



WFD AND HYDROMORPHOLOGICAL PRESSURES

TECHNICAL REPORT



- CASE STUDIES -

Potentially relevant to the improvement of ecological status/ potential by restoration/ mitigation measures

Separate Document of the Technical Report

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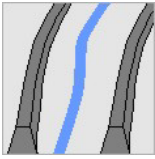


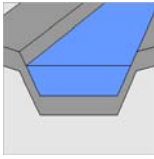
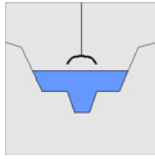
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Key for using the separate document of case studies

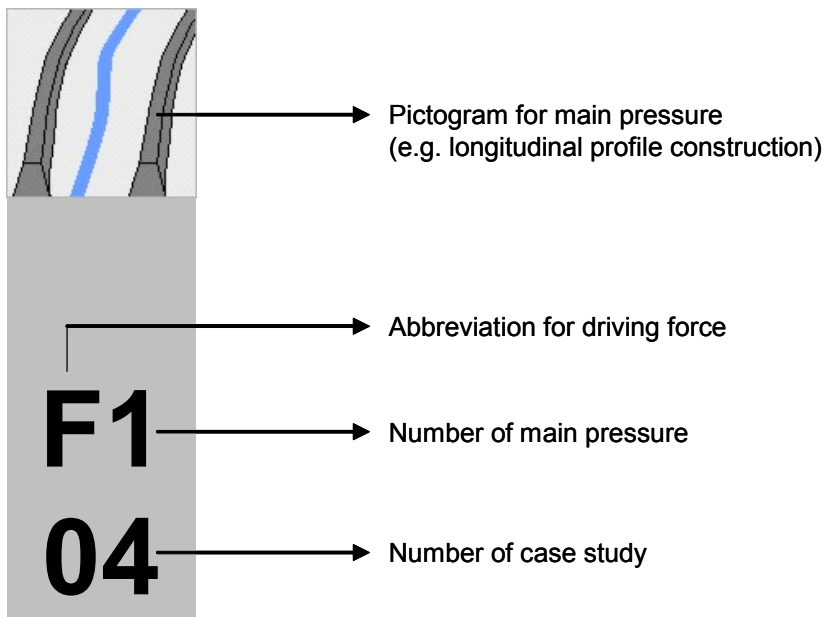
1. Abbreviations for the driving forces

Flood protection	F
Hydropower	H
Navigation	N
other	o

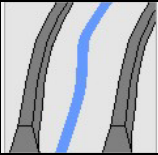
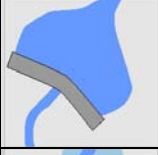

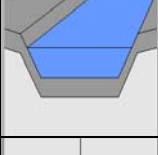
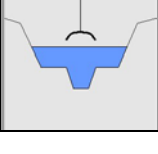
2. Identified main pressures and their pictograms

Main pressure				
Longitudinal profile construction	Cross profile construction	Changed routing	Bank reinforcement	Deepening
				
Dykes	Groynes, weirs, dams	Channelisation, straightening	Bank fixation, riprap	Channel maintenance, dredging, removal of material

3. Key



Tabular summary of the case studies:

				Driving force				
Main pressure			Subtype of pressure	F	H	N	o	Sum
Pictogram	No.	Description						
	1	Longitudinal profile construction	Summer and winter dykes	4				4
	2	Cross profile construction	Groynes, weirs, dams	1	20	2	1	24
	3	Changed routing	Channelisation, straightening	6		5	1	12
	4	Bank reinforcement	Bank fixation, riprap			6		6
	5	Deepening	Channel maintenance, dredging, removal of material			3		3
				11	20	16	2	49

F = Flood Protection
H = Hydropower
N = Navigation
o = other

Case studies with driving force "flood protection":

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
F 1 01	Construction of a bank protection to prevent erosion of salt marshes (Oosterschelde estuary, SW Netherlands)	NL	Changes in hydromorphological conditions (tidal range and silt supply) due to the construction of a storm-surge barrier and dams	Stop erosion of salt marshes by a low dam	high
F 1 02	Restoration of a brackish water reduced tidal area with natural abiotic and biotic processes	NL	Dyke between polder and sea	Installation of exchange between salt and freshwater habitat by culvert	medium
F 1 03	Creation of intertidal habitat as part of a flood risk reduction scheme, Essex, Eastern England	UK	Technical flood defence (bulkhead) – Loss of habitat	Creation of new intertidal habitats	high
F 1 04	Habitat creation at Freiston Shore, the Wash, England	UK	Dyke, constraint on freshwater/saline habitat transition, regional loss of habitat	Creation of breaches in the sea wall in order to open the site to tidal action	high
F 2 01	Manshanden fishway for pumping stations	NL	Dykes – pumping stations for water level management, damage of fish – no biological continuum	Installation of behavioural barrier and fish friendly pumping device (Manshanden fishway)	high
F 3 01	Restoration of the Jeseniscica River	SI	River straightening, bank reinforcement, cross sectional and longitudinal profile alteration	Renaturation of the river	medium
F 3 02	Connection of a sandpit and creation of dynamic oxbow lake along the IJssel, a branch of the Rhine	NL	Winter and summer embankments, bank reinforcement, floodplain aggregation	Creation of a side channel with a permanent connection to the river, breach in summer dike, removal of riprap	high
F 3 03	Creation of side channels along the Rhine	NL	Winter and summer embankments, bank reinforcement	Creation of three side channels, rehabilitation of riparian zone	high

F 3 04	Symbiosis as the basis for a natural system of flood risk management in the Dijle valley, Flanders/Belgium	BE	River channel normalisation	Restore the natural flooding system (removal of drain ditches)	high
F 3 05	Restoration of the River Brent	UK	River straightening, river deepening, concrete channel; ecological deficiency, habitat destruction and no landscape or visual amenity value as a result of construction of an artificial channel, disconnecting the river from its natural floodplain	Removal of artificial concrete banks, restoration of the meandering planform of the river, creation of backwater habitat	high
F 3 06	Restoration of the Bear Brook	UK	Brook straightening, deepening and agricultural siltation. Poor ecological value, habitat destruction and channel disconnected from its natural floodplain.	Restoration of sinuous course, design of shallow bank slopes	high

Case studies with driving force "hydropower":

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
H 2 01	Minimum flow requirements and new small weirs in a 5 km long river section in River Numedalslaagen	NO	Cross profile construction; no environmental flow requirements	Installation of minimum water flow, reconstruction of weirs	high
H 2 02	Mitigation measures in and downstream of Halnefjorden Reservoir in River Numedalslaagen	NO	Cross profile construction; no minimum flow requirements; erosion of the littoral zone	Installation of minimum water flow, Installation of fish pass, erosion protection	high
H 2 03	Dam removal on the Mirna River	SI	Damming; interruption in the river continuum	Removing of obsolete dam and construction of rocky glide	medium
H 2 04	Restoration of migration path on the Sava River, Tacen	SI	Damming; interruption in the river continuum	Reconstruction of dam and construction of rocky glide	high
H 2 05	Removal of barriers for fish migration in Norralaån, Sweden	SE	Damming; interruption of river continuum	Installation and reconstruction of fish passes, removal of dam and plant	high
H 2 06	Fishway as a mitigation measure	FI	Damming; interruption of river continuum and habitat loss	Installation of fishways	medium-low
H 2 07	Replacement construction of a large scale hydropower plant – Rheinfeldern (High Rhine)	DE	Dam; impaired continuity; loss of the specific riverine habitats	Installation of a bypass channel, fish ladders, removal of bank reinforcement, improvement of habitat structures	medium
H2 08	Hydropower plant Albruck-Dogern	DE/ EUR	Dam; insufficient residual water flow; interrupted continuum and fish migration	Installation of dynamic minimum water flow, creation of a fish ladder	high
H2 09	Hydropower plant Gottfrieding	DE/ EUR	Dam; interrupted continuum and fish migration	Creation of a concept study for positioning a fish bypass	medium
H 2 10	KW Steinbach Refurbishment -Optimizing energy generation and ecological measures	AT/ EUR	Cross profile construction; disruption in river continuum	Providing fish migration by establishing a vertical-slot-fish-ladder	high
H 2 11	KW Agonitz Refurbishment - Optimizing energy generation and ecological measures	AT/ EUR	Cross profile construction; disruption in river continuum	Establishing a fish bypass designed as combination of natural-like-rivulet and vertical-slot-fish-ladder.	high

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
H 2 12	Fishway as a mitigation measure	FI	Damming; interruption in the river continuum	Installation of fish ladder	medium-low
H 2 13	Minimum water discharges	FR/ EUR	Dams; deterioration of habitats of trouts	Increasing of minimum discharge downstream of dam from 1/40 of the mean annual discharge of the river to 1/10	medium
H 2 14	Optimizing the minimum flow in the Maronne river for migrating fish species	FR	Dams; impaired flow dynamics; change in habitat diversity and quality; disruption in river continuum and lateral connectivity	Installation of a minimum flow	high
H 2 15	Bypass channels at the short-term regulated River Oulujoki	FI	Damming; hydromorphological changes affecting habitat and species diversity	Consideration of the installation of bypass channels to both- create rapid-like streams and continuity; stream habitat restoration	medium-low
H 2 16	Catch and transport of migrating fishes	FR/ EUR	Multiple obstacles limiting fish migration (loss of ecological continuity at the dams)	Catch and transport (by van) of migrating species	medium
H 2 17	Fish compensation measures in the regulated River Klarälven	SE/ EUR	Damming; hydromorphological changes affecting habitat and species diversity	Fish stocking; restoration and installation of fishways in tributaries	high
H 2 18	Hydroecological diagnosis and hydropower installations management – the case of La Fontaulière	FR	Dam; impaired flow dynamics; disruption in river biological continuum and lateral connectivity	Comparison of artificial regimes, optimization of minimum flow & ratio between hydropeaking and base flow	high
H 2 19	Minimum flow requirements and reconstruction of riverbed after canalization and overgrowing in Børselva river, northern Norway	NO	No environmental flow requirements, hence none or low water discharge downstream of the dam; canalisation and eutrophication; heavy impact on biology at site; reduced floods, less water and high increased amount of nutrients	Minimum continuous flow requirements and restoration measures to optimize the physical and ecological conditions for wildlife and river biota	high

H 2 20	Restoring the Loire. The “Plan Loire Grandeur Nature”	FR/ WWF	Dams, dykes; decrease in migratory fish species	Restoration programme (e.g. removal of dams; building of fish ladders)	high
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Case studies with driving force "navigation":

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
N 2 01	Bed load management in the river Elbe	DE	River training by groynes, dyke construction, impounding; increased sediment transport capacity	Bed load supply	low – high
N 2 02	Modification of groynes at Elbe riverbanks – ecological investigations on the impact of construction on habitats and distribution of species	DE	Cross profile construction (groynes); loss of structural diversity along riverbanks	Modification of groynes	low – high
N 3 01	Establishment of a floodplain-typical island habitat dominated by the dynamics of varying river stages with an adjacent floodway	DE	Changed routing; loss of typical floodplain sites dominated by the dynamics of varying river stages	Enlargement of the flood spillway and connecting it with the River Moselle for water exchange above mean-flow levels	high
N 3 02	Controlling water levels in river-training projects to preserve floodplain habitats. The example of the Öberauer Schleife (cut-off meander)	DE	Changed routing; loss of typical floodplain sites with characteristic water-level variations	Preserving essential elements of the hydrological dynamics in the floodplain by artificial floods and low-water stages	high
N 3 03	Irrigation System in the riparian woodland between Korneuburg and Altenwörth (Danube river)	AT/ EUR	Changed routing; riverbed erosion, decreasing groundwater level	Installation of a bypass channel (irrigation system)	high
N 3 04	Reconnection of oxbow lakes/ wetlands	SK	Straightening of the river channel, bank reinforcement, uniform shape of river channel	Four meanders in three localities were reconnected with the river channel	-
N 3 05	Groundwater management	AT/ EUR	Changed routing; sinking groundwater level	Establishment of a groundwater management	high
N 4 01	Removal of a bank reinforcement on a slip-off slope of the Lower Rhine	DE	Bank reinforcement; loss of structural diversity	Removal of bank reinforcement	high
N 4 02	Interruption of a bank reinforcement on the bank of the limnetic tidal river Elbe	DE	Bank reinforcement; loss of structural diversity	Interruption of bank reinforcement	medium
N 4 03	Removal of a bank revetment in several sections of the limnetic tidal river Elbe	DE	Bank reinforcement; loss of structural diversity	Removal of bank revetment	high

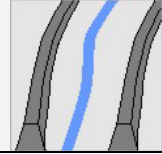
Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
N 4 04	Establishment of a shallow water zone protected against the impact of ship-induced waves	DE	Bank reinforcement; loss of characteristic bank zones	Construction of training wall parallel to the bank with connection to the river flow	high
N 4 05	Establishment of a shallow water zone protected against the impact of ship-induced waves, vegetation-free gravel and pebble areas and succession zones. New harbour Würzburg. River Main	DE	Bank reinforcement; loss of characteristic river and floodplain habitats	Establishment of shallow-water zones with connection to the River Main	high
N 4 06	Improving the structural diversity of river banks by creating a bypass (floodway) in order to promote shallow waters and protect banks against impacts of ship-induced waves	DE	Bank reinforcement; loss of natural river banks; impacts on fish and macrozoobenthos communities	Establishment of an artificial water body (oxbow) in the floodplain with a connection to the River Main	medium
N 5 01	Water column recharge of dredged material to sustain protected intertidal habitats	UK/ NAVI	Dredging; removal of sediment from estuarine system	Restoring and mitigating the effects of dredging on the intertidal mudflats	high
N 5 02	Accountability in maintenance dredging decision making	UK/ NAVI	Maintenance dredging	Development of a transparent decision making framework	high
N 5 03	Morphological management in estuaries conciliating nature preservation and port accessibility	NL/ NAVI	Sediment removal associated with maintenance dredging and capital dredging	Precise placement of dredged material using a diffuser	high

Case studies with other driving forces:

Number	Title of case study	Country	Pressure	Measure	Ecological efficiency
o 2 01	Restoration of sediment flow control dam on the Kokra River	SI	Damming; interruption in river continuum	Construction of a fishway	medium
o 3 01	Doñana wetland	ES/ WWF	Mining, agriculture; water quality and wetland degradation, heavy alteration of river dynamics	Restoration of the ecological and hydromorphological dynamics of the water streams draining into the wetland	high

Pressures & Measures

Longitudinal profile construction



Scope of measures	Measure	Case study
Improvement of retention, creation of dynamical riverine habitats	Breach in summer dykes, creation of bypass channels and oxbow lakes	F3 02, F3 03
	Removal of drain ditches	F3 04
Prevention of erosion and habitat protection	Construction of a low dam of stones	F1 01
Recreation of brackish water areas	Building of a culvert in the dyke, recreation of intertidal habitats, breaches in sea wall	F1 02, F1 03, F1 04

Cross profile construction



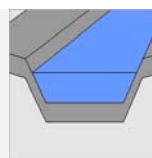
Scope of measures	Measure	Case study
Restoration of continuity	Removal of dams or power plants	H2 05, H2 20
	Reconstruction of weirs (cell type weirs, rocky glide)	H2 01, H2 03, H2 04, H2 05, H2 06
	Installation of fish pass/ fish ladder	H2 02, H2 05, H2 06, H2 07, H2 08, H2 09, H2 10, H2 11, H2 12, H2 20
	Installation of bypass-channels	H2 05, H2 06, H2 07, H2 15
	Trap & Truck, fish stocking	H2 16, H2 17
	Protection of downstream migrating fish (fish friendly pumping device)	F2 01
Creation of fish habitats and shallow water zones	Improvement riparian zone (prevent erosion)	H2 02
	Modification of groynes	N2 02
	Creation of bypass channels as spawning grounds and fish habitats	H2 07, H2 15, H2 20
Improvement of the connection floodplain and river	Bed load supply	N2 01
Improvement of discharge pattern	Minimum continuous flow requirement	H2 01, H2 02, H2 13, H2 14

Changed routing



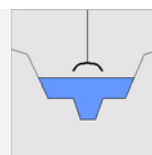
Scope of measures	Measure	Case study
Improvement of the connection floodplain and river	Reconnection and creation of bypass channels and oxbow lakes, creation of softwood forest	F3 02, F3 03, F3 01, N3 01, N3 02, N3 03, N3 04
	Improvement of river sinuosity	F3 05, F3 06
	Enlargement of the flood spillway	N3 01
	Restoring the natural water storage capacity of flood plains (remove culvert)	F3 04
	Installation of groundwater management system	N3 05
Elimination of colmation	N3 03	
Enlargement of shallow water zones	Establishment of flat banks, isle habitats and shallow-water zones	N3 01, N4 06, F3 06

Bank reinforcement

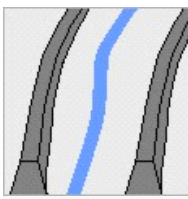


Scope of measures	Measure	Case study
Creation of fish habitats and shallow water zones	Removal of the embankment material	N4 01, N4 02, N4 03, N4 05
	Reduce impact of ship waves on banks - construction of a training wall	N4 04
	Establishment of shallow-water zones	N4 05, N4 01, N4 02, N4 03

Deepening



Scope of measures	Measure	Case study
Mitigation of the effects of dredging	Using water column recharge or placement by diffuser	N5 01, N5 03
	Development of a transparent decision making framework	N5 02



F1/01 - Construction of a bank protection to prevent erosion of salt marshes (Oosterschelde estuary, SW Netherlands)

Driving force:	Flood protection
Pressure:	Changes in hydromorphological conditions (tidal range and silt supply) due to the construction of a storm-surge barrier and dams
Impact:	Erosion of salt marshes
Country:	Netherlands
Location:	Oosterschelde estuary
Water Body at risk:	Yes, provisionally identified as HMWB

**F1
01**

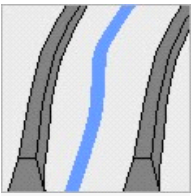
A Status before reconstruction

Status of construction:

- As a consequence of the construction of a storm surge barrier in the mouth of the Oosterschelde and the construction of dams in the eastern and northern landward branches of the estuary, the tidal range in the estuary diminished and silt concentrations have decreased. This resulted in a reduction of the accretion of the salt marshes, while erosion continued. The natural dynamical cycle of accretion and erosion changed into a continuous erosion process.
- Due to the construction of the landward dams 1000 ha of salt marshes were lost (became part of freshwater systems with no connection to the estuary).
- The average loss of salt marsh surface area caused by the net erosion is approximately 3 ha/year on a remaining total surface of 500 ha.



Figure 1: Picture of an eroding salt marsh.



**F1
01**

Ecological deficiency:

- Loss of salt marsh surface area

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Construction of a low dam of stones along the edge of salt marshes

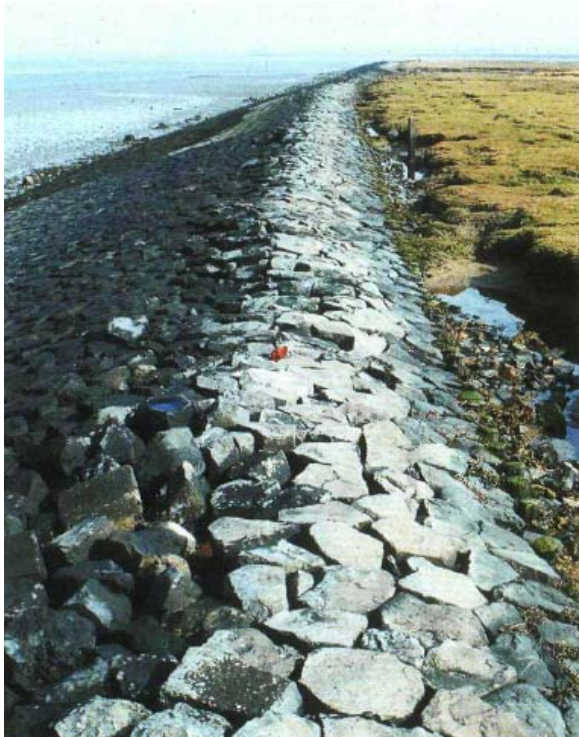


Figure 2: Picture of a marsh protection.

Hydromorphological improvements:

- Reduction of the exposure of the marsh edge to wave attacks

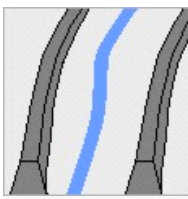
Ecological improvements:

- Preservation of the present area of salt marshes

Assessment of the ecological efficiency:

- The measure protects a valuable habitat from further losses.

High	Medium	Low
X		



Effects on the uses:

- Positive effect on safety, as the marshes (when present) reduce the wave-attack on the dykes that protect the polders below sea level bordering the Oosterschelde.

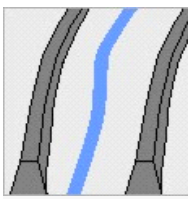
Costs of the measure (€):

500,000 € (per salt marsh – about 4-5 km)

Literature and/or contact:

E. Schuilenberg (e.schuilenberg@dzl.rws.minvenw.nl)

**F1
01**



F1 02

F1/02 - Restoration of a tidal area with natural abiotic and biotic processes in the polder Breebaart (Netherlands)

Driving force:	Flood protection (safety)
Pressure:	Dyke between polder and sea
Impact:	Biological deficiency as a result of loss of structural diversity
Country:	Netherlands
Location:	Polder Breebaart near Ems-Dollart estuary
Water Body at risk:	Yes, provisionally identified as (part of a) HMWB

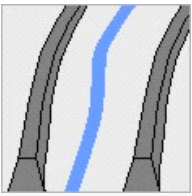
A Status before reconstruction

Status of construction:

- In 1979 the polder was created for safety related to the construction of a canal for shipping and water transport.
- Destination partially agricultural, partly natural habitat



Figure 1: Culvert in the dyke between the Ems-Dollart.



Ecological deficiency

- Abrupt transition between salt and freshwater aquatic habitats

B Reconstruction by restoration / mitigation measures

F1
02

Execution of the measure:

- Digging of the former watercourse (approx. 2 km length) in the polder
- Building of a culvert in the dyke between the polder and the Ems-Dollart
- Introduction (from 4 January 2001 onwards) of partial tidal processes (first with an amplitude of 0.6 m, later 0.3 m; in the estuary the tidal amplitude is 3 m)

The aim was:

- to develop and restore a brackish water area with natural abiotic and biotic processes;
- to create an opportunity for migratory fishes to migrate from the sea into freshwater and vice versa;
- to increase environmental awareness and public support for conservation.

Accompanying measures:

Monitoring:

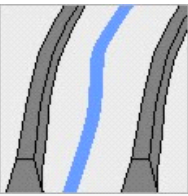
- Morphology (bottom profiles)
- Physical-chemistry (e.g. salinity, nutrients, suspended matter, several chemical substances)
- Biology (vegetation, phytobenthos, macroinvertebrates, fish and fish migration, breeding birds)

Hydromorphological improvements:

- Partial restoration of the former tidal watercourse



Figure 2: Restored tidal watercourse in the former polder Breebaart.



**F1
02**

Ecological improvements:

- Fish migration between salt and freshwater is made possible and occurs according to preliminary monitoring results.

Assessment of the ecological efficiency:

High	Medium	Low
	X	

Effects on the uses:

- Effects on agriculture: poorly
- Effects on safety: none

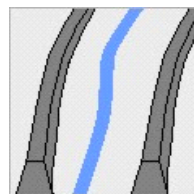
Costs of the measure (€):

1.8 million €

Literature and/or contact:

Stichting Het Groninger Landschap, Haren, the Netherlands
(B. Speelman, Tel. +31 50 313 59 01)

RIKZ, Haren, the Netherlands (Peter Tydeman, Tel. +31 50 533 13 78)



F1/03 - Creation of intertidal habitat as part of a flood risk reduction scheme, Essex, Eastern England

Driving force:	Flood protection
Pressure:	Technical flood defence (bulkhead)
Impact:	Loss of habitat
Country:	England, UK
Location:	Tidal river Crouch in Essex, Eastern England
Water Body at risk:	Yes, provisionally identified as HMWB

**F1
03**

A Status before reconstruction

Status of construction:

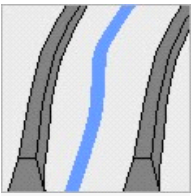
- In the village of Hullbridge there were approximately 40 properties, a residential caravan park, and two sailing clubs which required improved flood defences. The area adjoins a site which has SSSI, cSAC, SPA and Ramsar environmental designations.
- The improvements to the tidal defences involved widening the whole of the embankment to give a minimum of 3 metre wide crest and an increase in level by approximately half a metre to provide a 1 in 50-year standard of protection.
- The flood defence works led to some loss of intertidal habitat, and would lead to future losses by failing to allow migration of habitats landwards as sea levels rise. Mitigation for the effect of these works was required.



Figure 1: Defences which required improvement (left) and new defences at end of works (right).

Ecological deficiency:

- Loss of intertidal mud and salt marsh surface area



**F1
03**

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- An area of land close to the site was identified as suitable replacement habitat. It consisted of rough grassland and low-lying arable land.
- The landowner agreed to sell his land and by constructing two additional closure banks, there was no risk of flooding to any adjacent land. This area was surveyed and modelled to confirm that approximately 7 ha of intertidal habitat would form when the existing low-level defences were breached to allow tidal inundation.

Accompanying measures:

- Some morphological and ecological monitoring of the site and aerial photography to chart development of habitat establishment.

Hydromorphological improvements:

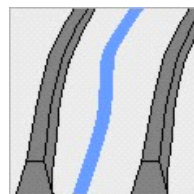
- The extent of physical habitat has been maintained and the local floodplain reinstated. Transition from freshwater to saline habitats has been provided.

Ecological improvements:

- Creation of new intertidal habitats and ensuring no longer term deterioration in the extent of existing saltmarsh. The retreat area now has a fuller range of saltmarsh communities.
- Provision of breeding area for fish species.



Figure 2: New area of intertidal habitat



**F1
03**

Assessment of the ecological efficiency:

- Where appropriately designed, the measure can effectively create valuable habitat.

High	Medium	Low
X		

Effects on the uses:

- Positive effect on flood risk management, as it delivers improvement for people which is legally compliant.
- No effect on navigation
- No detrimental effect on agriculture as the landowner sold the land.

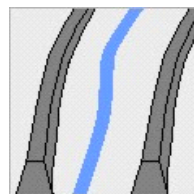
Costs of the measure (€):

Approximately €1.5 million, including the cost of flood defence works

Literature and/or contact:

Paul Miller, Environment Agency

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F1/04 - Habitat creation at Freiston Shore, the Wash, England

Driving force:	Flood protection
Pressure:	Flood defences
Impact:	Constraint on freshwater/saline habitat transition. Regional loss of habitat.
Country:	England, UK
Location:	The Wash, Eastern England
Water Body at risk:	Yes, provisionally identified as HMWB

**F1
04**

A Status before reconstruction

Status of construction:

- This is an unusual scheme for flood management and the environmental benefits gained were not strictly part of mitigation activity. However, the techniques demonstrated here are transferable to other situations requiring mitigation, and the results are significant.
- Before work started the flood banks were in varying states of repair and offered different levels of protection. In addition, they were not all owned and maintained by the Environment Agency. The implementation of the Flood Risk strategy included raising and strengthening secondary flood defences and removing sea banks to flood an area previously reclaimed from the sea. This was to provide a 1:200 year level of defence to over 80,000 ha of low lying fen land, many villages and the town of Boston. The technique of managed realignment is used here as it is the best engineering option to reduce flood risk; it has the side effect of increasing biodiversity which was not a requirement for this water body at the time. In many other areas this technique may help ensure no deterioration and to increase ecological status.

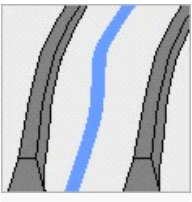
Ecological deficiency:

- Saltmarsh in front of the defences which were breached were in poor condition but across the water body as a whole were in good condition.

