Watercourse system:
River Brede

3.12

Sønderjylland County

Bodil Deen Petersen
Mogens Bjørn Nielsen

River Brede at Bredebro

Introduction to the project

In connection with the channelization and regulation of the river Brede in the mid 1950s, two large concrete weirs were built in the lower reaches of the watercourse system. The weir at Bredebro was the furthest downstream, and with an 8.4 metre wide spillway was also the largest. The water drop over the edge of the weir was up to 1.2 metres during the summer period and an average of 0.6 metre in the winter months. It was therefore a very effective hindrance to the migration of fish up the river.

Aim of the project

The quality objective designated for the majority of the watercourse system upstream of the weir (294 km^2) is salmonid waters or salmonid spawning and nursery waters. These quality objectives were not fulfilled, partly because of the obstruction caused by the weir. The aim of the project was therefore to restore free passage for migratory fish and thereby render possible the fulfilment of the quality objectives upstream of the weir. This would also increase the area of watercourse available to the threatened salmonid species, the houting, which, among other places, has been stocked in the river Brede.

Removal of the weir at Bredebro and the restoration of free passage to fauna was also a precondition for being able to restore and remeander the river Brede at Løgumkloster further upstream in the system (see example 3.11). In connection with that project, the other large weir in the river Brede was removed.

Implementation of the project

The project was undertaken in late summer 1990. The original concrete weir was not altered. Immediately downstream of the weir, a 250 metre long riffle was created with an average slope of 5‰. The riffle is comprised of three sub-riffles with a total length of 110 metres. The three sub-riffles each have a slope of 10‰ and a bed width of 4 metres as compared with 6 metres in the parts between the sub-riffles. This arrangement creates two resting pools between the three sub-riffles. Downstream of the riffle spawning grounds have been established for trout and salmon.

When undertaking the project care was taken to ensure that drainage conditions upstream and downstream of the riffle were not changed, there being major agricultural interests in the intensively cultivated surrounding area.

Impact studies in connection with the restoration project

Electrofishery is undertaken each year in the river Brede in collaboration with the local angling association. This has shown that large numbers of trout now migrate up the river, as do houting and salmon.

The weir at Bredebro prior to and following conversion to a riffle.

Project data:

Project organizer:	Sønderjylland County
Contractor:	Sønderjylland County
Project commenced:	September 1990
Project completed:	October 1990
Total costs:	DKK 550,000 (excl. VAT)
Financing:	Sønderjylland County and Danish Environmental Protection Agency

Watercourse data:

Catchment:	294 km^2
Discharge:	
Mean:	3,500 l s^{-1}
Max:	30,000 l s^{-1}
Min:	1,000 l s^{-1}
Quality objective:	B2 (Salmonid waters)
Pollutional class:	II (1991–92)

Restoration data:

Coordinates:	55° 03´ N 8° 51´ E
Width (bed):	4–6 m
Slope:	5‰
Discharge capacity:	30,000 l s^{-1}
Spawning gravel laid out:	150 m^3
Stones laid out:	1,500 m^3

3.13

Funen County

River Odense at Ejby Mølle, Odense

Ann Fuglsang
Annette Sode
Claes Levin Pedersen

Watercourse system:
River Odense

Introduction to the project

The river Odense is the largest and most important watercourse on Funen. It has a total length of 54 km and with its 631 km^2 catchment area with many valuable tributaries drains approx. 1/5 of the total area of Funen. Since the 13th century, there has been a water mill at Ejby Mølle. The 2 metre high millpond dam effectively obstructed all upstream migration of fish to approx. 85% of the river's catchment area.

Aim of the project

The aim of the project was to restore free passage for fish and macroinvertebrates past the mill dam at Ejby Mølle.

The water level upstream of the mill had to be preserved unchanged and it had still to be possible to lead water to the mill.

Implementation of the project

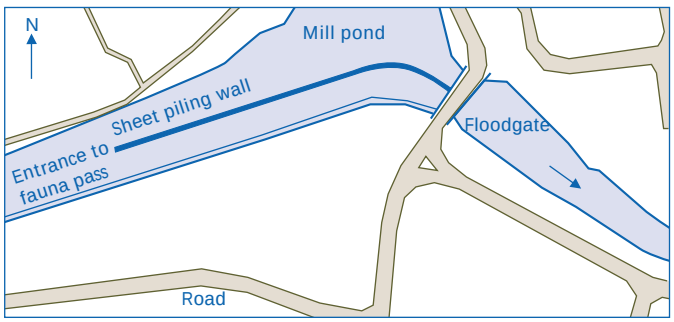
The work began in June 1992 and was carried out in collaboration with Odense Municipality.

The project was undertaken by constructing a 166 metre fauna-passable stone riffle upstream and through the floodgate. Downstream of the latter it continues as a further 99 metre riffle.

Above the former floodgate, a 166 metre long sheet piling wall has been driven into the bed parallel to the bank such that a 7 metre wide stone riffle could be established between the sheet piling wall and the adjacent bank.

Downstream of the floodgate, the riffle was established in the full width of the river (approx. 23 metres) for a length of 99 metres. As resting basins are incorporated in the riffle, the average slope is 8‰ and the maximum slope 12‰. At the average minimum discharge (870 l s^{-1}), the riffle's run-in profile is fully charged. At higher discharge, the excess water will spill over the edge of the sheet piling wall and down into the riffle. The 166 metre spillway can thereby drain away approx. 25,000 l s^{-1} before the water level reaches flood levels. By regulating the weir at the floodgate it is possible to drain away a total of approx. 45,000 l s^{-1}.

When discharge exceeds the average minimum, a small quantity of water can be led to the mill channel, although ensuring that the guide current from the fauna passage is always strongest. In connection with the project a sewer had to be relaid and an overflow conduit moved.



Sketch map of the fauna pass at Ejby Mølle (Scale approx. 1:2,000).

Impact studies in connection with the restoration project

Since completion of the riffle, electrofishery has been undertaken 4 times in winter 1992–93 in order to determine whether the riffle ensures the upstream migration of sea trout.

In addition, the macroinvertebrate fauna in the lower part of the riffle has been studied before and after completion

Riffle and spillway viewed facing upstream from the floodgate.

The riffle and floodgate viewed facing upstream from the lowermost resting basin.

Project data:

Project organizer:	Funen County
Contractor:	Carl Bro Ltd.
Project commenced:	June 1992
Project completed:	Winter 1992/spring 1993
Total costs:	DKK 5,290,000 (excl. VAT)
Financing:	Funen County, Odense Municipality and Danish Environmental Protection Agency

Watercourse data:

Catchment:	631 km^2
Discharge:	
Mean:	5,360 l s^{-1}
Max:	36,500 l s^{-1}
Min:	250 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	II and II–III (1993)

Restoration data:

Coordinates:	55° 24´ N 10° 25´ E
Length:	265 m
Width:	7–23 m
Slope:	6–12‰
Discharge capacity:	45,000 l s^{-1}
Earth incorporated:	4,680 m^3
Stones laid out:	3,290 m^3
Earth excavated:	7,540 m^3
Piling inserted:	1,227 m^2

of the project. A riffle that was present there prior to the project was removed in connection with the establishment of the newriffle. The analyses have been undertaken since 1989 and involve two annual fauna samples. The analysis series makes it possible to assess how rapidly macroinvertebrates colonize the newly established riffle.

