European Commission

NWRM

Natural Water Retention Measures

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Individual NWRM

Floodplain restoration and management

Environment

This report was prepared by the NWRM project, led by Office International de l'Eau (OIEau), in consortium with Actéon Environment (France), AMEC Foster Wheeler (United Kingdom), BEF (Baltic States), ENVECO (Sweden), IACO (Cyprus/Greece), IMDEA Water (Spain), REC (Hungary/Central & Eastern Europe), REKK inc. (Hungary), SLU (Sweden) and SRUC (UK) under contract 07.0330/2013/659147/SER/ENV.C1 for the Directorate-General for Environment of the European Commission. The information and views set out in this report represent NWRM project's views on the subject matter and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this report. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

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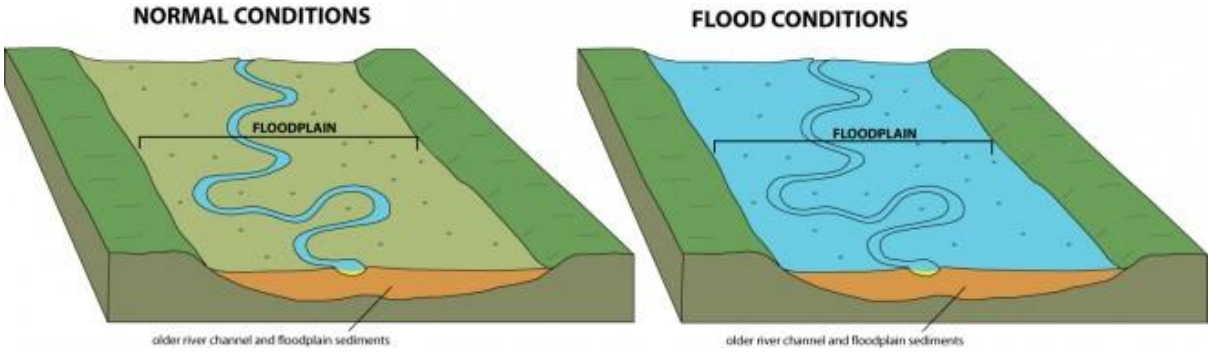
I. NWRM Description

A floodplain is the area bordering a river that naturally provides space for the retention of flood and rainwater. Floodplain soils are generally very fertile and they have often been dried-out to be used as agricultural land. Floodplains in many places have also been separated from the river by dikes, berms or other structures designed to control the flow of the river. They have also been covered by legacy sediments. Major floodplains roles have thus been lost, due to land drainage, intensive urbanization and river channelization. The objective is to restore them, their retention capacity and ecosystem functions, by reconnecting them to the river.

Restoring the floodplain roles requires measures such as:

- modification of the channel,
- removing of the legacy sediment
- creation of lakes or ponds in the floodplain
- new/modification of agricultural practices,
- afforestation, etc.
- plantation of native grasses, shrubs and trees
- creation of grassy basins and swales
- wetland creation
- invasive species removal
- riparian buffer installation and development

II. Illustration



Natural functioning of a floodplain

Source: http://www.wired.com/2011/05/flooding-creates-floodplains/

"Skjern A during and after restoration in 2000", photo JW Luftfoto, from "Ecoflood guidelines - How to use floodplain for flood risk reduction - European commission", 2006:

http://ecrr.org/publication/floodrisk_doc5.pdf

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Possible	Floodplain restoration can be applied on any type of land use, as long as a (current or former) natural floodplain is present. If Artificial areas (Urban, Industrial, etc…) are located on the floodplain though, the associated cost for the measure's implementation is likely to be higher, due to land acquisition costs and to the high land anthropisation. These costs will also be important for agricultural areas.
Agricultural Areas	Yes	
Forests and Semi-Natural Areas	Yes	
Wetlands	Yes	

