Fact sheet: Medium-large, anastomosing, lowland rivers

General description

Anastomosing channels are a subcategory of the island-braided channel pattern with interconnected, coexisting channels separated by terraces or floodplain islands, with erosion-resistant cohesive banks, gentle gradient, and relatively low width-depth ratios of individual channels. The distinguishing feature of anastomosing channels is that hydraulic and sediment transport dynamics of each channel are independent of the other channels. Anastomosing channels are generally stable in the short term with cohesive banks, low width to depth ratio channels, and gentle channel gradient that exhibit little or no lateral migration. The dominant channel migration process is avulsion.

Valley- and planform	The valley has a flat bottom that can be wide to very wide with gentle slope margins. The channel planform consists of a multiple channel river characterized by vegetated or otherwise stable alluvial islands that divide flows. Each channel in itself can have a straight/sinuous to a more meandering planform. Primary, secondary and lost channels can be present.
Hydrology	In the natural situation entrenchment of the channels is reasonable; the channels are relatively narrow and deep. The floodplain is completely inundated during floods. Anastomosing, large, lowland rivers can be permanent or some channels maybe intermittent. The hydrograph is moderately dynamic and most of the time there is bank full discharge. The floodplain islands are often flooded for a few weeks or more during water level rises.
Morphology	The valley is more often largely covered with peat and organic deposits (organic wetland). The channels are laterally stable due to stabilizing vegetation in combination with relatively low stream power. The erosion-sedimentation processes are only local. Channel formation is slow (patterns can last for >100 years). Changes are due to channel sedimentation, the formation of vegetation blocking the flow through or ineffective flow due to the very low channel gradient. The channel banks are often quite vertical, formed by plant roots in a 'grill-like' shape. The river bottom is dominated by sand and organic silt (dark organic slurry), and fine and coarse particulate organic matter (e.g. dead helophytes), clasts of peat, and local stands of vascular hydrophytes. The floodplain islands are only slightly elevated over the mean water level.
Chemistry	Depending on the upstream geology the floodplain has become organic (peat formation) and the pH can vary from 5.5 to 7. The water quality is mesotrophic.
Wetland zone	The wetland consists of densely vegetated marshy grounds that are dominated by rushes, sedges, reeds and gramnoids, locally a deciduous swamp forest (Salicetum) could develop but large parts of the area are without trees due to the high water levels.

Photo: Large, anastomosing, lowland river (Narew) in Poland.

Pressures

Major pressures

The prevailing hydromorphological pressure in large, anastomosing, lowland rivers is drainage of the floodplain and channelization of the main channel with filling other channels. These changes go in combination with flow alteration (resulting from impoundment and drainage of agricultural and urban lands upstream and along the sides in the catchment), and alteration of the floodplain vegetation.

Score of pressure level imposed on large, anastomosing, lowland rivers categorised according to pressure category and pressure, respectively (score in comparison to other pressures within this river type: No = no pressure/stress, L = low pressure/stress, M = moderate pressure/stress, H = high pressure/stress).

Pressure category	**Pressure**	**Score**
Point sources	Point sources	H
Diffuse sources	Diffuse sources	H
Water abstraction	Surface water abstraction	M
	Groundwater abstraction	M
Flow alteration	Discharge diversions and returns	M
	Interbasin flow transfer	No
	Hydrological regime modification including erosion due to increase in peak discharges	H
	Hydropeaking	No

Pressure category	Pressure	Score
	Flush flow	M
	Impoundment	H
Barriers/Connectivity	Artificial barriers upriver from the site	M
	Artificial barriers downriver from the site	M
Channelization	Channelisation / cross section alteration (e.g. deepening) including erosion due to this	H
	Sedimentation	M
Bank degradation	Bank degradation	H
Habitat degradation	Alteration of riparian wetland vegetation	H
	Alteration of in-rivers habitat	L
Others	Maintenance	H
	Exotic species	L

Problems and constraints for river restoration

Floodplain drainage and channelization strongly lower the ground and surface water levels and results in a more dynamic hydrograph. Side channels are filled in, will become intermittent or will dry up. Due to downstream channelization the main channel will incise with further water level lowering and drying up of the floodplain. More dynamic flows will scour the river bed and change it to a more mineral single thread system.

