NWRM Natural Water Retention Measures

Concept Note

Natural Water Retention Measures (NWRM) and the WFD and other daughter Directives

Disambiguation, issues and open questions

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This note aims at raising some basic methodological issues that might be key to clarify both the content and the scope of the *Pilot Project. Atmospheric Precipitation. Protection and Efficient use of Freshwater: Integration of Natural Water Retention Measures (NWRM) in River basin Management.* **This version is intended to contribute to the drafting process of a guidance document within the scope of the WG PoM of the WFD CIS.** It is therefore more accessible to anyone, trying to avoid as much as possible too specific jargon, while remaining accurate, and has been adapted as an *ad-hoc* version from the working document in progress (full Concept Note) that is being drafted to contribute to the different tasks of the DG ENV assignment.

The following issues are explored in this note:

1. How may NWRMs be best defined?
2. What is the distinctive character of NWRMs and how these relate to those recommended so far as the core of River Basin Management Plans (RBMPs)?
3. How may NWRMs be better classified?
4. What advantages can NWRMs bring about for the purposes of water management?

As compared to the other measures considered so far in the Programs of Measures (PoM), NWRMs have some distinctive characteristics that need to be considered in order to assess their potential contribution to improve and protect the status of water bodies or to reach other RBMP's objectives such as flood management, climate adaptation, tackling water scarcity and drought, etc.

To provide an answer to the above-mentioned questions is of paramount importance to build a common ground that will hopefully allow us to get into more detailed questions such as: How to assess and compare NWRMs when building a PoM? What meaningful recommendations can be derived regarding the design, implementation, and assessment of NWRM within the context of river basin management plans? And what role can NWRMs play in the cross coordination between water policy, rural development, land planning, green infrastructure, biodiversity conservation, and other interlinked policy areas? These further issues will be explored in a new discussion paper that will also be made available for DG ENV as part of this study and also for the drafting group of the CIS WG PoM, if so DG ENV wishes.

1. The distinctive character of NWRM as part of Green Infrastructure

Natural Water Retention Measures aim at restoring and maintaining water related ecosystems by natural means. They are Green Infrastructures intended to maintain and restore landscape, soils and aquifers in order to improve their natural properties, the environmental services they provide, and to favour climate change adaptation and reduced vulnerability to floods and droughts [1].

NWRMs have been brought to the water policy arena because of their potential contribution for water management[2], among other important contributions to attain environmental policy objectives. More specifically, "among the measures that can greatly contribute to limiting the negative effects of floods and droughts, is green infrastructure, particularly natural water retention measures. These include restoring and maintaining floodplains and wetlands, which can hold water in periods of abundant — or excessive — precipitation for use in periods of scarcity. Green infrastructure can help ensure the provision of ecosystem services in line with the EU Biodiversity Strategy. Reducing soil sealing is another measure that can diminish flood risks. These measures should be included in both RBMPs and [Flood Risk Management Plans] (FRMPs) and, as mentioned, should become a priority for financing under the [Common Agricultural Policy] (CAP), Cohesion and Structural Funds" (COM (2012) 673).

The distinctive character of NWRMs can be deduced from their own definition, as above. The definition at the onset of this section appeals both to a single purpose (i.e. restoring and maintaining water related ecosystems) and to a particular set of means (i.e. by natural means) [3]. We can deduce from that the following distinctive characteristics of NWRMs.

