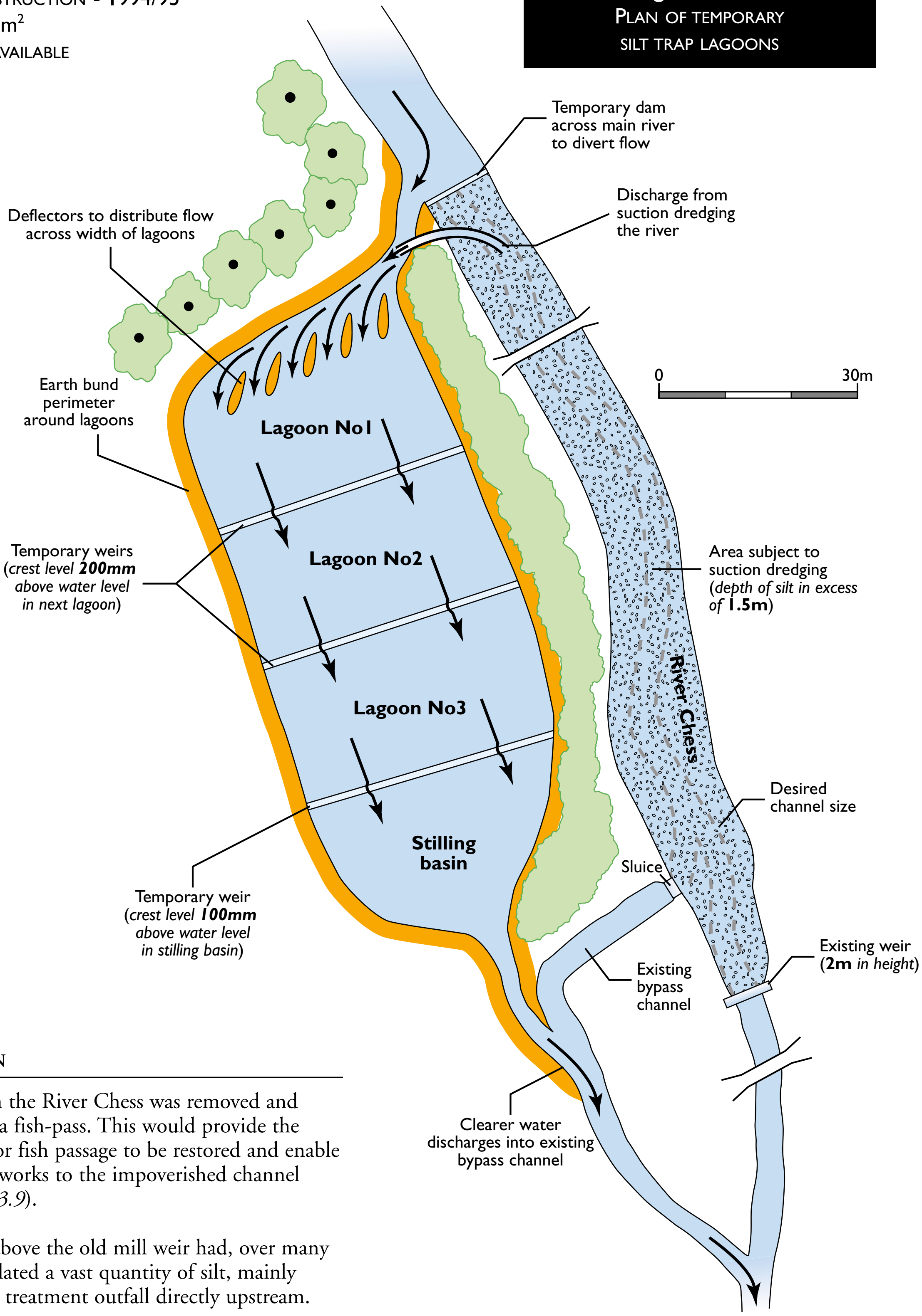
UTILISING SPOIL EXCAVATED FROM RIVERS

10.3 Cost effective silt removal from an impounded channel

RIVER CHESS

LOCATION - Blackwell Hall, Latimer, Buckinghamshire SU 980997
DATE OF CONSTRUCTION - 1994/95
AREA – c3000m^2
COST - NOT AVAILABLE

Figure 10.3.1
PLAN OF TEMPORARY SILT TRAP LAGOONS



DESCRIPTION

A mill weir on the River Chess was removed and replaced with a fish-pass. This would provide the opportunity for fish passage to be restored and enable enhancement works to the impoverished channel upstream (*see 3.9*).

The channel above the old mill weir had, over many years, accumulated a vast quantity of silt, mainly from a sewage treatment outfall directly upstream.

Mill weir and replacement fish-pass

Dredging and re-profiling of the wide silted lagoon behind the weir was carried out in association with the fish-pass works. Prior to the implementation scheme, the water company relocated its effluent outfall downstream of the site.

By lowering the water level, sufficient gradient was returned to the river to re-form a narrow sinuous channel within the previously deep over-widened and ponded section. The impounded channel size needed to be drastically reduced, both in width (8m to 2m) and in depth (in places silt was up to 1.5m deep).

Exposed silt, looking towards mill weir.
Inset above: Dredged.
Inset right: 4 years later

To achieve this the accumulated silt retained by the old weir had to be removed. In order to avoid moving spoil off-site the dredged material was incorporated into an adjacent grass field. Removal off-site of such material is often expensive and, if sent to a landfill site, unsustainable.

DESIGN

Using an excavator a series of low bunds were constructed in the adjacent field. The earthworks followed the fall in land levels to allow gravity flow. These bunds formed three shallow lagoons and a stilling basin. The first lagoon incorporated deflectors to ensure an even distribution across the width of the lagoon. The lagoons were separated by low temporary earth weirs (*figs. 10.3.2 and 10.3.3*).

The silted river was temporarily dammed and de-watered via the old mill bypass sluice. The river was diverted via a bunded inlet channel through the 'silt-trap'. To remove the large volume of saturated silt, suction dredging was used, the discharge being pumped into the first lagoon. The silt laden river water proceeded through the 3 lagoons depositing its silt load before ultimately rejoining the existing bypass channel.

Retention time within the silt-trap was approximately 2-4 hours. In this way 1300m^3 of excavated and suspended material was removed from the stream.

The area of field used was c. 3000m^2 resulting in a maximum increase in height over the field of c. 200mm.

The silted lagoons were allowed to de-water for 1 month and the temporary weir materials (tarpaulin and sandbags) removed. The silt and earth bunds were then flattened and graded into the field. The surface was hand raked and the whole area grass seeded with a meadow mix.

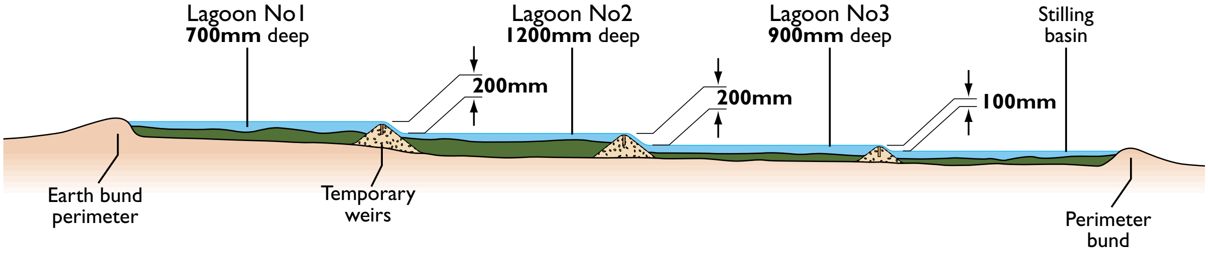

Lagoons and stilling basin – February 1995


Lagoons, stilling basin and overspill – March 1995


Retained silt load – April 1995


As a grass field 4 years later

Figure 10.3.2
TYPICAL SECTION THROUGH LAGOONS



Dewatering – April 1995. View from inlet channel

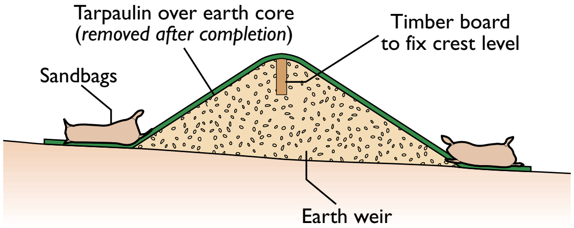


Figure 10.3.3
TYPICAL DETAIL OF TEMPORARY WEIRS

Graded, harrowed and seeded – June 1995

SUBSEQUENT PERFORMANCE 1995 – 2001

Now fully grassed over, the field is not noticeably out of character. Indeed it appears to be a normal field.

Where sufficient gradient exists and loss of floodplain storage capacity is not affected or is not an issue, this technique for de-silting may be a suitable alternative to removal off-site.

Contacts:

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Chris Catling. Environment Agency – Thames Region, North East Area Office, 2 Bishops Square Business Park, St Albans Road West, Hatfield,Herts, AL10 9EX, Tel: 01707 632370.

UTILISING SPOIL EXCAVATED FROM RIVERS

10.1 Landforms at Keepsafe and Rockwell

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – August 1995, Summer 1996
AREA – 1.5 ha Rockwell and 1.1 ha Keepsafe (c. 19,000m^3 of spoil carted to landforms)
COST – £60k Carting and creation of landforms

Rockwell after landform completion – 1998

DESCRIPTION

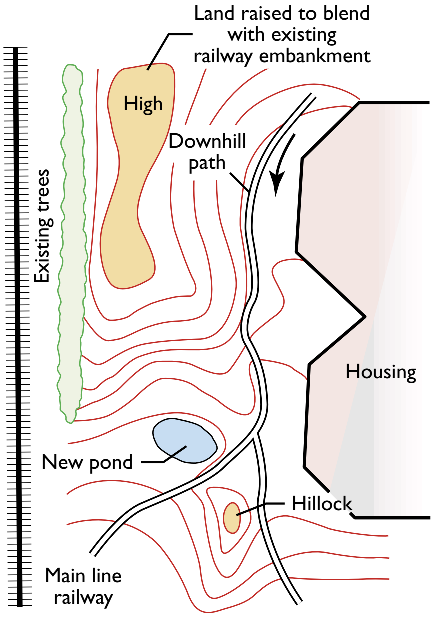
The restoration of the River Skerne necessitated the disposal of c.19,000 m^3 of surplus spoil (*see 1.4*). Two locations on the adjacent valley slopes (known as Rockwell and Keepsafe) were considered suitable for re-profiling and accommodating the spoil. These were the only areas that had not been either modified through industrial landfill or developed for housing. Although they retained some desirable features, they were out of keeping with the severely modified landscape around them. New landforms were designed to ameliorate the impact of the old landfill and to enable planting to screen unsightly buildings.

DESIGN

The landform of the two areas was generally designed to simulate naturally occurring 'gullies and hummocks' found in some parts of the north of England. Involvement of the community including schools, local wildlife trust and residents was deemed essential. Ideas for formal and informal paths were included for use in the detailed design.

Rockwell (fig. 10.1.1)
This area positioned between housing, the main railway and a nature conservation area, was rough land with some dumped builders rubble. As part of a community environmental project a pond was excavated in a former 'seep' on the valley side. Key features are gentle slopes facing the housing and small hummocks to provide topographical interest.

Figure 10.1.1
PLAN OF ROCKWELL LANDFORM WORKS



French drains were installed in key places to prevent waterlogging of access routes and to alleviate surface water erosion problems.

Keepsafe (fig. 10.1.2)
This was a field gently sloping towards the river. The new landform has introduced a small valley feature and has raised the land adjacent to the industrial estate, built on landfill. Carefully positioned tree and shrub planting screens the industrial area on one side and ties in with an original hedgerow on the other. Most importantly, a smooth topographical transition has been created at the old tip face. A land drain was incorporated in the newly formed valley which also acts as a dry route for walkers.

Once the landforms were complete a landscape architect was appointed to design and install a suitable planting scheme. Each was seeded with a low maintenance grass mix incorporating wildflowers, followed a year later with 10,000 trees and shrubs planted in discreet planting areas. Bulbs were also planted on the lower slopes.

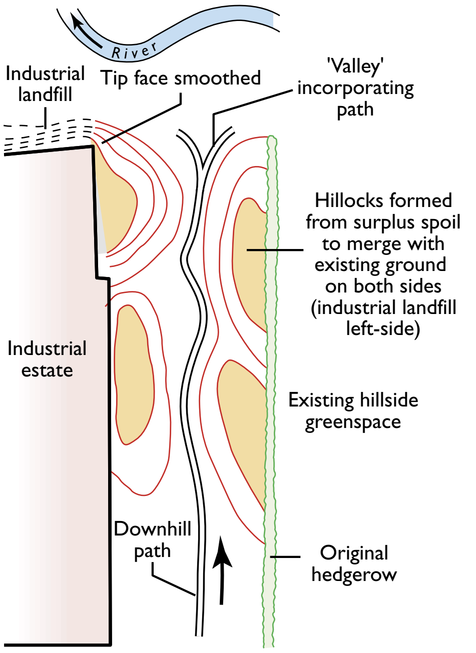
SUBSEQUENT PERFORMANCE – 1995/98

Participation in landscape design and planting has given the community ownership of these open spaces and may be a factor in the minimal level of vandalism experienced. Both areas blend with the surrounding landscape and they are not obviously artificial. Each is now more widely used by walkers taking natural desire lines. The tree and shrub planting is already helping to screen the industrial area and the railway.

The creative use of spoil in this beneficial way has overcome what would otherwise have been a prohibitively expensive operation of carting off site.

Keepsafe landform during construction

Figure 10.1.2
PLAN OF KEEPSAFE LANDFORM WORKS



Similar view of Keepsafe after tree planting – 1998

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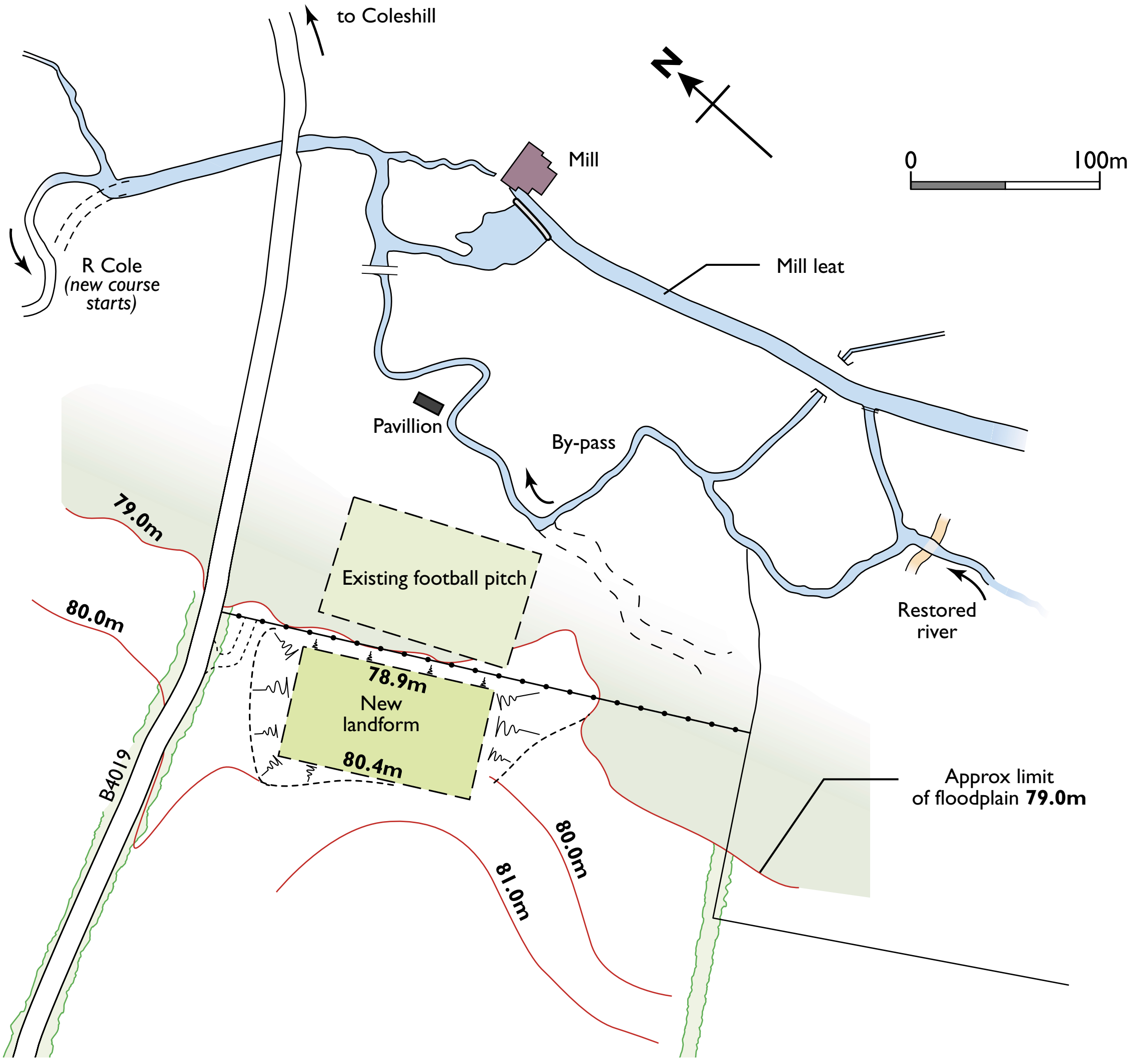
10.2 Landform areas

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995 – June 1996
AREA – 0.6ha (c. 4,000m³ – main site)
COST – £13.6k Carting and creation of landform



DESCRIPTION

Excavation to create over 1 km of new meandering river channel resulted in c. 4,000m³ of spoil that needed to be transported away from the riverside. This was used to re-contour a nearby area of sloping arable field just off the floodplain. The landform created resembles a natural river terrace. It is large enough to serve as a second football pitch to compliment an existing pitch located on the adjacent floodplain, if needed. In addition, shallow mounds of spoil were created at two locations on the floodplain to serve as stock refuges in times of flood.

DESIGN

Most of the material excavated was used to infill redundant lengths of the old straight river channel, but not all. As an intrinsic part of the overall scheme, several lengths were left unfilled and developed to create sheltered off-river habitats (*see 2.2 and 9.2*).

Spreading of surplus material on the floodplain was not considered complimentary to the river restoration project objectives and carting all spoil off site would have been too costly. The concept of terracing the adjacent valley side was therefore adopted.

The site for the terrace was chosen to assist the local football club whose pitch is located on the floodplain of the river and suffers periodic inundation. It was possible to ensure that the area of the terrace was large enough for a pitch and that it was elevated above flood levels. In practice, the new terrace was restored to arable production but the opportunity for future flood free recreational use remains.

Construction of the terrace was a straightforward operation involving bull dozing of top soil to one side (post harvest) for re-use, prior to carting and spreading of fill. Detailing involved smoothly graded contouring around the edges to blend at 1 in 40 with existing land levels and ensuring a 1 in 130 cross-fall over the terrace to maintain surface run-off.

Elsewhere two smaller landform features were created on the floodplain in the form of gently sloping shallow mounds that will serve as stock refuges in times of flood, in areas where this is critical *(see 1.3)*. These do not adversely affect flood storage capacity because the amount of spoil utilised is small in comparison to the substantial surplus of spoil carted to the main landform.

SUBSEQUENT PERFORMANCE 1995/98

The new terrace is in full arable use with only a small part lost to production for one season. Although not unduly intrusive within the landscape, part of the designed 1 in 40 transitional slopes were steepened at the end of the contract to accommodate additional spoil resulting from extra works.

Concerns that increased flood frequencies generated by the river restoration works would advance the need to establish a second flood free football pitch have not materialised to date. The restored river has not developed the amount of in-stream growth conservatively estimated in the design, and seasonal rainfall has been below average since construction. Both these factors may account for this although hydraulic modelling did predict a manageable situation for the football club.

The concept of re-profiling valley sides near to the floodplain has proved to be a very effective way of avoiding excessive spoil disposal costs without any obvious detriment to the landscape.

Construction of landform in arable field to right of football pitch – 1995
Photo: Environment Agency

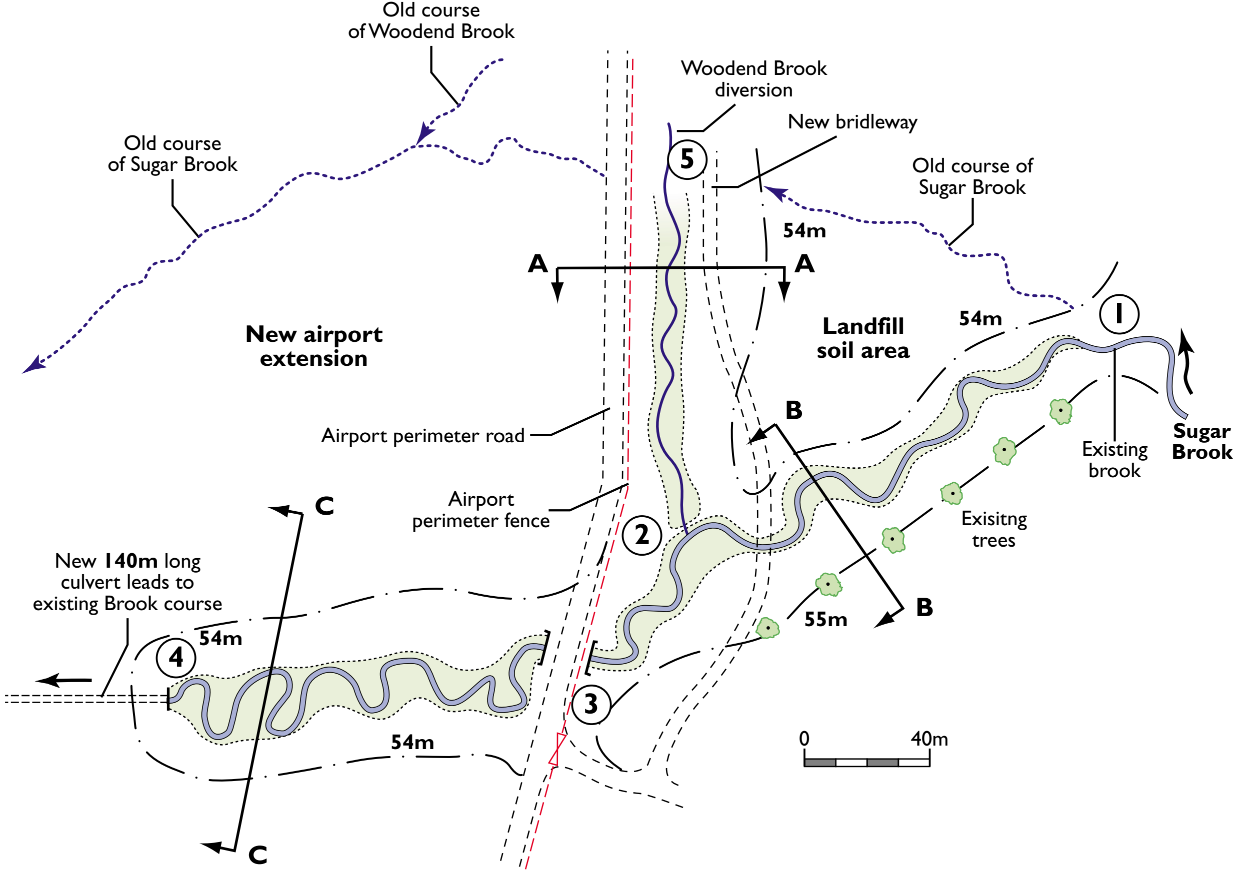
RIVER DIVERSIONS

11.1 Diversion of a River Valley

SUGAR BROOK

LOCATION - Manchester Airport SJ 7981
DATE OF CONSTRUCTION - 1998
LENGTH – 360m of main river plus a tributary
COST - NOT AVAILABLE

Figure 11.1.1
PLAN OF DIVERSION



Key

- · — Contours at 54/55m indicating top edge of new valleys created
▨ Indicates extent of relatively flat valley floor (floodplain) with small incised channel meandering through

① Start of Sugar Brook diversion
② Woodend Brook confluence
③ Perimeter road culvert
④ Airport culvert
⑤ Start of wetland on Woodend Brook

DESCRIPTION

The construction of a second runway at Manchester Airport required the back-filling of a 350m long reach of Sugar Brook, and its valley, to bring ground levels up to the required elevation for the runway, the runway approaches and marginal safety grasslands. Rather than place the entire reach in a buried culvert the brook was realigned over a 500m long reach that reduced the length of culvert involved to 140m where it unavoidably passed under the runway approaches and lighting strip. The remaining length of the diversion, some 360m, was constructed as an open watercourse.

A small tributary stream, Woodend Lane Brook (Woodend Brook) was similarly affected and needed to be diverted into the realigned Sugar Brook. This was achieved entirely in an open watercourse further avoiding culverting.

Sugar Brook before culverting, a reference site for the new channel

Figure 11.1.1 shows the previous route of the two watercourses and the route of the diversions to the south that take them clear of the airport perimeter fence towards the new culvert under the airport approaches (airport culvert). This culvert reconnects directly to the existing Sugar Brook course at its exit. The length of the diversion equalled the length that it replaced, thus maintaining the same overall bed gradient.

Many issues arose in the design of the watercourse diversions, but perhaps of greatest significance was the depth to which excavations needed to be taken to achieve the required bed levels. The new bed falls fairly uniformly at about 1 in 200 gradient between existing bed levels of Sugar Brook at each end of the 500m diversion. In contrast to this, the ground levels along the diversion route increased in elevation to heights of over 5m above the new bed. Channel depth of this magnitude (5m) far exceeded the natural channel depth of approx. 1m that are typical of Sugar Brook, so a novel approach to design was essential.

The diversion presented an opportunity to recreate the natural features found on unmodified reaches of the brook.

DESIGN

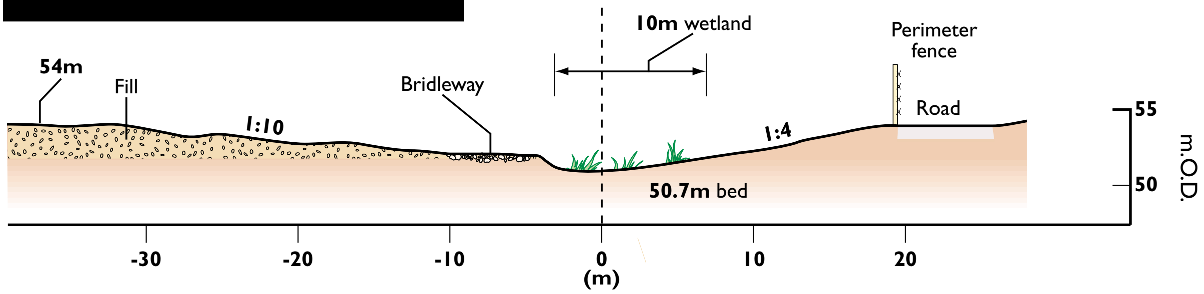
A preliminary outline design prepared at the planning permission stage indicated a slightly sinuous channel that was trapezoidal in cross-section over its full depth and lacked any of the detail and refinement needed to mimic the natural character of Sugar Brook. This approach aimed to acheive the least possible excavation width and set new bank tops around which various roads, paths and a surplus spoil disposal site were all positioned and linked to the subsequent planning permission. This resulted in an unduly narrow 'approved' corridor of land within which to achieve the detailed design of the diversion.

A trial excavation at the upper end of the diversion reach was undertaken to test the outline design. This was shown to be completely inappropiate. Apart from its deep 'canyon-like' appearance, the predominant clay soils could not be relied upon to remain stable at the depths of excavation involved. Undercutting of the toe of the slopes could be expected to accelerate collapse of the high banks.

A new approach to design was needed which recognised that the formation of the valley within which the brook naturally flows involved different geomorphological processes than those that sustain the small watercourse that is incised within the floor of the valley. Inspection of the undisturbed reach just downstream of the airport demonstrated a narrow rounded valley formed during glacial retreat with a fairly flat bottom of more recent fluvial sediments through which the brook course meandered. Cross-sectional templates were taken from this reference reach and used to design the new valley.

The approach to detailed design thus involved treating the diversion as a diversion of the valley of Sugar Brook and not as a channel diversion. If an acceptable valley form could be achieved then the creation of a small meandering stream within its floor became a relatively straightforward task.

Figure 11.1.2
SECTION A THROUGH WOODEND BROOK



Woodend Brook

Creating the New Planforms
Figure 11.1.1 shows the top edge of the newly created valleys of both Sugar Brook and Woodend Brook along contours of between 54 and 55 metres O.D. with a top width of between 30 and 50 metres. The relatively flat valley floor of each is also indicated at widths of between 10m and 20m.

The meandering plan form of Sugar Brook, which is cut into the valley floor by up to 1m only, was strongly influenced by templates of meander patterns elsewhere on the brook (*figs 11.1.3 and 11.1.4*). Woodend Brook does not feature an incised course in the new floor but has been encouraged to form a wetland across its full width of around 10m (*fig 11.1.2*). Natural channel incision is expected to develop slowly.

Valley Profiles
The manner in which the new valley side slopes were shaped was carefully excavated to mimic natural profiles which vary from concave, where ancient soil slips have arisen, to convex, where they have not. The mean slope associated with concave (slipped) profiles is likely to be flatter than when convex, creating desirable variations and mild sinuosity when looking down the valleys. Compound slopes involving both concave and convex slopes were also incorporated. Three cross-sections A, B and C indicate these variations which are also apparent on the photographs.

The River Channel
This was meandered down the valley floor following the design principles described elsewhere in

Sugar Brook looking upstream

Figure 11.1.3
SECTION B THROUGH SUGAR BROOK UPSTREAM OF CONFLUENCE

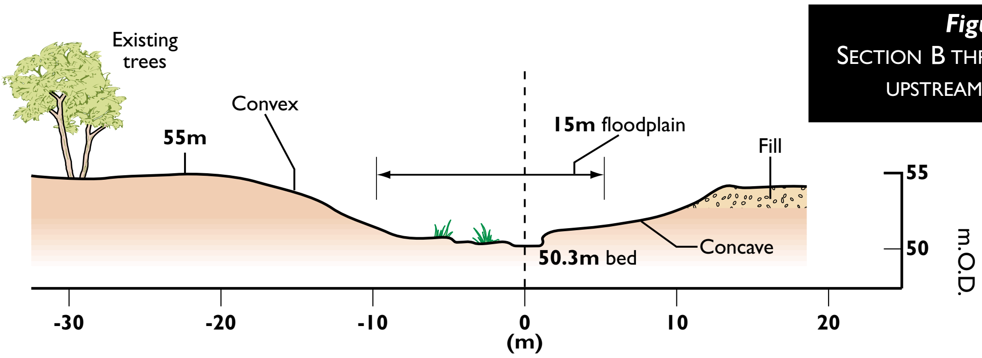
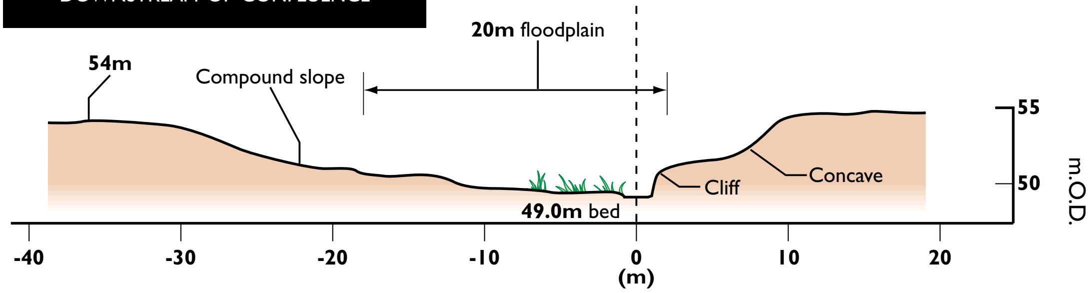


Figure 11.1.4
SECTION C THROUGH SUGAR BROOK DOWNSTREAM OF CONFLUENCE




September 1999. Sugar Brook Valley below confluence


November 2001. The river valley vegetation is developing well

this manual (*see 1.1, 6.2.*). Cliffs, riffles, pools and shoals were all initiated within the excavated channel profiles, but it was expected that rapid changes would arise during subsequent flood periods. The aim of the design was to create a channel form that anticipated the type of regime that was appropriate whilst leaving it to the stream to adjust to a reasonably stable form over succeeding years.

Extensive marginal and bankside planting was undertaken as part of the planning permission and a monitoring programme was set up with the first survey in 1999, one year after construction.

SUBSEQUENT PERFORMANCE 1998 – 2001

Although the extent to which the form of the newly created valley could be naturalised is severely constrained by spatial limits relating to the early planning decisions, its overall appearance is good. It is certainly far better than the trapezoidal profiles envisaged at the start, which suggests that the concept of river valley diversion, rather than channel diversion, is one that needs to be taken up early in similar circumstances.

An MSc study in 2000 (*M Guy, University of Nottingham*) found that considerable geomorphological activity is occurring on the channel, with active erosion and deposition patterns. It appears that the channel is still adjusting to reach dynamic equilibrium but is comparable with the undisturbed stretches of the stream.

As part of a post project monitoring scheme baseline information was compiled using water quality, benthic invertebrate data, topographical and river corridor surveys. In the first year, monitoring results of the aquatic planting confirmed all species planted had begun to establish, but a short term abundance of annual watercress was influencing low flow characteristics. Some self-seeding willow and alder are already evident along the riparian channel.

No significant changes in water chemistry have been recorded, with the exception of fluctuating suspended solids during construction and very high flows. Within 2 years, the benthic invertebrate fauna of the new channel comprises almost all taxa found in the original. The remaining high scoring rare taxa have yet to return. (*MSc dissertation 2001 Z. James*). Manchester Airport plc continues to monitor the site.

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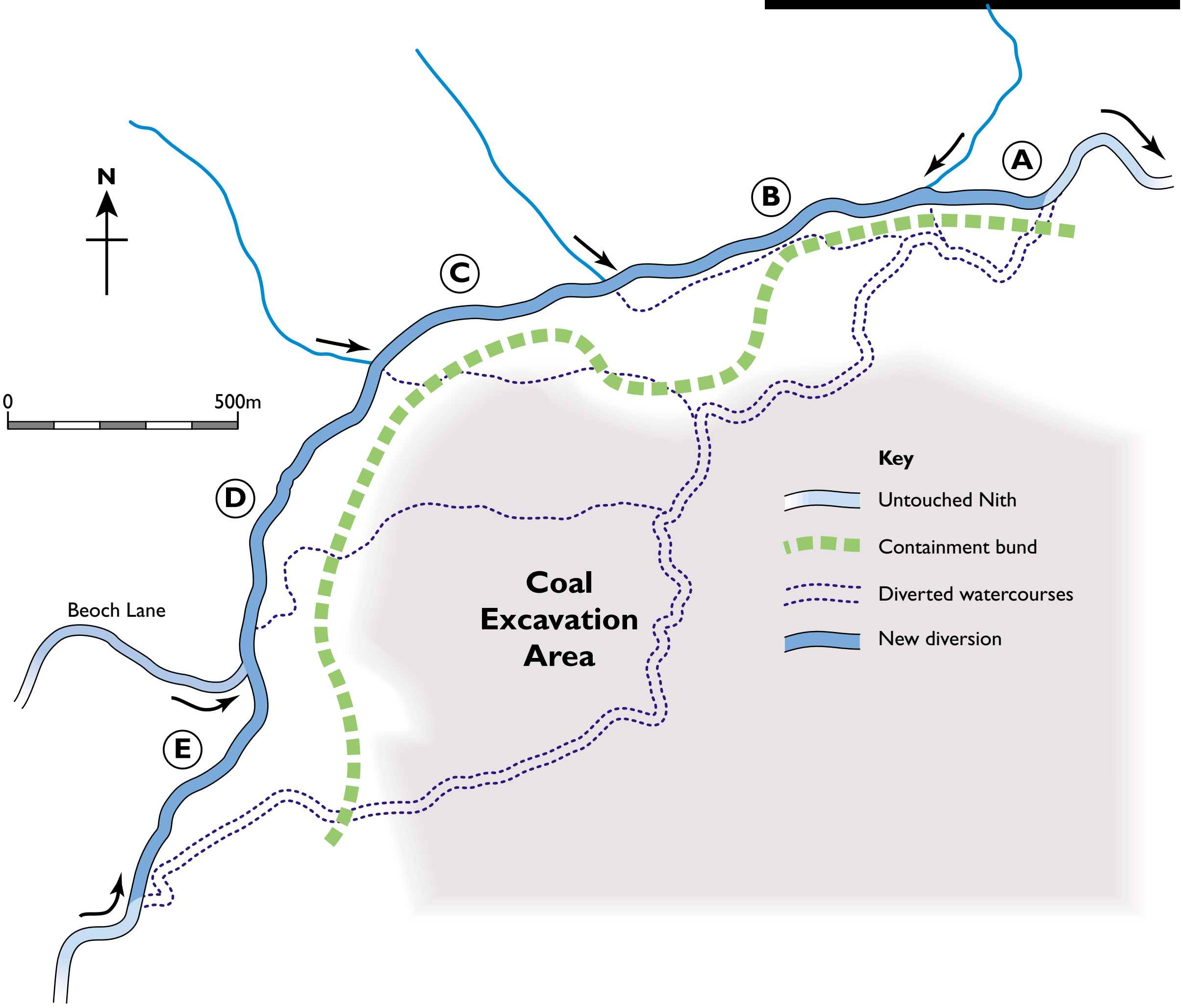
11.2 Clay Lined River

RIVER NITH

LOCATION - West of New Cumnock, Ayrshire NS 5412
DATE OF CONSTRUCTION - April – September 2000
LENGTH – 3km
COST - £3,300,000

Figure 11.2.1
PLAN OF KEY FEATURES AND SEQUENCES (A – E)



DESCRIPTION

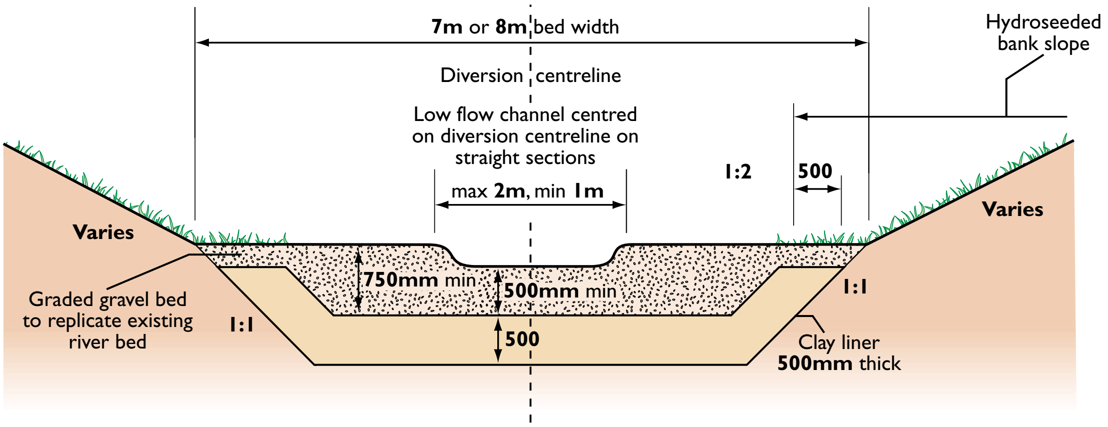
The River Nith rises at around 500m OD in the uplands of south-west Scotland and is an important salmon and trout fishery. It drops sharply within 7km to meander through a wide grazed valley floor at only 220m OD. The Nith has a mixed gravel, pebble and boulder bed, with stable and eroding earth cliffs, a common feature of the banks.

In 2000 an existing adjacent open-cast coal site was extended requiring the permanent diversion of a 3km reach of the River Nith, Beoch Lane and three tributaries. The whole floodplain site covers an area of approx. 3km^2.

The route of the diversion was restricted to a narrow corridor through areas of highly permeable strata and previous mine workings. In places the channel would need to be lined to prevent the river flowing below ground. In addition, to stop floodwater and ground water entering the opencast area, a containment bund, with an integral slurry wall constructed down to bedrock, was built between the new river channel and the coal excavation area.

The design flood standards adopted were the Mean Annual Flood for the river channel itself and the 1 in 50 year return period flood for the river corridor. Detailed hydraulic modelling established the diversion channel route and cross sections as well as the extent of flood protection measures required.

Figure 11.2.2
TYPICAL SYMMETRICAL CROSS-SECTION



DESIGN

A clay lined two-stage channel profile was adopted incorporating suitable run-pool-riffle sequences modelled on those in the existing river channel. Construction materials, including the 0.5-1m thick clay liner, river bed gravels and boulders, riffles and bund material, scour protection and in-stream features all came from the adjacent opencast excavations. It was anticipated that the new channel could match the length of the old one, but ultimately a reduction of 10% was necessary.

Figure 11.2.1 shows the diversion channel to the north of the floodplain, with the containment bund protecting the opencast area. Works progressed from A to E upstream, enabling the tributaries and burn to be progressively captured by the new channel. These flows were used to wash silt from the new channel, then intercepted by temporary settlement lagoons at the confluence prior to controlled discharge to the Nith. On completion, flow was intercepted above point E and allowed to flow through the new channel.

The key components of the design are shown in Figures 11.2.2 to 11.2.5 and include:

- a channel, between 0.5 and 1m deeper than the required depth, was excavated;
- along 80% of the diversion length a clay liner was compacted to form a barrier between the river flow and the permeable ground below. A very detailed specification was provided to the contractor regarding the quality of material, and the method of compaction;
- overlying the clay the new bed was formed from mixed cobbles, boulders, and gravels. Many thousands of cobbles and boulders, many of them covered in plant growth and harbouring invertebrate life, were carefully transplanted from the existing Nith and the captured tributaries to assist with the colonisation of the new channel;

Shaping the new channel within the clay lining

The 'constructed' run-pool-riffle sequence

- a 1-2m wide depression was formed to create the low-flow channel, centrally on straight sections and towards the outside on bends (*figs 11.2.2 and 11.2.3*);
- precautionary stone rip-rap was placed on meander bends to maintain the designed plan-form;
- The bare banks were immediately seeded with a grass mix to reflect the grassy moorland surroundings to maximise vegetation cover before the onset of winter.

Run-pool-riffle sequences were constructed by over-excavating the ground where the pools would be located. When forming the bed, cobbles and boulders were pushed into the graded gravel upstream of the pool, forming a raised bed and a central faster 'run' of water entering the pool.

Some natural erosion of the riverbank was accepted, though the design aimed to restrict the lateral migration of the river outside the clay liner. To further stabilise the banks planting was undertaken, including reeds and grasses along the water margins, and alder, ash and willow alongside the rip-rap.

An extensive programme of electro-fishing was undertaken to transfer fry, parr and other life stages of fish from the length to be diverted to assist with colonisation of the new channel.