After completion of the project, hydraulic measurements and calculations have been undertaken in the riffle to verify the calculations on which the project was based.

The results of the studies have not yet been reported, but some experience with the fauna passage has already been gained.

Experience gained

The riffle at Ejby Mølle ensures satisfactory passage for sea trout migrating upstream. The hydraulic measurements made after completion of the project show that the calculations on which the project was based held true. The new riffle has proved stable in its construction and, as predicted, has the sufficient capacity to cope with the levels of discharge seen in the river.

The future

The project should be viewed in the context of the plan for the river Odense up to the year 2000 whereby Funen County, in collaboration with the Municipalities and trade and industry, intends to develop the Odense river system into European top-class trout waters.

3.14

Funen County

River Odense at The Seahorse, Odense

Ann Fuglsang
Annette Sode
Claes Levin Pedersen

Watercourse system:
River Odense

Introduction to the project

At Munke Mose in the centre of odense, the river Odense runs through public parkland where a sculpture called "The Seahorse" stands in the river. It is known that Knuds Kloster monastery had a water mill there in 1175. The water mill no longer exists, but the dam and sluice bridge have been preserved. In order to safeguard the water level at The Seahorse approximately 70 metres downstream of the sluice bridge, two solid spillways had been established at a point further downstream where the river divides around an island. These created a 1 metre high falls that obstructed effective upstream passage of fish and fauna to 85% of the river's catchment area.
In connection with the rebuilding of the sluice bridge in 1987, two fish ladders were built into the 1 metre high falls at the bridge such that fish now have free passage past the obstruction.

Aim of the project

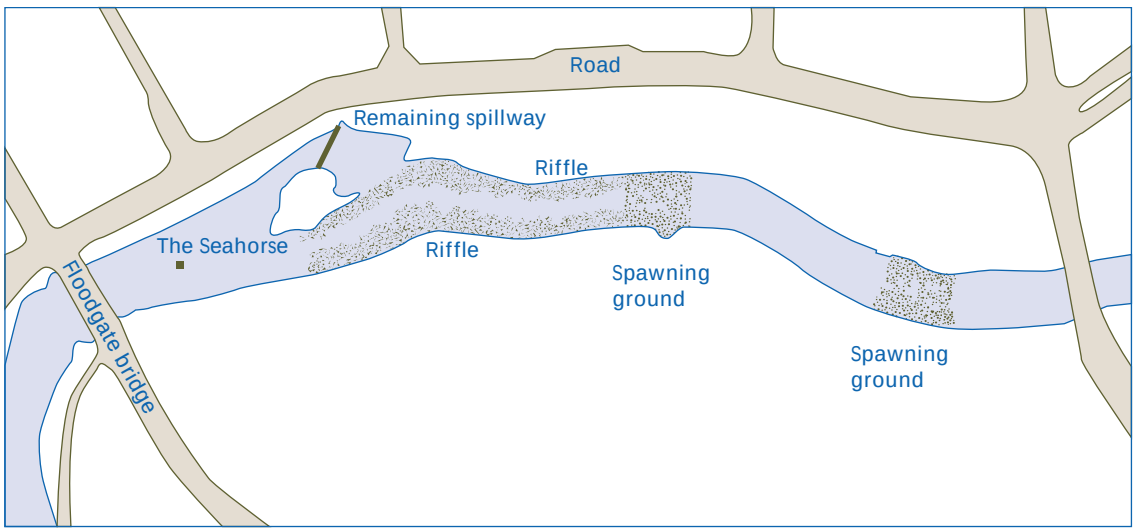
The aim of the project was to recreate free passage for fish and fauna past the solid spillways downstream of "The Seahorse", and at the same time improve thespawning possibilities for salmonid fish in the river Odense. The water level was to be preserved largely unaltered between the spillways and the sluice bridge, as well as upstream of the sluice bridge.

Implementation of the project

In spring 1993, Odense Municipality approached Funen County with a proposal for establishing spawning grounds in the river Odense. The result was a joint project between the Municipality and the County comprising the establishment of a stone riffle and two spawning grounds downstream of the two solid spillways near The Seahorse.

The work commenced in autumn 1993 and was completed in spring 1994. A 115 metre long riffle of stones was established over the full width of the river downstream of the southernmost spillway (see sketch map).

The slope of the riffle varied between 5‰ and 12‰. The riffle was completed with a 25 metre long spawning ground. In addition, a 40 metre long spawning ground was laid out 75 metre further downstream. Both spawning grounds were laid across the whole width of the river and sloped 5–6‰.



Sketch map of the riffle and spawning grounds (scale approx. 1:2,200).

The riffle viewed facing upstream towards the island.

The spawning ground viewed facing downstream.

The northern of the two spillways was raised 10 cm. A large deep pool below the spillway has been preserved by damming the river slightly where it merges with the new riffle behind the island.

Impact studies in connection with the restoration project

Specific impact studies have not yet been undertaken, but experience from similar projects indicates that the new riffle will have restored free passage past the obstruction for both fish and fauna.

The future

The project should be viewed in the context of the plan for the river Odense up to the year 2000 whereby Funen County, in collaboration with the Municipalities and trade and industry, intends to develop the Odense river system into European top-class trout waters.

Project data:

Project organizer:	Funen County and Odense Municipality
Contractor:	Danish Land Development Service
Project commenced:	November 1993
Project completed:	June 1994
Total costs:	DKK 940,000 (excl. VAT)
Financing:	Funen County, Danish Environmental Protection Agency and Odense Municipality

Watercourse data:

Catchment:	631 km^2
Discharge:	
Mean:	5,360 l s^{-1}
Max:	36,470 l s^{-1}
Min:	250 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters) and/or B2 (Salmonid waters)
Pollutional class:	II and II–III (1993)

Restoration data:

Coordinates:	55° 24´ N 10° 25´ E
Length:	115 and 65 m
Width:	18–24 m
Slope:	5–12‰
Discharge capacity:	44,600 l s^{-1}
Spawning gravel laid out:	390 m^3
Stones laid out:	4,090 m^3
Earth laid out:	4,160 m^3
Earth excavated:	500 m^3

Watercourse system:
River Odense

Introduction to the project

Lindved stream is the lowermost county watercourse that runs into the Odense river system. In former times, the watercourse had been channelized upstream of the mill at Hollufgård (southeast of Odense), and was enclosed by dykes, partially obstructed, flat and slowly flowing. Over the course of time, several valuable wet meadows had formed that were important to preserve. From the meadowland, Lindved stream ran through Hollufgård millpond and over a 2 metre high falls at the dam. This effectively obstructed the passage of the stream fish and macroinvertebrates.

3.15

Funen County

Lindved stream at Hollufgård, Odense

Ann Fuglsang
Annette Sode
Claes Levin Pedersen

Aim of the project

In 1990, Odense Municipality planned to establish a "prehistoric landscape" at the Culture Centre Hollufgård.

In this connection, it was wanted to create a watercourse that on one hand could form a natural part of a "prehistoric landscape", and on the other could improve biological conditions in and around the watercourse, including restoring free passage past the obstruction for the watercourse fauna.

