European Commission

Natural Water Retention Measures

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Individual NWRM

Re-meandering

Environment

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I. NWRM Description

A river meander is a U-form taken by the river, allowing it to decrease water velocity. In the past, rivers have been straightened by cutting off meanders. Many rivers in northern and western Europe have been straightened and channelized to, for example, facilitate log floating and/or speed up the drainage of water and control/limit the river bed movements. Channelizing was also a way to gain land for cultivation. River re-meandering consists in creating a new meandering course or reconnecting cut-off meanders, therefore slowing down the river flow. The new form of the river channel creates new flow conditions and very often also has a positive impact on sedimentation and biodiversity. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals.

II. Illustration

Example of before and after re-meandering, Morava and Dyje floodplains, Slovakia & Czech Republic
http://riverwatch.eu/en/the-morava-anniversary-project-2014

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Possible	Re-meandering should only be conducted on a meander alluvial system (past or present). The definition of the fluvial style is essential to consider if re-meandering is applicable or not. So it is not suitable for rivers in braids, in alternating patches or anastomoses. If the style is a river meandering course, re-meandering could be envisaged following the determination of the type of meanders: - Migrants meanders - Curved meanders - Intermediate meanders. Re-meandering a river is not creating meanders to control floods. On a river that never had meanders, this kind of modification shows that it may increase the risk of flood events. This type of action in wetlands has to be carefully considered, as it should not perturb their ecological functioning.
Agricultural Areas	Yes	
Forests and Semi-Natural Areas	Yes	
Wetlands	Yes	

N4: Re-meandering

Region	Applicability	Evidence
Western Europe	Yes	Re-meandering has been implemented in a wide range of EU climatic zones, but mainly in the Atlantic, Mediterranean and Continental climatic zones.
Mediterranean	Yes	
Baltic Sea	Yes	
Eastern Europe and Danube	Yes	

IV. Scale

	0-0.1km2	0.1-1.0km2	1-10km2	10-100km2	100-1000km2	>1000km2
Upstream Drainage Area/Catchment Area	✓	✓	✓	✓	✓	✓
Evidence	Meanders are present on brooks as well as on large rivers.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	Medium	By expanding the functional river area, re-meandering allows a slowing of runoff on the shores of rivers, therefore allowing increased storage, especially if the vegetation cover and the associated soil properties are prone to favour this storage.
	Slow Runoff	Medium	
	Store River Water	Medium	Increase of the stream length and reconnection of old meanders increase the storage capacity of the river.
	Slow River Water	High	Re-meandering slows down flows by increasing channel length.
Reducing Runoff	Increase Evapotranspiration	Low	If the action of re-meandering locally leads to vegetation development, thus it can have an impact in increasing evapotranspiration. This is closely linked to the time necessary for the development of the different vegetal strata (from 2 to 30 years, depending on the distance to the river).
	Increase Infiltration and/or groundwater recharge	Medium	Meanders create wet environments supporting infiltration and ground water recharge. By modifying land cover and sometimes removing legacy sediment, re-meandering can change soil capacity retention.

	Increase soil water retention	Medium	The increasing impact is proportional to the length of the meander.
Reducing Pollution	Reduce pollutant sources	Low	The restoration of the river functional area pushes the prerequisites and potentially polluting activities outside of this area. Nevertheless, it has very low impact on pollution sources localised on the floodplain.
	Intercept pollution pathways	High	Re-meandering, especially if accompanying with the modification of soil cover, soil properties, development of natural buffer zones, wetlands and afforestation, provides an important impact on pollution pathways, essentially due to the action of vegetation in filtering pollutants. As an example, the river functional area must be 50 meters wide to achieve halt most agricultural nitrates (von Bluecher 2010)
Soil Conservation	Reduce erosion and/or sediment delivery	High	By modifying the river profile and decreasing water velocity, re-meandering decreases erosion and increases sedimentation. Moreover, as re-meandering leads to an increased length of the riverbanks, there are more surfaces prone to be eroded. Therefore riverbank stabilization with bioengineering structures should be considered.
	Improve soils	Medium	Re-meandering, by modifying land cover in a larger river functional area, improves soil quality.
Creating Habitat	Create aquatic habitat	High	Re-meandering provides habitat for species such as aquatic plants, otter, salmon, insects and birds, fish, macroinvertebrates, macrophytes and phytoplankton, and kingfishers. The existence of hydraulic annexes, quiet water areas or wet lowlands that can be created by the dynamics of meandering, improves the preservation and resilience of ecological communities and habitats. The modification of the erosion process also affects the quality and habitat diversity of benthic fauna and fish, as well as riparian species. The first positive impacts of re-meandering habitat, fauna and flora are visible after about two years, including riparian forest.
	Create riparian habitat	High	
	Create terrestrial habitat	Medium	Knowing that animals, especially birds choose their breeding grounds on the basis of the appearance and structure of the environment (Roche 2010), the diversity and complexity of the meandering vegetation mosaic should reflect on those animal populations. The bird populations characterizing the meandering sector are close to those of the great marshlands, calm water surfaces and reedbeds (Roché and Frochot 1993). Several years are needed to see appearing various types of vegetation in the river functional area.

Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	Medium	If the action of re-meandering locally leads to vegetation development, thus it will generate shadow on the river channel and decreasing water temperature.
	Absorb and/or retain CO2	Low	If the action of re-meandering locally leads to vegetation development, thus it will imply a positive impact on CO_2 absorption. The low impact is due to the surface of the river functional area impacted by the increased vegetation cover, which is smaller than a restoration measure at the floodplain scale for example.

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	Medium	Increase of the stream length and reconnection of old meanders increase the storage capacity of the river
	Fish stocks and recruiting	Medium	The stone bed check structures all along the loop could act as spawning grounds for many of fish species.
	Natural biomass production	High	The enlargement of the river functional area linked with the improvement of water quality, hydromorphological conditions, changes in land use and natural or artificial revegetation make re-meandering a measure which can lead to increase biomass production and biodiversity. According to seniority, the blind channels are more or less wetlands, ponds or marshes, even simple wet depressions. So they contain flora and fauna different from those of stream waters, and contribute to the biodiversity preservation and a greater biomass production.
Regulatory and Maintenance	Biodiversity preservation	High	
	Climate change adaptation and mitigation	Medium	The adaptation of species to climate change is enhanced particularly by limiting the current anthropogenic impacts they suffer. By restoring a part of the habitat and the "natural" circulation conditions, and improving the water quality, re-meandering facilitates the adaptation of these native species to climate change and enables them to compete with non-native species. The role of shade on the water temperature is important because the temperature is one of the rising gradients conditioning species upstream. The more water temperature decreases, the more it leaves time for the species to adapt to new conditions.
	Groundwater / aquifer recharge	High	By creating wet environments and sometimes removing legacy sediment, re-meandering can change soil capacity retention, therefore restoring the natural connectivity between the river and aquifer, promoting their recharge.

	Flood risk reduction	High	By improving the connectivity between the river and the floodplain and restoring a high retention and storage capacity and buffer zones, re-meandering leads to the attenuation of flood impacts. The reallocation of the functional river area to natural processes suppresses the immediate flood risk for previous anthropic activities.
	Erosion / sediment control	High	
	Filtration of pollutants	Medium	With the development of the riparian vegetation and terrestrial vegetation in the river functional area, the purification capacity of this area is enhanced.
Cultural	Recreational opportunities	High	A stable stream meandering through a restored landscape will produce lush green vegetation, bright flowers, and seeds and fruits that will attract a variety of butterflies, birds, and other wildlife species. Restored river functional areas can be managed as natural or manicured areas, depending on the site and its intended use.
	Aesthetic / cultural value	High	
Abiotic	Navigation	none	
	Geological resources	none	
	Energy production	none	

VII. Policy Objectives

Policy Objective		**Rating**	**Evidence**
Water Framework Directive			
Achieve Good Surface Water Status	Improving status of biological quality elements	High	Re-meandering, by providing better ecological conditions (habitat, water quality and temperature, appropriate floods, etc.) improves the biological quality elements.
	Improving status of physico-chemical quality elements	High	Re-meandering can improve the capacity of the river to assimilate physico-chemical elements, since the quantity of microorganisms that degrade certain pollutants, mostly living in the land-water interface, increases if we restore a more natural river morphology.
	Improving status of hydromorphological quality elements	High	By reducing the flow velocity and the impact of floods, re-meandering reduces the inappropriate riverbed erosion, moving it to meander system erosion. By increasing the vegetation cover in the river functional area, re-meandering reduces erosion at the edge of the stream and allow sediment deposition.