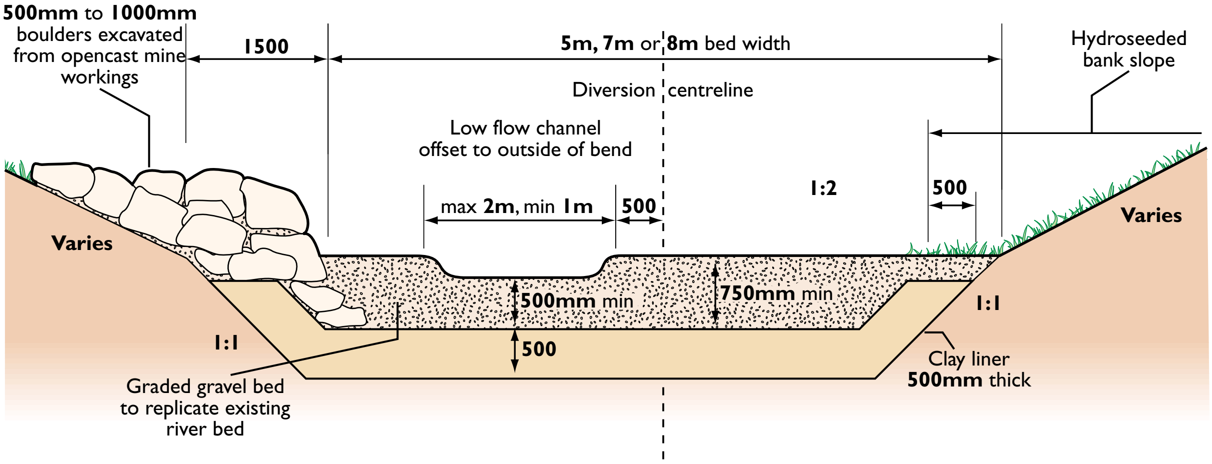
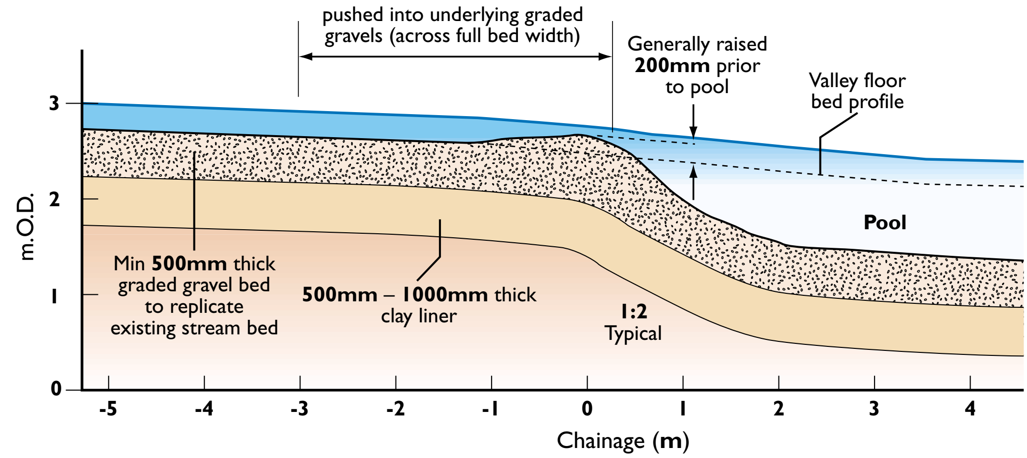


Figure 11.2.3

TYPICAL ASYMMETRICAL CROSS-SECTION

Figure 11.2.4
TYPICAL LONGITUDINAL SECTION THROUGH POOL



One year on and natural redistribution of in-channel sediments is helping to 'soften' the engineered channel

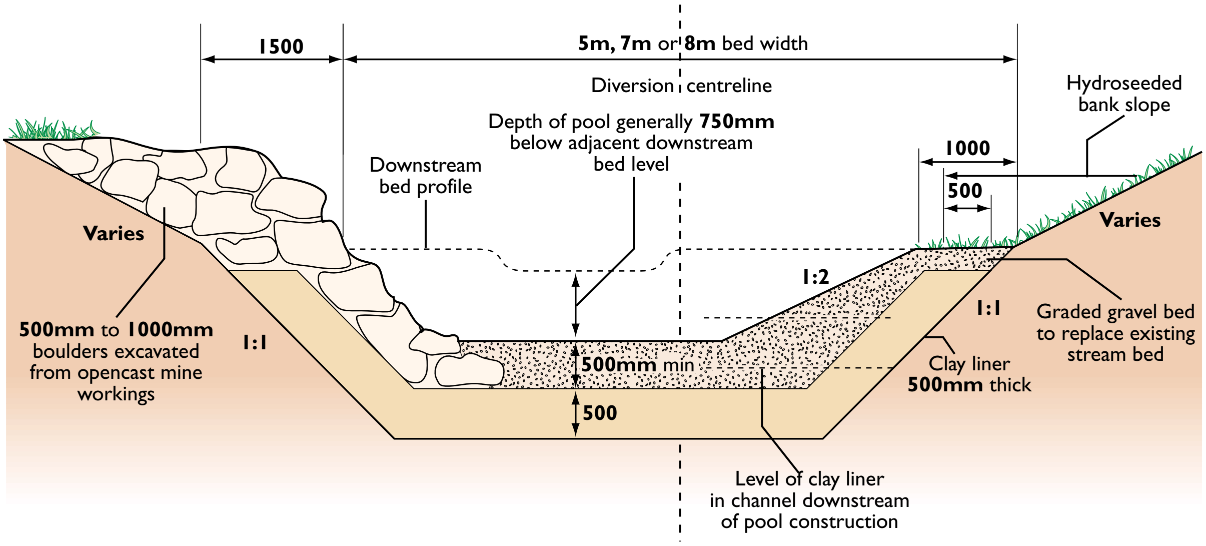
A matrix of wetland and other habitats was established in the new corridor with the intention of creating suitable habitats for a variety of wetland and grassland birds, otters, insects and amphibians.

SUBSEQUENT PERFORMANCE 2000–2001

The ongoing biological and geomorphological performance of the diverted channel is being monitored under a PhD programme at the University of Stirling, sponsored by those sharing responsibility for the construction. A complete picture of the success of the project will only be possible following several more years of monitoring but the signs after twelve months are encouraging.

To date, recovery of the plant and benthic invertebrate communities is progressing well, although some species still remain low in abundance and others, found

Figure 11.2.5
TYPICAL POOL CONSTRUCTION



in the natural river, are absent from the diversion. This relates to low mobility and poor habitat and food availability due to the lack of vegetation. Fish have successfully recolonised the new channel, and the scheme has been hailed a success by the District Salmon Fisheries Board. Some additional planting is to be undertaken along the riverbanks to provide in-stream shelter.

During a 1 in 10 year flood event the channel planform remained stable with only minor bank erosion. Channel change was most apparent near

The overwide channel and plentiful bedload gives the river scope to shape its bed

The rip-rap is still very evident but the in-river form is developing well

tributary junctions; dynamic reaches in natural rivers. The bed material was mobilised, as it was in natural reaches up and downstream, and as a result the constructed low-flow channel was replaced by a natural thalweg. The movement of the bed material resulted in some reaches becoming shallower, and the creation of point bars not in the design, increasing diversity of water depths and velocities.

Sorting of the bed material has deposited finer material on the inside of meander bends, resulting in a more natural appearance than immediately following construction. Minor bed level and bank adjustment is anticipated as a result of further high flows, in the same way as would occur in a natural river, but this will not threaten the integrity of the diversion.

The works has an eight-year maintenance period that will encompass annual inspections and reporting of any erosion control and/or replanting works deemed necessary.

Contacts

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RRC, Silsoe, Beds MK45 4DT, Tel: 01525 863341.

2

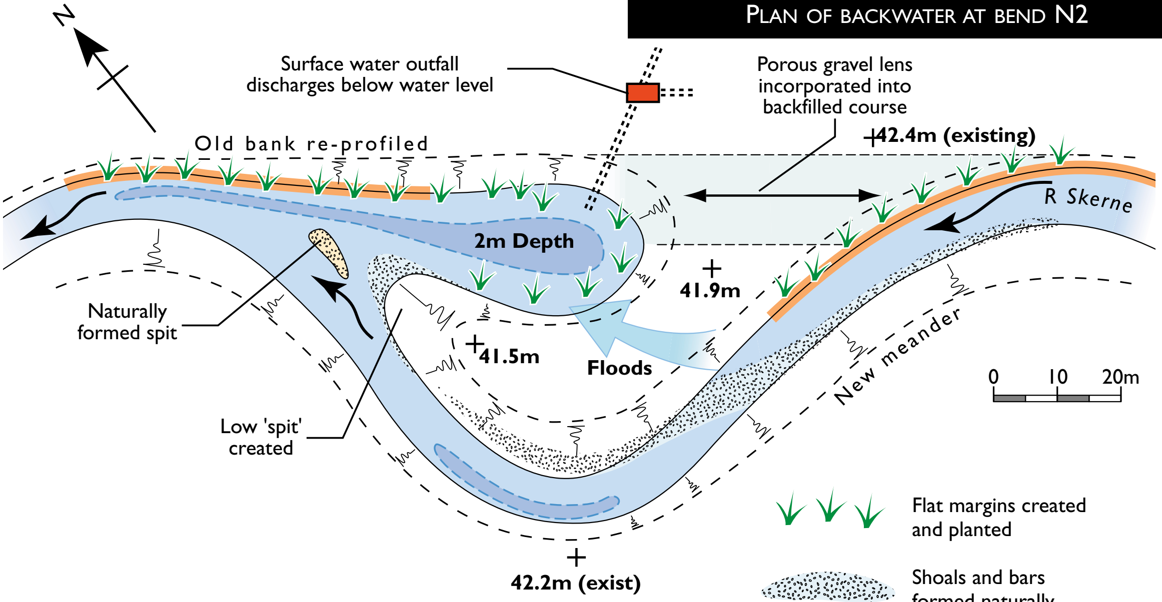
ENHANCING REDUNDANT RIVER CHANNELS

2.1 Creation of backwaters

RIVER SKERNE

LOCATION - Darlington, Co. Durham NZ 301160
DATE OF CONSTRUCTION - Autumn 1995
COST - £3k

Figure 2.1
PLAN OF BACKWATER AT BEND N2



DESCRIPTION

The creation of a new meandering river course, to one side of the existing straight channel, rendered short sections of the latter redundant. At two such sections the old channel was only partially backfilled. The unfilled lengths were enlarged to form backwater areas that are connected to the downstream leg of the new meanders.

DESIGN

The redundant lengths of channel were trapezoidal in section and needed to be enlarged and reprofiled to achieve their full ecological potential. Both were similarly designed - the largest is shown in figure 2.1.

A normal water depth of 2m was needed in the centre to prevent emergent plants from occupying the whole water area. Conversely, shallow depths around the sides were needed to encourage both marginal and emergent plants. The margins also provide a natural safety buffer against children accidentally reaching deep water.

Development of a series of cross-sections to provide the variable depths led to the plan form shown, which is typically 'onion' shaped. The top width is greatest where the excavation is deepest. The effect is exaggerated further by widening the shallow ledges adjacent to the greatest depths.

The hydraulic design of the meander ensures progressive submergence of the backwater during floods. Figure 2.1 indicates the way in which the land between the backwater and the river channel is profiled to ensure that the downstream leg (and the backwater) submerges before floods flow directly across the meander corridor. Floods sweeping over the backwater flow on downstream, merging with the main river flow. The complex currents that result at this stage affect the patterns of sediment deposition at the junction of the backwater with the main river channel. Large eddies inevitably arise, and these can easily cause sediments to settle out right across the junction, eventually closing it off from the river completely. The floodwater currents passing through the backwater help to reduce this risk; it was anticipated that a shallow spit of sediments would form, but not complete close the backwater. The formation of such a spit was reflected in the profiling of the land at the junction.

Following excavation and final profiling, the flat shallow ledges were intermittently planted with appropriate species sufficient to encourage their spread.
A major surface water outfall was also located within the backwater after reconstruction *(see 9.1)*.

A final feature of the backwater is a simulated lens of gravel incorporated into the backfilled original straight channel. Such lenses can occur naturally during the formation of meanders. The purpose of the artificial lens is to encourage a small flow of river water to seep through to the backwater at all times. The amount of flow is dependent upon the difference in water levels between the backwater and the upstream river, which in this location is very small.

SUBSEQUENT PERFORMANCE - 1995/8

The backwaters are a strikingly successful feature of the project. They not only add to overall visual amenity but attract much bird life because of the diversity of habitats especially at the junctions. People are attracted to the backwater to feed the birds which further encourages them. The eddy currents anticipated are much in evidence, and have led to the natural formation of the small spit highlighted. This is a desirable feature that should help to maintain deep water because of the narrowing effect and increased velocity.

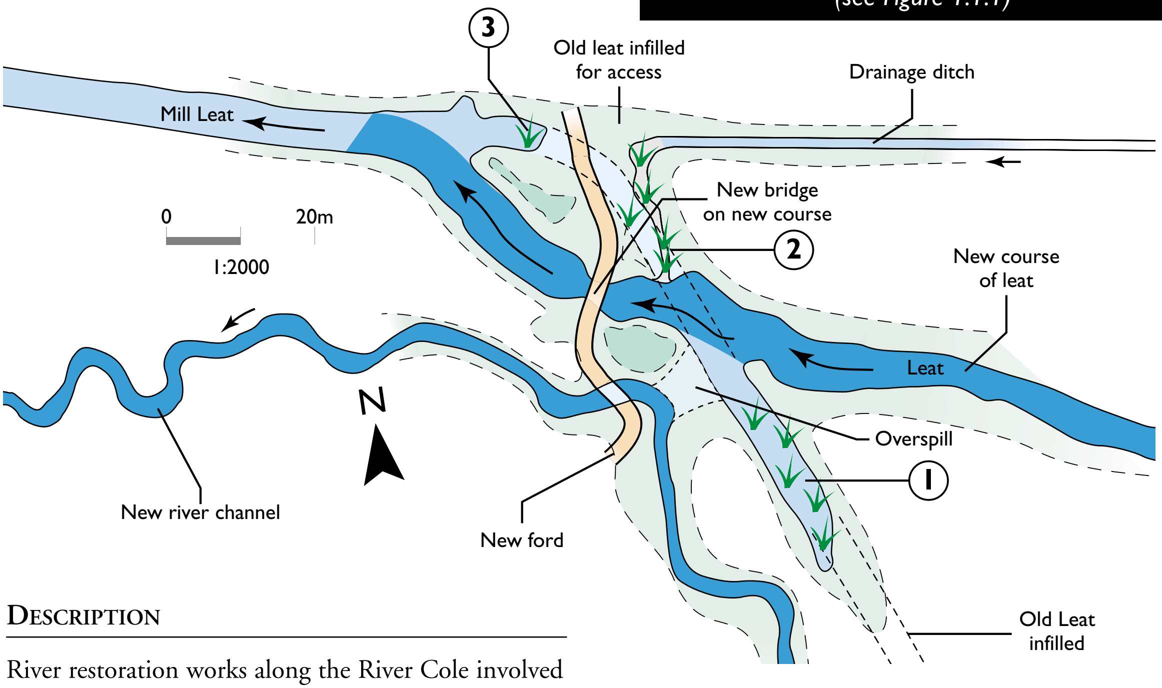
Large Backwater – *November 1996*

2.2 Creation of backwaters

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
COST – No direct costs but additional spoil carted to landform area

Figure 2.2.1
BACKWATERS AT **1, 2, 3** DELINIATE COURSE OF LEAT PRIOR TO NEW BRIDGE AND NEW MEANDER IN LEAT
(see Figure 1.1.1)



DESCRIPTION

River restoration works along the River Cole involved re-routing the river from its straight course into new meandering channels *(see 1.1 – 1.3)*. Remnants of the old river course were incorporated into the overall restoration as backwaters at 3 locations and as a bay at another location.

DESIGN

Each feature created is uniquely different, but all are based upon the common principle of only partial backfilling. This also avoids the need to revet or support backfill where it would otherwise abut the new channel.

Backwaters on mill leat (fig. 2.2.1)
A new bridge was built 'in the dry' before completing the diversion of the leat and backfilling the old course *(see 8.2)*. Backfilling was limited to providing a link to the new bridge, leaving the lengths denoted **2** and **3** on the figure open to the river. Backwater **2** is linked to a drainage ditch which backs up with river water when the leat rises, creating a reversal of flow into other parts of the drainage system, which in turn contributes to the seasonal flooding of fields. The bed of this backwater has been raised to just below normal water level to sustain a marshy aquatic habitat. In contrast, backwater **3** remains as open water with marginal ledges and willows.

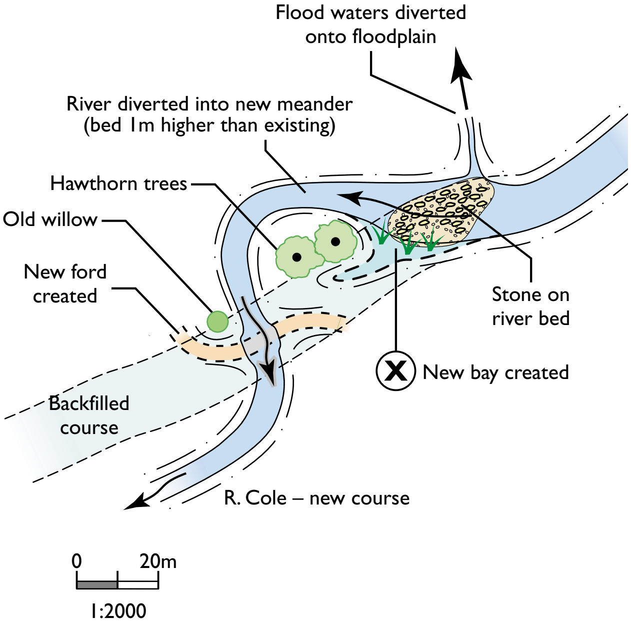
Backwater **1** was created after excavating a new meander in the leat *(see 1.3)*. It is an unfilled length of the old leat which was enhanced by removing the embankment from the left side so that rising floodwater could overspill to merge with floodwaters in the new river channel adjacent to it.

Backwater **1**

New bay at start of lower meanders (fig. 2.2.2)
The new meandering channel is smaller than the existing channel upstream and its bed is elevated c. 1m higher. As a result, water in the upstream channel is impounded and slow moving which contrasts with a marked increase in velocities within the new channel. The design of the junction of the old and new channels reflects these hydraulic conditions. The risk of downward scour of the new bed was alleviated by backfilling the existing channel bed where it abuts the new and adding a layer of stone to create a secure transition. To complete the diversion, the old channel was backfilled in a manner that created a small marshy bay within which the slower moving floodwaters approaching the new meander can eddy freely before entering it. This was preferable to complete backfilling and having to revet the fill to resist erosion.

Opposite the bay, an old drainage ditch entered the river. This was incorporated and enlarged to enable floodwaters to pass freely from the river out onto the lowest part of the floodplain, remote from the main river course. As a further safeguard against downward erosion of the new river bed, a stone ford was created 80m downstream where the new channel crosses over the line of the original *(see Part 8)*. This ford acts like a small weir and therefore 'fixes' both bed and normal water levels upstream.

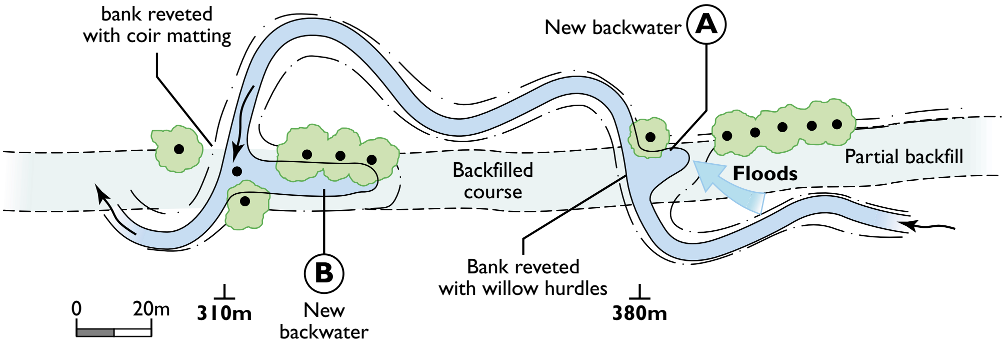
Figure 2.2.2
NEW BAY AT START OF LOWER MEANDERS
(For location see Figure 1.2.1)



View of shallow bay **X**

ENHANCING REDUNDANT RIVER CHANNELS

Figure 2.2.3
BACKWATERS ON LOWER MEANDERS AT CH 310m AND 380m
(see Figure 1.1.1)



Backwaters within lower meanders (fig. 2.2.3)
Two backwaters were created where the new course crosses over the old course. One is much larger than the other, and each is different in nature.

Backwater **A** is located where backfilling of the old channel was kept to a low level so that a valuable line of old river bank trees were not buried. The new river channel approaching the backwater marks the inside of a meander, necessitating further lowering of ground levels, with the result that floodwaters regularly sweep across it to enter the backwater as indicated. This flood flow sustains open water in the backwater as well as shoal deposition, creating varied off-river habitat.

Backwater **B** contrasts with **A** in that the retained trees along the old course all overhang open water and the new channel approaches from behind the trees rather than towards them. The hydraulics are entirely different as a result. The old river bank, behind the trees, remains at a high level preventing any floodwater from passing into the backwater save for small volumes that occasionally pass over the infilled length of channel. The backwater is thus a quiet refuge of still water, and hydraulic interaction with the river is limited to rise and fall of water levels.

The river banks opposite the mouth of each backwater were formed from backfill right up to the new channel profile after infilling of the old river bed. Each was reveted *(see 4.6).*

Small backwater **A**

Large backwater **B**

SUBSEQUENT PERFORMANCE 1995/8

The new backwaters and bay all add considerably to the overall ecology and landscape amenity of the restored river. Each represents a unique habitat feature created at virtually no direct cost. Savings on the cost of revetment were, however, offset by the need to haul surplus soil to nearby landform areas rather than simply infilling *in situ*. The value of the features created more than justifies the cost of haulage involved.

3

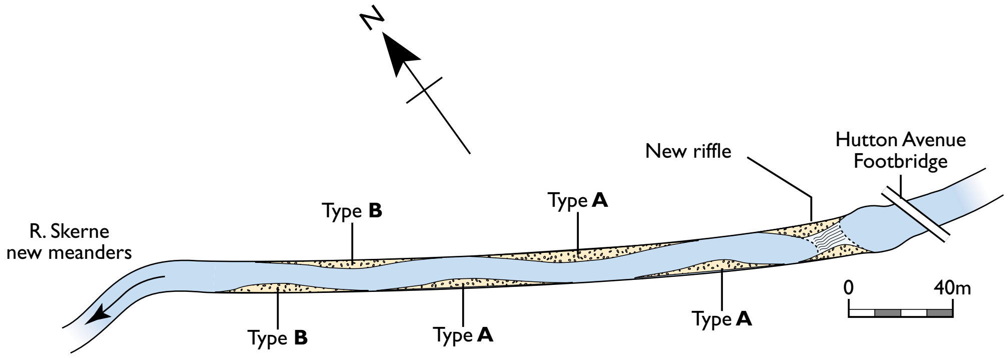
ENHANCING STRAIGHTENED RIVER CHANNELS

3.1 Current deflectors

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – August 1995
COST – Type A - £1100 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

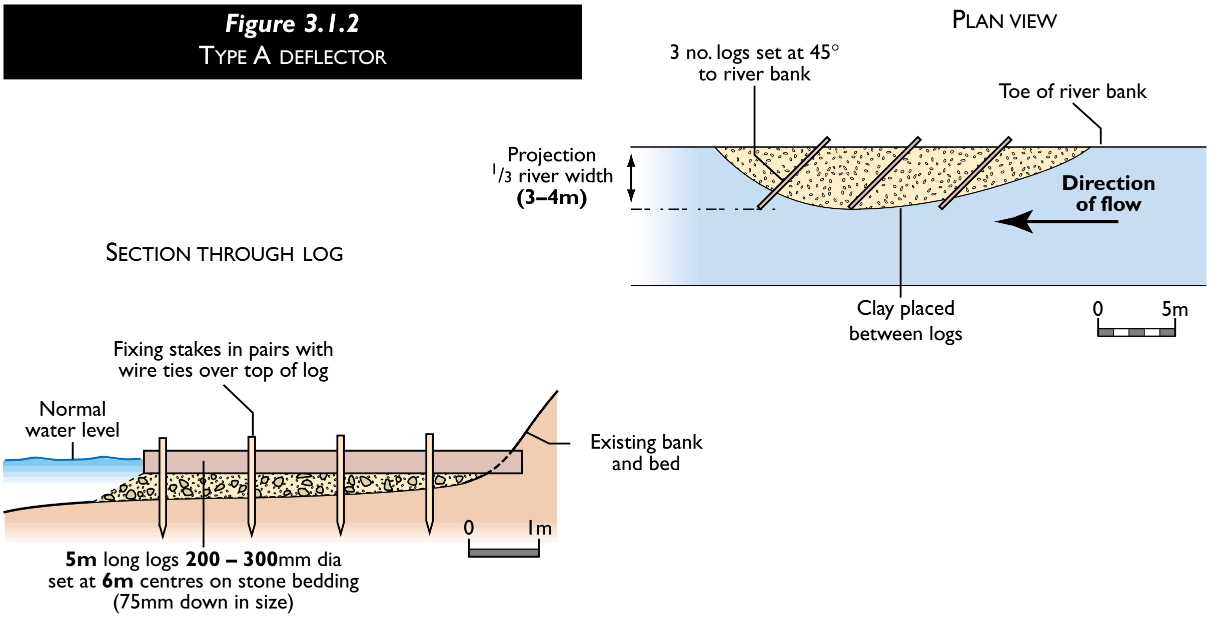
A series of artificial shoals were built, projecting up to one third of the way across the river bed (3m shoals in 9m bed). The shoals were semi-eliptically shaped in plan and elevated above normal water level by only a small amount. Their spacing along the reach varied, but they were placed on alternating 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 *(fig. 3.1.2)*, whereas those of 'type **B**' *(fig. 3.1.3)*, point upstream. This was done to help determine the most effective alignment for future application of the technique.

Figure 3.1.2
TYPE A DEFLECTOR



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.

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.

Type A deflector
– vegetation established

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 1995/98

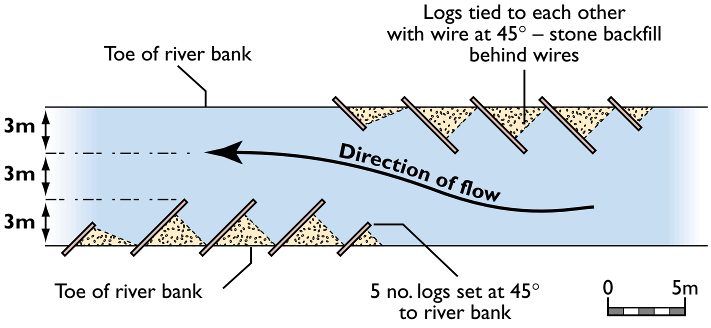
Whilst the deflectors have added a useful degree of diversity to the reach, this was not achieved without post-works modification following reaction by the river to their imposition; particularly those of 'type A'.

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.

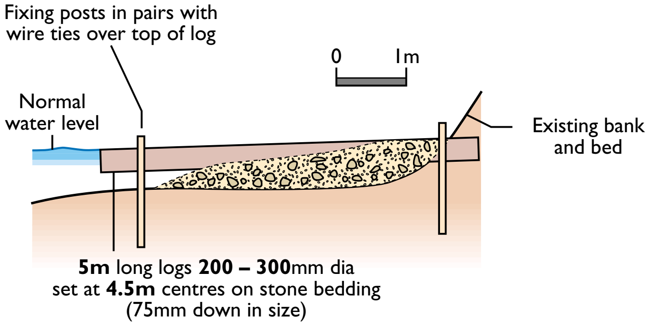
Type B deflector before planting

Figure 3.1.3
TYPE B DEFLECTOR

PLAN VIEW



SECTION THROUGH LOG



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 3.2).*

ENHANCING STRAIGHTENED RIVER CHANNELS

3.2 Narrowing with aquatic ledges

A) RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – Type A – Autumn 1997, Type B – Autumn 1998
LENGTH – 320m
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 *(fig. 3.2.1)*. The ledges created were either planted with pre-grown materials or left to colonise from planting introduced nearby.

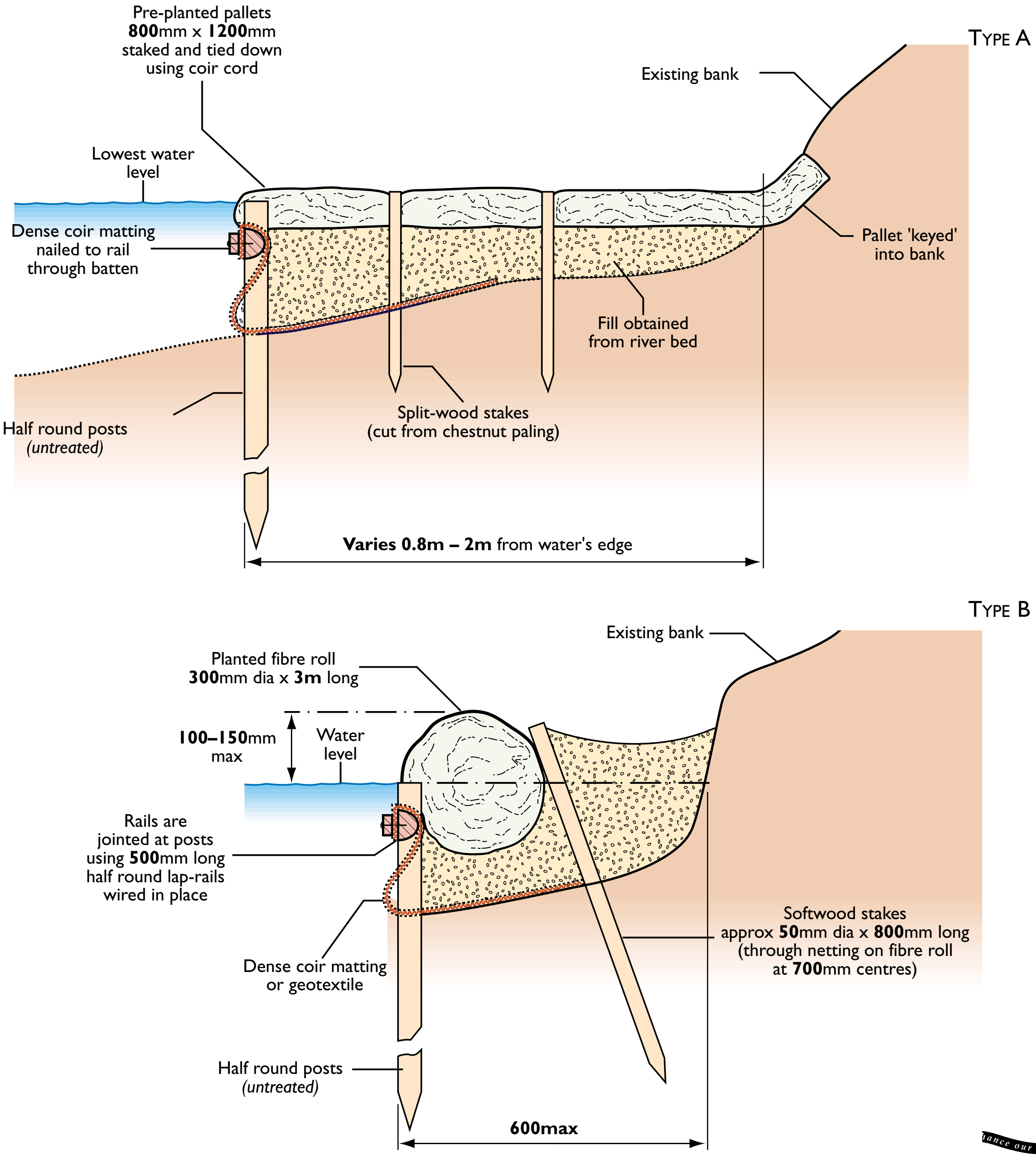
Type **A** design is suited to wide ledges (up to 2m at this site) but the width can be varied to introduce curvature to the plan alignment.

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
SECTIONS THROUGH TYPE A AND
TYPE B LEDGE DESIGNS



Type A Ledge on the Skerne – May 1998

SUBSEQUENT PERFORMANCE 1996/8

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

B) RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1997
COST – £56/metre

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 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 1997/8

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.

Type A and B ledges on the Cole after one winter

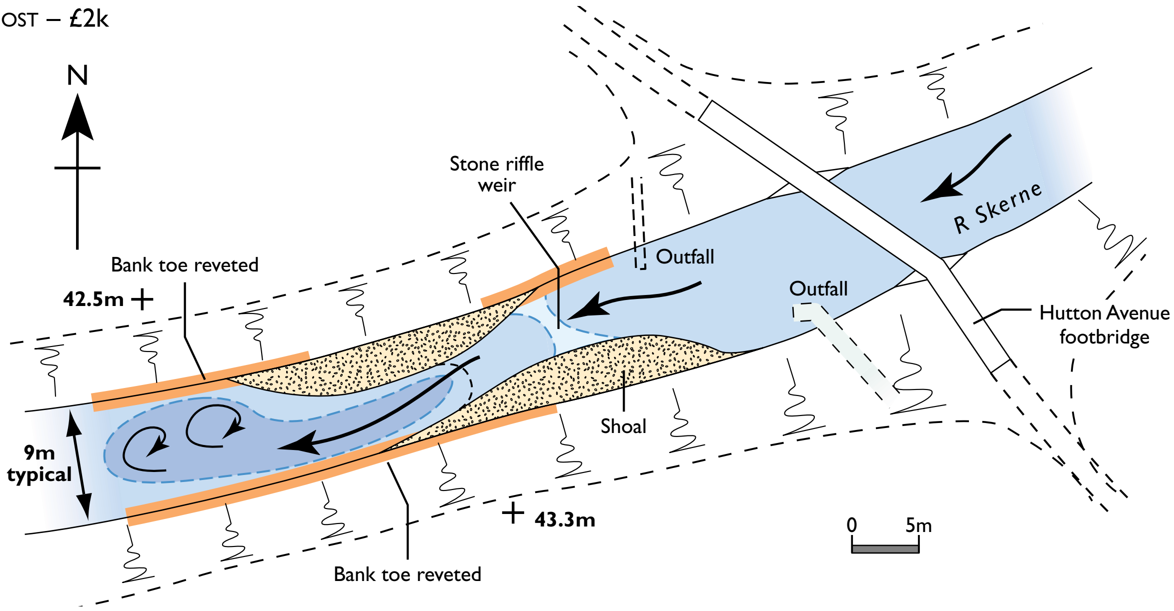
Prior to re-profiling and ledge construction – May 1996

3.3 Stone riffle

RIVER SKERNE

LOCATION – Darlington, co Durham, NZ 301160
DATE OF CONSTRUCTION - August 1996
LENGTH – 60m
COST – £2k

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 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 where 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 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.

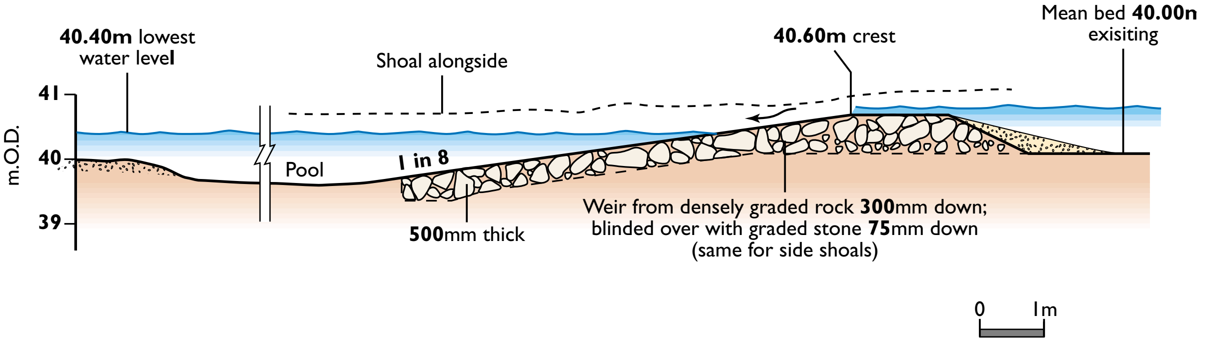
Stone Riffle downstream of Hutton Avenue footbridge

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,

Figure 3.3.2
SECTION THROUGH WEIR



faster flow of water around the downstream shoal that noticeably 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.

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 – 1996/8

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.

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

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

RIVER ALT

LOCATION – Knowlesley, Liverpool, Merseyside SJ 435927
DATE OF CONSTRUCTION – 1996
LENGTH – 140m
COST – £40,000

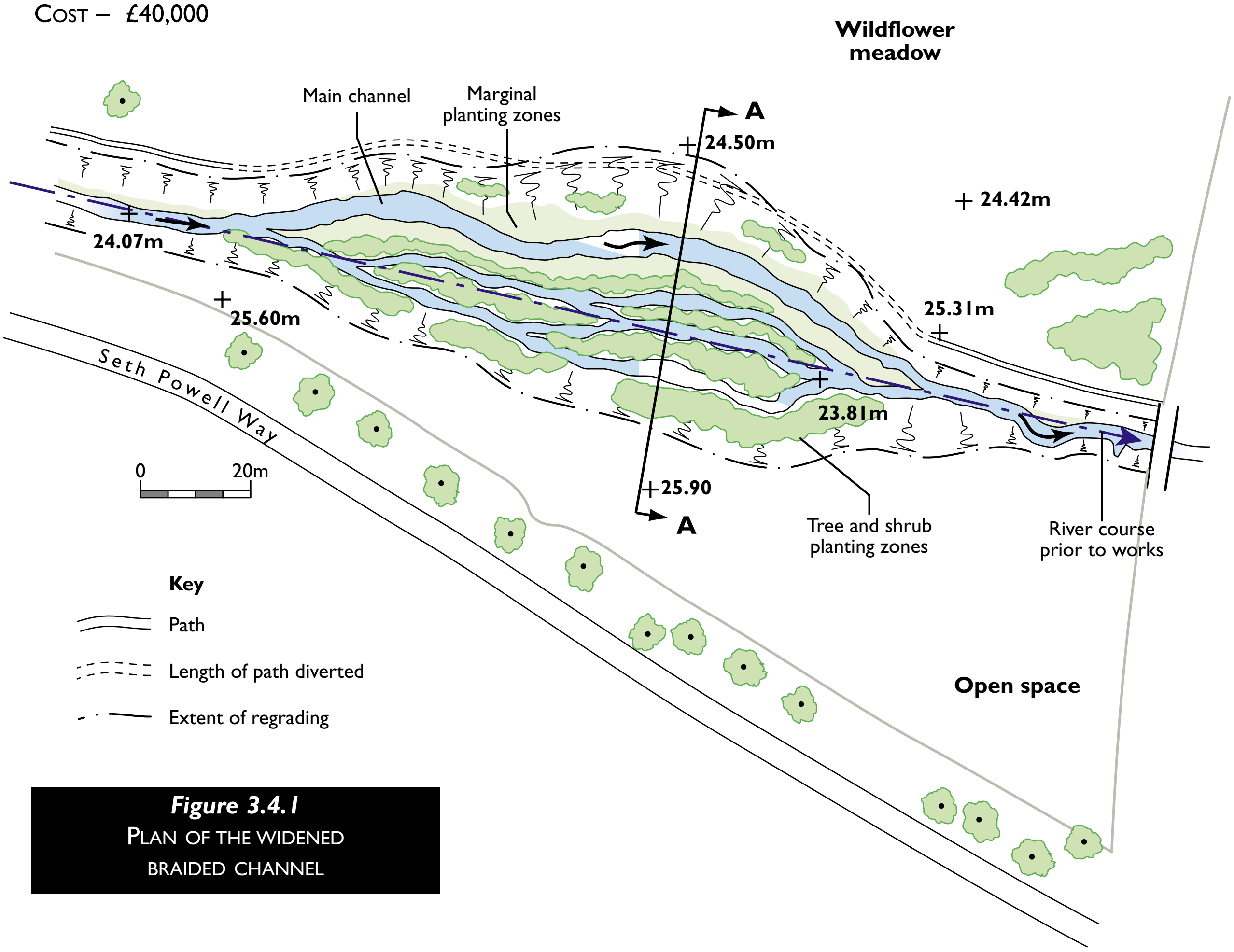


Figure 3.4.1
PLAN OF THE WIDENED BRAIDED CHANNEL

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

Trees, shrubs and marginal plant species

Trees at 2m centres	Shrubs at 1m centres	Marginals at ~ 4/m²
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 600-900mm, 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

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.

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

The excavated ‘floodplain’ area

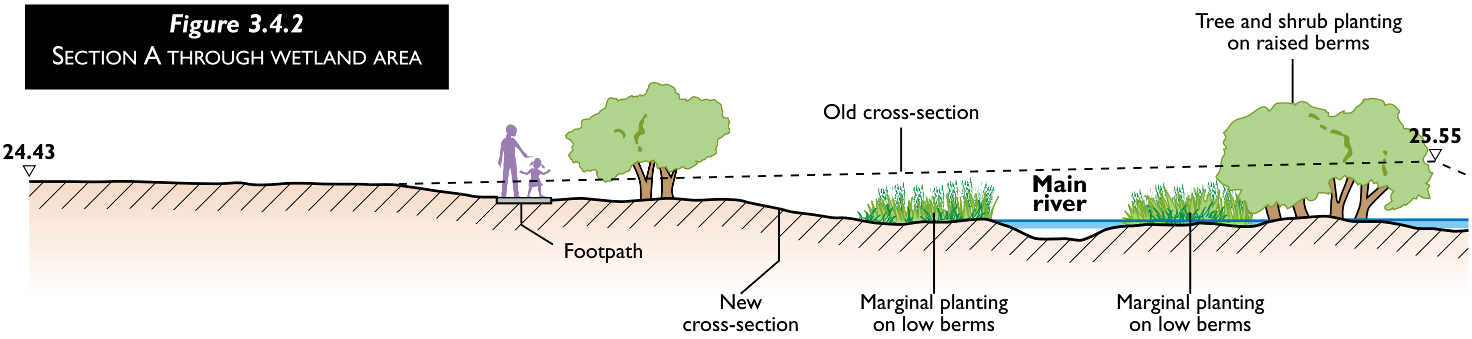
route, and was located along the left bank, nearest to the footpath route. It was accepted that high flows would possibly alter this pattern and that such natural changes could take place due to the excess flood capacity within the new ‘floodplain’.

