European Commission

NWRM

Natural Water Retention Measures

www.nwrm.eu

Service contract n°07.0330/2013/659147/SER/ENV.C1

Case Study

Restoration of the Odense River

ACTeon environment research & consultancy

Office International de l'Eau

amec foster wheeler

BEF LATVIA

enveco Environmental Economics Consultancy

I.A.CO Ltd Environmental & Water Consultants

institute IMdea water

REGIONAL ENVIRONMENTAL CENTER

REKK

SLU

SRUC

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 Key words: Biophysical impact, runoff, water retention, effectiveness - Please consult the NWRM glossary for more information.

NWRM project publications are available at
http://www.nwrm.eu

Table of content

I. Basic Information

Application ID	*Denmark_01*			
Application Name	**Odense**			
Application Location	Country:	Denmark	Country 2:	
	NUTS2 Code		*DK03-Syddanmark*	
	River Basin District Code		*DK1-Jutland and Funen*	
	WFD Water Body Code			
	Description		*The Odense is a river in southern Denmark. It was channelized and deepened in the late 1940s to improve agriculture. The NWRM consists of a series of measures to restore floodplain connectivity along a 17 km section of the river.*	
Application Site Coordinates	Latitude: 55.2196		Longitude: 10.2824	
Target Sector(s)	Primary:	Agriculture		
	Secondary:	Hydromorphology		
Implemented NWRM(s)	Measure #1:	*N3 Floodplain reconnection*		
	Measure #2:	*N4 Re-meandering*		
	Measure #3:	*N8 River bed (alluvial mattress)*		
Application short description	The NWRM involved re-meandering, channel depth restoration and re-connection of the floodplain to a section of the Odense river.			

II. Policy context and design targets

Brief description of the problem to be tackled	*The measure will prevent flooding in downstream towns and cities. This will have a number of effects on the pressures relevant for the WFD. Reduced risk for flooding of urban environment reduces the risk for storm overflows from sewers (PN 1.1) as well as diffuse pollution resulting from flooding in general (PN 2.1). Re-meandering reduces the pressure from previous physical alterations for flood protection and agricultural purposes (PN 4.1.1 and 4.1.2). It will also potentially have a positive effect on ground water recharge in temporarily flooded areas (PN 6.1).*		
What were the primary & secondary targets when designing this application?	Primary target #1:	Regulation of the chemical status of freshwater	
	Primary target #2:	Flood control and flood risk mitigation	
	Secondary target #1:	Biodiversity and gene-pool conservation in riparian areas	
	Remarks		
Which specific types of pressures did you aim at mitigating?	Pressure #1:	WFD identified pressure	*4.1.2 Physical alteration for agriculture*
	Pressure #2:	Floods Directive identified pressure	Natural Exceedance
	Remarks		
Which specific types of adverse impacts did you aim at mitigating?	Impact #1:	WFD identified impact	*Altered habitats due to morphological change*
	Impact #2:	WFD identified impact	*Altered habitat due to*

			hydrological change
	Impact #3:	Floods Directive identified impact	*Waterbody status*
	Remarks		
Which EU requirements and EU Directives were aimed at being addressed?	Requirement #1:	WFD-achievement of good ecological status	
	Requirement #2:	Floods Directive-mitigating Flood Risk	
	Remarks		
Which national and/or regional policy challenges and/or requirements aimed to be addressed?			

III. Site characteristics

Dominant Land Use type(s) *CORINE LU types and codes*	Dominant land use	*2.1.1 Non-irrigated arable land*
	Secondary land use	
	Other important land use	
	Remarks	
Climate zone	cool temperate moist	
Soil type	*Fluvisol or luvisol*	
Average Slope	very gentle (1-2%)	
Mean Annual Rainfall	600 - 900 mm	
Mean Annual Runoff	300 - 450 mm	
Average Runoff coefficient (or % imperviousness on site)	0.3 - 0.5	10 - 20%
	% impervious estimated	
Characterization of water quality status (prior to the implementation of the NWRMs)	The measure has a positive impact on the water quality parameters concerning nutrients (N,P); an estimate of 235 kg N/ha/yr is removed in the wetlands along the re-meandered river stretch.	
Comment on any specific site characteristic that influences the effectiveness of the applied NWRM(s) in a positive or negative way	*Positive way:*	
	Negative way:	

IV. Design & implementation parameters

Project scale	Large (e.g. watershed, city, entire water system)	*The area affected by flooding during extreme precipitation events was for the investigated river stretch 43,8 ha.*
Time frame	Date of installation/construction (MM.YYYY)	*2003*
	Expected average lifespan (life expectancy) of the application in years	