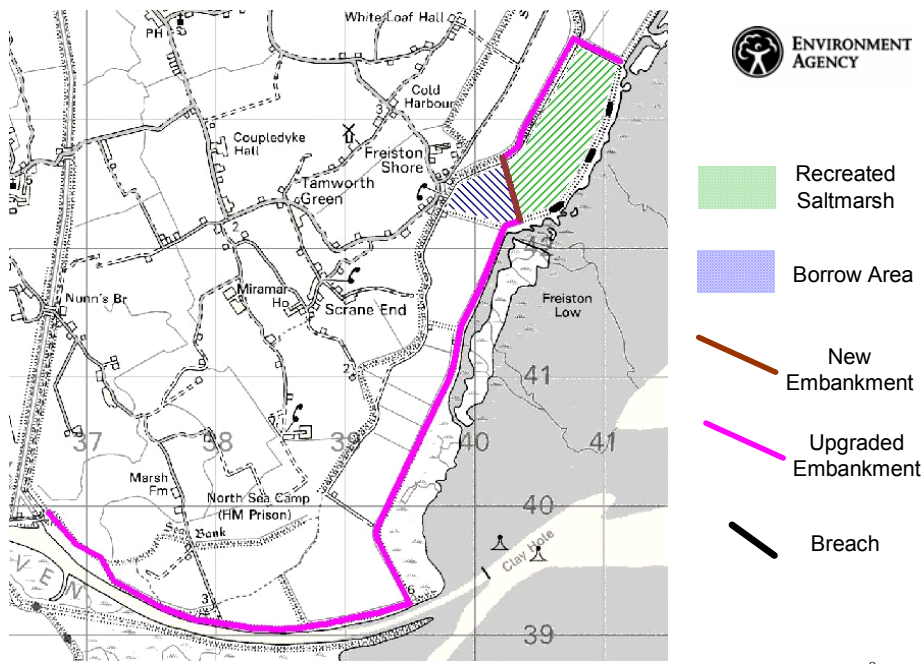
B Reconstruction by restoration / mitigation measures

Execution of the measure:

- After extensive monitoring and modelling of the site, 1.1 km of existing secondary defences at the rear of the realignment site were raised and strengthened, and a 500 m new defence built. Field drains were filled, the vegetation was removed and the field was ploughed and levelled, and primary creeks were created using an excavator. Three breaches were made in the sea wall, each 50 m wide, in order to open the site to tidal action. Material for the new defence was sourced from the next field and a lagoon was created as part of that process.



F1
04



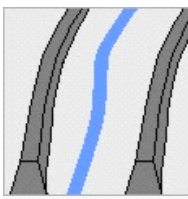
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Figure 1: Plan of works.

- During construction, there were typical mitigation measures additionally placed on the work being undertaken. These included:
 - No construction work to be carried out one hour either side of high tides greater than 3.6 m (ODN) (measured at Tab's Head) in order to reduce disturbance to roosting birds.
 - A walkover survey to be carried out no more than one month before construction to ensure no nest sites are in the area. If there are, mitigating action may be required.
 - If bank raising extends into period between September and May then the working area should be split into two zones, with only one zone being worked at any one time in order to reduce disturbance to roosting and feeding waterfowl.
 - Works traffic over saltmarsh areas to seaward of the outer wall should be reduced to a minimum and only be carried out along a working corridor agreed with EN.
 - Plant used to deepen channels on the seaward side of the bank should be restricted to the route of the channel to avoid damage to saltmarsh.
 - The realignment site was purchased by the Royal Society for the Protection of Birds (RSPB) and opened as a reserve.

Accompanying measures:

- Monitoring of the realignment site includes:
 - Topography
 - Sedimentation rates
 - Fish
 - Invertebrate
 - Benthos
 - Vegetation
 - Wave and tides



Hydromorphological improvements:

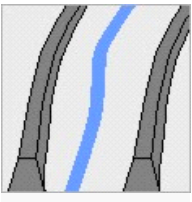
- The site has reverted to an intertidal area which is more natural and more sustainable. The transition zone has been widened and the quality of habitat has improved as the site accretes to a more natural land level. After a period of quick initial changes on the outer mudflats, tidal creeks and elevation is now more stable.



**F1
04**

Figure 2: The completed realignment site.

- After extensive monitoring and modelling of the site, 1.1 km of existing secondary defences at the rear of the realignment site were raised and strengthened, and a 500 m new defence built. Field drains were filled, the vegetation was removed and the field was ploughed and levelled, and primary creeks were created using an excavator. Three breaches were made in the sea wall, each 50 m wide, in order to open the site to tidal action. Material for the new defence was sourced from the next field and a lagoon was created as part of that process.



F1 04

Ecological improvements:

- Data shows that the site has vegetated with saltmarsh species very quickly - 13 months after the site was breached over 65% of the site was covered with saltmarsh plants.
- Accretion ranged from 1.5 to 90 mm and the site is supporting a range of invertebrates and 8 species of fish.
- It is providing a feeding ground for many wild birds.

Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

- This site is a functioning flood defence scheme. As it has now been turned into a nature reserve it has brought additional benefits. The investment in flood defence funding was matched by European 5B funding, which has paid for access and other improvements. The reserve and other nearby wildlife areas attracted 57,000 visitors in 2002/03. The presence of the reserve is estimated to have attracted around £150,000 into the local economy during 2003. This is estimated to support over four full-time equivalent jobs in local businesses.
- The changes in elevation on the adjacent mudflats have caused unexpected damage to a local oyster farm and compensation payments have been made.

Costs of the measure (€):

The capital works for realignment were £1.98 million. The agricultural land was purchased by the charity the RSPB, for £150,000. Ongoing management costs are partfunded through a 20-year agreement under a central government Habitats Scheme which generates an annual income of £34,500.

Contact for further information:

Andrew Usborne, Environment Agency.

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RSPB: www.rspb.org.uk



F2/01 - Manshanden fishway for pumping stations

Driving force:	Flood protection (water level management)
Pressure:	Dykes (water level management)
Impact:	Biological deficiency as a result of migration barriers
Country:	Netherlands
Location:	Outlet river Oude Aa
Water Body at risk:	Yes, provisionally identified as HMWB

F2
01

A Status before reconstruction

Status of construction:

- In the Netherlands more than 3000 pumping-stations contribute to the management of the water level.
- The noise of the pumps in the station makes fishes wary of passage, however when no alternative streams are present the fish will ultimately try to pass through the pumps. The passage through conventional pumping stations is dangerous for fish since the propeller- and centrifugal pumps that are often used for drainage rotate at high speed.

Ecological deficiency:

- For fishes, pumping stations represent migration barriers that disturb the natural connection between adjacent water bodies. Once fishes find themselves in a polder, they are unable to migrate downstream without the passage of at least one pumping station. The risk that fish passage through these pumps results in severe or lethal damage is high (cf. Figure 1).

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- The Manshanden fishway for pumping stations utilises the natural wariness of fishes to guide them. Fishes that approach the pumping station from the polder are discouraged from swimming into the inlet pipe of the station by strong stroboscopic lights from which fishes have an aversion.
- Dark and quiet inlet channels that are connected to a Venturi pump (cf. Figure 2) are provided as alternative routes. The Venturi pump constitutes the core of the Manshanden fishway and is placed at a pumping station in addition to conventional pumps. It creates a water flow that is forced through a narrow aperture into a discharge pipe where a vacuum develops as a result. The vacuum induces a water flow in the two side channels that are connected to the discharge pipe directly behind the narrow aperture. The water flow attracts fishes from the polder and moves them past the lethal pumps to the



downstream waters. The presence of the bypasses thus provides an obstacle-free connection between upstream and downstream waters.

**F2
01**



Figure 1: Damaged eel that migrated through a conventional pumping station with a propeller pump.

Accompanying measures:

- *Monitoring:* The first Manshanden fishway was installed on the Meerweg pumping station in the River Oude Aa, part of the conservancy area of the Hunze and Aa's Waterboard, in 2005 (cf. Figure 3). Total number of fish that passed through the pumping station in October 2005 and percentages mortality:

Total number of fishes passed	8354
Number of species	10 (eel, roach, bream, ruffe, pike, pikeperch, rudd, perch, river lamprey, gudgeon)
Length range	5-78 cm
Mortality with Venturi pump and stroboscopic lights turned on	0%
Mortality with Venturi pump turned on and stroboscopic lights turned off	18-23%
Mortality with Venturi pump and stroboscopic lights turned off	100% of the fish > 10 cm

Hydromorphological improvements:

- Not applicable

Ecological improvements:

- Restoration of fish connectivity

Assessment of the ecological efficiency:

High	Medium	Low
X		



Effects on the uses:

- There is only minor loss of pump efficiency.

Costs of the measure (€):

200,000 € (exclusive of constructional facilities)

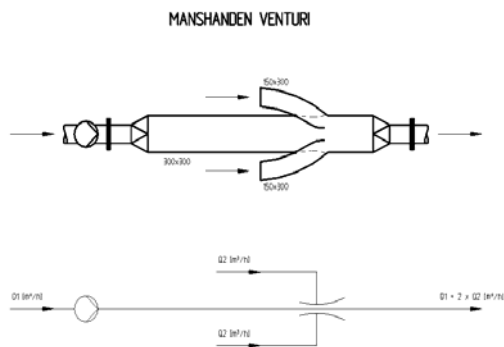


Figure 2: The Venturi principe.



Figure 3: The Venturi at Waterboard Hunze & Aa's.

Literature and/or contact:

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**F3
01**

F3/01 - Restoration of the Jeseniscica River

Driving force:	Flood protection (by land reclamation – drainage works)
Pressure:	River straightening, bank reinforcement, cross sectional and longitudinal profile alteration
Impact:	Ecological deficiency and habitat destruction as a result of decreased hydromorphological structural diversity
Country:	Slovenia
Location:	Jeseniscica River
Water Body at risk:	No

A Status before reconstruction

Status of construction:

- Straightened river course in length of 1.5 km
- Reinforced banks
- Alterations of cross section and longitudinal profile
- Lowered river bottom level
- Partially reinforced river bottom
- Unified current, width, depth and B / H ratio
- Removed aquatic and riparian vegetation, fallen trees and debris from the river

Ecological deficiency:

- Loss of river sinuosity
- Loss of current, river width and river depth variability
- Loss of micro and mezzo hydromorphological structures (pools, rapids, riffles, sand bars, dunes etc.)
- Loss of river corridor internal ecological structure (patches, corridors, mosaics, matrix)
- Loss of canopy
- Loss of habitat



F3
01



Figure 1: Jeseniscica River at Novo mesto, river course straightening in late 80', situation in 1990.



Figure 2: Jeseniscica River at Novo mesto, river course straightening in late 80', situation in 1990.



F3
01

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Installation of deflectors to initiate the process of bank erosion and consequently creation of river bends in the length of 1.5 km
- Alteration of the cross sectional steps from concrete to wooden structures, designed to initiate downstream pools
- Creation of temporary fish hideouts in river banks
- Planting of riparian vegetation



Figure 3: Jeseniscica River at Novo mesto, situation in 2006.



Figure 4: Jeseniscica River at Novo mesto, situation in 2006.

Accompanying measures:

- Intensive monitoring and maintenance of the restored river reach for the period of 5 years after restoration works were completed
- Seasonal periodical monitoring and maintenance afterwards

Hydromorphological improvements:

- Initiation of river bank erosion, followed with the increase of sinuosity ratio, increased current, river width and river depth variability. Re-creation of micro and mezzo hydromorphological structures (pools, rapids, riffles, sand bars, dunes etc.)

Ecological improvements:

- Development of internal river corridor ecological structure (patches, corridors, mosaics, matrix), determined with the hydromorphological process, as well as ecological functioning, especially in terms of restored fish habitat structures

Assessment of the ecological efficiency:

- Measures taken initiated semi-natural hydromorphological process in the river corridor, development of riparian vegetation canopy, fallen trees and debris appearance and consequently re-creation of stabile aquatic habitat

High	Medium	Low
	X	



F3
01

Effects on the uses:

- Restoration works were designed in manner not to have any impacts on the existing drainage works. Consequently, no impacts on use were recorded after restoration of the river.

Costs of the measure (€):

Costs of restoration works are estimated on today's prices of labour and material on 20,000 €. Costs of monitoring and maintenance are not included.

Literature and/or contact:

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**F3
02**

F3/02 - Connection of a sandpit and creation of dynamic oxbow lake along the IJssel, a branch of the Rhine

Driving force:	Flood protection (navigation, sand extraction)
Pressure:	Winter and summer embankments, bank reinforcement, floodplain aggregation
Impact:	Biological deficiency as a result of loss of shallow river bed and floodplain marshland
Country:	Netherlands
Location:	IJssel km 962-965, floodplain Duursche waarden
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- The main channel was bordered by elevated floodplains. Winter- and summer embankments caused inundation with a low frequency. Oxbow lakes filled up with sediment and became isolated from the main river channel. Floodplains were used by agriculture and a source for mineral extraction such as sand and clay.
- A deep river channel fixed by groynes

Ecological deficiency:

- Loss of the specific riverine habitats, especially marshland and dynamic water bodies
- Abrupt transition between aquatic and terrestrial habitats; loss of the hydromorphological continuity between main channel and side waters (floodplain channels)

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Connecting the existing water bodies in the floodplain to a new long channel with a permanent connection to the river on the downstream part
- Creation of an isolated water body
- A breach in the summer dyke in order to obtain a variety of inundation frequencies
- Removal of rip rap on the riverbank

Accompanying measures:

- Decreasing grazing intensity
- Monitoring:
 - Ecotope mapping of the current state of the floodplain
 - Physical-chemical survey of water and sediments
 - Biological survey
 - Recreation aspects



Figure 1: The Duursche Waarden, a rehabilitated floodplain near the river IJssel, attracts more than 10,000 visitors a year.

Hydromorphological improvements:

- The idea behind the nature development project Duursche waarden was the maintenance, rehabilitation and development of a natural floodplain. The inundation frequencies and, consequently, the diversity of riverine habitats increased. Reclamation of the old sandpit by natural sedimentation will take a long period. The connection of the small water bodies to one channel resulted in habitat variation.

Ecological improvements:

- After 10 years of development different ecological elements increased (+), while other decreased (-).

Vegetation	Riverbank plants	+
	Red list species	+
	Water plants	- -
	Vegetation structure	++
	Willow growth	+



Summer birds	Number of species	+
	Number of territories	++
	Rough herbage birds	++
	Marsh birds	+
	Wood birds	+
	Meadow birds	--
Fish	Stagnant water species	+
	Rheophilic water	+
Invertebrates	Branched channel	+
	Isolated channel	--
	Butterflies	+
	Dragonflies	++

Assessment of the ecological efficiency:

- The measure created dynamical riverine habitats typical for the river Rhine and the species associated with those habitats. The wideness of the floodplain is only several hundreds of meters compared to several kilometres in a natural state.

High	Medium	Low
X		

Effects on the uses:

- Each year more than 10,000 visitors coming to the floodplain. Schools, nature groups and clubs regularly explore the footpaths with a ranger.
- There is no sedimentation in the main channel or destabilization of the riverbank.
- The loss of agricultural area is significant for the floodplain, but insignificant compared with the total catchment and national agricultural area.

Costs of the measure (€):

Not available

Literature and/or contact:

Frank Kok – RWS Directie Oost-Nederland, P.O. Box 9070, 6800 ED Arnhem, the Netherlands. f.r.kok@don.rws.minvenw.nl.

Anonymous, 1999: The Duursche Waarden: 10 year of nature development. Brochure Staatsbosbeheer and Rijkwaterstaat, Arnhem.

Cals, M.J.R., Postma R, Buijse A.D., Marteiijn E.C.L. 1998, Habitat restoration along the River Rhine in the Netherlands; putting ideas into practice. Aquatic Conservation: Marine and Freshwater Ecosystems 8:61-70.

Coops H., Demon J.M.H., Gerritse. W, bij de Vaate A, Cals M.J.R, 1994: Evaluatie van de Duursche Waarden 1989 –1993. Publications and reports of the project Ecological Rehabilitation of the rivers Rhine and Meuse, no 60-1994. Lelystad.



F3/03 - Creation of side channels along the Rhine

F3
03

Driving force:	Flood protection (navigation)
Pressure:	Winter and summer embankments, bank reinforcement
Impact:	Biological deficiency as a result of loss of shallow river bed
Country:	Netherlands
Location:	Rhine-km 936-939, floodplain Gamerensche waard
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- The main channel was bordered by elevated floodplains. Winter- and summer embankments caused inundation with a low frequency and high amplitude. Floodplains were used by agriculture.
- A deep river channel fixed by groynes

Ecological deficiency:

- Loss of the specific riverine habitats, especially shallow riverbeds
- Abrupt transition between aquatic and terrestrial habitats; loss of the hydromorphological continuity between main channel and side waters (floodplain channels)

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Creation of three side channels in 1996-1999. A permanent channel of 2 km, a 1 km channel flowing approx. 265 day/year and a channel flowing approx. 100 days/year (Figure 1)
- 200 m rehabilitation of riparian zones by planting willows, transforming sandy beaches to softwood forest

Accompanying measures:

- Decreasing grazing intensity
- Monitoring
 - Ecotope mapping of the current state of the floodplain
 - Morphological activity in the main channel (sedimentation), floodplain channels (especially erosion in the direction of winter embankments)
 - Physical-chemical survey of water and sediments
 - Biological survey



**F3
03**

Hydromorphological improvements:

- Room for riverine processes resulted in a diversity in flow conditions and inundations frequencies, erosion and sedimentation. This created specific habitats, such as dynamic shallow water, sandy banks and soft wood forest, and a more natural gradient between water and land.



Figure 1: River Rhine at Gameren after hydromorphological improvement (photo Jaap de Vlas, July 2001).

- On the right the main channel with groynes and rehabilitated riparian zones.
- On the left winter embankments.
- In the middle the floodplain (128 ha) with three channels: on the left a permanent channel of 2 km, at the top a 1 km channel flowing approx. 265 days/year and below a partly silted up channel flowing approx. 100 days/year.

Ecological improvements:

- Riverine habitats were recreated. Rheophile fish and macro-invertebrate species profit from the shallow water habitat. The macroinvertebrates are less affected by invading species compared to the main channel. The floristic value improved by the change in management of the floodplain. Wintering birds (ducks, goose) partly replaced by typical riverine species.

Assessment of the ecological efficiency:

- The measure created dynamical riverine habitats typical for the river Rhine and the species associated with those habitats. The wideness of the floodplain is only several hundreds of meters compared to several kilometres in a natural state.

High	Medium	Low
X		



F3
03

Effects on the uses:

- There is only minor sedimentation in the main channel at the entrance of the largest floodplain channel.
- Due to erosion towards the winter embankment, several reinforcements have been made in the floodplain channel.
- The loss of agricultural area is significant for the floodplain, but insignificant compared with the total catchment and national agricultural area.

Costs of the measure (€):

Not available

Literature and/or contact:

Frank Kok – RWS Directie Oost-Nederland, P.O. Box 9070, 6800 ED Arnhem, the Netherlands. f.r.kok@don.rws.minvenw.nl

Molen, D.T. van der & A.D. Buijse, 2005. Assessment of the progress of the ecological rehabilitation of floodplains along the lower River Rhine (the Netherlands). Proceedings Lowland River Rehabilitation, Wageningen 2003, p. 443-464. In: Buijse, A.D., F. Klijn, R.S.E.W. Leuven, H. Middelkoop, F. Schiemer, J.H. Thorp & H.P. Wolfert [eds.] (2005) Rehabilitating large regulated rivers. Archiv fuer Hydrobiologie Supplement 155 (Large Rivers 15). E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart. 738 pp.

Simons, H.E.J., C. Bakker, M.H.I. Schropp, L.H. Jans, F.R. Kok & R.E. Grift, 2001. Man-made secondary channels along the River Rhine (the Netherlands): results of post-project monitoring. Regulated Rivers: Research & Management 17: 473-491.



F3/04 - Symbiosis as the basis for a natural system of flood risk management in the Dijle valley, Flanders / Belgium

Driving force:	Flood protection
Pressure:	River channel normalisation (decreasing channel roughness, floodplain drainage).
Impact:	Ecological deficiency
Country	Belgium
Location	Dijle river: from the border between the Walloon and the Flemish region up to the city of Leuven – 17 kilometres
Water Body at risk	Yes, partly identified as HMWB, most upstream part not HMWB

A Status before reconstruction

Status of construction:

- The capacity for a safe discharge of the river Dijle through Leuven, a historical city, is 25 m³ water per second.
- At peak flows the Dijle brings up to more than 30 m³ water per second to Leuven.
- As a result the city has been flooded regularly in the past.

Ecological deficiency:

- A network of drainage channels lowered the groundwater table of the floodplain for more than 500 years.
- River bank maintenance (mowing, systematic removal of shrubs, trees and of sediment deposits)
- The result was an alluvial ecosystem that no longer flooded, combined with an immobilised river (no significant erosion or sedimentation processes) and with a smoothed river channel.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

The original plan for tackling the flood problem was the traditional construction of a retention basin. Due to the predominant ecological deficiency, and an important potential for ecological restoration still present, this concept was abandoned. A nature oriented flood risk management concept was adopted for the first time in Flanders/Belgium in 1995.

- *Phase 1 (finished in 2004):* restoration of the natural water storage capacity of the Dijle valley upstream of Leuven by removing a culvert and the installation of a new connection of the river with its flood plains

- Upstream of Leuven the Dijle seeks its way through a one kilometre wide valley and an important nature reserve 'Doode Bemde'. Although the valley lost its function as a natural floodplain during the last centuries, its potential ecological values were still there, the river Dijle not being channelled as is the case for most of the rivers in Flanders. A few minor infrastructure works were necessary to restore the natural flooding system like removing a culvert of one of the major drain ditches. Instead of its original purpose meant draining, it became a new connection of the river with its flood plains. As a result the water storage capacity of the valley (backland) is used more intensely. At the same time the nature reserve 'Doode Bemde' gets wetter and natural inundations are stimulated. About 0.5 km², which is flooded more frequently, is now managed by a local nature conservation organisation
- The valley of this part of the Dijle is used as a natural flooding area and is able to store up to 1.2 million m³ if necessary. The uncontrolled flooding respects environment and nature constraints in the entire valley. This measure of flood risk management making use of natural processes costs far less than the formerly planned infrastructure works and results in flood risk protection of the city of Leuven at high peak flows.
- *Phase 2 (finished in 2006):* controlled retention basin Egenhoven
 - At the downstream end of the project, before entering Leuven, a more technical solution was necessary to increase the ultimate safety of Leuven against flooding. The total capacity for retention is now 2 million m³ and this results in a protection against floods with a frequency of once every 100 years.
 - This more technical solution consists of the building of a retention basin in Egenhoven. The existing dyke of an old railway track was given a new function as the dyke for the retention area. In the dyke a sluice was built. This sluice controls the amount of water flowing towards Leuven.

Accompanying measures:

- The building of a sand and sediment trap in phase 2 – downstream the sluice. As a result the costly dredging in the city centre of Leuven is reduced significantly.
- In the upstream part no more dredging or mowing of the riverbed and no reinforcement of riverbanks
- A real time forecast and warning system for the Dijle catchment area (phase 3) will be operational in 2007.

Hydromorphological improvements:

- Because of the increased river channel roughness, the hydromorphological processes of the river are strikingly present once more, resulting in meander-evolution (movements of up to 0.8 m/year), a more diverse river habitat facilitating the colonisation and population development of aquatic plant and animal species.



Ecological improvements:

- Due to the choice for the nature oriented flood risk management, an alluvial river-ecosystem was restored here. This resulted in the restoration (increase in surface) of groundwater dependent vegetation type such as Alder Carr (*Carici elongatae-Alnetum*), Tall Sedge Swamp (*Magnocaricion*), Fen Meadow (*Calthion palustris*) and Tall herb fen (*Filipendulion*). Due to the regular flooding, a number of flood dependent plant as well as animal species re-emerged or increased in numbers (Spotted cracke, Snipe, *Vertigo moullinsiana* (snailsp.)

Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

- Positive effects on the nature reserve. Improvement of the landscape and of the ecological and recreational value of the nature reserve.
- Management cost s of the nature reserve have increased due to the wetter conditions of the land.

Costs of the measure (€):

Phase 1: 484.000 euro
Phase 2 (and 3): 5.476.000 euro

Literature and/or contact:

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**F3
05**

F3/05 - Restoration of the River Brent

Driving force:	Flood protection
Pressure:	River straightening, river deepening, concrete channel
Impact:	Ecological deficiency, habitat destruction and no landscape or visual amenity value as a result of construction of an artificial channel, disconnecting the river from its natural floodplain
Country:	England
Location:	Tokington Park, Wembley - London
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- 2 km of straightened river course
- Artificial concrete channel
- Alterations to cross section and longitudinal profiles
- Lowered bed level
- Removed aquatic and riparian vegetation
- Poor water quality

Ecological deficiency:

- Loss of river sinuosity
- Loss of current, river width and river depth variability
- Loss of micro and mezzo hydromorphological structures
- Loss of river corridor internal ecological structure
- Loss of habitat

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Artificial concrete banks were removed.
- A two stage channel was designed to accommodate a range of flows.
- The meandering planform of the river was restored. However due to the close proximity of residential areas the degree of channel adjustment had to be constrained through the channel design. Two types of revetment were used; type A on the apex of the meanders was designed to withstand higher flow velocities; and type B formed a transition between type A and the natural bank.
- Further revetment was required where the old concrete channel joined the new channel in order to reduce erosion where the water flows from a hard surface to the natural bank.
- Creation of backwater habitat
- Landscaping and planting of riparian vegetation, one major landscape feature that was created was a bund, used to reduce the visual and noise impacts from the North Circular.

- Construction of a 75 m gabion wall to stabilise a section of the bank.
- Installation of a bridge to improve public access.



Figure 1: Status during construction.

Accompanying measures:

- Groundwork West London worked with local children to produce a river-themed mural to cover graffiti and a pebble mosaic, and have installed a new children’s play area.
- Local artists have designed two features to be placed at the park’s main entrances, again working with local school children to work up ideas.
- The Lea Rivers Trust Water Safety Officer has been giving water safety training to local youngsters and volunteers have been gluing labels onto surface water drains to warn of the dangers of pollution.
- Wembley Stadium has kindly loaned the base of the flagpole from the old stadium as an artwork feature for the park.
- A public consultation has been carried out by local school groups.
- The channel is being continually monitored through a geomorphological survey, River Habitat Survey and instream invertebrate survey

Hydromorphological improvements:

- Increased sinuosity ratio, increased current and increased variation in river width and river depth leading to re-creation of hydromorphological structures.

Ecological improvements:

- Improved quality and diversity of freshwater and terrestrial fauna and flora of the river, its corridor and surrounding open spaces.



**F3
05**



Figure 2: Site post construction.

Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

- The restoration works have improved the landscape, visual amenity and ease of access of the area which have resulted in increased use of the park for both formal and informal recreation.
- The flood service level of the area was not affected by the restoration works that were carried out.

Costs of the measure (€):

Costs of restoration were €1.75 million (£1.2 million). Costs of monitoring and maintenance are not included.

Literature and/or contact:

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**F3
06**

F3/06 - Restoration of the Bear Brook

Driving force:	Flood protection
Pressure:	Brook straightening, deepening and agricultural siltation.
Impact:	Poor ecological value, habitat destruction and little landscape or visual amenity value as a result of siltation and previous management, channel disconnected from its natural floodplain
Country:	England
Location:	Aylesbury, Berkshire
Water Body at risk:	Probably not at risk

A Status before reconstruction

Status of construction:

Status of channel:

- 1km of straightened river course
- Re-aligned clay bed channel
- Disconnection from floodplain
- Lowered bed level
- Removed aquatic and riparian vegetation
- Agricultural silt deposition (enrichment)
- Reduced landscape value for local community



Figure 1: Area view of the brook and flood storage/overspill area.