The 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 (9000m^3) ‘floodplain’ excavation. The nearby school planned to build an earth bank to prevent illicit vehicle access to its playing fields. By using 6000m^3 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 has increased markedly.

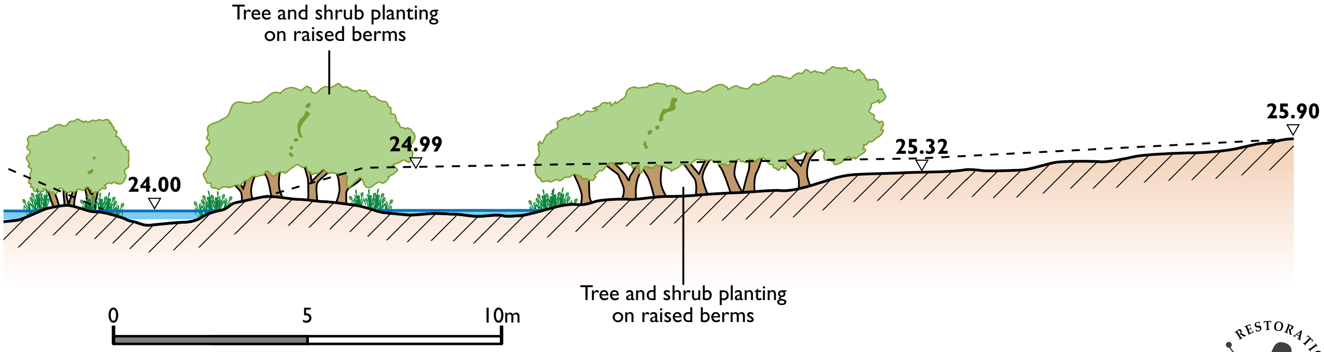
Anecdotal evidence suggests that people are happy with the scheme. However, there is also evidence that some people were expecting something different. A short study is due in 2001 looking at the public response to the scheme.

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.

Contact:
Neil Guthrie, Environment Agency – North-West Region,
Lutra House, Dodd Way, Walton Summit, Bamber Bridge,
Preston PR5 8BX, Tel: 01772 339882.

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

Wetland Area



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

RIVER AVON

LOCATION - Stratford-Sub-Castle, Salisbury, Wiltshire
SU 127327
DATE OF CONSTRUCTION - October 1997
LENGTH – 125m
COST - £2000 (excluding fencing)

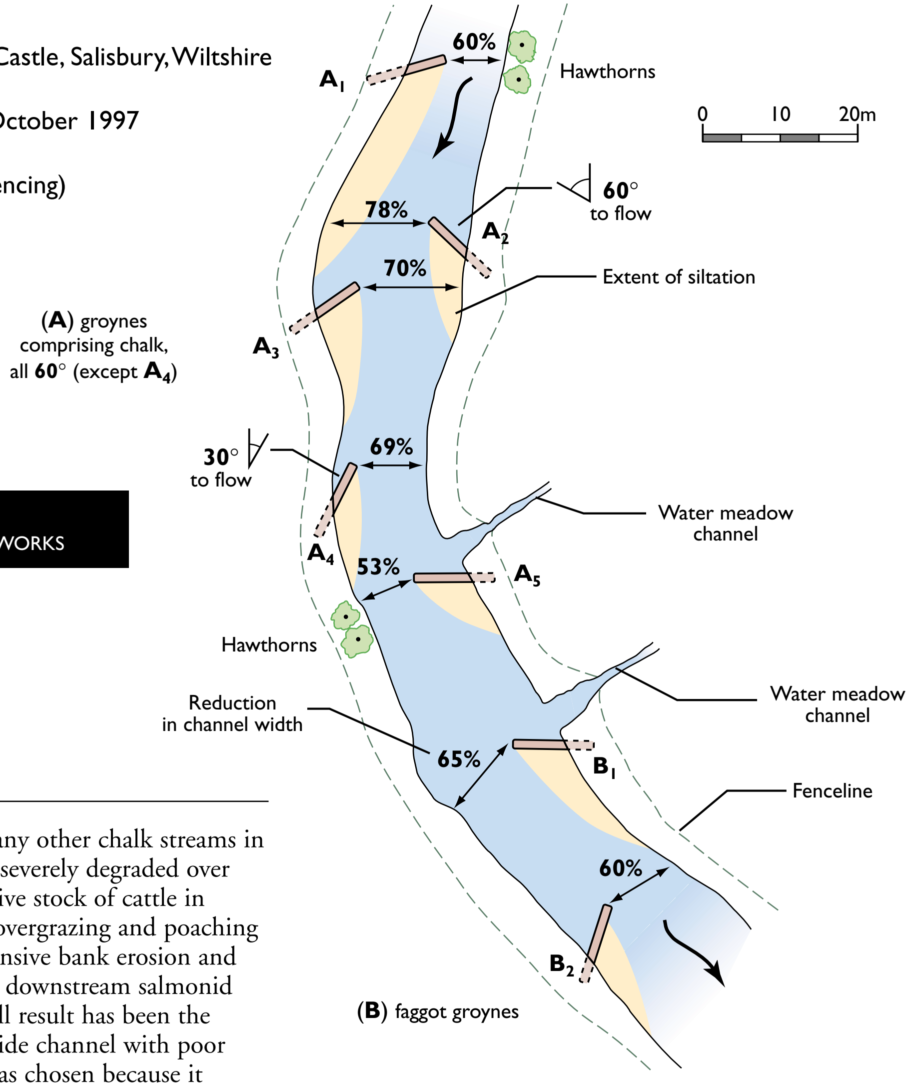


Figure 3.5.1
PLAN OF NARROWING WORKS

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, 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 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.

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 7 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.

Digging the groyne trench

Figure 3.5.2

SECTION THROUGH CHALK GROYNE

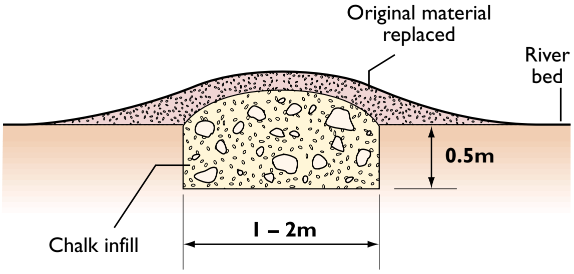
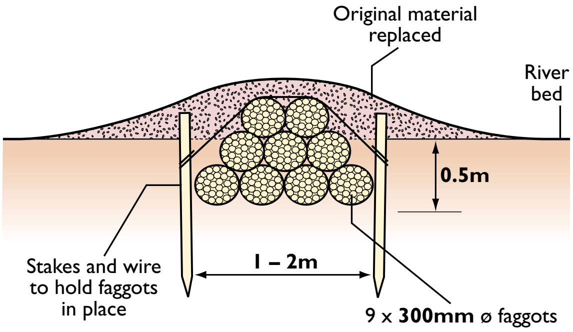


Figure 3.5.3
SECTION THROUGH FAGGOT GROYNE



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 salmon and trout for spawning.

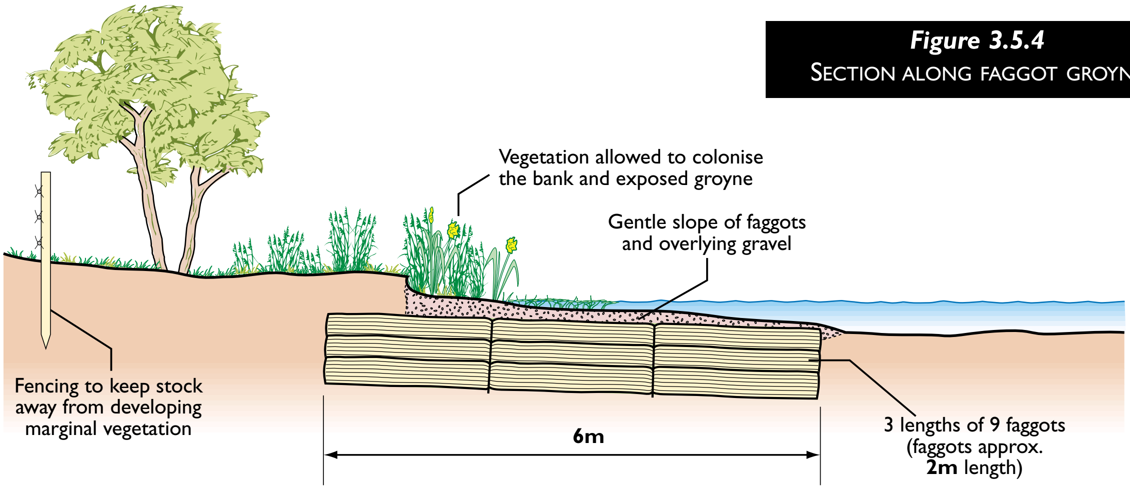
The desired accretion of material up and downstream of the groynes began soon after installation was completed. Particle sizes indicate a good mix of fine silt and organic material to coarse sand and gravel. This habitat has been colonised by a variety of submerged and emergent vegetation and is providing 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, 1 and 3 year post-works survey data on physical habitat and flow, fish population, macrophyte observations and macro-invertebrate community sampling.

Six months of siltation

Figure 3.5.4
SECTION ALONG FAGGOT GROYNE



Cattle poached, wide and shallow

Groynes in place already increasing flow diversity

Silt deposits were quickly colonised and the river narrowed

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. Macro-invertebrate diversity was not influenced by the rehabilitation work, and fish population density and diversity improved.

Contacts

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Tel: 01258 456080.

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

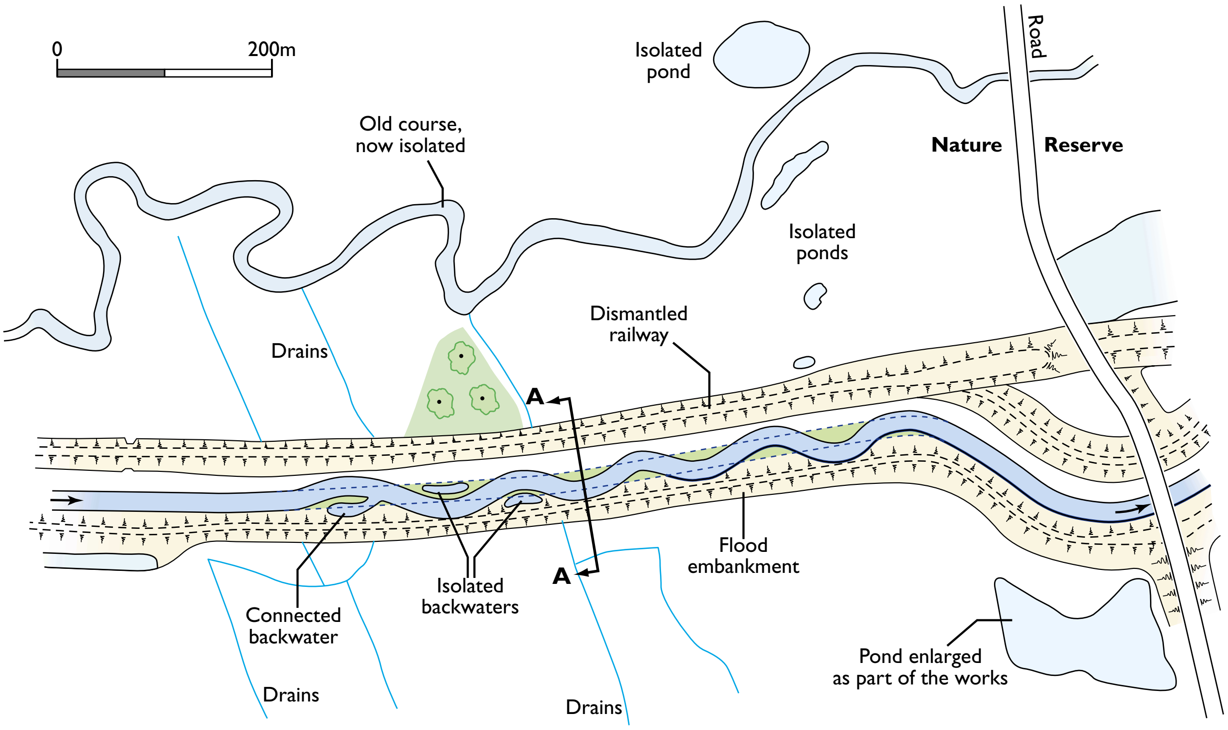
3 ENHANCING STRAIGHTENED RIVER CHANNELS

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

RIVER DEARNE

LOCATION – Mexborough, West of Doncaster, South Yorkshire SE 484012
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 1970's to ensure efficient evacuation of floodwater. The design standard for the channel was calculated to be approx. 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 floodbanks. 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 an 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 1980's 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 (mainly chub and dace) 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 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.

River Dearne. Wide and straight, choked in summer

New sinuous reed-fringed course

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.

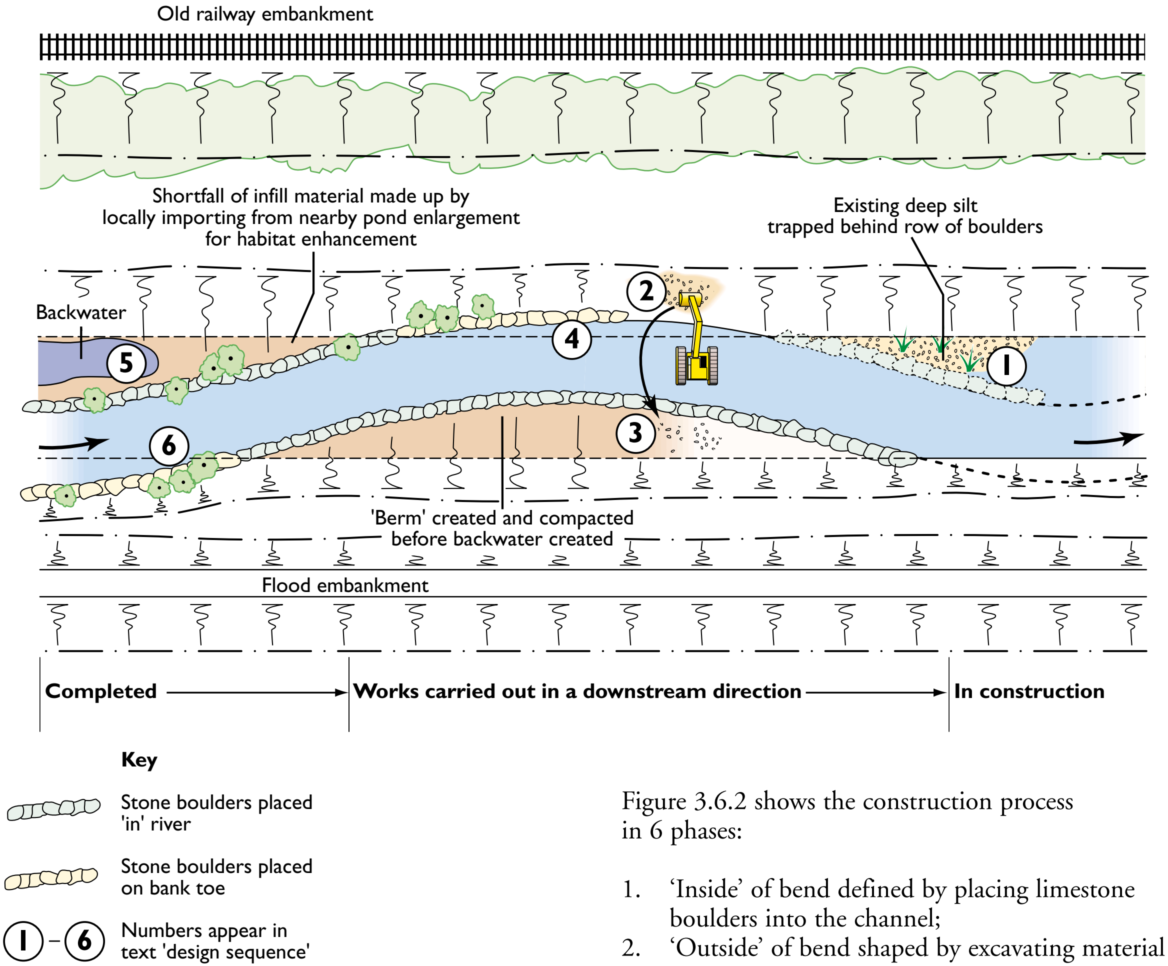
DESIGN

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 300 and 700mm. Work started upstream and looked initially to increase velocities in the first two bends to 0.5 m/s, reducing the increase to near existing flows (approx. 0.2m/s) at the final bend.

Placement of limestone boulders and berm back-filling

Figure 3.6.2
PLAN OF WORKS

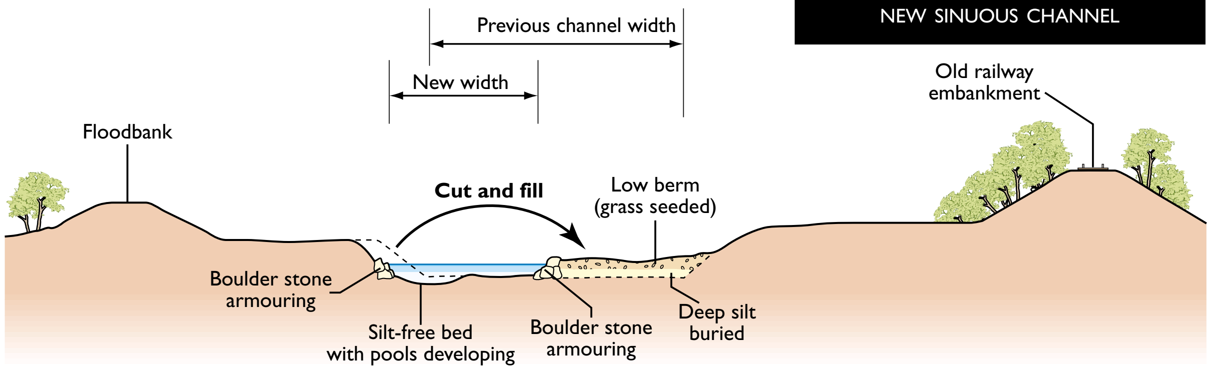


In this way the narrowing of the low-flow channel was determined by a combination of estimating the reduction required and measuring the velocity after placement of the boulders.

Figure 3.6.2 shows the construction process in 6 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 A THROUGH NEW SINUOUS CHANNEL



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.

Main channel and backwater
5 years on, Summer 2000

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, dace, barbel, roach and gudgeon 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 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 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 100mm dia. 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.

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THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

ENHANCING STRAIGHTENED RIVER CHANNELS

3.7 Replacing a concrete drain with a 'natural' channel

YARDLEY BROOK

LOCATION - Shard End, South-east Birmingham SP 118198
DATE OF CONSTRUCTION - March 1995
LENGTH – 100m
COST - £5,000

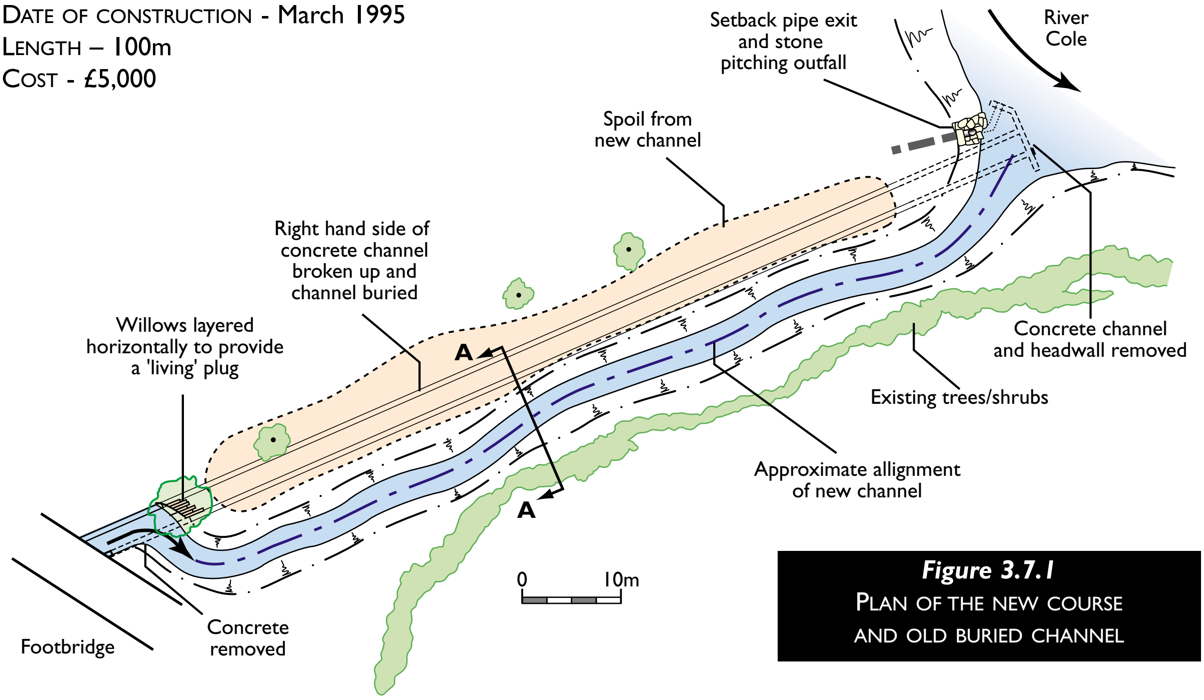


Figure 3.7.1
PLAN OF THE NEW COURSE AND OLD BURIED CHANNEL

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 c.30 years ago. 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

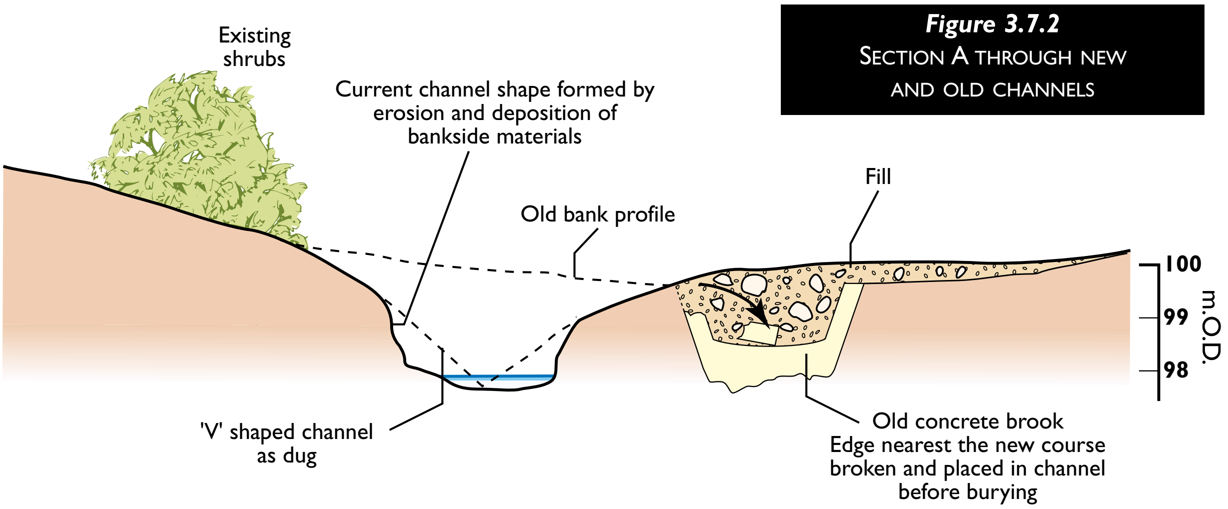
The lip of the concrete channel was broken up using an excavator, to ensure that once buried the remnant channel would not protrude above ground level. The broken concrete was pushed into the barely flowing channel.

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 approx. 700mm 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.

All spoil was stock-piled between the new and the old channel, and where this became too narrow, on

Concrete channel being broken up

Figure 3.7.2
SECTION A THROUGH NEW AND OLD CHANNELS



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

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

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 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.

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

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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

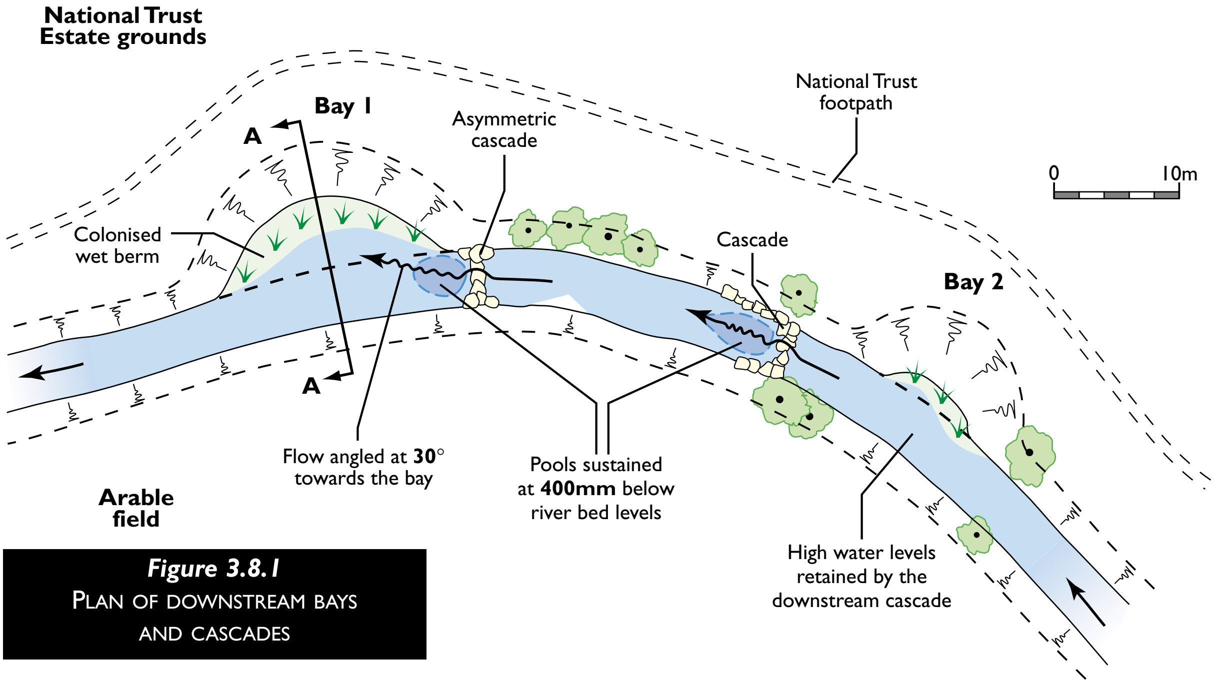

Figure 3.8.1
PLAN OF DOWNSTREAM BAYS AND CASCADES

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 1960's, 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 to 4m) (*figure 3.8.2*).

The stone cascades were constructed from 500mm+ 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 1995 – 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

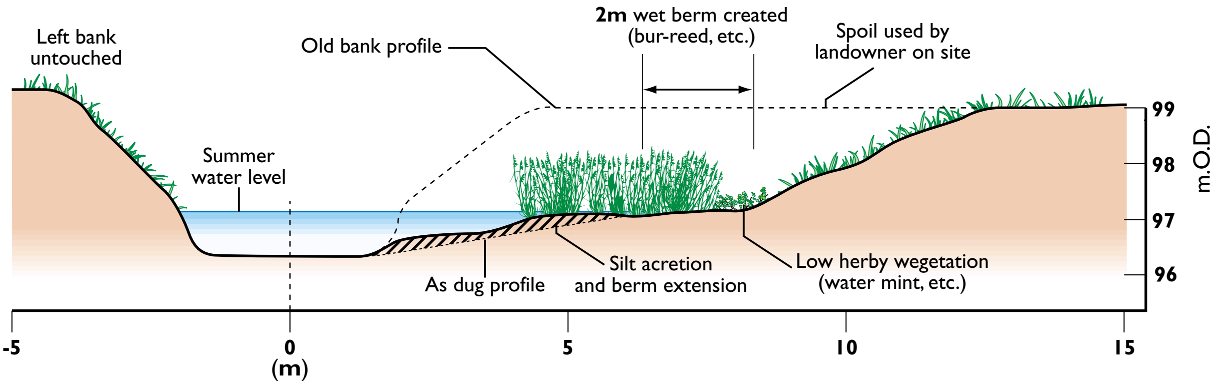

Figure 3.8.2
SECTION A THROUGH BAY 1

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

the water's edge, but the stocking densities are low enough not to be of concern. Grazing maintains a cropped but diverse macrophyte margin.

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) is dominating.

Bay 1 (*figure 3.8.1*) 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, approx. 30 degrees offset from the main channel. This directional flow is helping to maintain the bay at low and high flows.

Bay 2 (*figure 3.8.1*) 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.

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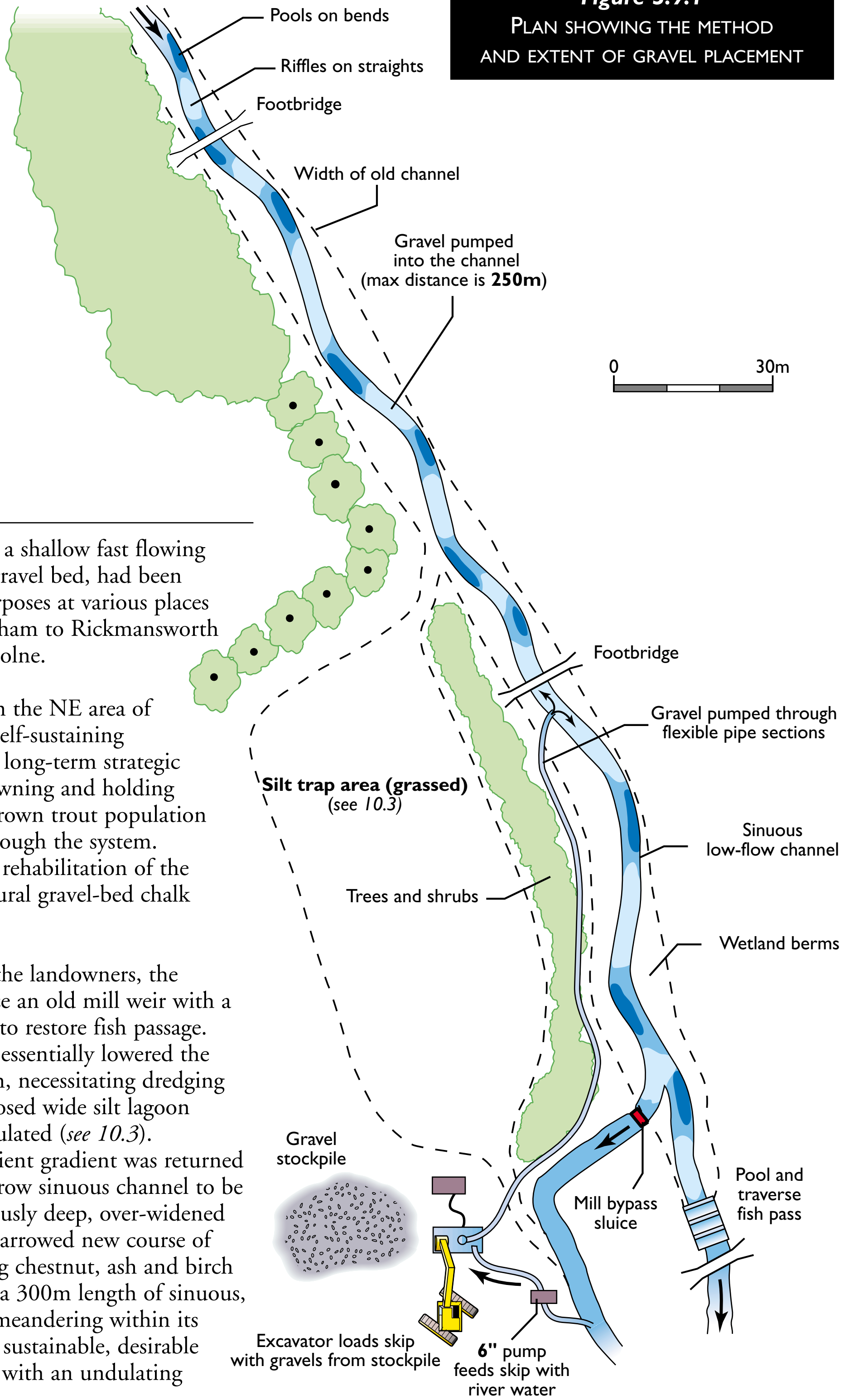
3.9 Introducing gravel to inaccessible reaches

RIVER CHESS

LOCATION - Blackwell Hall, Latimer, Buckinghamshire SU 980997
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 Thames Region to have a self-sustaining brown trout 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 10.3*).
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 300mm 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.

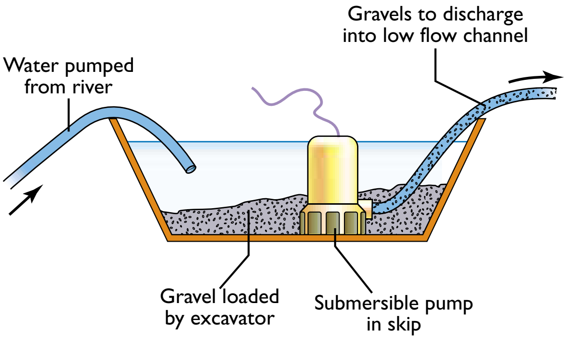
DESIGN

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 6” 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

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 5.5 for more detail on bed raising)*.

SUBSEQUENT PERFORMANCE 1995 – 2001

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

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Four years on
– gravel shoals and
deeper hollows remain

REVETTING AND SUPPORTING RIVER BANKS

4.1 Willow spiling

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – November 1995 and May 1996
LENGTH – 75 metres
COST – £115/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)

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.

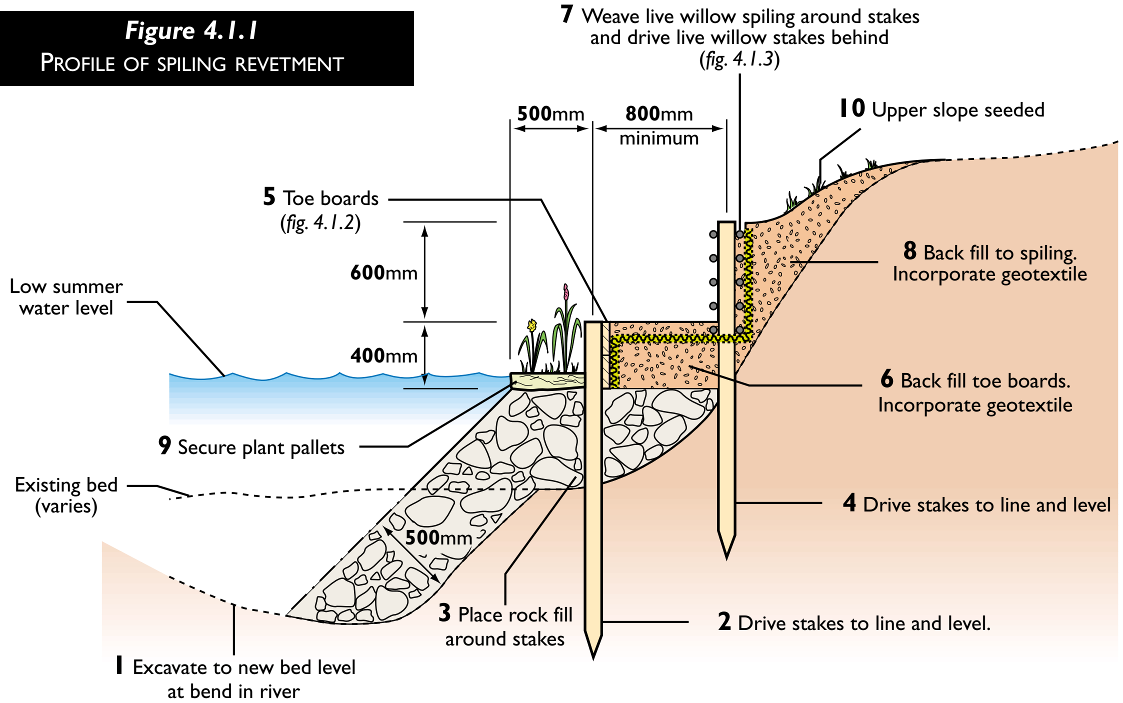
The technique often utilises osier willow because of its prolific production of long, slender, pliable poles suitable for weaving. Other species are less suited to weaving so the availability of indigenous river bank willow for spiling may be limited and other techniques might be more appropriate *(see 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 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

Figure 4.1.1
PROFILE OF SPILING REVETMENT



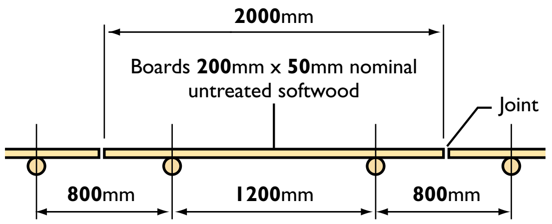
and the toe boarding to help stabilise the soil back filling which follows;

- 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.

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.

Figure 4.1.2
PLAN OF TOE BOARDS

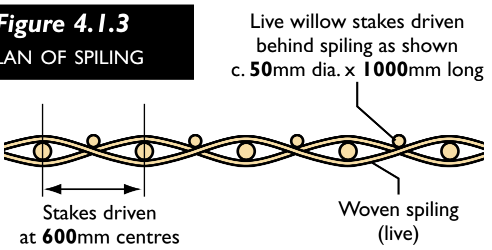


This technique does not have the intrinsic flexibility to accommodate bank settlement that is a feature of techniques 4.2 and 4.3 because it is, in essence, a vertical retaining wall. It is, however, less demanding of space which is sometimes advantageous.

SUBSEQUENT PERFORMANCE 1995/98

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 4.1.3
PLAN OF SPILING



4.2 Willow mattress revetment

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
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

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 (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 '300mm down' matrix to the following specification:

aGeneral 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

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, 50-100 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.

Ward *et al*, 1994. *New rivers and Wildlife Handbook*. RSPB, Sandy – case study 3.7c – River Clwyd, North Wales.

SUBSEQUENT PERFORMANCE 1995/98

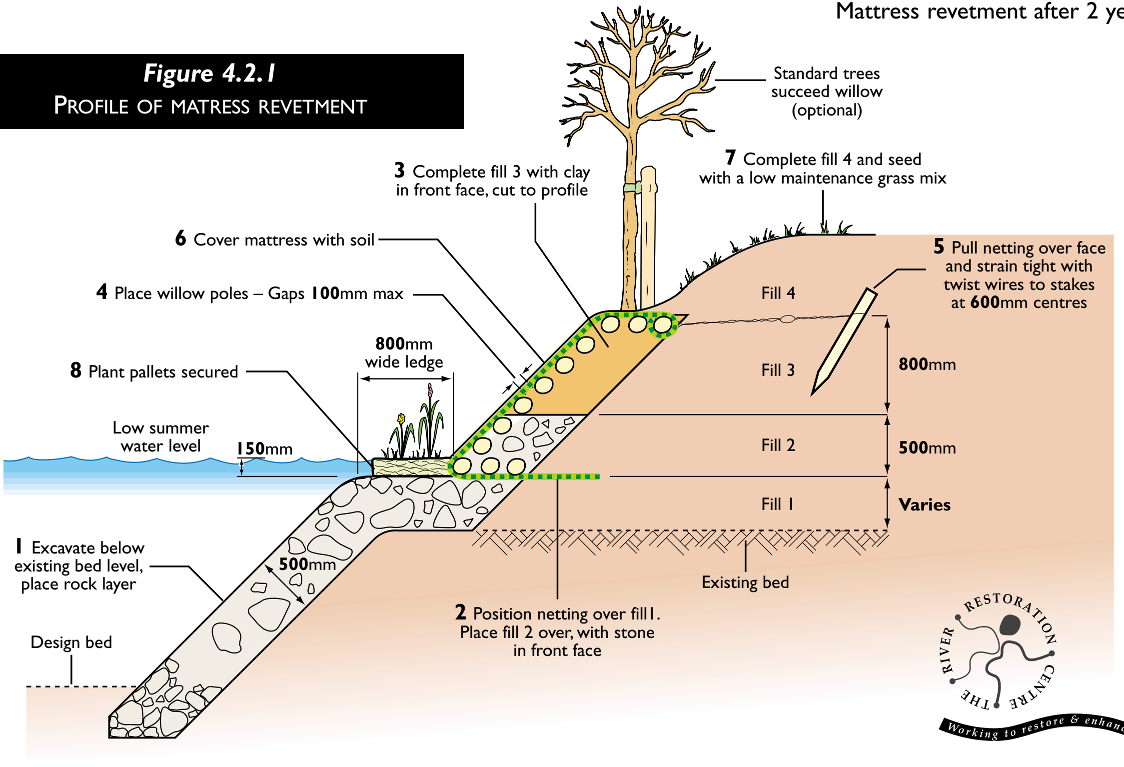
The revetment has remained stable, and dense willow growth up to 3m high covers the bank. Marginal sedge and iris complete what is a most desirable habitat niche favoured by water voles and birds.

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.

Mattress revetment after 2 years

Figure 4.2.1
PROFILE OF MATRESS REVETMENT



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

REVETTING AND SUPPORTING RIVER BANKS

4.3 Log toe and geotextile revetment with willow slips

River Skerne

LOCATION – Darlington, Co Durham, NZ 301160
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 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 500mm 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.