Region	Applicability	Evidence
Western Europe	Yes	Can be applied anywhere as long as it is a floodplain.
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	This measure cannot be implemented on basins with small catchment areas, as there is no floodplain for these basins. *But for measures to be implemented on river bordering, they could have a positive impact on any river hydrosystem.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	High	Ideally, actions for storing runoff should be conducted before it reaches the floodplain to leave space for the river floodwaters themselves. But land cover and uses are ones of main factors affecting runoff on the flood plain. The impact of floodplain restoration depends of the configuration and activities on the floodplain area. Generally the impact is very high when measures are impacting land cover and uses particularly through restoration of buffer zones and infiltration areas. Different measures targeted at floodplains can result in runoff control and appropriate land management (afforestation, installation of micro-ponds, limitation of the intensive use of the floodplain, etc.) will contribute to control runoff. Runoff reduction measures are most effective when implemented over a large proportion of the floodplain. Their efficiency is manifold for the reduction of low to medium peak flows. They are less effective for extreme flooding events in large rivers but in any case, their effectiveness always depends on the characteristics of the precipitation and the antecedent conditions.
	Slow Runoff	High	
	Store River Water	High	The storage of river water corresponds to the volume of water which spills into the floodplain. This is a natural function of a floodplain, hence restoration would be expected to use (and preferably maximise) this function. Breaches in the summer dikes, by-pass channels and oxbow lakes improve retention in the floodplain. The temporary retained water capacity can be increased by increasing the floodplain area, its depth and the storage time e.g. by increasing its roughness with vegetation cover.
	Slow River Water	High	The river water can be slowed down because of the roughness of the floodplain features, of vegetation in particular. .
Reducing Runoff	Increase Evapotranspiration	Medium	The impact of floodplain restoration could be positive or negative regarding local conditions. Measures for floodplain restoration such as land use change from artificial or agricultural to forest or wetlands should increase evapotranspiration, having an impact on local climate conditions (could increase local humidity).
	Increase infiltration and/or groundwater recharge	High	Changes in land use (increase of forest and wetlands areas) and slower runoff can lead to higher discharges of water into the ground. The amount of groundwater recharge also depends on local conditions, such as geology, legacy sediment that could be impervious and the hydrological condition of the aquifer.

N3: Floodplain restoration and management

	Increase soil water retention	Medium	Changes in land use (increase of forest and wetlands areas) lead to increase organic matter content and thus higher water retention into the soil. Removing of legacy sediment also impacts the soil water retention capacity by improving its permeability.
Reducing Pollution	Reduce pollutant sources	Medium	By modifying uses and practices on the floodplain, especially by ensuring modification of agricultural practices, floodplain restoration could contribute to reduce anthropic pollutant sources.
	Intercept pollution pathways	Medium	One of the impacts of the vegetation development is to modify pollution pathways. A significant change on land cover, the restoration of the riparian vegetation and of wetlands could have a significant impact on pollution pathways by reactivating vegetation and soil filtering roles.
Soil Conservation	Reduce erosion and/or sediment delivery	High	Floodplain restoration will help in recovering natural erosion and sedimentation processes in the river, by increasing deposition of fine sediment on the floodplain and therefore reducing transport downstream or deposition of this sediment in the channel. Not conclusive, but planting riparian vegetation and constructing a low dam of stones at the floodplain boarders can contribute to prevent erosion.
	Improve soils	High	Land-use change from agricultural land to forests, as well as creation of small and medium wetlands allow improving soil structure. Sediment deposition in floodplains can also help maintaining fertility and soil development.
Creating Habitat	Create aquatic habitat	Medium	Land use change from artificial and agricultural land to forest and wetland, especially with native vegetation, generates direct benefits to aquatic habitat by increasing base flows.
	Create riparian habitat	High	Stabilisation of floodplain boarders with bioengineering structures and reduction of the channel erosion lead to the creation and the sustainability of aquatic and riparian life habitats.
	Create terrestrial habitat	High	Land use change from artificial and agricultural land to forest and wetland, especially with native vegetation, generates direct benefits to terrestrial habitats by providing new positive ecological conditions.
Climate Alteration	Enhance precipitation	Low	For large afforestation measures, floodplain restoration could have a local impact on precipitations through evapotranspiration.
	Reduce peak temperature	Medium	If measures increase the evapotranspiration via land use change (from Artificial or Agricultural to Forest or Wetlands), a positive impact on air temperatures could be observed.

			Remark on water temperature: Trees and shrubs help shade the stream, keeping it cooler and healthier for aquatic wildlife.
	Absorb and/or retain CO2	Medium	By increasing the vegetal biomass via land use changes (from Artificial or Agricultural to Forest or Wetlands), floodplain restoration measures have an impact on CO2 absorption and retention. Floodplains are expected to have an effect on climate regulation through the fixation of carbon dioxide by photosynthesis and C-burial.