Drying of the floodplain reduces the bank stability and the amount of organic material from decaying macrophytes in the channels. Incision of the main channel bed due to channelization and flow alteration will strongly reduce the hydrological connectivity between river and wetland floodplain.

Depending on the catchment (ground)water abstractions can also play an important role in river flow alteration. Groundwater abstractions may lower the discharge of the river, thereby decreasing the flow velocity and water depth with further terrestrialisation of smaller channels.

In many cases maintenance consisting of removing of aquatic vegetation and/or dredging is performed to counteract effects of macrophyte development and channel obstruction.

Apart from hydromorphological pressures these large, low gradient, lowland rivers often suffer from eutrophication and organic pollution resulting from a high proportion of agricultural land use upstream in the catchment.

Measures

Common restoration practice

There is little literature available on measures taken to recover and restore large, anastomosing, lowland rivers. Probably this is because of the high costs of floodplain wide measures that include either buying of land or changing land use due to a strong raise in ground water level. Thus, measures that deal with the whole floodplain are rare, but when taken always in combination combined with in river or channel planform measures. The length of a restored stretch must be long and cover large parts of the valley. In ideal cases the processes that result in multiple channels are restored. Knowledge on active multiple channel initiation lacks.

Score per measure category/measure of relevance, effect in-river, effect on the flood-plain and costs the measure in comparison to other measures within this river type (No = no relevance or effect, L = low relevance or effect, M = moderate relevance or effect, H = high relevance or effect of the measure) and indication a prioritisation of measures (L = low priority, M = moderate priority, H = high priority).

Measure category	Measure	Relevance	Effect in-channel	Effect floodplain	Costs	Prioritisation
Decrease pollution	Decrease point source pollution	M	L	M	H	M
	Decrease diffuse pollution input	H	M	H	H	H
Water flow quantity	Reduce surface water abstraction	H	M	H	L	H
	Improve water retention	H	M	H	H	H
	Reduce groundwater abstraction	H	M	H	M	H
	Improve water storage	H	M	H	H	H
	Increase minimum flow	H	H	H	H	H
	Water diversion and transfer	M	M	M	H	M
	Recycle used water	M	M	M	H	M
	Reduce water consumption	M	M	M	L	M
Sediment quantity	Add/feed sediment	L	L	L	M	L
	Reduce undesired sediment input	L	L	L	L	L
	Prevent sediment accumulation	L	L	L	M	L
	Improve continuity of sediment transport	M	M	M	M	M
	Trap sediments	L	L	L	M	L
	Reduce impact of dredging	M	M	L	M	H
Flow dynamics	Establish natural environmental flows	H	H	H	H	H
	Modify hydropeaking	No				
	Increase flood frequency and duration	H	M	H	H	H
	Reduce anthropogenic flow peaks	H	M	H	H	H
	Shorten the length of impounded reaches	L	L	No	L	L
	Favour morphogenic flows	M	M	M	M	M
Longitudinal connectivity	Install fish pass, bypass, side channels*	H*	M*	H*	L*	H*
	Install facilities for downriver migration	No				
	Manage sluice, weir, and turbine operation	No				
	Remove barrier	H	H	H	M	H
	Modify or remove culverts, syphons, piped rivers	H	H	H	M	H