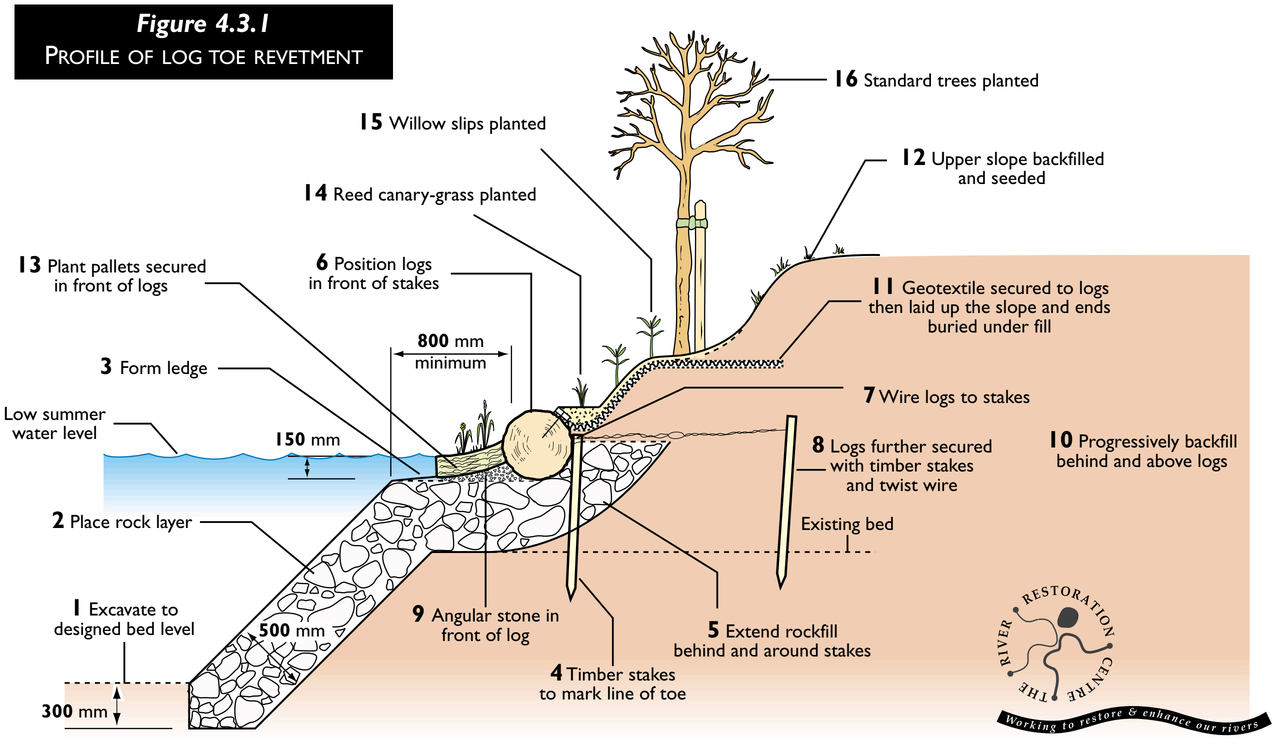
This mixture of plants is intended to be successional. Whilst the willow will quickly dominate the lower banks, as roots penetrate the underwater rock, the standard trees may eventually dominate the willow, particularly if this is regularly coppiced.

SUBSEQUENT PERFORMANCE 1995/98

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



4.4 Plant roll revetment

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
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 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.

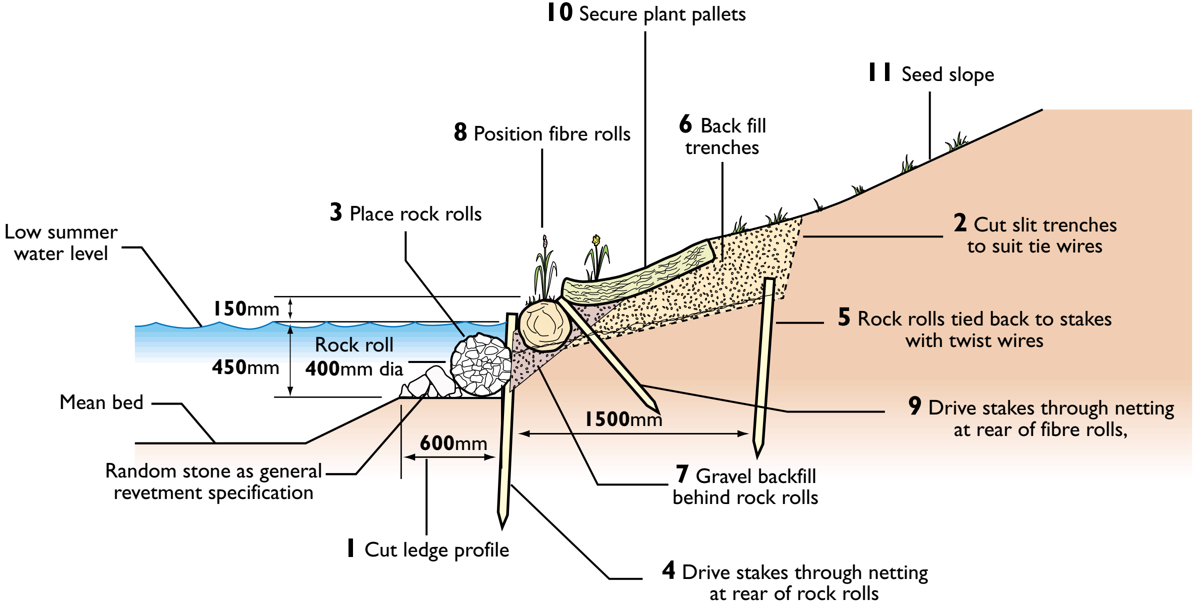
The toe of the bank needs to be permanently damp for this to be worthwhile, which is most likely in situations where undercutting has already occurred and the bank toe is being reinstated, e.g. through boat wash.

SUBSEQUENT PERFORMANCE 1995/98

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



4.5 Supporting bank slips and exposed tree roots

River Skerne

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – October 1995 / November 1996
LENGTH – 40 metres, 9 metres
COST – Bank Slip £3k, Tree Roots £400

Slipped slope during work – September 1995

DESCRIPTION

Slipped slope
During works, water seepage from gravel at the bottom of a newly excavated river bank caused it to slip. As the bank was close to bunded industrial fill, repair was necessary. The route of a proposed footpath was also at risk if this bank remained unstable.

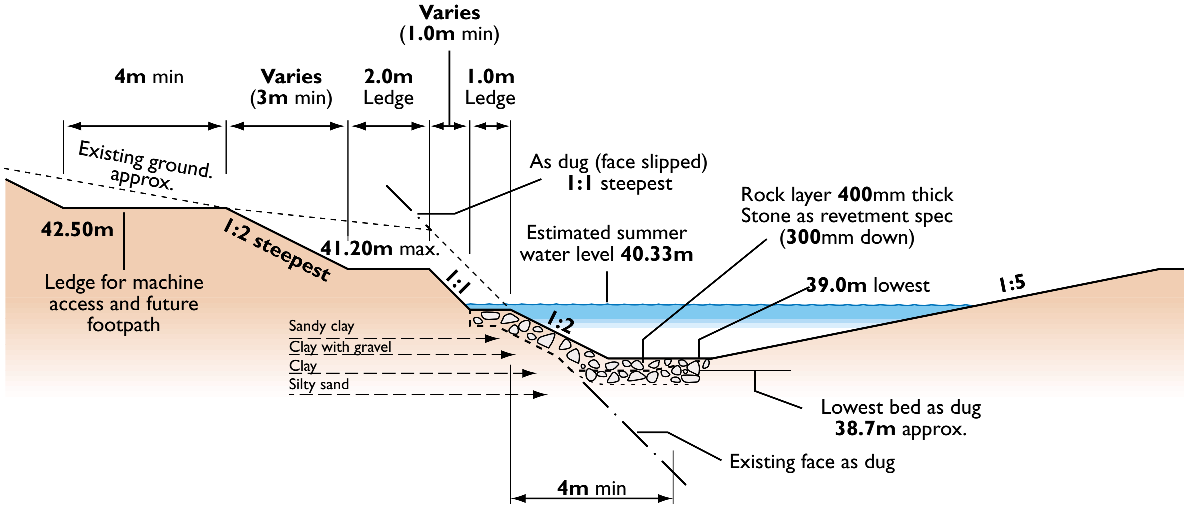
Exposed roots
The roots of a mature willow had been exposed during river bank re-profiling works and were being undermined by high flows and damaged by people. Although in no immediate danger, this tree had become an important resting place, providing the only shade along this bank. Positioned on the apex of a meander, it was decided to protect the roots using a simple revetment.

DESIGN

Slipped slope (fig. 4.5.1)
To stabilise this slope it was reformed incorporating a rock layer using stone sized 300mm 'down' as specified for use on nearby revetments *(see 4.2).* Ledges of varying widths were introduced at metre intervals up the slope, above water.

The underwater rock layer added weight to the toe of the slope to help support it and was free draining. The upper bank re-profiling removed weight from the slope further stabilising it. The ledge closest to water level was subsequently planted with trees to add visual amenity as well as a longer term revetment via their root system. The upper ledge later incorporated a new footpath.

Figure 4.5.1
PROFILE OF SLIPPED SLOPE



Slipped slope 2 years after repair – 1997

Figure 4.5.2
PROFILE OF EXPOSED ROOTS

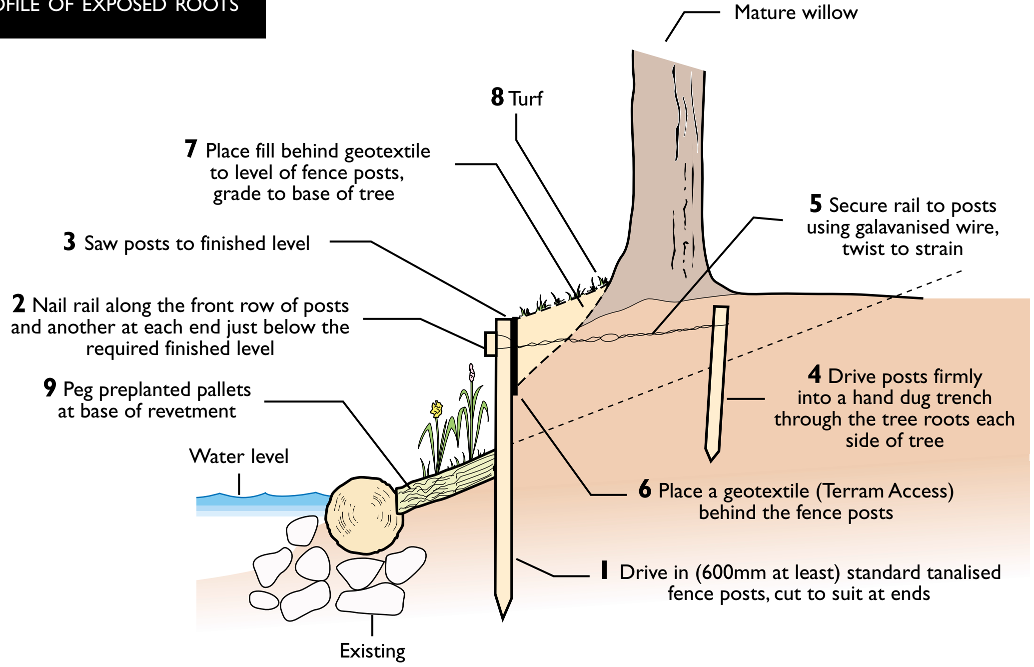
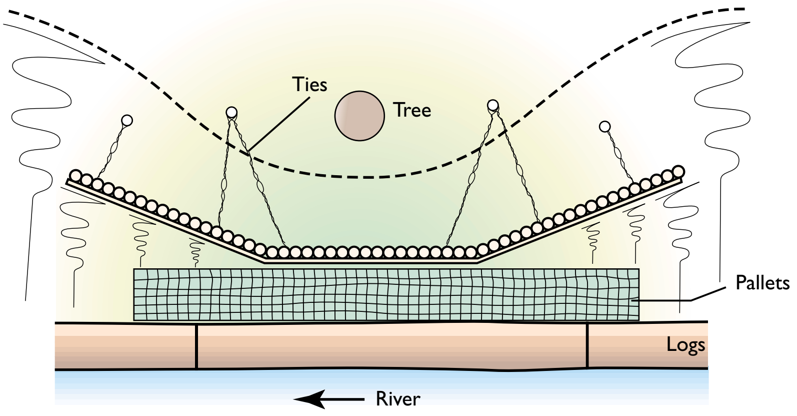
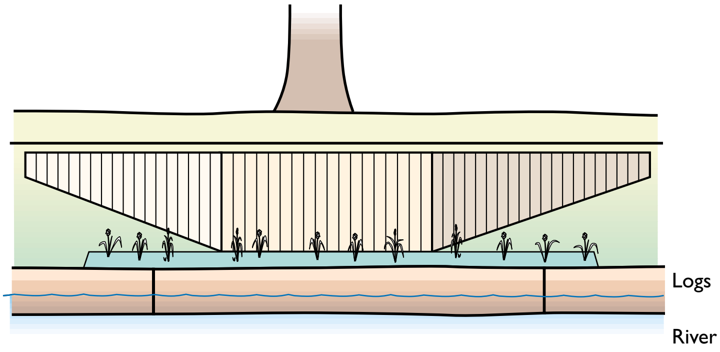


Figure 4.5.3
PLAN AND ELEVATION

PLAN



ELEVATION



Exposed roots (figs. 4.5.2 – 4.5.3))
The design had to ensure that people could continue to use the spot without further damage. Vertical fence posts were used to revet the bank before back-filling with soil. A geotextile, 'Terram Access', was placed behind the posts to prevent soil migration. Turf was placed on the surface to achieve an instant result.

SUBSEQUENT PERFORMANCE 1995–98

The bank slip has remained stable and appears natural with no visible signs of support. Water continues to seep from the bank and maintains a small wetland habitat on the ledge above river level.

The revetment of the exposed roots has performed well, following many high flows since its construction. The roots are no longer exposed and the turf and other planting has grown to give added protection. Well used by a variety of people, the structure has become a seating area providing shade.

Protected roots after work completed – February 1997

4.6 Hurdle and coir matting revetments

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
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

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 1.2.

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.

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 *(figs. 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 100mm -150mm and spread up to 300mm deep.

SUBSEQUENT PERFORMANCE 1995/98

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-

Figure 4.6.1
PROFILE OF COIR REVETMENT

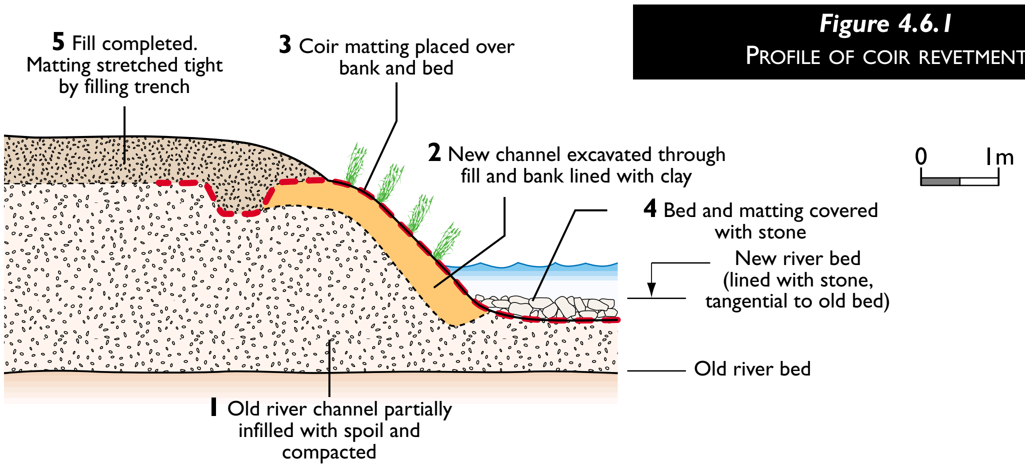
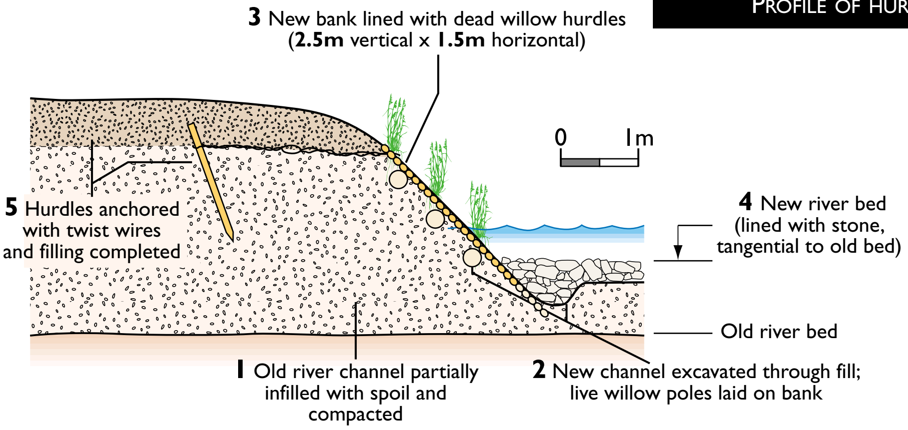


Figure 4.6.2
PROFILE OF HURDLE REVETMENT



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.

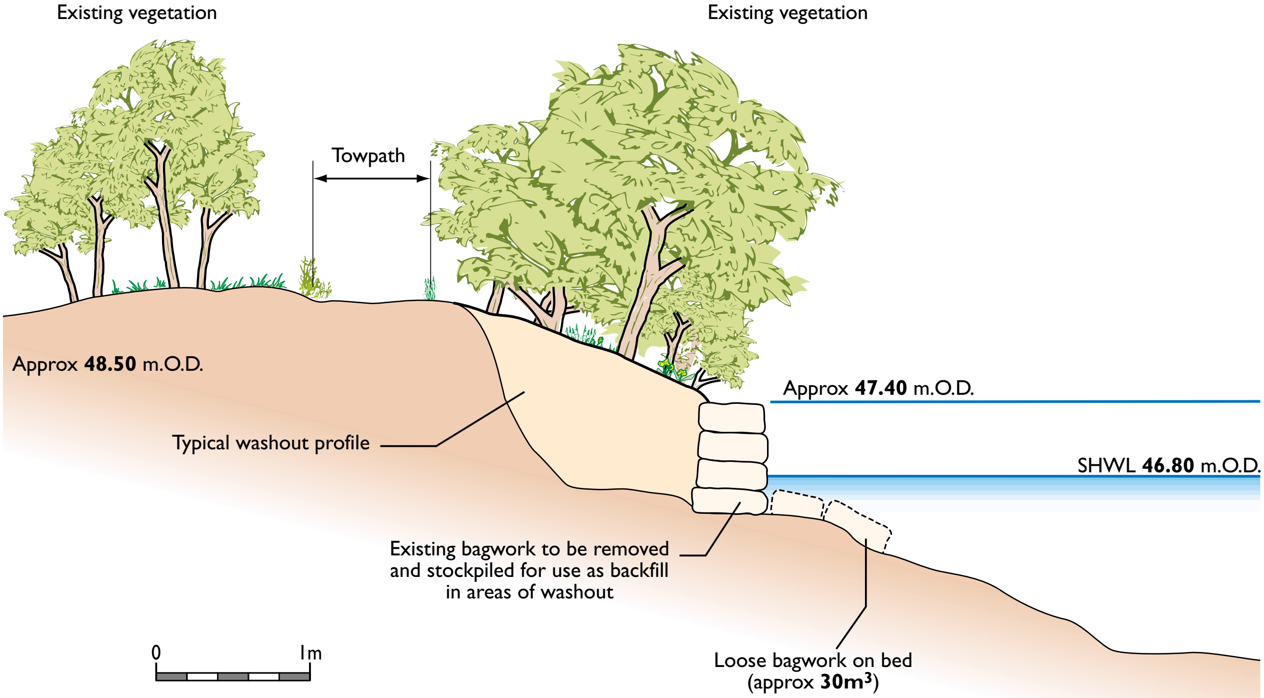
Alternative techniques for securing infilled river banks elsewhere on the same reach include bays, and backwaters *(see 2.2)*, and fords and stock drinks *(see 8.1)*. These alternatives have created much greater amenity/habitat value than the revetments and might, therefore, be regarded as preferable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

4.7 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

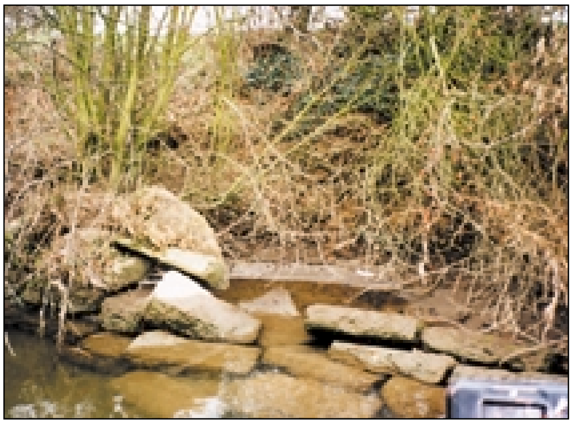


DESCRIPTION

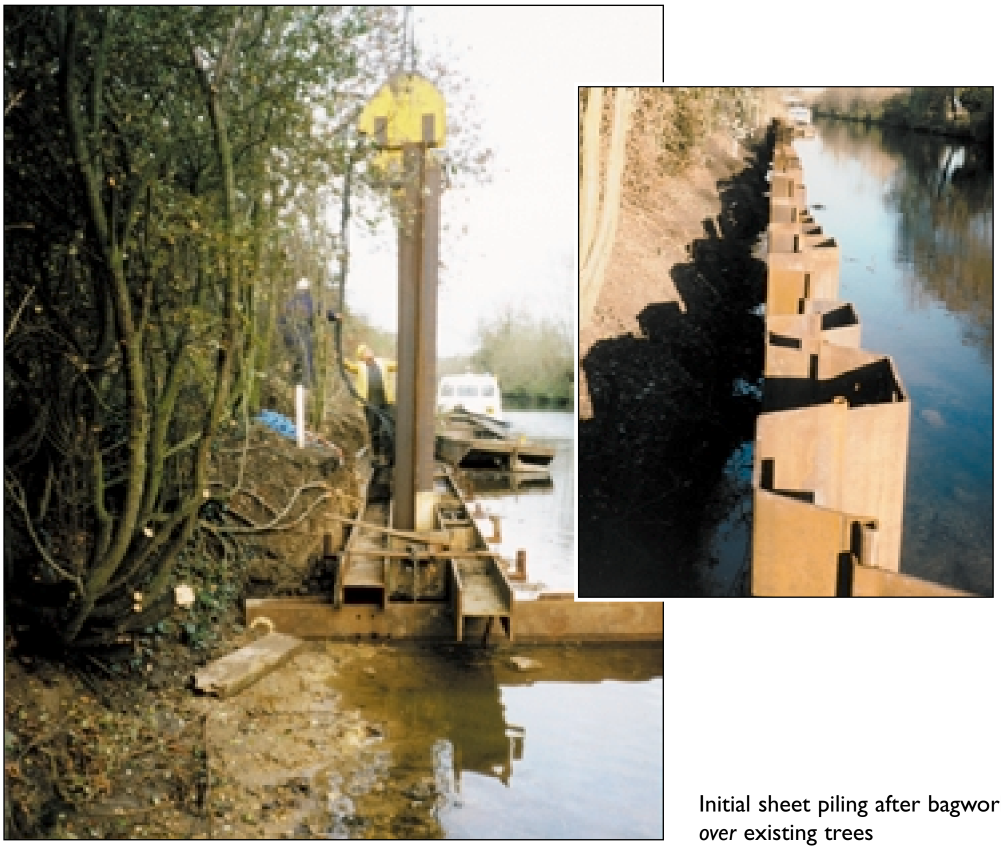
For centuries the River Thames has been heavily managed for the purposes of flood defence and navigation. In its lower reaches the river is restricted and controlled by weirs and locks. Various techniques of bank revetment are used along its banks including steel sheet piling and/or concrete bagwork. 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.


Failed section of bagwork at Clifton Lock Cut

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



Initial sheet piling after bagwork removal, *over* existing trees

of sheet piling (to 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 (*fig 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

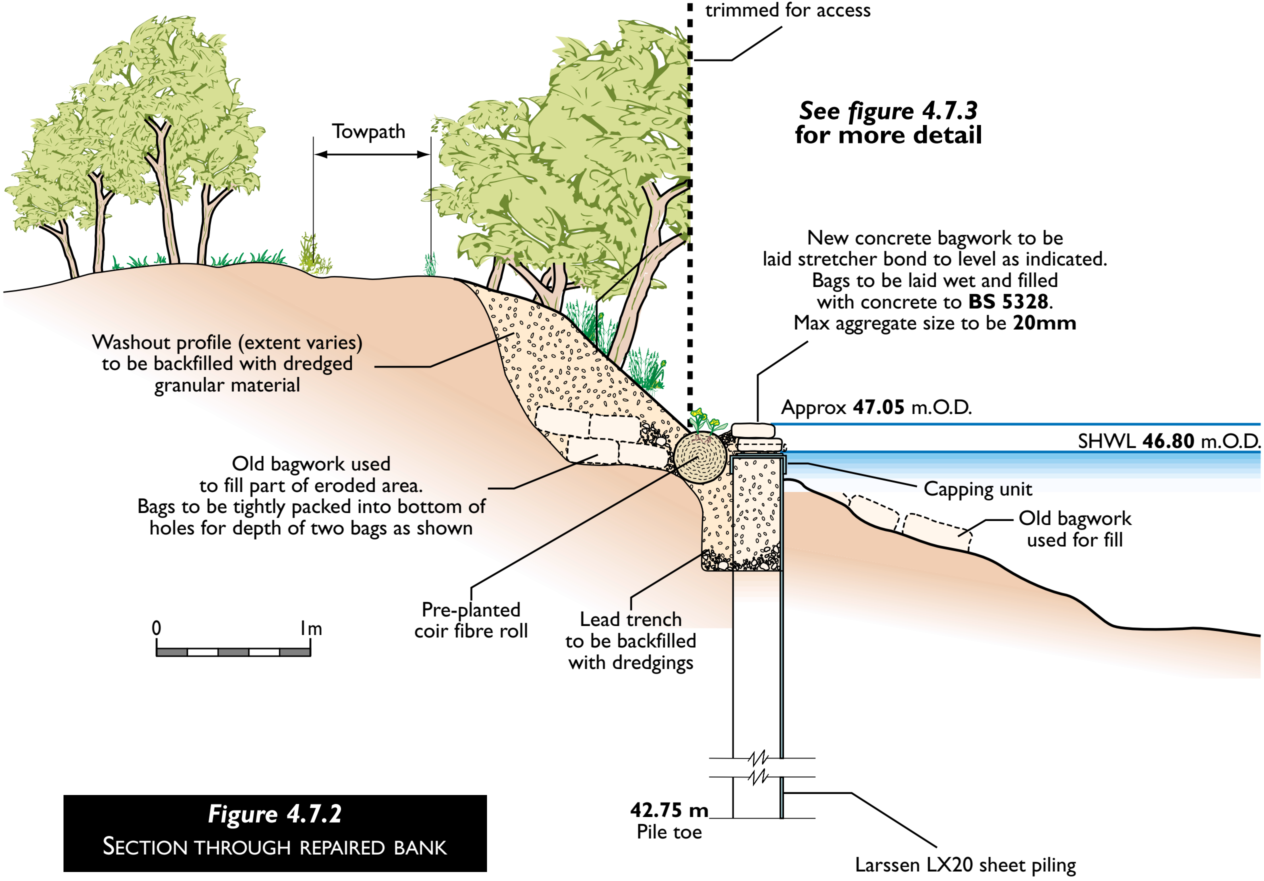


Figure 4.7.2
SECTION THROUGH REPAIRED BANK

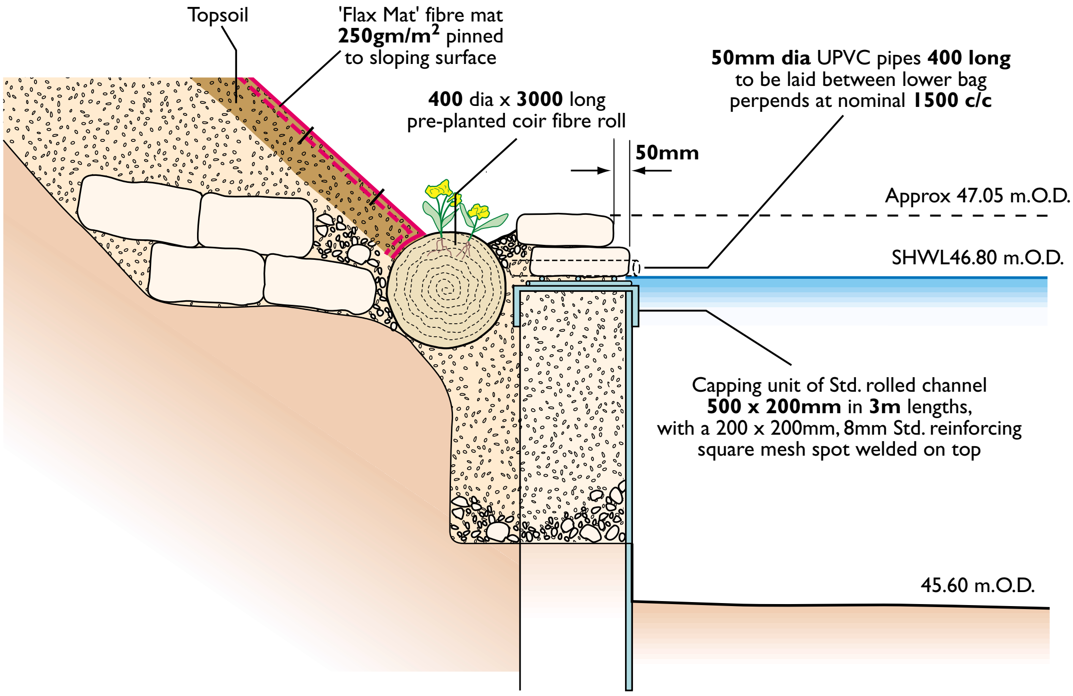
Flax mat secured, planted coir rolls installed and voids backfilled

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, 50mm dia. UPVC 'mammal' pipes were incorporated between the lower level bagwork at 1500mm 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.

Figure 4.7.3
SECTION DETAIL



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 1200mm into the bank.

SUBSEQUENT PERFORMANCE 1996 – 2001

The revetted bank shows 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 will be helping 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.


Vegetation establishment
after 18 months

Contacts:
Lesley Sproat and Martin Luker,
Environment Agency – Thames Region, Howbery Park,
Wallingford, Oxon, OX10 8BD, Tel: 01189 535000.

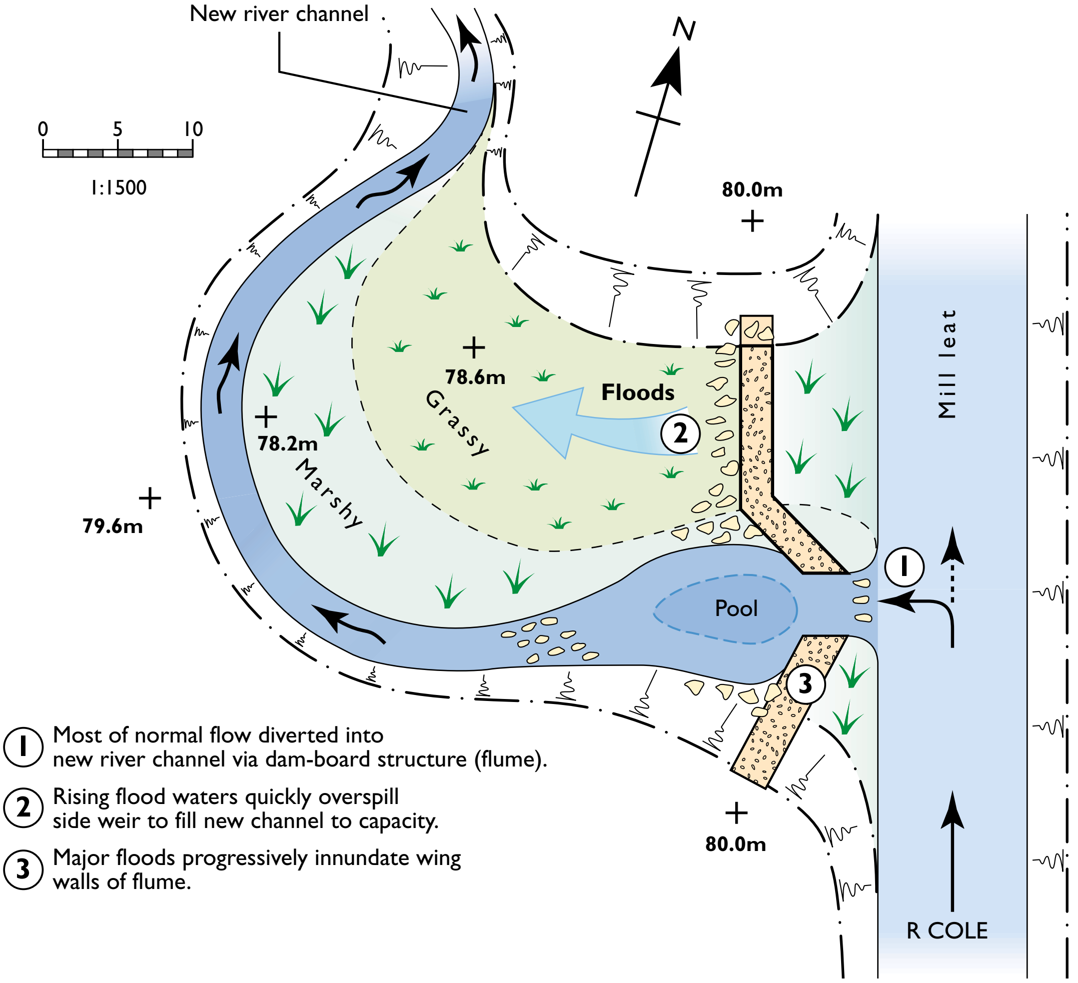
5 CONTROLLING RIVER BED LEVELS, WATER LEVELS AND FLOWS

5.1 Bifurcation weir and sidespill

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
LENGTH – 30m
COST – £10.5k

Figure 5.1.1
PLAN OF BIFURCATION WEIR



① Most of normal flow diverted into new river channel via dam-board structure (flume).

② Rising flood waters quickly overspill side weir to fill new channel to capacity.

③ Major floods progressively innundate wing walls of flume.

DESCRIPTION

Most of the flow in the river needed to be diverted from the mill leat, where it is impounded at a high level, into a newly created, free flowing channel that branches from it *(see 1.1)*. A structure was needed to meet the following criteria:

- control the level and volume of water retained in the leat;
- control the volume of water diverted to the new channel;
- maintain stable structural conditions when inundated by floods;
- create a visually attractive feature with ecological value;
- safeguard flow to the new channel should the mill sluices be suddenly opened.

A further hydraulic requirement was that the new channel should have filled with floodwater via the new structure just before the mill leat itself overspilled at a point some 250m further downstream. A designed 'high level' overspill exists here (at 79.2m) to initiate general inundation of the floodplain. If the new channel was only partially full at such time, then floodwaters would drop into it causing serious scour of the banks, risking breaching between the new channel and the leat.

DESIGN

Control weir (location ① on plan)

Figure 5.1.2
ELEVATION OF DOWNSTREAM SIDE OF WEIR

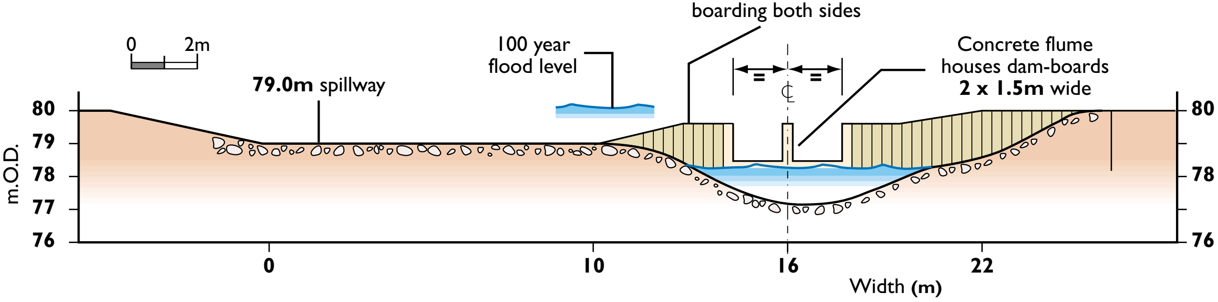
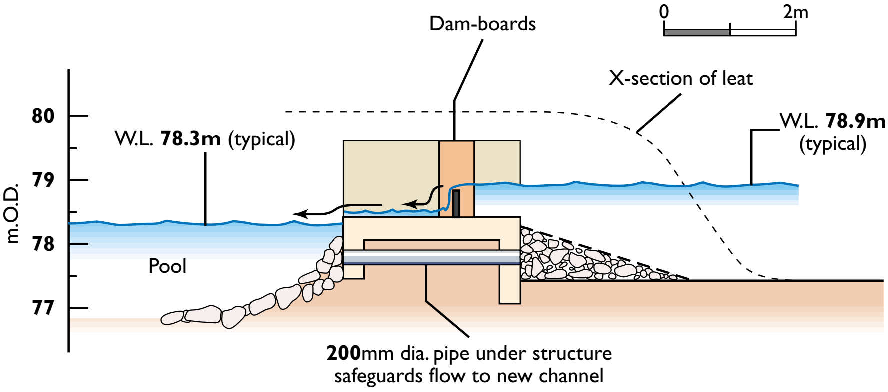


Figure 5.1.3
SECTION THROUGH DAM-BOARD STRUCTURE



The hydraulic capacity of the flume is small (to suit base flows) so a 10m wide spillway is incorporated alongside to feed sufficient floodwater to fill the new channel. The crest level is only 0.1m above the normal water level in the leat so it operates frequently. Below the spillway, a large area of land is gently graded out towards the new channel which sustains marshy conditions around its inner margins. This low lying area is largely flooded before overspill occurs, ensuring a fairly smooth combining of floodwaters passing downstream. Water in the new channel rises quickly, ensuring the overspill is completely submerged (drowned) at an early stage of a rising flood, thereby further reducing scour potential.

The spillway is defined by two parallel lines of road kerbs infilled with stone/gravel (a small amount of rock is incorporated along the downstream edge of the kerb line where eroding eddy currents are strongest). Reeds growing upstream of the structure also help to ensure stability and improve 'natural' blending between hard and soft elements.

Wingwalls link the flume to the spillway, and to the adjacent banks of the leat, through a smooth transition of levels. Large floods will inundate these walls so they are designed as weirs in their own right. Two parallel lines of vertical wooden planking are joined via walings and tie rods, infilled with clay, and topped with stone/gravel. The wingwalls are thereby free-standing structures that simply abut the sidewalls of the flume.

The spillway and wingwalls form a 'natural' footpath and are linked over the flume by a temporary wooden bridge.

SUBSEQUENT PERFORMANCE 1995/8

The structure has functioned exceptionally well and fulfils all design criteria. The complex configuration of channel and landforms combine with diverse patterns of flow currents to sustain a variety of habitat niches as well as an overall feature of landscape interest. Snipe are commonly seen probing the marshy areas intrinsic to the design. The National Trust (owners) plan to undertake landscape planting, and to provide a permanent bridge to further enhance the location. The abundance of fish in the new channel suggest that migration is ocurring satisfactorily.

Spilllway alongside bifurcation weir
– April 1997

Flood filled channel
downstream of
bifurcation weir

5.2 Drop-weir structures

RIVER COLE

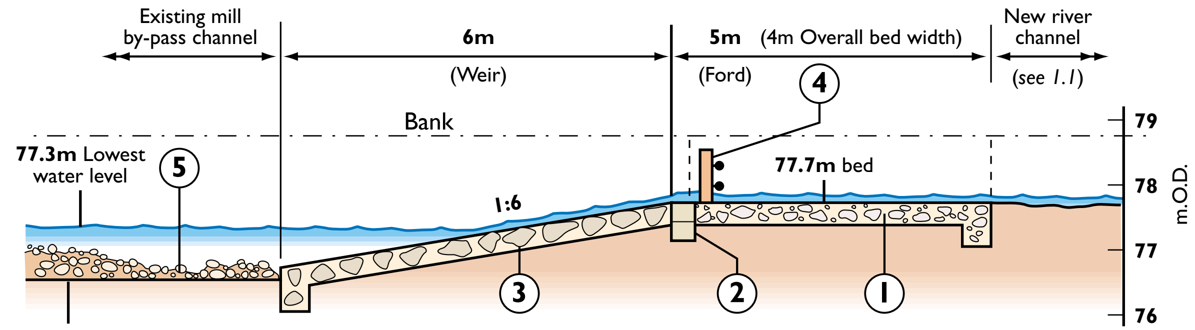
LOCATION – Coleshill, Oxon/Wilts border, SU 234935

DATE OF CONSTRUCTION – Autumn 1995

COST – Upstream drop-weir £2.8k. Downstream drop-weir £2.5k

Figure 5.2.1

DROP-WEIR ON NEW RIVER UPSTREAM OF MILL



① Ford – 150mm down densely graded stone over polythene membrane

② Cut-off wall – concrete kerb blocks (incorporates membrane)

③ Weir – 300mm down densely graded stone over filter membrane

④ Stock fence comprising two strained cables

⑤ Gravels deposited over existing bed of old mill by-pass

DESCRIPTION

New river channels that were created both upstream and downstream of Coleshill Mill have bed levels that are elevated c. 1 m higher than the bed of the existing channels into which they now flow *(see 1.1 – 1.2).* Measures were needed to stabilise the river geometry at both confluence points because of the sudden change in bed levels. Drop-weirs were built at each.

Weir and rock apron

DESIGN

Drop-weir on new river upstream of Mill
Consideration was given to partially infilling the existing downstream channel (mill by-pass) with gravel to achieve a transition between bed levels at the confluence. Infilling would have been undertaken over a long reach but would still have been intrinsically unstable for some time. This option was discounted in favour of the secure fixed structure shown.

The river bed approaching the structure increases in width from 2.6 to 4m where it is stoned (**1**) to create a useful fording point; slopes of 1:8 are incorporated each side. This increase in bed width is necessary to maintain a shallow depth of water for a wide range of flows. A vertical wall of mortared pre-cast concrete kerbing blocks (**2**) defines the downstream edge of the ford. It serves to set a fixed profile right across the section, as well as reducing the risk of river water flowing underneath the structure causing it to collapse. Water flowing over the wall passes evenly down to the lower channel over a rock apron (**3**) at a slope of 1:6. During time of spate, downstream water levels rise more quickly than those upstream causing the structure to eventually submerge or 'drown', although not frequently.

A livestock fence was incorporated in the form of two wire cables strained along the crest line and up each side to field level. The cables are strong enough to withstand the pressure of floating debris that inevitably catches on such 'fences' in time of flood but they do not form an impenitrable barrier that otherwise arises if woven fencing is used.

