1 Tøsbæk/Spånbæk brook, Dybvad.
Spawning grounds;
current concentrators; weed clearance

2 Pump station, Gjøl.
Eel pass

3 Lerkenfeld stream, Østrup.
Falls → riffles; spawning grounds

4 River Storå, Holstebro.
Bypass riffle

5 Idom stream, Idum.
New course

6 Rind stream, Herning.
New course; ochre removal

7 River Gudenå, Langå.
Spawning ground

8 Lilleå stream, Hadsten.
Falls → riffles; spawning grounds;
bypass riffle; current concentrators

9 Lammebæk brook, Daugård.
Culvert lamellae

10 Kvak Møllebæk brook, Skibet.
Bypass riffle; spawning grounds

11 River Brede, Løgumkloster.
New course; water table raised;
river valley; ochre removal

12 River Brede, Bredebro.
Falls → riffles

13 River Odense at Ejby Mølle, Odense.
Falls → riffles; historical project

14 River Odense at The Seahorse, Odense.
Falls → riffles; spawning grounds;
historical project

15 Lindved stream at Hollufgård, Odense.
New course; prehistoric landscape;
lakes; sand trap

16 Holmehave brook at Borreby Mill, Odense.
New course; spawning grounds;
historical project

17 Esrum stream, Lake Esrum.
Spawning grounds; current
concentrators; channel narrowing

18 Græse stream, Frederikssund.
Falls → riffles; fish ladder

19 Store Vejleå stream, Glostrup.
New course; removal of paving;
spawning grounds; current concentrators

20 Køge stream, Lellinge.
Sand trap

21 Køge stream, Bjæverskov.
Riffles; current concentrators

22 River Suså at Holløse Mill, Skelby
Falls → riffles; historical project

23 Lilleå stream, Kongsted.
Reopening culvert/removal of conduits;
river valley

24 Søbæk brook, Neksø.
New course; lakes; sand trap

3

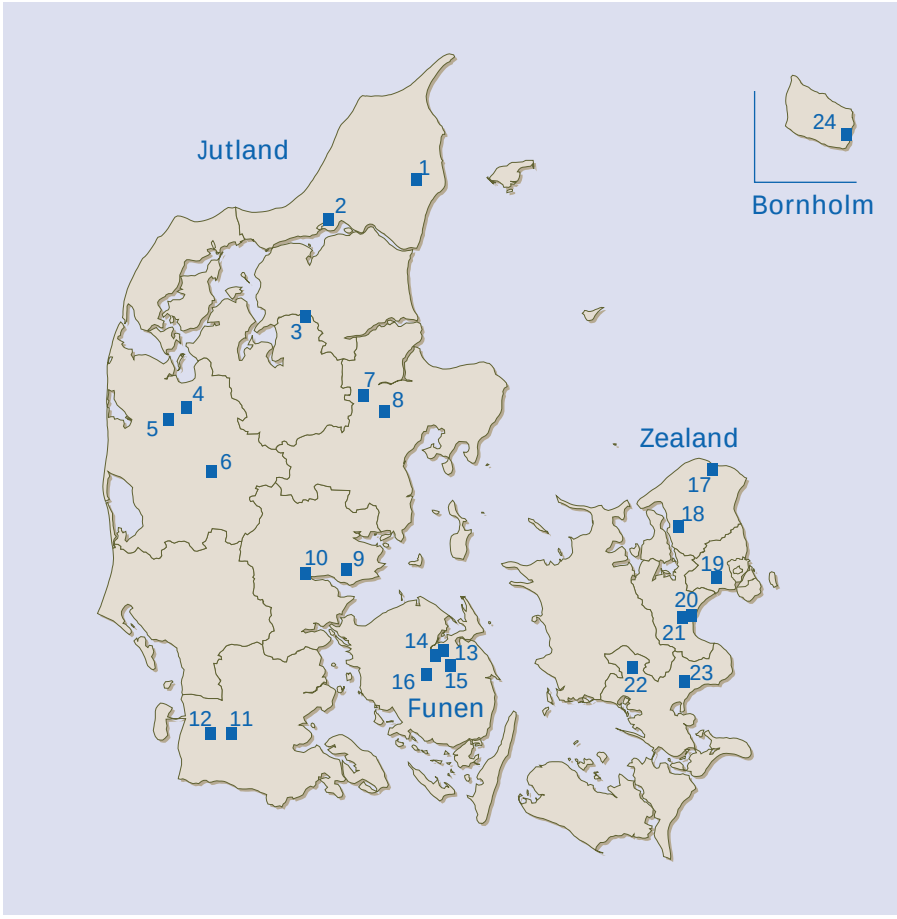
Examples from the Danish counties

Editor:
Hans Ole Hansen

Completed watercourse rehabilitation projects

All 14 Danish counties and many of the municipalities have undertaken a wide variety of different watercourse rehabilitation projects over the last decade. These range from simply laying out large stones, to major projects that remeander watercourses and involve the whole river valley.

In this chapter, staff from 12 County Councils describe 24 watercourse rehabilitation projects undertaken in different parts of the country. The examples provide a good impression of the variety of solutions and methods employed to improve watercourses and their environment.



The geograpical position of the 24 examples described.

3.1

Nordjylland County

Niels Sloth
Jens Berthelsen
Hans Heidemann Lassen

Tøsbæk/Spånbæk brook at Dybvad

Watercourse system:
Voer stream

Introduction to the project

Voer stream is a relatively large watercourse that flows into the Kattegat. Until 1980, Tøsbæk/Spånbæk brook, which is a tributary to Voer stream, was a strongly channelized drainage channel with a slight slope of 0.5–1.5‰ over most of its course. Tøsbæk brook was up to 3 metre wide with uniform weed growth dominated by bur reed. Spånbæk brook was a 1–2 metre wide harshly regulated brook. The watercourses were maintained in accordance with traditional practice, i.e. weed clearance in the whole width of the watercourse and on the banks, removal of tree roots and large stones, and frequent dredging. Because of the slow flow, the bed of the watercourse was comprised of fine sediments.

Aim of the project

In 1976, the Outdoor Council asked Nordjylland County to participate in drawing up a project on ecological watercourse maintenance and re-establishment of the fish population in the Voer stream watercourse system. The Voer stream system was well suited on account of a number of factors: The water quality had been markedly improved, among other reasons because major effluent discharges had been stopped, there were no freshwater fish farms in the system, there were only minor discharges of untreated urban sewage, and there were no dams. Moreover, although parts of the main course and tributaries were channelized, many of the upper parts of the tributaries were natural with good conditions for the fauna.

In collaboration with various government bodies, the County drew up a project outline in 1978 aiming at restoring approx. 3 km of Tøsbæk/Spånbæk brook andapprox. 1 km of Voer stream in order to improve watercourse quality while maintaining good drainage conditions. The measures involved included the establishment of current concentrators, gravel banks and pebble banks, the establishment of artificial fish hiding places, modified and more environmentally sound maintenance, and shady vegetation. The project outline was passed by the County Council in 1978.

Implementation of the project

To undertake the detailed planning of the project and coordinate the practical work a project group was established comprised of a hydraulic engineer and a biologist. In September 1979, the Agricultural Commission approved the project. Some of the landowners affected appealed the approval decision to the Higher Agricultural Commission, which in July 1980 ruled in favour of the project. Restoration work started three months later and was completed at the end of 1993.

The restoration work was undertaken partly by the County Council's field personnel, and partly by a team of young unemployed persons as part of a youth unemployment project.

