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NWRM

Natural Water Retention Measures

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Individual NWRM

Restoration and reconnection of seasonal streams

Environment

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I. NWRM Description

Seasonal streams or intermittent rivers are rivers for which surface water ceases to flow at some point in space and time. They comprise a large proportion of the global river network and are characterized by dynamic exchanges between terrestrial and aquatic habitats. These habitats support aquatic, semi-aquatic, and terrestrial biota. Seasonal streams provide essential ecosystem services to society, including flood control and irrigation. The abundance and distribution of seasonal streams, and their natural intermittent flow regimes, are being altered by climate change, water abstraction and inter-basin transfers. Despite their values and ongoing alterations, seasonal streams are chronically under-studied and protective management is inadequate.

These rivers require rigorous management to protect biological values. However, current management practices and protective policies and legislation for seasonal streams are often inadequate, or inexistent. As a result, many of seasonal streams and the communities that inhabit them are degraded by human activities during both flowing and non-flowing phases. The most common threats to these communities are alterations in natural flow regimes due to surface and groundwater abstraction, impoundment, and artificial flow augmentation. Unfortunately, minimal effort has been made to protect or restore naturally intermittent flow regimes.

Consideration of the cumulative impacts from anthropogenic uses (hydraulic structures, artificial streams, based recreational facilities, low water levels of support, pumping, gravel extraction and use of herbicides) on these streams is critical in watershed-based assessments and land management decisions to maintain overall watershed health and water quality.

In a watershed context, landscape hydrologic connectivity refers to the maintenance of natural hydraulic connections of surface and subsurface flow between source, headwater, or contributing areas and downstream/down gradient receiving waters. This connectivity could be restored by:

- Decreasing human pressures,
- Restoring river bed as buffer zones,
- Protecting banks and the vegetation,
- Protecting the flow channel itself.

More precisely, restoring and reconnecting seasonal streams with the river consists in, therefore favouring the overall functioning of the river by restoring lateral connectivity, diversifying flows and ensuring the proper functioning of these seasonal streams for a better water retention during floods. It could be, as examples:

- Maintenance and protection of the river system, its natural dynamics and environment; in particular, removing terrestrial lands between the river and the seasonal streams
- Upstream:
    - Preservation of a buffer space (banks, non-cropped area near the banks, structures to prevent poaching, bank erosion and eutrophication by animal excretions)
    - Limitation of pumping
- Downstream
    - Maintenance of jams (natural dams)
    - Carding of invasive plants (mechanical check-pass and finish a few weeks later to remove re-growth).

Warning: Recommendations given in this sheet are examples and considerations generally observed in different climatic conditions. Seasonal streams present a high diversity of hydrological functioning and measures to be implemented. Each restoration measure should be decided after the implementation of a hydrological study of the dedicated system.

II. Illustration

Example of seasonal stream during flooding, (Scotland, UK)

Source: http://www.fadsdirectory.com/flood-alleviation

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	No	Seasonal streams, except in arid and semi-arid regions, are often localised on basin heads. Their restoration and reconnection can be applied on any type of land use, except in artificial surfaces. Straightening river beds and artificial cutting off the meanders, oxbow lakes and seasonal streams have been common practice in many regions. It was particularly intensive in Western Europe in XX century. Seasonal streams can also form naturally and, in that case, it might not be sensible to try to re-connect them as they form when the river naturally re-routes itself.
Agricultural Areas	Yes	
Forests and Semi-Natural Areas	Yes	
Wetlands	Yes	

Region	Applicability	Evidence
Western Europe	yes	Seasonal stream are not restricted to arid regions.
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						

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	High	In some cases, seasonal stream flows are generated in major part by the runoff in the river basin. As it increases the length of the river, this measure helps the storage of runoff.
	Slow Runoff	High	As seasonal streams are often located in river basin heads, they often play the role of buffer zones for permanent systems downstream by providing a river bed aiming at slowing runoff flows.
	Store River Water	High	As it increases the length of the river this measure helps increasing the storage of river waters.
	Slow River Water	High	This measure can help slowing the river flow by temporarily diverting a part of the flow on these tributaries. Indeed, flow takes longer to reach the main channel because seasonal streams provide additional storage before water reaches the main channel
Reducing Runoff	Increase Evapotranspiration	Low	In case vegetation is largely present on the temporary streams banks, increased surface of the water table and humidity in soils can result in increased evapotranspiration
	Increase Infiltration and/or groundwater recharge	High	Infiltration of stream flow occurs into the unconsolidated alluvium forming channel boundaries. Nevertheless, groundwater recharge in ephemeral stream channels is effective and increased by their reconnection with the main river. It can be significant in some years and negligible in others. It is due to the high variability of precipitations which has a direct impact on runoff flows and flood intensity.