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[1] NWRM can be defined as those "measures that aim to safeguard natural storage capacities by restoring or enhancing natural features and characteristics of wetlands, rivers and floodplains, and by increasing soil and landscape water retention and groundwater recharge". They can be implemented singly, or in combination, in a broad range of land-uses including agricultural and urban lands." (Stella Consulting, 2012) This definition is in accordance with the one adopted (although not officially) by the European Commission that defines NWRM as "measures aimed to safeguard and enhance the water storage potential of landscape, soils and aquifers, by restoring and maintaining ecosystems, natural features and characteristics of water courses and by using natural processes. See: Stella Consulting (2012) Costs, benefits and climate proofing of natural water retention measures (NWRM). European Commission, DG Environment. Contract 070307/2010/581332/SER/D1. See also: http://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm

[2] Other mentions to NWRMs in the Blueprint to Safeguard Europe's Water Resources (COM (2012) 673), its Impact Assessment (SWD (2012) 382) or the Stella Report develop a particular aspect: NWRMs are a type of Green Infrastructure; NWRMs are one amongst other kinds of measures to enhance resource efficiency; etc.

[3] Yet, what actually distinguishes NWRM seems to be the particular means used to pursue this set of aims since: "they are adaptation measures that use Nature to regulate the flow and transport of water so as to smooth peaks and moderate extreme events (floods, droughts, desertification, salinity)" (*ibid*.). NWRM might be considered an alternative term to designate green infrastructures or, in other words, a subset of them. As the defined by the EPA the latter "uses natural hydrologic features to manage water and provide environmental and community benefits" (http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm). More specifically: Green infrastructure is an approach to water management that protects, restores, or mimics the natural water cycle. Green infrastructure is effective, economical, and enhances community safety and quality of life. It means planting trees and restoring wetlands, rather than building a costly new water treatment plant. It means choosing water efficiency instead of building a new water supply dam. It means restoring floodplains instead of building taller levees. See:

1. Not every measure that increases the water stored in water bodies is a NWRM.

Thus, not every measure aiming at improving and protecting the status of the water bodies and their water storage potential is a NWRM.

Within the means to couple increasing water demands with the preservation of the ecological status of water sources, different alternatives can be combined, such as saving water through reducing leakages in the distribution network (an efficiency measure), replacing natural freshwater sources by recycled or desalinated water (an alternative water supply source) or safeguarding and enhancing the ability of freshwater ecosystems to provide water in the long term (a NWRM).

For example, retaining water in an aquifer may be the result of afforestation and changes in land practices that reduce runoff and increase water infiltration or, alternatively, of reductions in water abstractions due to demand management, water savings, substitution of water sources, and technical efficiency improvements. The first set of measures belongs to the category of natural water retention ones while the latter does not [4].

2. NWRMs are interventions over water related ecosystems

That means that the intended effect is not the indirect result of actions taken somewhere else but directly over soil, an aquifer, a floodplain, a forest or any other element that regulates the water cycle. This is all in order to restore and maintain the potential of these systems to provide water services and other environmental services such as flood security, drought resilience, water quality regulation and so forth [5].

For example, the *artificial* recharge of aquifers is, for the state of the art, a clear example of a *natural* water retention measure. The recharge is a *direct* intervention over a disturbed system that increases the amount of water it stores. The same outcome may be obtained by reducing abstractions but the measures required are not direct interventions over the aquifer as such but actions taken somewhere else in the economy (water savings in households, substitution of water using devices, technical efficiency of water distribution networks, price changes, etc., which are *not* NWRMs).

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http://www.americanrivers.org/initiatives/pollution/green-infrastructure/what-is-green-infrastructure/#sthash.hqa6yXDm.dpuf

[4] In the Stella Report (Stella Consulting, 2012, p. 131) a clear distinction is drawn between saving and efficiency measures on one side and NWRMs on the other. This can be confirmed by the identification of the three main categories of measures to improve water resource efficiency and sustainability as identified in the Blueprint (SWD (2012) 381[4], p. 3). These are: NWRMs, water efficiency measures and alternative water supply. The first category relies on enhancing and restoring Nature's potential to deliver water services, the second one in using those water services more efficiently and the third one in adding up additional non-conventional water sources.