Ecological deficiencies:

- Loss of river sinuosity
- Loss of current, river width and river depth variability
- Loss of micro and mezzo hydromorphological structures
- Loss of river corridor internal ecological structure
- Loss of habitat

B Reconstruction by restoration / mitigation measures

Execution of the measures:

- Sinuous course restored along the approximate line of the old channel.
- New channel cut at a higher level than the old bed to increase connectivity with 'new' floodplain.
- Flood storage area dug adjacent to the course to mimic a natural floodplain, allowing overspill and storage at times of high flow.
- In stream and bankside diversity increased by designing more varied cross sectional profiles, variety of channel widths and depths, variation in channel gradient and flow velocity.
- Shallow bank slopes designed to encourage colonisation by a range of macrophytes from aquatic to marginal to bankside, maximising the wetted margins.

Accompanying measures:

- Linear footpath built to encourage community use and appreciation of the site.
- Information boards installed to promote the reasons for this 'novel' approach to flood storage.
- Inclusion of county importance wet grassland into the storage area to increase frequency of inundation.
- Planting of native trees and shrubs to provide riparian habitat and isolate some sections of the brook from the path.
- New footbridge over tributary brook
- Protection for local inhabitants increased to 1 in 100 by inclusion of a new embankment set back along the left bank (incorporated into the landscape planting scheme).
- Informal rights of way agreed with the landowner of the flood storage area (grazed by ponies) to allow greater public access.

Hydromorphological improvements:

- Increased sinuosity has led to a greater diversity of bed forms.
- Silt still enters the system but is deposited to form marginal berms and provide habitat niches for marginal plants.
- The greater diversity of forms has resulted in more diverse flow patterns.
- Increased velocity due to self narrowing has exposed and maintained a clean gravel bed.
- Raising the restored bed and lowering the floodplain (storage area) has increased connectivity and natural storage of moderate flood events.



- Severe flood events are controlled by the downstream spillway and throttle structure.



Figure 2: Narrowing as a result of silt deposition and marginal plant growth. The open channel section has a clean bed.

Ecological improvements:

- Increased diversity and abundance of flora and fauna,
- New riparian habitat (woodland copses and riparian colonisation)
- More varied habitat (silt, gravel, bare and vegetated banks) relating to morphology and hydrology diversity,
- New floodplain habitat, increased wet grassland area, permanent and temporary wetlands and pools

Assessment of the ecological efficiency:

- Significant improvements to both in channel and riparian/floodplain habitat with associated improvements in flora and fauna.

High	Medium	Low
X		



Figure 3: Vegetation is shaping the low flow channel, establishing in the deposited silty margins (four years after construction).

Effects on the uses:

- The restoration works have improved the landscape, visual amenity and access to the area which have resulted in increased use of the brook for informal recreation.
- The increase in habitat (specifically the ponds and wetlands) has increased opportunities for bird watching and 'duck feeding'.
- The inhabitants of the downstream area of Aylesbury now benefit from 90,000m³ of storage volume providing a 1 in 100 year level of protection.

Costs of the measure (€):

Costs of itemized brook restoration and landscape work were €145,800 (£100,000). Costs of entire flood alleviation scheme (including brook restoration, landscaping, storage areas and structures) were €1,166,600 (£800,000).

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H2/01 - Minimum flow requirements and new small weirs in a 5 km long river section in River Numedalslaagen

Driving force:	Hydropower production from existing project bypassing the river
Pressure:	No environmental flow requirements, hence none or low water discharge downstream of the intake
Impact:	Heavy impact on biology at site (only stagnant water behind weirs during low flow periods), loss of river continuum, reduced floods
Country:	Norway
Location:	River Numedalslaagen, southern Norway; river section between Rødberg dam and the Norefjord lake
Water Body at risk:	Yes, provisionally identified as HMWB

H2 01

A Status before reconstruction

Status of construction:

The river section is approximately 4 km long, has been provisionally identified as HMWB, and its typology parameters show low alkalinity and low colour, of medium altitude (i.e. below the tree limit).

- The hydropower production upstream Lake Norefjorden was licensed in 1914, without any requirements for release of minimum flow. This section of the river had therefore only water discharge during floods.
- Some small weirs constructed across the river stretch maintained still pools of water for esthetical purposes during low flow periods. The weirs were of an old type, made of concrete and not well adapted to maintaining good habitats for fish and other aquatic species.

A natural water fall is acting as a barrier far downstream of the selected river section, and this part of the river has therefore never been accessible for anadrome fish. Another natural water fall is found at the upper parts of the selected river section, and is acting as a barrier for local trout and other species. An ecological continuum can therefore not be maintained all the way up to the Rødberg dam.

Ecological deficiency:

- Almost no flowing water during long periods
- Disrupted hydrological and ecological continuum and no migration of fish



H2 01

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- In the new concession of 2001, the following requirements were given for this river section:
 - Minimum continuous flow requirement of 3 m³/s during winter and 5 m³/s during summer
 - Reconstruction of the existing concrete small weirs across the river stretch; new weirs are so-called cell type weirs.
- Cell type weirs (cf. Figure 1) are – as the name implies – constructed as smaller cells, thus providing a series of pools across the river. The water flow direction is changed and energy is dissipated in steps, resulting in decreased erosion of the river banks, and easier passage for migrating fish. The construction of cell type weirs had the following objectives:
 - More natural looking weirs
 - Conditions for resident species of fish and benthos are improved, including greater ease of upstream migration and greater diversity of *in-situ* micro-habitat
 - Mitigating effects during flood situations; less bank erosion
- The hydropower company is responsible for the construction and maintenance of the weirs, as well as the release of minimum flow.
- Figure 1 shows the river section at 3.5 and 5.5 m³/s (slightly more than the minimum required flows of 3 and 5 m³/s).



Figure 1: Section of river stretch at 3.5 m³/s (left) and 5.5 m³/s (right).
(Photo: NLB)

- Figures 2 and 3 show situations at two sites before and after the construction of new weirs.



Figure 2: Section of part of the river before (left) and after new weir constructions (right - water flow from right to left) (Photo: NLB).



Figure 3: Man-made weir in part of the river before (left) and after weir reconstruction (right). Water flow from right to left. (Photo: NLB)

H2
01

Assessment of the ecological efficiency:

- No systematic monitoring of the site has been done after the new mitigation measures, but electro-fishing has revealed that trout (*Salmo trutta*) and minnow (*Phoxinus phoxinus*) are living in the river section. By ensuring a river habitat of chutes and pools, the conditions for invertebrates should have improved significantly.
- It should be noted that minnow is a fish species that is exotic and largely unwanted in Norwegian rivers, and it has been speculated if such weirs create habitat which favours this species. However, minnow has been present in the river a long time before the new measures were implemented.

High	Medium	Low
X		

Effects on the uses:

- Loss of production amounts to 28 Gwh annually. However, the hydropower company is planning a new mini-hydro plant which will utilise the



environmental flow. This will be positioned close to the natural water fall (and barrier), and should therefore not affect the ecological continuum of this water body significantly.

- In terms of effects on other types of uses, the river is now more suitable for angling, and the new cell type weirs is contributing to a more natural-looking river, which should be beneficial for tourism.

Costs of the measure (€):

Approximately € 20,000 per weir for reconstruction works, thus a total of € 100,000. O&M costs are not yet available, since the measure is relatively recently finalised.

Upgrading the dam for release of minimum flow had a cost of € 250,000 (most Norwegian old dams do not have facilities for releasing minimum flows and reconstruction therefore has to be carried out).

H2

01

Literature and/or contact:

Not available



H2/02 - Mitigating measures in and downstream of Halnefjorden Reservoir in River Numedalslaagen

Driving force:	Hydropower
Pressure:	Reservoir with 4 meter regulation level; no minimum flow requirements downstream of dam, no hydrological continuum downstream of dam
Impact:	Erosion in littoral zone and exposure of lake bed to sub-zero climate due to winter drawdown of the reservoir. No migration of fish possible between reservoir and downstream river
Country:	Norway
Location:	River Numedalslaagen, Norway, on the Hardanger mountain plateau; Halnefjorden Reservoir (previously a natural lake)
Water Body at risk:	Yes, provisionally candidate for HMWB, but needs confirmation

H2
02

A Status before mitigation measures (before 2001)

Status of Halnefjorden reservoir:

The Halnefjorden dam was finalised in 1953, and the reservoir has a total regulation level of 4 meters. The lake is located at high altitude (about 1100 masl), and the water typology parameters show low alkalinity and low colour.

- Although the regulation level is only 4 meters, erosion problems in the littoral zone cause disruption of littoral water vegetation and increase the turbidity of lake waters. Erosion is also threatening cultural heritage sites near the banks.
- Before 2001, there was no hydrological continuum between the reservoir and the downstream river, no fish pass, and the downstream river was occasionally dry.

Ecological deficiency:

- Loss of vegetation in littoral zone, causing erosion and increased turbidity in waters, as well as decreased food production for fish (especially trout) in the littoral zone
- No flowing water during low flow periods in downstream river caused severe stress on aquatic flora and fauna.
- Disrupted hydrological continuum and no migration of fish between reservoir and downstream river



B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Minimum continuous flow requirement of $0.5 \text{ m}^3/\text{s}$ in the river downstream of the dam; and a requirement to keep the water level stable at the highest regulated level in the period between the spring flood and October 1st.
- New fish pass; to ensure that migratory fish can access spawning and breeding grounds. Also diversion barrier to prevent fish migrating up the wrong river channel (cf. Figure 1).
- Coconut matting erosion protection laid out in littoral zone to improve re-vegetation of barren zones and hinder erosion progressing towards cultural heritage sites (cf. Figure 3)

H2
02



Figure 1: Downstream the dam of the Halnefjord reservoir.

- In the river channel to the left there is now a new requirement of $0.5 \text{ m}^3/\text{s}$ of minimum flow (photo shows situation at significantly higher discharge).
- A barrier has been constructed to ensure that fish do not swim up the channel to the right.
- The new fish pass is constructed at the top of the left-hand channel, cf. Figure 2.



**H2
02**



Figure 2: New fish pass at the dam of the Halnefjorden reservoir.



Figure 3: Coconut matting in the littoral zone of the Halnefjorden reservoir.

Assessment of the ecological efficiency:

The mitigation measures are relatively recent, but experiences from similar measures at other sites have shown that

- The fish pass ensures that trout and other fish species may gain access to upstream spawning grounds.
- Minimum flow in the downstream river ensures that fish may migrate all year, and that other aquatic species have a better chance of surviving during low flow periods.
- Coconut matting enhances re-vegetation and reduces erosion from lake littoral zones

High	Medium	Low
X		



Effects on the uses:

- 0.5 m³/s continuous environmental release is a small constraint to reservoir operations and subsequently reduces power income to a small extent.

Costs of the measure (€):

Total costs of fish pass and erosion abatement measures amount to € 550-600,000.

Literature and/or contact:

Not available

**H2
02**



H2/03 - Dam removal on the Mirna River

Driving force:	Hydropower (watersaw operation)
Pressure:	Damming
Impact:	Interruption in the river continuum
Country:	Slovenia
Location:	Mirna River
Water Body at risk:	No

H2
03

A Status before reconstruction

Status of construction:

- Dammed river
- Obsolete structure, watersaw out of operation



Figure 1: Dam on the Mirna River, view of an artist.



Figure 2: Dam on the Mirna River, situation in 2002.

Ecological deficiency:

- Loss of river continuum
- Interrupted migration path of cyprinide (Nase carp *Chondrostoma nasus*, Barbel *Barbus barbus*, Danube roach *Rutilus pigus virgo*) and salmonoid (Danube salmon *Hucho hucho*) freshwater fish species

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Removing of obsolete dam
- Construction of rocky glide



Figure 3: Rocky glide on the Mirna River, situation in 2006.



Figure 4: Nase carp passing the rocky glide on the Mirna River, 2006.

H2

03

Accompanying measures:

- Monitoring of freshwater fish migration during the spawning period (March – May)

Hydromorphological improvements:

- Improvement of flow conditions. Re-creation of mezzo hydromorphological structures (e. g. pools, rapids, riffles, sand bars and fords). Improvement of river continuum between rivers of 1st (the Sava River) and 2nd order (the Mirna River).

Ecological improvements:

- Re-construction of river continuum between river and tributary in the catchment area. Migratory fish species gain migration possibility in order to use more spawning areas in the catchment area.

Assessment of the ecological efficiency:

- Measures taken initiated development of dynamic riverine habitat, typical for the Sava river reaches in the area. Developed habitats are supporting autochthonous fish communities and species as well as macroinvertebrates.
- The construction of fishway enables migration of Brown trout upstream and downstream river towards the proper spawning places in different parts of the river.

High	Medium	Low
	X	

Effects on the uses:

- Use did not exist any more even before restoration works.

**Costs of the measure (€):**

Costs of restoration works are estimated on today's prices of labour and material on 175,000 €. Costs of monitoring and maintenance are not included.

Literature and/or contact:

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**H2
03**



H2/04 - Restoration of migration path on the Sava River, Tacen

Driving force:	Hydropower production
Pressure:	Damming
Impact:	Interruption in the river continuum
Country:	Slovenia
Location:	Sava River, Tacen
Water Body at risk:	No

A Status before reconstruction

Status of construction:

- Dammed river
- Unsuitably constructed and not properly functioning fish way

Ecological deficiency:

- Loss of river continuum
- Interrupted migration path of freshwater fish species (*Nase Chondrostoma nasus*, Barbel *Barbus barbus*) between the Tacen hydropower water reservoir and downstream river stretch

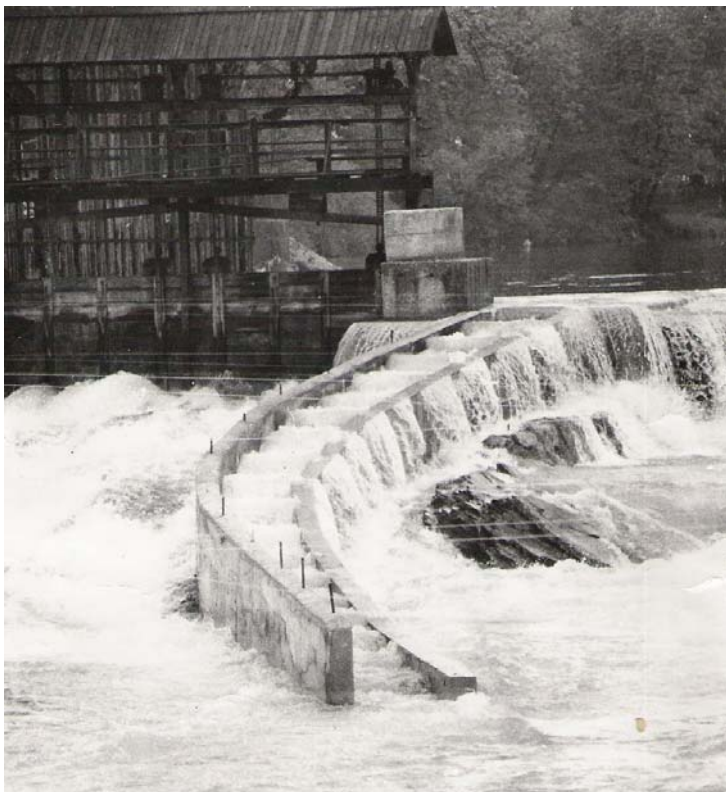


Figure 1: Sava River at Tacen, unfunctional fish way, situation in 1982.



H2
04

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Reconstruction of old dam
- Removing and replacement of unfunctional existing fishway with rocky glide



Figure 2: Sava River at Tacen, rocky glide, situation in 2006.

Accompanying measures:

- Monitoring of freshwater fish migration during the spawning period (April – May)
- Intensive monitoring of sport fishing by the local angling society

Hydromorphological improvements:

- Improvement of flow conditions
- Re-creation of mezzo hydromorphological structures (e. g. pools, rapids, riffles, sand bars and fords)

Ecological improvements:

- Improvement and defragmentation of aquatic habitat
- Migratory fish species gain possibility for migration in order to use spawning areas in the upstream parts of the river.



Assessment of the ecological efficiency:

- Measures taken initiated development of dynamic aquatic habitat, typical for the Sava river reaches in the area. Developed habitats are supporting autochthonous fish communities and species as well as macroinvertebrates.

High	Medium	Low
X		

Effects on the uses:

- Restoration works were already designed in manner not to have any impacts on the existing hydropower production. No impacts on use were recorded after restoration of the river.

Costs of the measure (€):

Costs of restoration works are estimated on today's prices of labour and material on 500,000 €. Costs of monitoring and maintenance are not included.

Literature and/or contact:

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H2
04



H2/05 - Removal of barriers for fish migration in Norralaån, Sweden

Driving force:	Hydropower
Pressure:	Damming
Impact:	Interruption of the river continuum
Country:	Sweden
Location:	River Norralaån, mid-eastern Sweden
Water Body at risk:	Preliminarily not

A Status before reconstruction

Status of construction:

- Water regulation dams of different types and use, were located at five locations in the main branch of the river system. The dams were barriers for fish migration. About $\frac{3}{4}$ of the length of the main branch of 40 km was not available for fish migration from the Baltic Sea. The Norralaån drainage area is about 320 km² and the mean water flow is 3.6 m³/s at the mouth into the Baltic Sea.

Ecological deficiency:

- The fish migration according to the natural reference state of the river system was obstructed at five locations, which interrupted the reproduction and production capacity of migrating fish species. The population of other species, like fresh water mussels, could also be deficient due to their dependence of fish migration possibilities.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- One of four parallel flow channels leading water to old mills was rebuilt and opened for fish migration.
- One small-scale power plant was taken away.
- Construction of a fish way passing by an old mill
- A 30 year old fish ladder, out of function, was re-built to allow fish migration.
- Removal of a dam in the outlet of a lake and reconstruction of the outlet to make it function as the former natural outlet. See Figure 1.

Accompanying measures:

- Not specified

H2
05



H2 05

Hydromorphological improvements:

- The natural continuum of the main branch of the river system was recovered to a state near the natural continuum regarding fish migration. The natural flow regime was recovered at the outlet of a lake. There is no flow regulation site located upstream of that lake.

Ecological improvements:

- The trout population has improved. Further ecological improvements are still to be investigated.
- Due to the measures performed during the years 2004 – 2006 the good or high ecological status may be achieved in the river main branch within a few years. Therefore the water bodies should not be regarded as being at risk of failing to achieve good or high ecological status.



Figure 1: The pictures show the outlet of Storsjön before (to the left) and after (to the right) reconstruction of the natural outlet of the lake. The lake is situated in the upper part of the river basin drainage area. The drainage area of the lake is 33 km² and the mean flow in the outlet is 0.4 m²/s.

Assessment of the ecological efficiency:

- No assessment of the ecological efficiency has been done, but the efficiency should be regarded as high because the measures have resulted in permanent restoration of nearly natural prerequisites for natural fish migration in the whole river system.

High	Medium	Low
X		

Effects on the uses:

- The owners of the dams were no longer interested in the original use of the dams, but some dams are maintained due to their high cultural values.

Costs of the measure (€):

About 250,000 €

Literature and/or contact:

Håkan Olsson, SMHI, Sweden, has written this case study based on information from Jan Lundstedt, The municipality of Söderhamn, Sweden.



H2/06 - Fishway as a mitigation measure

Driving force:	Hydropower
Pressure:	Damming
Impact:	Interruption in the river continuum and habitat loss
Country:	Finland
Location:	River Perhonjoki, Western Finland
Water Body at risk:	No

A Status before reconstruction

Status of construction:

- Hydropower station of Kaitfors was built off the original river channel and its turbine tailrace runs in a 1250 m long tunnel. The power plant has a head of 15 m. The plant has been used for short term regulation. The catchment area is 2316 km². Original river channel has been used as a flood channel/spillway. Only 0.5-1.0 m³/s minimum perennial flow is required. Total length of low-watered channel is 3 km and there were several structures which block fish migration: old mill, 4 weirs (built for scenery of water surface for inhabitants) and the reservoir dam.

H2
06

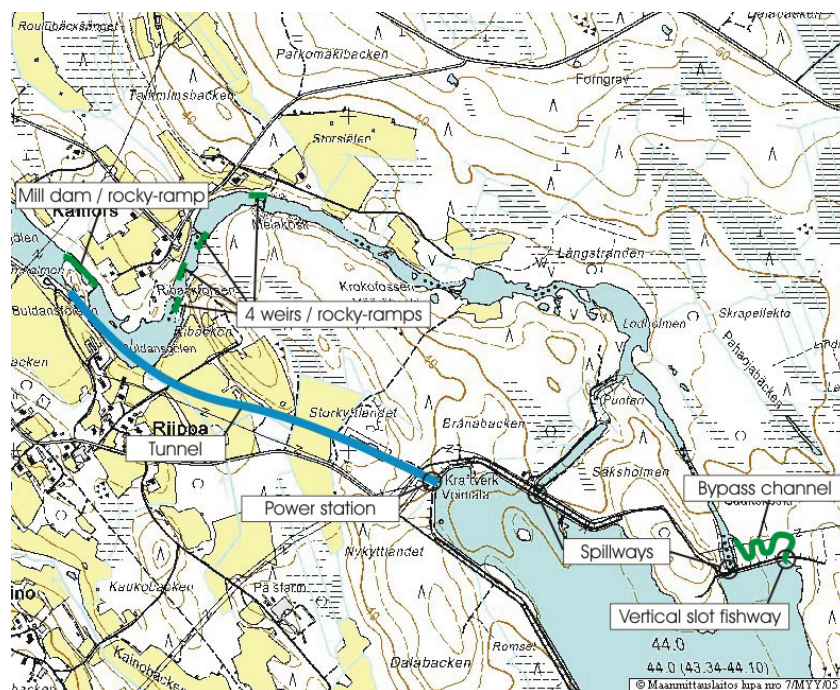


Figure 1: Map of Kaitfors power plant area.

Ecological deficiency:

- The dam system is the lowest fish block in the river and prevents fish migration upstream. Also habitat loss and degradation take place due to damming and short term regulation. Among other impacts, populations of lake trout, river lamprey and crayfish have declined. In addition disturbed river reach produces huge amount of black flies.



H2 06

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Old channel is used as a fish passage. 5 Rocky-ramp fishways were built to pass an old mill and weirs and a nature-like bypass stream was constructed with short section of vertical slot fishway to pass the dam. Construction work was done at fall 2005 and finishing work will be done in 2006.

Accompanying measures:

- Spawning and rearing habitats have been constructed in the bypass stream. Several gravel bed riffles have been done for trout. River restoration practices have also carried out in the old channel to improve crayfish habitats.

Hydromorphological improvements:

- Restoration increases the amount of riverine habitats.

Ecological improvements:

- Large variety of species is enabled to pass the dam and controlled spawning and rearing habitats have been made in the regulated river system.

Assessment of the ecological efficiency:

- Ecological improvement will be monitored by radio telemetry and electro fishing from 2006.
- On site increase of spawning and rearing habitats in fish passes
- Restoration of old channel for fisheries, regional importance
- Restoration of connectivity in the whole river system

	High	Medium	Low
In the area of the measure		X	
In the upstream areas		X	
In the whole water body			X

Effects on the uses:

- No effects on the uses. Nowadays minimum flow for the old channel runs through the fishways instead of spillways.

Costs of the measure (€):

The cost of the vertical slot fishway construction was approximately 100,000 €, nature-like bypass stream 60,000 €, 5 rocky-ramps all together 80,000 € and other river restoration works 15,000 €.

Literature and/or contact:

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H2/07 – Replacement construction of a large-scale hydropower plant - Rheinfelden (High Rhine)

Driving force:	Hydropower
Pressure:	Dam
Impact:	Impaired continuity, loss of the specific riverine habitats
Country:	Germany
Location:	Rheinfelden/High Rhine
Water Body at risk:	Yes, provisionally identified as HMWB

H2
07

A Status before reconstruction

Status of construction:

- Existing hydropower plant (build in 1898)
 - Design discharge: 600 m³/s, installed capacity: 25.7 MW, annual output: 185 million kWh

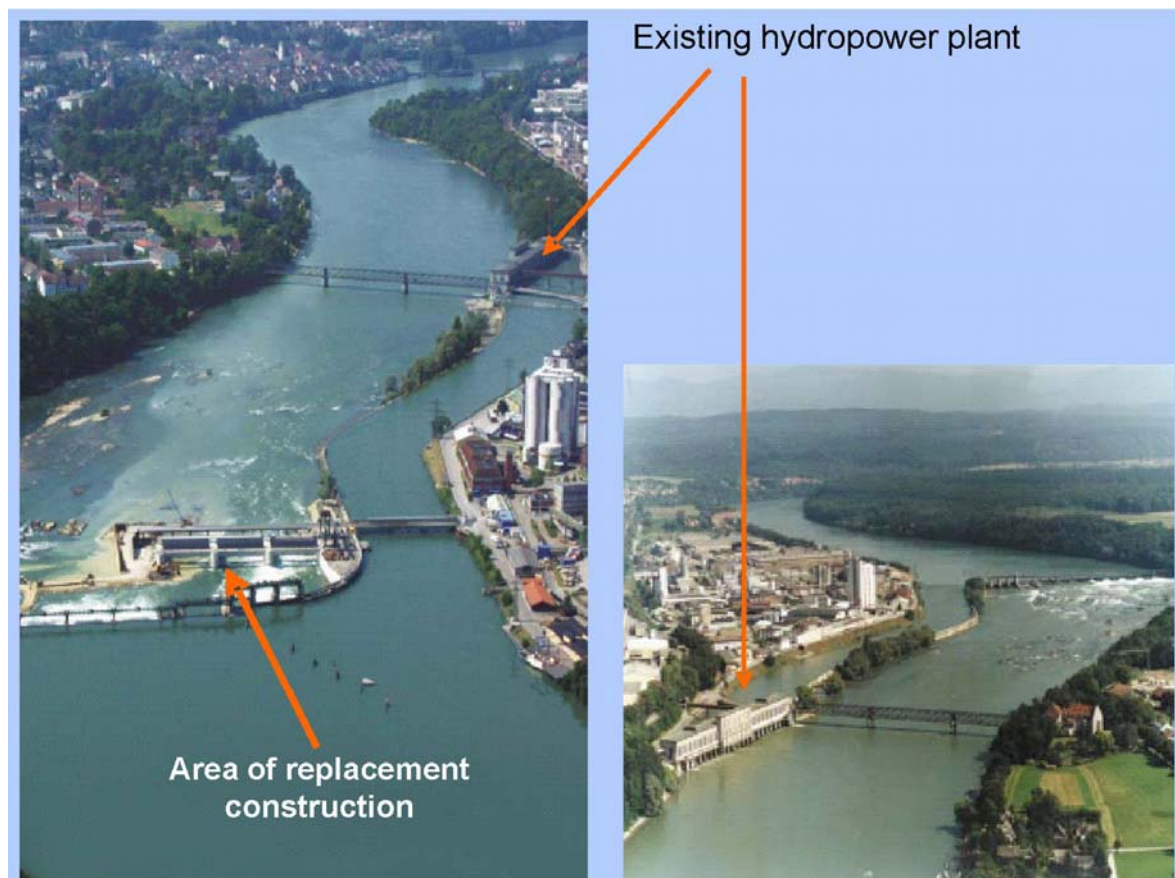


Figure 1: Existing hydropower plant, build in 1898.



H2 07

Ecological deficiency:

- Impaired continuity
- Loss of a part of the specific riverine habitats

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Replacement construction hydropower plant Rheinfelden
- After completing in 2011:
 - Design discharge: 1500 m³/s
 - Installed capacity: 100 MW
 - Annual output: 600 million kWh
- The objective of the ecological measures within the hydropower project is to compensate the interventions and to reach a better ecological status than before the construction.
 - Natural-like bypass channel with spawning possibilities and comprehensive gravel structures over a length of about 900 m (cf. Figure 2 – “Umgebungsgewässer”)
 - Construction of a pool fish pass with rough bottom (close to the natural structure of the so-called “Gwild” (cf. Figure 2 and 3))
 - Vertical slot fish pass to allow the circumvention of the new machine house (cf. Figure 2 – “neues Maschinenhaus”)
 - Maintenance of an adequate flow in the rest of the “Gwild”
 - Removal of bank reinforcement and gravel fillings over a length of 700 m up- and downstream of the new hydropower plant
 - Structures like groynes, deadwood, hatcheries for the fauna which accompanies the river up- and downstream of the new hydropower plant



Figure 2: Hydropower plant of the replacement construction (completion in 2011)



Figure 3: The 150 m long pool fish pass at the new weir.