Impact studies in connection with the restoration project

In 1979, detailed baseline studies were undertaken encompassing the physical, chemical and biological conditions. In addition, a thorough literature report was prepared in 1981 based on the current international literature on watercourse ecology and restoration.

After restoration work had been completed, thorough studies were made

Environmentally sound maintenance of Tøsbæk/Spånbæk brook

of the impact of the various measures. A report was prepared whose main conclusion was that the environmental quality of the watercourse reaches had been improved considerably without their drainage capacity having been detrimentally affected. The density of salmonid fish has increased 4–5 fold, and both sea trout and brown trout have been noticed spawning on the gravel banks.

In addition, the studies have shown that the gravel banks and current concentrators laid out in the watercourse do not have any major effect on discharge capacity, and that environmentally sound maintenance considerably improves watercourse quality. This also applies to the reaches where changed maintenance practice is the only measure that has been implemented. Neither does environmentally sound maintenance have any negative impact on discharge capacity, which even increased in some reaches where the weed is cleared more frequently. In places where the current channel is narrow, the bed is rinsed clean of sediment because of the stronger current.

Experience gained

The watercourse is still maintained in an environmentally sound manner, and there is still a meandering current channel free of sediment deposits. The trees (common alder) have grown up well, and their roots have now stabilized the banks and, together with the very diverse vegetation, provide good hiding places for the fish. The current concentrators, hiding places and stone beds in Tøsbæk-Spånbæk brook are now virtually invisible as it has changed its course, while most of those in Spånbæk brook are still visible and functional. The spawning grounds have sanded over in some places, while others are still visible and usable by salmonids. The density of the latter is still high, as it was already shortly after completion of the original restoration work.

The project was one of the first of its kind in Denmark, and influenced general discussion and formulation of watercourse restoration measures for incorporation in the new Watercourse Act of 1982. The project is currently a good example of how much one can achieve using environmentally sound maintenance undertaken by well-trained personnel. With the aid of environmentally sound maintenance and the planting of vegetation it is in many cases possible to achieve the same physical diversity as with more substantial measures such as current concentrators, artificial hiding places for fish and pebble beds.

Project data:

Project organizer:	Nordjylland County
Contractor:	Nordjylland County
Project commenced:	October 1980
Project completed:	December 1983
Total costs:	DKK 332,000 + studies and administration (incl. VAT)
Financing:	Nordjylland County and Dronninglund and Sæby Municipalities

Watercourse data (Tøsbæk/Spånbæk brook and Voer stream):

Catchment:	23 and 121 km^2
Discharge:	
Max:	2,280 / 12,100 l s^{-1}
Min:	79/436 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters), B2 (Salmonid waters)
Pollutional class:	I, II (1991)

Restoration data:

Coordinates:	57° 17´ N 10° 23´ E
Current concentrators:	22
Gravel beds:	14
Slope:	0.5 – 3.3‰
Fish hiding places:	45
Spawning gravel laid out:	14 beds
Stones laid out:	10 beds
Vegetation:	1,500 trees

3.2 Pump station at Gjøl

Nordjylland County

Niels Sloth
Jens Berthelsen
Hans Heidemann Lassen

Watercourse system:
Limfjorden fjord

Introduction to the project

The land drainage pump station at Gjøl drains water to Limfjorden fjord from an approx. 12 km² low-lying catchment area separated from the fjord by a dyke. Water is pumped from approx. 150 km of drainage ditches and an unknown number of private and municipal watercourses estimated to a total of approx. 200 km.

The area has a very good eel population, but the pump station completely blocks the passage of eel and other fish. It has not been possible to construct an eel pass in the usual manner because the water level inside the dyke is lower than outside.

The organic production of the drainage ditches and watercourses leading to the pump station is high. In most cases the designated water-course quality objective is B3 – ciprinid waters, although the designated quality objective in the upper reaches of a few watercourses is B1/B2 – salmonid waters.

Aim of the project

In 1992, Brovst Municipality approached Nordjylland County to enquire about the possibilities for establishing a fish pass between Limfjorden fjord and the watercourses leading to the pump station. The County agreed to participate in the project because it seemed likely that the watercourses would provide a good habitat for eel to grow and thrive.

It was estimated that it would be possible to grow 9.3 g eel m^{-2} yr^{-1}. When the eel migrated to Limfjorden fjord, they could be caught, for example in eel traps.

Implementation of the project

The project was initiated in autumn 1992. An outline project for an eel pass was drawn up and submitted to the Ministry of Agriculture and Fisheries, which approved the project. Brovst Municipality also recommended the project for a three-year trial period, and an agreement was entered into with the dike owners' association on the establishment of the pass.

Water from the lower-lying inner pump canals is pumped to a distribution well (500 l min^{-1}). From there, half of the water flows out to the outer pump canal through a pipe filled with loosely intertwined plastic strips designed to facilitate the passage of eel (see diagram). This water serves as a guide current to enable the young eel to move up to the distribution well. The other half of the water runs through a pipe from the bottom of the distribution well back to the inner canal. This water flushes any young eel that have been guided into the distribution well into the watercourses. The pipe ends in a trap box containing a small elver trap. The pumps and the eel pass function during the period April-September, when the eel migrate.

As the system was untried, two pilot systems were established – one on each side of the canal that leads the water from the pump station out to the fjord.

Impact studies in connection with the restoration project

The pumps were started for the first time in April 1993. The trap box was emptied once-twice weekly in 1993–94. Elvers that could pass the trap's 2 mm mesh net were not registered. In 1995, the 2 mm mesh net was therefore replaced by a 1 mm mesh net. Four eel were caught in 1993, all of which probably entered by chance, while no eel were caught in 1994.

The reason for the poor result is probably that the guide current was insufficiently strong and/or that the difference in salinity in the area was insufficient to enable the eel to find the outer pump canal, which ends in a brackish area with a high-tide sluice. In addition, the sluice was closed for most

of the time in summer 1994 due to the dry weather, and hence there was no connection between the fjord and the canal.

Salinity measurements made at regular intervals have revealed a salinity difference of 2–4 ‰ between the water pumped from the inner canal and the water in the outer canal. At one point in the summer 1994, the water being pumped out was more saline than the surface water in the outer canal. This was due to density stratification in the inner canals caused by seepage of salt water into the bottom of the canals, from where the water was drawn by the pump. A pump inlet was therefore established in fresh surface water.

Experience gained

Impact studies have revealed that the eel pass does not yet function in the manner envisaged. The trial period will be prolonged and modifications will be made underway.

Fish surveys will be undertaken to determine if eel are in fact present in the outer pump canal, or whether it is the eel pass itself that does not work. In addition, the occurrence of eel inside the dike will be investigated. An alternative to the eel pass could be to release eel directly into the watercourses leading to the pump station.