Responsible authority and other stakeholders involved	*Name of responsible authority/ stakeholder*	*Role, responsibilities*
	1. Fyn County	The authority that carried out the project.
	2. The Municipality of Faaborg-Midtfyn	Responsible authority since 2006 after the county decommissioning
	3.	
	4.	
	5.	
The application was initiated and financed by	The project was part of the national action plan II for the aquatic environment from 1998. The objective was to restore 16.000 ha of wetlands in Denmark to retain nitrogen. The application was finaced by a state program under the Danish Nature Agency.	
What were specific principles that were followed in the design of this application?		
Area (ha)	Number of hectares treated by the NWRM(s).	The area affected by flooding during extreme precipitation events was for the investigated river stretch 43,8 ha. If the remaining 95% of restored river stretch behaves in the same manner, the figure only represents 5% of the entire area affected.
	Text to specify	*The entire area affected by the measure consists of 78 ha.*
Design capacity	Maximum water detention capacity for the investigated part of the restored river stretch (5%): 3648 m^3. If it is assumed that the remaining 95% of the restored river stretch behave in the same manner, this figure thus represents 5% of the total water volume that can be detained.	
Reference to existing engineering standards, guidelines and manuals that have been used during the design phase	*Reference*	*URL*
	1.	
	2.	
	3.	
	4.	
	5.	
Main factors and/or constraints that influenced the selection and design of the NWRM(s) in this application?	The main barrier was the willingness of the landowners to participate in the project, However - the "toolbox" offered contained several measures (including land consolidation) to overcome this problem. Therefore the project succeded in establishing voluntary agreements with and among the landowners in this project.	

V. Biophysical impacts

Impact category (short name) Select from the **drop-down menu** below:	**Impact description** (Text, approx. 200 words)	**Impact quantification** (specifying units)	
		Parameter value; units	% change in parameter value as compared to the state prior to the implementation of the NWRM(s)
Runoff attenuation / control	No overall attenuation in runoff is expected, but the timing of runoff, and hence the height of the flood peak, will be altered.		
Peak flow rate reduction	*Limited reductions in peak flow could be expected due to the remeandering and floodplain reconnection.* The measure has led to a reduction in peak flow during events of extreme precipitation.		
Impact on groundwater			
Impact on soil moisture and soil storage capacity	*Wetter riparian soils will probably result*		
Restoring hydraulic connection	*The main focus of the NWRM was an improved hydraulic connectivity between the river and its surrounding floodplain*		*Modelling results suggest improved hydraulic connectivity between the floodplain with potential beneficial effects on upstream and downstream areas.*
Water quality Improvements	*The NWRM affected water quality insofar as it led to increased deposition of sediment, phosphorus and organic matter on the floodplain as well as removal of nitrogen in the wetlands along the re-meandered river stretch.*	*235 kg N/ha/yr*	
WFD Ecological Status and objectives	*The NWRM contributes to WFD Ecological status objectives by remediating historical hydro morphological alteration and by reducing the nutrient levels in the stream itself and the discharge of nutrients in the recipient coastal water.*		
Reducing flood risks (Floods Directive)	*The measure has led to a reduction in peak flow during events of extreme precipitation.*		
Mitigation of other	*Restoration of riverbeds and re-meandering are themselves measures that strengthen biodiversity in terms of improved*		

biophysical impacts in relation to other EU Directives (e.g. Habitats, UWWT, etc.)	*biotopes for stream benthos. The periodical flooding of wetlands in connection to the restored river enhances this effect for a number of species, both flora and fauna. In addition; the conversion from arable land to grazed meadows of land adjacent to the river will result in decreased energy use in farm operations.*		
Soil Quality Improvements	*The NWRM may contribute to an overall improvement in soil quality, related primarily to increased inputs of riverine sediments to floodplain areas.*		
Other			

VI. Socio-Economic Information

What are the benefits and co-benefits of NWRMs in this application?	There are no monetary valuation of the direct benefits accruing from the re-meandering and wetlands available. Qualitatively, the direct benefits can be described as reduced risk for flooding in downstream villages, towns and land adjacent to the Odense Å during events of extreme precipitation. The additional benefits from this measure are connected to the reduction of nutrient leakage and consequent eutrophication in the Odense Å and in the coastal water receiving the river discharge. The riverbed restoration also bring about a strengthened biodiversity as migrating fish and benthos return to the stream. Positive effects can also be anticipated on cultural ecosystem services such as recreation in the affected areas.		
Financial costs	***Total:***	*Value in €*	*14 520/ha*
	Capital:	*Value in €*	*3 120/ha*
	Land acquisition and value:	*Value in €*	*11 400/ha*
	Operational:	*Value in €*	*Unknown / Not available*
	Maintenance:	*Value in €*	*Unknown / Not available*
	Other:	*Value in €*	
Were financial compensations required? What amount?	*No, the application was constructed by means of voluntary agreements.*		
	Total amount of money paid (in €): Unknown		
	Compensation schema: Unknown		
	Comments / Remarks: Unknown		
Economic costs	*Actual income loss: The average decrease in income from farm operations due to the conversion from arable land to grazed meadows of land adjacent to the river has been assessed to €11 400/ha*		
	Additional costs:		
	Other opportunity costs:		
	Comments / Remarks: Further investigation is warranted to determine the net change in landowner income associated with the		

	Odense floodplain reconnection.
Which link can be made to the ecosystem services approach?	Other ecosystem services provided by this NWRM include amenity services related to aesthetics and recreation, and potentially an increase in biodiversity. The floodplain reconnection will improve water quality in the river, which may have positive effects for drinking water provisioning or wastewater treatment.