	Improving chemical status and priority substances	Medium	Re-meandering can improve the capacity of the river to assimilate physico-chemical elements, since the quantity of microorganisms that degrade certain pollutants, mostly living in the land-water interface, increases if we restore a more natural river morphology.
Achieve Good GW Status	Improved quantitative status	High	Through the improved connectivity between the river, which has a high storage and infiltration capacity, and aquifers, groundwater quantitative status is improved by river re-meandering.
	Improved chemical status	Medium	Through the improved connectivity between the river, which has a high filtration capacity, and aquifers, the chemical status of groundwater is improved by the river re-meandering.
Prevent Deterioration	Prevent surface water status deterioration	High	The recovery of the connectivity between the floodplain, the river and groundwaters especially with the "creation" of an extended functional river area (improving all filtration and purification processes through buffer zones, microorganisms, soil modification, etc.) participates to the prevention of water deterioration.
	Prevent groundwater status deterioration	Medium	
Floods Directive			
Take adequate and co-ordinated measures to reduce flood risks		High	Reduction and storage of surface runoff will contribute to reduce peak flows and flood risk
Habitats and Birds Directives			
Protection of Important Habitats		High	Re-meandering, by improving native species (aquatic, riparian and terrestrial) habitats, allows them to compete with invasive and colonizing species which install as a result of human pressures on the environment.
2020 Biodiversity Strategy			
Better protection for ecosystems and more use of Green Infrastructure		High	Meandering alluvial zones have a cross zonation of vegetation (Moor 1958 Roulier 1998) and animal communities (Schnitzler and Carbiener 2007). Longitudinal connectivity is provided by the rivers and riparian land located along the stream environments. The cross-connectivity brings together the links and contact zones between the rivers, the alluvial zone and the surrounding areas of the floodplain. The shoreline can take many forms: - Extensive grassland, extensive grazing, litter surface - Wooded pasture, vegetated bank, country grove - Alluvial forest. The diversity and connectivity of these environments are conducive to biodiversity and to prevent, by the extension of suitable environment, biodiversity loss.
More sustainable agriculture and forestry		None	
Better management of fish stocks		High	
Prevention of biodiversity loss		High	

		Regarding the impact of re-meandering on fish stock, it enhances the possibility of natural self-regulation

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Re-meandering can be applied at any scale, depending on the length of river to be re-meandered
Space required	The river functional area of a meandering system is the minimal space for which meanders can reach the maximum amplitude they would under natural conditions (Malavoi, 1998). Concretely, the width of this area is equal to the maximum amplitude of a meander. The definition of this area is equivalent to setting the maximum potential amplitude of a meander in a given sector. The width of the stream full board could be connected with the maximum amplitude of a meander and thus the functional area, according to its dynamic type: - Bending Meanders: Ampl = 11 x width full board. - Intermediate Meanders: Ampl. = 7 x width full board. - Meandering migrants: Ampl = 6 x width full board.
Location	On a river which has been channelled in the past.
Site and slope stability	Mostly implemented in lowlands (less than 200m), in areas at around 0,5 - 1% slopes (i.e. conditions in which meanders naturally occur).
Soils and groundwater	There is no specific condition on soil permeability or depth
Pre-treatment requirements	n/a
Synergies with Other Measures	Re-meandering is usually implemented with reconnecting cut-off meanders, floodplain restoration and creation of wetlands, in to a lesser extent with other NWRM.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition	610€/ha	Land acquisition and compensation costs for natural areas
Investigations & Studies	n/a	
Capital Costs	400 000€/km	Cost per km of river re-meandered i.e. additional river length

Maintenance Costs	n/a	
Additional Costs	n/a	

X. Governance and Implementation

Requirement	Evidence
Definition of the responsibilities	The implementation of re-meandering should be initiated by water managers and decisioners. A large consultation/participation process involving all concerned stakeholders should be planned. The successful of a re-meandering is largely conditioned by this process.
Cost effectiveness analysis	Re-meandering is a solution regarding flood management and risk mitigation.

XI. Incentives supporting the financing of the NWRM

Type	Evidence
National Water Agencies	Acting on their geographic perimeter of competencies
LIFE Nature and Biodiversity	Article 10 of the Habitats Directive promotes the natural rivers which are "essential for the migration, dispersal and genetic exchange of wild species"

XII. References

Reference	Comment
"Costs, benefits and climate proofing of natural water retention measures"	Stella Consulting, NWRM Final Report - May 2012
Optimisation of the pSCI "Lippe floodplain between Hamm and Hangfort" (LIFE05/NAT/D/000057)	Ahlen-Dolberg http://wiki.reformrivers.eu/index.php/Ahlen-Dolberg_-_Optimisation_of_the_pSCI_%E2%80%9CLippe_floodplain_between_Hamm_and_Hangfort%E2%80%9D_%28LIFE05/NAT/D/000057%29
Damon Block	Manual of river retoration techniques – Reconnecting a remnant meander, Environment Agency
Gregory Paccaud – Christian Roulier	Espace nécessaire aux cours d'eau en méandres – Office Fédéral de l'Environnement
Skjern - Restoration of habitats and wildlife of the Skjern River (LIFE00 NAT/DK/007116)	http://wiki.reformrivers.eu/index.php/Skjern_-_Restoration_of_habitats_and_wildlife_of_the_Skjern_River_%28LIFE00_NAT/DK/007116%29