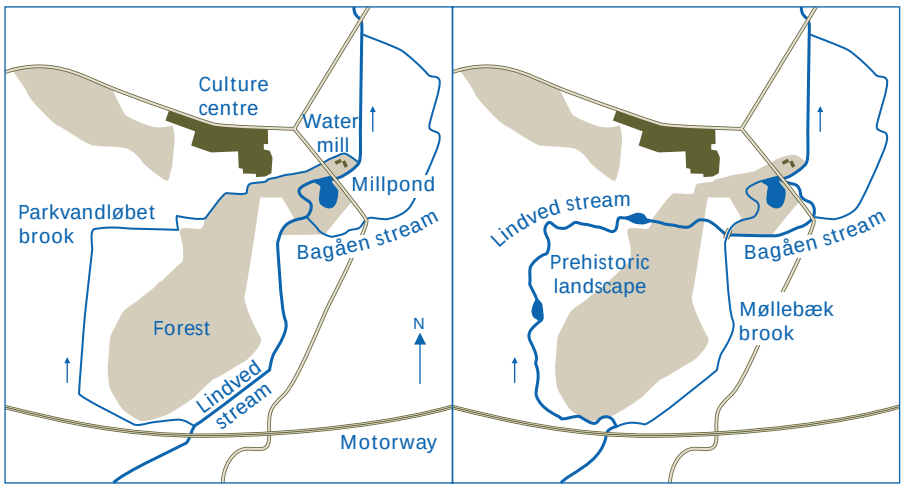
Among other things, the plans necessitated altering the course of Lindved stream so that it ran through the landscape along part of the former path of a small watercourse called Parkvandløbet.

Because of the valuable wet meadows along Lindved stream it was important to preserve the high water level. Similarly, the historical importance of the water mill necessitated preserving the flow of water to the millpond.

Implementation of the project

In summer 1991, Odense Municipality and Funen County carried out the rehabilitation project in collaboration with the National Forest and Nature Agency.

The new course of Lindved stream was approx. 2 km long (see sketch map). The stream was led through the newly established "prehistoric landscape" along part of the former path of the watercourse Parkvandløbet. This reach of the watercourse has a very flat cross-sectional profile and floods its banks in the winter. Two ponds were excavated that serve as sand traps. A new course was excavated through the forest after which the stream



Sketch map of the course of the stream before and after rehabilitation (scale approx 1:20,000).

The riffle bypassing the mill dam viewed facing downstream towards the water mill.

runs under a newly constructed aqueduct that now leads Møllebæk brook along the former path of Lindved stream. From there the stream runs in part of the former course of Bagåen stream to a newly erected road bridge. From the road bridge to the water mill the new course has been constructed as a stone riffle thereby ensuring the fauna free passage around the millpond dam.

Discharge in Møllebæk brook is now lower, but is still sufficient to preserve the wet meadows and ensure adequate water flow to the millpond.

Odense Municipality has established a highly ramified network of public footpaths in the 20 hectare "prehistoric landscape". The area has subsequently been fenced in and highland cattle put out to graze.

Impact studies in connection with the restoration project

Following rehabilitation of Lindved stream regular biological investigations have been undertaken in and around the stream, and the composition of the streambed and depth of the water have been recorded. In addition, the watercourse has been photographed regularly from fixed positions.

The biological investigations encompass the following: Species composition and estimated coverage of aquatic and swamp plants (once yearly), species composition and relative number of aquatic macroinvertebrates (twice yearly), and species composition and number of fish inhabiting and passing through the reach (once yearly).

Weed clearance has not hitherto been undertaken in the new reach. In order to investigate whether this will lead to drainage problems, the water level upstream of the reach is measured continually.

The results of the investigations have not yet been reported, but some experience has already been gained.

Experience gained

The number of species and number of plants and macroinvertebrates has increased steadily since rehabilitation of the stream. At the same time, physical conditions in the watercourse have changed considerably with the bed becoming increasingly varied as the banks have become more and more overgrown. Progress is least rapid at the shaded parts. The fish population increased steadily from 1991 to 1993 but was small in 1994. However, there are only very few if any fish in the most shallow, gentle and flat sections through the "prehistoric landscape".

Since completion of the project, Funen County and Odense Municipality have set up a permanent exhibition on the interaction between watercourses and man.

The future

The project should be viewed in the context of the plan for the river Odense up to the year 2000 whereby Funen County, in collaboration with the Municipalities and trade and industry, intends to develop the Odense river system into European top-class trout waters.

The newly established course of Lindved stream through the "prehistoric landscape".

Project data:

Project organizer:	Funen County and Odense Municipality
Contractor:	Danish Land Development Service
Project commenced:	May 1991
Project completed:	July 1991
Total costs:	DKK 1,180,000 (excl. VAT)
Financing:	Funen County, Odense Municipality, National Forest and Nature Agency

Watercourse data:

Catchment:	65 km^2
Discharge:	
Mean:	420 l s^{-1}
Max:	4,400 l s^{-1}
Min:	26 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	I – II and II (1993)

Restoration data:

Coordinates:	55° 24´ N 10° 25´ E
Length:	890 → 1,820 m
Width:	3–5 → 2–6 m
Slope:	0.4 → 1–10‰
Meanders:	10 → 24
Spawning gravel laid out:	180 m^3
Stones laid out:	440 m^3
Earth excavated:	6,800 m^3

Technical aspects:

One concrete bridge
One concrete municipal road bridge
One concrete aqueduct
Two lakes / sandtraps
One wooden distribution structure
Five wooden forest road bridges / footbridges
Crossing a 30 cm dia. drain

3.16

Funen County

Holmehave brook at Borreby Mill, Odense

Ann Fuglsang
Annette Sode
Claes Levin Pedersen

Watercourse system:
River Odense

Introduction to the project

Holmehave brook is the next lowermost county watercourse that runs into the river Odense. In 1970, the watercourse was channelized upstream of Borreby mill, immediately before it runs into the river. As a result it was canal-like, flat and slowly flowing. At the same time as the brook was channelized, the millpond was dismantled, the sluice gate removed and the inflow to the mill filled in such that Holmehave brook ran through the remaining wing walls of the sluice. The former brook bed upstream of the sluice was not filled in completely, and in 1988 was still visible in the terrain. At the sluice, there was still an approx. 1.5 metre difference in water level that effectively obstructed the passage of fish and macroinvertebrates in the watercourse.

Aim of the project

In 1988, the owner of Voldsgård, a farm through which the brook runs, approached Funen County to enquire whether the County was interested in remeandering Holmehave brook upstream of Borreby mill. He was himself very interested, and was therefore willing to give up the necessary land free of charge.

In connection with the County's endeavours to improve conditions in watercourses, including free passage past obstructions, it was agreed with the owner to undertake a project aimed both at restoring free passage past the obstruction at the sluice, and improving the physical and chemical conditions in and around the watercourse. In view of the historical significance of the water mill, it was important to preserve the remaining wing walls of the sluice.

Implementation of the project

Before drawing up the project, the former path of the watercourse upstream of the sluice was determined from studying old maps and probing the terrain. This path was roughly followed when excavating the new watercourse.