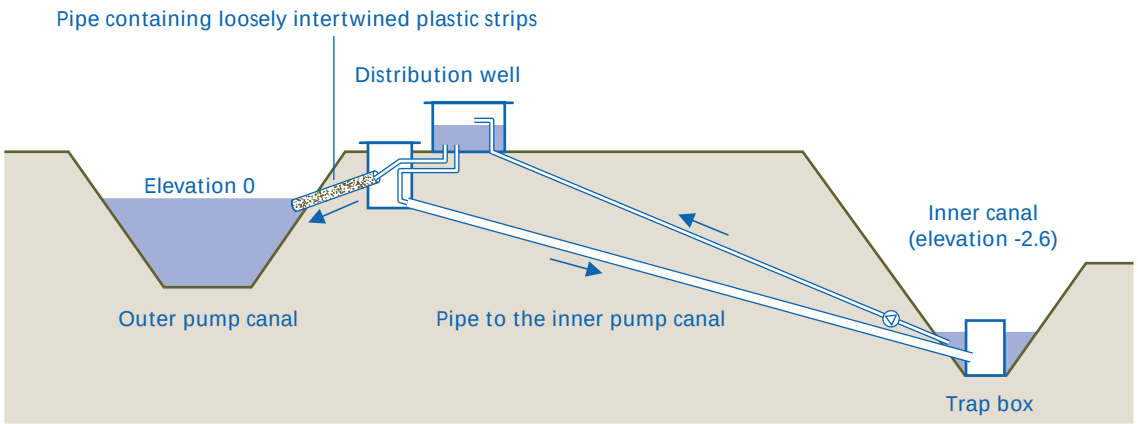
Project data:

Project organizer:	Nordjylland County
Contractor:	Nordjylland County
Project commenced:	1992
Project completed:	1996
Total costs:	DKK 40,000 (incl. VAT)
Financing:	Nordjylland County

Watercourse data:

Coordinates:	57° 04´ N 9° 44´ E
Catchment:	12 km^2
Discharge:	
Max:	1,200 l s^{-1}
Min:	0 l s^{-1}
Quality objective:	B3 (Cyprinid waters) (B1 Salmonid spawning and nursery waters; B2 Salmonid waters)
Pollutional class:	II–III (II) (1991)

Cross section of the pump station at Limfjorden fjord.



3.3

Viborg County

Lerkenfeld stream at Østrup

Rolf Christiansen

Watercourse system:
Lerkenfeld stream

Introduction to the project

Lerkenfeld stream arises in Nordjylland County, from where it runs west into Limfjorden fjord. The stream lies in a narrow valley with numerous springs in the meadows alongside the whole of the stream. The land adjacent to the reach in question has been identified as potentially ochreous. The reach was channelized at the end of the 1950s, at which time seven weirs were established in the stream. From the agricultural point of view channelization was unsuccessful since the riparian areas were only cultivated for a few years before being turned back into meadow again.
The reach of the stream is relatively deep with a uniform sandy bottom. Further downstream there is a freshwater fish farm with a fish ladder that has to be open from October to February each year.

Aim of the project

As part of their general work on the clearance of obstructions, Viborg and Nordjylland Counties are in the process of dismantling the seven weirs in order to improve passage to the upstream reaches that are designated as salmonid spawning waters.

Four of the weirs are located immediately downstream of bridges and other constructions. These weirs were evened out in 1994 by laying out stone mixes, chiefly comprised of large-sized stones. At one of the other concrete weirs the drop in water level was only 25 cm, and the weir was therefore removed without any form of reinforcement. No erosion of any importance has since been noted in the reach.

When removing two of the seven weirs a study was made of whether it was possible to build stable riffles and spawning grounds just by using the different gravel sizes that comprise spawning gravel. At the same time, the riffles were to be established in such a way as to maintain the previous upstream water level. The following only concerns the experience gained in that study.

Implementation of the project

In December 1993, the two weirs were converted to spawning grounds. As there was a risk of ochre washout if the upstream water level fell, the spawning grounds were laid out as a carpet with an even slope such that the top of the bank was at the same level as the upper edge of the former weir.

The spawning gravel was laid out over a length of 35 metres. Downstream of the spawning ground a 10-m long cross-sectional profile was built up using fist-sized stones in order to stabilize the spawning grounds. The profile lies approx. 15 cm lower than the top of the spawning ground. In order to protect the banks from erosion during the initial period after their establishment, spawning gravel was also placed along the sides of the stream along the spawning grounds.

Construction costs for the two spawning grounds amounted to approx. DKK 100,000 (excl. VAT), which is less than half of what a more traditional solution was estimated to cost.

Experience gained

From the stabilization point of view it was expected that the two newly established riffles would undergo considerable

One of the weirs in Lerkenfeld stream prior to restoration (left).
A newly established riffle (right).

rebedding during high discharge periods. The winter 1993/94 was particularly wet, as was also reflected in discharge in the stream.

After the winter discharge period, Viborg County re-surveyed one of the spawning grounds. It transpired that there had only been a minor amount of erosion on the lower 25 metres of the spawning ground. The upper 10 metres was the same as when it had been laid out. This is in accordance with the visual evaluation of current conditions over the spawning ground. Water velocity accelerates over the upper part of the spawning grounds and does not reach a velocity high enough to erode the gravel until some way down along the spawning ground.

In contrast, the gravel that had been laid along the sides of the stream was considerably eroded, forming a new spawning ground approx. 5 metres downstream of the first, and a pool formed between them.

Project data:

Project organizer:	Viborg County
Contractor(s):	Viborg County and Agroplan aps
Project commenced:	December 1993
Project completed:	December 1993
Total costs:	DKK 120,000 (excl. VAT)
Financing:	Viborg County, Nordjylland County and Danish Environmental Protection Agency

Watercourse data:

Catchment:	85 km^2
Discharge:	
Mean:	950 l s^{-1}
Max (10-year):	6,300 l s^{-1}
Min:	520 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters) / B2 (Salmonid waters)
Pollutional class:	II–III (1992)

Restoration data::

Coordinates:	56° 46´ N 9° 30´ E
Length:	45 m
Width:	8 m
Slope:	2‰
Discharge capacity:	>6,300 l s^{-1}
Spawning gravel laid out:	110 m^3
Stones laid out:	60 m^3

3.4 River Storå at Holstebro

Ringkjøbing County

Per Søby Jensen

Watercourse system:
River Storå

Introduction to the project

In 1942, a hydroelectric power station was built at Holstebro. The river Storå was dammed in order to provide electricity to the town's i This hindered the free passage of fish to the upper 2/3 of the Storå river system. Although a fish ladder was built when the power station was erected and had subsequently bbuilt, it had onlyr worked to a very limited extent.
The hydroelectric power station dam completely prevented the passage of the lavaret, a salmonid fish that migrates into the river Storå in large numbers to spawn. It was quite clear that the lavaret was unable to pass the old fish ladder. When the lavaret migrated up the river Storå in November-December in an attempt to reach their spawning grounds, they could be seen standing in large shoals just below the power station.

Aim of the project

Because the fish ladder functioned so badly, Ringkjøbing County decided to improve passage past the power station. By establishing a bypass riffle past the station, virtually all fish species should be able to pass the obstruction at the power station, and thereby ensure the fish free migration to the upper 2/3 of the Storå river system.

Implementation of the project

The new fish pass was formed as a 655 metre long looped riffle of stones that evened out a difference in height of just over 5 metres (see diagram). This ensured a sufficiently low current to allow fish of all species to pass thehydroelectric power plant. Six resting pools were also established in the bypass riffle and spawning gravel was laid out on some reaches so that it could also serve as a breeding and nursery area for the fish. In addition, a bar screen was erected downstream of the turbine outlet to guide the fish to the fish pass.

Impact studies in connection with the restoration project

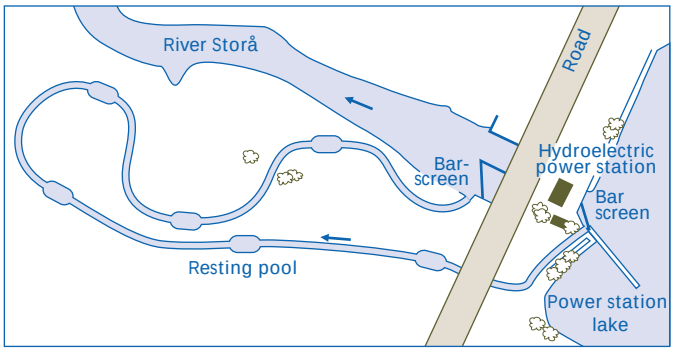
After the bypass riffle had been constructed a follow-up group was established to regularly assess how it functions and decide on any necessary changes in discharge and the shape of the riffle. The follow-up group is comprised of representatives of Holstebro Municipality, Ringkjøbing County and the Inland Fisheries Laboratory under the Ministry of Agriculture and Fisheries.