**H2
07**

Accompanying measures:

-

Hydromorphological improvements:

- The structures create rest areas for the fish fauna and working surface for the natural erosion. Furthermore, they secure the change between dry and wet stages in the “Gwild”.
- The bypass channel creates a river-like, new habitat with gravel structures and different flow conditions.

Ecological improvements:

- Improvement of the situation of fish through creation of new spawning and resting areas as well as the improvement of passability of the weir
- Creating of rest and protection zones as well as hatcheries for the fauna which accompanies the river especially birds, insects and bats
- The permanent removal of the bank reinforcement restores the natural situation of the river Rhine bank and readmits natural erosion processes.
- The creation of spawning, rest and protection areas upgrades the otherwise urban industrial bank zones and provides new habitats. Especially the bypass channel will be a significant ecological improvement in the so far industrial landscape.

Assessment of the ecological efficiency:

- Planning and execution will be discussed in an ecological advisory board, which will also control the proper technical execution.

High	Medium	Low
	X	



Effects on the uses:

- There are no known effects on the uses hydropower or navigation. The annual output of the hydropower plant will be quadrupled. The region will be upgraded regarding the uses recreation and fishery.

Costs of the measure (€):

High costs for the ecological measures (about 10 Mio. €), especially for the construction of the bypass channel and the fish passes.

Literature and/or contact:

Energiedienst AG
Rheinbrückenstraße 5/7
79618 Rheinfeldern
<http://www.energiedienst.de>

**H2
07**



H2/08 – Hydropower plant Albruck-Dogern

Driving force:	Hydropower
Pressure:	Dam
Impact:	Insufficient residual water flow, interrupted continuum, interrupted fish migration, low fish population, low population of aquatic fauna
Country:	Germany (EURELECTRIC)
Location:	River Rhein, Hochrhein, km 101.52, between Albruck and Dogern; operating company: RADAG, Rheinkraftwerk Albruck-Dogern AG
Water Body at risk:	Yes, provisionally identified as HMWB

**H2
08**

A Status before reconstruction

Status of construction:

- Hydropower plant since 1933 at the end of an 3.5 km long intake canal
- No weir-power-plant

Ecological deficiency:

- Insufficient residual water flow (3-8 m³/s) due to the diversion section for the existing power plant “Albruck Dogern”
- Interrupted continuum by river weir



H2
08

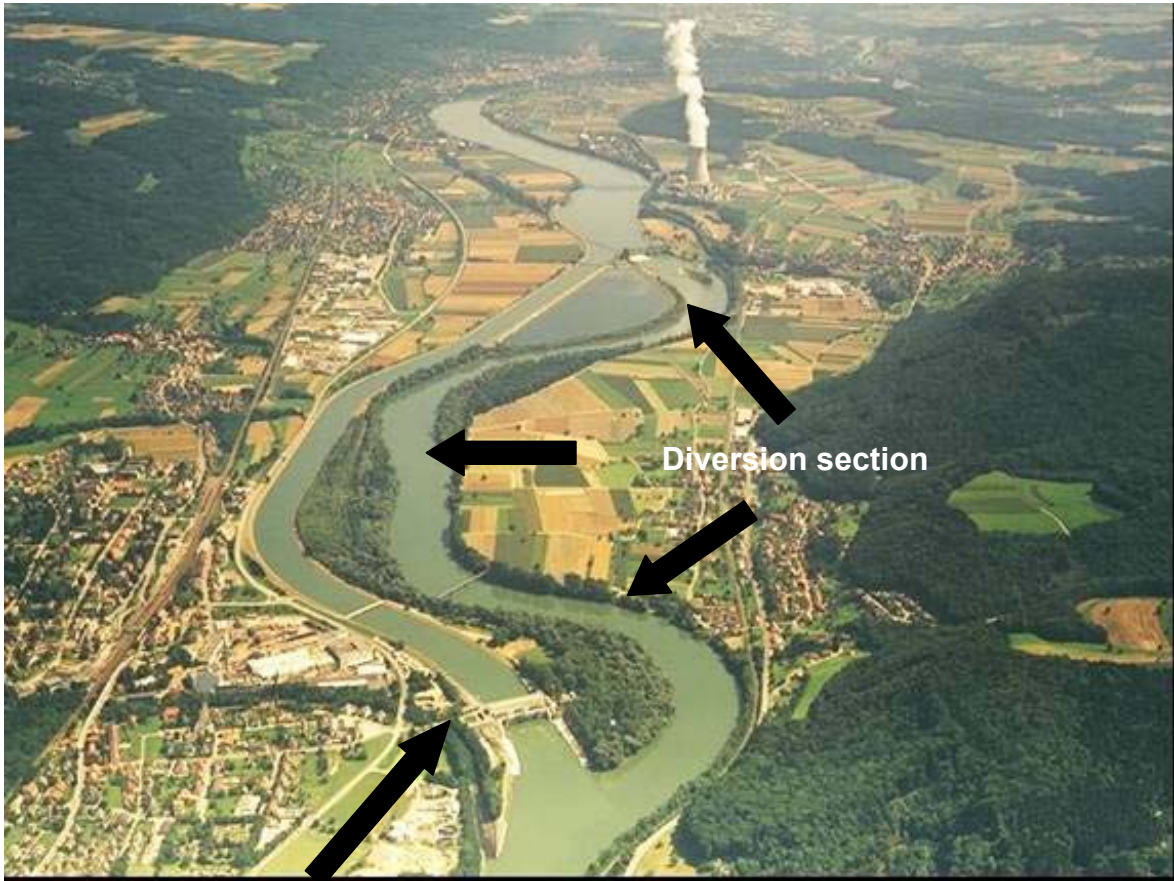


Figure 1: Albrbruck Dogern Hydropower station.

B Reconstruction by restoration / mitigation measures

- To receive a new concession for the Rheinkraftwerk Albrbruck-Dogern plant in connection with the building of an additional hydropower plant by the weir (weir-power-plant)
- Increase of power generation and improvement of the ecosystem in diversion sections (cf. figure 1).

Execution of the measure:

- Immediate increase of the residual water flow: $3.8 \text{ m}^3/\text{s}$ to $40 \text{ m}^3/\text{s}$
- Creation of a nature like fish ladder with collection gallery, renaturing of former gravel islands, upvaluation of an bird-island
- From 1st January 2008 increase of the residual water flow up to $70\text{-}100 \text{ m}^3/\text{s}$
- The commission of the new weir-power plant is planned in 2009/2010 and in operation the turbines use a water flow of min. $200 \text{ m}^3/\text{s}$
- Implementation of the ecological measures until 2012

Accompanying measures:

- No accompanying measures

Hydromorphological improvements:

- Improvement of the connection of the sidewater Alb of the Rhine
- Creation of a nature like bed structure in the diversion with gravelbars



Ecological improvements:

- Improvement of the ecological conditions in the whole area of the river diversion and in the river course under the weir
- Improvement of the ecological diversity of the shoreline



H2
08

Figure 2: Location of the weir power plant.



Figure 3: Natural like fish ladder.



Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

- Increase of the design flow rate from 1100 m³/s to 1400 m³/s and of the annual energy output of about 87 GWh/year

Costs of the measure (2002e):

Costs of the ecological measures: 4 Mio. €
Costs of the weir-power plant: 51 Mio. €

**H2
08**

Literature and/or contact:

Michael Moltrecht, RWE Power AG, Renewable Power Generation, PNS-B,
D-54470 Bernkastel Kues, Gewerbegebiet Andel

Mail to: michael.moltrecht@rwe.com



H2/09 – Hydropower plant Gottfrieding

Driving force:	Hydropower
Pressure:	Dam
Impact:	Interrupted continuum and fish migration
Country:	Germany
Location:	Federal state: Bavaria, district: Niederbayern; operating company: E.ON Wasserkraft GmbH
Water Body at risk:	Yes, provisionally identified as HMWB

**H2
09**

A Status before reconstruction

Status of construction:

- No fish ladder in the existing barrage

Ecological deficiency:

- Interrupted fish migration

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- At the moment the type of execution is being checked with the licensing authority and the responsible technical authorities.
- A concept study was created which includes four design versions of the fish bypasses on the left riverside.
- To assess the functional capacity, echogramms were necessary to assess the depth-situation and in addition the velocity of flow was measured at several river-profiles.
- The most useful solution is a technical fish bypass.



H2
09

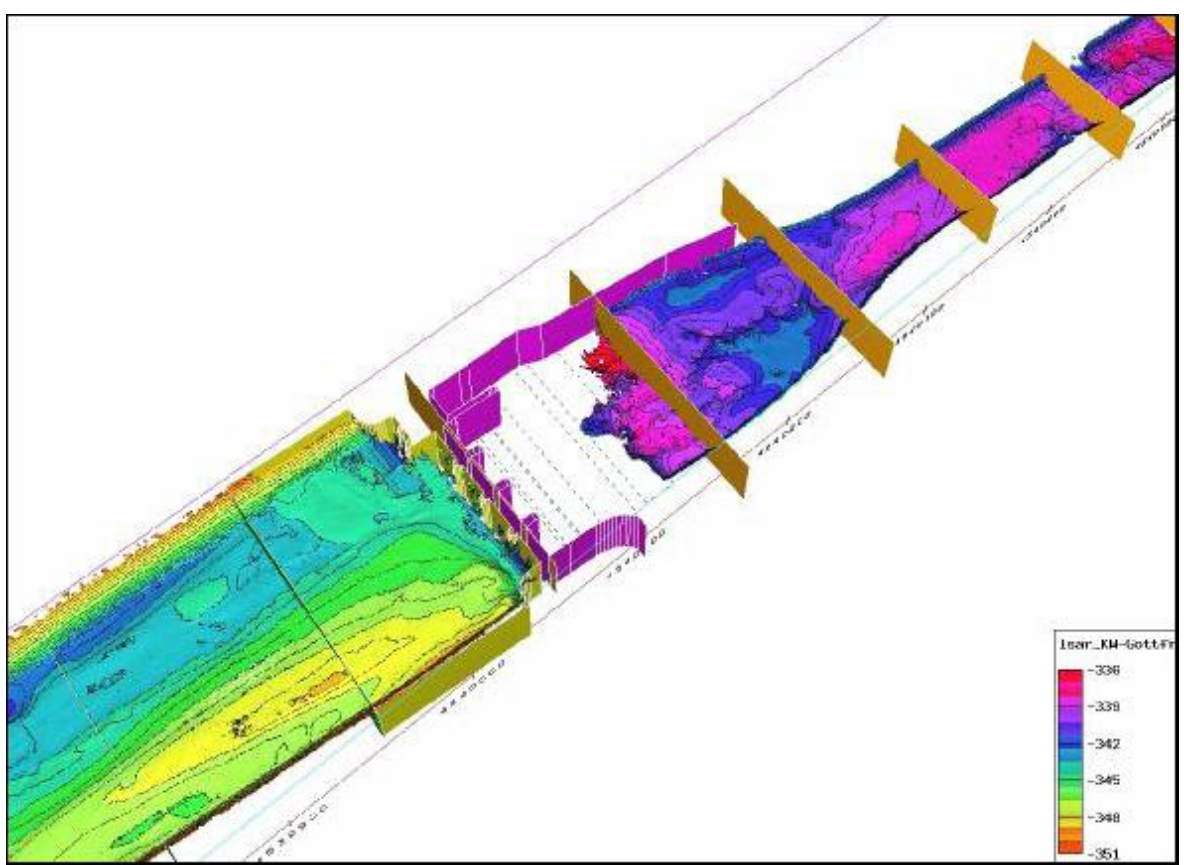


Figure 1: Diagram of the depth-situation between river-km 41.8 and 41.1.

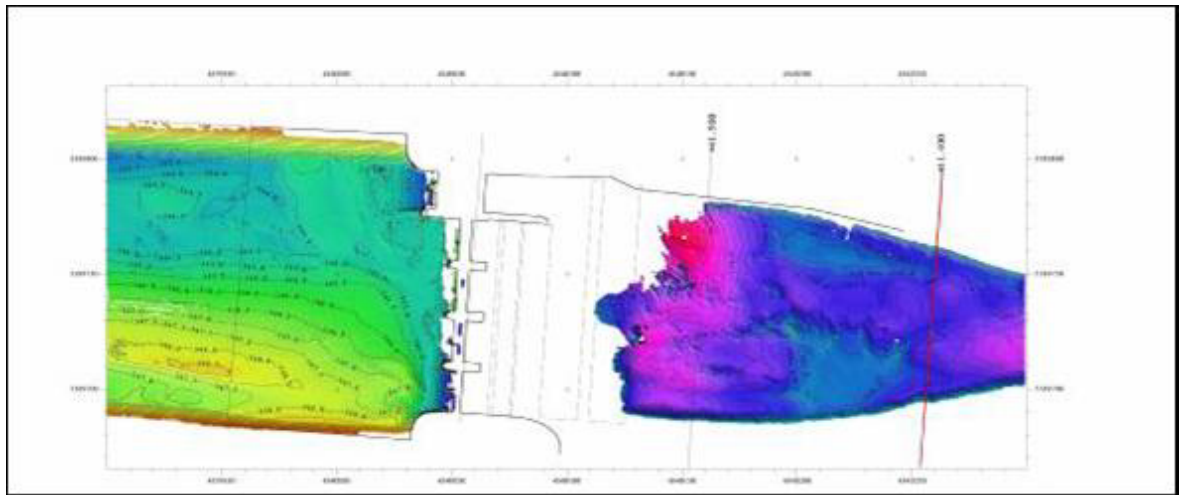


Figure 2: Schematic diagram of the flow-course-forecast () downstreams.

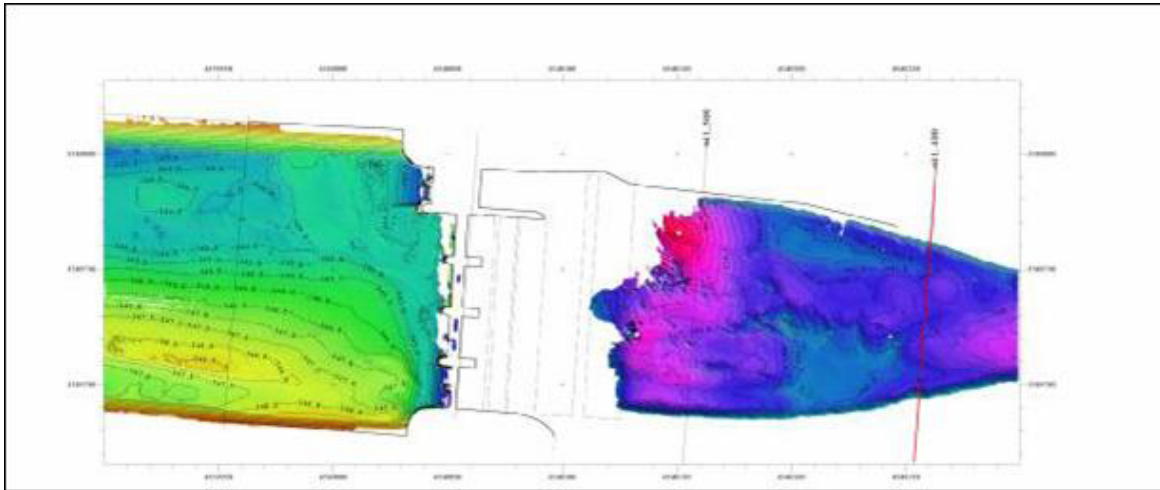


Figure 3: Schematic diagram of the forecasted main fish migration course (red hatched area).

**H2
09**

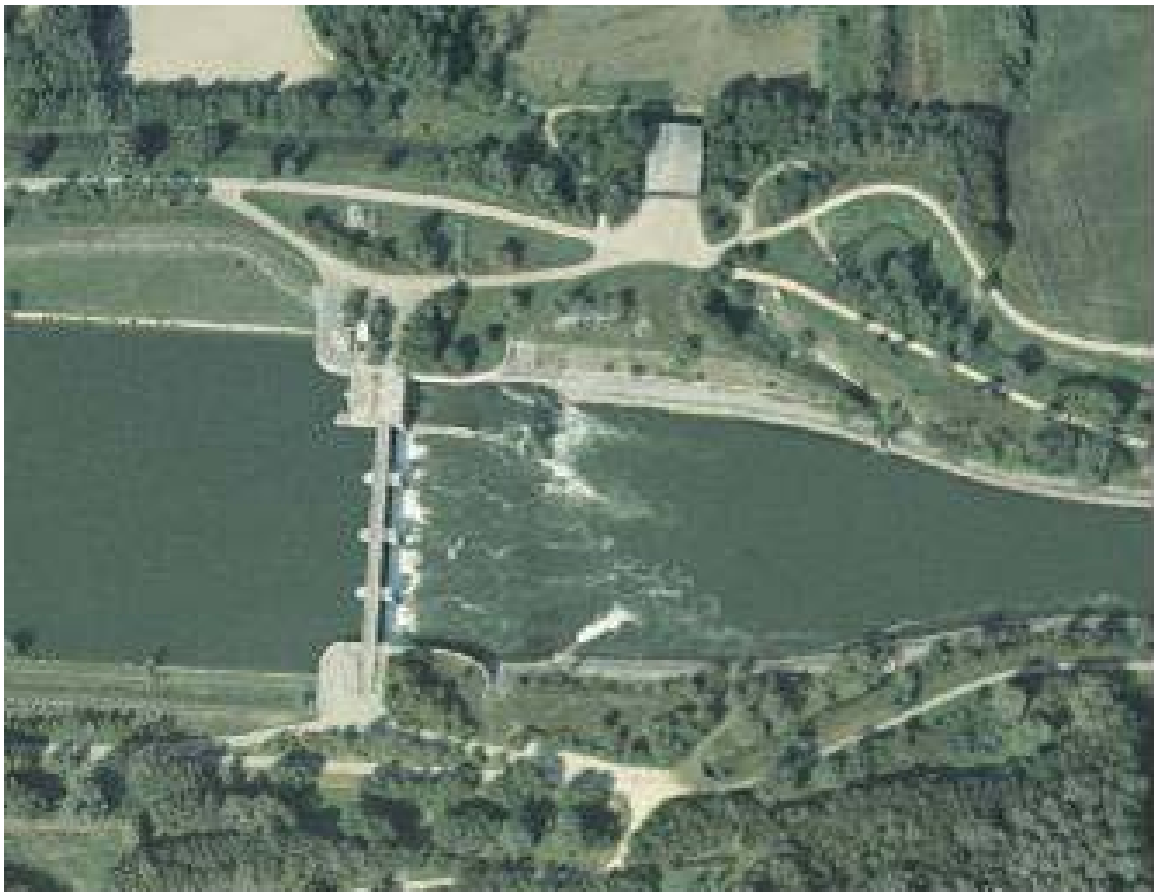


Figure 4: Air photograph of the existing barrage with the electric power plant at the left riverside.

Accompanying measures:

- Concept study for fish passage optimisation



H2 09

Hydromorphological improvements:

- None, the focus is on the improvement of the fish migration.

Ecological improvements:

- Possibility for fish to penetrate the barrage, additional water flow (500 l/s)
- With modernising the plant ecological improvement will be achieved by establishing an ecological passage in the form of a fish bypass.

Assessment of the ecological efficiency:

- At the moment the ecological efficiency is not really foreseeable; for the fish migration it will be high.

High	Medium	Low
	X	

Effects on the uses:

- Increase of the REA (Renewable Energy Act in Germany)-subsidy for the energy production because of the ecological improvements

Costs of the measure (€):

Construction of the fish bypass: 350,000 €

Literature and/or contact:

Michael Moltrecht , RWE Power AG, Renewable Power Generation, PNS-B, D-54470 Bernkastel Kues, Gewerbegebiet Andel

Mail to: michael.moltrecht@rwe.com



H2/10 - KW Steinbach Refurbishment - Optimizing energy generation and ecological measures

Driving force:	Hydropower
Pressure:	Cross profile construction
Impact:	Disruption in river continuum
Country:	Austria (EURELECTRIC)
Location:	River Steyr at km 18.61
Water Body at risk:	Risk to fail GES, candidate for HMWB

H2
10

A Status before reconstruction

- KW Steinbach HPP is situated in the federal state “Upper Austria” on the river Steyr at km 18.61. The old HPP consisted of two separate utilities. The elder one was built in 1910, installed capacity 25 kW and the other one in 1942, installed capacity 75 kW. Equal gross head of 2.8 m and maximum discharge of 4.1 m³/s together were used to produce an average annual energy amount of 0.8 GWh.
- Due to bad condition and old age of the facility a refurbishment study was carried out in 1999. In conclusion following implementations had been decided:
 - Demolition of old plants and replacement by a single power-house and two generating units. Expanding total discharge from 4.1 m³/s to 50 m³/s and capacity from 100 kW up to 1,100 kW
 - Alteration of bottom weir gate
- Expanded discharge and enhanced efficiency have permitted an average annual energy production of 5.3 GWh - more than six times the amount before refurbishment. Total costs: € 5,000,000.- (several floods during construction exceeded estimated costs of € 3,800,000.-).

Status of construction:

- Old facility in bad condition and low capacity was replaced in 2002

Ecological deficiency:

- Disruption in river continuum inhibited fish migration

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Providing fish migration by establishing a vertical-slot-fish-ladder

Accompanying measures:

- Fish bypass



H2 10



Figure 1: New Steinbach HPP.

Hydromorphological improvements:

- River continuum established

Ecological improvements:

- Fish migration provided

Assessment of the ecological efficiency:

- Limnology professionals assisted the planning and construction works for the fish ladder that is integrated in the partition wall between bottom weir gate and power house. Tests proved the performance of this fish ladder that obviously was welcomed by the fish.

High	Medium	Low
X		

Effects on the uses:

- Costs for ecological improvement have been compensated by increasing power generation

Costs of the measure (€):

Fish bypass: approx. € 70,000.-

Literature and/or contact:

Owner: Energie AG Oberösterreich, Böhmerwaldstr. 3, A-4021 Linz



H2/11 - KW Agonitz Refurbishment - Optimizing energy generation and ecological measures

Driving force:	Hydropower
Pressure:	Cross profile construction
Impact:	Disruption in river continuum
Country:	Austria (EURELECTRIC)
Location:	river Steyr at km 32.00
Water Body at risk:	Risk to fail GES, candidate for HMWB

**H2
11**

A Status before reconstruction

Status of construction:

- KW Agonitz HPP is situated in the municipal area of “Grünburg” in the federal state “Upper Austria” on the river Steyr at km 32.00. The HPP once was built in 1924.
- The old utility, gross head 7 m and maximum discharge 20 m³/s, used two generating units, installed capacity 990 kW, to produce an average annual energy amount of 6.4 GWh.

Ecological deficiency:

- Disruption in river continuum inhibited fish migration

B Reconstruction by restoration / mitigation measures

- Due to bad condition and old age of the facility a refurbishment study was carried out in 2001. In conclusion following implementations had been decided:
 - Replacement of power-house and generating units. Expanding discharge from 20 m³/s to 45 m³/s
 - Alteration of bottom weir gate
 - Raising hydraulic head to 8.3 m by 1.3 m bed excavation downstream (Total costs: € 7,600,000.-)
- Expanded discharge and more hydraulic head have permitted an average annual energy production of 15.8 GWh - more than twice the amount before refurbishment.
- Ecological measures were performed by limnology professionals who also assisted the construction works.



H2 11



Figure 1: New Agonitz HPP, bird's eye view.

Execution of the measure:

- Providing fish migration by establishing a fish bypass designed as combination of natural-like-rivulet and vertical-slot-fish-ladder.

Accompanying measures:

- Fish bypass

Hydromorphological improvements:

- River continuum established

Ecological improvements:

- Fish migration provided

Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

- Costs for ecological improvement have been compensated by increasing power generation

Costs of the measure (€):

Investment: Fish bypass: € 380,000.-

Literature and/or contact:

Owner: Energie AG Oberösterreich, Böhmerwaldstr. 3, A-4021 Linz



H2/12 - Fishway as a mitigation measure

Driving force:	Hydropower
Pressure:	Damming
Impact:	Interruption in the river continuum
Country:	Finland
Location:	River Kuusinkijoki, North-eastern Finland
Water Body at risk:	No

H2
12

A Status before reconstruction

Status of construction:

- Myllykoski power plant has a head of 11 m and specified flow rate of 16 m³/s. There is practically no regulation of the discharge. The power plant is located in the River Kuusinkijoki at the outlet of the Lake Ala-Vuotunkijärvi where the catchment area is 784 km². The upper watercourse consists of several lakes and streams. The length of the river downstream is some 15 km ending to the Lake Paanajärvi in Russia. There are no other power plants on the area and no other hydromorphological changes.

Ecological deficiency:

- The watercourse has a lake trout population, some of which used to migrate to the upper reaches while most of the population left to the river area downstream of the power plant. Lake trout migration to the upper reaches was blocked by the power plant.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- A fish ladder of combined denil and borland type was constructed in the beginning of 1990's at the power plant. It is in use three months a year during summer time.

Accompanying measures:

- Additional fish stockings are carried out to compensate efficient fishing and lost breeding habitats under the power plant.

Hydromorphological improvements:

- Continuity of the river has been improved so that fish can nowadays migrate.



H2 12

Ecological improvements:

- Fish are allowed to migrate to their upstream breeding areas. Migration has an important role in maintaining the lake trout population in the upper reaches of the watercourse.



Figure 1: Takkupyörre downstreams of the Myllykoski power plant.

Assessment of the ecological efficiency:

- The fishway has worked as assumed. Number of migrant fish has been in proportion to the size of the upstream migrative population and breeding areas. Natural life cycle of the lake trout has been strengthened.
- The ecological effects are directed at the whole water body. However, in the scale of the whole water body, the ecological efficiency is minor. The breeding areas downstream of the fishway might alone be adequate to achieve the good status classification of the water body.

	High	Medium	Low
In the upstream areas		X	
In the whole water body			X

Effects on the uses:

- No significant effects on the use. Discharge through the fishway is about 0.2 m³/s three months a year. This equals to 40 MWh.

**Costs of the measure (€):**

The cost of the fishway construction was approximately 150,000 €. Energy losses can be assessed to be 1200 €/year. Additional fish stockings cost 12,000 €/year.

Applications:

- The fish pass constructions may be suitable in water bodies with remaining migrative populations and breeding areas upstreams. The fewer migrations obstructions have to be passed, the fewer are the losses in the migration. Effects on the uses are probable and have to be assessed case by case.

Literature and/or contact:

Mika Marttunen, Finnish Environment Institute, mika.marttunen@ymparisto.fi

H2
12



H2/13 - Minimum water discharges

Driving force:	Hydropower generation
Pressure:	Dams (Hydromorphological change)
Impact:	Deterioration of habitats of trouts
Country:	France (EURELECTRIC)
Location:	7 river sites in 3 WFD districts (Loire, Rhône, Garonne)
Water Body at risk:	Among the 7 sites considered, 3 were considered as natural WB (good status expected in 2015), 1 was considered natural WB possibly not reaching good status in 2015, 2 were considered HMWB (to be confirmed) and 1 was considered provisional HMWB which should reach good status in 2015.