Measure category	Measure	Relevance	Effect in-channel	Effect floodplain	Costs	Prioritisation
In-channel habitat conditions	Remove bed fixation	H	H	H	M	H
	Remove bank fixation	H	H	H	M	H
	Remove sediment	L	L	L	M	L
	Add sediment (e.g. gravel)	L	L	L	M	L
	Manage aquatic vegetation	M	M	M	H	M
	Remove in-channel hydraulic structures	H	H	H	M	H
	Creating shallows near the bank	L	L	L	M	L
	Recruitment or placement of large wood	M	M	L	H	H
	Boulder placement	No				
	Initiate natural channel dynamics	M	M	M	L	H
	Create artificial gravel bar or riffle	L	L	No	M	L
Riparian zone	Develop buffer strips to reduce nutrients	M	M	M	M	M
	Develop buffer strips to reduce fine sediments	M	M	M	M	M
	Develop natural vegetation on buffer strips	No				
River planform	Re-meander water course	No				
	Widening or re-braiding of water course	H	H	H	M	H
	Create a shallow water course	M	M	M	M	M
	Narrow over-widened water course	M	M	M	M	M
	Create low-flow channels	H	H	H	M	H
	Allow/initiate lateral channel migration	H	H	H	M	H
	Create secondary floodplain	H	H	H	M	H
Floodplain	Reconnect backwaters, oxbow-lakes, wetlands	H	H	H	M	H
	Create backwaters, oxbow-lakes, wetlands	H	H	H	M	H
	Lower embankments, levees or dikes	H	M	M	L	M
	Replace embankments, levees or dikes	H	M	M	L	M
	Remove embankments, levees or dikes	H	M	M	L	M
	Remove vegetation	L	L	M	L	L

Problems and constraints with common restoration practice

The major problem is the rise of the ground water table in the floodplain, necessary for recovery processes but mostly limited by other societal interests. Thus, the most often applied measure in large, anastomosing, lowland rivers is improving the water table in the floodplain. Hereby, the floodplain islands are rewetted. Active anastomosing of a large floodplain did not occur yet.

Hydrological measures are more often only applied along river stretches in low to zero slope areas without considering the hydrological dynamics that results from catchment wide activities, like drainage, water abstraction and paved surfaces.

Another constraint is a high eutrophication level due to fertilisers from agricultural activities. The supply of nutrients can strongly increase plant growth and terrestrialisation.

Giving room for free marshy area development also meets a lot of resistance from other users of the floodplain.

Promising and new measures

In general, the multiple, interconnected, low-gradient, relatively deep and laterally stable channels (stabilised by vegetation) characterise the river aspect. The low gradient valley bottom, the flatness and the small elevation of the floodplain islands over the mean water level in the channels typify the floodplain islands. Here peat formation is not uncommon. Changes in these large anastomosing systems are slow and driven by avulsion favoured by vertical aggradation. The cause of avulsion are more often obstructions formed by plants and preferred sites for new channels are zones with less dense vegetation, e.g. due to animals activity (paths). Restoring large, anastomosing, lowland rivers implies an integrated restoration of the processes described above at the scale of the floodplain and extends much further into a catchment in comparison to a single-thread river.

Restoration of large, anastomosing, lowland rivers is until now a unique possibility for large, lowland river valley restoration. By restoring processes that create a multiple channel pattern in a rewetted area three major objectives can be reached at the same time; 1) the rewetted area can serve as a large water retention area for water safety downstream, 2) the multiple channel network provides a higher water flow through area then one single channel and has a has a higher width : depth ratio, 3) the biodiversity in a gradient of channels, marshy floodplain islands is much higher.

The chances of reaching a stable multiple channel network that is controlled by vegetation, as is the case for large, anastomosing, low energy rivers in the lowlands, is highest in parts of the floodplain were valleys with a gradient of around zero. Historically, here marshy bogs occurred which can amongst others be seen in the upper layer of the soil where peat is deposited.

