European Commission

NWRM

Natural Water Retention Measures

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Individual NWRM

Appropriate design of roads and stream crossings

Environment

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I. NWRM Description

Forest access roads and other roads in rural areas often cross streams and other small watercourses. Design and material used in forest road building may have strong impact on erosion risk and water quality in streams. The bridges or culverts used to cross these watercourses must be designed appropriately if negative impacts on the aquatic environment are to be minimized. Poorly designed or poorly implemented stream crossings can have numerous negative effects on the aquatic environment including increased sediment mobilization and changes in flow patterns. For example, flooding upstream of the road crossing can occur when the bridge or culvert is unable to transport a sufficient volume of water. Such floods can also wash out bridges or stream crossings, leading to increased costs for the road owner and downstream sediment pollution. Increased sediment mobilization results in loss of aquatic habitat and may extirpate threatened species including freshwater pearl mussel as well as destroying spawning habitat.

II. Illustration

River with inappropriate design

River after designing a proper crossing

Source: http://www.huronpines.org/projectinfo.asp?pjt=pv&pid=37

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Possible	This measure might be relevant in urban forest parks where appropriately designed stream crossings will contribute to hydrological functions and prevent harmful effects on aquatic biota.
Agricultural Areas	Possible	Extensive agriculture may necessitate access roads. Appropriately designed stream crossings in these areas can contribute to hydrological function and prevent harmful effects on aquatic biota.
Forests and Semi-Natural Areas	Yes	Forests and other semi-natural areas in Europe have a dense network of access roads for forestry, fire management and other purposes. Appropriately designed stream crossings in these areas can contribute to hydrological function and avoid harmful effects on aquatic biota.
Wetlands	Possible	Wetlands should typically not be avoided when constructing forest and agricultural access roads. Appropriately designed stream crossings can ensure that wetlands are not created upstream of the crossing or lost downstream.

Region	Applicability	Evidence
Western Europe	Yes	While this measure is most relevant in wet and temperate areas, it can also help to preserve water quality in drier areas.
Mediterranean	Yes	While this measure is most relevant in wet and temperate areas, it can also help to preserve water quality in drier areas.
Baltic Sea	Yes	While this measure is most relevant in wet and temperate areas, it can also help to preserve water quality in drier areas. In the northern Baltic region, this measure can be enhanced by restricting driving to winter months when soils are frozen and rivers are ice covered.
Eastern Europe and Danube	Yes	While this measure is most relevant in wet and temperate areas, it can also help to preserve water quality in drier areas. In the northern parts of Eastern Europe and the Danube basin, this measure can be enhanced by restricting driving to winter months when soils are frozen and rivers are ice covered.

IV. Scale

	0-0.1km^2	0.1-1.0km^2	1-10km^2	10-100km^2	100-1000km^2	>1000km^2
Upstream Drainage Area/Catchment Area	Yes	Yes	Yes	Possible	No	No
Evidence	The beneficial effects of properly designed stream crossings will be most apparent at a small spatial scale. However, like many of the measures presented here, the beneficial effect of measures implemented at a small scale can have beneficial effects on downstream rivers. For example, the negative effects of poorly designed stream crossings in catchments smaller than 1 km^2 can have noticeable effects on water quality in catchments larger than 100 km^2.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	Medium	Properly designed forest roads and stream crossings will have a minor effect on slowing or storing runoff. Poorly designed roads and stream crossings can negatively affect river flow dynamics in the forest landscape by speeding up or excessively slowing flows. When forest roads (or any non-paved road) run across contour lines, they have the potential to channelize and speedup runoff. This can then mobilize excessive quantities of sediment, leading to downstream water pollution and in the worst case, destroying the road itself.
	Slow Runoff	Medium	
	Store River Water	Medium	Properly designed stream crossings will not slow the flow or store the river water. Stream crossings that are too small for stream flow can store and slow river water, but this is a negative effect as it will lead to upstream flooding and potentially catastrophic downstream flooding if the stream crossing is washed out.
	Slow River Water	Medium	
Reducing Runoff	Increase Evapotranspiration	None	
	Increase Infiltration and/or groundwater recharge	None	
	Increase soil water retention	None	
Reducing Pollution	Reduce pollutant sources	Medium	Properly designed road and stream crossings have the potential to reduce mobilization of sediment-associated pollutants including phosphorus.
	Intercept pollution pathways	None	