**H2
13**

A Status before reconstruction

Status of construction:

- Minimum discharge (instream flow) downstream of dam = 1/40 of the mean annual discharge of the river
- Sites with dominant hydromorphological pressures (physico-chemistry is good)

Ecological deficiency:

- On site data and use of the Instream Flow Incremental Methodology (IFIM) indicated that an increase of the minimum discharge would improve the habitat of brown trouts. It was decided to test if an effective increase of the minimum discharge would improve the biomass of adult brown trouts in the downstream water bodies.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Minimum discharge downstream of dam = 1/10 of the mean annual discharge of the river

Accompanying measures:

- On site monitoring (flow discharge, fish population), modelling of fish population



H2 13

Hydromorphological improvements:

- Habitat improvement (better velocity and depth conditions for the four development stages)

Ecological improvements:

- No significant improvement in the biomass of adult brown trouts

Assessment of the ecological efficiency:

- A 4 year in-depth on site study of the 7 sites under the new status, conducted by 5 French research laboratories; and use of statistical tools and a fish population dynamic model (MODYPOP) to try to explain the absence of improvement
- Conclusion: flood regime (major factor), connectivity with tributaries, substrate of the spawning areas are determining factors which have hidden the potential effect of the discharge increase. Long term MODYPOP simulations suggest that long term data (at least 10 years) are needed to disclose the respective role of all these factors.

High	Medium	Low
	X	

Effects on the uses:

- Hydropower loss

Costs of the measure (€):

About 800,000 €/year (energy production losses) for the 7 sites experienced (from 30 to about 250,000 € according to the sites and associated flow discharge evolution).

Literature and/or contact:

References:

Sabaton et al, 2004: The “Guaranteed Flow Working Group”: A French evaluation of microhabitat component of IFIM based on habitat and brown trout population monitoring. Hydroecol. Appl.14, 245-270.

Long term MODYPOP simulations (paper presented at the 2007 Ecohydraulics Congress)



H2/14 - Optimizing the minimum flow in the Maronne river for migrating fish species

Driving force :	Hydropower
Pressure:	Dams & hydropower plants
Impact:	Impaired flow dynamics (reduced flow, artificial discharge regime), change in habitat diversity and quality, disruption in river biological continuum and lateral connectivity
Country:	France
Location:	La Maronne (Dordogne basin)
Water Body at risk:	- uppest WB (from spring to Enchanet dam): not identified as HMWB, its likely environmental objective is a Good Status by 2015, - middle WB (from Enchanet to Hautefage dam): HMWB, - downstream WB (from Hautefage dam to Dordogne confluence): WB not identified as HMWB, NB. for these two WB, work is still carried out in order to define their environmental objective.

H2
14

A Status before reconstruction

Status of construction:

- The Maronne river is one of the most upper tributaries of the Dordogne river, on which a programme is set for restoring migrating fish species (Salmonidae). Most of the spawning areas of the Dordogne basin are located within the Maronne river. It is therefore a river of high importance for reproduction of migrating fish species. Nevertheless, several installations, namely for hydropower, are built.
- In the downstream part of the Maronne, its hydrological regime is mainly influenced by the Hautefage power plant (minimum flow $\approx 0.5 \text{ m}^3/\text{s}$; peak $\approx 17 \text{ m}^3/\text{s}$ in summer to $45 \text{ m}^3/\text{s}$ in winter).

Ecological deficiency:

- The artificial hydrological regime leads to great change in habitat diversity and quality. Spawning areas are systematically dried when the Hautefage power plant stops each year.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- A two year study enable to propose modulations of minimum flows, depending on the season, taking into account ecological requirements namely for, salmon reproduction and development, and economic requirements of stakeholders.



H2 14

The first proposal, including a small turbine, so as to adapt precisely the minimum flow, was considered too expensive.

- Then, another solution has been proposed and accepted; it consists in:
 - A minimum flow $\approx 3 \text{ m}^3/\text{s}$ from December to end of April;
 - A minimum flow $\approx 0.5 \text{ m}^3/\text{s}$ from 1st of May (with intermediary inflows, this leads to a flow $\approx 4 \text{ m}^3/\text{s}$);
 - Stopped or reduced locking in summer;
 - Re-connection with oxbows, improvements of bed granulometry, installation of small weirs...

Ecological improvements:

- Studies still go on in order to assess ecological improvement of biological communities in long term, but the first results are promising (cf. hydromorphological improvements).
- Additional studies are carried out in order to make concrete proposals for improving reconnection with tributaries and habitats quality and diversity.

Hydromorphological improvements:

- More than 90% of the spawning zones appeared already preserved.

Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

From the hydroelectricity producer point of view, the cost is estimated at about 200k€/year (production optimization loss).

Costs of the measure (€):

Not specified

Literature and/or contact:

M. Larinier, Groupe d'Hydraulique Appliquée aux Aménagements Piscicoles et à la Protection de l'Environnement (GHAPPE), Toulouse, France - Larinier@imft.fr



H2/15 - Bypass channels at the short-term regulated River Oulujoki

Driving force:	Hydropower
Pressure:	Damming, short-term regulation
Impact:	Hydromorphological changes affecting habitat and species diversity
Country:	Finland
Location:	River Oulujoki, North Ostrobothnia
Water Body at risk:	Yes, preliminary identified as heavily modified

H2 15

A Status before reconstruction

Status of construction:

- The River Oulujoki is efficiently built for hydropower production. The seven power plants are using almost all of the 122 m natural head loss at the distance of 110 km between Lake Oulujärvi and the sea. The plants have small water reservoirs. Due to short-term regulation, the discharge varies daily and weekly. Typical summer time variation is between 50 and 250 m³/s and specified flow rate 450 m³/s.

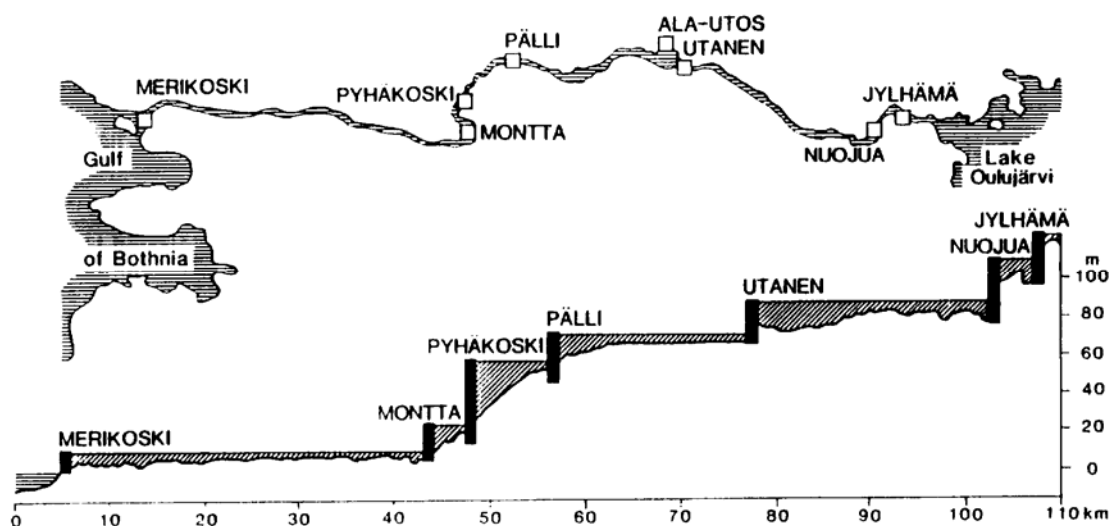


Figure 1: Schematic picture of the River Oulujoki and the power plants.

Ecological deficiency:

- Nature of the river has changed into a chain of small lakes with short retention times and river stretches with slow water flows due to hydromorphological



changes. As a consequence, the original fish fauna of the river has changed. Damming has interrupted the migration of fish such as salmon and trout. All the notable rapid sections (some 400 - 500 ha) have disappeared affecting the breeding and living areas of fish and bottom fauna species. In the tributaries there are altogether 40 hectares of rapid sections.

B Reconstruction by restoration / mitigation measures

Implemented measures:

- The lowermost power plant Merikoski has a fishway which allows migration to the half of the river as well as to the two main tributaries.
- Currently, fish stockings are made systematically in the river area and sea in front of the river.
- Additional stream habitat restoration measures have been carried out in certain places of the river. These measures cover practically all suitable places. Altogether the extent of these measures is only few hectares.

Further ecological improvements:

- Building bypass channels to the six power plants has been considered in a preliminary study. The aim would be to create rapid-like stream habitat in the river and allow access to the upper reaches and tributaries.

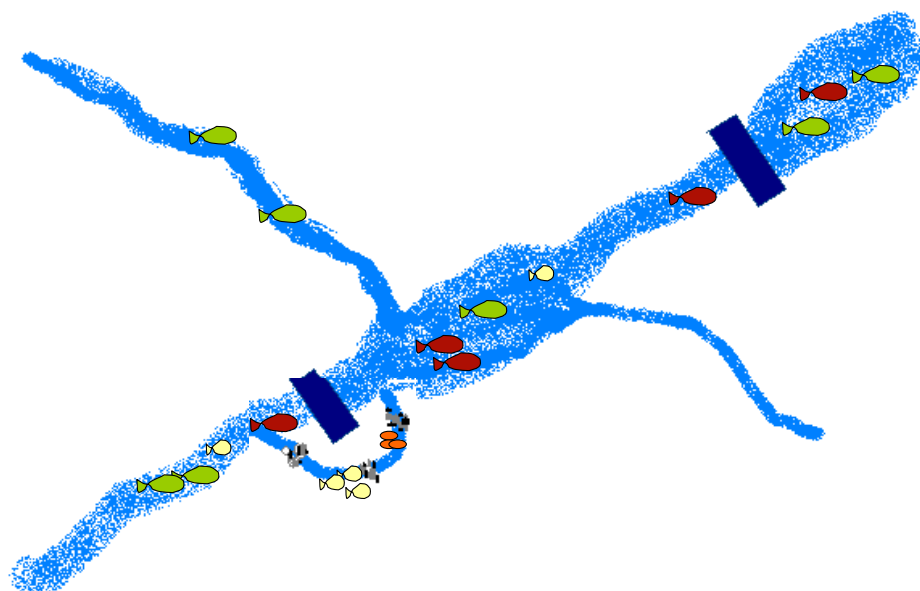


Figure 2: Schematic picture of the bypass channel in one power plant.



Further hydromorphological improvements:

- The continuity of the river would be improved by the six bypass channels. Also access to the tributaries would be allowed.
- A flow of 2 - 5 m³/s in a bypass channel would produce in total 5 - 12 hectares of stream habitat. The rapid-like areas would increase diversity on water velocities and depths. Additionally, the bottom structure of the bypass channels could be designed to have variation in coarseness.

Ecological improvements:

- 5 - 12 hectares of stream habitat could produce 500 - 1200 smolts. According to different studies survival of natural smolts is higher than stocked fish.
- The channels would create brook-like habitat for bottom fauna species.

Assessment of the ecological efficiency:

- The expansion of the smolt-producing area would be relatively small. It is unlikely that the habitats could maintain a self-sustaining population and life-cycle due to the mortality and uncertain migration to the furthest power plants.
- The brook-like habitat might be better for trout and grayling than salmon. Salmon normally requires bigger streams.
- The bottom fauna species maintained by the new habitats would not be typical for a larger river but for a smaller stream. A demand of type-specific communities in the Water Framework Directive would therefore not be fulfilled.
- To sum up: The ecological changes would not extend to the scale of whole water body but they would concentrate on narrow sections of the artificial channels. It is obvious that the changes do not affect the WFD status classification in the scale of the whole water body.

	High	Medium	Low
In the area of the measure		X	
In the upstream areas			X
In the whole water body			X

Effects on the uses:

- Effect on the use due to the loss of water. The six bypass channels with 2 - 5 m³/s discharge would cause energy loss of 2 - 4.8 MW which equals 18 - 45 GWh.

Costs of the measure (€):

Construction costs are not assessed. Cost assessment is inaccurate due to the small amount of cases implemented in large power plants in Finland. Based on the experience of earlier built natural bypass channels the costs can roughly be assessed by:

- Water intake constructions: 100,000 €/plant x 6 plants = 600,000 €
- Channel construction: 15 – 40,000 € / head meter x 112 m = 1,700 – 4,500 k€
- Totally: 2.3 - 5.1 million €.



- Annual cost due to the lost energy: 500,000 – 1,250,000 € with 2 - 5 m³/s discharge
- For comparison: The annual costs of current fish stocking measures (250,000 smolts) are 20,000 € on the river area and almost 400,000 € on the sea area.

Applications:

- The fish pass constructions may be suitable in water bodies with remaining migrative populations and breeding areas upstreams. The fewer migrations obstructions have to be passed, the fewer are losses in migration. There may also be populations that benefit from breeding areas created by the pass construction, but the extent of the ecological efficiency varies case by case. Effects on the uses are probable and have to be assessed case by case.

H2 15

Literature and/or contact:

Mika Marttunen, Finnish Environment Institute, mika.marttunen@ymparisto.fi

References:

Studies on effects of the short-term regulation of hydro power plants. 1996. Suomen ympäristö 66. North Ostrobothnia Regional Environment Centre, Oulu.

Multiple use and related environmental problems of northern river basin. Oulujoki-case study - first phase/third milestone. Hellsten, S & Visuri, M. (ed). Oulu 28-feb-06. "Watersketch."



H2/16 - Catch and transport of migrating fishes

Driving force:	Hydropower generation
Pressure:	Dams
Impact:	Morphological change (impaired continuity); impaired passage for migrating fishes
Country:	France (EURELECTRIC)
Location:	Garonne River between Camon and Carbonne
Water Body at risk:	Yes; provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Succession of dams on the river Garonne

Ecological deficiency:

- Multiple obstacles limiting fish migration (loss of ecological continuity at the dams)

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Construction of capture sites on the Garonne river
 - In the lower part (Carbonne) to catch and transport (by van) migrating species to an upstream site, from which they swim up to adapted spawning areas
 - In the upper part (Camon) to catch and transport (by van) migrating species to a downstream site, from which they swim down to the sea



Figure 1: Left:
The downstream capture site for transport upstream.



Right:
The upstream capture site for transport downstream.

H2
16



H2 16

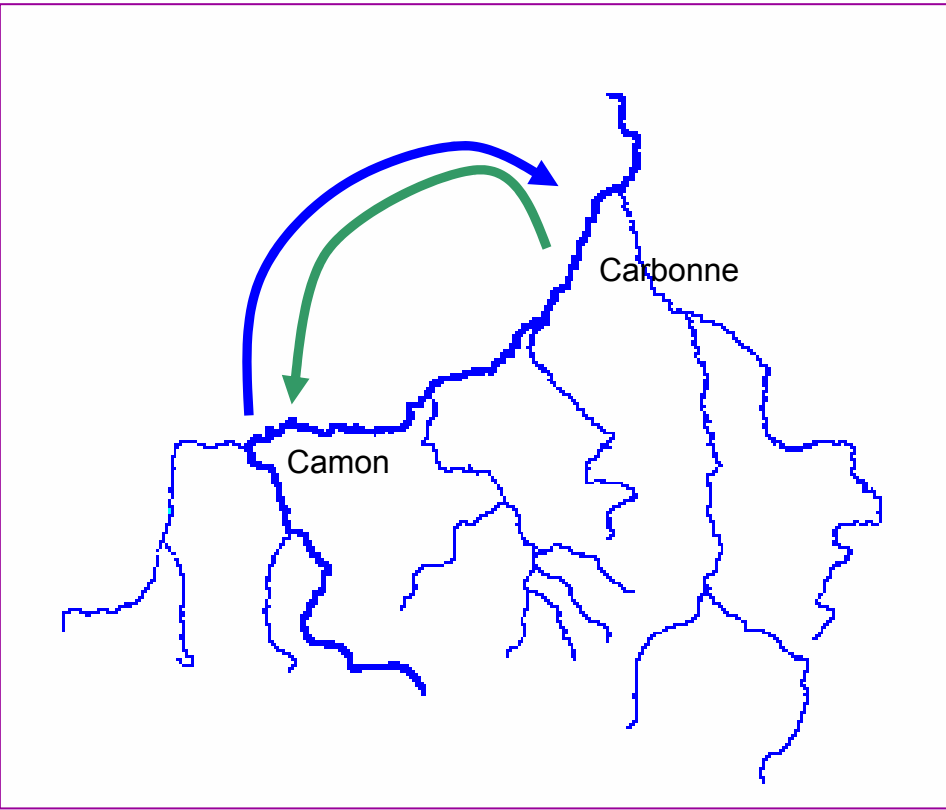


Figure 2: Garonne river and capture sites for up and down transport (distance of around 50 km between Camon and Carbonne).

Accompanying measures:

- Monitoring: quantitative assessment of the migrating population
- Sanitary monitoring of migrating fishes
- Removal of some genitors for pisciculture in order to improve natural recovery

Hydromorphological improvements:

- No hydromorphological improvements

Ecological improvements:

- Restoration of a migrating fish population in the Garonne river (mainly salmon): higher number of young fishes reaching the sea while genitors reach the most adapted spawning areas

Assessment of the ecological efficiency:

- Monitoring stations have been operational since 1999 on the Garonne (3 for upstream at Golfech (fish pass), Le Bazacle (fish pass) and Carbonne and 2 for downstream counting devices at Pointis and Camon). In 2005, the monitoring system recorded 600 adult salmon back to the Garonne river.

High	Medium	Low
	X	



Effects on the uses:

- No adverse effect on hydroelectricity production.

Costs of the measure (€):

Estimated around 1.5 – 2.3 M€ (and running costs of 0.1 M€/year)

Literature and/or contact:

References: www.Migado.fr

**H2
16**



H2/17 - Fish compensation measures in the regulated River Klarälven

Driving force:	Hydropower
Pressure:	Damming, short-term regulation
Impact:	Hydromorphological changes affecting habitat and species diversity
Country:	Sweden (EURELECTRIC)
Location:	River Klarälven
Water Body at risk:	Yes, preliminary identified as heavily modified

**H2
17**

A Status before reconstruction

Status of construction:

- In the mainstream of the River Klarälven there are 9 hydropower plants. The annual production of these plants is 1.3 TWh. They were built between the years 1906 and 1962. There is a refurbishment program ongoing.
- The top level at the uppermost Höljes power plant is 304 meters above sea level. The Höljes reservoir has regulation amplitude of 34.5 m. The other eight plants have small water reservoirs. The degree of regulation is 9 %. Due to the short-term regulation at Höljes the discharge varies daily and weekly. The mean flow in river Klarälven is 165 m³/s and the highest measured flow is 1650 m³/s.
- The lowermost plant, Forshaga is situated close to the mouth of river Klarälven into the lake Vänern (45 m.a.s.l), the largest lake in Sweden. Karlstad, the county town, is located on a delta at the river mouth. The Klarälven catchment area is 11,820 km², and 44.6 % of the area is situated in Norway. The Norwegian name of the river is Trysilleva. The river length is 460 km totally, 300 km of it in Sweden.
- Log driving was carried out till 1991. The log driving was made possible by dredging the river.
- Electricity produced by seven power plants is sold as eco-labelled according to the Swedish Society of Nature Conservation "Bra Miljöval" label. There are requirements of a minimum discharge in the licensed plants and also funding of part of the income for environmental measures. There is a habitat restoration program for creating spawning areas after dredging has removed them. This project is partly financed by the Hydro Power Company and the municipality of Torsby, and it is carried out during the summer of 2005 and 2006.

H2 17

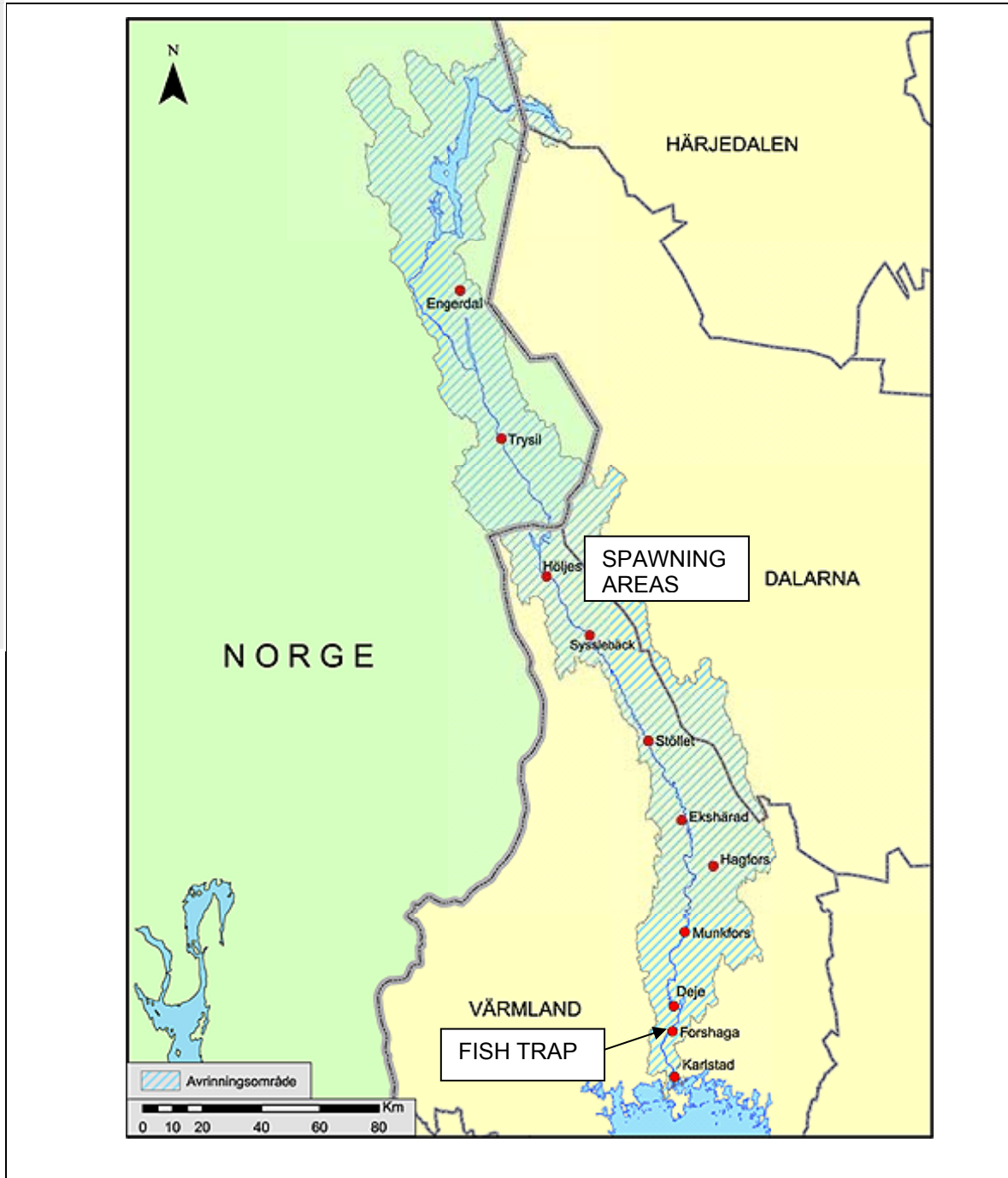


Figure 1: Map showing the River Klarälven catchment area.

Ecological deficiency:

- Damming has interrupted the migration of fish such as salmon and trout. The fish have to pass eight dams to reach spawning grounds. Damming and dredging have reduced the spawning and breeding areas. There is a stretch in the river between Höljes and Edsforsten where there are still some rapids and good spawning grounds.
- There are two famous salmon species (and two trout) that migrate in Klarälven; the Klarälven and the Gullspång salmon. They are special because they are freshwater salmon.



B Reconstruction by restoration / mitigation measures

Execution of the measure:

- The lowermost power plant Forshaga has a fish trap which is used during the season of fish migration. Fish captured in the trap are used as parent fish for stocking, both salmon of both types and trout, all according to the permit of the power plant. After two years at the fish stocking the fry are ready to leave for a life in the lake Vänern.
- Some fish trapped at Forshaga are just let out on the upper side of the dam, they are of the Gullspång type and it must not breed in the river Klarälven. That measure is just for leisure-fishing.
- Klarälven salmon captured at the Forshaga are transported upstream in the river. They are transported to spawning grounds upstream the Edsforsen Hydro Power Plant. All is done with full control from fishery authorities.

Accompanying measures:

- Restoration in tributaries has been carried out. Fishways have been built and restoration of the log dredging, these measures have been financed by the Torsby municipality.

Hydromorphological improvements:

- Hydromorphological improvements due to fishways in tributaries. The transportation of fish could also be considered as an improvement of the continuity in the river, and when fish pass the power plants on their way to Vänern they survive to a large extent.

Assessment of the ecological efficiency:

- Fish are transported efficiently to their breeding areas without losses caused by fishing or difficulties in passing several fishways. In addition, parent fish are caught for stocking purposes which helps maintaining the unique populations of lake salmons and trout. Measures can be adapted according to the fish disease situation in Lake Vänern.
- According to fishery authorities, fishways would not be efficient when fish have to pass several dams to reach spawning areas. The loss would be high and only a small percentage would be able to pass.
- Annual salmon and trout amounts have varied between 2300 and 4500 in the recent years. Among the trapped fish the portion of trout from natural life cycle is 7 % and salmon from natural life cycle 35 % due to the transportation to the upper breeding areas. The result from 2005 shows that the portion of salmon from natural life cycle was more than 50 %.
- The ecological effects are directed at the whole water body to the extent that is possible.
- The measure is suitable for places with several migration obstructions. Ecological efficiency can be gained without major fishing restrictions.

**H2
17**



High	Medium	Low
X		

Effects on the uses:

- No effects on the hydropower production. All measures are done without loss of water.

Costs of the measure (€):

Annual costs of the trapping and transportation measures are approximately 35,000 €.

Literature and/or contact:

Contact persons: Per Nyberg at Swedish Board of Fisheries in Örebro
alt. Birgitta Adell Fortum Generation AB Stockholm

**H2
17**



H2/18 - Hydroecological diagnosis and hydropower installations management - the case of La Fontolière

Driving force:	Hydropower generation
Pressure:	Dam & hydropower plants
Impact:	Impaired flow dynamics (reduced flow, artificial discharge regime); disruption in river biological continuum and lateral connectivity
Country:	France
Location:	La Fontolière (Ardèche basin; WFD district: Rhône)
Water Body at risk:	WB not provisionally identified as HMWB Likely environmental objective: Good Status by 2015

H2
18

A Status before reconstruction

Status of construction:

- River of 20 km-length and a 134 km² catchment area with a Mediterranean hydrological natural regime and a good chemical quality.
- Two hydropower plants are built:
 - A dam at Pont de Veyrières, with a base flow $\approx 1 \text{ m}^3/\text{s}$ and a ratio between hydropeaking and base flow ≈ 15 ;
 - A micro-power plant at Pradel, with a base flow ratio $\approx 0.12 \text{ m}^3/\text{s}$ between hydropeaking and base flow ≈ 150 .
- Two sites, one downstream Pont de Veyrières (S2) and another downstream Pradel (S3) are compared to a reference site (S1) upstream obstacles.

Ecological deficiency:

- Impaired flow dynamics lead to changes in biological communities, especially:
 - Fish :
 - At S1, fish populations are composed by *Salmo fario* (trout) and *Phoxinus phoxinus* (minnow) (reference coenosis),
 - At S2, *Salmo fario* and *Phoxinus phoxinus* are also the dominant fish species but many others are also present in low density: *Cottus gobio* (miller's thumb), *Gobio gobio* (gudgeon), *Noemacheilus barbatulus* (loach), *Leuciscus* (blageon in French) and *Anguilla anguilla* (eel),
 - At S3, the dominant species are *Phoxinus phoxinus*, *Gobio gobio* and *Noemacheilus barbatulus*; *Leuciscus* is also present,
 - Density and biomass of trout population are lower at S2 than at S1; they are lower at S3 than at S2 and very much lower than at S.
 - Macroinvertebrates: diversity is reduced at S2 and very much reduced at S3 compared to S1, with a loss of most of the specific sensitive species (*Plecoptera*, *Ephemeroptera*, *Diptera*).



- Moreover, due to the very low base flow at S3, excess of algal and high chlorophyll biomass are observed.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- This three year study allows to compare two different artificial regimes and their biological impacts.
- It demonstrates the importance of maintaining:
 - A base flow which is not too low;
 - A ratio between hydropowering and base flow which is not too high.