Restoring large, low energy, anastomosing rivers with a channel network starts with a catchment and floodplain analysis. A number of features of these systems should be kept in mind to reach a successful approach:

- A stable anastomosing channel system with biotic (partly) channel spanning obstructions, like patches of plants that form ‘floating islands’.
- Overbank flows occurs regularly, for longer duration, and with larger magnitude compared to a meandering system.
- Avulsions are the main mechanism for channel change; primary and secondary avulsions occur with new dam formation, like obstructions through vegetation overgrowth (patches of plants that form ‘floating islands’), and during overbank flows.
- Channel migration is a secondary mechanism for channel change; less cohesive sediment and less stabilizing vegetation in a more or less continuous wet environment (water almost year round at or above mowing level) create a more dynamic environment.

- There is more sediment deposited in the channel behind plant, logs or beaver dams and much fine sediment is deposited in the floodplain as a result of more frequent overbank flows; sedimentation is heterogeneous.
- There are lower energy flows (less high peak flows), but overbank flows affect a larger area and saturate the ground.
- The riparian zone extends across the valley, past the channel closest to valley edge; a higher water table across the valley supports riparian vegetation.
- The wetter environment promotes growth of rushes and sedges.
- Reed and other plant roots stabilize the banks.

To restore or newly create a anastomosing channel system through a wetland along a very low gradient trajectory of a river, preferably floodplain remnants are still present and space is available or can be obtained. Restoration can be processes based using the natural hydromorphological processes as illustrated in figures 1 and 2.

Next, the restoration of the hydromorphological infrastructure at the scale of the whole floodplain area is the key to success. In most cases, the anastomosing channel network is reduced to one single channel and measures must be taken to change the channel physical features back by e.g. cleaning the former channel beds (side or secondary channels) by removing the excess of sediment and vegetation that has overgrowing these beds or filled them in and by reconnecting them to the main channel. Additionally, to rise the water level for the entire plain (natural) weir structures, like underwater thresholds made by logs, must be placed. To divert part of water flow from the main channel into the secondary channels wide openings at the diversion points and structures, like deflectors can be very helpful. Another important measure is the reduction of the in-flow of nutrients discharged by diffuse sources, like agricultural activities, upstream. Also turning over the agriculture land use in the riparian area to an extensive form (e.g. hay production needs attention.

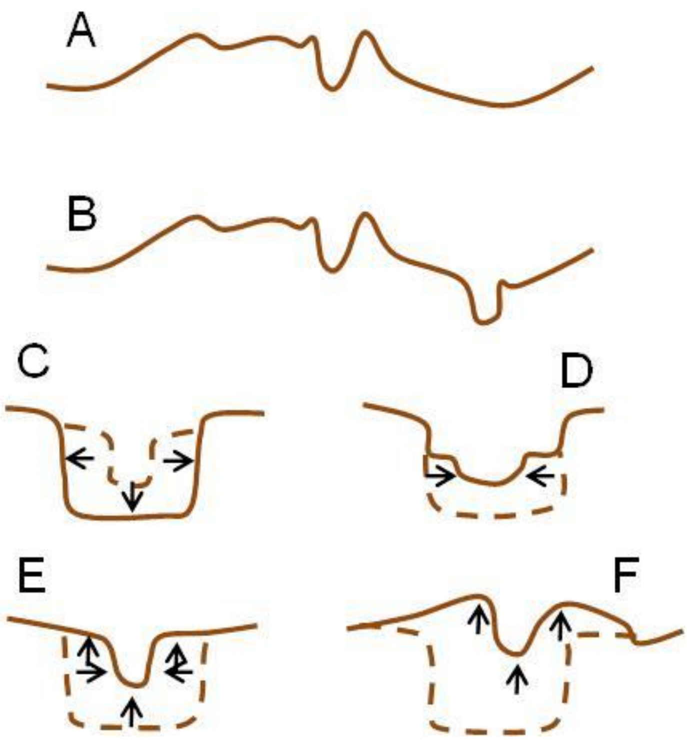

Figure: Six steps in channel evolution of an anastomosing system. A. Wetland cross section with the old channel prior to development of a new channel incision, B. initial incision of the new channel, C. incision and widening of the new channel, D. increased sedi-

ment deposition, E. channel narrowing and sinuosity increase; (f) channel is raised by deposition and natural levees form.