F8: Appropriate design of roads and stream crossings

Soil Conservation	Reduce erosion and/or sediment delivery	High	One of the biggest environmental risks associated with poorly designed forest roads and stream crossings is increased erosion and delivery of sediment to water courses. Non-paved roads that are able to channel flows off hillslopes have a high potential to mobilize sediments from material used for road construction, as well as the surrounding soil. Consequently, properly designed forest roads and stream crossings will reduce potential negative impact. Road surface thickness and material used may significantly reduce erosion risk, especially if combined with other measures, e.g., reducing truck tire pressure.
	Improve soils	None	
Creating Habitat	Create aquatic habitat	High	Properly designed stream crossings usually do not create aquatic habitat *per se* but instead prevent its destruction. Properly designed stream crossings which do not impede the movement of fish and aquatic invertebrates are vital for ensuring aquatic habitat connectivity. Sediment mobilization associated with poorly designed roads and stream crossings has the potential to smother fish spawning beds and habitat of red list species such as freshwater pearl mussel. Smothering of aquatic habitat is especially problematic as a single terrestrial sediment mobilization event has the potential to render aquatic habitats unusable for many years. Larger bridges and crossings, on the other hand, may create specific conditions for aquatic fauna and thus in some cases contribute to creation of aquatic habitat.
	Create riparian habitat	None	
	Create terrestrial habitat	None	
Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	None	
	Absorb and/or retain CO_2	None	

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	Low	When roads and stream crossings are designed in an appropriate manner, there should be little overall effect on catchment-scale water storage. However, if crossings are not designed to cope with the volume of water flowing through the stream, undesirable water storage, including flooding upstream of the crossing can occur.
	Fish stocks and recruiting	High	By preserving access to spawning habitat, appropriately designed stream crossings can help to preserve fish stocks. Properly designed and constructed forest roads can help to prevent the mobilization and transport of sediment to streams. This can be critical for ensuring spawning beds which are critical for fish recruitment and the availability of habitat for red list species such as the freshwater pearl mussel.
	Natural biomass production	None	
Regulatory and Maintenance	Biodiversity preservation	High	By preserving access to spawning habitat, appropriately designed stream crossings can help to preserve fish stocks and maintain migration corridors for fish and aquatic mammals such as otter and beaver.
	Climate change adaptation and mitigation	None	
	Groundwater / aquifer recharge	None	
	Flood risk reduction	Low	Poorly designed stream crossings may contribute to local flooding under some circumstances. When properly designed, roads and stream crossings should have no effect on flood risk reduction as they will not alter the natural hydrologic regime.
	Erosion / sediment control	High	When roads and stream crossings in the forest landscape are designed, built and maintained in the correct manner, they have a high potential to reduce erosion and control sediment transport. When unpaved roads are planned to run along contour lines instead of up and down hillslopes, there can be large reductions in sediment mobilization and transport.
	Filtration of pollutants	Lowe	As stormwater runoff from the road surface may contain contaminants that are toxic to aquatic organisms, proper design of roads and stream crossings may prevent pollutants from reaching the waterbodies.
Cultural	Recreational opportunities	None	
	Aesthetic / cultural value	Medium	Properly designed roads and stream crossings will have higher aesthetic value compared to poorly designed ones.

Abiotic	Navigation	Low	In the case of larger streams and small rivers, it is possible that poorly designed stream crossings could impede navigation.
	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	Medium	When implemented correctly, this measure will contribute to status improvement of surface waters.
	Improving status of physico-chemical quality elements	Low	
	Improving status of hydromorphological quality elements	Medium	
	Improving chemical status and priority substances	None	
Achieve Good GW	Improved quantitative status	None	
	Improved chemical status	None	
Prevent Deterioration	Prevent surface water status deterioration	High	Appropriately designed and constructed roads and stream crossings have a high potential to prevent surface water status deterioration. When roads are designed, built and maintained in such a manner as to minimize sediment production and transport, both biological and chemical quality elements can be protected.
	Prevent groundwater status deterioration	None	
Floods Directive			
Take adequate and co-ordinated measures to reduce flood risks		Medium	Appropriately designed stream crossings can contribute to a reduction in flood risk. Poorly designed crossings which constrict high flows can lead to localized flooding upstream of the stream crossing. In some circumstances, this upstream flooding can wash out the bridge or stream crossing, resulting