Accompanying measures:

- Hydraulic support by water transfers from bordering river basins

Hydromorphological improvements:

- The assessment of biological elements shows that hydromorphological conditions enable the achievement of Good Ecological Status by 2015.

Ecological improvements:

- When the base flow is too low (S3), lentic conditions become a limiting factor and aquatic communities are destructured in comparison with the natural reach.
- In contrast, biological communities (fish, macroinvertebrates and algae) are less impacted when a minimum base flow is maintained and the ratio between hydropowering and base flow is reduced (S2).
- This study shows also that in order to guide hydropower installations management, ecological diagnosis can't only rely on monitoring a monospecific community biomass, but should include a study of the structure and composition of biological communities.

Assessment of the ecological efficiency:

High	Medium	Low
X		

Effects on the uses:

- Low

Costs of the measure (€):

Not specified

Literature and/or contact:

Valentin S., Effets des éclusées hydroélectriques en rivière : diagnostic hydroécologique et aide à la gestion, exemple de la Fontaulière (Ardèche), in la Houille Blanche n°25-1996.



H2/19 - Minimum flow requirements and reconstruction of riverbed after canalization and overgrowing in Børselva river, northern Norway

Driving force:	Hydropower production from existing project bypassing the river
Pressure:	No environmental flow requirements, hence none or low water discharge downstream of the dam. Canalisation and eutrophication.
Impact:	Heavy impact on biology at site. Reduced floods, less water and high increased amount of nutrients
Country:	Norway
Location:	River Børselva, northern Norway
Water Body at risk:	Yes, provisionally identified as HMWB

H2
19

A Status before reconstruction

Status of river section:

- The river section is approximately 4 km long, and has been provisionally identified as HMWB. Its typology parameters show high alkalinity, low colour and altitude.
- The hydropower production was licensed in 1922, without any requirements for release of minimum flow. The upper part of the river was also canalized due to the old hydropower construction. As a result the upper part of the river had higher flow velocity combined with inadequate water supply. The down part of the river had calm water kept in wide pools in the river but much lower flow velocity in many stretches.
- The river system is a very important area for demanding water birds and also inhabits a big-growing trout stock. A natural threshold downstream the river stretch acts as a barrier for anadromous fishes.

Ecological deficiency:

- Almost no water flow for long period of time.
- Loss of river biota and change in river biota.
- Eutrophication causes low water quality less habitats and habitat diversity and change in vital species composition.
- Difficulties for fish migrating, continuity breach. High density of water plants causes migration barriers.

B Reconstruction by restoration/mitigation measures

Execution of the measure:

- In the new concession of 1997, the following requirements were given for this river section:
 - Minimum continuous flow requirements of 0.1 m³/s and maximum continuous flow requirements of 0.5 m³/s. For two annual periods the flow requirements are 5 m³/s in ten days duration.



- The government authorities are allowed to require necessary restoration measures to optimize the physical and ecological conditions for wildlife and river biota.

Accompanying measures:

- Norwegian Water Resources and Energy Directorate, NVE and Norwegian Water Research Institute, NIVA worked out measures on the requirement for minimum water flow and flooding like flow periods. The intentions were to create a water environment adapted to the new flow regime and at the same time optimize the ecological and physical conditions in and along the riverbed.

Hydromorphological improvements:

- The upper part of the water course was withdrawn by putting the sterile channelled river flow with mass terrain. Masses were originally, due to the old power station, put up like a rough embankment along the left side of this river stretch. The river was then manoeuvred back towards its original profile and stratum with a combination of wide pools and smaller weirs creating moderate runs. Spawning material was also added to the riverbed in places with moderate water flow velocity.
- Further down the river stretch with calm water and overgrowing areas and profiles. A continuous and open river stretch was created. The river stretch was opened partly by digging and by putting mesh and filling the bottom of the river with gravel. Some areas were also added with some bigger stones and large woody debris to increase the diversity in current condition and river biota. Moreover, there were build two weirs to raise the water level some in the lower part of the river stretch. As a result, a more current flow was established, and at the same time more open water surface and areas covered with water was created. This was important for essential river biota.

H2
19



Figure 1: Mesh and gravel are added to create an open stretch through a river profile which originally was totally overgrown by vegetation.



H2
19

Figure 2: Bigger stones are also added to the river bottom to increase velocity of the flow and to create bigger variety in habitats.



Figure 3: River stretch in the upper part before mitigation. A low amount of water is flowing and the stone embankments are lying along the canalized profile. Done in 1922.



H2 19



Figure 4: The same river stretch after the new requirement of minimum flow and after creating a new riverbed with pools and moderate runs adapted to the new discharge.

Ecological improvements:

- In the meantime, water environment, water quality as well as fish habitats have already shown positive effects by the measures taken.

Assessment of the ecological efficiency:

- In connection with measures taken, a number of surveys were conducted as well as testing of water quality, wildlife and aquatic plants in the river system. Further surveys are planned in the next few years.

High	Medium	Low
X		

Effects on the uses:

- The effects seem to be high according to angling and outdoor life.

Costs of the measure (€):

250,000 EU

Literature and/or contact:

NIVA publication reports
Contact: Karl Jan Aanes (NIVA) Norwegian Institute for Water Research



H2/20 - Restoring the Loire: The “Plan Loire Grandeur Nature”

Driving force:	Hydropower and Flood protection
Pressure:	Dams, dykes
Impact:	Sharp decrease in migratory fish species, i.e. Eel, Atlantic Salmon (on the brink of extinction), Shad, Lamprey. Disappearance of the Sturgeon.
Country:	France (WWF)
Location:	Loire basin
Water Body at risk:	Yes, provisionally identified as HMWB. (Upper Allier, Vienne, middle and upper Loire (Loire catchment))

H2
20

A Status before reconstruction

Status of construction:

- 53 large dams on the basin, and at least, according to official figures, 10 000 structures, many of them abandoned, on the basin. 1000 km of dykes on the medium part of the river.
- A public body, the Epala wanted to build four more dams on the basin. The Loire Vivante struggle, between 1986 and 1994, managed to prevent building. In 1994, a promising “Plan Loire Grandeur Nature” has been launched by France. The Epala, with a new name, EPL - Etablissement Public Loire -, is cooperating strongly with the NGO’s, especially with WWF France.

Ecological deficiency:

- Sharp decrease in migratory fish species, i.e. Eel, Atlantic Salmon (on the brink of extinction), Shad, Lamprey. Disappearance of the Sturgeon.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Since 1994, a massive restoration programme has been launched, the “Plan Loire Grandeur Nature”. Two large dam projects have been given up; 4 small dams have been torn down; fish ladders have been built where it was impossible to remove the dams. A large restoration programme, Loire Nature (15 millions euros) has been implemented (2002-2006), with the help of national NGO’s: LPO, Conservatoires, WWF, following a LIFE / Loire Nature programme, 1993 –1997.

Accompanying measures:

- Almost the whole Loire basin is now designated in the Natura 2000 network. A Life programme has been implemented, 2000 –2004, through LOGRAMI (Loire Grands Migrateurs), around 2.5 million euros, to help Salmon restoration.
- WWF has launched a campaign, together with 30 other organizations, among them professional fishermen, to replace the Poutès-Monistrol dam, on the

upper Allier, very destructive for salmon with energy efficiency and other renewable sources (windmills, wood energy, solar)

Hydromorphological improvements:

- Restoration of the river’s continuum through the removal of some obsolete dams
- In the city of Brives-Charensac, on the upper Loire basin, three plants (250 workers) have been removed and installed in non floodable parts of the basin to let more room for the floods.

Ecological improvements:

- An increase in Salmon return, from 100 in 1992 to 900 in 2006
- Massive return of Lampreys and Shads, since removal of the Maisons-Rouges dam
- Return of other species: Rôle des Genêts, through replacement of maize fields with pastures, in cooperation with farmers

Assessment of the ecological efficiency:

- The returns are high, and rewarding

High	Medium	Low
X		

Effects on the uses:

- Almost every user is now taking into account the fact that a water body is fragile, and that the resource is limited. There are nevertheless progresses to make, especially in the agricultural field, and in the hydroelectricity sector. Salmon is still at high risks.

Costs of the measure (€):

Around 600 million euros have been spent up to now, mainly in the flood risk management issue. A phase 3 of the programme, 2007 –2012, is currently under discussion between all the partners, including the NGO’s.

Literature and/or contact:

Managing Rivers Wisely
 Lessons form WWF’s work for integrated river basin management
 Living Waters Programme WWF Internaitonal Avenue du Mont Blanc 1196 Switzerland
 Tél. 41 22 364 9030
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N2/01 – Bed load management in the river Elbe

Driving force:	Navigation, Flood protection, Hydropower
Pressure:	River training by groynes, dyke construction, impounding
Impact:	Increased sediment transport capacity, reduced bed load supply, bed degradation, lowering of water levels, drawdown in the floodplain
Country:	Germany
Location:	River Elbe, km 120-230
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Narrowing of the floodplain and river training by groynes have increased the sediment transport capacity of the free flowing river. On the other hand the impounding of the upper course by weirs has drastically reduced the natural bed load supply from upstream.
- The resulting bed degradation due to erosion of bed material is clearly indicated by the increase of bed load and suspended sand load between Torgau and Barby (cf. Figure 1).

Ecological deficiency:

- Bed degradation causes lowering of surface water and groundwater levels. This leads on the long term to drawdown in the floodplain and to a potential loss of alluvial forest with its specific vegetation and fauna.

N2
01

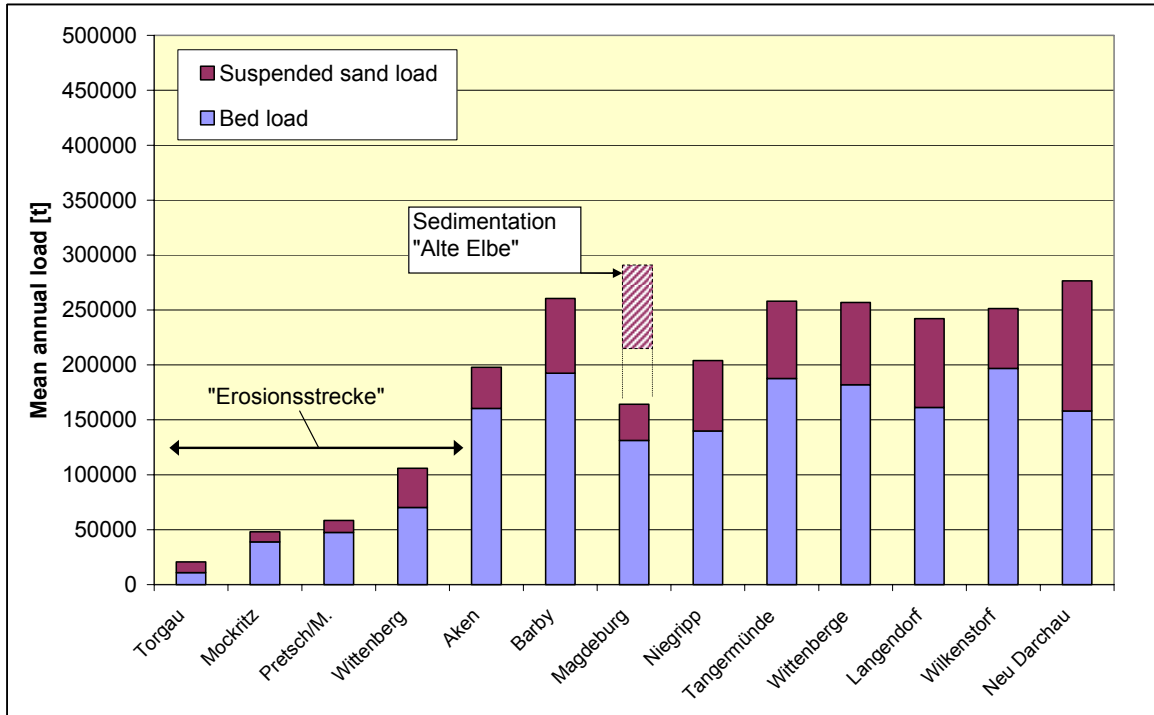


Figure 1: Bed load and suspended sand load in the Elbe River from km 155 (Torgau) to km 536 (Neu Darchau).

**N2
01**

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: Water and Shipping Authority Dresden, Water and Shipping Directorate East, Federal Institute for Hydraulic Engineering, Federal Institute of Hydrology

Project: Bed load management in the “Erosionsstrecke” of the Elbe river

- A dynamic bed stabilization is aimed at by artificial bed load supply at four sites between Elbe-km 153.8 and Elbe-km 193.2. Between 1996 and 2002 all in all 242,000 tons of gravel and sand were dumped by special barges (cf. Figure 2). After a break in 2003 the operation was resumed in 2004. The material dumped originates from both adjacent gravel pits and from dredging sites in the river itself.
- Two tracer tests, one using a petrographic tracer, the other operating with luminescent material allow to quantify the migration velocity of the dumped material.
- Changes of the riverbed morphology are controlled by echo-sounding surveys and modelled by an one dimensional morphodynamic model.



Figure 2: Dredging and dumping of additional bed load into the "Erosionsstrecke" of the Elbe River.

Accompanying measures:

- Surveying of the macrozoobenthos communities along the "Erosionsstrecke" to check whether bed load management has an impact on the river fauna.

Hydromorphological improvements:

- The additional bed load material reduces bed degradation and decelerates the lowering of the river- and groundwater levels.

Ecological improvements:

- Stabilization of the groundwater level and preservation of the alluvial forest in the floodplain (cf. Figure 3).

Assessment of the ecological efficiency:

- Assessment of the ecological efficiency is not yet possible. The monitoring of the hydromorphology indicates a local stabilization of the riverbed. Long term monitoring is necessary to verify the success of the measure.

High	Medium	Low
high - low		

**N2
01**



**N2
01**

Figure 3: Alluvial forest along the Elbe River.

Effects on the uses:

- No negative consequences for navigation

Costs of the measure (€):

Not available

Literature and/or contact:

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Homepage: <http://www.bafg.de>



N2/02 – Modification of groynes at Elbe riverbanks – ecological investigations on the impact of construction on habitats and distribution of species

Driving force:	Navigation
Pressure:	Cross profile construction (groynes)
Impact:	Loss of structural diversity along riverbanks, loss of river type specific and wetland specific communities
Country:	Germany
Location:	River Elbe, km 439-445
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

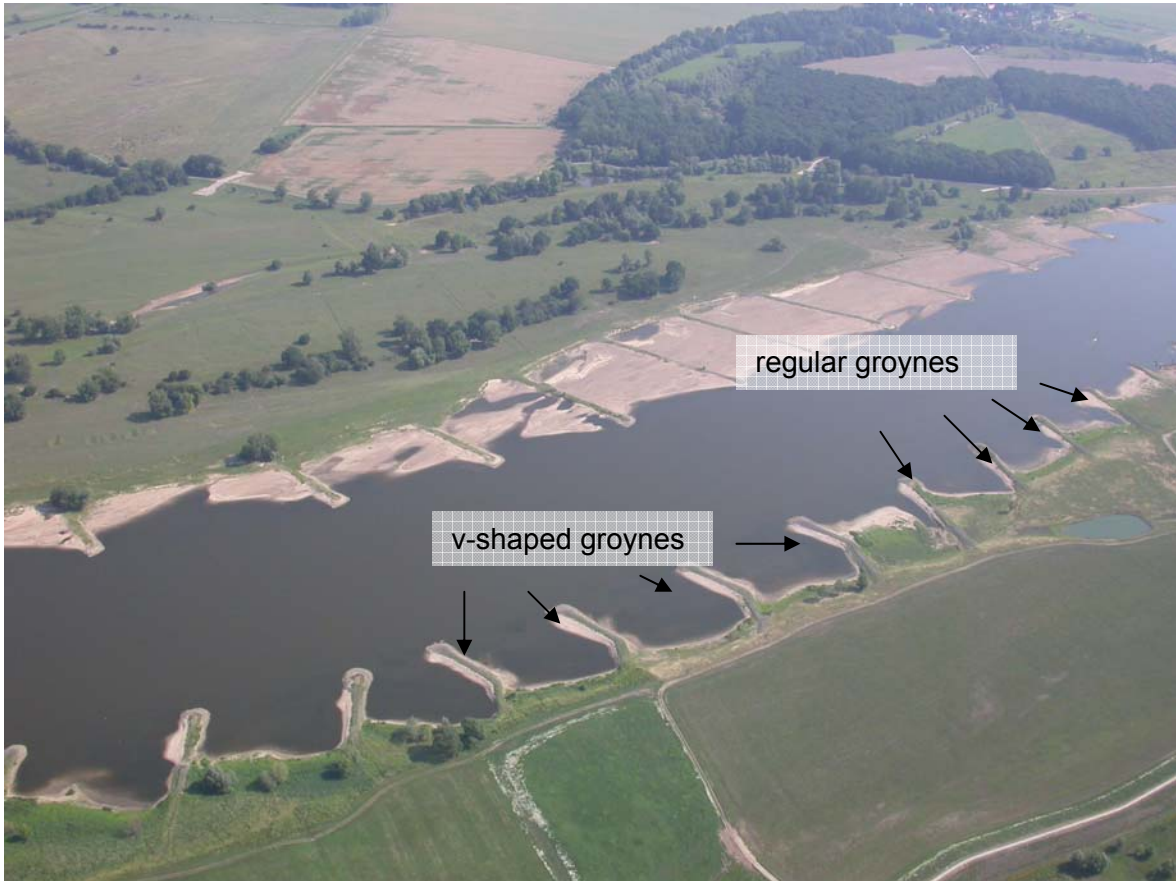
Status of construction:

- More than 6,900 groynes stabilize the riverbed at mean water level and assure the navigability along the whole river Elbe.
- In parts of the middle Elbe river regulation measures have been reduced until German unification. For this reason about 1,500 groynes are full or partially damaged and therefore lose their hydraulic function.

Ecological deficiency:

- The fixing of the riverbed results in a loss of structural diversity along the riverbanks.
- The regular inclined groynes induce a long-term siltation process in the groyne fields leading to a loss in typical riverine habitats such as scours or gravel banks.

**N2
02**



N2
02

Figure 1: Study site 1 (Elbe-km 440.2 - 441.1) with regular and modified groynes; silted groyne fields.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: Federal Institute for Hydrology, Federal Institute for Hydraulic Engineering, Water and Shipping Authority Magdeburg

Project: Ecological modification of groynes at Elbe riverbanks

- Developing and monitoring of alternative groyne forms (cf. Figure 1 and 2):
 - Type I: v-shaped groyne inclined on the bank side and declined on the river side and
 - Type II: inclined groyne lowered by 1.20 m below mean water level on the riverbank sideto induce higher hydromorphological dynamics at the riverbanks.
- Modifying of partially damaged groynes to the new groyne forms within maintenance activities at two study sites in the middle Elbe region. At study site 1 (Elbe-km 440.2 - 441.1) four type I and two type II groynes were constructed (cf. Figure 1 and 3) and at study site 2 (Elbe- km 443.4 – 444.1), three type II groynes were built.

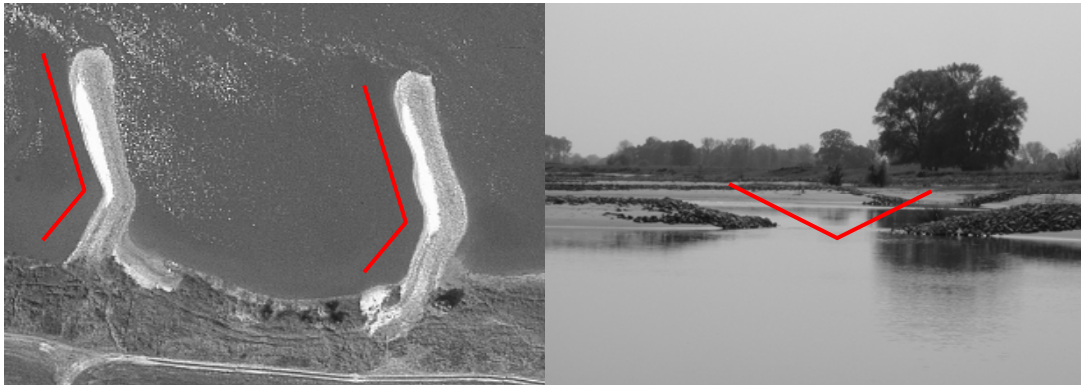


Figure 2: Modified groyne types

Left: type I – v-shaped groyne; Right: type II – lowered groyne

- Choosing of adjacent traditional inclined groynes as reference

Accompanying measures:

- Hydromorphological investigations (depth, current recording etc.) along the groynes and in the groyne fields were carried out.
- Carabid beetles, macrozoobenthos and fish were sampled to assess the influence of the different groyne forms on hydromorphological processes in the groyne fields.
- Biotope characteristics (vegetation etc.) along the regarded riverbank were mapped.

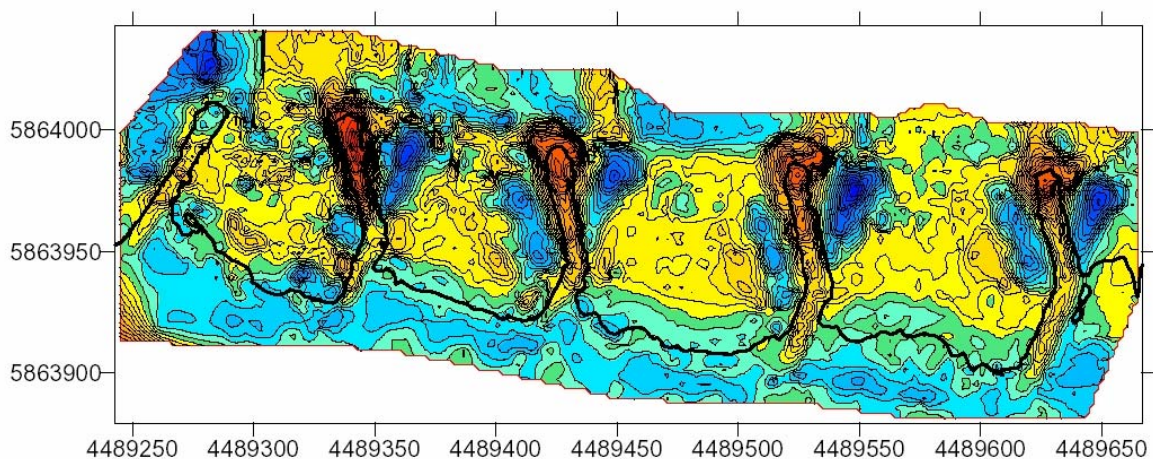


Figure 3: Study site 1 – changes in bed level after groyne modification.

Red areas: increasing bed level; Blue areas: decreasing bed level

Hydromorphological improvements:

- Induce higher hydromorphological dynamics at the riverbanks and thus decelerate the aggradation processes in the groyne fields

**N2
02**



Ecological improvements:

- Improve the structural diversity in the groyne fields to achieve better conditions for the aquatic fauna, especially juvenile fish, and thus compensate natural riverbank structures

Assessment of the ecological efficiency:

- Assessment is not yet possible, first results will be available at the end of 2006.

High	Medium	Low
high - low		

Effects on the uses:

- No negative consequences for navigation

Costs of the measure (€):

Not available.

Literature and/or contact:

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**N2
02**



N3/01 - Establishment of a floodplain-typical island habitat dominated by the dynamics of varying river stages with an adjacent floodway

Driving force:	Navigation
Pressure:	Changed routing
Impact:	Loss of typical floodplain sites dominated by the dynamics of varying river stages, loss of adequate spawning and breeding sites for fish and habitat for macrozoobenthos
Country:	Germany
Location:	River Moselle, km 183.8 - 184.7, near the harbour of Trier, District Ehrang
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Island (5.2 ha) including a flood spillway connected with the bank by a causeway

Ecological deficiency:

- Perturbation by recreational uses
- Deficiency in water exchange between river and flood spillway
- Lack of adequate habitat conditions for fish and macrozoobenthos

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: WSA Koblenz and WSA Trier

Project: Deepening of the River Moselle, measure pursuant to "Domestic nature conversation act"

- Interruption of the causeway (cf. Figure 1)
- Enlargement of the flood spillway and connecting it with the River Moselle for water exchange at mean-flow levels
- Initial planting of typical floodplain trees and shrubs

Accompanying measures:

- 10-year monitoring with morphological, faunistic and vegetation surveys (1994-2004)

**N3
01**

Hydromorphological improvements:

- Improvement of water exchange between flood spillway and river
- Improved physical-structural diversity of floodplain habitats
- Enlargement of shallow water zones



Figure 1: Hahnenwehr floodway (Photo of 1999 left, photo of 2004 right-arrow marks the interrupted courseway).

**N3
01**

Ecological improvements:

- Increased species diversity of macrozoobenthos
- Improved habitat conditions for fish
- Unhindered growth of vegetation typical for aquatic and floodplain habitat

Assessment of the ecological efficiency:

- Significant improvement of species richness and abundance of fish (shift of two quality classes), macrozoobenthos and birds (breeding and resting), significant expansion of aquatic vegetation and riparian woodland (willow species)

High	Medium	Low
X		

Effects on the uses:

- No significant negative consequences for navigation

Costs of the measure (€):

Not specified.

Literature and/or contact:

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**N3
01**



N3/02 - Controlling water levels in river-training projects to preserve floodplain habitats. The example of the Öberauer Schleife (cut-off meander)

Driving force:	Navigation
Pressure:	Changed routing
Impact:	Loss of characteristic flow and water-level variations in a cut-off meander, loss of river type specific and wetland specific communities (fauna, vegetation)
Country:	Germany
Location:	River Danube, Öberauer Schleife (cut-off meander) in the impoundment of Straubing
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Technically necessary cut-off of a river meander for river training of the Danube



Figure 1: The Öberauer Schleife (aerial view; south direction).

**N3
02**

Ecological deficiency:

- Because of the cut-off and the total sealing of the flood-defence dykes during the Danube river training, the river loop lost any connection to the main river and became an oxbow lake
- No flow of river water through the oxbow lake
- No variations of groundwater levels as responses to floodflow, mean-flow, or low flow conditions

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: Rhein-Main-Donau Wasserstrassen GmbH
Project: River training by impoundments and flood protection

- Measures taken to preserve the best possible water quality and to prevent eutrophication
- Preserving essential elements of the hydrological dynamics in the floodplain by artificial floods and low-water stages (cf. Figure 2)
- Maintaining a certain influence of seep water on the polder areas behind the dykes
- Preserving the floodplain meadows for breeding birds



Figure 2: Artificial flooding with influence on the adjacent polder of the Pittricher Wiesen (floodplain meadows) in March 1998.



Accompanying measures:

- Long-term monitoring over 10 years of the effectiveness of measures defined in the landscape plan

Hydromorphological improvements:

- Maintaining the groundwater dynamics in polder areas
- Supporting the water level during most of the growth period (imitating the former mean groundwater levels): Generating a flood situation in the upper part of the oxbow from mid-February to the end of March by surface water

Ecological improvements:

- Oxygenation of the water in the oxbow (the upstream inflow was backfilled and shaped as a rapid, strongly meandering watercourse with gravel bed).
- Trenches parallel to the dyke prevent access to the foreland, on the one hand, and divert water for artificial flooding into the remote furrow drains, on the other hand.
- The artificial flooding ensures the waterlogging of the meadows in spring and fills the furrow drains.
- In areas lying below the lower mean-water level, extremely flat slopes of river banks enlarge the amphibious zones and establish a wider bank vegetation zone.
- Establishment of a succession area south of the cut-off dam where nearly the whole species inventory of the amphibious zone is represented.

Assessment of the ecological efficiency:

- Assessment is not yet possible (The report will be submitted at the end of the 10-year effectiveness-monitoring period at the end of the year 2006.)