[5] Using economic concepts, one may say that NWRMs are alternatives to invest directly in natural capital and improve its potential to better deliver flows of services, while all other alternatives use other means and the effects over natural capital might be comparable though. By contrast, one may say that, for example, improving water distribution networks and installing more water efficient devices are ways of investing in fixed human-made (physical) capital, alternative sources are ways to substitute natural by human-made capital and reallocating water to its more productive uses is a way to use the combined natural and man-made capital more efficiently. NWRMs are different because they only rely on natural capital and they basically consist in ways to restore or to adapt it in order to enhance its potential to deliver ecosystem services such as flood protection, drought resilience, etc.

3. *NWRMs use natural processes.*

That is to say functions commonly performed by nature. For instance, soil infiltration (hence a permeable pavement becomes a natural mean), or vegetation to control temperature (then a green roof is a natural mean), or even using an aquifer to store and regulate water (artificial groundwater recharge cannot look more natural now), etc.

When defining a NWRM we mainly focus on functions such as slowing down water flows, increasing infiltration rates, controlling storm flows, storing water, reducing pollution loads and so on, not in the assets themselves. Rather than Nature restoration alternatives, NWRMs are better defined as types of green infrastructures deliberately designed for the provisioning of water-related environmental services [6].

4. *Natural water retention is not the end but the means that make NWRMs relevant for water resource efficiency and sustainability*.

NWRMs should be considered as part of an integrated water management system in which, in most cases together with other water management measures (i.e. water efficiency measures, alternative water supply, etc.), NWRMs can safeguard or enhance the ability of a modified freshwater ecosystem to better deliver water related ecosystems services. Retaining water in the environment is essential because it allows for the production of different (biophysical) flows of services (flood security, drought resilience, natural water purification, biodiversity, etc.).

Unlike the term ‘retention’ may imply, the objective of a NWRM is not limited to the quantity of stored water. Further, NWRMs may provide flood security by slowing down peak flood; increasing water reliability through enhancing water storage; reducing pollution loads by filtering contaminated water; improving landscape, biodiversity, providing recreation amenities, etc. The reason why they are considered as a way of water retention is because only through retaining water on site this plethora of services may be delivered.

5. *NWRMs are not simply means to restore to its original natural condition the assets modified by human action, which is often not an affordable (if at all possible) task, but to adapt current existing developments in order to enhance or recover the water regulation functions provided by them and that were reduced or lost when these developments took place.*

Restoring does not necessarily mean recovering the natural system that was previously in place. An ecosystem may not be returned to its original state. This possibility, though, cannot be excluded: for instance, giving rivers room to dissipate energy and retain water might be a sensitive restoration option.

It is also obvious that this kind of restoration alternative is not an option in many relevant cases where the natural system once there is irreversibly lost. For instance in urban areas, we would still have the option to recreate some functions that the disturbed system cannot spontaneously perform

[6] This is clearly the case of sustainable urban drainage systems (SUDS), which are measures to adapt existing land developments such that they are better able to control the quantity and improve the quality of runoff as well as to enhance the amenity value of the site and its surroundings.

(such as temperature control, flood and storm control or water infiltration) by putting in place some “non-completely natural” structures (such as green roofs, soakaways or permeable pavements).

In fact, sometimes restoration comes closer to recovering the original structure (e.g. floodplain recovery), some others it consists in recovering the functions although not the original structure delivering them in the past (e.g. permeable pavements), some other times restoration lies in between recovering the structure and recovering the functions (e.g. in sustainable farming practices).

By restoring we understand "repairing disturbed ecosystems through human interventions”. NWRMs fall under the umbrella of restoring once you see all that from the standpoint of restoration ecology where presumably the concept comes from: “Restoration ecology is the scientific study of repairing disturbed ecosystems through human intervention”. According to that, *restoration is any means to “recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed* […] *Restoration activities may be designed to replicate a pre-disturbance ecosystem or to create a new ecosystem where it had not previously occurred*” [7].