Gabion weir and pool

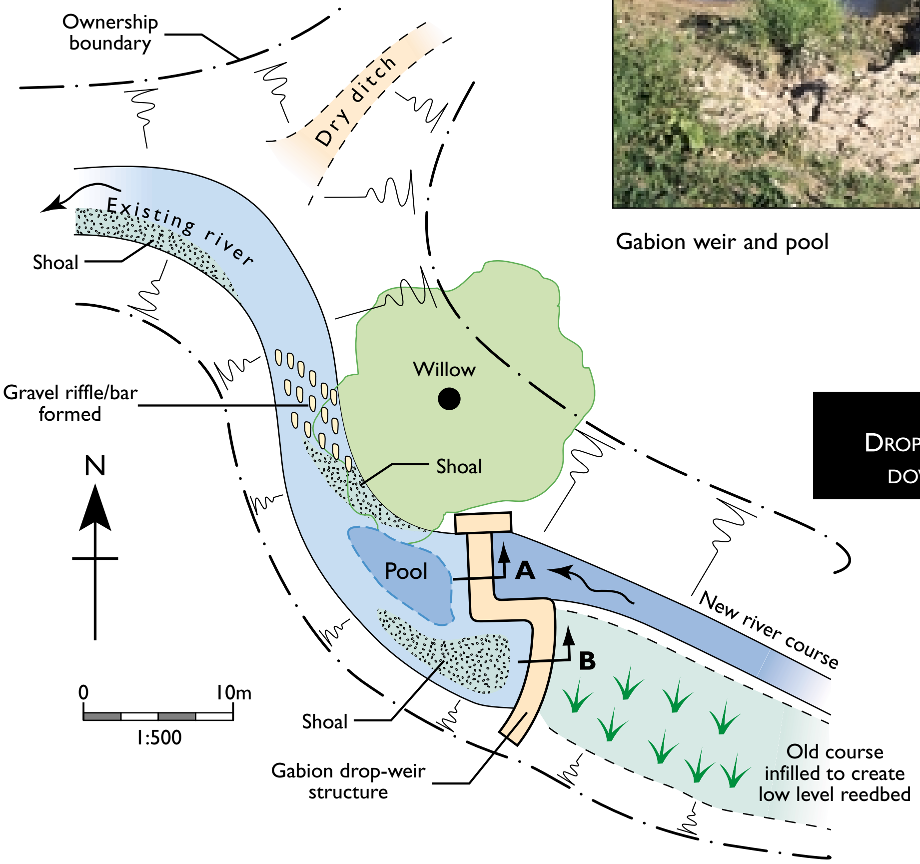


Figure 5.2.2
DROP-WEIR ON NEW RIVER DOWNSTREAM OF MILL

Figure 5.2.3
SECTION A THROUGH GABION DROP-WEIR

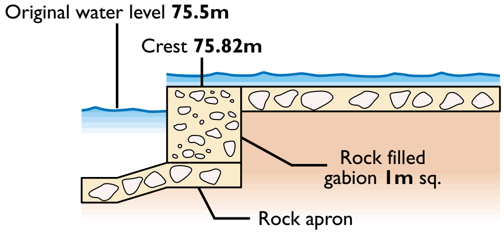
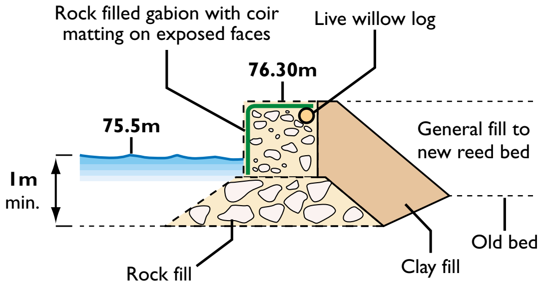


Figure 5.2.4
SECTION B THROUGH GABION DROP-WEIR



Drop-weir on new river downstream of Mill
The confluence of existing and new river is located at the downstream limit of land on both banks owned by the National Trust. No agreements had been reached with adjoining owners but the continuation of river restoration into the lower reach was regarded as a future possibility. A 'temporary' structure was therefore designed, albeit its existence may be long term. A particular feature of this confluence is a new reedbed that runs parallel to the new river course; it was created by partial backfilling of the old river bed (*see 9.2*).

A wall of stone filled wire baskets (gabions) was built along the line shown to retain and secure both the new river bed and the new reed bed alongside it. The gabions at the reedbed are elevated above river levels and are visible, so coir matting was incorporated on exposed faces to attract vegetation and improve visual amenity. Two gabions, incorporating willow branches, form a short wall on the opposite bank.

A scour pool was expected to form below the gabion wall so larger rock was incorporated underneath the wall and the bed excavated to achieve a minimum water depth of 1m under normal flow conditions. The structure was expected to submerge fairly soon in a rising flood so no further revetment of river banks was undertaken.

SUBSEQUENT PERFORMANCE 1995/8

Both have performed well benefiting from the formation of substantial gravel riffles just downstream which raised bed and tailwater levels reducing the overall drop described.

The lower confluence has been an outstanding success and the change in normal water levels at the structure is now barely discernable, but is marked by a change from fast flowing water in the new channel to a deep, still pool of water that precedes the riffle. The gabion structure is virtually hidden from view among the vegetation that has grown up within it.

The upper confluence structure has lost stone from the weir because the size used was below the 300mm graded mix specified. The structure remains functional because the block wall is stable - numerous larger stones have settled out below it. The stone work was re-built in summer 1998.

Fish have migrated into each new channel suggesting that neither structure is a significant hindrance.

5.3 Restoring and stabilising over-deepened river bed levels

RIVER OGWEN AND NANT FFRANCON

LOCATION - 5km south of Bethesda,
Gwynedd SH 641615
DATE OF CONSTRUCTION - Autumn 1998
LENGTH – 900m
COST - £48 000 construction,
£8 000 flood model, £5 000 design

DESCRIPTION

The Ogwen is in a mountainous location of Snowdonia below Llyn Ogwen (Lake Ogwen), alongside the A5 trunk road. Water from Llyn Ogwen cascades over Rhaeadr Ogwen (Ogwen Falls) down into the large glacial valley of Nant Ffrancon through which the Ogwen flows northwards. During the 1960's the Ogwen was deepened by dredging over a 4km length downstream of the waterfall. This was to reduce the frequency of flooding over the valley floor to improve livestock grazing. The dredging of the river proved to be difficult in places where substantial deposits of boulders were present. Rock outcrops were blasted at the lower limit of works at Pont Ceunant. Most dredgings were piled along the river banks forming irregular embankments, some were removed from site.

Over the succeeding 30 years the river responded to the channel deepening by flushing through virtually all of the finer river bed gravels and scouring both river bed and bank soils in many places. The reach became severely denuded of any stable habitat for flora and fauna and a once thriving salmon fishery declined. Flooding was still troublesome to farmers. An appraisal of the problem concluded that far too

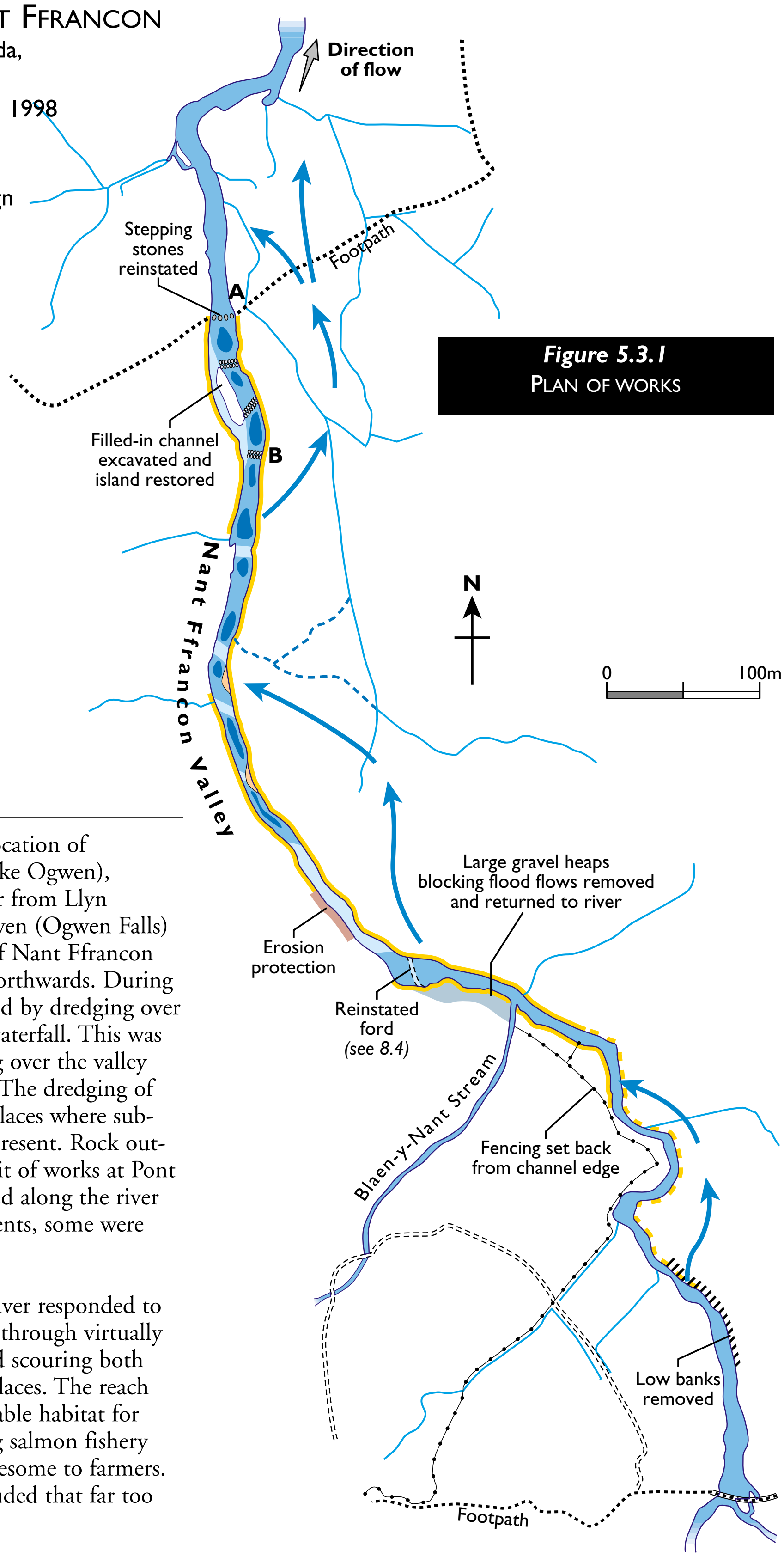


Figure 5.3.1
PLAN OF WORKS

Key

A – B	Boulder cascades
▨	Pool-riffle sequence re-installed
←	Flood routes re-established
- - - -	Re-sectioned ditching
▨	Point bars restored
▨	Spoil heaps from 1969 scheme

Deep channel and dredgings on bank at Blaen-y-Nant confluence

Restored bed levels and bank profile

much floodwater was being conveyed in the enlarged channel and that it would be necessary to restore pre-works river bed profiles to correct this imbalance. Re-routing of more frequent floods over the flood-plain fields would result from this, helping to sustain other desirable habitats.

Detailed designs were prepared and implemented for the upper 1km of the river, close to Rhaeadr Ogwen, after detailed consultation with the National Trust (landowners) and farmers.

DESIGN

Stage I works (fig. 5.3.1)
The figure shows the extent of restoration works undertaken. Figure 5.3.2 shows the longitudinal profile of the reach and highlights the extent of river bed restoration needed. The long profile was the most important design reference.

The profile of the floodplain fields clearly indicated strong post-glacial influences on the natural landforms. Downstream of chainage 00m the fields lie horizontal and comprise an old lake bed (*fig. 5.3.2*). The fields rise steeply upstream to chainage 400m (at gradients of c. 1 in 100) but flatten to 1 in 600 upstream of this. The river dredgings along the steeply graded reach were predominantly glacial boulders and old Ordnance Survey maps indicated that an island in the river was once sustained at the same location.

It was therefore evident that a post-glacial 'dump' of large boulders at the island site was the primary control over the river bed levels and gradients, and the restoration of this feature became fundamentally important.

A boulder cascade (A to B) was designed comprising four drops of around 40cm over a reach of 100m, giving an average gradient of 1 in 100 to parallel the

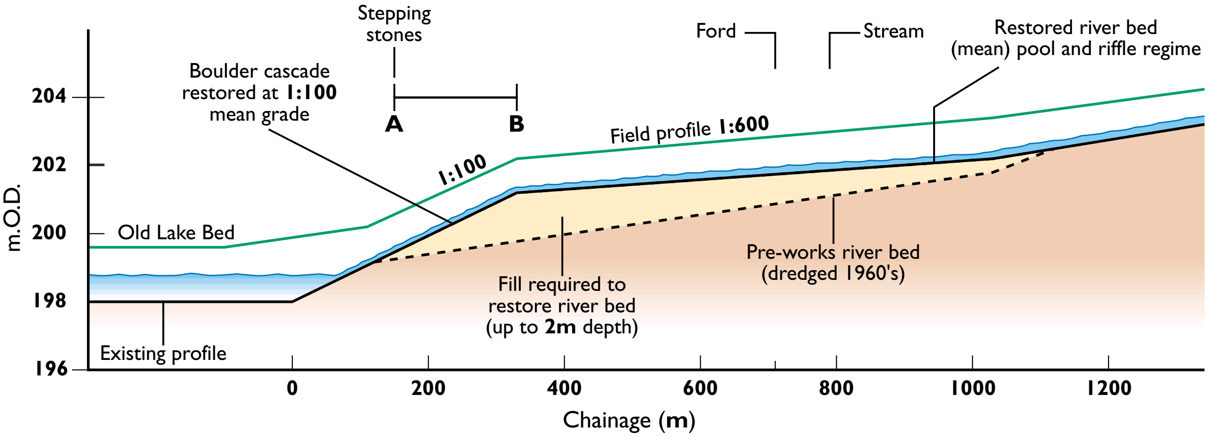
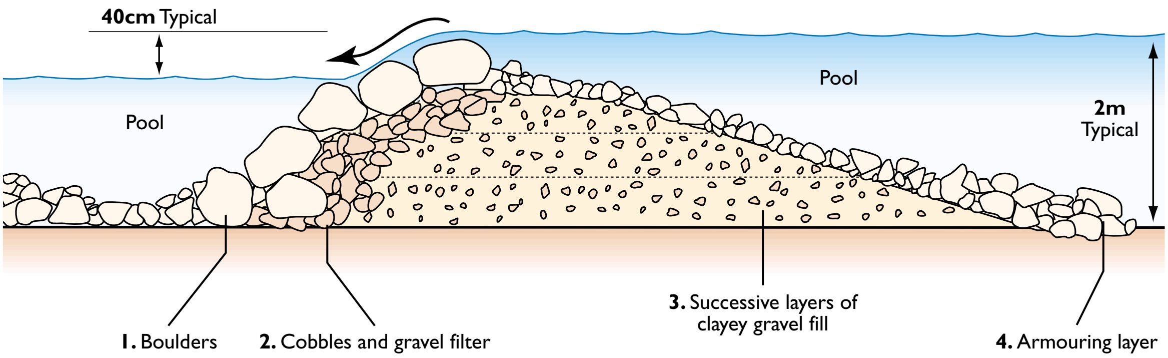


Figure 5.3.2
LONGITUDINAL PROFILE

Figure 5.3.3
SECTION THROUGH A CASCADE



natural field gradients alongside. Old maps were studied to determine the planform, which included the secondary channel that formed the island. Trial digs were undertaken to determine the historic bed elevations and thus the crest level of the upper cascade. It was concluded that river flow around the island was probably a seasonal feature so the bed elevation here was kept marginally above restored river water levels consistent with site investigations.

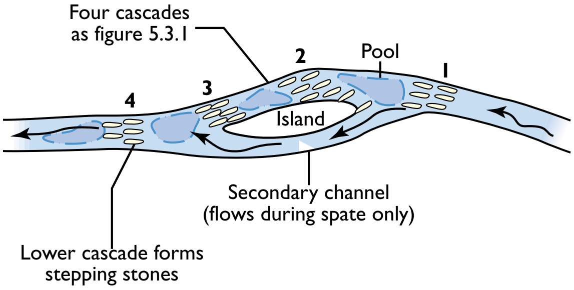
The design for each of the four elements of the cascade is detailed in figure 5.3.3. Boulders face-up more general fill in a structured way. Construction comprised a series of 'lifts' undertaken whilst the river was flowing over the works. Each lift comprises a line of selected boulders that are backed up by a layer of mixed cobbles and gravels that are sufficiently large not to eventually wash out through the interstices between boulders. Behind this 'filter' layer a further layer of more clayey gravel fill was placed. The structure was built up in successive lifts to achieve a 'wedge' shaped profile that is sufficiently stable to impound water upstream. An armouring layer of rocks was finally dropped over the general fill. All material was carefully sorted from the original dredgings.

Restored island

Restoration of boulder cascade, stepping stones and braided channel

Lower 'stepping stone' cascade

Figure 5.3.4
PLAN OF CASCADES



The lower cascade was the smallest of the four so was readily adapted to restore a series of large stepping stones recorded on O.S. maps. The effect of restoring the cascade was to impound the upstream reach of river to a water depth of 2m. Ideally this upper reach would have been completely backfilled to the 1 in 600 gradient shown on figure 5.3.2. but insufficient material was available for this because dredged gravels had been removed from site.

The practical alternative to full bed restoration was to concentrate the material available into a series of individual cascades along the upstream reach. These took a similar form to the main cascade but the downstream slopes were much flatter to simulate 'riffle' characteristics rather than true cascades. The upper of these 'riffles' at chainage 700m took the form of a long diagonal ford which restored a feature recorded on old O.S. maps – (*see 8.4 for details of this ford*).

Flatter 'riffle' cascade
with upstream pool

The remaining gravels and clayey gravel dredgings on site were all utilised to enhance the riffle/pool sequence that was created in the upper reach. Some runs of gravel bed were introduced near to the ford and shoals were built on the inside of bends.

A major erosion site downstream of the ford was reinstated using the willow mattress technique featured in this manual in 4.2. The willow used was a species found locally (grey willow type) which sprouted well initially but has subsequently been grazed by livestock, although it has held firm.

The re-routing of floods overland was investigated by a combination of hydraulic modelling and close scrutiny of precise ground topography. It was found that by removing 'embankments' of dredgings at key locations floods would follow patterns that left open routes for retreat of livestock to 'high' ground, and that traditional lambing fields were the least prone to floodings. This was a critical element of discussion with farmers.

SUBSEQUENT PERFORMANCE 1998–2001

The works have transformed the visual appearance of the river from a deeply incised, canalised waterway to a shallower, wider regime that displays many more dynamic features as water tumbles over and between boulders into long pools and runs. Severe flooding during the succeeding two winters has not caused any significant structural damage to the restoration works and flood patterns overland are as predicted.

Improvements in the biodiversity of the reach and in the salmon fishery are being monitored by the Environment Agency. Early indications of the monitoring are all positive, but of particular note is the extent to which migratory fish are utilising the river rather than simply passing through to reach the limited spawning gravels that had survived the dredging works close to Rheaedr Ogwen.

Work is now in hand to progress further stages of works building upon the confidence gained from the success of stage I. This success was particularly useful in gaining financial support for the much wider 'Wetlands for Wales' project that has since been launched.

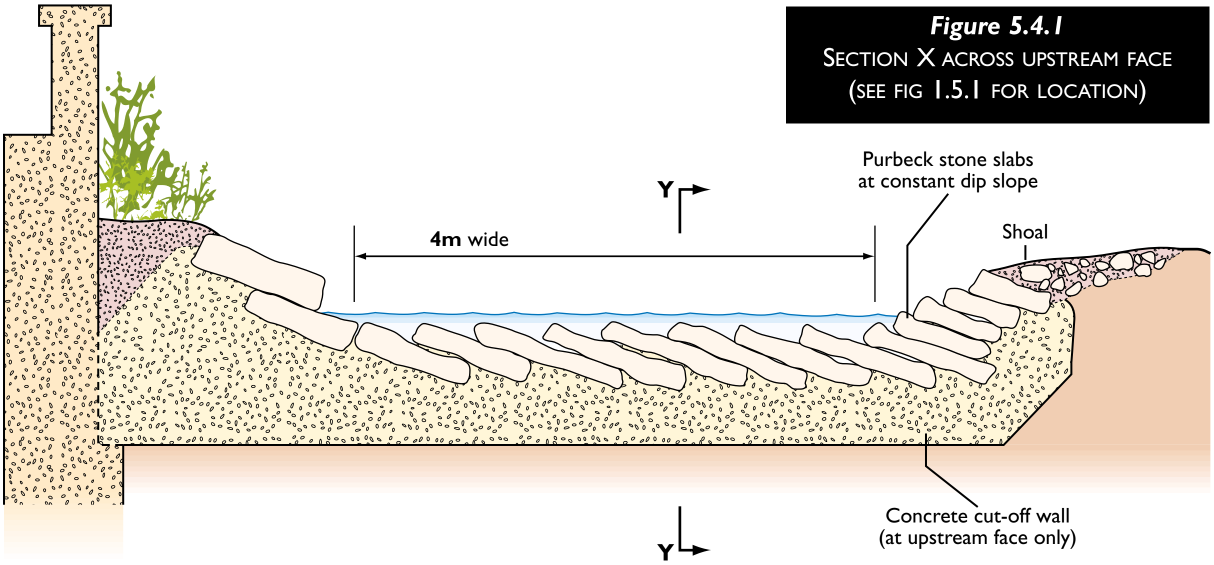
Contacts:
RRC, Silsoe, Beds MK45 4DT, Tel: 01525 863341.
Bryan Jones, Environment Agency, Llwyn Brain, Ffordd Penlan,
Parc Menai, Bangor, Wales LL57 4DE, Tel: 01248 670770.
Elfyn Jones. National Trust,
Carneddau & Ynys Mon Property Office,
Tan y Celyn, Ty'n y Maes, Nant Ffrancon,
Gwynedd, Wales LL57 3LX.

5.4 Simulated bedrock outcrops

RIVER MARDEN

LOCATION – Town centre at Calne, Wiltshire ST 998710
DATE OF CONSTRUCTION – 1999
LENGTH – 100m
COST – not available

Figure 5.4.1
SECTION X ACROSS UPSTREAM FACE
(SEE FIG 1.5.1 FOR LOCATION)



DESCRIPTION

A straight, concrete lined, section of river channel was diverted and restored in the form of a double meander. Refer to Technique 1.5 for a plan and full description of the project.

The bed of the restored meandering channel needed to be stabilised against scour because of its steep gradient (1 in 140 mean) and the consequential high water velocities that exceed 2 metres per second during flood conditions. Two simulated rock outcrops were built into the bed to provide stability.

DESIGN

The influence of the two rock outcrops can clearly be seen in figure 1.5.2 (*see 1.5*); the longitudinal profile of the restored reach. The mean bed gradient is modified by projecting the outcrops above this profile and creating deeper pools both upstream and downstream of each. The purpose of the outcrops is to 'fix' the bed at two points thus checking any tendency of the river bed to scour deeper and to wash away the stone substrate introduced over the underlying clays. A varying hydraulic regime is created in keeping with the aims described for the project (*see 1.5*).

The design of the rock outcrops is the subject of this technique.

Simulated rock outcrop with downstream pool

Flat slabs of Purbeck limestone had been selected for a variety of purposes throughout the site and for use in the two outcrops. The slabs needed to be laid with a constant angle of dip and needed to provide a gently sloping face over which the water would tumble down to the lower level. A practical method of arranging the slabs needed to be developed; the outcome is shown in figures 5.4.1 and 5.4.2

Firstly, the upstream row of slabs was laid carefully to line and level in a bed of concrete. The concrete secures the required crest level along the tips of the slabs and also forms a cut-off wall that prevents water from flowing under the structure which can otherwise cause collapse. The angle of dip and the thickness of individual slabs determine the size of the jagged 'notches' created along the crest. Slab thickness of between 10cm and 15cm were found to be best suited. The slabs are extended upwards into each bank to become part of the revetments indicated on the site plan (*see 1.5*).

Successive rows of stone were then laid parallel to the above, working down the slope, with the final row being stepped down to a level below any likely scour depth. These rows were all bedded in gravel reject stone to introduce flexibility to the lower structure and to improve the opportunity for plants to root between the stones, e.g. *Ranunculus*.

The random nature of stone slab size and thickness meant that a certain amount of selection was needed to achieve a reasonably tight fit where each abuts another, but this was not unduly critical. The structure is sufficiently robust and flexible to ensure security without resorting to the use of concrete or mortar in joints. Each outcrop was built in a day by 3 men and a machine for lifting.

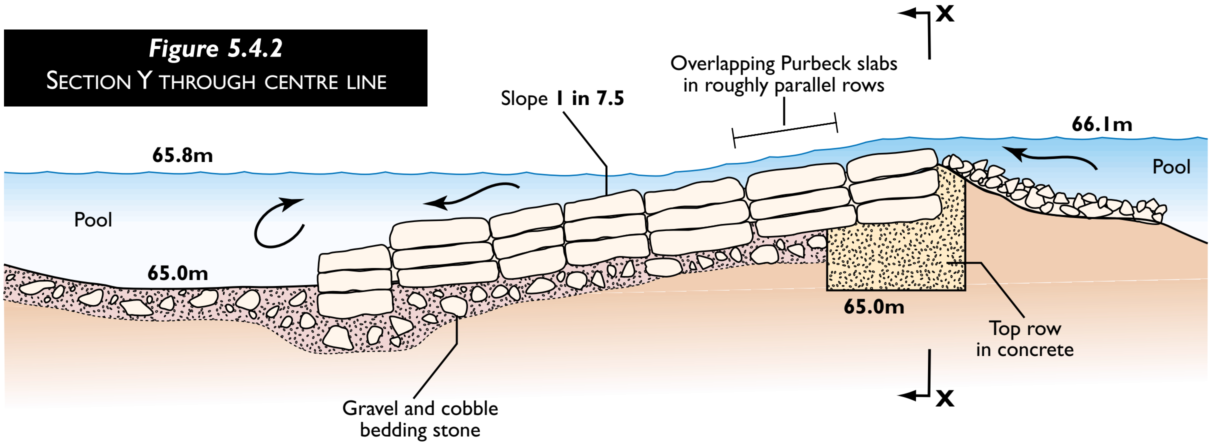
SUBSEQUENT PERFORMANCE 1999 – 2001

The structures have achieved the main purpose of stabilising the river bed against scour without any problems. The appearance is excellent and will improve once vegetation is established between the stone slabs.

The effect of the jagged notches created by laying the stones at an angle is to generate an audible tumble of water over the whole structure. The concentration of flow down these irregular notches is likely to prove helpful to the passage of fish.

Contacts:
RRC, Silsoe, Beds. MK45 4DT, Tel: 01525 863341.

Figure 5.4.2
SECTION Y THROUGH CENTRE LINE



The outcrops provide stability to the bed and banks as well as aesthetic interest

5.5 Raising river bed levels

UPPER KENNET

LOCATION - Ramsbury, Wiltshire
DATE OF CONSTRUCTION - 2nd October – 20th October 2000
LENGTH – 210m
COST - £12, 000 – £14, 000 for construction and reinstatement works only†

† The cost of £14,000 did not cover design, surveys, administration and consents. The work was carried out by an experienced local river keeper and not a commercial contractor.

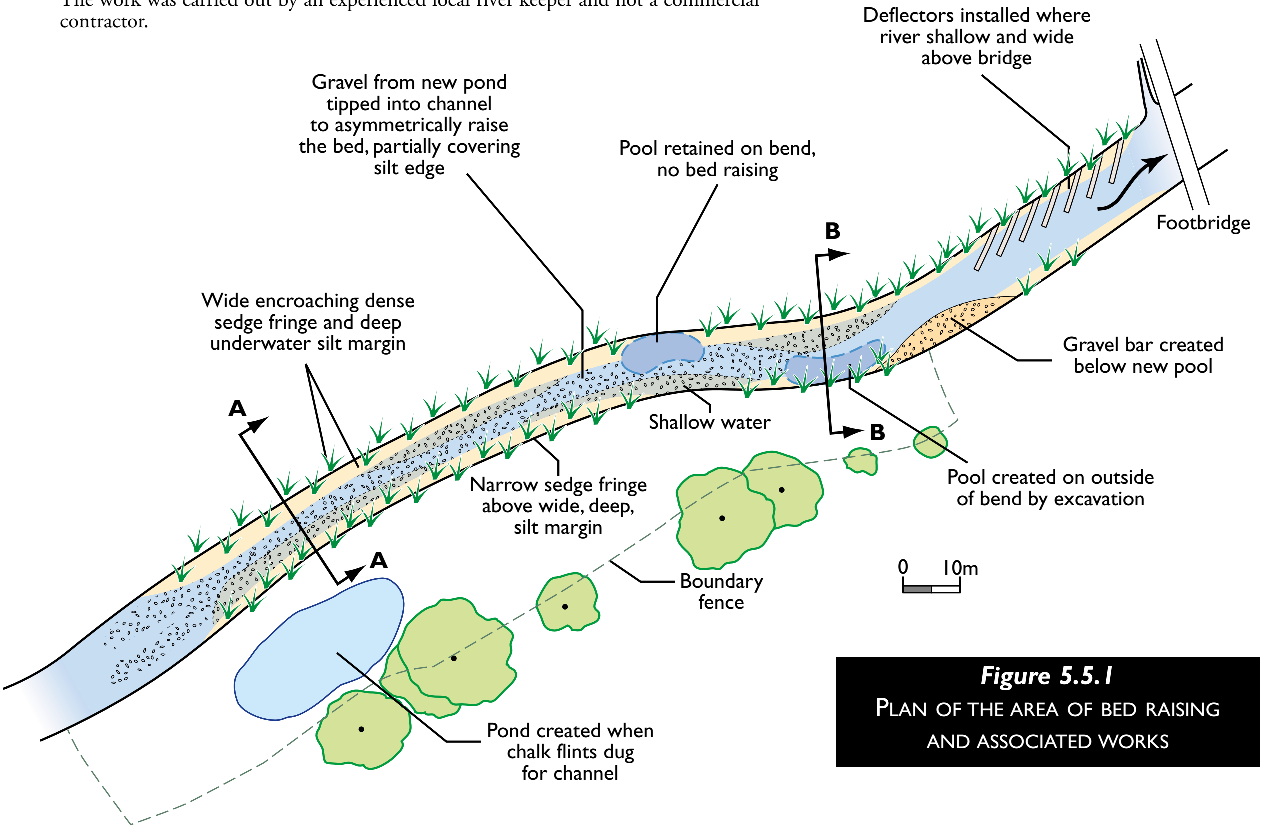


Figure 5.5.1
PLAN OF THE AREA OF BED RAISING AND ASSOCIATED WORKS

DESCRIPTION

The Upper River Kennet is a chalk river (Habitat Action Plan interest) under European Regulations and notified under UK legislation as a Site of Special Scientific Interest. Despite its designation, the river exhibits interesting contrasts in habitat quality. Some stretches support pristine chalk river characteristics (beds of abundant *Ranunculus* (Water-crowfoot) and clean gravels suitable for sustaining wild brown trout populations). However, past management works, ranging from mill impoundments to more recent dredging activities, have resulted in over-widened, over-deepened, sluggish, stretches that are prone to silt deposition and lack gravel or crowfoot.

The site is a secondary channel of the Kennet, the probable natural course of the river prior to splitting into a leet to feed a mill. The channel had been widened and deepened many decades ago, but did not recover its natural characteristics. However, it did exhibit some signs of self-narrowing where marginal sedge had spread into the channel and accreted


Before: sluggish deep water with encroaching sedge

significant silt shoulders. Despite this development, the channel remained too wide to sustain fast water currents and even in mid-channel the bed was subject to deep silt accretion.

A common approach to achieving self-sustaining habitats in enlarged degraded rivers is to narrow the river bed width and thereby concentrate flows within a defined low-flow channel. However, where the river also has a history of deepening, this may simply lead to the formation of a very constricted, deep course. To restore a more appropriate width to depth ratio, bed raising may also need to be considered (*see 1.2 for further discussion on selecting the appropriate cross section*).

A 210m stretch upstream of Ramsbury was re-configured, primarily through raising the bed. The channel bed was raised asymmetrically to ensure that there was a narrow low-flow course and shallow edges to encourage marginal vegetation encroachment.

As the Kennet is a chalk stream the predominant flow is derived from groundwater, so major fluctuations in water level and velocity are much less than in rivers fed primarily by surface water. Consequently, a more flexible approach can be adopted for the location of gravel materials to raise the bed, as there is less risk of subsequent mass re-distribution.

Detailed flow modelling was a key element to determine the effects of the works under low-flow and flood conditions, for land drainage consent and to allay potential landowner concerns.

DESIGN

Throughout, bed levels were raised to leave a maximum water depth of 500mm at low water level (based on the Q90 discharge level - the level at which flows are exceeded 90% of the time). At this discharge, the margins of the channel would have a depth of <100mm. The Q90 flow was indicative; the desire was to ensure that under very low flows the bed-width would be constricted to sustain at least some clean gravel at all times. The maximum depth of 500mm at Q90 was based on a target reference width and depth.

Work was scheduled to commence in early October when river flows are usually at an annual low, approximating to Q90. Prior to undertaking work, stakes were placed in the river to mark this level as a guide to the contractor during the gravel placement process. This was especially important since water levels would change if silt entrapment measures had needed to be installed downstream (on standby but not needed).

Gravel placement may influence or be influenced by fluctuating water levels

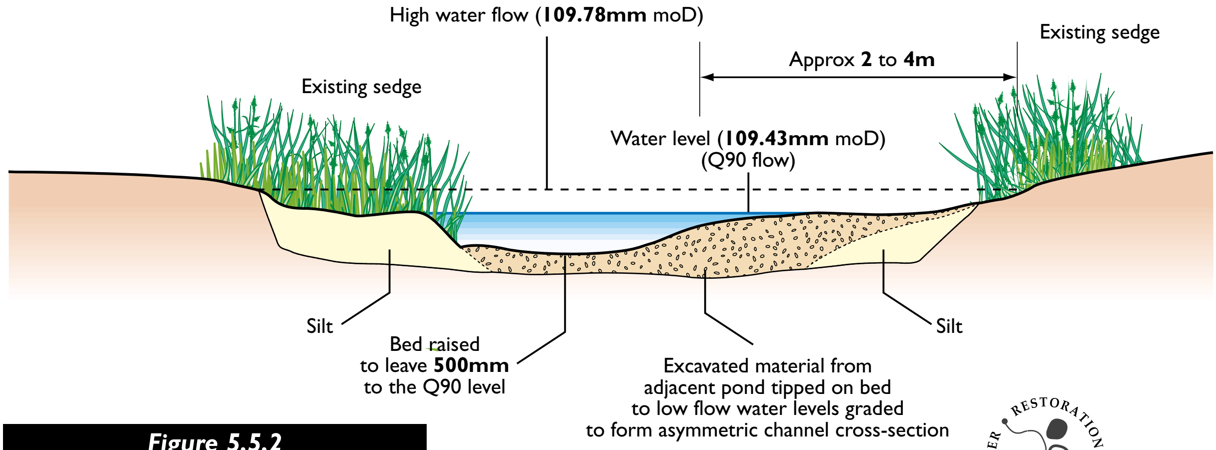
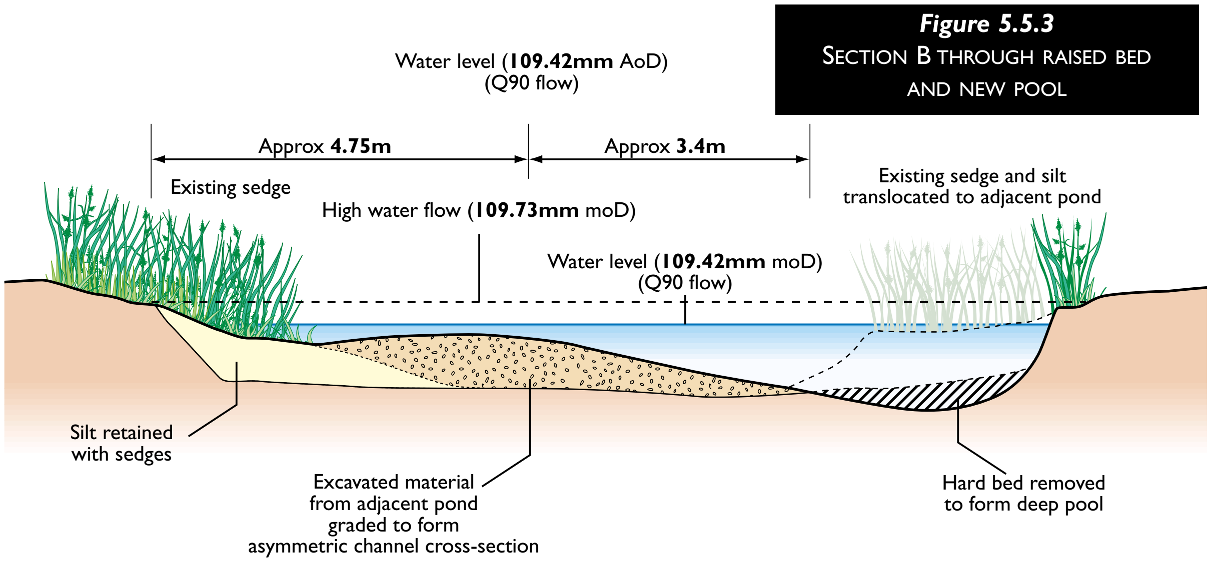


Figure 5.5.2
SECTION A THROUGH RAISED BED AND MARGINAL SHOAL

Figure 5.5.3
SECTION B THROUGH RAISED BED AND NEW POOL



The material used to shallow the channel depth was chalky and gravel flints. Where possible it is advisable to use material from the immediate area to reflect the type of bed that would have been present under natural conditions. Here the gravel fill was excavated from the floodplain by the creation of an adjacent pond on the right bank. The suitability of the material was checked beforehand by the inspection of machine-excavated trial pits. Infill material was predominantly a mixture of gravels and flints varying in size from 20 to 10mm, with <5% coarse sand and minimal silt. A few larger flints were also present.

Flinty gravel used to narrow and raise the river bed

Topsoil and overburden were first stripped and stored before the gravel was dug out and transported by dumpers to the river bank. Representative cross sections were produced as references for the placement of material so that a degree of sinuosity was created under low flow.

The contractor followed the drawings and had the advantages of both knowing the river stretch well and having been involved in the final design. Regular on-site supervision was provided by an experienced team member.

The works length can be divided into three sections.

A. *Straight with marginal sedge on both sides*
Cross section A (*fig. 5.5.2*) is a typical section across this reach. Silt colonised by sedge represents up to half of the total channel width.

New pond with early growth, showing the gravelly nature of the floodplain material

Gravel has been used to shallow and narrow the remaining open water channel by up to a half, with the shallower margins finishing just below the Q90 level. The remaining low-flow channel is raised to within 500mm of the Q90 surface.

B. *'S' bend with some marginal sedge*
The outsides of each bend are enhanced with a pool, the first by retaining existing very deep

A few months after completion, the raised bed evident

water, the second by dredging the silty sedge margin (material then used to provide marginal substrate in the new pond). Cross section B (*fig. 5.5.3*) shows the asymmetric section with fill material for this latter scenario. To ensure the pools are sustained by scour, the inside of bends had gravel deposited on them to simulate natural point bars.

C. *Straight, wide and shallow section*
After exiting the bends the channel widens. Significant narrowing is expected to naturally develop as sedge encroaches from the bank and entraps newly accreted silt. This narrowing process has been enhanced by the addition of deflectors (up to 5m in length and facing upstream), installed to help to deflect flow into mid-channel and accelerate silt deposition between the deflectors (*see 3.1 for further discussion of deflectors*). Here deflectors were chosen due to the shallower and wider nature of the channel, and the limited access requiring hand installation.

The associated pond, from which material was won, was re-profiled to give shallow margins and bank slopes, and planted with emergents excavated from the channel, and additional native wetland species.

SUBSEQUENT PERFORMANCE 2000 – 2001

Work was only completed in October 2000, prior to very high flows. Evidence after 1 year indicates that the reduction in channel size has not resulted in any bank erosion, and that the gravel has stayed predominantly in place. Minor local changes in gravel composition have occurred, with less fines in the low-flow channel.

The re-configured channel has restored typical chalk stream habitat, establishing a self-cleansing gravel bed suitable for *Ranunculus* to establish and for wild brown trout spawning.

During subsequent high flows the full (c10m) channel width will be occupied by water, yet under Q90 flows the channel width will narrow in most places to less than half of this, maintaining a cleaning velocity to keep the new gravels free of silt.

Contact:
Nick Lutt and Mike Crafer, Thames Water, Environment & Quality (RBH2), Clearwater Court, Vastern Road, Reading. RG1 8DB, Tel: 0118 957 7666.
Kevin Patrick, Hankinson Duckett Associates, Landscape Studio, Reading Road, Reading. RG8 9NE, Tel: 01491 872185.

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

5.5 Raising river bed levels

UPPER KENNET

LOCATION - Ramsbury, Wiltshire
DATE OF CONSTRUCTION - 2nd October – 20th October 2000
LENGTH – 210m
COST - £12, 000 – £14, 000 for construction and reinstatement works only†

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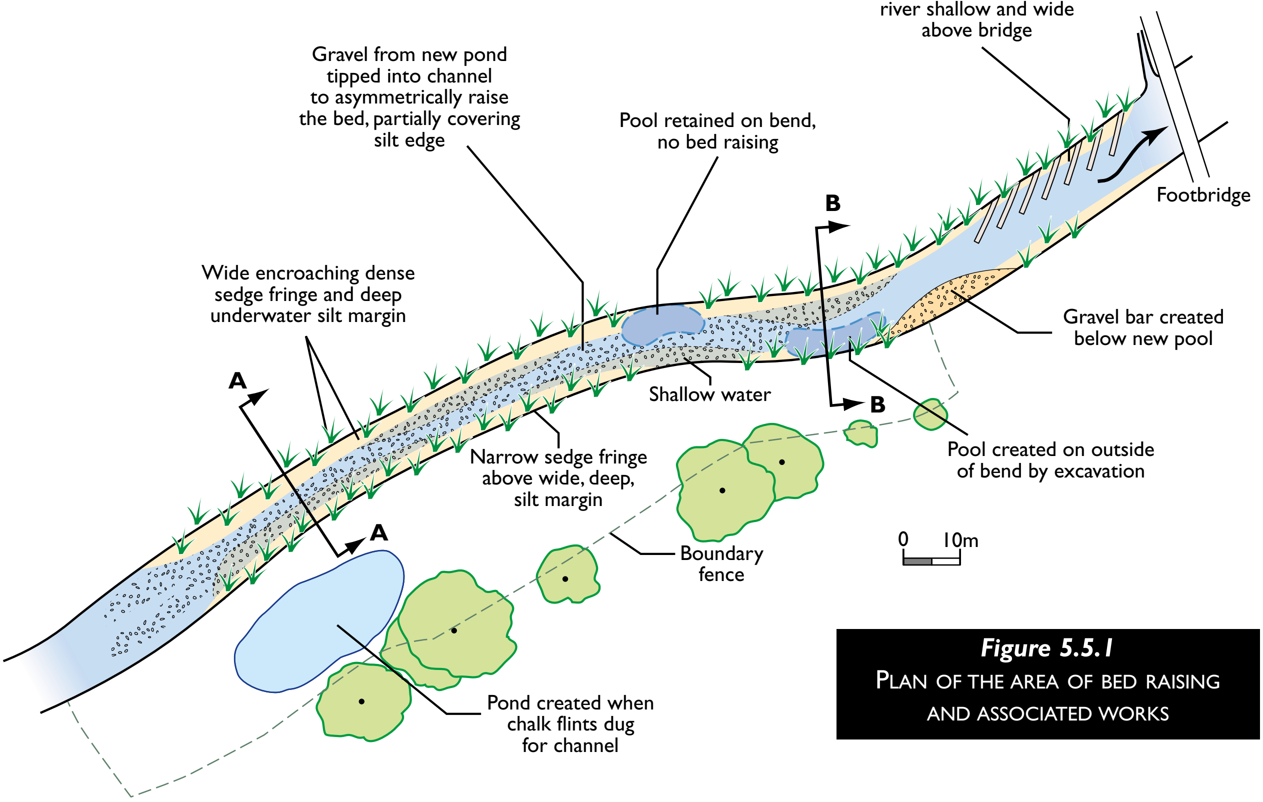

Figure 5.5.1
PLAN OF THE AREA OF BED RAISING AND ASSOCIATED WORKS

DESCRIPTION

The Upper River Kennet is a chalk river (Habitat Action Plan interest) under European Regulations and notified under UK legislation as a Site of Special Scientific Interest. Despite its designation, the river exhibits interesting contrasts in habitat quality. Some stretches support pristine chalk river characteristics (beds of abundant *Ranunculus* (Water-crowfoot) and clean gravels suitable for sustaining wild brown trout populations). However, past management works, ranging from mill impoundments to more recent dredging activities, have resulted in over-widened, over-deepened, sluggish, stretches that are prone to silt deposition and lack gravel or crowfoot.