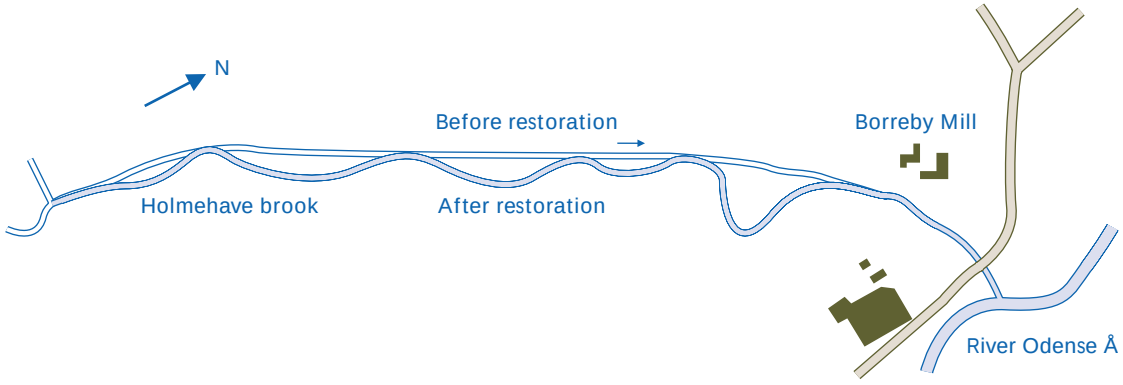
Free passage was created past the sluice by lowering the bottom of the sluice approx. 1 metre and by extending an existing stone riffle up to the sluice. The new course was constructed to have an average slope of 1.1‰, and was excavated with a two-step profile. After completion of excavation work, spawning grounds were laid out in the straight stretches between meander bends, and large stones were laid out to protect the bends from the current. Since completion of the project, a public footpath has been established alongside part of the new watercourse.

Impact studies in connection with the restoration project

Biological investigations have been undertaken both before and after the reach of Holmehave brook had been remeandered. The biological investigations were undertaken once yearly during the period 1988–94, and encompassed the following: Species composition and estimated coverage of aquatic, swamp and bank plants, species composition and relative number of aquatic macroinvertebrates, species composition and number of fish, as well as composition of the bed sediment based on distribution analysis of grain size.

All the investigations were undertaken at two locations in the new watercourse reach as well as at two reference

The riffle and modified sluice.



Sketch map showing the course of Holmehave brook before and after restoration (scale approx. 1:5,500).

locations located upstream of the remeandered reach. Weed clearance has not hitherto been undertaken in the reaches used for the investigations. The results of the investigations have not yet been reported in detail, but some of the experience can already be described.

Experience gained

The number of plant species has increased since the brook was remeandered. With regard to macroinvertebrates, species composition can vary markedly at the locations investigated; as a consequence, changes in species composition have to be large before they can be ascribed to the restoration measure with any degree of certainty. Several unlawful toxic discharges upstream of the investigated reaches and inter-annual variation in bed conditions have thus caused large variation in macroinvertebrate species composition. However, conditions seem to have improved for the fauna in the lower part of the remeandered brook, although the change is not marked compared with the variation seen at the reference reaches.

The trout population was very small immediately after the brook had been remeandered, and at several of the reaches investigated other fish species disappeared completely. In the following years, the trout population has grown in step with colonization by vegetation, and the brook is now more varied, with weeds, pools and undercut banks. This trend has been particularly marked since 1990, and the current fish population is generally considerably greater than before remeandering.

As the new course has been established in an area with a very loose soil structure, it was very unstable immediately after excavation. This unfortunate tendency was counteracted by laying out spawning gravel, but only really ceased when the banks and slopes became stabilized by vegetation.

The future

The project should be viewed in the context of the plan for the river Odense up to the year 2000 whereby Funen County, in collaboration with the Municipalities and trade and industry, intends to develop the Odense river system into European top-class trout waters.

Project data:

Project organizer:	Funen County
Contractor:	Funen County
Project commenced:	September 1988
Project completed:	November 1988
Total costs:	DKK 270,000 (excl. VAT)
Financing:	Funen County and Danish Environmental Protection Agency

Watercourse data:

Catchment:	70 km^2
Discharge:	
Mean:	640 l s^{-1}
Max (20-year):	11,830 l s^{-1}
Min:	35 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	II and II–III (1993)

Restoration data:

Coordinates:	55° 22´ N 10° 22´ E
Length:	790 → 910 m
Width:	4.25 → 3.75 m
Slope:	0.3 → 1.1‰
Meander bends:	2 → 10
Spawning gravel laid out:	110 m^3
Stones laid out:	75 m^3
Earth excavated:	4,200 m^3
Earth transported away:	1,000 m^3

Technical aspects:

Four outfalls re-established
Sluice and footbridge rebuilt
Water mains crossed

Watercourse system:
Esrum stream

Introduction to the project

Esrum stream starts at a sluice in the northern part of lake Esrum. The lake and much of its surroundings are under a preservation order. Moreover, a preservation order is under consideration for Esrum Canal and the associated canals and historical monuments. The canal was dug from lake Esrum to Dronningmølle at the beginning of the 1800s. It enabled wood to be transported from Gribskov forest to Copenhagen by barge.

Esrum stream is one of the best fishing streams in Frederiksborg County. Sea trout migrate upstream and several reaches have a gravel bed and spawning grounds for trout.

The stream was channelized at the end of the 1800s, but in most places now only appears slightly regulated.

3.17

Frederiksborg County

Esrum stream at lake Esrum

Birthe Petersen

Aim of the project

In 1990, the County decided to restore approx. 3.5 km of the stream, the aim being to create more varied physical conditions in the watercourse and hence improve its environmental quality. Because of marked erosion, the bed of one channelized reach was very wide. A further aim of the project was therefore to narrow the watercourse in that reach and thereby attain a more varied bed.

Implementation of the project

The project was started in autumn 1990. A 55 metre long spawning ground was laid out near Esrum town and three other spawning grounds were laid out over a 2 km reach further downstream. Current concentrators were established along an approx. 500 metre reach by impaling stakes of split oak. The concentrators were established at 25 metre intervals alternately on the left and right banks of the stream.

As a supplement to existing spawning grounds, spawning gravel was laid out wherever bed conditions permitted.

The majority of the practical work with the project was undertaken by a firm of contractors selected from among four invited to submit tenders. In addition, spawning gravel and large stones were laid out along an approx. 300 metre section at the beginning of the reach in collaboration with local anglers. The

Esrum stream.

County arranged for the gravel and stones to be transported to the site as well as for the hire of wheelbarrows, etc., while the anglers undertook the work of laying out the material. The contractor completed the work in December 1990.

In 1991, a bypass was constructed around the downstream millpond at Esrum Møllegård and there is now free passage between the Sound and lake Esrum.

Impact studies in connection with the restoration project

The impact of the restoration project has not been studied.