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	High	Floodplain restoration aiming at promoting actions against soil impermeability and increasing buffers and storage areas will help the floodplain in ensuring its natural storage role.
	Fish stocks and recruiting	High	By promoting natural functioning of the aquatic ecosystem and of immediate and remote environments, floodplain restoration measures will have a positive impact on water quality, vegetation population, temperatures and habitat conditions. This will naturally be followed by a recovery of the aquatic ecosystem, and thus an increase in fish populations, a greater biodiversity and a higher natural biomass production.
	Natural biomass production	High	
Regulatory and Maintenance	Biodiversity preservation	High	The restoration site could be planted with native grasses, shrubs, and trees. This is the first step to develop biodiversity. Environment resilience could be very important especially when the original seed bank, which has been covered by legacy sediment, is once again near the surface, and the dormant seeds begin to germinate and grow. So native flowering plants that have not been planted could appear. Creating a more natural stream channel and floodplain should also be accompanied by the immediate removal of invasive species on the site. The post-construction planting of native vegetation along the stream corridor discourages the re-establishment of invasive, non-native vegetation. Leaf litter from riparian woody plants also provides a source of food for macroinvertebrate life in the stream.
	Climate change adaptation and mitigation	Medium	Large floodplain restoration could have an impact on climate change through CO2 storage linked especially to afforestation.
	Groundwater / aquifer recharge	High	Measures for floodplain restoration can have low to high impact on groundwater recharge. In particular, wetland restoration enhances high aquifer recharge due to high water connection between surface flows and groundwater. Revegetation measures can also more or less favour

			groundwater recharge, as they enhance water infiltration in soils.
	Flood risk reduction	High	By allowing the stream naturally functioning, with controlled flooding, floodplain restoration measures reduce the risk of flooding damages. Buffer zones and storage infrastructures slow the water transfer time between the floodplain and the river, thereby spreading the flow and thus decreasing the flood intensity. Remark: For a high positive impact, floodplain restoration measures should be accompanying by management measures, corresponding to the full range of codes, ordinances and other regulations adopted for minimizing flood damage, including zoning codes, building codes and subdivision regulations that may either prohibit construction in flood-prone areas or allow some construction under certain conditions. Floodplain regulations also may be enacted to prevent consumer fraud by requiring disclosure of possible flood hazards.
	Erosion / sediment control	High	Land use and cover on riverbanks are closely linked to the river capacity for erosion and sediment control, by protecting soils, regulating flows and protecting the most vulnerable areas of erosion as the banks (increasing their cohesiveness). By reducing flood intensity, floodplain restoration decreases streambed and banks erosion during extreme events. River morphology may change as the water and sediment discharge conditions change. Restoring a balance between erosion and sedimentation conditions will help in recovering adequate hydrologic functioning and hydromorphologic conditions.
	Filtration of pollutants	Medium	Herbaceous plants in the wetland pockets help in reducing nutrients through nitrogen and phosphorus trapping. Riparian vegetation also provides a pollutant filtration action.
Cultural	Recreational opportunities	High	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 floodplains 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	Through impacts on sediment and biodiversity, floodplain restoration measures have a significant positive impact on nutrient recycling, aeration, fauna and flora populations.
	Improving status of physico-chemical quality elements	High	Through impacts on sediment and biodiversity, floodplain restoration measures have a significant positive impact on the water physico-chemical status.
	Improving status of hydromorphological quality elements	High	Through impacts on sediments, floodplain restoration measures have a significant positive impact on the hydromorphological quality element status.
	Improving chemical status and priority substances	Medium	Through impacts on pollution sources and pathways, floodplain restoration measures have a positive impact on the water chemical status.
Achieve Good GW Status	Improved quantitative status	Medium	By improving groundwater recharge, floodplain restoration measures have a positive impact on water quantity.
	Improved chemical status	Medium	By improving wetland functioning, acting for groundwater recharge, and modifying some practices, floodplain restoration measures contributes to improve the quality of groundwaters.
Prevent Deterioration	Prevent surface water status deterioration	High	By promoting as much as possible a "natural" functioning including maintaining base flows and controlling erosion, floodplain restoration measures help the environment in recovering his main filtration and relay zones, supporting the prevention of surface water status deterioration.
	Prevent groundwater status deterioration	Medium	By improving wetland functioning , acting for groundwater recharge, and modifying some practices, floodplain restoration measures contributes to prevent groundwater status deterioration.
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 in receiving watercourses, reducing flood risk as an alternative to hard flood defence. The protection and enlargement of the floodplains will thus contribute to the reduction of the flood impact. Floods Directive clearly integrates the use of floodplain management as one kind of tool to be included in Flood Risk Management Plans.
Habitats and Birds Directives			
Protection of Important Habitats		High	By creating terrestrial habitat notably in the riparian zone, promoting the biodiversity and so the well-functioning of

		the ecosystems, limiting the pollution, floodplain restoration measures support the preservation of protected species linked to the surface aquatic environment.
2020 Biodiversity Strategy		
Better protection for ecosystems and more use of Green Infrastructure	High	By: - promoting agricultural practices more respectful of the environment, - promoting afforestation, - restoring and preserving habitats, - limiting the impacts of floods, - restabilising the "natural" transport and deposition of sediment, - limiting pollutions and invasive species, floodplain restoration measures support the 2020 Biodiversity strategy.
More sustainable agriculture and forestry	High	
Better management of fish stocks	High	
Prevention of biodiversity loss	High	