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Before: sluggish deep water with encroaching sedge significant silt shoulders. Despite this development, the channel remained too wide to sustain fast water currents and even in mid-channel the bed was subject to deep silt accretion.

A common approach to achieving self-sustaining habitats in enlarged degraded rivers is to narrow the river bed width and thereby concentrate flows within a defined low-flow channel. However, where the river also has a history of deepening, this may simply lead to the formation of a very constricted, deep course. To restore a more appropriate width to depth ratio, bed raising may also need to be considered (*see 1.2 for further discussion on selecting the appropriate cross section*).

A 210m stretch upstream of Ramsbury was re-configured, primarily through raising the bed. The channel bed was raised asymmetrically to ensure that there was a narrow low-flow course and shallow edges to encourage marginal vegetation encroachment.

As the Kennet is a chalk stream the predominant flow is derived from groundwater, so major fluctuations in water level and velocity are much less than in rivers fed primarily by surface water. Consequently, a more flexible approach can be adopted for the location of gravel materials to raise the bed, as there is less risk of subsequent mass re-distribution.

Detailed flow modelling was a key element to determine the effects of the works under low-flow and flood conditions, for land drainage consent and to allay potential landowner concerns.

DESIGN

Throughout, bed levels were raised to leave a maximum water depth of 500mm at low water level (based on the Q90 discharge level - the level at which flows are exceeded 90% of the time). At this discharge, the margins of the channel would have a depth of <100mm. The Q90 flow was indicative; the desire was to ensure that under very low flows the bed-width would be constricted to sustain at least some clean gravel at all times. The maximum depth of 500mm at Q90 was based on a target reference width and depth.

Work was scheduled to commence in early October when river flows are usually at an annual low, approximating to Q90. Prior to undertaking work, stakes were placed in the river to mark this level as a guide to the contractor during the gravel placement process. This was especially important since water levels would change if silt entrapment measures had needed to be installed downstream (on standby but not needed).

Gravel placement may influence or be influenced by fluctuating water levels

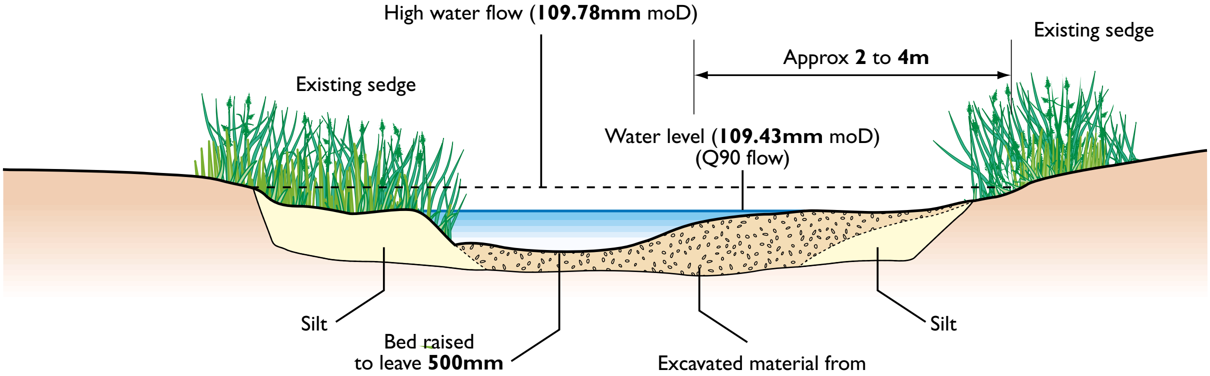
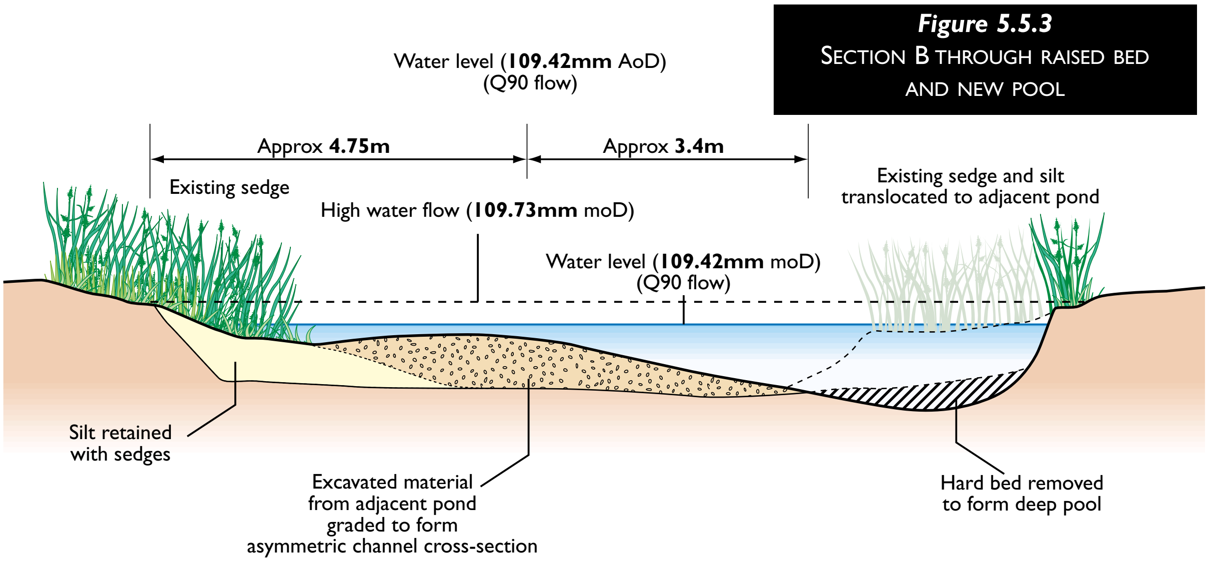


Figure 5.5.2
SECTION A THROUGH RAISED BED AND MARGINAL SHOAL

Figure 5.5.3

SECTION B THROUGH RAISED BED AND NEW POOL



The material used to shallow the channel depth was chalky and gravel flints. Where possible it is advisable to use material from the immediate area to reflect the type of bed that would have been present under natural conditions. Here the gravel fill was excavated from the floodplain by the creation of an adjacent pond on the right bank. The suitability of the material was checked beforehand by the inspection of machine-excavated trial pits. Infill material was predominantly a mixture of gravels and flints varying in size from 20 to 10mm, with <5% coarse sand and minimal silt. A few larger flints were also present.

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Topsoil and overburden were first stripped and stored before the gravel was dug out and transported by dumpers to the river bank. Representative cross sections were produced as references for the placement of material so that a degree of sinuosity was created under low flow.

The contractor followed the drawings and had the advantages of both knowing the river stretch well and having been involved in the final design. Regular on-site supervision was provided by an experienced team member.

The works length can be divided into three sections.

A. *Straight with marginal sedge on both sides*
Cross section A (*fig. 5.5.2*) is a typical section across this reach. Silt colonised by sedge represents up to half of the total channel width.

New pond with early growth, showing the gravelly nature of the floodplain material

Gravel has been used to shallow and narrow the remaining open water channel by up to a half, with the shallower margins finishing just below the Q90 level. The remaining low-flow channel is raised to within 500mm of the Q90 surface.

B. *'S' bend with some marginal sedge*
The outsides of each bend are enhanced with a pool, the first by retaining existing very deep

A few months after completion, the raised bed evident

water, the second by dredging the silty sedge margin (material then used to provide marginal substrate in the new pond). Cross section B (*fig. 5.5.3*) shows the asymmetric section with fill material for this latter scenario. To ensure the pools are sustained by scour, the inside of bends had gravel deposited on them to simulate natural point bars.

C. *Straight, wide and shallow section*
After exiting the bends the channel widens. Significant narrowing is expected to naturally develop as sedge encroaches from the bank and entraps newly accreted silt. This narrowing process has been enhanced by the addition of deflectors (up to 5m in length and facing upstream), installed to help to deflect flow into mid-channel and accelerate silt deposition between the deflectors (*see 3.1 for further discussion of deflectors*). Here deflectors were chosen due to the shallower and wider nature of the channel, and the limited access requiring hand installation.

The associated pond, from which material was won, was re-profiled to give shallow margins and bank slopes, and planted with emergents excavated from the channel, and additional native wetland species.

SUBSEQUENT PERFORMANCE 2000 – 2001

Work was only completed in October 2000, prior to very high flows. Evidence after 1 year indicates that the reduction in channel size has not resulted in any bank erosion, and that the gravel has stayed predominantly in place. Minor local changes in gravel composition have occurred, with less fines in the low-flow channel.

The re-configured channel has restored typical chalk stream habitat, establishing a self-cleansing gravel bed suitable for *Ranunculus* to establish and for wild brown trout spawning.

During subsequent high flows the full (c10m) channel width will be occupied by water, yet under Q90 flows the channel width will narrow in most places to less than half of this, maintaining a cleaning velocity to keep the new gravels free of silt.

Contact:
Nick Lutt and Mike Crafer, Thames Water, Environment & Quality (RBH2), Clearwater Court, Vastern Road, Reading. RG1 8DB, Tel: 0118 957 7666.
Kevin Patrick, Hankinson Duckett Associates, Landscape Studio, Reading Road, Reading. RG8 9NE, Tel: 01491 872185.

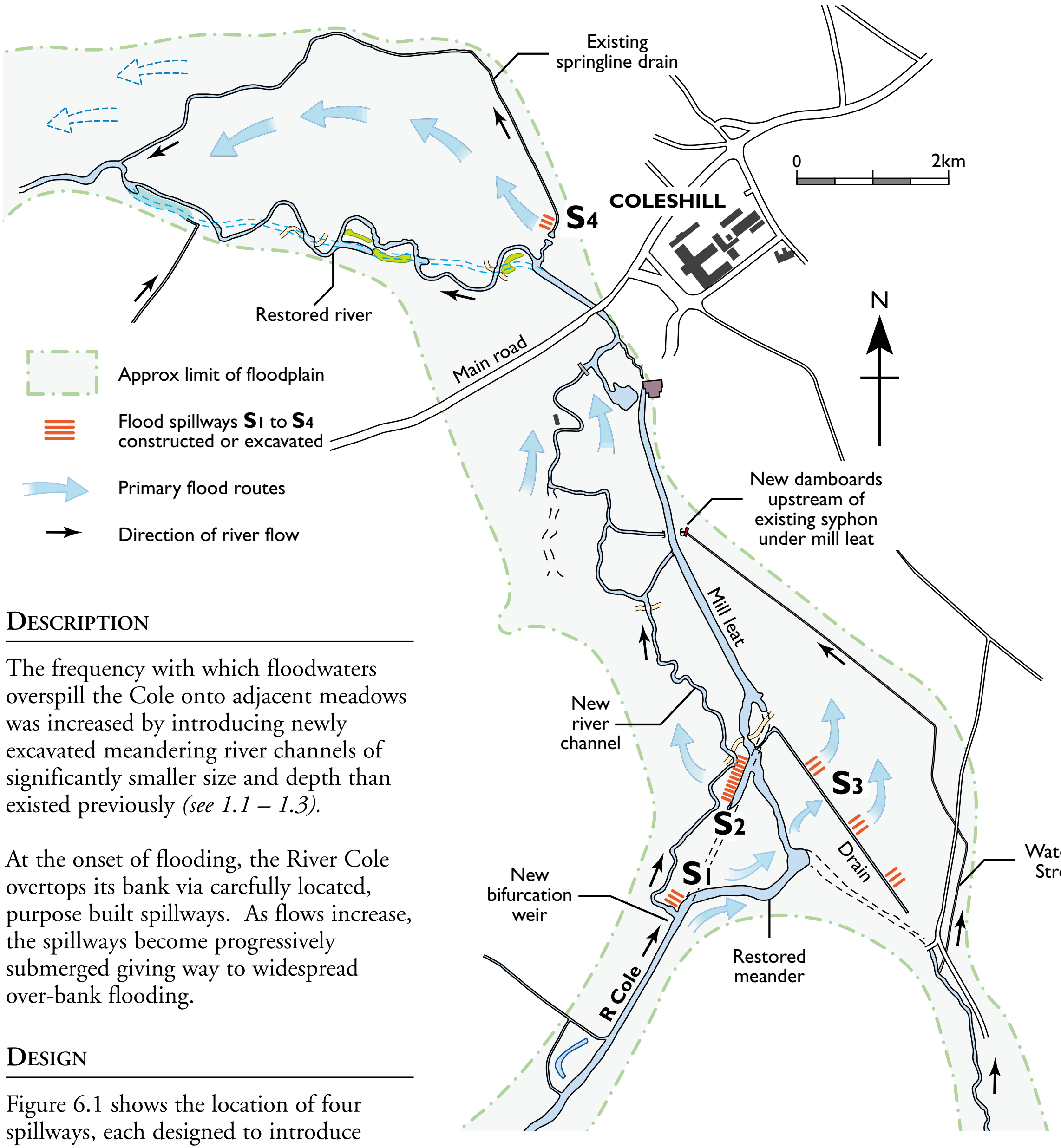
6 MANAGING OVERLAND FLOODWATERS

6.1 Floodplain spillways

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
FLOODPLAIN AREA – 50ha.
COST – Approx. £28/metre for 100m of spillway

Figure 6.1
PLAN OF FLOOD ROUTING



DESCRIPTION

The frequency with which floodwaters overspill the Cole onto adjacent meadows was increased by introducing newly excavated meandering river channels of significantly smaller size and depth than existed previously *(see 1.1 – 1.3).*

At the onset of flooding, the River Cole overtops its bank via carefully located, purpose built spillways. As flows increase, the spillways become progressively submerged giving way to widespread over-bank flooding.

DESIGN

Figure 6.1 shows the location of four spillways, each designed to introduce floodwaters into discrete compartments of the floodplain. Upstream of the main road three spillways (S1 to S3) operate with incremental rises in river level and flow. Downstream of the main road a single spillway (S4) introduces water to the right bank meadows. Flood waters pass under the road via the river bridge and two existing flood culverts set at field level.

Spillways upstream of the main road

Spillway **S1** is located alongside the bifurcation weir which feeds water into the newly excavated river channel *(see 5.1).*

The spillway operates early on in a rising flood and is sized such that the new channel fills to bankfull in advance of any overspill elsewhere.

Spillway **S2** . Flood flows indicated by the arrows overtop the spillway, merging with the new channel *(not visible)*

Spillway **S2** begins to operate only after **S1** has filled the new channel with water. Water spilling over **S2** passes directly into the new channel causing it to overflow its banks and initiate field flooding. Scour of the overspill is minimal because this design ensures floodwaters from both **S1** and **S2** merge without excessive turbulence.

The level at which **S2** is set is critical; it is 300mm lower than the floor of the mill further down river, to ensure floodwater is diverted away from the mill.
In practice, **S2** replaced an unsightly concrete cascade weir built at the mill to protect it from flooding. The cascade has been boarded off and will be infilled once the performance of **S2** is proven to be satisfactory.

The length and longitudinal profile of **S2** was also critically determined, by hydraulic modelling, to ensure sufficient flow of floodwater down the valley to avoid worsening 1 in 100 year flood levels for isolated properties on the fringes of the floodplain. The crest has a compound profile which is surfaced in stone over the lower part.

Spillway **S3** is a previously existing low embankment alongside a field drain built to prevent water in the leat backing up the drain and overspilling into a large meadow to the east. In 1995, when the main project works were completed, no modifications to this embankment were made. Subsequently, it was verified through observation that floods rarely overtopped the embankment, so in 1998 the crest was lowered at several locations, just sufficient to gain the flood frequency desired. The only escape for floodwaters entering the meadow is via a ditch and syphon pipe under the leat. Water levels build rapidly due to this ‘throttle’, creating a floodlake. The embankment low spots created are all elevated 100mm higher than the crest level of **S2** so that flooding of compartments arises incrementally giving the farmer time to react if livestock are present.

Spillway downstream of the main road (fig. 8.2.2)
Spillway **S4** is located alongside a spring line drain that discharged to the river. The drain was firstly blocked with soil well back from the river to help keep the meadow damp. The redundant length of drain between the river and the staunch was then modified to carry floodwaters from the river out onto the floodplain. This was neccessary because the land alongside the river is higher than the general field levels, thereby delaying the onset of natural flooding. The drain modifications overcome this problem.

Spillway **S2** in flood

Spillway **S4**. Floodwaters spilling into field gully.

form spillway **S4**. The spillway is located close to a natural gully that meanders down through the floodplain fields and probably marks an ancient river course. The spillway was completed by shallow excavation of the field to extend the gully right up to the bank of the drain.

An access bridge was built over the drain using two 1m diameter pipes, sized to allow reasonable volumes of floodwater to pass through. The top of the crossing was kept up at the prevailing river bank level so that livestock could be evacuated, after flooding commenced via the nearby spillway **S4** (*see 8.2.)*

SUBSEQUENT PERFORMANCE 1995/98

The hydraulic performance has closely matched the predictions of the hydraulic model, which were conservatively judged to avoid excessive summer flooding when hay or livestock are in the fields. Experience of flood levels during the two summers post construction led to the slight lowering of levels at S**3**, described above, as well as a similar degree of lowering at **S4**.

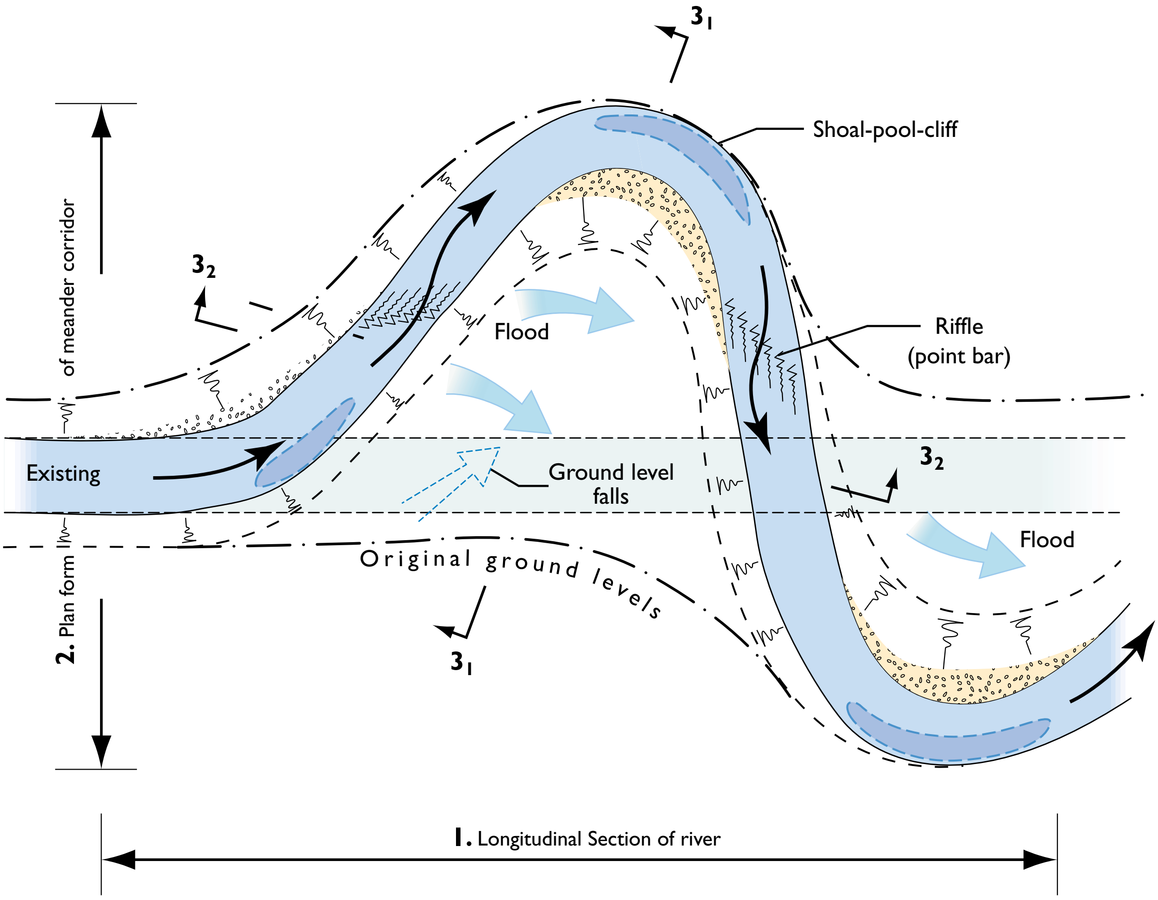
The stone surfacing of **S1** and **S2** suffered localised scour damage which was rectified by partial reconstruction, taking greater care to ensure the predominant stone size (200mm) was evenly distributed and well compacted into turfy soil that quickly generated root and sward binding. Level pegs were driven near **S2** so that its designed crest could easily be checked for trampling by cattle or erosion by water..

6.2 Profiling of land between meanders

RIVERS COLE AND SKERNE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
– Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – Autumn 1995
LENGTH } – Integral part of new meandering works
COST }

Figure 6.2.1
PLAN OF SCHEMATIC MEANDER



DESCRIPTION

The creation of new meandering channels required a design that reflected the hydro-geomorphological processes that naturally lead to meander formation. The natural geometry of meanders is complex, but certain basic principles were followed at both the Cole and Skerne sites to develop simplified designs that could be implemented using conventional excavation plant.

DESIGN

Figure 6.2.1 depicts an idealised meander where the outer bank is eroding and the inner bank accreting, thereby generating a slow migration of the meander down the river valley. This fundamental process means that the profile of the land within the meander naturally results from deposition during successive floods, and that it will usually be markedly different from the generally flat profile of the wider floodplain.

The creation of the new meanders reflected this process by including reprofiling of land within the meander corridor. If this was not done, and works were limited to simply excavating a sinuous channel, then erosive forces would have been un-naturally high, due to the confinement of the river, until such time as the river had itself adjusted to the more balanced form depicted.

The design of meanders at the sites is fully explained in 1.1 to 1.4. This involved the sequential determination of the following dimensional details:

1. The mean longitudinal bed profile of the whole reach;

Figure 6.2.2
SECTION $3_1 - 3_1$

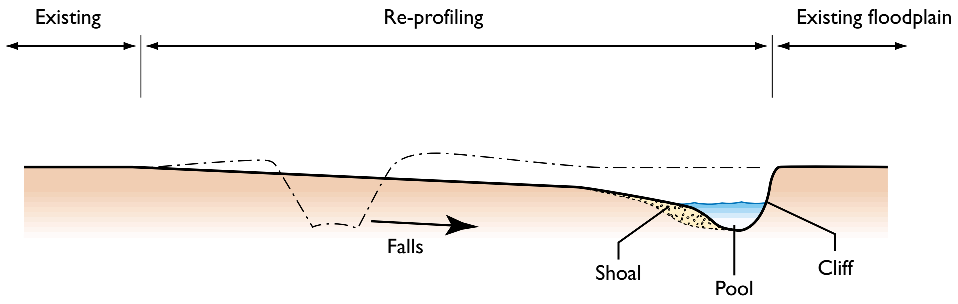
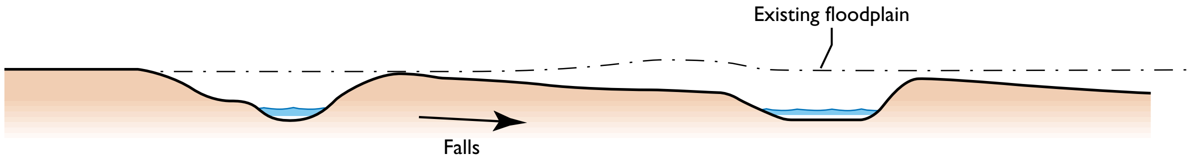


Figure 6.2.3
SECTION $3_2 - 3_2$



2. The alignment of meanders in plan;
3. The variable channel cross-sections to suit 1 and 2 above;
4. The profile of the land within the meanders.

The aim of 4 (re-profiling) was to integrate the other three aspects (bed, bank and plan form) creating a sustainable river corridor. The extent and nature of re-profiling was influenced by the way in which floods would pass between successive meanders before reaching water levels that gave rise to general over-bank flow onto the wider floodplain.

The conveyance of floodwaters between meanders proved to be a significant factor in achieving the necessary hydraulic capacity of the river.

The two most important aspects of re-profiling are indicated in the two cross-sections *(figs. 6.2.2 – 6.2.3)* and summarised below:

- Gradually falling levels laterally across the meander profile merging into a shoal-pool-cliff profile at the apex *(see 3.1);*
- Gradually falling levels longitudinally between the start of the meander and the return leg *(see 3.2).*

This approach ensures that submergence of the meander in a rising flood will commence at the return leg, starting where shoal deposition is most active and progress back towards the entry bend. This pattern of submergence generates flow currents that are complex and varied but are generally smooth. This contrasts with the turbulent conditions that arise if re-profiling is not undertaken.

Other practical benefits of re-profiling in this way include a safer environment for people and livestock. Easy access down to the waterside is intrinsic to the design, and the risk of being trapped by floodwater suddenly cutting straight across the meander is greatly reduced.

The formation of sustainable pools, riffles and cliffs in the locations indicated on the plan is similarly an intrinsic feature of these design principles.

Subsequent performance – 1995/98

Although the principles of the design were well understood, their full application was compromised for a number of reasons, including underground services, although every meander, at both locations, was subjected to re-profiling to some degree. It was evident after the first winter season that some further re-profiling was desirable to get much closer to the idealised form described *(see 1.1 – 1.2).*

The re-profiling has proved to be a very important aspect of the design, the best example being the largest meander on the Skerne where a backwater is incorporated *(see 2.1).*

6.3 Removing and setting back floodbanks

LONG EAU

LOCATION - Manby, Lincolnshire TF 407863
DATE OF CONSTRUCTION - May – June 1995
LENGTH – 900m
AREA – 16ha
COST - £60,000

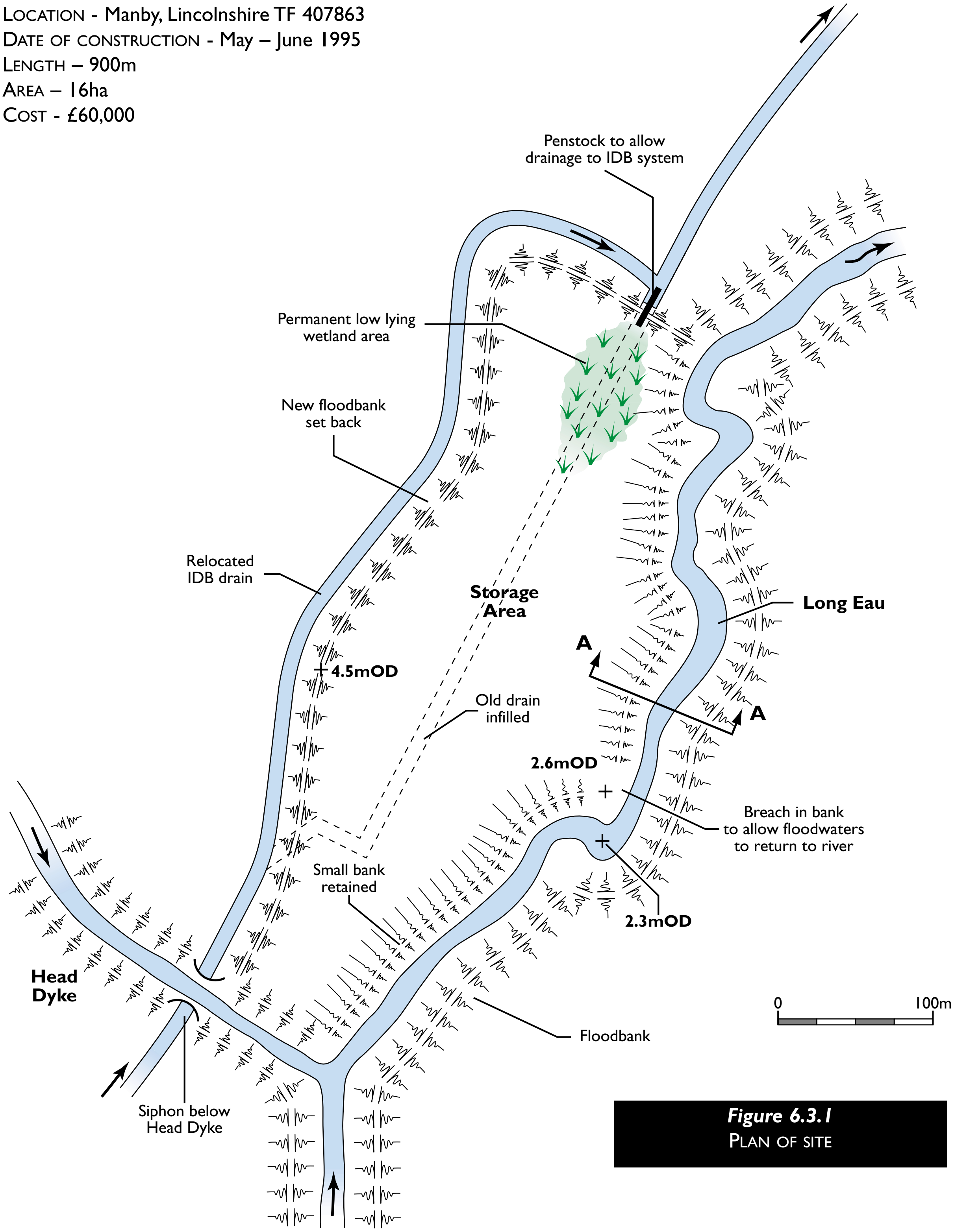


Figure 6.3.1
PLAN OF SITE

Removal of the left floodbank and marginal berm creation on the Great Eau at Withern

DESCRIPTION

The Great and Long Eau drain large areas of predominantly agricultural land. Both rivers have been heavily modified and embanked to increase capacity to protect the surrounding land, and both are high-level carriers relative to the surrounding land. Regular dredging to maintain capacity has removed any natural substrate.

Three sites were chosen along the Long and Great Eau to demonstrate improved flood protection standards through a process of relocating floodbanks previously located along the riverbank. At each site the floodbank was removed and a flood storage area created on adjacent land. The site selection process also took into account the opportunity to combine floodplain restoration with river channel enhancement and marginal habitat creation.

Landowner support was key to the implementation of the schemes, and some form of financial mitigation was essential to landowner support. FWAG and the Countryside Commission helped landowners successfully enter into the Countryside Stewardship Scheme, to gain compensatory funding of a total of £60,000.

Relocating the IDB drain and set-back floodbank

Apart from in the upper reaches, the majority of the Long Eau has little gradient and is virtually bereft of any habitat structure. There is little contact with the previous floodplain as the river has been deeply dredged, and seasonal over-topping cannot occur due to high floodbanks.

DESIGN

Long Eau – Manby
The left floodbank was lowered to just above ground level, so still retaining a low embankment. The field-side slope was widened and flattened to 1 in 10 as this would now act as an overspill. The river-side bank was also re-profiled, sloping gently down to a wet berm up to 2m wide where marginal plants could establish.

The 2100m^3 of spoil from the bank removal was used to fill in an Internal Drainage Board drain that ran through the centre of the proposed storage area. This had to be re-routed behind the new 'set-back' floodbank to maintain the integrity of the upland and lowland drainage system. Material excavated from the construction of the new drain was used to form the new floodbank, set back from the river by up to 300m. The new bank is large due to the volume of material that needed to be excavated to re-route the IDB drain. The new embankment is constructed of clay with slopes of 3:1 to a height of 2.5m to 2.7m above the adjacent ground level. This gives a designed crest level of 4.5m above OD with a crest width of 3.5m minimum. The volume of material used for the embankment was 18,500m^3.

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

View along the trapezoidal right bank of the Long Eau

View from the new embankment across the restored floodplain. Showing wintering wildfowl, January 1999

Water is designed to spill onto the 16ha site from the Long Eau when levels reach 2.6m above OD, just 0.3m over their normal retained level. This floods progressively outwards from the old course of the IDB drain, which represents the lowest levels within the area. This low spot remains damp for much of the year, the downstream end forming a permanent wet scrape/shallow pool.

The project team and landowner were keen to avoid prolonged springtime surface inundation by floodwater trapped in low lying pockets and not returning to the river. Where such areas were evident the bank was lowered locally to allow drainage back to the river as river levels subsided, as well as into the area as levels rise. As the water depths lower through gravity drainage and evaporation a penstock can be accessed by the landowner to discharge water to the IDB system to allow the grass sward to recover for early summer grazing.

Long Eau - Little Carlton and Great Eau - Withern
Similarly, upsteam at Little Carlton the floodbanks were removed and set back, and at Withern the natural rise in slope was used to contain floodwaters without the need to replace the bank. As with Manby both sites included work on the floodplain and river's edge, creating scrapes, reedbeds, berms, riffles and, where suitable, exposed cliff faces.

SUBSEQUENT PERFORMANCE 1995 – 2001

Initial hydrological modelling indicates significant local benefits, including an increase of 30 years to the standard of protection over a 3km stretch of the Long Eau at Little Carlton and at Manby.

Long Eau, Manby
Water will spill onto the site from the Long Eau when levels reach 2.6m above OD and has reached a maximum of 4m above OD. Levels are then reliant on conditions in the Eau subsiding and, depending on the intensity of the event, have been retained for two or three days. Below the Eau level of 2.6m, 75% of the washland will retain water to a depth of up to about 0.5m. This can remain for 3-4 months providing ideal conditions over the winter months for dabbling and grazing ducks such as widgeon, teal, gadwall and mallard.

Floodplain, penstock and permanent wetland area, October 2001

Waterfowl and waders have increased on the floodplain. Lapwing and redshank have bred on the site. Flocks of over 60 redshank and snipe, curlew, ruff, common and green sandpiper are amongst the birds that use the washlands in the winter.

Contact:

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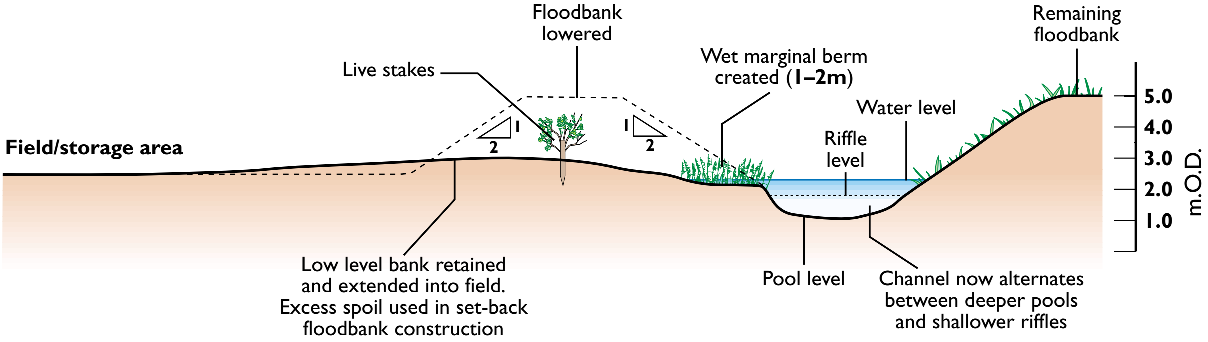
Figure 6.3.2
SECTION A THROUGH FLOODBANKS



Berm at section A after 4 years

CREATING FLOODPLAIN WETLAND FEATURES

7.1 Floodplain scrapes

RIVER SKERNE
LOCATION – Darlington, Co Durham NZ 301160
DATE OF CONSTRUCTION – Autumn 1995 (in meanders), May 1996 (at Rockwell)
NUMBER– 2 excavated; 1 in backfilled chanel
COST– £1k each for excavation

Completed spring-fed scrape

DESCRIPTION

The term 'scrape' is used to describe a shallow pond that forms in a natural lowspot in a floodplain. Scrapes are sometimes dry during the summer unless they are fed by springs. The most common reason for their occurrence is probably the historic migration of a river across a floodplain leaving only partially filled channels behind but there are many other reasons. Scrapes afford off-river habitat for plant and animal species dependent on their unique characteristics, including frogs and newts.

Three new scrapes were formed on the Skerne floodplain. The first two were located within the meanders of the newly re-aligned river *(see 1.4)* and the third within Rockwell Nature Reserve, alongside the main east coast railway line *(see key plan preceding the technique section).*

DESIGN

Scrapes within meanders
The south side of the floodplain is partially overfilled with industrial waste contained within a clay bund. Clean water was observed to be seeping from the toe and to be sustaining a lush growth of grass (mown) all year round. A scrape was excavated within this area of low artesian water pressure so that full advantage could be taken of the opportunity to introduce a significant wetland feature to the floodplain *(fig. 7.1.1).*

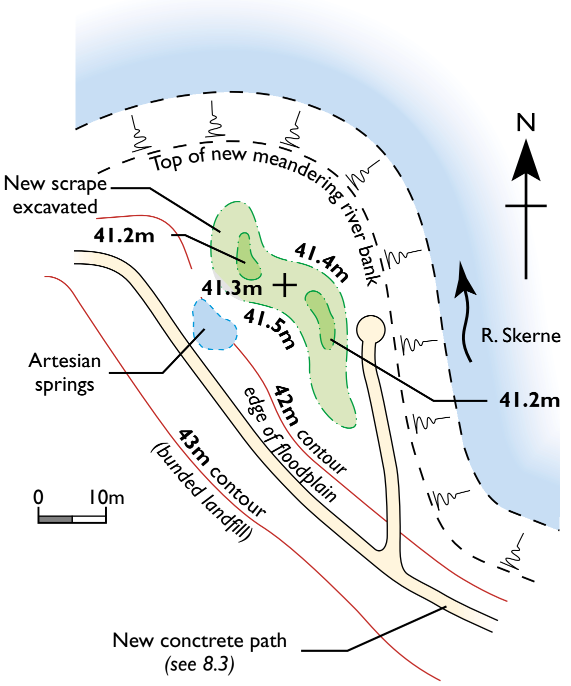
The irregular shape fits comfortably within the limited area available and the depth has been limited to 300mm in the interest of public safety, as well as to suit the emergent and marginal aquatic vegetation sought. The side slopes are very shallow for similar reasons. No overspill was built. In very wet periods excess water seeps towards the river over the grassed area alongside.

On the north side of the new meanders the old, straight, river channel has been infilled in places. Immediately downstream of the first meander (entry bend) infilling was profiled to leave a shallow depression, intended to attract surface water from the adjoining parkland, thereby creating a small wetland feature during the winter.

Both scrapes were subsequently planted by organised parties of local school children. Species included Ragged Robin, Loosestrife, and Meadowsweet that were grown from seed as part of a school project linked to an English Nature series of freshwater guidance publications.

Scrape at Rockwell Nature Reserve
The reserve is a well-established wetland site where several ponds and scrapes have been excavated in an area of low artesian ground water pressure sustained by rising ground alongside. Great crested newts are a protected species found in the reserve. The area of the reserve nearest to the river was, however, marred

Figure 7.1.1
PLAN OF SCRAPE WITHIN MEANDER FED BY GROUNDWATER



View of Rockwell scrape site after removal of rubble piles

Comparitive view of Rockwell scrape after work completed

by piles of dumped soil and rubble that have overgrown with less desirable ruderial plants.

Some piles were cleared from site and the ground taken down to expose historic floodplain soils, although these were found to be interspersed with deposits of dumped foundry sand. These sands were also evident throughout the restored floodplain, marking Darlington's industrial history of iron works.

Working closely with the local Wildlife Trust, a new scrape was then excavated and the spoil removed from site. The scrape is about 50m^2 in area and slopes gently down from one side to a maximum depth of 1m where it returns steeply to ground level forming a small cliff that is overhung by pre-existent willow carr.

SUBSEQUENT PERFORMANCE 1995/6 – 98

Both scrapes excavated within artesian ground water areas have proved to be very successful, sustaining wetland habitat year round and providing visual interest to previously unremarkable areas.

The scrape formed in the backfilled river course has not been successful, although it does collect water occasionally. This has not been sufficiently frequent, or prolonged, to establish any wetland plants. The scrape has been colonised by the same species of grass and wild flowers sown around it, but they are weakened as a result of occasional waterlogging. It is arguably a nuisance in this public open space since it provides no discernible ecological or amenity benefits.

It is reasonable to conclude that for floodplain scrapes to provide worthwhile ecological value they are dependent upon a reasonably reliable source of groundwater or surface water, albeit most are intrinsically seasonal features that do not have to be wet for more than 6-9 months of the year.

Surprisingly both duck and moorhen spend time on the artesian fed scrape within the meanders where they are highly visible from the new path built alongside *(see 8.4)*.