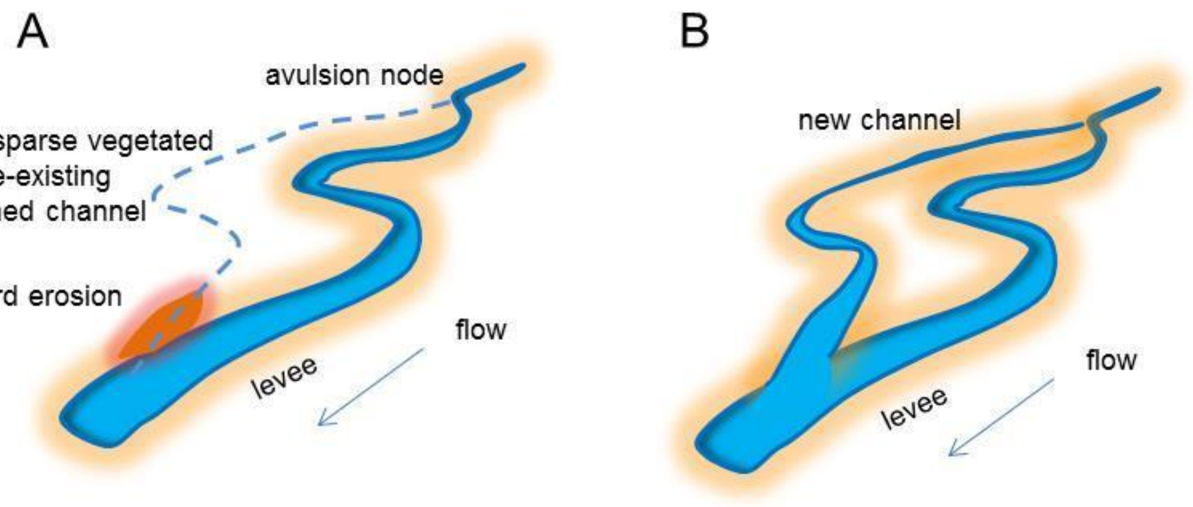

Figure: Establishment of a new channel after the main channel was partially blocked at the avulsion point (A,) and during high flow a new channel is formed and later by head ward erosion is shaped (B).

Restoration of an anastomosing channel network (Figure 3).