Experience gained

Planned initiation of the project was delayed as a result of complaints and appeals by landowners during the formal processing of the case, and the field work was therefore undertaken at a time of year that was sub-optimal with respect to both the watercourse fauna and environment. Thus construction work was carried out in the last three months of the year, during which the sea trout migrate upstream and when there are usually many rainy days that can delay the work. The late time of the year also meant that the vegetation that should have erased the traces of theexcavation and spreading of earth in and around the project area was slow to re-establish.

Despite the difficulties caused by the season the work schedule drawn up by the contractor held. Access and work roads for the excavators and transport of materials had to be reinforced by laying out metal plates and wood chippings, which increased the costs of the project. However, worries that the construction work would scare away the trout from the spawning grounds proved unfounded, and considerable spawning activity was seen at both the newly established and existing spawning grounds already while the work was being undertaken.

Project data:

Project organizer:	Frederiksborg County
Contractor:	Frederiksborg County
Project commenced:	October 1990
Total costs:	DKK 500,000 (excl. VAT)
Financing:	Frederiksborg County DKK 325,000 (excl. VAT); Danish Environmental Protection Agency DKK 175,000 (excl. VAT)

Watercourse data:

Catchment:	125 km^2
Discharge:	
Mean:	600 l s^{-1}
Max:	1,400 l s^{-1}
Min:	300 l s^{-1}
Quality objective:	A (Areas of special scientific interest) and B1 (Salmonid spawning and nursery waters)
Pollutional class:	I–II (1993)

Restoration data:

Coordinates:	56° 00´ N 12° 25´ E
Length:	3,200 m
Width:	2.5–3.5 m
Slope:	3‰
Discharge capacity:	1,800 l s^{-1}
Meanders:	0 → 8
Spawning gravel laid out:	150 m^3
Stones laid out:	100 m^3
Earth excavated:	20 m^3

Technical aspects:

Extension of three drains that formerly had their outfalls on spawning grounds
Establishing two manholes in connection with the above

3.18

Frederiksborg County

Græse stream at Frederikssund

Birthe Petersen

Watercourse system:
Græse stream

Introduction to the project

Græse stream is a 15 km long watercourse that runs into Roskilde Fjord. At Græse Mill approx. 3 km from the mouth of the stream there was previously a water mill. The stream had been dammed there since construction of the mill. When the mill was dismantled, there remained an approx. 2.8 metre fall over an approx. 15 metre reach just after a road culvert. The water was held back by planks just before the culvert. The falls was only passable by eel via an eel pass.
In the current County Plan, the designated quality objective for Græse stream is ciprinid waters. Because of improvement in the quality of the watercourse, consideration is now being given to raising the quality objective to salmonid spawning and nursery waters. Fulfilment of such a quality objective required that free passage for migratory fish be restored at Græse Mill.

Aim of the project

The aim of the project was therefore to restore free passage for fish at Græse Mill by converting the falls to a riffle. In 1991, Frederiksborg County therefore initiated a study of how this could be done. It was already known that trout migrated up the lower part of the stream from Roskilde Fjord to Græse Mill, and a trout fry stocking programme was undertaken upstream of the falls.

Implementation of the project

The study initiated in 1991 led in 1993 to the establishment of a 125 metre long stone riffle upstream from the road bridge, and a basin ladder downstream from the bridge. The stone riffle was established with a small winding current channel inthe watercourse profile in order to ensure a reasonable water depth during summer periods of low discharge. At the same time, the stream bed was

The basin ladder in Græse stream viewed facing upstream towards the road culvert.

lowered such that the riffle fell evenly towards the road culvert. The planks in front of the road culvert were removed and a basin ladder constructed using 10 basins positioned such that there was a height difference of 31 cm between adjacent basins. In order that the basin ladder could blend into the surroundings as naturally as possible, the surfaces that would be visible above the water level were decorated with fist-sized pebbles. The basin ladder was fitted with an eel pass.

Impact studies in connection with the restoration project

In connection with earlier trout stocking plans for Græse stream, experimental release of trout fry was undertaken upstream and downstream of the mill dam. In its supervision programme for 1994–95, the County undertook studies aimed at determining whether sea trout can pass through the basin ladder, and whether the upstream migration of sea trout results in successful spawning.

Similarly, macroinvertebrate studies will enable comparison of the restored reach with upstream reaches, and hence will reveal whether the improved physical conditions result in greater species diversity.

Experience gained

In order to prevent sediment transport from the upstream reach to the riffle and basin ladder during and following construction work, a sand trap was established upstream of the riffle. This proved to be a good idea as sediment transport from the upstream reach was greater than anticipated. Despite the establishment of the sand trap, which has been emptied several times since completion of the work, it nevertheless proved necessary to empty the basin ladder of sand approximately half a year after completion of the work.

The local inhabitants have shown great interest in the basin ladder, and often route their walks past it.

Project data:

Project organizer:	Frederiksborg County
Contractor(s):	Niels Lonnebjerg and Frederiksborg County
Project commenced:	August 1993
Project completed:	October 1993
Total costs:	DKK 575,000 (excl. VAT)
Financing:	Danish Environmental Protection Agency and Frederiksborg County

Watercourse data:

Catchment:	28 km^2
Discharge:	
Mean:	75 l s^{-1}
Max:	1,075 l s^{-1}
Min:	25 l s^{-1}
Quality objective:	B3 (Ciprinid waters)
Pollutional class:	II (1993)

Restoration data:

Coordinates:	55° 51´ N 12° 05´ E
Length:	Riffles: 125 m
	Basin ladder: 30 m
Width, riffle:	1.25 → 0.5–2 m
Slope, riffle:	0.6 → 6.1‰
Discharge capacity:	
Max:	1,000 l s^{-1}
Min:	75 l s^{-1}
Gravel laid out:	210 m^3
Stones laid out:	210 m^3
Earth excavated:	150 m^3

3.19

Copenhagen County

Store Vejleå stream near Glostrup

Peter Malmolin
Jørgen Johansen

Watercourse system:
Store Vejleå stream

Introduction to the project

Store Vejleå stream runs in a 0.5–1 km wide river valley corridor that serves as a recreational green belt running through otherwise closely built-up districts on the outskirts of Copenhagen. The stream is severely channelized along its whole course. In one 1.5 km long reach the stream has been moved from former marshland and led through two artificial lakes that serve as stormwater basins with a storage capacity of approx. 0.5 million m^3.

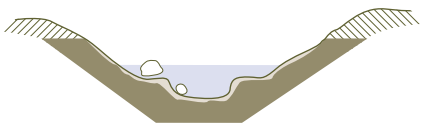
The upper reach of Store Vejleå stream was regulated in the 1940s and the sides and bed lined with concrete paving slabs. This was done to protect the rather superficial water table at a nearby water supply borehole site from percolating diluted sewage.

Aim of the project

Store Vejleå stream is one of the few watercourses in the Copenhagen area where the physical conditions are conducive to attaining a high watercourse quality objective. As the watercourse also lies in an area of great recreational value, it has been justifiable to invest the sum that the project costs.

Implementation of the project

The construction work was undertaken over the period 1992–94. The concrete paving slabs were removed along a 1.7 km reach of the stream. The watercourse was remeandered along its former bed and a 400 metre stretch was rerouted completely.