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	Increase soil water retention	Medium	Reconnection increases the surface of interaction with soil, therefore increasing soil water retention. In regions with seasonal precipitation, depth to ground water could be particularly important since ground water is closely coupled with stream flow to maintain water supply to riparian vegetation (Groeneveld and Griepentrog, 1985).
Reducing Pollution	Reduce pollutant sources	Low	Indirect impact by increased self-purification capacity
	Intercept pollution pathways	Medium	Headwater streams and wetlands are in a position allowing intercepting nutrients and contaminants from upland environments before they reach larger perennial streams (Brinson, 1988). As water moves through small, shallow channels and comes in contact with sediment, vegetation, coarse and fine woody debris and soil organic matter, elements and compounds are removed from the water, either by direct uptake or by conversion into inactive forms. Important variables in assessing the capacity of ephemeral and intermittent streams to perform this function include the amount of vegetative cover and soil organic matter on the stream banks (Lee et al., 2004).
Soil Conservation	Reduce erosion and/or sediment delivery	High	As it increases the length of the river, therefore slowing down the river flow, this measure allows reducing erosion on the river bed and banks, as well as favouring sediment deposition. Vegetation may thus establish on sand bars, and subsequently initiate the formation of various depositional features such as small current shadows, bars, benches, ridges, or islands (Tooth and Nanson, 2000). Spatially extensive assemblages of any plant species have the potential to alter geomorphology and geomorphic processes through bio-turbation, alteration of nutrients and patterns of succession (Lovich, 1996).
	Improve soils	Low	Where soil is protected against erosion, especially on riverbanks, soil conservation and improving can be effective.

Creating Habitat	Create aquatic habitat	High	It should be firstly mentioned that the creation of aquatic and riparian habitats is closely linked to the duration of water flow. Additionally to changes in channel form and sediment yield, the geomorphic response to anthropogenic disturbance can also have significant consequences for riparian ecosystems and water supplies. As streams become entrenched, formerly rich biological communities on the flood plain can become hydrologically disconnected from ephemeral stream flow and transform into dry terraces. Additionally, as channels become narrower and unconsolidated alluvial bed material is removed, there is less capacity to absorb passing flows and for vegetation to establish. Vegetation structure and diversity determine wildlife species diversity and abundance, and if a portion of habitat on which a species depends is damaged or destroyed, the breeding population of that species could be lost (Anderson and Ohmart, 1977). The riparian environments created by ephemeral and intermittent streams, especially when they are reconnected with the main stream, provide and maintain important habitat for wildlife, and are responsible for much of the biotic diversity.
	Create riparian habitat	High	
	Create terrestrial habitat	Low	Reconnecting oxbow lakes with the main river will allow better connecting aquatic and terrestrial lands, therefore creating or enhancing terrestrial habitat at the interface between both lands.
Climate Alteration	Enhance precipitation	Low	In case vegetation is largely present on the temporal streams banks, increased evapotranspiration may result in increased precipitation.
	Reduce peak temperature	Low	In case vegetation is largely present on the temporal streams banks, peak temperature may be reduced.
	Absorb and/or retain CO2	Low	In case vegetation is largely present on the temporal streams banks, CO2 may be absorbed and retained.

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	Medium	These reconnected seasonal streams help storing water within the basin head as they interact with the perennial stream as buffer zones, especially slowing down the water flow.
	Fish stocks and recruiting	Medium	As they enhance diversity and the development of aquatic habitats, these temporary streams can improve the fish stock.