High	Medium	Low
X		

Effects on the uses:

- No significant negative consequences for navigation

Costs of the measure (€):

Not specified

Literature and/or contact:

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 56068 Koblenz
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N3/03 - Irrigation System in the Riparian Woodland between Korneuburg and Altenwörth (Danube river)

Driving Force:	Navigation
Pressure:	Changed routing (river regulation)
Impact:	Riverbed erosion, decreasing groundwater level, changing frequency of flood events
Country:	Austria (EURELECTRIC)
Location:	Danube between Altenwörth and Korneuburg
Water Body at risk:	At risk, HMWB candidate

A Status before reconstruction

Status of construction:

- The Greifenstein hydropower scheme with its impounded river reaches from the southern boundary of the largest riparian woodland in Central Europe, extending from the village of Altenwörth to the town of Korneuburg, and covering an area of more than 10,000 ha.

Ecological deficiency:

- As a result of the regulation of the Danube in the middle of the 19th century (which was to provide improved navigation, land reclamation and flood protection) a process of riverbed erosion began, the groundwater level decreased, and also the frequency of floods affecting the riverside forests was reduced. This resulted in an adverse impact on the environment, as the biotope of the river was threatened.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- *Irrigation System in the Riparian Woodland:*

When the power plant was built in the 1980's steps had to be taken to revitalize the old wooded area. Therefore an irrigation system, named "Giessgang", was installed. In the area concerned a lot of river branches, pools, hollows and creeks from the old widespread river system still existed, but these were mostly covered by layers of sedimentation or silted up. By the connection of this already existing system of old river branches a naturally structured irrigation channel of about 40 km length was created. Where possible, the layer of silt and mud were removed to give the water opportunity to infiltrate and to recharge the aquifer. Today the irrigated area looks revitalized and a significant change towards a flourishing riparian landscape has taken place.

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A flow of some 1.5 m/s to 5 m/s for irrigation is provided by small creeks draining the hinterland, by seepage from impoundment dykes, rainfall and – if necessary – by four intake structures on the backwater dykes of the Danube. The intake at the beginning of the irrigation system consists of an overfall dyke with a flood sill at a lower level. When high floods occur, water discharges over the whole length of the overfall and subsequently irrigates the floodplain of the hinterland.

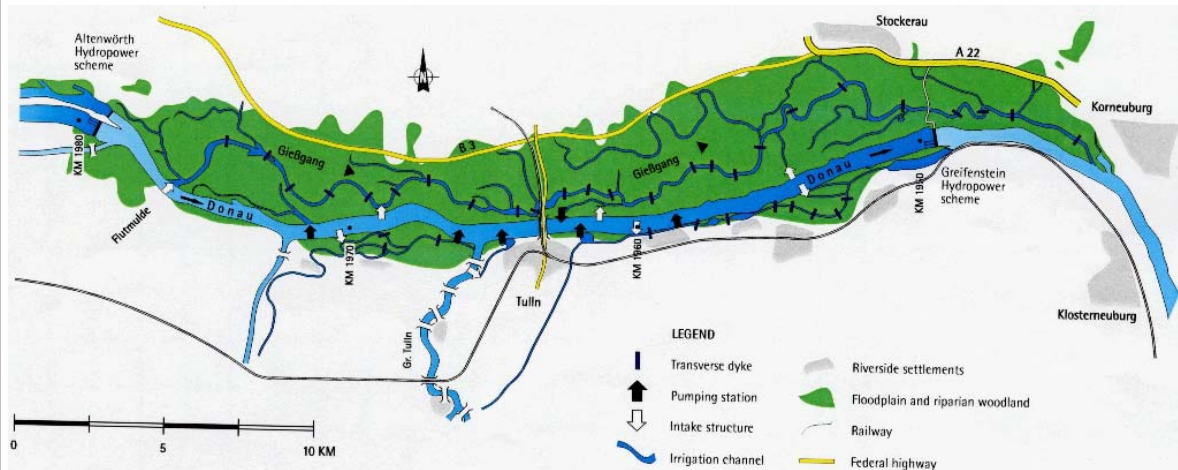


Figure 1: Overview of the “Giessgang system” between Altenwörth and Korneuburg.

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03**



Figure 2: “Giessgang” detail with transverse dyke



Figure 3: “Giessgang” with transverse dyke (airborn photograph)

Accompanying measures:

- The “Giessgang” itself is an accompanying measure of the Greifenstein HPP. The entire project was accompanied by research work of independent research institutes.



Hydromorphological improvements:

- In this way it was not only possible to stop the prevailing trend on the sinking groundwater level, but in addition, more favourable growth conditions could be created for the floodplain and its extensive forests. 25 transverse dykes with integrated culvert and adjustable flashboards also serve to regulate the groundwater level.
- It was a particular objective to raise the water table to its former original level and to maintain the influence of natural level fluctuation at the same time.
- To summarize, the results of the investigations and analyses on the ecological system of the Danube and the “Giessgang Greifenstein irrigation system” have led to a successful approach towards environmentally sound hydraulic engineering, especially in restoring the natural water-table, and revitalizing of the landscape of the riverside floodplain in this area.

Ecological improvements:

- Sustainable preservation of the Riparian Woodland and its ecosystem

Assessment of the ecological efficiency:

- Research work during a period of more than 10 years showed that the substantial goals of the project were achieved. Today the Riparian Woodland is secured in its substance.

High	Medium	Low
X		

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03

Effects on the uses:

- Positive image, advantages on flood protection

Costs of the measure (€):

Not available (included in the total costs of the Greifenstein HPP)

Literature and/or contact:

Verbund Austrian Hydropower AG, Am Hof 6a, A-1010 Vienna



N3/04 - Reconnection of oxbow lakes/ wetlands

(restoration measures proposed and implemented regardless of river processes)

Driving force:	Navigation, Flood protection
Pressure:	Straightening of the river channel, bank reinforcement, uniform shape of river channel
Impact:	Successive degradation of an oxbow river system, reduced hydrological connectivity
Country:	Slovakia
Location:	The Morava River, Slovak – Austrian border reach
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction

- The Morava river is lowland meandering river and in its lower reach creates one of the most valuable wetlands in Europe. Natural conditions have been significantly influenced by river engineering and training works (navigation and flood protection). The watercourse was considerably shortened (24 meanders were cut off) creating oxbow system. Lateral migration on the Morava river was prevented by hard type of bank revetments. Original floodplain of the river was significantly narrowed by continuous flood dykes.

Ecological Deficiency:

- River training works resulted in changes of the ecological character of the adjacent wetlands, but also in the loss of swampy biotopes, penetration of alien invasive species of plants; significant reduction of lateral connectivity and associated loss of side water bodies; successive degradation of the oxbow system; poor in-stream habitat diversity.
- *Abiotic consequences:*
River channel straightening, reduction in sediment supply (due to sediment being trapped in dams in upper reaches), bank pavements, commercial dredging and other human impacts resulted in: degradation of the river bed followed by decrease of surface and ground water levels; river bank instability – bank erosion; increased floodplain sedimentation - particularly in the oxbow system; limitation of hydrological connectivity.

B Reconstruction by restoration / mitigation measures

Execution of the measures:

- Four meanders in three localities were reconnected with the river channel (including inflow and outflow parts). The main aim of these measures was the

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04

restoration of hydrological connectivity, increasing of flow dynamics and protection of the oxbow system against successive degradation.

- Proposal and implementation of meander's reconnection was done with strong emphasis on ecological improvement regardless of present state of flow dynamics, sediment transport and overall functioning of the river ecosystem.

Impact of ecological improvements:

- The initial benefits of meander reconnection, resulting from increased flow dynamics, induced changes in the community structure of the aquatic fauna. These improvements proved to be short-lived due to successive degradation induced by high sediment supply and insufficient flow dynamics. Subsequently ecological conditions have been worsened.



Figure 1: Scheme of the Morava River in the section with reconnected meanders.

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Assessment of the hydromorphological efficiency:

- Monitoring results focused on ecology and hydromorphology (9 years) as well as the research results of surface and groundwater modeling and sediment transport indicated:
 - Water discharges transported relatively large volumes of sediments into meanders,
 - Dividing the flow between the river and the meander bend ensures that flow in the meander is not sufficient to transport the sediment load;
 - Considerable decrease of flow velocity has caused massive sedimentation and the resultant deposits rapidly blocked the entrance to the meander bend,
 - Present flow conditions are worse than those prior to meander reconnection

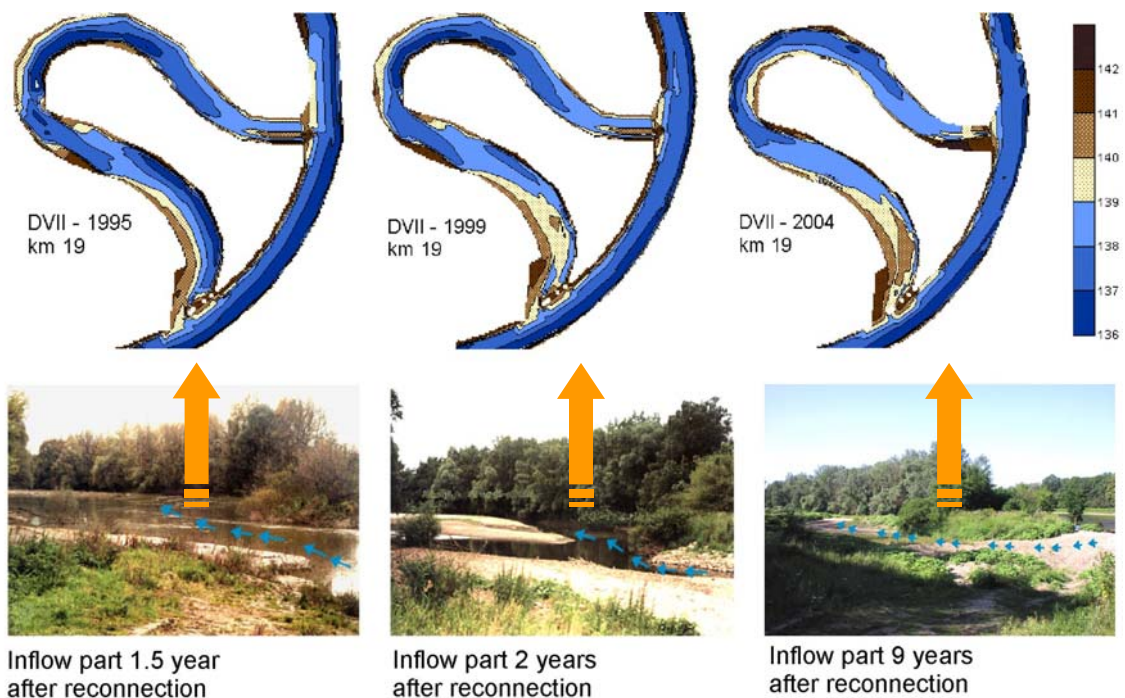


Figure 2: Inflow part of reconnected meander – successive degradation.

Assessment of the ecological efficiency:

- The failure to sustain hydrological connectivity in the bends caused that the required ecological response did not materialise and it worsened the meander bends to become even more isolated from the river,
- The reopening of meanders caused the decrease in species richness of the local hydrofauna. This was observed both in zooplankton and benthos in spite of the fact, that the content of biogenic elements increased as documented on chlorophyll-*a*,
- Present ecological conditions are not favorable neither for lenitic plesiopotamal nor for eupotamal biota,
- Former meander's reconnection requires essential improvement to stop the accelerated process of the meander's degradation and to minimize negative ecological and hydromorphological impacts

Effects on the uses:

- There was no specific impact on water uses.

Proposed improvement

Results of bio/abio monitoring and the research results indicated two types of restoration measures that could provide ecological improvement of the present state

1. Full meander integration (all flows diverted into meander) implemented in selected localities of the river in order to re-establish the dynamic equilibrium within the river reach. Meander integration would provide the required flow dynamics in the meanders, higher sinuosity and increased channel habitat diversity. This would also enable degraded river bed to be re-established later followed by associated changes in surface and ground

water regime (water level increase). Implementation of this measure would aid to habitat diversification and benefiting aquatic biota with high potential to achieve GES.

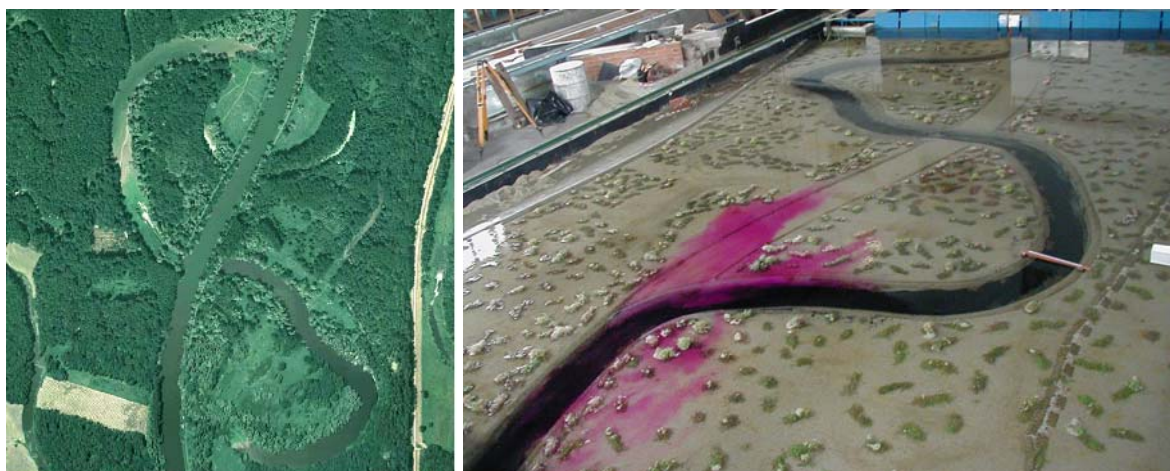


Figure 3: Present state and proposed improvement of the oxbow system on the Morava river (km 63) Current conditions - aerial photograph. Full meander integration – efficiency verification on physical model scenarios were analyzed on the hydraulic physical model.

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2. Reconnecting of the meanders only from lower part (outflow) would provide partial interaction with the main river channel and higher fluctuation of water levels but this would require continuous maintenance.

Further scenarios of meander's reconnection (verified by numerical and physical models) included various types of barriers and groyens in the main river channel with the aim to divert higher discharges into the meander and reduce sediment supply. The results of simulations for these scenarios indicated evident deterioration in the reconnected meanders due to low flow dynamics and high volumes of sediment, thus their implementation would require expensive maintenance and would mean further ecological devastation of the oxbow system.

Lesson learnt:

- Analyses of the present river processes have to be done prior to implementation of restoration measures; design of restoration measures have to be done with respect to this knowledge;
- Prior to implementation – the effect of proposed restoration measures on flow dynamics and sediment transport (at the rivers with active sediment transport) has to be evaluated considering the natural river processes and their interaction with the ecological functioning of the river ecosystem;
- Examples of restoration measures from the case study can be transfer to another river only if it is comparable in every detail to that in the case study – the river has to be of the same hydromorphological type and also has to have the same constraints and be of the same size.

Even if the implementation of the WFD requires simplified procedure for designation of restoration measures, some necessary analyses and evaluations have to be done prior to the implementation in order to avoid expensive rehabilitation failures and costly mistakes.



Literature and/or contact:

Katarina Holubova, Water Research Institute, Bratislava
holubova@vuvh.sk

References:

HOLUBOVÁ, K - LUKÁČ, M. (2000): Numerical modeling as a tool for optimal design of the Morava river wetland restoration. *Hydroinformatics' 2000*, 4th Intern., Conference, Iowa, USA.

HOLUBOVÁ, K. & LISICKÝ, M. (2001): River and environmental processes in the wetland restoration of the Morava River. Conference: *River Basin Management 2001*, Cardiff, Wales, UK.

HOLUBOVA, K., HEY, R. & LISICKY, M. J. (2005): Middle Danube Tributaries. Constraints and opportunities in Lowland River Restoration, : *Large Rivers* Vol. 15, No.1-4, Arch. Hydrobiol. Suppl. 155/1-4, p.507-519.

**N3
04**



N3/05 - Groundwater Management

Driving Force:	Navigation (River regulation (Danube), hydropower (HPP Freudenau))
Pressure:	Changed routing
Impact:	Sinking groundwater level
Country:	Austria (EURELECTRIC)
Location:	2 nd and 20 th district of Vienna, Danube area
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- As a result of the Danube river regulation in the 19th century the river erosion due to channelisation also led to a subsidence groundwater level at the “Prater” wetlands.

Ecological deficiency:

- Sinking groundwater level

B Reconstruction by restoration / mitigation measures

Execution of the measure:

In former days, the Danube represented a river system with intact bayous and river branches. Since 1850 flood protection measurements have been executed, which changed the hydromorphology; as a result, the Danube became more and more canalized. Due to the construction of the Freudenau Danube power plant, it became possible on one hand to raise the water balance in the side channels to a level which corresponds to the initial state. On the other hand due to the ensuring need for a sealing system along the right bank of the Danube over a 13 km distance, a groundwater management system and monitoring system had to be installed for the 2nd and 20th district of Vienna.

- *Management system:*

The essential components of the groundwater management system are: a groundwater model, recharging and abstraction wells and controlling wells, all connected to a control centre through a data transmission system. The groundwater level is controlled via 25 pairs of wells, each consisting of an abstracting and an infiltration well located on each side of the sealing wall. Depending on the discharge of the Danube and the groundwater levels, bank-filtered water is pumped from the extraction well to the infiltration well or pumped back from the infiltration well into the Danube.

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05

- Objectives:
- Preserving groundwater dynamics as a function of the water flow rate of the Danube
 - The prevention of the flooding of house basements
 - Raising the groundwater level in the “Prater” lowlands during the vegetation period
 - Monitoring and improving groundwater quality

Water management is automatically controlled by means of a mathematical groundwater model to assure the desired water quantity. All data relating to the management system such as water levels, pumping rates and water quality parameters from the on-line monitoring stations are continuously transmitted to the control centre.

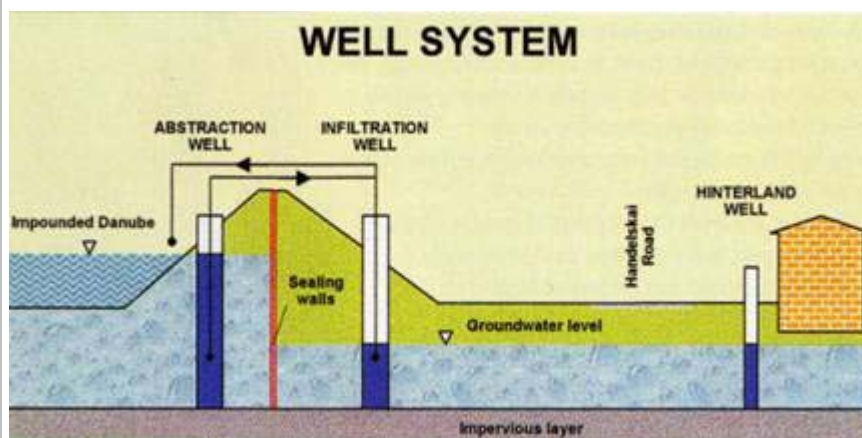


Figure 1: Well system of the groundwater management Freudenuau.

- *Model calculation:*

A numerical groundwater flow model was developed, which permits the simulation of groundwater dynamics in the entire project area. The transient model is based on representative hydrographic data series which were monitored over a long period. With the aid of this model, an optimum management concept could be devised and a system of wells (abstracting and recharging wells) planned.

- *Groundwater Monitoring:*

The infiltration of contaminated bank filtrate into the groundwater of the 2nd and 20th Vienna district is prevented through round-the-clock monitoring of the water quality in seven on-line monitoring stations. The bank-filtered water is analysed in three on-line stations and the Danube water in four monitoring stations. If a maximum permissible value is exceeded either in groundwater or in river water, the well operation is shut off. The following parameters are continuously analysed and recorded:

- Temperature
- Electrical conductivity
- pH value
- Redox potential
- Turbidity
- Oxygen concentration
- Ammonia



- Spectral absorption coefficient
- Organic carbon
- Total hydrocarbon (mineral oils and other petroleum products)



Figure 2: “Mauthnerwasser” in the Prater prior and after the introduction of the water management system.

- *Special remarks:*

This kind of groundwater management is a very special solution for urban areas as we have in Vienna. Due to the costs (investment costs and operating cost) of this kind of measure, such solutions can be realized only in connection with large hydropower project.

Accompanying measures:

- *Biomonitoring:*

The on-line monitoring station at Nussdorf for the Danube water monitoring is also equipped with a biomonitoring system using water fleas which are kept in a continuous flow system. The swimming pattern of the water fleas are constantly controlled using infrared sensors. If drastic changes occur in the behaviour pattern of the fleas, the system triggers an alarm and transmits the findings to monitoring service. Biomonitoring serves as an alternative to chemical tests which is capable of detecting active toxic conditions in the river water.

Hydromorphological improvements:

- Sustainable improvement of the groundwater situation in the “Prater” wetlands

Ecological improvements:

- Sustainable improvement of the groundwater situation in the “Prater” wetlands

Assessment of the ecological efficiency:

High	Medium	Low
X		

**N3
05**



Effects on the uses:

- High investment costs and operation costs

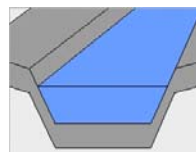
Costs of the measure (€):

Not available

Literature and/or contact:

Verbund Austrian Hydropower AG, Am Hof 6a; A-1010 Vienna

**N3
05**



N4/01 - Removal of a bank reinforcement on a slip-off slope of the Lower Rhine

Driving force:	Navigation
Pressure:	Bank Reinforcement
Impact:	Biological deficiency as a result of loss of structural diversity
Country:	Germany
Location:	Rhine-km 774.3 – 775.7 Duisburg Rhine floodplain (urban industrial landscape)
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Continuous stone filling (LD-slag¹); used to stabilize the slip-off slope over a length of 1.4 km; partly with poured groyne (cf. Figure 1)
- A 400 metre wide strip of grassland adjoins the river bank.



Figure 1: River Rhine at Duisburg, bank reinforcement (stone filling).

¹ LD-slag is an industrial by-product resulting from the transformation of hot metal into steel by oxygen refining. Selective process steps allow this slag to be transformed into building material, which is considered as one of the hardest "stone".



Ecological deficiency:

- Loss of the morphological continuity of the slip-off slope with its extensive gravel bank; loss of the structural diversity and therefore of the natural habitat zoning according to the different water depths and water current conditions
- Abrupt transition between aquatic and terrestrial habitats

B Reconstruction by restoration / mitigation measures

Execution of the measure:

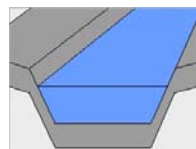
- Removal of the embankment material (building rubbish) at the toe of the groyne fields, which are located at the down stream river bank
- Covering of the LD-slag with a 0.5 m thick gravel layer over a distance of 1.4 km (cf. Figure 2)
- The removal was gradually carried out according to the demand for slag and basalt material, which is used elsewhere for maintenance measures.



Figure 2: River Rhine at Duisburg after morphological improvement; structures will be created by the next floods and should be maintained

Accompanying measures:

- Quantity survey of the current state of the structure
- (Monitoring) Inventory documentation in the year 2003 (situation before the measure)
 - Habitat mapping, hydrographic structural mapping



- Detailed inventories and photographic documentation of the altitude profile and the vegetation along transects
- The inventory documentation will be repeated in 2006.

Hydromorphological improvements:

- Initiation of the development of a shallow gravel bank, determined by erosion and sedimentation, with different water depths and water current conditions depending on the water level

Ecological improvements:

- Development of a morphological and vegetational zoning of the river bank determined by the dynamic of the river; associated with the development of habitat structures particularly for rheophile fish species

Assessment of the ecological efficiency:

- The measure initiates the development of a natural river bank typical for the river Rhine.

High	Medium	Low
X		

Effects on the uses:

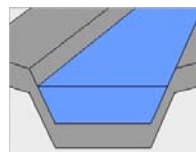
- Effects on the waterway and its function are not known.

Costs of the measure (€):

Not specified

Literature and/or contact:

**N4
01**



N4/02 - Interruption of a bank reinforcement on the bank of the limnetic tidal river Elbe

Driving force:	Navigation
Pressure:	Bank Reinforcement
Impact:	Biological deficiency as a result of loss of structural diversity
Country:	Germany
Location:	Nature conservation area "Heuckenlock" (tidal section of the river Elbe near Hamburg)
Water Body at risk:	Yes, provisionally identified as HMW

A Status before reconstruction

Status of construction:

- Massive reinforcement of the bank of the limnetic tidal river Elbe through an extensive stone filling; prevention of bank erosion through currents

Ecological Deficiency:

- Loss of the formerly shallow bank profile with the typical zoning (at low tide) of shallow water zone, freshwater tidal flat and tidal reeds; thus loss of valuable fish spawning and breeding habitats in the sandy and muddy shallow water zones.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Stone fillings were removed at short bank sections (cf. Figure 1). The construction works were carried out within few days.

Accompanying measures:

- (Monitoring) So far, no systematic investigations of the hydromorphological and biotic development have been carried out. But the area is regularly surveyed by a local nature conservation organisation (NGO).

Hydromorphological improvements:

- Restoration of the formerly continuous shallow bank profile in the short sections of the bank leads to activation of the typical hydromorphological processes through small-scale erosion and sedimentation.

Ecological improvements:

- During the last years, the small-scale shallow river profile and the dynamic of the river caused the development of the typical natural habitat zoning with direct connection to the alluvial forest (Weichholzaue?). Due to the opening of the bank, the alluvial forest is directly linked to the tide river.
- The fish fauna uses this small bank section, which is structured through different water depths, substrates and moderate current conditions, as feeding,

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02

spawning and breeding habitats and as resting place, which is even accessible at low tide.



Figure 1: Inlet in the stone filling at the shore of the limnetic tidal river Elbe (January 2006, at low tide).

- The iced area marks the small-scale mud and sand flat, which appears at low tide.
- The course of the interrupted stone filling is visible in the middle of the picture. Approaching from land, tidal reeds infiltrate the stone filling.
- The pictured situation can be found in several sections of the river bank in the natural conservation area “Heukenloch”.

Assessment of the ecological efficiency:

- The measure resulted in a development, which represents, on a small-scale, a significant improvement of the ecological status.
- It is an **ecological effective initial measure** that is suitable to examine small-scale hydromorphological and ecological development possibilities under the specific conditions of a navigated tidal river.

High	Medium	Low
	X	

Effects on the uses:

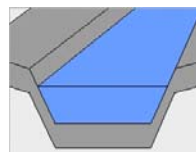
- Effects on the waterway and its function are not known.

Costs of the measure (€):

The measure involves comparatively low costs.

Literature and/or contact: Not available

N4
02



N4/03 - Removal of a bank revetment in several sections of the limnetic tidal river Elbe

Driving force:	Navigation
Pressure:	Bank Reinforcement
Impact:	Biological deficiency as a result of loss of structural diversity
Country:	Germany
Location:	Nature conservation area "Borghorster Elblandschaften" near Altengamme (Hamburg) in the range of the limnetic tidal river Elbe; downriver of the impoundment Geesthacht
Water Body at risk:	Yes, provisionally identified as HMW

A Status before reconstruction

Status of construction:

- Bank reinforcement of the limnetic tidal river Elbe through a massive revetment consisting of a rough stone filling; prevention of bank erosion through currents and wash of the waves

Ecological Deficiency:

- Loss of a bank section with gently sloping profile of sand and mud substrate and corresponding zones (at low tide) of shallow water and freshwater tidal flat; thus loss of valuable fish spawning and breeding habitats in the sandy and muddy shallow water zones. The tidal reeds are separated from the river and are no longer inundated at high tide.

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Bank revetment was removed at several sections (cf. Figure 1 and 2). The execution of the measure was carried out within few weeks.

Accompanying measures:

- The German Federal Waterways and Shipping Administration carries out controls of the bank.
- (Monitoring) Significant erosion and sedimentation processes are noticed. Until now, systematic observations of the hydromorphology, habitat development as well as of the colonisation by plant and animal species are not available. Thus so far, a revision of the concept of the measure was not needed.