30 cm thick clay membrane

The watercourse profile was altered to a two-step profile and lined with a 30 cm thick clay membrane designed to hinder hydraulic contact between the stream water and the superficial water table at the nearby water supply borehole site (see figure). The laying down of the clay membrane was one of the preconditions for undertaking the project.

Remedial pumping of polluted groundwater at the water supply borehole site ensures that there is always flow in the stream as treated groundwater is pumped 2.7 km upstream through a high pressure hose at the rate of 10–15 l s^{-1} to be discharged again near the stream's watershed.

A number of large stones were laid out in the watercourse profile to provide shelter from the current. In addition, stones and gravel were spread on the stream bed. Three obstructions to the passage of fish were removed and four spawning grounds were laid out

Impact studies in connection with the restoration project

The former paved section of the now restored watercourse lacked any flora and fauna of significance. Since completion of the restoration project, a monitoring programme has been initiated to follow colonization by plants and animals. The first data are being collected but no conclusions can yet be drawn.

The quality of the treated groundwater derived from remedial pumping at the water supply borehole site is regularly controlled relative to the criteria stipulated in the discharge permit.

The future

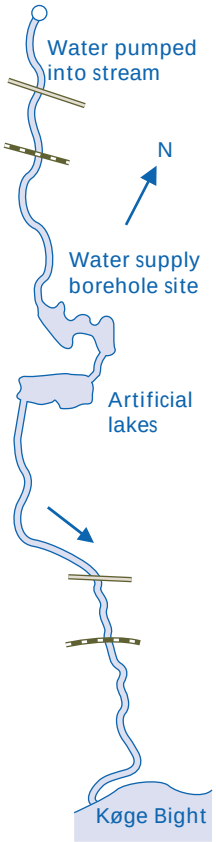
A large number of trout have been caught in the lower part of Store Vejleå

stream in recent years, many of which were over 60 cm long. In the same reach, a perch population is starting to form that on the basis of fish size measures up to the best Danish fish waters. At the present time, there still remains to remove an obstruction to fish halfway up the watercourse system. When this has been done, the fish population will be able to spread upstream into the restored reach.

Experience gained

The project proved complicated to undertake because of the many different interests at stake. On the other hand, though, the project has attracted great interest locally, and there has been good media coverage during the whole course of the restoration project. Angling organizations have followed the project with particular interest.

Store Vejleå stream before and after restoration.



Outline map of Store Vejleå stream.

Project data:

Project organizer:	Copenhagen County
Contractor:	Danish Land Development Service
Project commenced:	1992
Project completed:	1994
Total costs:	DKK 2,800,000 (excl. VAT)
Financing:	Copenhagen County, Danish Environmental Protection Agency, Albertslund and Høje-Tåstrup Municipalities

Watercourse data:

Catchment:	9.8 km^2
Discharge:	
Mean:	56 l s^{-1}
Max:	930 l s^{-1}
Min:	15 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	“Cannot be determined” (1994)

Restoration data:

Coordinates:	55° 41´ N 12° 25´ E
Length:	1,547 → 1,711 m
Width:	1.5 → 1.2/0.6 m (two-step profile)
Slope:	2.7 → 2.6‰
Discharge capacity:	930 → 930 l s^{-1}
Meanders:	0 → 8
Spawning gravel laid out:	40 m^3
Stones laid out:	550 m^3
Earth excavated:	5,700 m^3

3.20 Køge stream at Lellinge

Roskilde County

Anne-Marie Kristensen

Watercourse system:
Køge stream

Introduction to the project

Køge stream runs through largely agricultural land. The first 10 km have been restored through the construction of current concentrators and the laying out of gravel and spawning grounds (see example 3.21). Thereafter, the watercourse runs through uncultivated forested countryside and in this reach the slope is sufficient to prevent sand or sediment deposition. The lowermost part of Køge stream runs through an area of extensively farmed meadows before flowing out into Køge Bight. Along this reach, the stream is a meandering watercourse with a good environmental quality.

Aim of the project

Large sand deposits were regularly found in the reach that runs through meadow land and dredging was therefore necessary. The deposits had a detrimental impact on watercourse quality as sand migration and frequent dredging reduced the physical variation necessary to support a varied flora and fauna in the watercourse. The designated watercourse quality objective for this reach of Køge stream is salmonid waters.

In order to minimize the need to dredge this reach of Køge stream and thereby improve the physical conditions to the benefit of fish, macroinvertebrates and plants, a sand trap was established in 1991 at the upstream end of the reach.

Implementation of the project

Prior to establishing the sand trap, the necessary authorization permits were obtained and compensation was agreed with the affected landowners. The practical work was undertaken by the County's own watercourse maintenance staff.

The sand trap was established outside the main course of the stream such that part of the water ran through the main course, and part through the sand trap so as to ensure the discharge capacity stipulated in the Provisional Order governing the watercourse. A 10 metre long culvert was established in the main course dimensioned such that any discharge in excess of 200 l s^{-1} would run through the sand trap, and that there

The sand trap on Køge stream

was free passage to fauna throughout the year.

Impact studies in connection with the restoration project

Biological investigations have not been undertaken in the project area or downstream of the sand trap especially aimed at revealing the effects of the project.

The pollutional class of the stream upstream and downstream of the sand trap has remained unchanged at an unsatisfactory level. One of the greatest problems with Køge stream with respect to fulfilling the watercourse quality objective is the very low discharge in summer, which makes it difficult to achieve a more satisfactory pollutional class.

Experience gained

The project was undertaken in 1991 and sand has since been removed from part of the sand trap once in summer 1992 and from the whole sand trap once in 1994. The sand trap has functioned as expected and the excavated sand has been used to raise the ground level of the area around the lake/sand trap.

The area has rapidly become overgrown with vegetation, and trees and bushes have been planted out. The whole area now appears as meadow land of natural beauty, especially in winter, when the water level in the lake/sand trap is high.

Project data:

Project organizer:	Roskilde County
Contractor:	Danish Land Development Service
Project commenced:	June 1991
Project completed:	September 1991
Total costs:	DKK 266,350 (excl. VAT)
Financing:	Roskilde County and Carlsen-Langes Foundation

Watercourse data:

Catchment:	153 km^2
Discharge:	
Mean:	900 l s^{-1}
Max (10-year):	11,500 l s^{-1}
Min:	10 l s^{-1}
Quality objective:	B2 (Salmonid waters)
Pollutional class:	II–III (1990–94)

Restoration data:

Coordinates:	55° 28´ N 12° 08´ E
Length:	200 m
Width:	5 m
Slope:	0.6‰
Discharge capacity:	8,000 l s^{-1}

Watercourse system:
Køge stream

Introduction to the project

Køge stream was formerly a pearl among the watercourses of Zealand, having a very rich and varied fish community. Thus around the beginning of the century, it was possible to catch numerous sea trout in the lower reaches of the stream.
At Bjæverskov, the stream runs through an area with intensive agriculture and was characterized by former channelization and rather hard-handed maintenance. Much of the reach had deepened to more than half a meter below the stream bed stipulated in the Provisional Order governing the stream. Moreover, it was canal-like with little physical variation and little possibility for a varied flora and fauna.