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	Natural biomass production	Low	This measure creates new aquatic habitats, and in doing so may slightly increase natural biomass production. Patterns of primary productivity vary depending on whether the main water source for the vegetation is direct precipitation, channel flow, or stored water (Leenhouts et al., 2006; de Soyza et al., 2004). When stored water is accessible, productivity of plant species can be high for much of the growing season (Atchley et al., 1999). De Soyza et al. (2004) found that plants along an ephemeral stream channel responded more to channel flow than direct precipitation, indicating the importance of maintaining intact channel networks throughout a watershed.
Regulatory and Maitenance	Biodiversity preservation	High	Vegetative communities along ephemeral and intermittent streams provide structural elements of food, cover, nesting and breeding habitat, and movement/migration corridors for wildlife that are not as available in the adjacent uplands. Functional services of these communities include moderating soil and air temperatures, stabilizing channel banks and interfluves, seed banking and trapping of silt and fine sediment favourable to the establishment of diverse floral and faunal species, and dissipating stream energy which aids in flood control (Howe et al., 2008). Habitat fragmentation caused by human activities can jeopardize the survival of wildlife species by diminishing their ability to access the resources they need, retain genetic diversity, and maintain reproductive capacity within a population. By preserving the seasonal stream channels and connections, this measure avoids this fragmentation and hence contributes to preserving biodiversity. Species diversity varies with seasonal rain and stream flow patterns, and also varies on longer temporal scales. Following infrequent large winter floods, stream flow can be sustained for several months in ephemeral stream reaches of large rivers that drain humid mountains. During this period of sustained runoff, the ephemeral stream washes can support a high density and diversity of wetland (hydroriparian) plant species (Stromberg et al., in press). These "ephemeral wetland" communities develop with a recurrence interval linked to the climatic environment.
	Climate change adaptation and mitigation	Medium	By storing large quantities of water, limiting flood intensity and playing an essential role in the river basin functioning, restoration and reconnection of seasonal streams can be important to support climate change adaptation for downstream system.

	Groundwater / aquifer recharge	Medium	The temporary tributaries temporarily store water, hence increase the water ground interface and the possibilities of infiltration and groundwater recharge. In some cases, seasonal streams are more dependant of connection with groundwaters than of the precipitation falls.
	Flood risk reduction	Medium	This measure does help reducing flood risk by storing water, whether from runoff or river water. Seasonal streams are of particular importance when it comes to water storage and time retention especially in flash flood prone areas. Vegetation structure also shifts as watershed size and flood intensity increase.
	Erosion / sediment control	High	Water flowing in stream channels is subject to two key forces: (1) gravity that moves the water downslope and (2) friction between the water and channel boundaries that resists the downslope movement. These two forces determine, to a large degree, the ability of the water to modify the channel geometry and transport debris. In addition, channel roughness, slope, and depth determine the velocity of the flowing water (Leopold et al., 1964; Wakelin-King and Webb, 2007). Sediment deposition can have varying effects. For example, sediment deposited during flow events can encourage plant germination by providing seed beds and scarifying seeds, but it also can inhibit the growth of seedlings or some types of vegetation, such as non-native. This can be beneficial in some instances where stream restoration efforts are occurring. However, some aquatic species can be adversely affected by excessive sediment, which can interfere with reproduction and feeding.
	Filtration of pollutants	Medium	This measure does help filtering the pollutants by storing water, whether from runoff or river water, and slowing down the river flow, increasing the natural purification capacities of the river. As far as it is present and developed, riparian vegetation plays a filtration role of pollutants.
Cultural	Recreational opportunities	None	
	Aesthetic / cultural value	Medium	The creation of new aquatic areas through the tributaries adds some aesthetic value.
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	Medium	The benefit of the hydrologic connectivity of small headwater streams to perennial waters is clear and unambiguous to ecologists. Every important aspect of the river ecosystem, the river geomorphic system, and the river chemical system begin in headwater streams (Freeman et al. - 2007) The biogeochemical functions of ephemeral and intermittent streams include cycling of elements and compounds, removal of imported elements and compounds, particulate detention, and organic matter transport. These functions influence water quality, sediment deposition, nutrient availability, and biotic functions. Biogeochemical features are affected directly and indirectly by land-use and land-cover change. Hydrologic modifications such as direct alteration of flow regime and hydrologic flow paths, and indirect alterations such as increased impervious cover in contributing areas of the watershed can cause biogeochemical changes. Elimination of the surface-water/ground-water connection or disruption of the connection between a stream and its watershed by large-scale changes such as urban and suburban development also influences biogeochemical functions (Grimm et. al., 2004).
	Improving status of physico-chemical quality elements	Medium	
	Improving status of hydromorphological quality elements	High	As headwater streams occur upstream, and may ultimately discharge into higher order perennial streams, they connect landscape processes through their influence on the supply, transport, and fate of water and solutes in the watershed, with increased latitudinal connectivity (Alexander et al., 2007; Leibowitz et al., 2008).
	Improving chemical status and priority substances	Medium	By playing roles in filtration, deposition and degradation of pollutants, restored and reconnected seasonal streams contribute to improve river water chemical status.
Achieve Good GW Status	Improved quantitative status	Medium	By acting as buffer zones, restored and reconnected seasonal streams improve river water quantitative status.
	Improved chemical status	Medium	By playing a filtration role and infiltration role, restored and reconnected seasonal streams contribute to improve river water chemical status.