Restoration might also consist in creating new sui-generis “ecosystems” (e.g. green-roofs) to perform “ecosystems functions” that were (or not) previously performed by nature (water retention in the plain to avoid the flood reaching a large city: e.g. the Thames and the City of London).

2. How may NWRMs be better classified?

The best way to classify NWRMs is by distinguishing these alternatives that focus on land use from those that are addressed directly to restore or adapt water bodies.

The former set includes modifying and adapting forest, meadows and pastures, agricultural and urban practices. The latter includes actions to repair or restore the potential to store water in lakes, rivers, wetlands and aquifers [8]. The table below (**Table 1**) shows, in columns 1 and 2, a minimal classification of NWRM. This allows streamlining the Stella Report typology (columns 3 to 5); however, these three columns are just examples. From our viewpoint, what is really critical is to be clear about columns 1 and 2.

All measures included in the Stella Report may be classified according to these two basic criteria. From the second column one can easily see that the number of potential measures fitting into the table is high (… and increasing). Each one of the classes above may include an unlimited number of alternatives so it might not be desirable to build a locked list of the available alternatives from the onset of the project.

The above discussion and the table emphasize on selection criteria rather than on in-detail lists of potential measures. The usefulness of the conclusions drawn in the project critically depends on the relevance of the measures considered and of the case studies (NWRM applications) selected for further analysis. Hence, it might not be desirable to produce a closed list of alternative measures within those classes. That may entail the risk of excluding relevant measures that may arise throughout the study but most importantly might lead to include several alternatives that although interesting for one purpose (e.g. making forestry or cropping practices sustainable) might not be relevant for water policy (or might not be assessed under the criteria of water policy because of poor information available).

7 For instance: Vaughn, K. J., Porensky, L. M., Wilkerson, M. L., Balachowski, J., Peffer, E., Riginos, C. & Young, T. P. (2010) Restoration Ecology. Nature Education Knowledge 3(10)

[8] This is aligned with the classification proposed by Stella Consulting (2012).

An in-detail list with many measures combined with anyone's ability to cover only a limited number of them might leave the impression in the end that our study is not representative of available alternatives when that is not the case. Instead of focusing on lists of measures, choice criteria must be based on the interest of the specific measures selected for the purposes of water policy. This should be the anchorage, from our viewpoint, especially when all this effort will lead to guidance documents.

3. What contribution can be expected from NWRMs to the Purposes of Water Management?

Undoubtedly NWRMs are valuable on their own. The question is why and how they should be integrated in RBMPs and FRMPs.

1. *NWRMs might be cost-effective alternatives to be considered as part of the programs of measures*

NWRMs can help meet the desired RBMP's aims as stated in the WFD, the FD, the Strategy for Water Scarcity and Droughts, climate change adaptation, sustainable urban development... and the costs and benefits associated to both the traditional measures already considered and the NWRMs.

Regarding effectiveness as water policy instruments NWRMs can deliver "hydrological, hydro-morphological, physicochemical and ecological effects" (Stella Consulting, 2012, p.7), which are relevant to implement the WFD and FD as well as for managing scarcity and droughts.

The effectiveness of NWRMs to attain RBMPs' objectives is clear. As an example, the following table gives a catalogue with the potential contribution of Sustainable Drainage Systems (SUDS) to improve water quantity and quality (**Table 2**).

The potential of NWRMs for flood management is also clear and evident since enhancing the water storage potential is a means to enhance the natural provision of flood security (e.g. restoring floodplains is a way to dissipate energy through reducing flows and slowing its pace as a way to reduce flood risk).

The ability of NWRMs to improve the potential to provide water quality services is a new opportunity for water policy (e.g. higher phreatic levels prevent saltwater intrusion, higher rates of water infiltration may be an alternative to wastewater treatment plants as a means to improve water quality in aquifers, and re-naturalizing a river is a means in turn to increase its resilience to water pollution and its natural water purification potential).