7.2 Floodplain wetland mosaic

RIVER THAMES

LOCATION - Pinkhill Meadow, Farmoor Reservoir, Oxfordshire SP 439067
DATE OF CONSTRUCTION - JUNE 1990, December 1991
AREA – 1.5ha
COST - £112,000

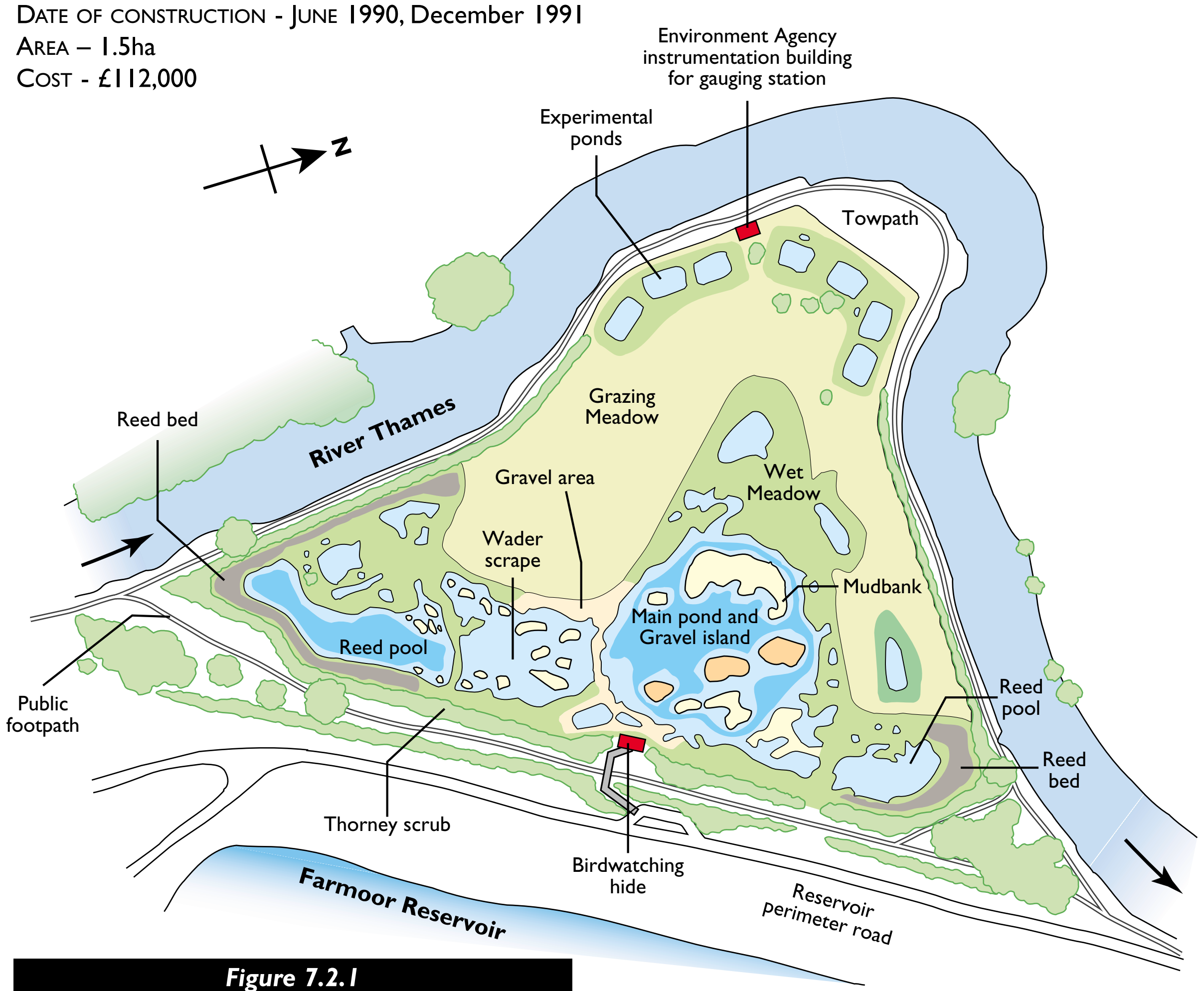


Figure 7.2.1
PLAN OF PINKHILL MEADOW

DESCRIPTION

Pinkhill Meadow is located in a 4 hectare meander of the River Thames at Farmoor Reservoir. In a detailed landscape assessment of the reservoir site in 1988 the meadow was identified for its potential for wetland creation. Few areas of wetland had survived agricultural improvement in this part of the Upper Thames Valley. Approx. 1.5 hectares of the meadow still had a valuable relic meadow flora including species such as Adders Tongue, Great Burnett and Pepper-saxifrage.

The aim of the scheme was to compliment the river and the reservoir habitats by restoring the floodplain wetland within the meadow which had been largely disturbed during reservoir construction.
A key objective was to restore habitat for breeding waders and wildfowl, notably Redshank, and to create a place where people could experience a wide variety of wetland wildlife at close quarters and enjoy a more "natural" floodplain landscape.

The project was a collaboration between the landowners (Thames Water) and the National Rivers Authority, advised by Pond Action. Large parts of the Farmoor wetland complex are open to members of public, and keys to the birdwatching hides can be obtained from the Wardens Lodge at Gate 3.

DESIGN

A concept plan for the site was prepared from the landscape appraisal and developed into the detailed design, incorporating the project objectives with the site constraints.

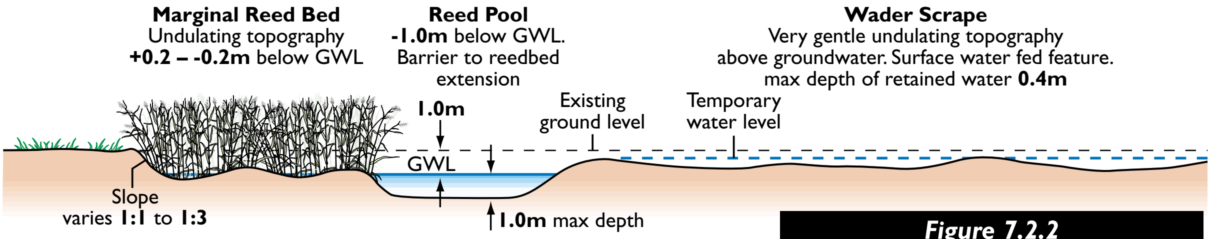


Figure 7.2.2
INDICATIVE SECTION THROUGH REED POOL

The mosaic of over 40 ponds and pools was designed to maximise the topographical, hydrological, biological and visual diversity of the site. This included specific creation of individual waterbodies with a wide range of maximum depths and permeability, and low angle, undulating drawdown zone areas to encourage both wetland plant diversity and wading bird habitat.

Two phases of excavation were undertaken, the first in June and July 1990 and the second over the winter period in 1991/2. By phasing the works it was possible to better understand the detail needed for the more complex works in the second phase.

Excavation was based on detailed landscape design drawings provided by the NRA landscape architect, and firmly led by close project management and continuous on-site supervision from key members of the project team. In this way the inexperienced machine operator was able to achieve the very subtle variations in topography in relation to water levels. The 20,000m^3 of excavated material was carefully graded into a low hill near the adjacent Pinkhill Lock, but outside of the floodplain. This was then planted with trees and shrubs and sown with a wildflower seed mix.

In phase 1 four waterbodies were created; the main pond, wader scrape and two reedbed pools. In phase 2 the existing waterbodies were extended, added to and re-profiled to create areas of shallow water, wet meadow, mudflat and temporary pool habitat.

Observations of the phase 1 works provided valuable detail for the improvements undertaken in phase 2. Observations of actual as opposed to design water-levels in the pools were used to refine the new excavation levels, marginal areas and undulating contours of the wet meadow. The location of the mudflats was also based on the usage of the various areas of the site by different target wader species.

Key features created:

Deep water

The main pond is up to 2.5m deep and covers an area of just under 0.5ha and was excavated down into the gravel aquifer. The size and depth increases the diversity of habitats and isolates the several islands reducing the likelihood of predation of bird nests. The depth also ensures open water and from a management viewpoint it also restricts the complete colonisation by marginal wetland plants.

Shallow-water areas and edges

These areas were designed to between 300mm below and 100mm above normal water levels. As the main pond level will fluctuate by about 300mm, reflecting groundwater levels, these areas are important to retain shallow slopes at the water's edge.

Wader scrapes
(February 1992)

Main pond, pool and reedbed creation (February 1992)

Temporary ponds and pools
The site also includes small temporary pools, some isolated and some bordering the larger waterbodies. Sizes vary from a few square meters to the larger two semi-permanent ponds (approx. 100m^2). These transient ponds are designed to dry out in drought years (two or three times since excavation) and provide a habitat with low fish predation, benefiting many aquatic invertebrates and some amphibians.

Wader scrape
A 400mm maximum depth shallow pool was formed within the alluvium overlaying the gravel aquifer and the water level controlled by means of a connecting pipe to the main pond. This feature provides extensive muddy margins for feeding waders and Teal, particularly during autumn migration.

Gravel islands and margins
Created over an area of 0.1ha, these provide nesting habitat for Little Ringed Plover and Common Tern. The gravel was carefully selected from a local source to ensure a good size distribution, important for these species. Selectively placed cobbles and boulders also provide surface variation.

Mudflats and islands
These were created by excavating into the alluvium. Gentle slopes of 1:20 min. provide bare feeding and nesting habitats for wading wildfowl, but also created a more open habitat suitable for some marginal wetland plants.

Undulating wet grassland
Small variations in topography were engineered to create an undulating meadow with water levels close to the surface (between 100 and 200mm above normal water level). This marshy/tussocky Rush and Sedge dominated area was designed to provide feeding and nesting areas for waders, particularly Redshank and Snipe.

Reedbeds
Two linear reedbeds, totalling over 250m in length, were excavated along the eastern edge of the site. Shallow trenches were dug and planted with pot

Figure 7.2.3
INDICATIVE SECTION THROUGH MAIN POND AND GRAVEL ISLANDS

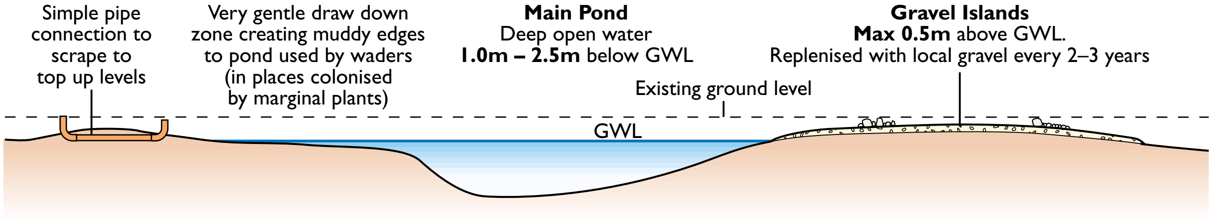
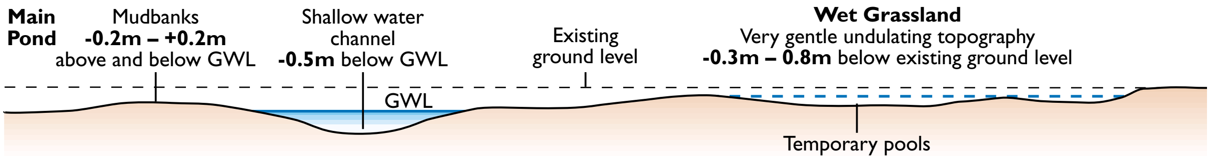


Figure 7.2.4
INDICATIVE SECTION THROUGH WET GRASSLAND



grown Common Reed. These serve as a boundary to human disturbance from adjacent footpaths and provide valuable nesting and foraging habitat for wetland birds such as Reed Warbler and Water Rail.

Scrub
A double row of mixed shrubby Willow (incorporating some Hawthorn, Blackthorn and Dog Rose) forms a 4m wide hedge at the eastern edge of the site linking adjacent areas of reed, meadow, hedges and woodland. As with the reedbed the presence of the hedge also helps to mitigate the disturbance of the nearby footpath, as well as sustaining a rich insect population and providing over-wintering cover for frogs, toads and newts. The scrubby character is to be retained by staggered coppicing on an annual basis ensuring a permanent screen is maintained.

SUBSEQUENT PERFORMANCE 1999 – SPRING 2001

Continuous post-project appraisal was carried out on this site for the first 5 years after construction and the results showed that this small wetland creation scheme quickly acquired an extremely rich wildlife community.

In these 5 years over 20% (over 60 species) of all Britain's wetland and aquatic plant species colonised the site. In the main pond alone the plant community was one of the richest recorded in ponds in the county. Similarly 22% (over 150 species) of Britain's macroinvertebrate species were recorded on the site, including 12 breeding species of dragonfly.

Breeding wader densities have been very high, in one year up to 100pairs/km^2 equalling that of grazing marsh and other important British wader habitats.

Aerial view of site

In 1993 and 1994 two pairs of Little Ringed Plover bred, representing 15% of Oxfordshire's breeding population . Unfortunately the site was too small to sustain such densities and the plovers have not returned since 2000.

As a result of the commitment of the partners and individuals involved, the continued appraisal of the site's development some minor and major modifications have been funded in every second or third year between 1992 and 2002.
These have included:

- managing gravel islands;
- scraping new mudflats;
- creating new pools;
- doubling the size of the main reedbed;
- annual coppicing and thinning of the willow scrub.

A key reason for the success of Pinkhill is the combination of critical factors for creating biologically high quality sites:

- good water quality;
- high degree of landscape connectivity to other wetlands;
- complex mosaic design integrated sensitively into the floodplain;

and specifically at Pinkhill;

- wetland creation with people in mind;
- combining 6 Key River Thames habitats in one place;

Similar design principles as those used to create Pinkhill Meadow have subsequently been adapted to create two further wetlands at the site, known as Shrike Meadow and Buckthorn Meadow.

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Oxford, OX3 0PB.
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PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.1 Fords and stock watering point

RIVER COLE
LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
LENGTH – 4 fords and 1 watering point
COSTS – Fords £1k each. Watering point £1k

Stock watering point at ch. 100m

DESCRIPTION

Two new fords and a stock watering point were created in the restored reach of the river downstream of Coleshill mill. Upstream of the mill two new fords were created *(see Part 1, figs. 1.1.1 – 1.1.2)*. Each ford enables livestock to cross the river easily, as well as doubling as a drinking place. Those upstream of the mill are also used by farm vehicles and those downstream form part of an equestrian trail. Although all are similar in concept the configuration of each is significantly different to take advantage of local topography.

DESIGN

Downstream of mill
All three features were created at locations where the old, straight river course was crossed by the newly excavated meandering course. Each is formed within the old backfilled river course where the soils are loose and susceptible to erosion. Rather than protecting the banks with revetments, each was set back from the true line of the new river by incorporating stoned access ramps (1:6 or flatter) to form either a ford or a stock watering point. As the new river bed at each point is filled to c. 1m above the old bed this too needed to be protected with stone surfacing.

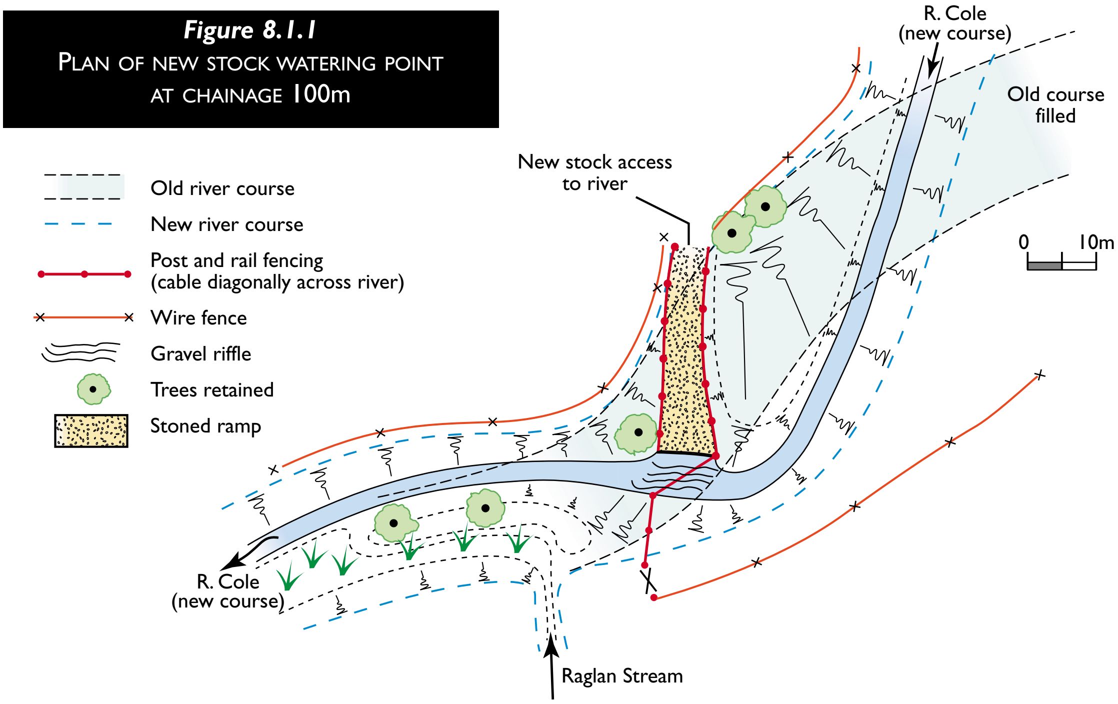
Stock watering point at ch. 100m (fig.8.1.1)
Located at ch. 100m just downstream of a sharp bend in the new river course where a fast flowing riffle of gravel was expected to form. This hydraulic condition, combined with the careful contouring of the adjacent river banks, helps to avoid the risk of siltation that all too often renders watering points useless. The post and rail fencing around the ramp is tied into bank top fencing on either side, as well as across the river, to form a secure field boundary point.

The river fencing comprises a single heavy wire cable strained tightly across on a diagonal line (see photograph). The extra length of the diagonal renders the cable less likely to form a complete blockage of the river if floating debris becomes snagged on it. The angle of the diagonal is aligned to direct turbulence caused by its presence towards the mouth of the watering point, further reducing the risk of siltation.

The ramp, its upstream flank, and the river bed are all formed over compacted fill, and flat surfaces are covered with stone over a filter fabric.

The ford at ch. 280m (fig.8.1.2)
Aligned between three mature trees on the old river bank to create an 'S' shaped feature, it crosses the new river bed on a long diagonal (c. 15m compared

Figure 8.1.1
PLAN OF NEW STOCK WATERING POINT AT CHAINAGE 100m

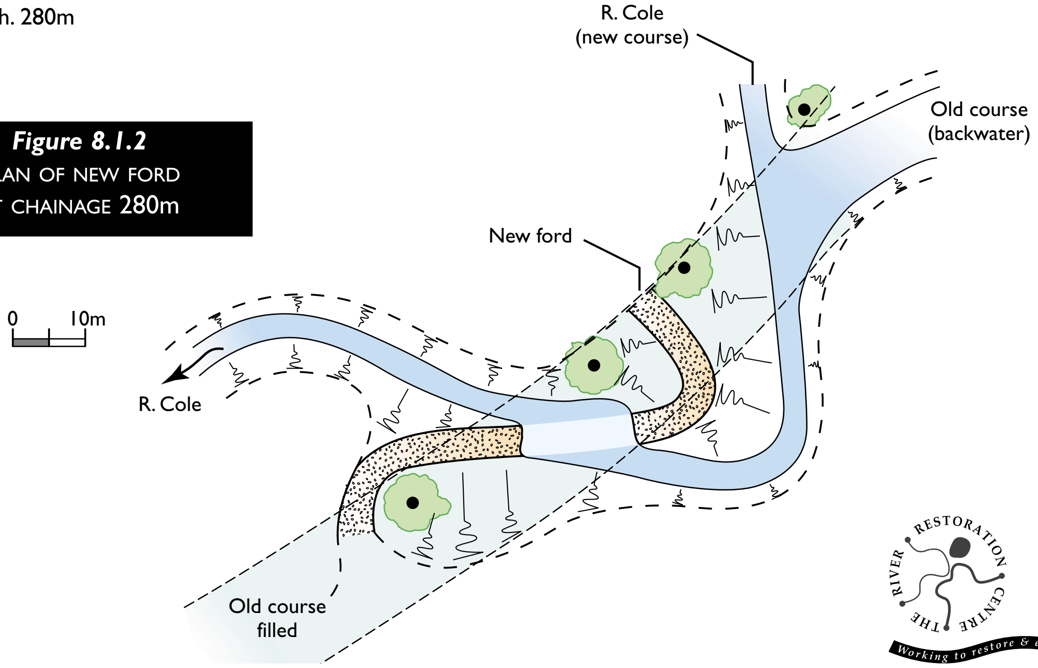


Ford at ch. 280m

with the typical bed width of c. 3m). The position of this diagonal approximates to the likely position at which a self-sustainable point bar of gravel would form, because of the sharp bend just upstream.

Most of the ford is formed within the old backfilled river channel, which is carefully contoured to create smooth transitions with undisturbed ground on both sides of the river, as well as with the root levels of the three trees and with the newly excavated channel. The river bed and ramps are surfaced with stone over a filter fabric to suit livestock rather than heavy vehicles.

Figure 8.1.2
PLAN OF NEW FORD AT CHAINAGE 280m



The ford at ch. 620m (fig.8.1.3)
This ford incorporates an old bankside willow on one side and crosses the new river course tangentially. This is not a natural gravel deposition point in the river (unlike the examples above) so the ford needed to be artificially strengthened if it was to remain in position. Another reason for strengthening was that the ford helps to avoid the risk of the new river channel down-cutting at this vulnerable point *(see 1.2)*.

The ford was formed to provide an 'overwide' river bed (c. 6m compared with c. 3m typical) and was elevated above the mean bed by c. 0.3m. This configuration was necessary to ensure that the normal river base flows 'weir' over at shallow depths so that it remains passable without being unduly sensitive to small increases in flow. During floods, the ford is completely 'drowned' and has no significant effect on water levels.

The old river bed was infilled to a depth of 1m and reinforced with a 400mm thick layer of 150mm sized stone that was run-out downstream to provide a gently sloping 'riffle' effect. The ramps each side were sloped at 1 in 6 and smoothly contoured into the bank lines of both old and new channels, as indicated in the figure. This contouring resulted in flat bank slopes that did not need revetting, although largely formed within fill.

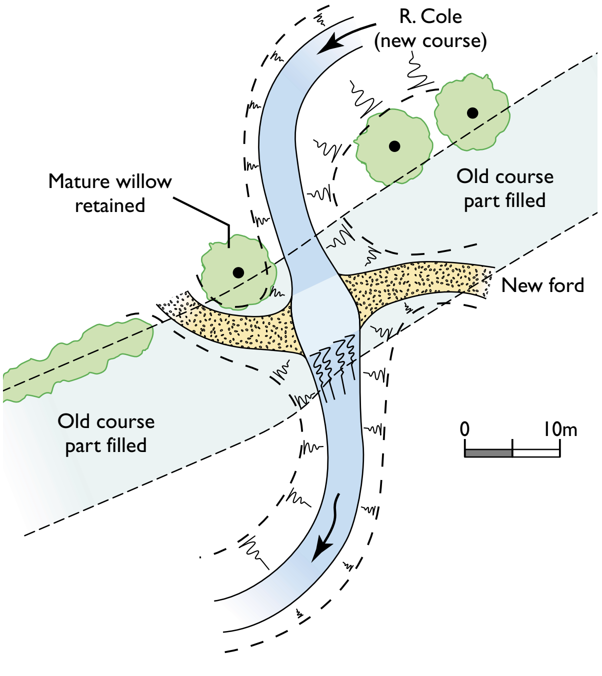
Upstream of the mill
Two fords are incorporated into the new meandering river channel excavated in undisturbed ground throughout its length.

Ford at ch. 0m
This is integrated into a new drop weir and is fully described in 5.2. The ford is not essential to the restoration project but given the small cost additional to the building of the weir it represents a worthwhile extra for the tenant farmer.

Ford at ch. 250m
The ford is shown diagrammatically in 2.2, Figure 2.2.1. Its purpose is to provide vehicular access across the river in conjunction with the nearby crossing over the mill leat *(see 8.2)*. The ford is configured as a point bar located downstream of a sharp bend in the river. It crosses the river diagonally such that the ramp on the inside of the bend could take the form of a natural shoal of gravel that gently rises up to field level, mimicking the geomorphology of upland rivers where point bars and shoals of gravel often serve as crossing points. Because there is no significant bed load of gravel in the River Cole, the bar and shoal had to be artificially created using crushed stone and aggregate.

Equestrian ford at ch 620m

Figure 8.1.3
PLAN OF NEW FORD AT CHAINAGE 620m



The ramp on the outside of the bend was simply graded up to the new crossing over the leat and its flanks were contoured to form smooth transitions with the river banks on both sides. A flood spillway on the side of the mill leat is located near to the ford (spillway **S2** *see 6.1*) so the hydraulics at the location are fairly complex. The bank contouring needed to reflect this by ensuring that all slopes were flatly graded and rounded off to minimise the risk of scour damage from turbulence during high flows.

SUBSEQUENT PERFORMANCE 1995/98

All of the structures described have established well without the need for any adjustments or maintenance. This is particularly important since each is designed to be sustainable within the natural hydraulics of the new river channel.

Despite the commonality of the design concept, each is individually configured to take advantage of local conditions and this is evident in the variety of visual interest and habitat diversity that has resulted. Of particular note, water crowfoot is thriving in the tailstone of the equestrian ford and ch. 620m.

The fords and stock watering point downstream of the mill were created in preference to forming reveted river banks and have proved to be a practical option. As the marginal cost differences of this approach are small it should be worthy of consideration at other similar locations.

Vehicular ford upstream of mill at ch. 250m

PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.2 Watercourse crossings

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
COST – concrete culvert £8.7k
– steel culvert £3k

New concrete culvert crossing under construction

DESCRIPTION

Two new crossings were required to suit farm vehicles and river maintenance plant. The design needed to be functional but at the same time to be visually acceptable without incurring excessive additional costs to achieve this balance. The use of readily available pre-fabricated materials was favoured, since this typified the practice of most farmers and landowners who need such crossings - the aim was to demostrate easily replicable and cost effective design concepts.

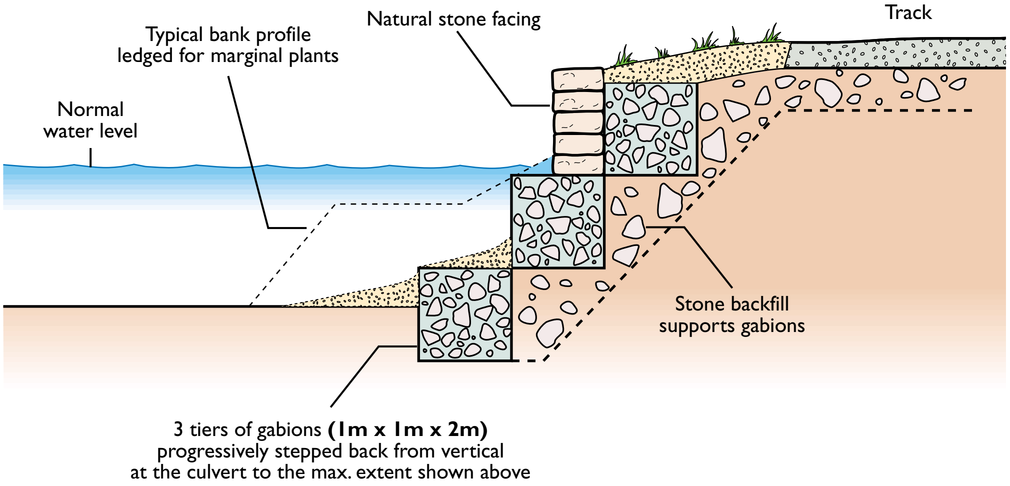
One structure crosses the c. 10m wide mill leat, and the other a newly enlarged drain feeding floodwaters from the main river channel out onto the adjacent meadows *(see 6.1 for description and location)*.

DESIGN

Mill leat crossing (fig. 8.2.1)
The structural elements comprise a pre-cast concrete box culvert 3m wide and 2.1m high that is flanked at each corner with stone filled box gabion wing walls. This arrangement is functionally satisfactory but is most unsightly so great care was taken to detail the wing walls such that visual amenity and habitat potential were improved.

Three tiers of gabions were needed to achieve the full wingwall height from invert to track level. The lower two were set just below the retained water level in the mill leat where they are permanently out of sight. These two layers were set out in plan to follow a

Figure 8.2.1
SECTION THROUGH WINGWALL OF BOX CULVERT CROSSING



90 degree curve creating a wider river cross-section than the culvert. They were progressively stepped back from the vertical to create a ledge at the top of the first tier.

The upper tier followed a similar curve but was continuously stepped back sufficient to allow a stone wall to be built around the front face - this wall is the only visible element and it is decorative rather than structural. By stepping back the gabions the sloping river banks adjacent could be brought smoothly into line with the gabions and also accommodate an underwater ledge for aquatic marginal plants. The combination of marginal plants

Completed ‘bridge’

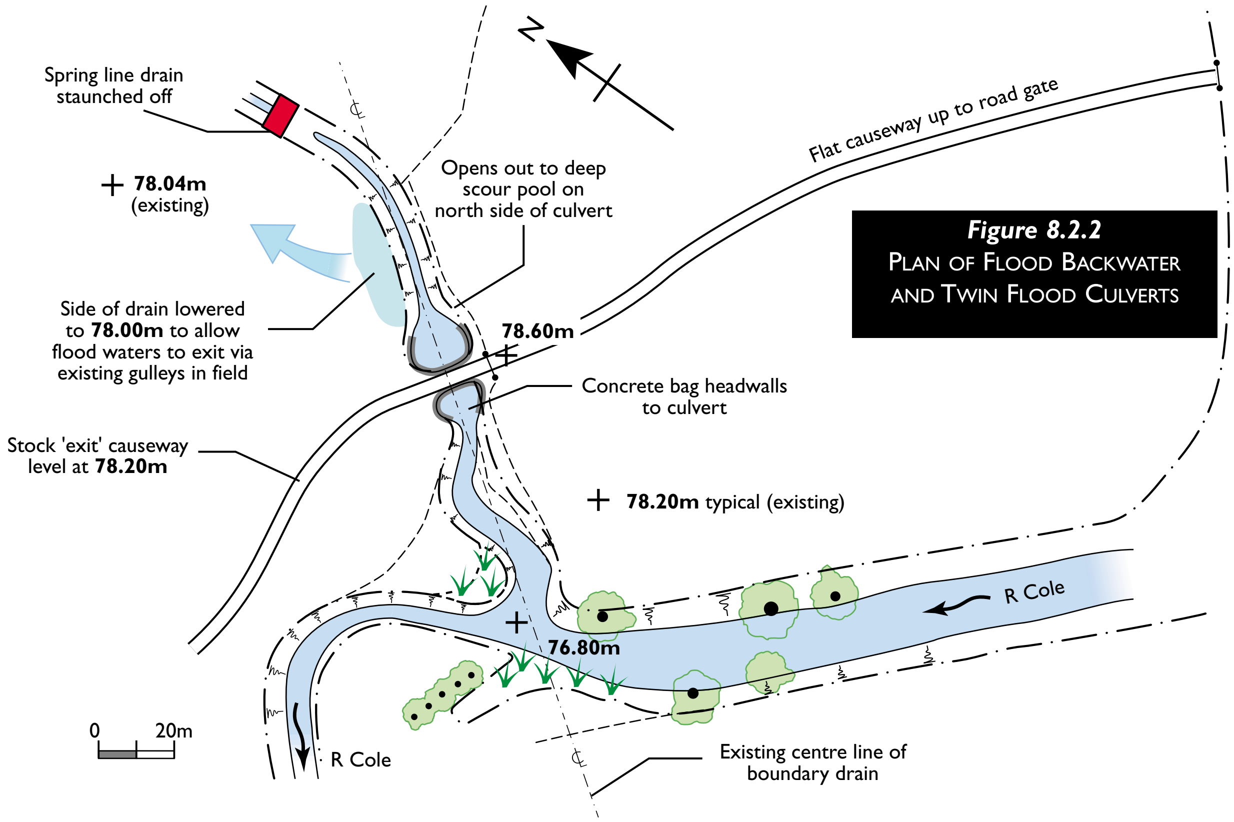


Figure 8.2.2
PLAN OF FLOOD BACKWATER AND TWIN FLOOD CULVERTS

and stone walling are intended to draw the eye away from the concrete box which is a relatively minor feature of the overall visual aspect evident in the photo.

Flood drain crossing (fig. 8.2.2)
This crossing is located downstream of the main road adjacent to spillway S4 *(see 6.1 for plan and details of the drain).*

The flood drain is only 1m deep and two pipes of this diameter were needed to provide sufficient area to pass floodwater. Corrugated galvanised steel pipes were selected by the contractor; they are readily available and easy to install. When laid side-by-side they measure about 2.5m across, which is wider that the drain. The design of the headwalls at both ends, therefore, needed to form a smooth transition between the 'over-wide' pipes and the relatively narrow trapezoidal channel.

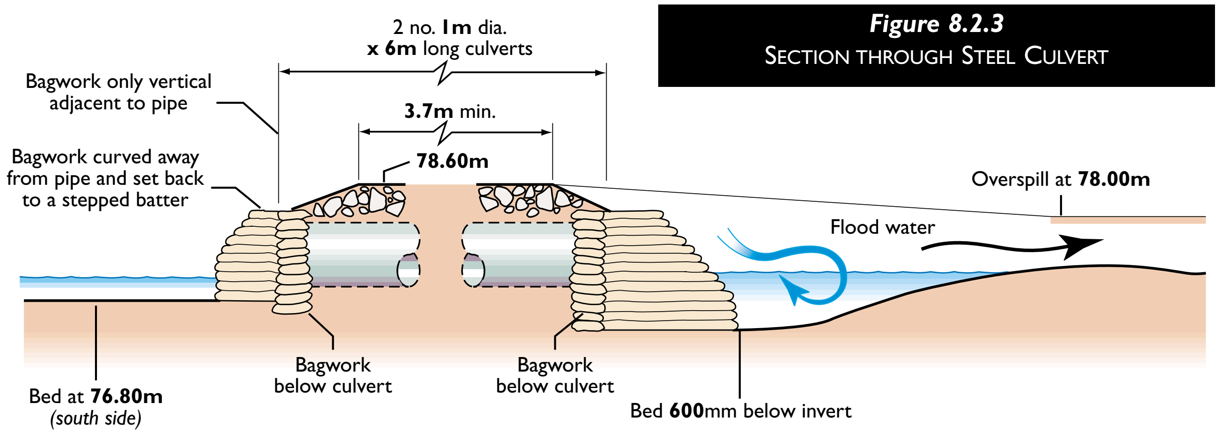


Figure 8.2.3
SECTION THROUGH STEEL CULVERT

Flood drain crossing seen from bank of R. Cole.
(bagwork wing walls incomplete)

Concrete filled hessian sandbags were used to achieve this complex geometry. Another consideration was that the pressure of floodwaters passing through the pipes might produce high velocities and turbulence on exit. A distinct scour pool was excavated that was 'onion' shaped in plan and section to dissipate this energy. This is preferable to heavy revetment to contain the scour. Such pools can be attractive and also provide habitat potential.

The bagwork is built vertically across the face of the pipes and then curved gently outwards through 90 degrees or more with a slowly increasing batter until it merges smoothly into the sloping banks of the drain. The slopes are achieved by stepping the bagwork rather than laying it flat on the banks; the ledges thus formed attract silt and plant growth. The height of bagwork was curtailed close to the level of the pipe soffits.

Concrete bagwork is a versatile method of achieving complex shapes and it can rapidly take on a reasonably aesthetic appearance. This is because the concrete is invariably less dense than pre-cast or poured concrete alternatives and therefore provides a suitable surface for a variety of vegetation. The hessian rots away in a year or two, but in the short term it attracts silts which help to establish vegetation, particularly if the hessian is not impregnated with preservatives.

SUBSEQUENT PERFORMANCE 1995/98

Both crossings have functioned entirely satisfactorily and present a reasonably attractive appearance within their respective settings.

The design is deliberately utilitarian in concept to demonstrate that even the most basic engineering materials, such as steel and concrete, can be enhanced at little extra cost.

Clear span bridges of good design are generally preferable in all respects to culverts but the additional cost involved could not be justified at Coleshill where short culverts afforded adequate flow area with little risk of problems caused by blockages.

PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.3 Access paths suitable for disabled users

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – June 1997
LENGTH – Concrete path 1000 m x 1.8 m, Bitmac path 225 m x 2.5 m
COST – Concrete path £55k, Bitmac path £43k

Concrete footpath and meanders

DESCRIPTION

Prior to the restoration project formal paved access alongside the river was very limited but was found by survey to be high on local peoples priorities for improvements. Two separate paths were included at the locations indicated on the project plan that precedes the techniques section of this manual.

The first passes along the south bank of the river where new meanders were created *(see 1.4)* and links an existing footbridge at Hutton Avenue with a new footbridge near the railway line. A smooth concrete path was built after discussion with the Fieldfare Trust. The Trust is concerned with access for all but has special knowledge of disabled peoples' needs.

The second links an existing high level path bordering housing at Albert Road with the historic Skerne railway bridge that is featured on the UK £5 note. The path drops down to pass under Albert Road and then runs along the north bank of the river. It will form part of a future cycleway through Darlington and is built in bitumen macadam (Bitmac).

DESIGN

Concrete Path
Designed to enable wheelchairs and pushchairs to pass freely, the gradients and surface of the path were such that all users would have easy passage. Resting/passing areas were placed approximately every 100m in positions affording interesting views of the site. The route was determined by the gradient of the land, the extent of winter floodwater and suggestions from the Fieldfare Trust. A proprietary concrete material and surface finish was selected to provide a smooth non slip footing and low maintenance. A buff colour was chosen to blend with the surroundings once weathered.

To intercept rain water running down from the adjacent slopes gravel drains were placed under the path and in others they were positioned alongside the path. A 100mm layer of crushed stone was laid as standard but where vehicle crossing points were designated, extra stone was used to accommodate the extra loading. Coloured concrete (75mm min.) was poured and the surface finished in the prescribed pattern.

Bitmac Path (figs. 8.3.1 – 8.3.2)
A great deal of preliminary work was needed before the path could be laid, including:

- revetment of the river bank either side of the bridge;
- retaining walls alongside a gas main and contaminated landfill;
- lowering land levels;
- lowering of manholes.

The route was designed as a combined footpath and cycleway and runs down a grassy slope, beneath Albert Road bridge and along the riverside to Skerne Bridge. Several safety features were incorporated:

- where the ground slopes away steeply, a small mound was placed on the downward side to restrict cyclists to the path;
- riverside hand railing either side of the bridge at the bottom of the slope;
- cycle barriers were placed at the bottom of the slope to slow cyclists as they pass under the bridge;
- the width of path allows wheelchairs to pass;
- level resting areas at intervals down the slope.

Drainage was important. To accommodate this, there is a fall of 50mm across the 2.5m wide path and a longitudinal gulley drain to collect run off from the slope above.

SUBSEQUENT PERFORMANCE 1997/8

Both paths have proved to be extremely popular with all sections of the community and are used by different social groups throughout the day. Initial fears that the paths might become motorcycle tracks have not materialised, probably because they are 'policed' by so many pedestrians. Seating has been requested by older people wishing to rest and view the riverlife nearby.

Drainage of rain water from adjacent slopes proved critical and some remedial works were needed to clear occassional puddles and associated silts that muddied the path.

Bitmac footpath towards Skerne Railway Bridge

Figure 8.3.1
PLAN OF RIVERSIDE PATH TO SKERNE RAILWAY BRIDGE

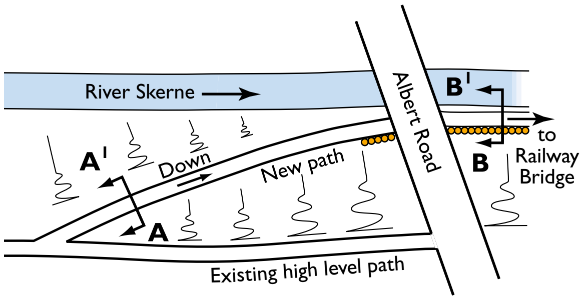
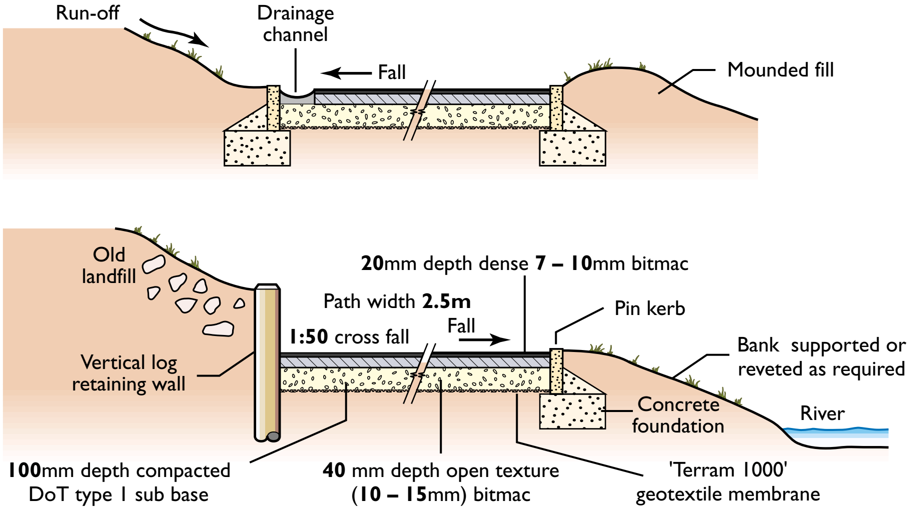


Figure 8.3.2
SECTION THROUGH RIVERSIDE RATH TO SKERNE RAILWAY BRIDGE



SECTION **A – A'**
(downhill path)

SECTION **B – B'**
(riversidel path)

8.4 Restoring a ford as a stock and vehicular crossing point

RIVER OGWEN

LOCATION – 5km south of Bethesda, Gwynedd SH 641615
DATE OF CONSTRUCTION – October 1998
LENGTH – 20m
COST – approx. £1500

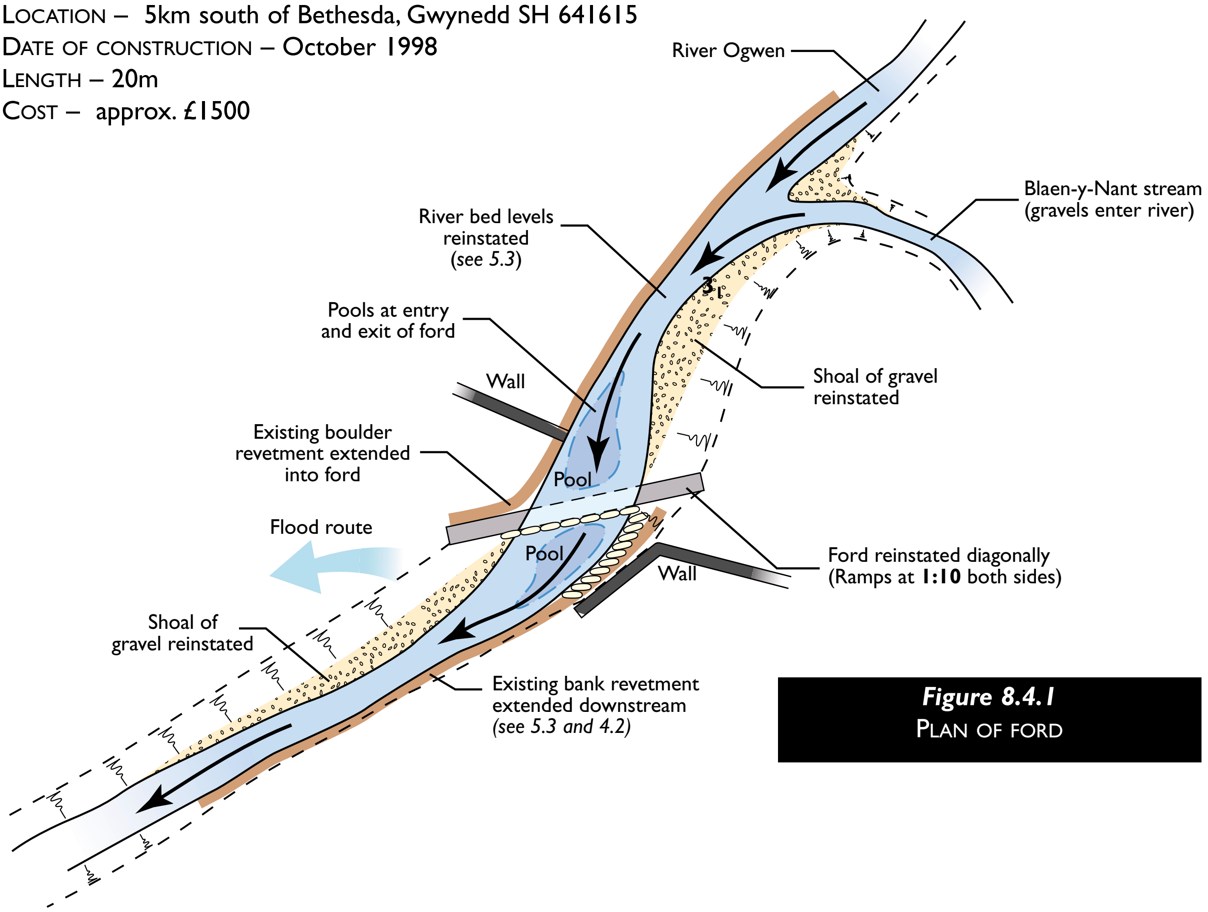


Figure 8.4.1
PLAN OF FORD

View across the deepened river at the old ford location

DESCRIPTION

The ford was built as part of comprehensive restoration of the river bed after deepening by dredging in the 1960s (*See 5.3 for full details and a location plan*). The ford forms one of a series of fixed points that stabilise the bed at its restored level.