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	An extensive area is required to conduct integrated actions, ideally corresponding to the original floodplain area of the river (i.e. returning the floodplain to its natural extent): 10-100 ha and more
Space required	Land acquisition is required in some areas to proceed with the implementation of restoration measures.
Location	More likely in the downstream reaches of rivers where there is naturally more floodplain.
Site and slope stability	According to Habersack et al.(2008), the slope of the river and of the floodplains is one of the most important variables when evaluating the floodplain retention potential: "shallow slopes reduce discharge peaks and prolong retention periods, while steeper slopes worsen the effects of retention, especially when the flood wave is totally discharged in the channel"
Soils and groundwater	There is no specific condition on soil permeability or depth. Remark : The tons of nutrient-rich topsoil excavated from a stream and floodplain restoration site can be recycled back into farming practices, can be mixed with a wide variety of other materials to create "manufactured" soils for a multitude of uses, or can be used as high-quality topsoil in newly developed or mine reclamation areas. The economic benefits of re-using legacy sediments are just now beginning to be explored.
Pre-treatment requirements	n/a
Synergies with Other Measures	Gives the opportunity to implement other measures such as re-meandering, creation of wetlands and ponds, etc.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition (Dispropriation cost grounds) Land acquisition (Dispropriation cost buildings per building)	Residential area: 700,000 €/ha Industrial area: 24,000 €/ha Recreational area: 12,000 €/ha Agricultural areas (high-value crops): 10,000 €/ha Houses: 100,000€ Farms: 250,000€ Companies: 250,000€ Destruction cost: 30,000€	Cost-benefit analysis for the flood risk management plan of the Scheldt estuary (Sigmaplan): Costs included the investment costs, maintenance and operation costs of flood protection measures and necessary expropriation costs for houses, industry and agriculture. The cost estimates of creating additional flood control areas on existing agricultural area was based on the opportunity costs or the cost of lost earnings from current to future agricultural activities. Agriculture could be maintained within a flood control area. However, it was expected that high-value crops such as vegetables, sugar beets and orchards will be moved into other areas and replaced by low-value crops as corn or pasture for livestock. The costs shown in this table are examples from the Sigmaplan programme (wide-scale programme).
Investigations & Studies		
Capital Costs	Dyke heightening () Standard 300–2,000 €/m Wall on top 800–2,500 €/m Sheet pile wall 3,500–5,000 €/m Quay wall (Antwerp) 16,100 €/m Flood control area Inner dike adaptation 770 €/m Outer dike construction 840 €/m Outlet sluices 19,000 €/ha Inlet sluices CRT 4,000 €/ha Engineering cost: 10% investment cost	
Maintenance Costs	0.5–1.5% investment cost	
Additional Costs	Other cost: 5% investment cost	

X. Governance and Implementation

Requirement	Evidence
Definition of the responsibilities	The implementation of floodplain restoration measures should be initiated by water managers and decisioners. A large consultation/participation process involving all concerned stakeholders should be planned. The successful of a floodplain restoration is largely conditioned by this process.
Cost effectiveness analysis	Floodplain restoration and management are often one of the best solution regarding flood management and risk mitigation.

XI. Incentives supporting the financing of the NWRM

Type	Evidence
National and local legislative and regulatory requirements	The entire Room for the Waal project (NL) was financed by Rijkwaterstraat as part of the Room for the Rivers program. The Restoration of the Aurino river was initiated, financed and implemented by the Special Enterprise for River Regulation and Land Protection, which is a body of the Autonomous Province of Bozen. Arga-Aragon rivers restoration have been financed partly by Ministry of Agriculture, Food and the Environment + Government of Navarre and Ebro River Basin Authority
LIFE + Nature and Biodiversity	Article 10 of the Habitats Directive promotes the features of a floodplain 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
"Ecoflood Guidelines - How to use floodplains for flood risk reduction"	M.S.A. Blackwell and E. Maltby, Ecoflood project, European Commission, 2006 http://ec.europa.eu/ourcoast/download.cfm?fileID=951
"Flood risk reduction by PReserving and restOring river Floodplains (PRO_Floodplain) - CRUE Research Report No I-3"	CRUE Funding Initiative on Flood Risk Management Research, 2008 http://www.crue-eranet.net/calls/final_report_pro_floodplain.pdf
Land studies – Floodplain restoration	http://landstudies.com/images/pdfs/LS-FloodplainRestoration.12sm.pdf
"Designing a long-term flood risk management plan for the Scheldt estuary using a risk-based approach"	Broekx et al., 2010.