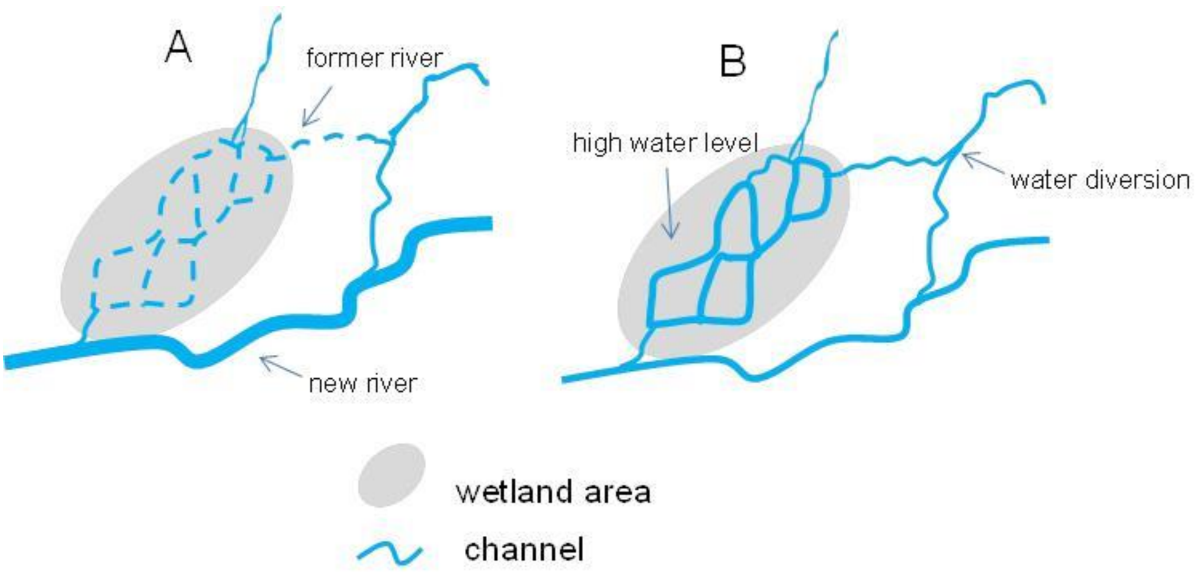

Figure: The anastomosing river valley can be restored by reconnecting and opening old river beds (dotted lines in A), and diverting larger parts of the flow through the wetland (B).

Monitoring scheme

Monitoring schemes should follow some basic principles that apply to all river types:

- Biotic as well as abiotic variables should be monitored. The restoration measures might have succeeded to create the desired habitats but the effect on biota might be limited due to other pressures at larger scales which have not been addressed in the restoration project.
- In-channel, riparian, as well as floodplain conditions should be monitored. Besides the biological quality elements relevant for the Water Framework Directive, restoration can also have positive effects on other semi-aquatic and terrestrial organism groups, like ground beetles and floodplain vegetation. Indeed, there is empirical evidence that effects on other organism groups can be larger.
- Monitoring has to be conducted at appropriate spatial and temporal scales that reflect (i) the habitat needs of the organisms (e.g. monitoring microhabitat substrate patches for macroinvertebrates, mesohabitat features for fish), (ii) all life stages (e.g. monitoring in-channel and riparian habitats for macroinvertebrates with terrestrial life-stages), (iii) and the reproductive cycle as well as dispersal abilities (long-term monitoring to also cover effects of restoration on long-lived species and weak dispersers).
- Looking at the spatial and time scale of many current restoration measures macro-invertebrates are most suited for river monitoring. Fish population are strongly managed and reflect larger scale conditions, macrophytes bear a long history as they disappear only slowly and algae reflect to short time scales and very, very local conditions. Floodplains are large scaled and best be monitored by vegetation. Riparian zone can be monitored by using vegetation or carabid beetles.
- A Before-After-Control-Impact design should be applied to allow disentangling the effect of restoration from general trends in the whole river or catchment.
- However, the final selection of the organism groups, and spatial / temporal scales monitored strongly depends on the objectives and applied measures. Of course, it is reasonable to focus on the abiotic and biotic variables and scales that potentially have been affected by the restoration measures (e.g. in-channel habitat conditions by in-channel measures).
- Monitoring results should be used for adaptive management, i.e. to react on unanticipated effects and trends, and this should be included in the planning from the beginning ("Plan-B").

For further reading and practical guidelines we refer to the handbook of the River Restoration Centre (River Restoration Centre 2011).

The relevance of a variable at the scale of the river, riparian zone and floodplain scored in comparison to other variables within this river type (No = no relevance, L = low relevance, M = moderate relevance, H = high relevance)

Variable group	**Variable**	**River**	**Wetland zone**	**Floodplain**
River and wetland hydrology		H	H	H
Wetland and in-river hydraulics		H	H	L
Floodplain and wetland morphology		L	H	L
Wetland and in-channel morphology	Profile (longitudinal, transversal)	H	L	M
	Meso-/micro-	M	M	No

Variable group	Variable	River	Wetland zone	Floodplain
	structures			
Chemistry	Nutrients	H	H	M
	Toxicants	H	H	M
	Others			
Biology	Algae	H	M	No
	Macrophytes	H	H	No
	Macroinvertebrates	H	H	No
	Fish	H	M	No
	Floodplain/riparian vegetation	L	H	L
	Terrestrial fauna	No	M	L