Old O.S maps indicated a ford had existed prior to dredging but it had been removed during these works; see photo of conditions pre-restoration. The farmer was keen for the ford to be restored as a stock and vehicular crossing point.

DESIGN

The practicalities of sustaining a ford at this location demanded an understanding of the hydraulic and sediment patterns that would exist after the river bed had been raised by about 1m as part of the river bed restoration works. The river conditions at the approach and exit would be important factors.
The length of the submerged part of the ford needed to be at least 20m i.e. twice the normal width of the river, in order to ensure that normal water depths were 'fordable', typically 30cm or less. Approach ramps on both sides needed to be flatly graded at about 1 in 10 to suit vehicles and should blend with natural bank profiles rather than be severely cut into them. The overall length of the ford, between bank tops, needed to be 40m to meet these requirements. This compared with just 15m between bank tops for the natural channel.

Study of the old OS maps indicated that the original ford was broadly of the dimensions that were needed but it was still necessary to form a view on why it was sustained by the river and did not narrow through sediment deposition making it unusable. It was well known that many fords constructed at inappropriate sites become unusable due to rapid siltation.

The ford is located between two opposing bends in the river alignment such that shoals of gravel naturally accumulate on the inside of each. The two shoals would typically be joined by an underwater bar of gravel aligned diagonally across the channel. The natural cross-section of the river, drawn across this diagonal bar and up the flat shoal profiles each side, would roughly match the ford profile needed. The sustainability of the shoals and the bar of gravel would depend upon continuing inputs of material to

The restored ford, shoals and riverbed

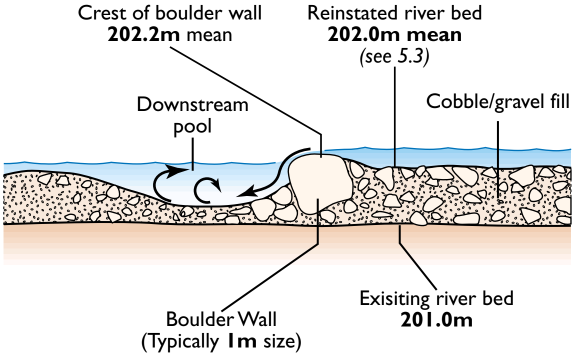


Figure 8.4.2
SECTION THROUGH FORD

the river. The tributary stream located just upstream (Blaen-y-Nant) was known to be the primary source of sediment on this reach of river. It was therefore concluded that a diagonal ford aligned between the opposing bends was sustainable and that it would be typical of the natural fording points adopted by farmers on many gravel bed rivers where similar geomorphology arises. It was necessary to develop the design of the ford in accordance with these principles.

It was decided to define the downstream edge of the submerged length of ford with a line of glacial boulders as shown on figure 8.4.2. This provided the stable bed level that needed to be defined as part of the overall river bed restoration. It was not possible to completely restore the river bed elevations with gravel due to lack of suitable material (*see 5.3*), so the new ford might have washed downstream if the profile had not been fixed by the boulders. They also ensured a clear route across the river remained visible between the ramps on each side. The gravels that were available from previous dredging operations were utilised to restore the two important shoal profiles upstream and downstream of the ford. The river bed was also fully restored with gravel upstream and downstream of the ford with particular attention to the profiling of pools and runs that naturally form at opposing bends (*see plan*).

Downstream crest defined by boulders

A potential threat to the stable profile needed at the ford was the 'migration' of the bends through erosion of the outer banks of each. Serious erosion had arisen further downstream of the ford site but old river bank revetments were evident at the site and upstream of it. Existing revetments of small boulders were repaired and consolidated into the ford. The erosion downstream was repaired using the willow mattress technique featured in this manual (*see 4.2*).

The location of two solid stone walls on opposite banks of the river were a further consideration. The routing of overland floodwaters down the valley would clearly be interrupted by these opposing walls with all flow being concentrated between them coincident with the location of the ford (*see plan*).

Careful study of the topography of the adjoining fields indicated that the natural flood route involved overtopping the bank on the right side of the ford (looking downstream). This bank was carefully graded to blend with a discernible 'gulley' down the field such that floodwater passing between the two walls could easily escape out onto the natural floodway again without causing undue stress at the ford. The arrow on the plan indicates this important floodway.

SUBSEQUENT PERFORMANCE 1998 – 2001

The entire configuration of the ford, shoals, pools and runs has proved to be sustainable, with the ford in regular use by the farmer.

The visual appearance of the ford is excellent as it has sympathetically blended into its location and is not intrusive in anyway.

This success is attributed to the care taken to understand the underlying river geomorphology and the sympathetic adaptation of this in both the historic context of the site and that of the wider river restoration project.

Contacts:
RRC, Silsoe, Beds MK45 4DT, Tel: 01525 863341.
Bryan Jones. Environment Agency, Llwyn Brain, Ffordd Penlan, Parc Menai, Bangor, Gwynedd, Wales LL57 4DE, Tel: 01248 670770.
Elfyn Jones. National Trust,
Carneddau & Ynys Mon Property Office, Tan y Celyn, Ty'n y Maes, Nant Ffrancon, Gwynedd, Wales LL57 3LX.

PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.5 Urban riverside access

RIVER MARDEN
LOCATION – Town centre at Calne, Wiltshire ST 998710
DATE OF CONSTRUCTION – 1999
LENGTH – 100m
COST – not available

The river and weirs before construction

DESCRIPTION

A straight, concrete-lined, section of river channel was diverted and restored in the form of a double meander. *Refer to 1.5 for a plan and full description of the project.*

The inner part of each meander is configured as a gravel shoal. People enjoy being close to the river at such locations although the opportunity to do so in a town centre location is rare. This technique is concerned with the means by which people are afforded safe access to the shoals. In addition, the Environment Agency required occasional access for maintenance plant, particularly to the twin road culverts at the downstream end where flood washed debris may accumulate.

Gravel margins and seeded soil form the shallow banks opposite 'rocky' walls

DESIGN

The meander configuration effectively divides the reach into two parts for access purposes. The lower part comprises the meander approaching the road culverts where access is from the south side. The upper part comprises the meander fronting new retail development where access is from the north side.

Access on the lower part
A gently sloping ramp was achieved by aligning this parallel to the course of the river channel thereby maximising the distance over which a drop of c1.5m could be incorporated. The ramp blends smoothly into the shoal and falls at 1 in 12.5 at its steepest. Figure 8.5.1 indicates the profile of the inner bend and shoal. The upper part of the ramp is reinforced against wear and tear with limestone block paving. Purbeck limestone was used extensively throughout the project (*see 1.5*). Grass is seeded between the paving blocks ensuring a good blend with the grassed areas around the shoal.

Access on the upper part
A gently sloping ramp was again built parallel to the river course at about 1 in 12.5. This ramp gives access to a 20m long section of waterside that is flat and is within 40cm of normal water level. Dense marginal aquatic vegetation will front this short reach. The reach leads into the shoal fronting the development.

The inner bend that fronts the retail development is shown as a cross-section in figure 8.5.2. Three wide steps surfaced in slabs of Purbeck limestone form the riverbank. These ‘stepped platforms’, as they have come to be called, are up to 1.5m wide and are expected to provide informal seating areas for people at the riverside. The steps give direct access to the shoal and are integrated into the parade that fronts the new retail area.

SUBSEQUENT PERFORMANCE 1998 – 2001

The public will not have full access to the river until the retail development work is completed during 2001

View of the accessible new river course, November 2001

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

Seating and gentle grass and gravel slope to waters' edge

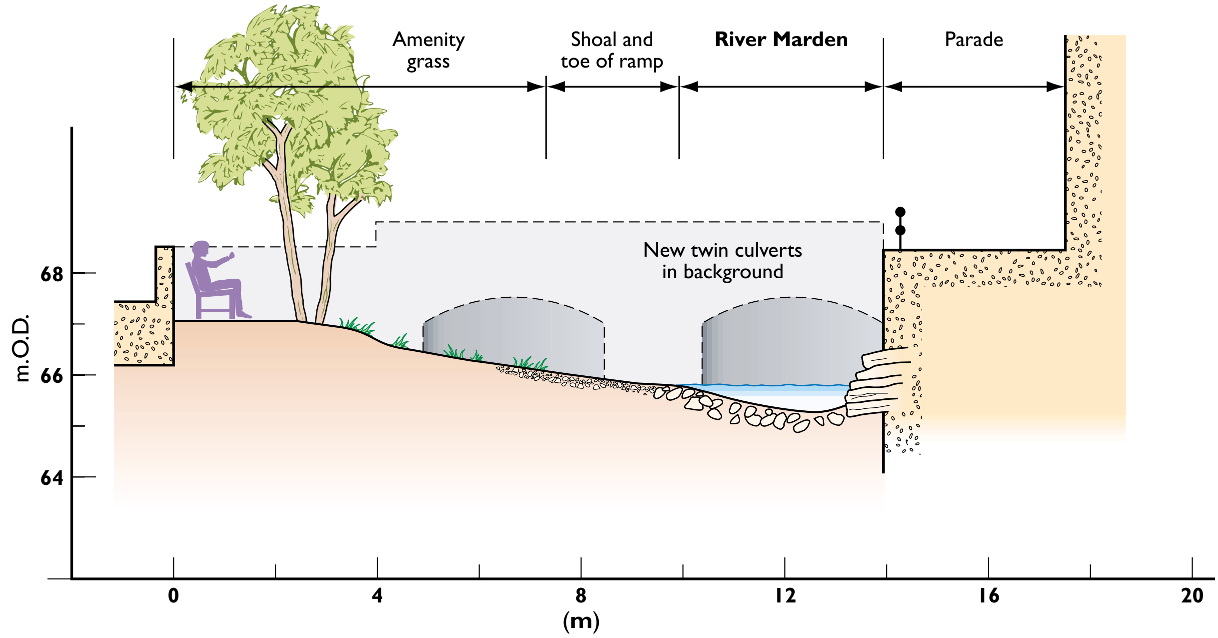
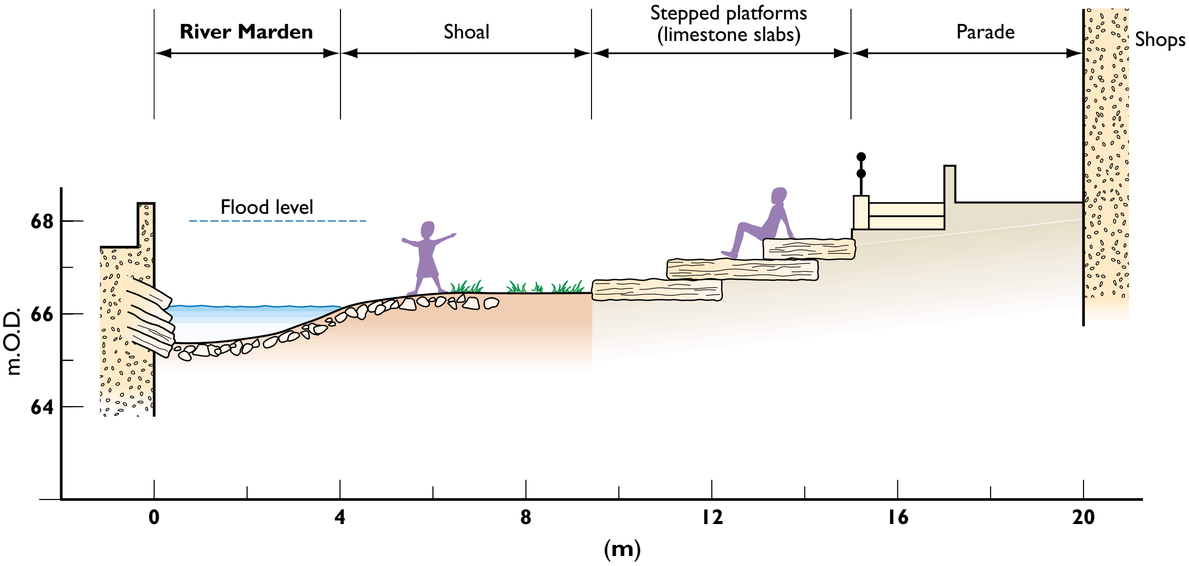


Figure 8.5.1
SECTION C (*SEE 1.5 FOR LOCATION PLAN*)

Figure 8.5.2

SECTION B (*SEE 1.5 FOR LOCATION PLAN*)



Stone steps leading down to grass and gravel shoal

but the overall appearance of the access provision is inviting and safe during normal river conditions.

During times of flood all of the features described will be submerged. Some cleaning of silt and debris is anticipated but should not be onerous.

The overall concept of maximising the opportunity for access to the waterside within the whole river channel and floodway is expected to work well.

Contacts:

RRC, Silsoe, Beds MK45 4DT, Tel: 01525 863341.

9 ENHANCING OUTFALLS TO RIVERS

9.1 Surface water outfalls

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – August to October 1995
COST – £15k - cross connection survey, £23k - renewal of 13 headwalls, construction of pipe works and new chambers

Typical outfall before replacement

DESCRIPTION

Although the water quality of the Skerne has been steadily improving, public perception of the river was one of a polluted watercourse. Along the core reach of the river restoration project there were 13 public surface water outfalls with ugly concrete headwalls marking their points of discharge. Those with grills were cluttered with plastic and other litter. The project provided a unique opportunity to instigate further improvements to water quality and visual amenity.

Initial inspection by Northumbrian Water of surface water drainage areas and some 1125 premises revealed a number of pollution sources from illegal connections of washing machines, dishwashers, showers, baths and toilets. The water company helped property owners to rectify irregularities before issuing certificates of compliance.

DESIGN

The aims of the design for the surface water outfalls were:

- to improve the quality of discharge by reducing silt, oil, petrol and floating solids reaching the river;
- to improve visual amenity by removing concrete headwalls and positioning discharge pipes below river water level;
- to reduce the number of outfalls and make future management and monitoring more efficient and easier.

New underground outfall chambers were designed such that the amount of both silt and floating solids discharged into the river would be reduced. Under low surface water flows, silt settles and is trapped in a sump. A dip plate ensures that any oil, petrol and floating sewage items are also retained in the chamber. These can all be removed using a suction unit at regular intervals and disposed of appropriately. Initially this was planned at a frequency of four times per year. Under high flows some effluent will be carried into the river but will be much diluted.

Inspection of the chambers is via recessed covers, incorporating turf, which lie just above ground level and so are visually unobtrusive. These allow sampling and pollution monitoring when needed.

Angled to discharge below low water level, the outfall pipe lies on a concrete apron which reduces scour during high flows. The outlet is turned to face downstream so that the river draws the discharge. Additionally, an underwater gabion was installed upstream of the outlet to reduce the risk of pipe damage by floating tree branches, etc. Direct jetting via the chamber is possible if outlets become silted but they are expected to be self cleansing. The velocity of discharge achievable has been seen to make the river 'boil' after heavy rain.

At the large backwater *(see 2.2)* three outfalls have been combined to run into one inspection chamber linked to a single outfall pipe.

The advantages of discharging to a backwater include:

- introduction of periodic flow into the backwater;
- potential for natural filtration of the discharge;
- ease of staunching 'off-river' should any pollution incident occur.

SUBSEQUENT PERFORMANCE 1995/8

The outfalls appear to be working effectively. The level of maintenance required has not been as frequent as previously envisaged and is now undertaken once a year. No blockages by siltation of the river bed have occured. The outfalls are now virtually invisible.

New outfall chamber under construction

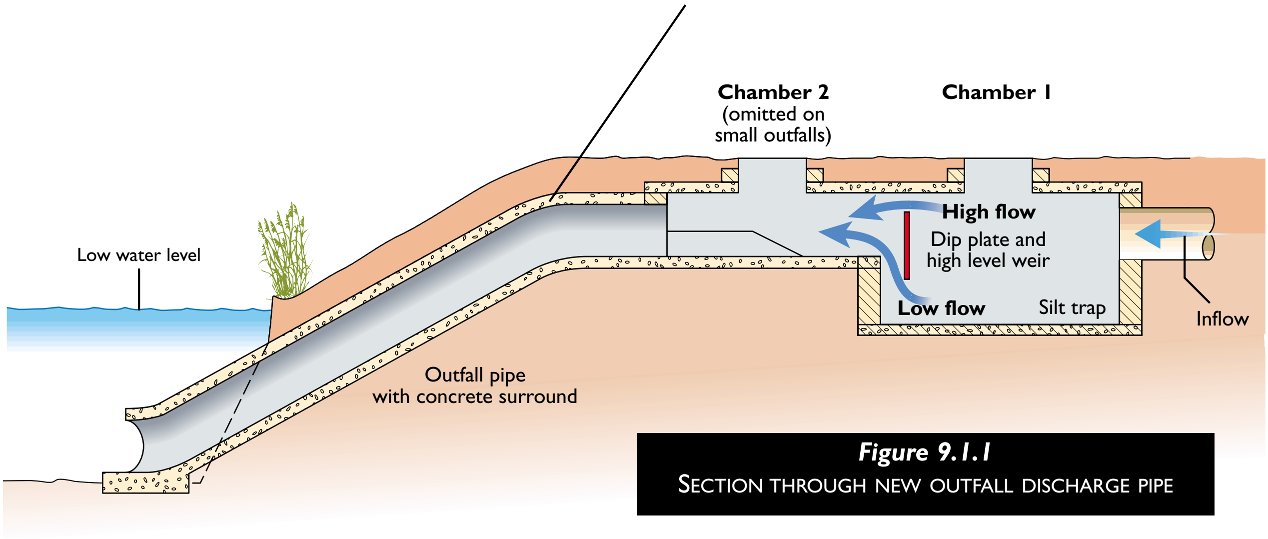


Figure 9.1.1
SECTION THROUGH NEW OUTFALL DISCHARGE PIPE

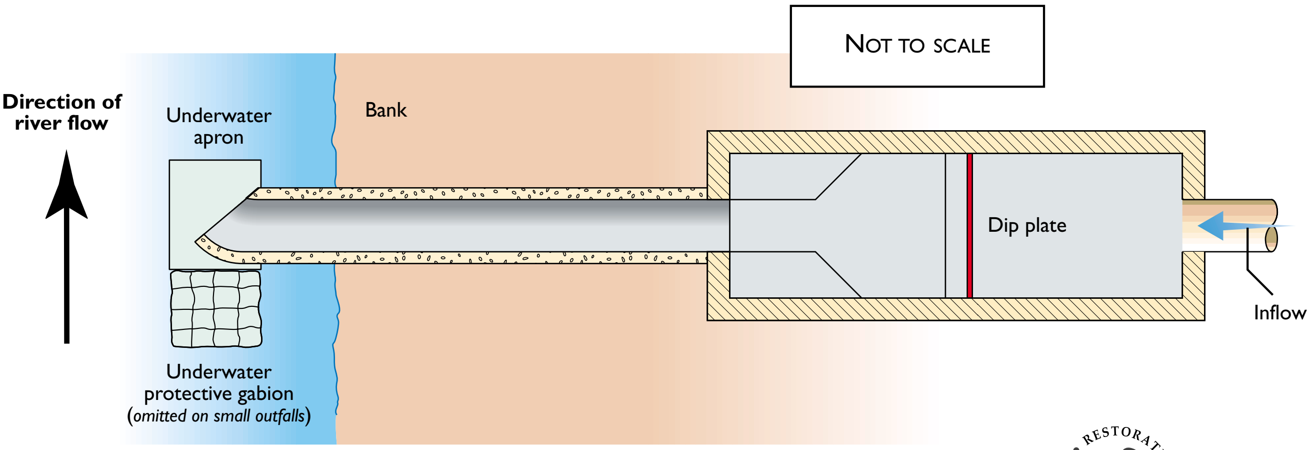


Figure 9.1.2
PLAN OF NEW OUTFALL DISCHARGE PIPE

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

ENHANCING OUTFALLS TO RIVERS

9.2 Reedbed at Raglan Stream

RIVER COLE
LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995 – Spring 1996
AREA – 640m²
COST – £500

Planting reedbed – Spring 1996

DESCRIPTION

A new reedbed was formed in a redundant length of the Cole following the river's diversion to restore a smaller meandering course *(see 1.2)*. An adjacent small tributary stream, the Raglan Stream, was diverted to flow through the reedbed before entering the river.

The aim was to create a small buffer zone to help intercept silts contaminated with agricultural pollutants and to add habitat diversity to the river. The likely effectiveness of the reedbed as a buffer zone was considered to be low due to its small size and to its location, where river floods would frequently wash over it. The habitat potential was however high, and the marginal costs of construction small, so the reedbed was considered worthwhile and would demonstrate a useful river restoration technique.

DESIGN

The new river course *(fig. 9.2.1)* was excavated near parallel to the old, and the latter partially infilled to create a flat area elevated about 500mm above the new river bed. The two were separated by a ridge of hard gravelly clay soil about 800mm above river bed.

The flat area was then contoured in a series of longitudinal furrows to hold ponded water between ridges of wet, but not saturated ground *(fig. 9.2.2)*.

The Raglan Stream was diverted to feed water into the furrows, but because the stream dries up in the summer a supplementary feed of water was diverted from the River Cole. The river flows into the reedbed through a 150mm diameter plastic pipe that discharges through a 90 degree bend which can be swivelled vertically to cut off the flow or reduce it, as required, to keep the reedbed wet but not flooded. This level of control was only critical during the establishment period of the reed.

Common reeds were introduced in spring 1996 using pot grown seedlings along one side of each furrow and seed along the opposite side *(fig. 9.2.3)*. The use of two methods increased the likelihood of successful establishment and enabled the performance of each to be monitored.

Figure 9.2.3
DETAIL OF REED FURROW

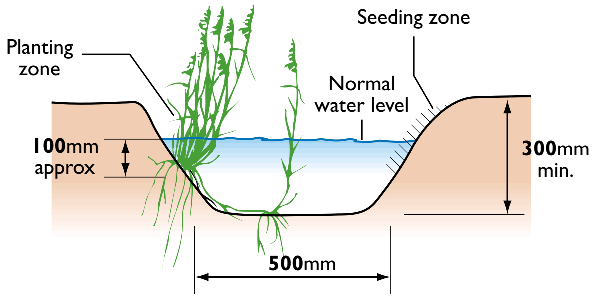


Figure 9.2.1
PLAN OF REEDBED

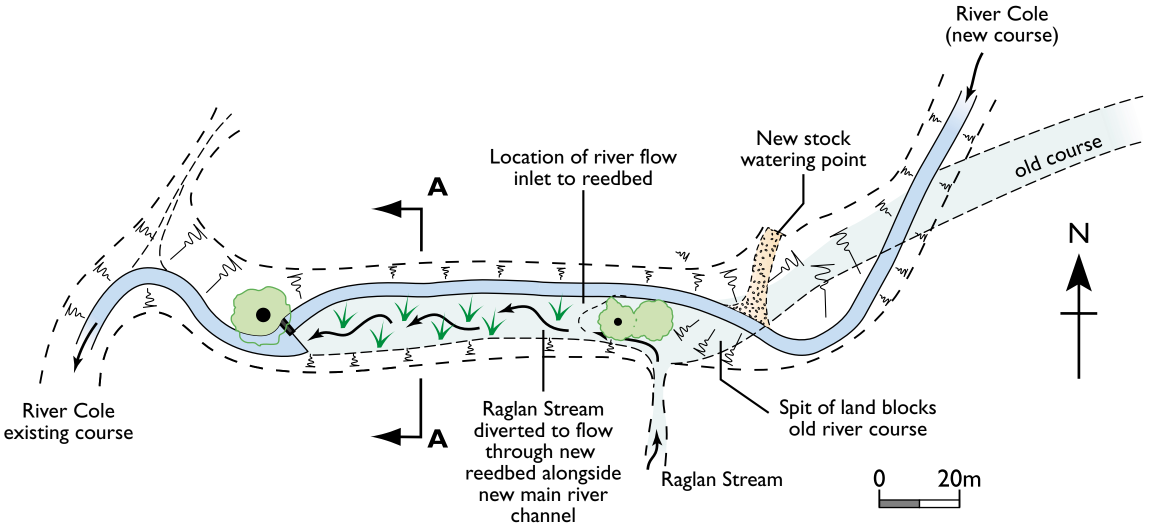
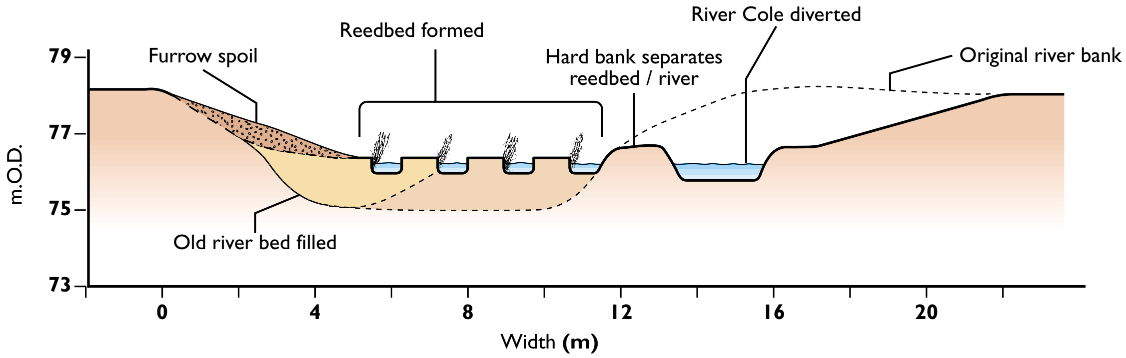


Figure 9.2.2
SECTION A – A



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

Reedbed established – Summer 1998

SUBSEQUENT PERFORMANCE 1995/98

The reedbed established exceptionally well with 93% of seedlings surviving to maturity, although seed germination was perhaps only 50%, but still sufficient to achieve full colonisation within two growing seasons. Other aquatic species colonised the area naturally, including greater water plantain and soft rush. Concerns that the River Cole might damage the reedbed when in flood proved unfounded because the overall size of the new river and adjacent reedbed is much greater than the exisitng cross-section downstream so flood flow velocities are low.

These hydraulic conditions may lead to progressive siltation of the reedbed in the longer term, but for the foreseeable future a valuable habitat has been created that additionally provides a buffer against contaminated silts from the Raglan Stream reaching the Cole.

River Restoration MANUAL of TECHNIQUES

For the Web

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BACKGROUND

This manual was inspired by the success of two comprehensive restoration projects undertaken on the Rivers Cole and Skerne which were led by the RRC's predecessor, The River Restoration Project, on behalf of key UK environmental organisations and the riparian owners.

The projects demonstrate a range of practical river restoration techniques from which a great deal was learnt during the course of their design and implementation, as well as from the scientific monitoring of what they ultimately achieved.

The project participants expressed their wish that the knowledge gained should be disseminated widely so that other river restoration initiatives may benefit from it. This manual is one of a series of RRC publications that help meet the participants wishes.

THE RIVER RESTORATION CENTRE

THE
PROJECT
PARTICIPANTS

ENVIRONMENT AGENCY

ENGLISH
NATURE

RIVERS
Agency

COUNTRYSIDE
COMMISSION

THE NATIONAL TRUST

NORTHUMBRIAN
WATER

DARLINGTON
BOROUGH COUNCIL

ACKNOWLEDGEMENTS

EDITION 1 – 1999

RRC could not have published this manual without the continuing support of organisations participating in the Rivers Cole and Skerne restoration projects. Each has differing interests in the benefits that river restoration can bestow, but their foresight in working together so that common goals are achieved efficiently has marked the foundation of River Restoration Centre as the UK catalyst for the topic.

Funding support for the production of this manual has also been provided by the Scottish Environment Protection Agency. SEPA was established in 1996 to provide efficient and integrated environmental protection in Scotland and recognises the contribution this manual can make to help SEPA staff, and others, conserve and enhance Scotland's rivers.

RRC most gratefully acknowledge the support of all participating organisations and individuals.

UPDATE – 2002

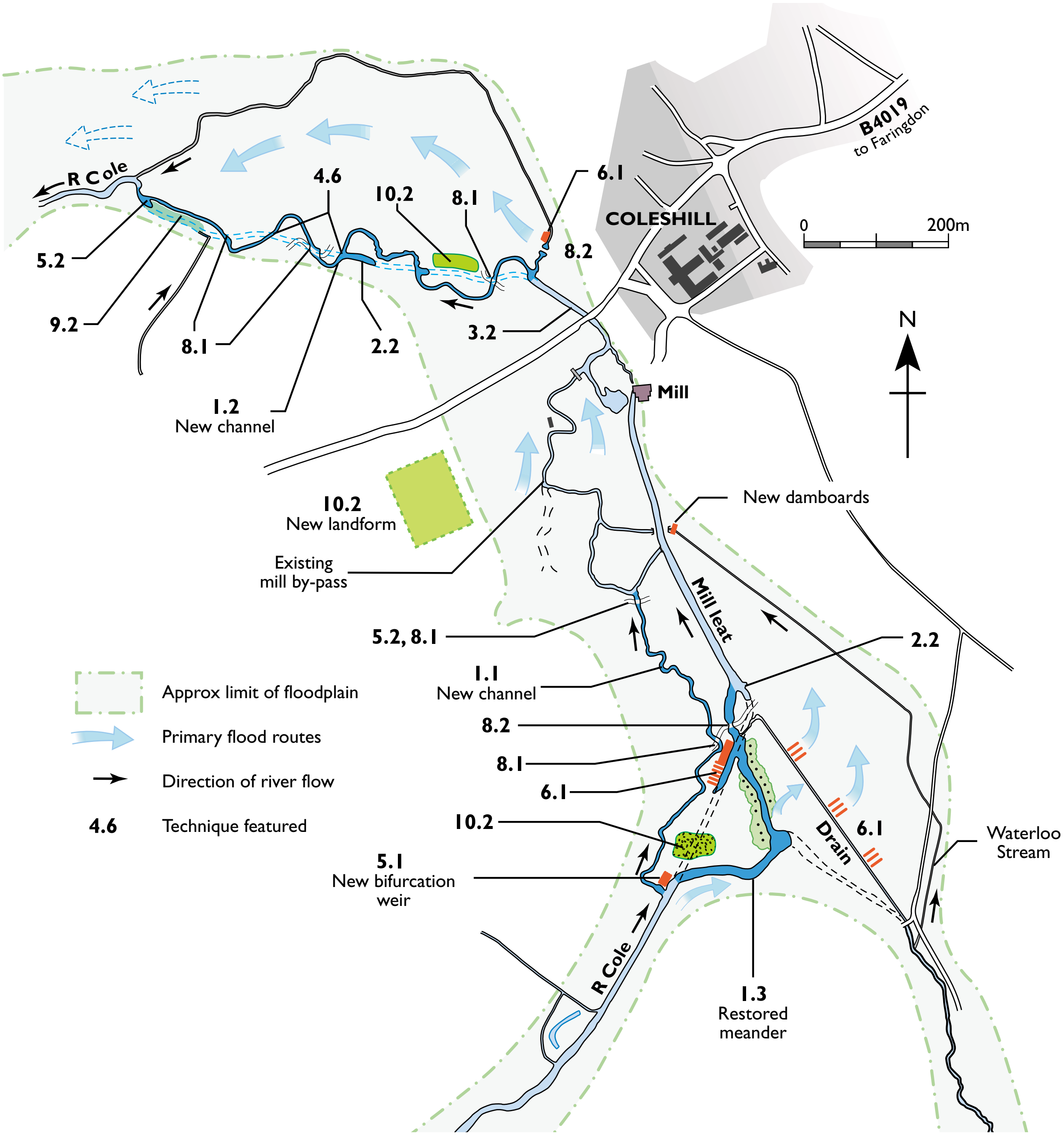
The production of this update has been funded from the R&D programme of the Environment Agency for England and Wales, R&D Project W5A-060.

RRC would also like to acknowledge the additional financial support for this manual from the Scottish Environmental Protection Agency.

RRC gratefully acknowledges the input of all those individuals and organisations who have supported the production of this update, by providing text, illustrations and photographic material, and more importantly their hard work and dedication in implementing the projects featured.

The River Cole Restoration Project

LOCATION - Coleshill, (Oxon/Wilts border) SU 234935
DATE OF CONSTRUCTION - Autumn 1995
LENGTH – 2km
FLOODPLAIN AREA – 50ha
COST – £140k



DESCRIPTION OF THE RIVER COLE AND THE COLE RESTORATION PROJECT

The river Cole is a tributary of the R.Thames located in the upper part of the catchment. Its headwaters include part of the large town of Swindon, Wiltshire. The Cole catchment is otherwise rural and is 130km^2 in area comprising clay, sand, limestone, and chalk geology. Sediments in the lower reaches, where the river is most modified, are confined to silts and muds. Land use is mixed arable and intensive grassland.

The restoration site is located within 6km of the R.Thames at the village of Coleshill where the floodplain is up to 400m wide and graded at about 1 in 1300. Here the river had been straightened for milling purposes, but more recently (1970s) further deepened and widened to reduce flooding of arable land.

Restoration works are shown on the accompanying figure. The principle achievement is the creation of a 2km long meandering river course that is much smaller in size than the previously enlarged channel. This has restored more frequent seasonal flooding to adjacent fields which are now farmed less intensively, supported by Countryside Stewardship.

Full details of the project's organisation, funding, engineering and scientific monitoring are available from RRC in a variety of formats.

List of techniques featured:

1.1 New meandering channel upstream of mill

1.2 New meandering channel downstream of mill

1.3 Single meander in Mill Leat

2.2 New backwaters in redundant river channels

3.2 New aquatic ledges

4.6 Short term bank revetments

5.1 Bifurcation weir and spillway

5.2 Drop weirs in bed

6.1 Floodplain spillways

8.1 Fords and livestock access

8.2 New crossings

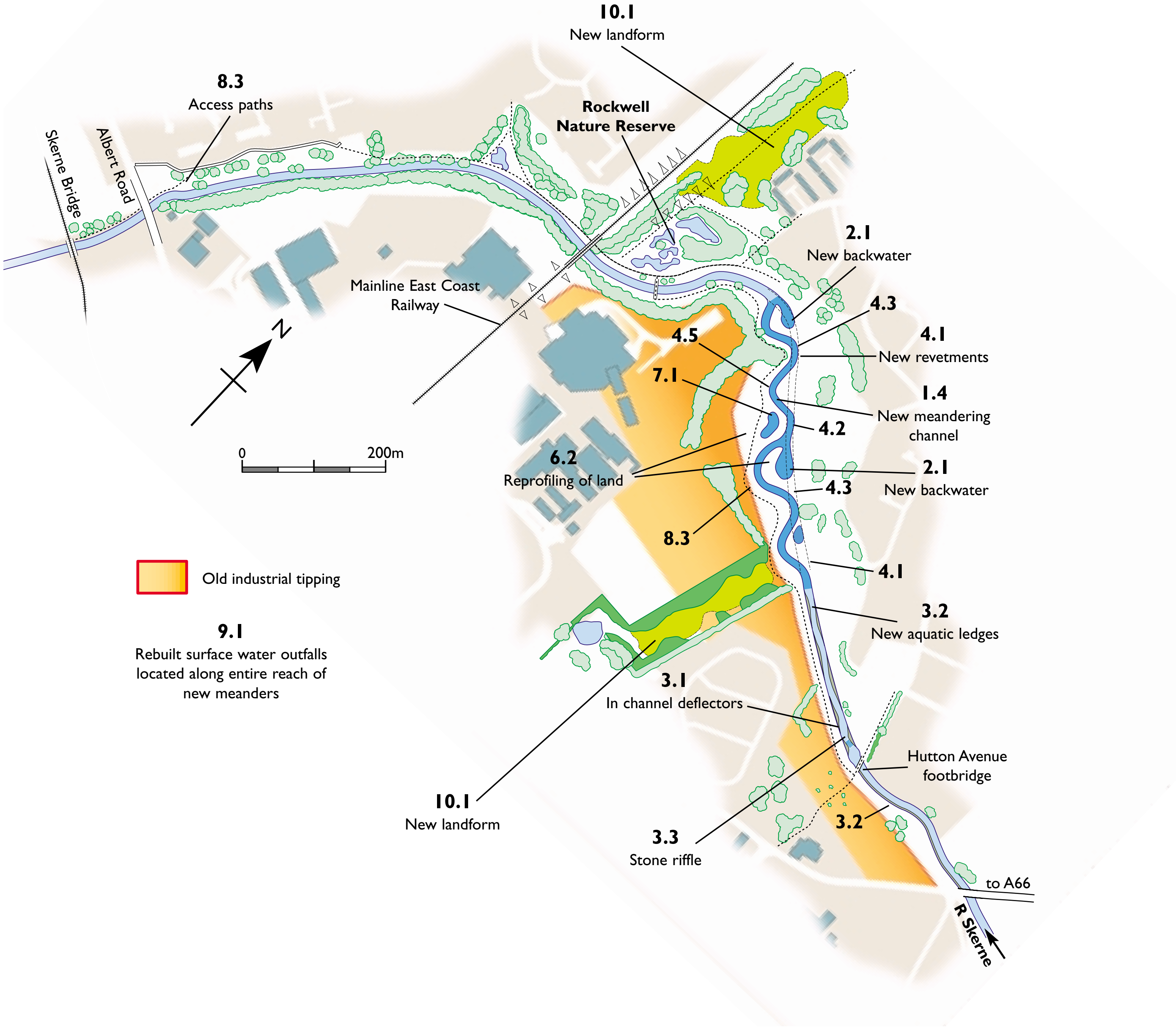
9.2 New reedbed

10.2 New landforms

The River Restoration Centre
Working to restore & enhance our rivers

The River Skerne Restoration Project

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – Autumn 1995 to Spring 1996
LENGTH – 500m
COST – £300k



9.1
Rebuilt surface water outfalls
located along entire reach of
new meanders

DESCRIPTION OF THE RIVER SKERNE AND THE SKERNE RESTORATION PROJECT

The River Skerne flows into the R.Tees just south of the town of Darlington, Co. Durham. It has a clay and alluvium based catchment area of 250km^2 that includes several small towns, as well as Darlington and a number of industrial sites that historically polluted the river.

The restoration site is located within a north east suburb of Darlington, Haughton-le-Skerne, where a small length of floodplain has survived the historic tipping of industrial waste and urban development that fully occupy it elsewhere. The surviving floodplain is, however, severely disturbed by previous river straightening works and backfilling, and has many utility services routed through it. The floodplain is less than 1km long, falling at about 1 in 1300. Housing and landfill partially encroach onto the floodplain, in places leaving little more than a 100m width open to public access.

Restoration works are shown on the accompanying figure. The principle achievements are the creation of new meanders on the south side of the old, straight course, and the enhancement of the existing course, both upstream and downstream of the new meanders, where it proved impossible to re-route the river. A reach of 2 km in all was either restored or enhanced. Extensive public amenities were incorporated including new paths and landscape planting.

Full details of the project's organisation, funding, engineering and scientific monitoring are available from RRC in a variety of formats.

List of techniques featured:

1.4	New meandering channel
2.1	New backwaters
3.1	In-channel deflectors
3.2	New aquatic ledges
3.3	Stone riffle
4.1 - 4.4	New revetments
4.5	Supporting river banks
6.2	Re-profiling of land within meanders
7.1	Floodplain scrapes
8.3	Access paths
9.1	Rebuilt surface water outfalls
10.1	New landforms

Project Locations – 2002 Update

LISTING OF THE PROJECTS FEATURED IN THE 2002 UPDATE

This update of Edition 1, 'Restoring the River Cole and River Skerne', introduces fifteen further projects where rivers have been enhanced, rehabilitated or restored by a variety of organisations and partnerships. Each entry is accompanied by a contacts list should further information be required.

Project featured:	**List of techniques featured:**
R. Marden, Wilts	1.5 New meandering channel replacing concrete weirs 5.4 Simulated bedrock outcrops 8.5 Urban riverside access
R. Ravensbourne, LB Bromley	1.6 Opening up a culverted stream
R. Little Ouse, Norfolk	1.7 Reconnecting remnant meanders
R. Alt, Merseyside	3.4 Radical re-design from uniform, straight channel to a sinuous, multi-channel river
R. Avon, Wilts	3.5 Narrowing of an over-widened channel using low cost groynes
R. Dearne, S. Yorkshire	3.6 Creating a sinuous low-flow channel in an over-widened channel
Yardley Brook, Birmingham	3.7 Replacing a concrete drain with a 'natural' channel
R. Tall, Co. Armagh	3.8 Creation of on-line bays
R. Chess, Bucks	3.9 Introducing gravel to inaccessible reaches 10.3 Cost effective silt removal from an impounded channel
R. Thames, Oxon	4.7 Bank revetment using low steel sheet piling and coir rolls
R. Ogwen, Gwynedd	5.3 Restoring and stabilising over-deepened river bed levels 8.4 Restoring a ford as a stock and vehicular crossing point
R. Kennet, Wilts	5.5 Raising river bed levels
Long Eau, Lincs	6.3 Removing and setting back floodbanks
R. Thames, Oxon	7.2 Floodplain wetland mosaic
Sugar Brook, Manchester	11.1 Diversion of a river valley
R. Nith, Ayrshire	11.2 Clay lined river