3.21

Roskilde County

Køge stream at Bjæverskov

Anne-Marie Kristensen

Aim of the project

The aim of restoring this reach of Køge stream was to create varied physical conditions in the watercourse so as to fulfil its quality objective as salmonid spawning and nursery waters. The physical measures taken were thus designed to enhance the environmental quality of the watercourse as well as to minimize the need for maintenance of the reach.

Implementation of the project

The restoration work was undertaken in the period 1990–92. The project comprised three types of restoration measures as well as the establishment of spawning grounds and planting of vegetation alongside the stream. Type 1 comprised the laying out of stone heaps as well as individual large stones, and was undertaken in reaches where restoration was not allowed to reduce the drainage capacity. Type 2 comprised laying out stone heaps and gravel riffles, and was undertaken inreaches with a slope exceeding 2‰. Type 3 comprised the laying out of gravel beds and individual large stones, as well as large stone heaps as current concentrators, and was

Laying out stones and spawning gravel in Køge stream.

undertaken in reaches where former maintenance and erosion had made the watercourse too deep or too wide, and where small falls had formed at drain outlets.

With all three types of restoration, spawning grounds were established if conditions were otherwise suitable. At a few reaches, restoration actually reduced the discharge capacity of the watercourse, but in no case did it fall below that stipulated in the Provisional Order governing the watercourse.

Impact studies in connection with the restoration project

At two experimental reaches, the fish population was investigated by electrofishery before and after restoration. At one of the reaches, the number of species increased from 2 to 6, thus indicating real progress. At the other reach, there was no evident corresponding effect, however.

The density of trout in the two reaches is still very low. At the reach with the least slope, trout have not been detected since 1992, while at the other reach, trout density is tending to increase slightly.

Macroinvertebrate samples were also collected at the two reaches before and after restoration. The number of clean-water macroinvertebrates in the stream seems to be on the increase since their number has increased in both experimental reaches.

Project data:

Project organizer:	Roskilde County
Contractor:	Danish Land Development Service
Project commenced:	October 1990
Project completed:	November 1992
Total costs:	DKK 924,830 (excl. VAT)
Financing:	Roskilde County and Danish Environmental Protection Agency

Watercourse data:

Catchment:	130 km^2
Discharge:	
Mean:	350–800 l s^{-1}
Max:	3,300–10,000 l s^{-1}
Min:	0–6 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters) (not fulfilled)
Pollutional class:	II–III (1991–94)

Restoration data:

Coordinates:	55° 28´ N 12° 02´ E
Length:	9,260 → 9,260 m
Width:	2.25–5 → 2.25–5 m
Slope:	0.55–5.7 → 0.55–7‰
Discharge capacity:	~ 6,000 l s^{-1}
Spawning gravel laid out:	400 m^3
Other gravel laid out:	3,000 m^3
Stones laid out:	1,500 m^3
Earth excavated:	90 m^3

Experience gained

Despite the improved physical conditions in the restored reach the fish and macroinvertebrate studies have not revealed any clear improvement in the environmental quality of Køge stream.

A probable explanation is the great variation in discharge in the stream, which is very low in summer, thereby precluding a satisfactory pollutional class. During the summer, waste water discharged to the stream is only diluted very slightly, and the high nutrient content of the stream water and the relatively low water level and slow current promote the occurrence of massive growths of filamentous algae. The result is marked daily fluctuation in the oxygen content of the water.

Another reason for the slow colonization by clean-water macroinvertebrates is probably that there are no reaches immediately upstream of the restored reach that house such species.

3.22

Storstrøm County

River Suså at Holløse Mill, Skelby

Poul Debois

Watercourse system:
River Suså

Introduction to the project

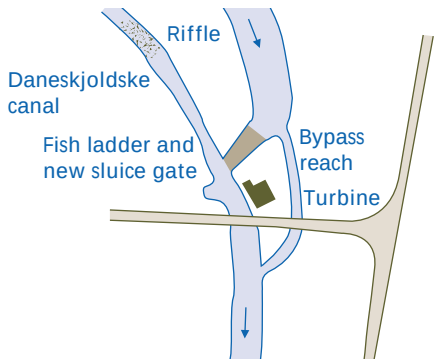
The Suså river system drains an approx. 815 km^2 catchment area and is the largest river system on Zealand. At Holløse Mill, the catchment area is 753 km^2. The river is characterized by marked seasonal variation in discharge. Summer discharge at Holløse Mill can thus be as low as a few hundred litres per second, while the highest discharge measured there was 37,000 l s^{-1}. At Holløse Mill, among structures of historical interest, the river Suså divides into two channels that merge again downstream of the mill. The two channels were each regulated by a sluice gate, thereby also regulating the water level in two lakes further upstream. Flow was further regulated by an additional spillway/sluice gate near the main channel sluice gate, as well as by the intake to a turbine. The main channel sluice gate, which incorporated an eel trap, was fitted with a fish ladder incorporating an eel pass in 1987.

Aim of the project

In 1991, the main channel sluice gate broke down and the other sluices proved to be in a state of disrepair. As the fish ladder is unlikely to ever have been sufficient to ensure adequate passage for fish, this gave rise to the total renovation of the whole area.

The aim of the project was therefore to ensure flow and water level regulation in the river Suså and the lakes Tystrup and Bavelse, to preserve the historical value of the area and to create a functional fish and fauna passage by establishing a riffle.

In 1991, a similar riffle was built at the river Suså's outlet to the sea. The river has probably been effectively closed to the passage of migratory fish since the 13th to 14th centuries. Establishment of the two riffles should therefore open up the whole Suså river system to migratory fish.



Sketch map of the vicinity at Holløse Mill.

Implementation of the project

The project was undertaken in winter 1992–93. The remainder of the main channel sluice gate with the eel trap was removed and replaced by a new, larger sluice gate. The fish ladder was preserved and shall primarily serve as a drop sluice for migratory fish. In connection with the project, approx. 1 km of dykes was renovated along the main channel.

The sluice gate in the secondary channel, "The Daneskjoldske canal", was dismantled and replaced by a riffle. The latter was sited in a manner that best preserved and protected the structures of historical interest. Since a false guide current can form at the main channel sluice gate during periods of high winter discharge, a current concentrator was constructed to guide the fish to the riffle. In addition, a new bridge was built over the canal to replace the road that once led over the dismantled sluice gate.

Impact studies in connection with the restoration project

Electrofishery undertaken at the riffle in autumn 1994 revealed the presence of gudgeon, burbot, spiny-finned loach, eel and roach. Holløse Mill had previously obstructed passage to the whole of the upstream river system. Future electrofishery will reveal the riffle's value as a passage for migratory fish.

The sluice gate at Holløse Mill (upper) and the riffle at Daneskjoldske canal (lower).

Experience gained

The project has always worked as expected, there always being water flow in the riffle with water only flowing over the main channel sluice gate during periods of high discharge.

It is too early to draw conclusions about the possibilities for fish to pass the riffle as sufficient electrofishery has not yet been undertaken upstream of Holløse Mill.

The project was undertaken in successful close cooperation with the local museum, which has had the opportunity to investigate the structures associated with the Daneskjoldske canal.