The follow-up group initiated an investigation aimed at determining whether and by what species the bypass riffle was used, and in particular the extent to which the passage of fish is dependent on discharge in the riffle, as well as the effectiveness of the spawning gravel laid out in the riffle.

From the results of the investigation it can be concluded that the bypass riffle is used by and can be passed by fish of all the species that inhabit the Storå river system. Moreover, based on the relatively large catches of a number of species, among others 4,695 lavaret, it can be concluded that all fish that wish to migrate upstream are able to find the bypass riffle and use it. A precondition, though, is that discharge over the riffle is varied periodically in accordance with the requirements of the individual species.

Optimal discharge for fish passes.

1,000 l s^{-1}	400 l s^{-1}	Discharge not decisive	Not determined
Perch	Gudgeon	Bream	Rainbow trout
Pike	Roach	Dace	River lamprey
Salmon		Eel	Sea lamprey
Sea Trout		Flounder	Tench
Steelhead		Grayling	Trout
		Lavaret	
		Ruffe	



Aerial photograph and sketch map of the bypass riffle at Holstebro hydro-electric power station.

Salmon and grayling have successfully spawned in the spawning grounds laid out in the riffle, albeit that it has not been possible to determine the extent.

Experience gained

The new operational practice for the riffle incorporating varied discharge takes into account both the requirements of the individual species as to discharge and the changes in the migratory patterns of the various species caused by discharge conditions in the river Storå.

It is clear that the bar screen erected downstream of the turbine outlet is of great significance in enabling sea trout, lavaret, salmon and steelheads to find the riffle. The distance between the screen bars should not exceed 20 mm.

It is noteworthy that high discharge and operation of the floodgate that apparently partly or completely masks the guide current from the riffle do not have any negative effect on the functioning of the pass.

Project data:

Project organizer:	Ringkjøbing County
Contractor:	Danish Land Development Service
Project commenced:	October 1989
Project completed:	December 1989
Total costs:	DKK 1,300,000 (incl. VAT)
Financing:	Danish Environmental Protection Agency (DKK 800,000), Ringkjøbing County (DKK 250,000), Holstebro Municipality (DKK 250,000)

Watercourse data:

Catchment:	725 km^2
Discharge:	
Mean:	8,900 l s^{-1}
Max:	30,600 l s^{-1}
Min:	2,500 l s^{-1}
Quality objective:	
Downstream:	B1 (Salmonid spawning and nursery waters)
Upstream:	A (Areas of special scientific interest)
Pollutional class:	I–II

Restoration data:

Coordinates:	56° 22´ N 8° 38´ E
Total length:	655 m
Height difference equalized:	5.3 m
Slope at riffle:	10‰
Slope at spawning grounds:	4‰
Number of spawning grounds:	3 @ 20 m
Number of resting pools:	6
Piped sections under roads:	29 m
Bed width at riffle:	2.75 m
Stone rubble for riffle:	1,025 m^3
Boulders for current shelters:	980
Spawning gravel:	50 m^3
Discharge Oct-May:	1,000 l s^{-1} (day and night)
Discharge June-Sept:	400 l s^{-1} (day)
	1,000 l s^{-1} (night)

3.5

Ringkjøbing County

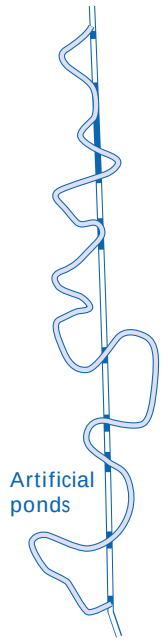
Idom stream at Idum

Per Søby Jensen

Watercourse system:
River Storå

Introduction to the project

Virtually the whole of Idom stream, which is a tributary of the river Storå, was placed under a preservation order in 1985. In this connection the uppermost of a series of freshwater fish farms was closed down. A reach downstream of the fish farm had previously been channelized to ensure water drainage from the fish farm. The reach has not been maintained since 1987.



Sketch map of the remeandered course of Idom stream.

Aim of the project

In 1990, it was decided that 280 metres of the channelized stream reach should be restored to its former meandering stream bed, thereby increasing its length to 570 metres.

The idea for the project originated in the County's landscape department. The reach was restored to the original stream path so as to fulfil both aesthetic and watercourse quality aims.

As weed clearance and dredging had not been undertaken between the closure of the fish farm in 1985 and the start of restoration in 1990, the reach had begun to meander in the excessively wide watercourse profile. As a result, a meandering current channel had already started to form and the physical conditions were becoming more varied. In a few places, the sand sediment had been flushed away to expose the underlying gravel. Thus the conditions that good watercourse quality demands with respect to undercut banks, deep pools and shallow gravel riffles could probably have been recreated by letting the reach develop on its own. Careful consideration was therefore given as to whether or not to let the forces of nature transform the reach towards an expected acceptable result.

In the majority of cases such natural restoration of channelized watercourse reaches is to be preferred from the financial point of view. The disadvantage, though, is that the aesthetic value to the landscape of the watercourse meandering through the whole stream valley would be lacking for many decades. By excavating the former meanders the result becomes visible much more rapidly, but the necessary construction work will in most cases be relatively expensive.

Implementation of the project

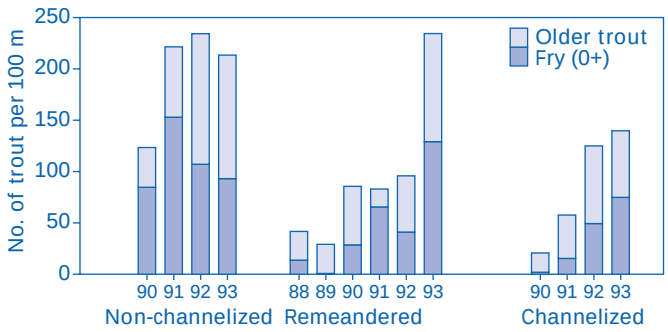
Determining the path of the former stream bed was relatively simple since nearly all the former meanders and wet areas could be identified on aerial photographs of the area as darker patches in the meadows. A preliminary path of the former stream was thereafter mapped out at a scale of 1:4,000. With this map in hand, it was thereafter relatively easy to find the exact course in the stretch of meadow land. By probing with an iron spear the original well-defined gravel bed of the former stream was found, whereafter the "former" and future stream bed could be staked out.

The material filling the former stream varied from 0.5–1 metres in depth, and was chiefly comprised of organic matter and a little sand lying above the stable gravel bed.

The excavated material was mainly spread out on the adjacent fields as a soil improver or otherwise used to close off the completely straight channelized reach in the places where it was crossed by the remeandered reach. By refraining from filling in the whole of the channelized reach, several large and small ponds were created that are now of benefit to the amphibians, animals and birds inhabiting the area.