Prevent Deterioration	Prevent surface water status deterioration	Medium	By slowing down the river water and creating new aquatic and riparian habitats, the restored and reconnected temporary tributaries may help preventing surface water status deterioration. Delivery of water to a stream is largely dependent on the timing, duration, and amount of water that falls on the surface and subsequently runs off, which is dependent on soil type, and condition of the watershed and buffer. The importance of hydrologic connectivity relates closely to the delivery of water, sediment, nutrients, compounds, etc. to downstream areas and so has a direct impact on surface water status non deterioration.
	Prevent groundwater status deterioration	Low	By playing a role of filtration, restored and reconnected seasonal streams contribute to prevent groundwater status deterioration.
Floods Directive			
Take adequate and co-ordinated measures to reduce flood risks		High	This measure helps storing water and slowing down the river flow, providing a solution to flood risk.
Habitats and Birds Directives			
Protection of Important Habitats		High	By creating new aquatic habitats and by preserving the current habitats for very high resilient species, this measure contributes to the protection of important habitats.
2020 Biodiversity Strategy			
Better protection for ecosystems and more use of Green Infrastructure		High	Watersheds and their surrounding ecosystems are linked by the flow of water. The restoration of the connectivity is highly valuable for the protection of resilient ecosystems and so to prevent biodiversity loss. In case of human presence, reconnection and restoration must be coupled with drastic sustainable agriculture and forestry practices. Kennedy (1977) discussed the interactions of stream-riparian-vegetation-energy-nutrients-water production-aquatic life and terrestrial life, noting that the key to wise management of aquatic ecosystems is wise management of the watershed. As it allows reducing flows and linking several temporary streams with the main river, this measure allows increasing fish habitats and facilitating their fish movements, which should allow increasing fish stocks.
More sustainable agriculture and forestry		Low	
Better management of fish stocks		Medium	
Prevention of biodiversity loss		High	

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Various: depends on the length of the seasonal streams.
Space required	Various: depends on the length desired for the secondary streams. Should focus on restoring the natural function of current or former temporary streams, and hence the space and dimension requirements are determined by those that would be present naturally. The size of temporary streams may vary from a few hundred metres to multiple kilometres.
Location	It can be applicable in a very large variety of geomorphologies. The relevance of this type of measure, and its characteristics, vary regionally across Europe and more locally dependent on geological, topographic and climatic conditions.
Site and slope stability	n/a
Soils and groundwater	There is no specific condition on soils and groundwater.
Pre-treatment requirements	n/a
Synergies with Other Measures	This type of measure can be treated as an integral part of 're-naturalising' a catchment, and hence may fit with a range of other measures to restore the natural functions of rivers, especially the measure "Reconnection of oxbow lakes and similar features"

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition	n/a	
Investigations & Studies	n/a	
Capital Costs	n/a	
Maintenance Costs	n/a	
Additional Costs	n/a	

X. Governance and Implementation

Requirement	Evidence
Implementation	A hydrological study is essential before envisaging any kind of reconnecting or restoring measure of seasonal streams.
Definition of the responsibilities	The effective planning, design, and operation of this type of measure requires the involvement of territory stakeholders and water managers. This include local planning authorities, environmental regulators, private landowners and land managers, farmers and other bodies with responsibilities water management (e.g. irrigation bodies, drainage boards, etc). "Involving stakeholders like farmers, fishermen and (local) citizens (during the design phase, through consultation meetings and sessions is) one the key factors of (this kind of) project".

XI. Incentives supporting the financing of the NWRM

Type	Evidence
National Water Agencies	Numerous national water agencies could provide incentives according to their programmes of measures. Their contribution is decided case by case on a concrete project proposition.
CAP	The GAEC standards include retention of landscape features (including ponds) and establishment/retention of habitats

XII. References

Reference
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