Project data:

Project organizer:	Storstrøm County
Contractor(s):	Waterconsult (outline) and Danish Land Development Service
Project commenced:	November 1992
Project completed:	March 1993
Total costs:	DKK 2,000,000 (incl. VAT)
Financing:	Storstrøm County, Vestsjælland County and Danish Environmental Protection Agency

Watercourse data:

Catchment:	753 km^2
Discharge:	
Mean:	2,941 l s^{-1}
Max (median):	21,900 l s^{-1}
Min (median):	600 l s^{-1}
Quality objective:	
Upstream:	A (Areas of special scientific interest) / B3 (Ciprinid waters)
Downstream:	A (Areas of special scientific interest) / B2 (Salmonid spawning and nursery waters)
Pollutional class:	II (1993)

Restoration data:

Coordinates:	55° 19´ N 11° 42´ E
Length:	140 → 140 m
Width:	9 → 2–9 m (two-step profile)
Slope:	Fall 14.5‰
Discharge capacity:	5,200 l s^{-1}
Meanders:	4
Stones laid out:	1,000 m^3
Earth excavated:	1,200 m^3

Technical aspects:

Dismantling of two sluice gates and eel traps
Construction of new sluice gate incorporating fish ladder and eel pass
Construction of riffle passable by fish
Construction of bridge
Renovation of 1 km dikes
Establishment of current concentrator

3.23

Storstrøm
County

Lilleå stream at Kongsted

Poul Debois

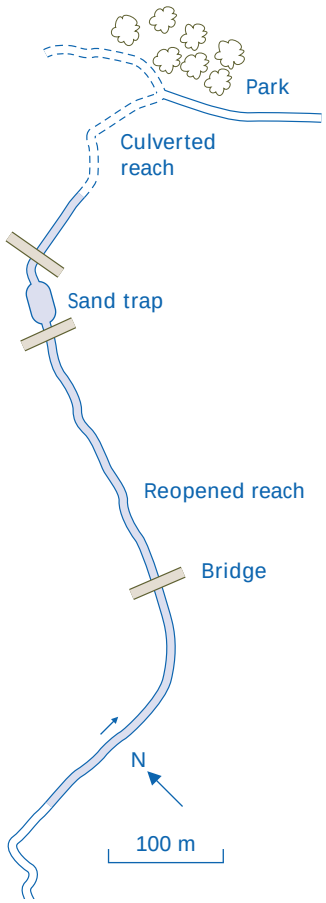
Watercourse system:
Fakse stream

Introduction to the project

Lilleå stream is a tributary of Fakse stream, and is a clean-water watercourse with a good slope and relatively good physical conditions. The designated watercourse quality objective for the stream is salmonid spawning and nursery waters. The quality objective for the upper reaches running through previously intensively cultivated land was not fulfilled because a 700 metre reach of the stream was culverted. In addition, there was a mill-pond and associated dam.

Aim of the project

The aim of the project was to restore an open watercourse with sufficient discharge capacity and good physical conditions sufficient to fulfil the watercourse quality objective, as well as to recreate the stream as a part of the stream valley.



Sketch map of the reopened reach of Lilleå stream.

Implementation of the project

The project was undertaken in winter 1993–94. A 600 metre length of the culvert was removed and re-established as an open watercourse. It was not possible to open the remaining 100 metres of the culvert as a single landowner did not wish to participate. The banks were reinforced with stones and stones were laid out on the stream bed at short intervals in order to create a meandering course that in effect serves as a two-step cross-sectional profile. Three minor track crossings were established and a larger diameter culvert was fitted under an existing track. In addition, a sand trap was established in the downstream part of the reach, and groups of local deciduous trees were planted along the reopened stream.

Attempts were made to render the remaining 100 metre culverted section passable by establishing an inflow manhole upstream of the culvert. The manhole is fitted with a plate at water level height that prevents branches etc. from entering the culvert.

Impact studies in connection with the restoration project

No impact studies have yet been undertaken but the project will be followed up by fauna studies and electrofishery. The studies will show whether the remaining culvert still comprises a hindrance to the passage of fish.

The new stream in summer 1994 (upper) and in winter 1995 (lower).

Experience gained

As restoration projects are generally undertaken on a voluntary basis, it is often difficult to achieve the optimal result. A weakness of the present project is thus that it has not been possible to re-establish the whole of the culvert as an open watercourse. Despite this the project was still undertaken, it being judged that opening the remaining 600 metres would in any case enhance the value of the landscape and environment.

Project data:

Project organizer:	Storstrøm County
Contractor:	Danish Land Development Service
Project commenced:	November 1993
Project completed:	December 1993
Total costs:	DKK 400,000 (excl. VAT)
Financing:	Storstrøm County

Watercourse data:

Catchment:	2.6 km^2
Discharge:	
Mean (summer):	5 l s^{-1}
Mean (winter):	30 l s^{-1}
Max:	79 l s^{-1}
Min:	0.1 l s^{-1}
Quality objective:	B1 (Salmonid spawning and nursery waters)
Pollutional class:	Not assessed because culverted

Restoration data:

Coordinates:	55° 15´ N 12° 03´ E
Length:	700 → 700 m
Width:	1 m (pipe) → 1 m
Slope:	6‰
Stones laid out:	80 m^3
Earth excavated:	3,000 m^3

Technical aspects:

Removal of 600 metre long culvert
Widening a culvert under a track
Crossing electricity cables
Establishing three track crossings

3.24 Søbæk brook at Neksø

Bornholm County

Klavs Nielsen

Watercourse system:
Søbæk brook

Introduction to the project

Søbæk brook arises approx. 6 km southwest of Neksø. The catchment area is a low-lying agricultural area. Nearly the whole of the watercourse is channelized, which is unusual on Bornholm. The slope averages 3.2‰, and is greatest at the source. The lower half of the brook runs through raised seafloor that has previously been meadow and marshland.

Aim of the project

It the 1980s, it was observed that there was a sea trout population in the brook with several spawning grounds. However, the latter were threatened by sand migration, and the possibilities for maintaining the population were therefore limited. The aim of the project was to improve conditions for plants and animals in and around the watercourse by relaying the main channel along an approx. 350 metre reach and establishing a couple of small lakes.

Watercourse data:

Catchment:	13 km²
Quality objective:	B4 (Watercourses with varied flora and fauna but of little value to fish)
Pollutional class:	II (1985)

Restoration data:

Coordinates:	55° 04´ N 15° 08´ E
Length:	334 → 381 m
Width:	1.5 → 2–3 m
Slope:	0.5‰
Meanders:	0 → 5
Stones laid out:	Scattered

Technical aspects:

Two new crossings established

Restoration of Søbæk brook.

Implementation of the project

The local angling association entered into an agreement with a local landowner and thereafter approached the County. The project was carried out in autumn 1991 using state funds for nature restoration projects. In connection with the relaying the main channel a couple of small lakes were established in the area and a short reach of a minor tributary was restored. In addition, a sand trap was established in the new watercourse to prevent sanding up of downstream spawning grounds. The former channelized watercourse was preserved so as not to have to move drains and tributaries.

After an unstable period with sand migration, a riffle was established uppermost in the restored reach. This has subsequently been used as a spawning ground.

Experience gained

The project attracted considerable public attention, and the landowner has been awarded an environmental prize by the Bornholm Angling Association.