Impact studies in connection with the restoration project

The restoration project was followed up by electrofishery surveys at three 100 metre



Total number of trout present at three 100 metre reaches of Idom stream during the years 1988–93: Station 1 – a non-channelized downstream reach; station 2 – the remeandered reach; and station 3 – an upstream still channelized reach.

stations. Station 1 lies downstream of the restored reach and has never been channelized, while station 2 lies in the restored reach and station 3 lies upstream and is still channelized (see the figure). It should be noted that electrofishery in 1990 was undertaken immediately prior to restoration in October, and that the trout population at station 1 has not been investigated before 1990. Between 1990 and 1991, the number of trout in the 100 metre reach at station 1 almost doubled, and has since remained constant at around 225 trout, which corresponds to a density of approx. 1 trout m^{-2}. This level probably represents the trout carrying capacity that the stream has in its non-channelized form. Similarly at station 2, the trout population has increased from 25 trout in the 100 metre reach in 1989 to approx. 225 trout in 1993. At station 3, the trout population increased from just under 25 trout in 1990 to just under 150 trout in 1993.

At all three stations, a satisfactory percentage of fry from natural reproduction and of older trout from several generations has been attained over the 3-year period.

Experience gained

The difference that is apparent in the development of the trout population at station 2 and station 3 from 1990 to 1992 is chiefly attributable to the development in physical conditions at the two stations. The reach at station 3 had been harshly maintained until the closure of the fish farm in 1985, and hence until then had also been marked by the effects of pollution from the fish farm. The positive development at station 3 is therefore largely attributable to removal of the impact of the pollution as well as to significant improvement in the physical conditions as a result of self-cleansing following cessation of maintenance. At station 2, in contrast, the population tended to remain constant during the same period, this being due to the fact that the restoration process retarded development for a period as time was needed for plants to recolonize the reach and for the gravel beds to be flushed free of sediment.

In 1993, however, the trout population at station 2 was considerably greater than at station 3; despite the delay, restoration created better physical conditions for the fish population than those attained in the upstream regulated reach by self-restoration. The total trout population in the restored reach is therefore 3–4-fold greater than could be expected had the reach only been allowed to undergoself-restoration to the same degree as at station 3. In the longer term, however, it can be expected that trout density at the restored and the self-restored reaches will eventually be the same.

Restoration of the stream reach has thus both helped improve the trout population as a result of the better physical conditions, and has doubled the length and hence area of the reach relative to that of the channelized reach prior to restoration.

Project data:

Project organizer:	Ringkjøbing County
Contractor:	Ringkjøbing County
Project commenced:	October 1990
Project completed:	November 1990
Total costs:	DKK 70,000 (excl. VAT)
Financing:	Danish Environmental Protection Agency

Watercourse data:

Catchment:	14 km^2
Discharge:	
Mean:	180 l s^{-1}
Max:	580 l s^{-1}
Min:	90 l s^{-1}
Quality objective:	A (Areas of special scientific interest) / B1 (Salmonid spawning and nursery waters)
Pollutional class:	I–II, I

Restoration data:

Coordinates:	56° 20´ N 8° 30´ E
Length:	280 → → 568 m
Width:	4 → 1 m
Slope:	3 → 1.5‰
Meanders:	0 → 15
Spawning gravel laid out:	0 m^3
Stones laid out:	20
Earth excavated:	500 m^3

3.6

Ringkjøbing County

Rind stream at Herning

Per Søby Jensen

Watercourse system:
River Skjern

Introduction to the project

At the beginning of the 1940s, part of Rind stream south of Herning was channelized in order to reclaim meadow land for cultivation. Together with decades of maintenance this left the stream as a straight channel with uniform banks that sloped straight down to an almost horizontal bed comprised chiefly of sand and mud deposits.

It was not only the physical conditions that inhibited the species composition and density in the watercourse, however, but also the quality of the water.

The reach in question was clearly affected by ochre from two upstream former lignite beds. As a consequence, pH was low and the iron content of the water exceeded permitted levels.

Aim of the project

Because of the ochre problems caused by the upstream lignite beds, an attempt was made to design a project that in addition to meeting drainage interests and environmental considerations, also minimized the ochre problem. The aim of the project was therefore to recreate a more natural, meandering watercourse, and to reduce the problems caused by ochre.

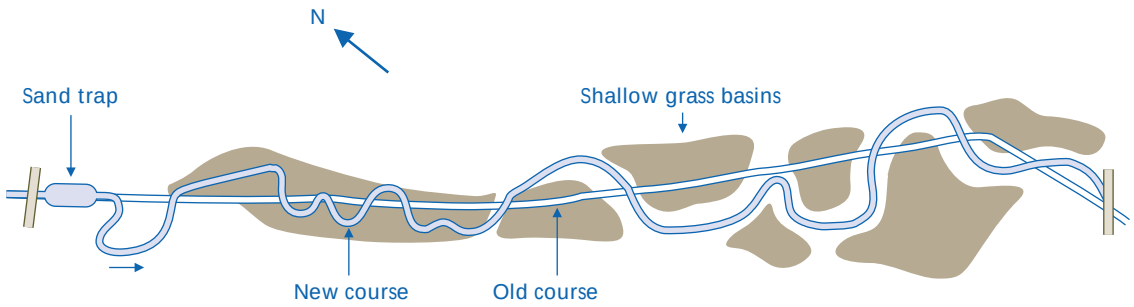
Implementation of the project

The channelized reach of Rind stream was previously 1,800 metres long. After the reach had been remeandered, it was approx. 500 metres longer. This has increased the number of hiding places for fish, and at the same time, new spawning grounds have been laid out.

The first part of the project – the actual remeandering work – was completed at the beginning of 1992. The ochre removal part of the project whereby the forces of nature are harnessed to clean the water of ochre was commissioned at the end of 1992.

The ochre is removed using grass trickling basins alongside parts of the reach, as well as by leading part of the water into six shallow basins excavated nearby, the beds of which have been sown with special species of grass able to tolerate being flooded for longer periods. The vegetation in the basins promotes oxidation of the dissolved iron and retains the ochre.

In connection with the remeandering work and the establishment of the ochre removal basins, approx. 35,000 m^3 material was excavated. This was used to fill in the former channelized sections of the reach as well as to level out other parts of the area. Now that the vegetation has grown up, it is no longer apparent that the countryside has been modified by man. Moreover, the area has become an ideal stopover for migratory birds.



Sketch map of the remeandered reach of Rind stream

Aerial photograph of the remeandered reach of Rind stream.

Impact studies in connection with the restoration project

The impact of the project on the iron content of Rind stream has been assessed regularly since completion of the plant through monthly analyses of the inflow and outflow water (total iron, dissolved iron, pH, temperature and oxygen content). Since operation started in 1992, the plant has continued to reduce the iron content of the water in reasonably close accordance with what was expected. The average degree of treatment over the period October 1993 to September 1994 has been around 43% for dissolved iron and 32% for total-iron. Three subsequent analyses have revealed a degree of treatment averaging 63% for dissolved iron and 30% for total-iron.

Experience gained

The idea for the project originated with two landowners who came to the county authorities wanting the stream restored to its former meandering path. In April 1991, the County held the first meeting with the landowners in the area, and in October the same year, the first part of the project was initiated. The last part of the project – the ochre removal basins – was completed in 1992. The main reason for the relatively short interval between idea and implementation was the great support for the project among the landowners.

The relatively low degree of ochre treatment attained in relation to dedicated ochre treatment plants, where the degree of treatment can reach 80–95%, is largely attributable to the small volume of the basins and poor flow of water into them.

In the construction phase dams were not established in the main course as it was expected that flow from the stream to the basins would gradually increase in step with colonization of the new vegetation-free meanders with weed.