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03



Hydromorphological improvements:

- Activation of the typical hydromorphological process through the extension of the flood plain and through small-scale erosion and sedimentation; objective is the development of a broad and gently sloping bank profile

Ecological improvements:

- Initiation of a typical bank zoning of the limnetic tidal river Elbe (at low tide) with shallow water zone, freshwater tidal flat on sand and mud substrate and tidal reeds; the resulting bank section is structured by the dynamic of the river and serves different fish species as spawning and breeding habitats due to its different water depths, current velocities and substrates; parts of bank section are even accessible at low tide.



Figure 1: View of a reconstructed section of the river bank (length of section: about 100 m), January 2006 at low tide. The iced marks the zone of the bank which is flooded at high tide.

N4
03

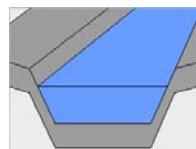


Figure 2: Southern end of the reconstructed revetment. The difference in the design of the bank profile can be noticed clearly.

**N4
03**

Assessment of the ecological efficiency:

- Over a longer bank section, a habitat development is initiated which leads to small-scale differentiated morphological, aquatic and semiterrestrial structures typically for the bank of the river Elbe.
- It is a measure with high ecological efficiency that is suitable to examine hydromorphological and ecological development possibilities under the specific conditions of a navigated tidal river.

High	Medium	Low
X		

Effects on the uses:

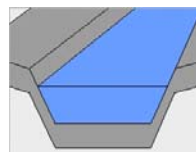
- Effects on the waterway and its function are not known.

Costs of the measure (€):

The measure involves comparatively low costs.

Literature and/or contact:

Not available



N4/04 - Establishment of a shallow water zone protected against the impact of ship-induced waves

Driving force:	Navigation
Pressure:	Bank reinforcement
Impact:	Decline of fish and macrozoobenthos communities and lack of amphibious and aquatic vegetation
Country:	Germany
Location:	River Moselle, km 135.1 - 135.8, right-hand bank between Brauneberg and Mühlheim
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Steep bank profiles, nearly continuously reinforced by natural rock rip-rap
- Riparian forest and extensively cultivated meadows adjacent to the bank
- Mouth of an inflowing rivulet in near-natural condition

Ecological deficiency:

- Steep banks and bank reinforcement restrict vegetation growth
- Steep banks impacted by ship-waves provide inadequate habitats for macrozoobenthic organisms and fish

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: WSA Koblenz and WSA Trier
Project: Deepening of the River Moselle, measure pursuant to "Domestic nature conversation act"

- Construction of a 700-m training wall parallel to the bank with connection to the river flow in 1993 (cf. Figure 1)

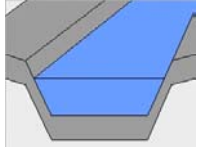
Accompanying measures:

- 10-year monitoring programme with morphological, faunistic and vegetation surveys (1994-2004)

Hydromorphological improvements:

- Enhanced structural diversity

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04



- Reduced impact of ship waves on banks
- Wide and shallow water area behind the training wall

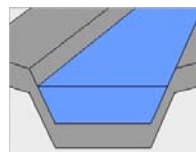


Figure 1: Training wall (Photo of 1999).

**N4
04**



Figure 2: Inflow of a rivulet in the area of the training wall.



Ecological improvements:

- High fish-ecological significance as habitat for different age stages of limnophilic species spawning on macrophytes such as carp and tench
- The alluvial fan of the inflowing rivulet is a potential habitat for fry of rheophilic, species spawning on gravel that is better protected by the training wall against detrimental impacts of ship waves (cf. Figure 2)
- Favourable conditions for the establishment of aquatic vegetation
- Ecologically significantly improved habitat conditions regarding diversity and abundance against the steep, rip-rap banks of the Moselle in this impounded reach

Assessment of the ecological efficiency:

- Significant improvement of habitat conditions for numerous animal species and amphibious and aquatic vegetation

High	Medium	Low
X		

Effects on the uses:

- No significant negative consequences for navigation

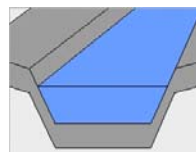
Costs of the measure (€):

Not specified

Literature and/or contact:

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N4
04



N4/05 - Establishment of a shallow water zone protected against the impact of ship-induced waves, vegetation-free gravel and pebble areas and succession zones. New harbour Würzburg. River Main

Driving force:	Navigation
Pressure:	Bank reinforcement (changed routing)
Impact:	Loss of characteristic river and floodplain habitats, decline of biological diversity
Country:	Germany
Location:	River Main, km 248.2 - 248.9, right-hand bank near Würzburg
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Ploughland between the area of the harbour of Würzburg and the River Main

Ecological deficiency:

- Decline of the macrozoobenthos community and of the bank vegetation through the construction works to facilitate navigation

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: Waterway New-construction Office (WNA) Aschaffenburg
Project: Development of the River Main/Measure pursuant to "Domestic nature conversation act"

- Establishment of shallow-water zones with connection to the River Main, succession zones, vegetation-free gravel and pebble areas as well as two bluffs on a former ploughland area of approximately 5 ha (cf. Figure 1 and 2). Implementation 1989

Accompanying measures:

- 10-year monitoring programme with vegetation surveys (1991-2002)

Hydromorphological improvements:

- Improved physical-structural diversity
- Reduced impact of ship waves on habitats of the water-land transition zone

**N4
05**

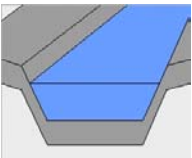
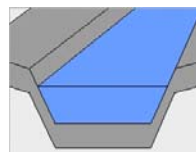


Figure 1: Wetland habitat "Neuer Hafen", a short time after the measure in 1990.

**N4
05**



Figure 2: Aerial view of the harbour in 1990.



Ecological improvements:

- Wide and shallow water areas offer favourable conditions for the establishment of aquatic vegetation
- Enlargement of the amphibious zone and thus promotion of amphibious plants and animals
- Diverse habitat structures (bluffs, vegetation-free areas, coppices, meadows, and tall forbs) offer favourable conditions for avifauna.
- High fish-ecological significance as habitat for different age stages of limnophilous species spawning on hydrophytes
- Significantly higher ecological habitat value in terms of species diversity and abundance than rip-rap banks

Assessment of the ecological efficiency:

- The ecological objectives and expectations were fully achieved.

High	Medium	Low
X		

Effects on the uses:

- No significant negative consequences for navigation

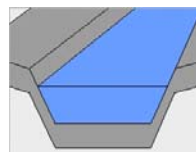
Costs of the measure (€):

Not specified

Literature and/or contact:

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**N4
05**



N4/06 - Improving the structural diversity of river banks by creating a bypass (floodway) in order to promote shallow waters and protect banks against impacts of ship-induced waves

Driving force:	Navigation
Pressure:	Bank reinforcement
Impact:	Loss of natural river banks and impact of fish and macrozoobenthos communities by steep, monotonous reinforced banks and ship induced waves
Country:	Germany
Location:	River Main, km 151.96-152.53, impoundment Freudenberg
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Steep and monotonous bank profile reinforced with rip-rap

Ecological Deficiency:

- Loss of adequate river bank habitats for fish and macrozoobenthos communities and aquatic and amphibious vegetation

B Reconstruction by restoration / mitigation measures

Execution of the measure:

Developer: Waterway New-construction Office (WNA) Aschaffenburg
Project: Development of the River Main/Measure pursuant to "Domestic nature conversation act"

- Establishment of an additional water body (floodway) beneath the bank connected to the River Main.
- Establishment of flat banks, isle habitats and shallow-water zones

Accompanying measures:

- Compilation of a catalogue of actions in the context of an expert report about the ecological improvement of measure sites along the River Main from an ornithological perspective

Hydromorphological improvements:

- Enhancement of the structural diversity of the river bank
- Elongation of the land-water transition zone

**N4
06**

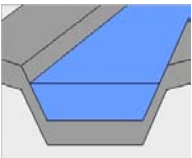


Figure 2: Faulbach, view of the floodway in 1997.

**N4
06**

Ecological improvements:

- Establishment of river type specific amphibious and aquatic vegetation
- Site where 'natural succession' can run off
- Additional benefit: Establishment of an island that is not accessible for visitors and has high ornithological benefit

Assessment of the ecological efficiency:

- Promotes numerous organism groups like macrozoobenthos, fish, insects (dragon fly) and birds

High	Medium	Low
	X	

Effects on the uses:

- No significant negative consequences for navigation

Costs of the measure (€):

Not specified

Literature and/or contact:

Federal Institute for Hydrology

Dr. Schleuter

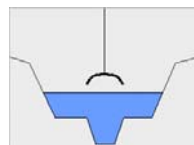
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N5/01 - Water column recharge of dredged material to sustain protected intertidal habitats

Driving force:	Navigation
Pressure:	Dredging; removal of sediment from estuarine system
Impact:	Potential to exacerbate erosion of intertidal habitats and hence reduce bird feeding area
Country:	UK (NAVI)
Location:	Harwich, Essex
Water Body at risk:	Provisionally a Heavily Modified Water Body

A Status before reconstruction

Status of construction:

- A major capital dredge of the Harwich Haven approach channel was required to enable bigger container ships to safely access the port of Felixstowe at most states of the tide. In excess of 18 million cubic metres of material required disposal.

Ecological deficiency:

- Modelling indicated that the proposed dredging would physically remove 4 ha of intertidal mudflat used by overwintering birds and that future maintenance dredging could lead to further erosion of up to 12 ha per year.

B Reconstruction by restoration / mitigation measures

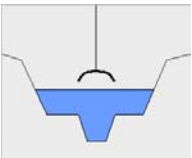
Execution of the measure:

- Instead of removing all the sediment from the estuarine system (ie. disposal at a licensed offshore disposal site) it was intended to retain a proportion of the material within the natural estuarine system. Options were therefore investigated with a view to restoring and mitigating the effects of dredging on the intertidal mudflats.
- Mitigation was achieved by replenishing the intertidal areas indirectly (by placing the material in the water column such that natural processes would deposit it on the foreshore areas).
- The bathymetric surveys associated with the water column recharge trials demonstrated that the placed material dispersed over a period of several weeks.

Accompanying measures:

- An extensive monitoring programme was undertaken so as to ensure that the proposed mitigation measures were having the desired effect.

N5
01



- Following concerns regarding the impact of a separate, later development, (Trinity III Quay extension) a number of foreshore enhancements were also put in place. These provided flood defence benefits by reducing wave impacts on the sea walls and conservation benefits by improving degraded inter-tidal areas. Half-tide bunds were placed using gravel and stiff clay, with the area between the bund and the seawall directly recharged with soft mud from maintenance dredging operations.

Hydromorphological improvements:

- Retention of sediment within the estuarine system, thus sustaining the natural morphological processes. The later foreshore recharge works to replenish the mudflats also provided greater protection to the adjacent flood defence embankments.

Ecological improvements:

- Effective mitigation of loss of the protected foreshore habitat used for feeding by internationally significant numbers of overwintering birds

Assessment of the ecological efficiency:

- Monitoring demonstrated that the solution was very effective in mitigating losses that would otherwise have taken place due to the dredging.

High	Medium	Low
X		

Effects on the uses:

- The port of Felixstowe was able to accept bigger vessels without significant detriment to the protected estuarine environment. Mitigation measures also helped to reduce expenditure on flood defence maintenance.

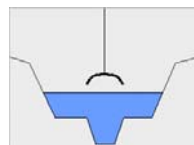
Costs of the measure (€):

Costs were broadly similar to those for conventional sea disposal of dredged material. Ongoing monitoring costs (UKP): approximately £150,000 per year for the foreseeable future.

Literature and/or contact:

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**N5
01**



N5/02 - Accountability in maintenance dredging decision making

Driving force:	Navigation
Pressure:	Maintenance dredging
Impact:	No proven impacts, but need for improved transparency of decision making and communication with stakeholders
Country:	UK (NAVI)
Location:	Thames Estuary
Water Body at risk:	Yes, provisionally identified as HMWB

A Status before reconstruction

Status of construction:

- Several locations on the tidal Thames require maintenance dredging on a regular basis (3 monthly to 3 yearly) to ensure continued safety of navigation and to provide access to berths.
- In total, approximately 500,000 m³ is dredged annually. Some 50,000 m³ is disposed to land-based sites which are managed for nature conservation benefits by the Royal Society for the Protection of Birds (RSPB). Most of the remainder is dispersed within the estuarine system through water injection dredging or ploughing to prevent a long-term depletion of the sediment budget.
- The Port of London Authority (PLA) is responsible for dredging of the main channel and, as the regulator of dredging, issues licences to operators to carry out dredging in access channels and berths
- Historically, the nature of the licensing process meant that stakeholders neither had a good understanding of why dredging was required and what was involved, or how decisions were made. In particular, environmental groups expressed concerns about how environmental sensitivities were considered. To deal with this an initiative was promoted to facilitate dialogue and information exchange.

Ecological issues:

- Concerns were expressed about the possibility of impacts of maintenance dredging on intertidal habitats, juvenile or migrating fish, and the physical processes operating in the estuary, for example, reductions in the sediment budget through offshore or land-based disposal and associated effects on the extensive Natura 2000 sites within the Thames Estuary.
- There was no evidence of particular adverse impacts, but data were lacking in some areas. The PLA had carried out research and monitoring but in isolation from the wider community. The issue was more one of perception and a lack of mutual understanding between stakeholders.

N5
02

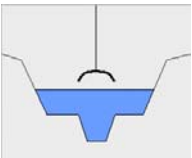


Figure 1: Photo courtesy of Van Oord UK Ltd.

**N5
02**

B Reconstruction by restoration / mitigation measures

Execution of the measure:

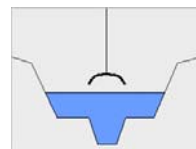
- A framework was established for guiding decision making, including dialogue with stakeholders represented on a neutrally-facilitated 'dredging liaison group'.
- In addition, a web-based GIS 'information exchange system' was set up, enabling stakeholders to better understand the location and scale of dredging activity, and share information they wanted the PLA to consider in making decisions on dredging licence applications

Accompanying measures:

- Data collection programmes, modelling and monitoring were initiated to improve understanding in certain key areas
- An agreement was made to constrain dredging to outside of the summer months of June to August to minimise the potential for additive impacts on juvenile and migratory fish during their most sensitive period.

Hydromorphological improvements:

- An improved understanding of the hydromorphology and, in particular, the sedimentary regime of the estuary.



- A change in dredging techniques from conventional dredge and dispose to more sustainable sediment management and recirculation.
- A better ability to predict and avoid/mitigate impacts

Ecological improvements:

- Greater confidence that potential ecological impacts would be identified and resolved. Improved planning of dredging programmes to periods of lower ecological sensitivity.

Assessment of the ecological efficiency:

- Improved understanding of the issues; opportunity to implement measures to improve water status

High	Medium	Low
X		

Effects on the uses:

- Better communication and shared understanding with stakeholders
- Reduced conflict and associated delays, etc.

Costs of the measure (€):

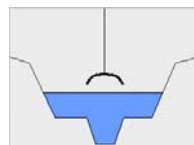
Development of maintenance dredging framework, setting up and management of information exchange system, attendance at dredging liaison group meetings, data collection, research and impact assessment: approximately £ 100,000 To set up over a two (?) year period with ongoing costs of around £ 15,000 per year. Significant reductions in costs facilitated by a change to sediment dispersion dredging techniques which has only been possible because of the enhanced understanding of dredging amongst environmental bodies. Savings of around £100,000 per year.

Literature and/or contact:

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**N5
02**



N5/03 - Morphological management in estuaries conciliating nature preservation and port accessibility

Driving force:	Navigation
Pressure:	Sediment removal associated with maintenance dredging and capital dredging
Impact:	A combination of human interference (poldering, dredging and other river works) on the morphology
Country:	Netherlands (NAVI)
Location:	Walsoorden – Scheldt Estuary (Belgium – The Netherlands)
Water Body at risk:	Yes, provisionally identified as HMWB.

A Status before reconstruction

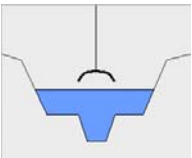
Status of construction:

- An expert team appointed by the Port of Antwerp was requested to give an opinion about the prospects for a further deepening and widening of the navigation route, the river Scheldt, mainly needed for the larger container ships.
- The Scheldt is the aorta to the Port of Antwerp, while it is one of the few remaining European estuaries covering the entire gradient from fresh to salt water tidal areas.
- One of the main questions considered was where to dispose the large volumes needed for such an enlargement.
- Important was the preservation in the Western Scheldt of a dynamic and complex flood and ebb channel network, the so called multi-channel system.

Ecological deficiency:

- There was an ongoing degradation of the ecological and morphological values of the estuary due to past morphological evolutions combined with human interference (poldering, dredging and other river works).
- The reducing mobility of the channels and shoals is for a large part due to the hard bordering of the estuary (levees, bank protections, groynes, jetties, and harbours); sandbars are rising too high, channels deepen, shallow water areas diminish.
- The local project focuses on possibly reconstructing the eroded tip of a sandbar by using sediment from dredging works. In that way flood and ebb flows would be preserved, a condition to maintain the multi-channel system in the reach.

N5
03



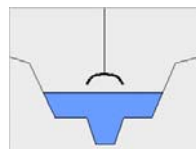
B Reconstruction by restoration / mitigation measures

Execution of the measure:

- In 2001 the Port of Antwerp Expert Team proposed the idea of morphological dredging aiming at steering the estuarine morphology.
- This strategy would not only cut back on the ongoing degradation of the ecological and morphological values of the estuary and maintaining the multi-channel-system, but it could also possibly help reducing the quantity of material to be dredged on the crossings by increasing the scouring or self-dredging capacity of the flow.
- The dredging companies contacted for advice about the disposal of material in a controlled way close to the riverbed, have developed a system by which the sediment is disposed quietly with a diffuser in shallow water.
- The expert team proposed to dispose the dredged material on the seaside of the Plate of Walsoorden to restore this western tip that erodes since several decades.
- The ultimate goal was to apply morphological management, using dredged material to reconcile nature conservation and port accessibility needs.
- In 2002-2003 research institutions examined whether the proposal was feasible. The research programme combine three tools: field measurements, physical scale models and 3D numerical models. The research results did not provide a decisive answer so it was decided to carry out an experimental disposal to give the final proof of the feasibility of this new disposal strategy.
- By the end of 2004, over one month, 500.000 m³ of sand was being placed nearby the Plate of Walsoorden, by using a diffuser.
- The main idea was to modify the morphology of this sandbar by disposing dredged material very precisely.
- The amount of 500.000 m³ was chosen as being large enough to see an effect of the disposed sediment, but small enough to be reversible if something were to go wrong.
- The experimental disposal was closely followed up by means of an intensive monitoring programme, assessing both morphological and ecological developments.
- Early 2006 the experimental disposal is being continued; another 500.000 m³ will be disposed. Also this disposal will be followed up with an extensive monitoring programme.

Accompanying measures:

- A comprehensive monitoring programme was absolutely needed as the current understanding of the morphological processes in rivers and estuaries is not sufficient to predict very precisely the response induced by dredging and disposing the sediment in specific places.
- A monitoring programme included, among other: flow measurements, topobathymetric observations (among with multibeam charts and LIDAR observations), bottom sampling for sediment size and biological data acquisition, sediment transport measurements and possibly sediment tracking.



Hydromorphological improvements:

- As regards the morphology the experimental disposal was a success. One year after the experiment 85% of the disposed sediments was still on the disposal location.
- An estimated volume of 4 to 5 million m³ could be disposed here, representing more than half of the the volume dredged yearly in the Western Scheldt
- Another advantage of the proposal is that the additional volumes produced by the capital dredging required for a further improvement of the navigation route could be kept within the estuary instead of exporting it out of the estuary, into the sea.

Ecological improvements:

- The placement of material influencing the estuarial morphology also regenerates degraded areas and their associated biotopes.

Assessment of the ecological efficiency:

- The ecological monitoring programme included both intertidal as subtidal measurements.
- The intertidal monitoring comprised of several stations on the Walsoorden sandbar where erosion-sedimentation, sediment composition and macrobenthos was measured.
- The subtidal monitoring was focused on sediment composition and macrobenthos samples using the BACI-technique (before-after-control-technique).
- Initially ecologists feared increased sedimentation, especially on coarser sediment and on the sandbar, which could have a negative impact on its biotopes. However, none of the results of this monitoring indicated that the in situ disposal led to any ecological changes or ecological deterioration. Moreover, the disposal could also regenerate degraded areas and their associated biotopes.

High	Medium	Low
	X	

Effects on the uses:

- No final effect on the uses can be concluded but it is very likely that there will be a clear win-win situation for the port of Antwerp and for the overall morphological and ecological quality of the estuary.

Costs of the measure (€):

- Not yet clear. However, if the need of dredging could be reduced because of an increasing self-eroding capacity, this would reduce dredging costs.

Literature and/or contact:

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o2/01 - Restoration of sediment flow control dam on the Kokra River

Driving force:	other (sediment flow control)
Pressure:	Damming
Impact:	Interruption in the river continuum
Country:	Slovenia
Location:	Kokra River
Water Body at risk:	No

A Status before reconstruction

Status of construction:

- Dammed river



o2
01

Figure 1: Dam on the Kokra River before restoration works, situation in 2002.



Ecological deficiency:

- Loss of river continuum
- Interrupted migration path of salmonoid freshwater fish species (Brown trout *Salmo trutta*)

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Reconstruction of old dam
- Construction of the fishway



Figure 2: Dam on the Kokra River after restoration works, situation in 2006.

o2
01

Accompanying measures:

- Monitoring of freshwater fish migration during the spawning period (October – December)

Hydromorphological improvements:

- Improvement of hydromorphological continuum and sediment flow control

Ecological improvements:

- Improvement and defragmentation of aquatic habitat
- Migratory fish species gain possibility for migration in order to use spawning areas in the upstream parts of the river.



Assessment of the ecological efficiency:

- The construction of fishway enables migration of Brown trout upstream and downstream river towards the proper spawning areas.

High	Medium	Low
	X	

Effects on the uses:

- Restoration works were already designed in manner not to have any impacts on the sediment flow control. No impacts on the purpose of the dam were recorded after restoration of the river.

Costs of the measure (€):

Costs of restoration works are estimated on today's prices of labour and material on 250,000 €. Costs of monitoring and maintenance are not included.

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o2
01



o3/01 - Doñana wetland

Driving force:	Mining, agriculture
Pressure:	Water and land pollution with mining spill (in 1998), land reclamation and floodplain draining for agriculture, transversal and lateral barriers in the river
Impact:	Water quality and wetland degradation, heavy alteration of river dynamics
Country:	Spain (WWF)
Location:	Doñana wetland/ Guadiamar river
Water Body at risk:	Not applicable

A Status before reconstruction

Status of construction:

- The Doñana wetland has lost its natural dynamics (e.g. increase of the erosion-sedimentation processes, flooding) and the natural connection with rivers and small streams originally draining into it. This happens due to land-use changes upstream in the rivershed and the disconnection of the wetlands from the rivers.
- The Guadiamar river, one of the main streams that originally fed the wetland is polluted (mining spill in 1998), hydromorphologically altered (alteration of cross and longitudinal profile; draining of floodplain for agricultural purposes) and disconnected from the Doñana wetland (transversal Entremuros wall separating the river from the wetland)

Ecological deficiency:

- For the Doñana wetland:
 - Homogenization and loss of habitats due to increased sedimentation
 - Changes in flooding (depth, period) of the marshes
 - Biodiversity loss (decrease of breeding success, habitats)
- For the Guadiamar river:
 - Loss of river sinuosity
 - Loss of current, river width and river depth variability
 - Loss of river corridor internal ecological structure
 - Loss of habitat

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- In the Doñana wetland:
 - Restoration of the ecological and hydromorphological dynamics of the water streams draining into the wetland, reconnection of the marshes to the main rivers

o3
01

- Restoration of several lagoons and secondary wetlands to recover their original dynamics
- Treatment of urban wastewaters draining into the wetland through a stream
- In the Guadiamar river:
 - Clean-up and restoration of 4000 hectares affected by acid water and heavy metals from a mining spill in 1998
 - Restoration of autochthonous plant communities through the creation of “vegetation source” plots to be use as natural points of diffusion of autochthons species
 - Reconstruction of the wetland shape according to the original conditions existing in 1956
 - Elimination of anthropogenic barriers due to agriculture (e.g. closure of irrigation channels and rice draining channels) rehabilitation or construction of shallow lagoons to foster educational and leisure activities linked to the wetland.

Accompanying measures:

- Research programme to monitor the evolution of toxic contamination due to the mining spill occurred in 1998
- Programme for public use, environmental education and participation and an economic programme to foster the welfare of local inhabitants
- Follow-up programme to monitor and assess the progress and effects of the restoration project

Hydromorphological improvements:

- Reestablishment of sand erosion-sedimentation dynamics
- Reestablishment of connection between the wetland and the surrounding land
- Restoration of drainage

Ecological improvements:

- Creation of a green corridor connecting Doñana with the Sierra Morena
- Slowing-down of erosion-sedimentation processes upstream the marshes
- Restoration of habitats in the wetlands
- Creation of specific habitats for endangered species

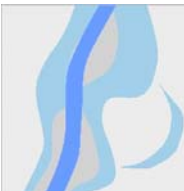
Assessment of the ecological efficiency:

- Creation of riverine habitats, increased use of the Guadiamar river as an ecological corridor, increased diversity of habitats, reduced sedimentation

High	Medium	Low
X		

Effects on the uses:

- Expropriation of low-value agricultural land to restore natural habitats and processes.





- Increase of tourism and leisure activities in the Guadiamar river

Costs of the measure (€):

This project is the combination of two projects (Doñana 2005, funded by the Spanish Ministry for Environment and the Corredor Verde del Guadiamar, funded by the Junta de Andalucía, the Andalusian Regional Government). It is made of seven different initiatives, whose total cost sums up 89,716,904 €.

Literature and/or contact:

<http://www.mma.es/parques/donana2005/htm/acercade/proyecto.htm>

http://www.juntadeandalucia.es/medioambiente/paisajeprotegido/cverde/idx_correverde.html

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03
01

Source

Member State/ stakeholder	Driving force				Sum	Delivered by	e mail adress	Number of case study
	F	H	N	o				
Austria								
Belgium	1				1	Adelheid Vanhille afdeling Water - VMM	adelheid.vanhille@lin.vlaanderen.be	F3 04
Denmark								
Finland		3			3	Mika Marttunen, Ville Hokka, SYKE - Suomen Ympäristökeskus, Asiantuntijapalvelut, Vesivarayksikkö	Ville.Hokka@ymparisto.fi	H2 06, H2 12, H2 15
France		2			2	Isabelle Vial	Isabelle.VIAL@ecologie.gouv.fr	H2 14, H2 18
Germany		1	10		11	Bundesanstalt für Gewässerkunde	Sommer@bafg.de	N2 01, N2 02, N3 01, N3 02, N4 04, N4 05, N4 06
						PG Ökologie+Umwelt Nord	pl-nord@T-Online.de	N4 01, N4 02, N4 03, H2 07
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Romania								
Slovenia	1	2		1	4	dr. Ales Bizjak; Institut za vode Republike Slovenije	ales.bizjak@izvrs.si	F3 01, H2 03, H2 04, o2 01
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Sweden		1			1	Håkan Olsson, SMHI, Swedish Meteorological and Hydrological Institute	hakan.olsson@smhi.se	H2 05
United Kingdom	4				4	David Corbelli - Hydromorphology Project Manager	david.corbelli@environment-agency.gov.uk	F1 03, F1 04, F3 05, F3 06
ESHA								
EURELECTRIC		7	2		9	Anna Törner, Environment & Sustainable Development-Union of the Electricity Industry – EURELECTRIC	atorner@eurelectric.org	H2 08, H2 09, H2 10, H2 11, H2 13, H2 16, H2 17, N3 03, N3 05
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WWF		1		1	2	Nicoletta Toniutti, WWF Italy, Freshwater Team	n.toniutti@wwf.it	H2 20, o3 01