		in damage to infrastructure and potentially significant downstream flooding.
Habitats and Birds Directives		
Protection of Important Habitats	Medium	Appropriately designed roads and stream crossings which do not lead to excessive sediment mobilization or unduly affect streamflow have a certain potential to protect important habitats.
2020 Biodiversity Strategy		
Better protection for ecosystems and more use of Green Infrastructure	Low	This measure can contribute to better protection of ecosystems by minimizing the negative effects of forest management operations on the aquatic environment. Forest roads and stream crossings can be an important component of areal green infrastructure as they provide access which facilitates forest management.
More sustainable agriculture and forestry	Low	This measure can contribute to more sustainable agriculture and forestry as it controls or reduces the potential negative impacts of rural roads on water quality.
Better management of fish stocks	Medium	This measure can contribute to better management of fish stocks and prevention of biodiversity loss by limiting damage to spawning beds and invertebrate habitat caused by sediment inputs to surface waters and by ensuring unimpeded passage of fish and aquatic invertebrates upstream and downstream of road crossings.
Prevention of biodiversity loss	Medium	

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Roads and stream crossings should be designed and built according to available technical instructions. Fords and open-box stream crossings are considered more favorable for movement of aquatic organisms.
Space required	Required spade depends on the dimensions of the infrastructure under construction and local conditions.
Location	This measure is appropriate to consider wherever there are unpaved roads in the rural landscape. In some cases it may be suggested to improve existing conditions, for example, improve the existing road surface or replace poorly designed culverts that inhibit migration of wildlife.
Site and slope stability	Careful consideration of site and slope stability is essential for appropriate design of roads. Ideally, the road should be designed so as to minimize slope and to be built on the most stable locations.
Soils and groundwater	Appropriately designed roads will avoid soft and fragile soils and areas where groundwater is close to the soil surface

Pre-treatment requirements	
Synergies with Other Measures	This measure can be performed in combination with water sensitive driving (F7) so as to minimize the impact of driving on water quality in the forest landscape.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition		There should not be any costs associated with land acquisition as the land will already be owned by the group or individual building the road or stream crossing.
Investigations & Studies		Field studies are required to ensure that the planned roads will not lead to excessive sediment mobilization and any stream crossings are large enough to handle the expected volume of flows.
Capital Costs		Implementing this measure may incur greater capital costs than would be incurred if it were not followed. Forest roads may need to be longer to avoid excessive slopes and to follow the contours of the landscape. Stream crossings may be more expensive as they will need to be larger and more robust than a minimalist approach.
Maintenance Costs		Implementing this measure may result in lower maintenance costs as roads and stream crossings are less likely to be destroyed by heavy rainfall events.
Additional Costs		

X. Governance and Implementation

Requirement	Evidence

XI. Incentives supporting the financing of the NWRM

Type	Evidence

XII. References

Reference	Comments
Neary, Daniel G., George G. Ice, and C. Rhett Jackson. "Linkages between forest soils and water quality and quantity." *Forest Ecology and Management*258.10 (2009): 2269-2281.	Good general reference on forest water issues
Soulis, K. X., N. Dercas, and C. Papadaki. "Effects of forest roads on the hydrological response of a small scale mountain watershed in Greece."*Hydrological Processes* (2014).	Very recent study from the Mediterranean region
Brown, Kristopher R., et al. "The effect of increasing gravel cover on forest roads for reduced sediment delivery to stream crossings." *Hydrological Processes*(2014).	US study showing how low cost measures can significantly reduce sediment inputs to streams from forest roads
Phil Roni, Karrie Hanson, and Tim Beechie. 2008. Global Review of the Physical and Biological Effectiveness of Stream Habitat Rehabilitation Techniques. North American Journal of Fisheries Management 28:856–890	A comprehensive literature review on potential effects of stream habitat rehabilitation techniques
Jackson, Scott D. Ecological Considerations in the Design of River and Stream Crossings. In 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garrett, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2003. 10 pp.	Highlights potential adverse effects of river and stream crossings.
Melvin L. Warren Jr. & Mitzi G. Pardew. 1998. Road Crossings as Barriers to Small-Stream Fish Movement.. Transactions of the American Fisheries Society 126(4): 637-644	Analyzes the impact of different types of road crossings on fish movement.