Project data:

Project organizer:	Ringkjøbing County
Contractor:	Ringkjøbing County
Project commenced:	October 1991
Project completed:	February 1992
Total costs:	DKK 910,000 (excl. VAT)
Financing:	Ringkjøbing County watercourse restoration funds (DKK 520,000); Danish Environmental Protection Agency ochre funds (DKK 390,000)

Watercourse data:

	Remeandered reach:	*Ochre removal reach:*
Catchment:	170 km^2	52.4 km^2
Discharge:		
Mean:	2,600 l s^{-1}	900 l s^{-1}
Max:	6,700 l s^{-1}	2,500 l s^{-1}
Min:	550 l s^{-1}	200 l s^{-1}
Quality objective:	B2 (Salmonid waters)	B2 (Salmonid waters) and F (Watercourses affected by ochre)
Pollutional class:	II–III	II–III, affected by ochre

Restoration data:

Coordinates: 56° 06´ N 8° 58´ E

	Remeandered reach:	*Ochre removal reach:*
Length:	1,020 → 1,340 m	750 → 950 m
Width:	10–12 → 6–12 m	4 m → (2–6 m and 2–40 m)
Slope:	0.65 → 0.55‰	0.8 → 0.65‰
Meanders:	0 → 12	0 → 14
Number of riffles established:	7	
Spawning gravel laid out:	115 m^3	30 m^3
Boulders laid out:	100	
Earth excavated/incorporated:	15,000 m^3	
Stone rubble laid out:		40 m^3
Earth excavated:		20,000 m^3
Number of shallow pools:		6
Watercourse corridors:		1
Sand traps:		1

The water level was therefore expected to increase, thereby resulting in more frequent flow of water to the basins. The last three series of measurements indicate that the increasing distribution of vegetation has in fact had a positive influence on the degree of ochre treatment.

For one thing, the water quality has increased, and for another, the physical conditions have improved considerably, as is apparent in the form of much more varied conditions with fish hiding places, riffles and pools, gravel bed and good hydraulic conditions.

3.7 River Gudenå at Langå

Aarhus County

Ole Helgren

Watercourse system:
River Gudenå

Introduction to the project

The river Gudenå downstream of the Silkeborg lakes has been channelized and deepened several times over the last century to facilitate navigation with barges, etc. The last time was in the 1930s. Large boulders were blown up, and smaller stones and gravel were excavated to ensure a good navigation channel. With the construction of a hydroelectric power station at Tange in 1921 the remaining natural spawning grounds in the lower reaches of the river Gudenå disappeared, and the formerly so rich salmon populations died out.

Aim of the project

After several years' discussion as to whether salmonids spawned in the main course of the river Gudenå and whether the physical conditions were suitable, the decision was made in 1992 to undertake a pilot project comprising the establishment of an artificial spawning ground approx. 2 km upstream of Langå.

The idea was to re-establish one of the former excavated spawning grounds. However, all such sites proved to coincide with areas of historical interest (fords, etc.) and it was therefore decided to establish a spawning ground from scratch at an otherwise suitable site.

The final location was chosen from among 10 possibilities after numerous investigations of water velocity, profile changes, bottom substratum and benthic fauna. Close examination of the historical aspects also played a decisive role in making the final choice.

Implementation of the project

The Environmental Division of Aarhus County was given the task of planning and undertaking the project. In order to ensure that all ideas and viewpoints were taken into consideration, the project was drawn up in close collaboration with the local committee of the Danish Society for the Conservation of Nature, anglers, local museums, the Natural History Museum, the municipal authorities, Aarhus and Vejle Counties, and affected landowners.

The project involved establishing two spawning grounds. Over an area of approx. 1,200 m^2 the spawning grounds were built up to a height of approx. 1.4 metres above the existing river bed on a base of unsorted stony material covered with an at least 40 cm thick layer of spawning substrate. The latter is comprised of naturally occurring stony material from the area having the following size distribution: 15% 8–16 mm, 35% 16–32 mm, 35% 32–64 mm and 15% 64–120 mm.

The water depth over the spawning grounds is at least 40 cm. Along the southern bank of the river there is an at least 5 metre wide and 1 metre deep navigation channel. Numerous large stones have since been placed in the river to protect the banks and provide shelter from the current.

The project was undertaken by a contractor during a 14-day period in autumn 1993.

Laying out the spawning gravel.

The physical and hydraulic conditions still fulfil those assumed in the project. Fish were observed spawning at the spawning grounds immediately after completion of construction work in October and for the remainder of the year 1993, and electrofishery in the early summer 1994 led to the catch of the first salmon fry (1 indiv.). Electrofishery and the biological investigations were continued in 1994–95. Experiments involving the laying out of hatching boxes are also planned.

In winter 1994–95, the spawning grounds was expanded with an associated shallow-water area designed to provide better hiding places for the fry.

Impact studies in connection with the restoration project

As the project was intended as a source of inspiration for future work on improving the environmental quality of the river Gudenå, a number of studies were undertaken before and after carrying out the project:

- Pre-, during and post-construction surveys
- Pre- and post-construction measurements of discharge
- Pre-construction geotechnical surveys of river bed conditions
- Diver surveys to register aspects of historical interest
- Pre and post construction investigation of the flora and benthic fauna
- Regular electrofishery
- Visual registration of fish at the spawning grounds

Experience gained

The accessibility of the selected sites considerably affects construction costs. In the case of the present project, which cost DKK 130,000, road access for the delivery of materials was particularly good.

Project data:

Project organizer:	Gudenå Committee
Contractor:	Aarhus County, Environmental Division
Project commenced:	September 1993
Project completed:	October 1993
Total costs:	DKK 130,000 (incl. VAT)
Financing:	Gudenå Committee

Watercourse data:

Catchment:	1,850 km^2
Discharge:	
Mean:	22,000 l s^{-1}
Max:	65,000 l s^{-1}
Min:	10,000 l s^{-1}
Quality objective:	B2 (Salmonid waters)
Pollutional class:	II (1993)

Restoration data:

Coordinates:	56° 23´ N 9° 55´ E
Length:	70 m
Width:	30 m
Slope:	Average 10‰
Discharge capacity:	35,000 l s^{-1}
Spawning gravel laid out:	180 m^3
Stones laid out:	90 m^3
Rubble laid out:	370 m^3

Watercourse system:
River Gudenå

3.8

Aarhus County

Lilleå stream at Hadsten

Ole Helgren

Introduction to the project

Lilleå stream, which arises approx. 20 km west of Aarhus and flows into the river Gudenå at Langå, is one of the river's main tributaries. The surrounding landscape varies from very hilly to flat plains, although there is a clearly defined river valley. Approx. 2/3 of Lilleå stream has been channelized over the years to meet the needs of agriculture. As a result of channelization and marked urban and industrial growth, Lilleå stream appeared as a barren watercourse characterized by harsh maintenance and sand migration. Water quality was affected by effluent, and discharge was very variable, often leading to major flooding.

Aim of the project

Due to repeated flooding of agricultural land in the 1980s and because the watercourse quality objectives were not fulfilled, the decision was made to do something about the problem.

The passage of migratory fish was also included since approximately half of the salmonids that migrate up the Gudenå river system enter Lilleå stream.

The task involved improving the stream's discharge capacity and hence drainage safety, while at the same time enhancing its environmental quality and ensuring free passage for fish in Lilleå stream and subsequently in the whole of the Lilleå watercourse system.

Implementation of the project

The complete project was drawn up by a working group involving the landowners, interest groups, weir owners, municipal and county authorities. The project took approximately five years to complete and encompassed:

- Constructing a two-step profile along 4 km of the stream
- Replacing a fish ladder
- Removing two dams and constructing riffles
- Constructing a bypass riffle
- Laying out approx. 3,000 m^3 stones
- Laying out approx. 300 m^3 spawning gravel
- Planting approx. 13,000 trees
- Drawing up new regulations and switching to environmentally sound maintenance.