2. *NWRMs might yield important direct benefits relevant for water management.*

The above-mentioned water retention measures may protect rivers and freshwater sources entailing benefits such as reducing other protection costs, increasing the rivers' natural assimilation capacity and making other quality measures redundant. Mulching and other NWRMs may reduce erosion and enlarge the lifespan of reservoirs while reduce its maintenance costs, etc. This means that an important benefit of NWRMs is their capacity to reduce or avoid costs and damages.

These benefits are context-based (and potentially site-specific) and therefore difficult to identify and quantify. Once the list of measures to be analysed for any River Basin District (RBD) would be available it would also be possible to identify these avoided costs and damages in the river basin. Valuation alternatives range from production losses to the cost of defensive and replacement measures (i.e. averting behaviour). **Table 3** presents the list of these direct benefits associated to the genuine objectives of RBMPs or those benefits of reaching the environmental objectives of RBMPs whatever the measures used.

3. NWRMs come along with other significant ancillary benefits

Such as biodiversity, amenity, etc. that are exclusive of natural preservation and not easily attainable via alternative water policy measures. These benefits, which are listed in **Table 4**, are then another distinctive characteristic of NWRMs.

4. Summing up

Natural Water Retention Measures aim at restoring and maintaining water related ecosystems by natural means. They are Green Infrastructures intended to maintain and restore landscape, soils and aquifers in order to improve their natural properties, the environmental services they provide, and to favour climate change adaptation and reduced vulnerability to floods and droughts.

The best way to classify NWRMs is by distinguishing these alternatives that focus on changing land use practices from those that are addressed directly to restore or adapt water bodies.

Apart from being effective means to attain the purposes of water policy with all the benefits associated compared with other alternative means to reach the same end NWRMs might result in significant cost reductions and bring about significant and exclusive ancillary benefits.

Table 1. Streamlining NWRM classifications…

Type	Class	Code	NWRM Measure	Short description
Restoration measures – partial recovery of functions or the structure of modified ecosystems by intervening directly over…	**Rivers and their wetlands**	N1	Basins and ponds	Basins and ponds store surface run-off. Detention basins are free from water in dry weather flow conditions but ponds (e.g., retention ponds, flood storage reservoirs, shallow impoundments) contain water in dry weather, and are designed to hold more when it rains.
		N2	Wetland restoration and creation	Wetlands restoration and creation can involve: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); technical small-scale measures such as clearing trees; as well as changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. Wetland restoration can improve the hydrological regime of degraded wetlands and generally enhance habitat quality. (Creating artificial or constructed wetlands in urban areas can also contribute to flood attenuation, water quality improvement and habitat and landscape enhancement).
		N3	Floodplain reconnection and restoration	A floodplain is a plain bordering a river which 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. Nowadays, the objective is to restore them, their retention capacity and ecosystem functions.
		N4	Re-meandering	In the past, rivers have been straightened by cutting off meanders. Re-meandering is bringing a river back closer to its naturally meandering state by creating a new meandering course and by reconnecting cut-off meanders. Re-meandering slows down the flow of a river. The new form of the river channel creates new flow conditions and very often also has an impact on sedimentation. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals.
		N5	Revitalisation of flowing waters	In the past, rivers flows have been modified through channelization, embankments or modification of river beds. Those modifications were aiming at flood prevention or supporting changes of agricultural practices for example. This has led to uniformed flows in the rivers and often having effect on the water time transfers. Current practices for revitalisation of flowing waters are trying to create the conditions for diversifying the water flows, inducing more diversity in habitats for fauna but also increasing the water time transfers in order to prevent flash floods in the downstream areas for example.
		N6	Restoration of the flows of temporary tributaries	Temporary streams are of particular importance when it comes to water storage and time retention especially in flash flood prone areas. Some measures can be directly implemented in order to ensure their proper functioning.
		N7	Reconnection of hydraulic annexes	To ease the overall functioning of the river, some hydrographic network elements could be reconnected, including the so-called hydraulic annexes. This will allow for improvement of lateral connectivity, diversifying flows and habitats, but also cleaning the secondary arms that play a key role for retention in high water periods