VII. Monitoring & maintenance requirements

Monitoring requirements	Ongoing monitoring of flows and riparian inundation could help to validate the modelling results used to justify this NWRM.
Maintenance requirements	The NWRM should not require maintenance
What are the administrative costs?	There are no apparent administrative costs associated with the biophysical dimensions of the NWRM, there may be administrative costs related to landowner compensation

VIII. Performance metrics and assessment criteria

Which assessment methods and practices are used for assessing the biophysical impacts?	Biophysical impacts were assessed by a combination of modelling and observational studies. Modelling was performed to assess the flow patterns in the floodplains while observational studies were performed to assess the amount of sediment and nutrients deposited.
Which methods are used to assess costs, benefits and cost-effectiveness of measures?	Cost information were provided by Claus Paludan at the municipality of Faaborg-Midtfyn No information was available on the assessment of cost effectiveness of measures.
How cost-effective are NWRM's compared to "traditional / structural" measures?	No “traditional / structural” methods are available to achieve the floodplain reconnectivity accomplished by the Odense NWRM, thus it is very difficult to make this comparison.
How do (if applicable) specific basin characteristics influence the effectiveness of measures?	The history of the basin influences the effectiveness of the measure. Floodplain reconnection can only be successful in a landscape where the floodplain has become disconnected from the river through anthropogenic modification.
What is the standard time delay for measuring the effects of the measures?	A delay of 5-10 years would be appropriate

IX. Main risks, implications, enabling factors and preconditions

What were the main implementation barriers?	The main barrier was the willingness of the landowners to participate in the project, However - the "toolbox" offered contained several measures (including land consolidation) to overcome this problem. Therefore the project succeded in establishing voluntary agreements with and among the landowners in this project.
What were the main enabling and success	The financial support of the Danish Nature Agency

factors?	through the national plan for the aquatic environment together with the initiative from the former Danish Counties played a cruicial part for enabling the project. Landbrugsinfo and Aarhus University were also contributing factors.
Financing	The application was finaced by a state program under the Danish Nature Agency. However, as time went by, the land prices became higher and higher and in the end the County had to hold the remaining financing (approx. 50 %).
Flexibility & Adaptability	There may be a potential to adapt the measure to changing baseline conditions either through additional re-meandering or further work on the channel bottom.
Transferability	Some elements of the NWRM implemented here are transferrable to many agricultural rivers throughout north and central Europe. In any place where historical channelization has disconnected rivers from floodplains, a potential may exist for NWRM which reconnect the river and its floodplain.

X. Lessons learned

Key lessons	Water detention through temporary flooding of wetlands can play a significant role in reducing flow peaks, and thereby decreasing water levels and flood risk in downstream towns and villages during incidents of extreme precipitation.

XI. References

Source Type	*Scientific Article*
Source Author(s)	JB Poulsen, F Hansen, NB Ovesen, SE Larsen, B Kronvang
Source Title	Linking floodplain hydraulics and sedimentation patterns along a restored river channel: River Odense, Denmark
Year of publication	2013
Editor/Publisher	Ecological Engineering, in press
Source Weblink	Weblink

Source Type	*Grey Literature*
Source Author(s)	JB Poulsen et al.
Source Title	Vandtillbageholdelse i vådområder: Odense Å case område
Year of publication	2014
Editor/Publisher	
Source Weblink	https://www.landbrugsinfo.dk/Miljoe/landmandensomvandforvalter/Sider/faktaark-landmanden-som-vandforvalter_pl_14_1609.aspx

Source Type	*Project Report*
Source Author(s)	Naturstyrelsen
Source Title	Odense Å ved Brobyværk
Year of publication	2013
Editor/Publisher	
Source Weblink	http://naturstyrelsen.dk/naturbeskyttelse/naturprojekter/tilskudsordninger/nye-vandprojekter/den-kommunale-vaadomraadeindsats/bag-om-indsatsen/viden-om-vaadomraader/eksempler-paa-vaadomraader/odenseavedbrobyvaerk/

		Name / affiliation	*Contact details*
Key People	1.	Claus Paludan/Faaborg-Midtfyn Kommune	*Tlf. nr. +45 7253 2026* *Mobil tlf.: +45 7253 2076* *cpalu@faaborgmidtfyn.dk*
	2.	Vibeke Lindberg Birkelund/Ministry of Environment, Danish Nature Agency	*Tlf.: (+45) 72 54 30 00* *vibbi@nst.dk*