The construction of a 12–18 metre wide two-step profile along 4 km stream was undertaken in 1989 in close cooperation with the landowners. The project was partly paid for by the landowners, who provided the land free of charge, and partly by the Municipalities and the County subsidized by the Danish Environmental Protection Agency. Free passage of fish was ensured by:

- Replacing the fish ladder at Løjstrup in 1988 (cost approx. DKK 200,000)
- Removing the dam at Hadsten Mill and establishing a riffle in 1989 (cost approx. DKK 700,000)
- Removing the dam at Grundfør Mill and establishing a riffle in 1990 (cost approx. DKK 450,000)
- Establishing a riffle at Granslev in 1991 (cost DKK 30,000)
- Establishing a bypass riffle at Voer Mill in 1992 (cost DKK 130,000)
- Removing the dam at Selling Mill and establishing a riffle in 1993 (cost DKK 60,000).

With the prior agreement of the landowners, interest groups and the authorities, each sub-project was administratively processed by the County and subsequently undertaken under contract under the County's supervision or by the County itself.

Subsequent to the project, work has been undertaken in the tributaries to Lilleå stream whereby one bypass riffle has been constructed and two dams removed. In addition, most maintenance is now undertaken in an environmentally sound manner.

Laying out stones in a two-step profile.

Impact studies in connection with the restoration project

Studies made prior to the project had revealed an impoverished aquatic environment characterized by few plant species and a barren sandy bed with a small population of stock fish and only a few migratory fish. Moreover, large areas of agricultural land were frequently flooded. Following completion of the project, sand migration has minimized, and long stretches can now be found having a stony or gravel bed. The species composition of the weed has changed considerably, and there is currently a good population of indigenous fish. In addition, migratory fish can now be found in nearly the whole of the river system.

Flooding of agricultural land has only taken place in the spring of 1994, and the newly created green corridor has provided a good habitat for fauna and flora.

Experience gained

The procedure chosen involving a broadly based working group and numerous meetings and public hearings is protracted and resource demanding. However, the subsequent implementation phase is correspondingly quicker and more problem free.

The construction work was undertaken at times that were favourable for both landowners and the environment.

The course of the project and the methodological manner in which it was carried out has led to a wide understanding of the complex problems that often arise when balancing agricultural and environmental interests, and has given rise to a good climate of cooperation between the landowners, the organizations and the authorities.

The result is a pleasant watercourse with a rich flora and fauna, a green corridor through the stream valley, and satisfied citizens, landowners, organizations and authorities.

The course of events and the result have generated considerable goodwill in the whole catchment area and, among other things, has led other landowners to approach the County with proposals for further improvements to the environment.

Project data:

Project organizer:	Aarhus County
Contractor(s):	Aarhus County and Danish Land Development Service
Project commenced:	1987
Project completed:	1993
Total costs:	DKK 2,700,000 (incl. VAT)
Financing:	Danish Environmental Protection Agency (DKK 350,000), Hadsten and Hinnerup Municipalities (DKK 770,000), diverse landowners (DKK 750,000), and Aarhus County (DKK 830,000)

Watercourse data:

Catchment:	310 km^2
Discharge:	
Mean:	2,914 l s^{-1}
Max:	26,000 l s^{-1}
Min:	720 l s^{-1}
Quality objective:	A (Areas of special scientific interest), B1 (Salmonid spawning and nursery waters); B2 (Salmonid waters)
Pollutional class:	II (Average, 1993)

Restoration data:

Coordinates:	56° 19´ N 10° 03´ E
Length:	31,200 m
Width:	1–7 → 1–4 m
Slope:	1.1‰
Discharge capacity:	26,000 l s^{-1}
Spawning gravel laid out:	300 m^3
Stones laid out:	3,000 m^3
Earth excavated:	35,000 m^3

3.9

Vejle County

Lammebæk brook at Daugård

Tony Bygballe
Jan Nielsen

Watercourse system:
Rohden stream

Introduction to the project

Lammebæk brook is a tributary of Rohden stream, which runs through a river valley covered with trees. Lammebæk brook falls 40 metres over a 4 km long reach. It has not been dredged or maintained for several years. As a result, it has developed a natural and varied course that alternates between small falls, riffles and deep pools. At Daugård, the brook runs under a main road through a 25 metres long concrete culvert.

Aim of the project

The culvert was previously an effective obstruction for migratory fish. Because of the culvert's 30‰ slope, the water level inside was so low and the current velocity so high that not even strong fish like the sea trout were able to swim upstream through the culvert. The project aimed to effectively improve the possibility for fish to migrate upstream in the brook.

Implementation of the project

The County constructed a simple but effective lamallae-like insert to mount inside the culvert so as to create refuge and resting places for fish attempting to migrate upstream in the brook. The insert is comprised of a wooden plank with a notch cut on the upper edge of alternate sides, and is fitted to an iron bracket having the same form as the culvert. The inserts are mounted on the base of the culvert at 2 metre intervals angled in the direction of the current. The water level at each of these lamellae-like inserts was thereby raised at least 30 cm, andtrout and other fish can now swim through the notches in the lamellae and rest in the basins between them.

At the same time, another culvert located approx. 500 metres upstream was altered such that there is now free passage to fish along the whole length of the watercourse.

Impact studies in connection with the restoration project

Two weeks after the lamellae had been mounted, sea trout had swum through the culvert and further on up the brook. The fish are now evenly distributed along the whole length of the brook. In 1993, there was a fine natural trout population of approx. 2.2 trout m^{-2}. Up to 1994, 2,000 trout fry were stocked in Lammebæk brook each year. However, stocking was ceased after 1994 as the population is now self-reproducing.

Experience gained

Culverts that lead watercourses under roads are one of the most common obstructions in smaller Danish water-courses. If there is insufficient water in the culvert, or if the current is too strong, the culvert forms an effective obstruction for even the strongest swimmers such a sea trout. If the culverts lie deep below the road surface it is often economically unfeasible to alter them. Mounting

lamellae in culverts has proved to be a very effective means of raising the water level and reducing current velocity. Moreover, it is a relatively cheap solution for a major problem.

The road culvert before and after mounting the lamellae.

Project data:

Project organizer:	Vejle County
Contractor:	Vejle County
Project commenced:	October 1992
Project completed:	October 1992
Total costs:	DKK 18,000 (incl. VAT)
Financing:	Vejle County

Watercourse data:

Catchment:	5 km^2
Discharge:	
Mean:	75 l s^{-1}
Max:	2,000 l s^{-1}
Min:	25 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	I

Restoration data:

Coordinates:	55° 44´ N 9° 43´ E
Length:	25 m
Diameter:	1.25 m
Slope:	30‰
Culvert discharge capacity:	6,000 → 5,000 l s^{-1}

3.10

Vejle County

Kvak Møllebæk brook at Skibet

Tonny Bygballe
Jan Nielsen

Watercourse system:
River Vejle

Introduction to the project

Kvak Møllebæk brook is a tributary of the river Vejle lying approx. 7 km upstream of Vejle Fjord. At Kvak Mill, a water-driven grain mill built in the last century, a 4.3 metres high dam prevented the passage of fish.

Aim of the project

The aim of the project was to construct a bypass riffle around the old watermill dam in order to restore free passage for the brook fauna and at the same time reduce sand deposition in the millpond. In addition, the channelized and deepened brook downstream of the dam was to be remeandered to give it a more natural course before its outlet into the river Vejle.

Implementation of the project

The bypass riffle was constructed in May–June 1991. Remeandering of the reach down to the river Vejle was undertaken in October 1992, and included planting the adjacent land with common alder.

Impact studies in connection with the restoration project

Subsequent studies have shown that many trout were already present in the bypass riffle one month after its completion. At that time, trout density was up to 1 trout m^{-2}. The following year, trout density in the bypass was 2 trout m^{-2}, the trout having started to spawn in the bypass itself. There were far more trout in

Bypass riffle at Kvak Watermill.

Electrofishery in the remeandered reach of Kvak Møllebæk brook.

the bypass than in the upstream and downstream reaches of the brook.

Moreover, studies undertaken during the sea trout spawning season have shown that numerous sea trout now migrate upstream of the millpond to spawn in the brook's upper reaches. Thus many more trout are now present in the brook than previously, and trout stocking has now been stopped. Furthermore, in the remeandered reach twelve spawning grounds were laid out and sea trout started to use them just a few days after completion of the project. In 1993, there was a fine natural trout population of approx. 1 trout m^{-2}.

Project data:

Project organizer:	Vejle County
Contractor(s):	Danish Land Development Service and Vejle County
Project commenced:	May 1991
Project completed:	October 1992
Total costs:	DKK 252,000 (excl. VAT)
Financing:	Vejle County, Danish Environmental Protection Agency and Vejle Municipality

Watercourse data:

Catchment:	4.8 km^2
Discharge:	
Mean:	72 l s^{-1}
Max:	136 l s^{-1}
Min:	36 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	I–II

Restoration data:

Coordinates:	55° 43´ N 9° 27´ E	
	Remeandered reach:	*Bypass riffle:*
Length:	150 → 190 m	0 → 260 m
Width:	3–4 → 0.6–3 m	0 → 0.5–1.3 m
Slope:	0 → 4–5‰	0 → 5–25‰
Discharge capacity:	Max 150 l s^{-1}	
Meanders:	9	
Spawning gravel laid out:	60 m^3	
Stones laid out:	70 m^3	
Earth excavated:	200 m^3	

3.11

Sønderjylland County

Bodil Deen Petersen
Mogens Bjørn Nielsen

River Brede at Løgumkloster

Watercourse system:
River Brede

Introduction to the project

At Løgumkloster the river Brede runs in a well-defined and rather narrow river valley, the majority of which is permanently grass-covered. From there the river continues past Bredebro, eventually to run out into the Wadden Sea. The river Brede originally followed a very meandering path, but was channelized in the mid 1950s. The river has since eroded deep down into the landscape and caused considerable sand migration. Only in very few parts of the river there was an actual gravel-bedded current channel and spawning grounds suitable for salmonid fish. In 1990, a large weir at Bredebro was rendered passable by converting it to a riffle (see example 3.12). This was the only downstream obstruction in the river system.

Aim of the project

There were several reasons for wanting to restore this particular reach of the river Brede. Firstly, to improve environmental conditions in the river, including reducing the destructive migration of sand. Secondly, to remove the last major weir in the river Brede, thereby enabling the upstream migration of salmonids, especially the rare salmonid, the houting, which is once again found in the majority of watercourses in southern Jutland courtesy of a successful breeding programme. The plan also encompassed improving the continuity between the river and adjoining meadows by raising the river bed.

Prior to the project, the latter lay up to 1 metre below the level stipulated in the Provisional Order governing the watercourse. The whole of the river valley is potentially ochreous, and raisingthe river bed and hence the water table in the river valley was also expected to reduce ochre input to the river.

Implementation of the project

The project was undertaken in the second half of 1991. A 2,680 metre channelized reach was converted to a 3,130 metre meandering reach and the river bed was raised. The weir was removed and two long riffles were established instead. Spawning grounds and stones were laid out, and some of the meanders were reinforced with stones.

The meandering course is now almost identical to that prior to channelization except alongside Løgumkloster town, where remeandering was not possible because a sewer and houses have since been constructed at the former course of the river.

In several places the former meanders were preserved after channelization. They were still present as open ponds in the meadows, but became incorporated in the new meandering watercourse after restoration. To replace them, two new ponds were excavated in the former channelized reach. During excavation work it transpired that one of the former meanders had been used as a landfill, and over 200 tonnes material had therefore to be transported to a controlled landfill.

The project was completed in May 1992.

The river Brede near Løgumkloster during restoration in October 1992. The new meanders have been dug and the former channelized path has not yet been filled in.

Impact studies in connection with the restoration project

The plants and benthic macroinvertebrates in the reach in question were studied prior to restoration (in 1991) and again after six and eighteen months, respectively (in 1992 and 1993). In addition, electrofishery is undertaken each year in much of the river Brede in collaboration with the local angling association.

Prior to restoration, the bank vegetation in the channelized reach was poorly developed, the banks being steep and having been reinforced with fascines. After restoration, the bank vegetation has become more diverse and well developed. The vegetation in the river itself was previously strongly dominated by filamentous leaves of the bur reed (*Sparganium Emersum*), but after restoration, there is a higher frequency of more environmentally beneficial species such as the water starwort (*Callitriche platycarpa*) and the large-flowered water crowfoot (*Batrachium peltatum*).

Compared with the former channelized reach the new reach has a greater number of benthic macroinvertebrate species and the density of macroinvertebrates is generally greater now because the river bed has become less uniform than previously.

Electrofishery has shown that numerous and large sea trout migrate up the river Brede, and that the houting is now found far up the river system. It has not yet been shown to spawn in the river, though.

Experience gained

The project affected a total of 10 private landowners as well as Løgumkloster Municipality. All the landowners were involved in the project at an early point so that they had the opportunity to influence the project. They were regularly kept informed during the whole course of events.

In 1994 and 1995, a further 6 km of the river Brede downstream of the above mentioned reach was restored in the same manner. This project was undertaken under the EU Life Programme in connection with similar projects in England. The significance of the project for the river and river valley is still being thoroughly investigated by Sønderjylland County in collaboration with the National Environmental Research Institute. It is planned to continue restoration of the river Brede both downstream and upstream, as well as to undertake projects in some of its tributaries aimed at reducing loading by ochre. The remeandering project is the largest of its kind so far undertaken in Denmark.

Project data:

Project organizer:	Sønderjylland County
Contractor:	Sønderjylland County
Project commenced:	July 1991
Project completed:	December 1991
Total costs:	DKK 1,750,000 (excl. VAT)
Financing:	Danish Environmental Protection Agency, Løgumkloster Municipality and Sønderjylland County

Watercourse data:

Catchment:	258 km^2
Discharge:	
Mean:	2,700 l s^{-1}
Max:	16,000 l s^{-1}
Min:	1,000 l s^{-1}
Quality objective:	B2 (Salmonid waters)
Pollutional class:	II (1990–91)

Restoration data:

Coordinates:	55° 04´ N 8° 58´ E
Length:	2,680 → 3,130 m
Width (bed):	6 m
Slope:	0.3‰
Discharge capacity:	12,000 l s^{-1}
Meanders:	0 → 13
Spawning gravel laid out:	300 m^3
Stones laid out:	5,750 m^3
Earth excavated:	48,200 m^3

Pilot studies:

Soil analyses in the river valley
Surveyance of the river and river valley
Collection of water discharge data for the latest years
Plants and macroinvertebrates in the river
Information on cables and conduits in the area (electricity, telephone, water, sewage, gas)
Information on other restrictions and plans for the area (County Plan, Municipal Plan, zoning restrictions, preservation orders, etc.)