		N8	Restoration of the riverbed (alluvial mattress)	The reconstitution of the alluvial mattress consists in levelling-up the riverbed and/or reactivating the bank erosion in order to stop the incision of the riverbed. It can allow better connection with side arms, level-up the water level at low flow periods, diversifying flows (depth, substrate, speed), diversify habitats and increase retention times
		N9	Levelling of dams/ longitudinal barriers	Levelling longitudinal barriers allows re-establishing fluvial dynamics and ecological continuity. The aim is to restore the slope and longitudinal profile of the river, to restore natural water flows, to allow for the solid transport (sediment) to take place, to diversify flows (depth, substrate, speed), diversify habitats and related flora and fauna
		N10	Natural bank stabilisation	In the past, various activities were undertaken to straighten rivers, such as the stabilisation of riverbanks with concrete or other types of retention walls. Such actions limited rivers' natural movements, leading to degradation of the river, increased water flow, increased erosion and decreased biodiversity. Natural bank stabilisation reverses such activities, allowing rivers to move more freely. Where bank stabilisation is nevertheless necessary, such as in residential areas, natural materials such as roots or gravel can be used. Natural materials are preferable as they allow water to infiltrate into the bank. They also provide better living conditions for aquatic fauna.
		N11	Elimination of riverbank protection	The suppression of lateral constraints consists in removing some bank protection in order to enhance lateral connection of the river, diversifying flows (depth, substrate, speed), diversify habitats but also capping floods in the mainstream.
	Lakes and their wetlands	N12	Restoration of lakes	Lakes are by definition water retention facilities; they store water (for flood control) and provide water for many purposes such as water supply, irrigation, fisheries, tourism, etc. In addition, they serve as sinks for carbon storage and provide important habitats for numerous species of plants and animals, including waders. In the past, lakes have sometimes been drained to free the land for agriculture purposes, or have simply not been maintained and have silted up. Restoring lakes is re-introducing them where they have been in former times or revitalising them.
	Aquifers	N13	Artificial groundwater recharge (AGR)	AGR stores large quantities of water in underground aquifers to increase the quantity of groundwater in times of shortage. It results in a lowering of run-off from surrounding land, and in an enhanced natural condition of aquifers and water availability. The natural cleaning process of water percolating through the soils when entering the AGR improves water quality.
Change or adaptation of land-use practices (partial recovery of functions or the structure of modified ecosystems by changing or adapting land-use practices such as…	**Agriculture**	A1	Restoring and maintaining meadows and pastures	Meadows are areas or fields whose main vegetation is grass, or other non-woody plants, used for mowing and haying. Pastures are grassed or wooded areas, moorland or heathland, generally used for grazing. Due to their rooted soils and their permanent cover, meadows and pastures provide good conditions for the uptake and storage of water during temporary floods. They also protect water quality by trapping sediments and assimilating nutrients.
		A2	Buffer strips	Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margins of fields, arable land, or roads. Due to their extensively used green cover, buffer strips offer good conditions for effective water infiltration and therefore promote the natural retention of water. They can also significantly reduce the amount of suspended solids, nitrates and phosphates originating from agricultural run-off.

		A3	Field margins and headlands	Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margins of fields, arable land, or roads. Due to their extensively used green cover, buffer strips offer good conditions for effective water infiltration and therefore promote the natural retention of water. They can also significantly reduce the amount of suspended solids, nitrates and phosphates originating from agricultural run-off.
		A4	Soil conservation crop practices: crop rotation	Various soil conservation crop practices (e.g., crop rotation, strip cropping, intercropping, interlayer crops) can ensure that the soil retains water by maintaining good soil characteristics. These practices minimise the alteration of the composition and structure of the soil, thereby safeguarding it against erosion and degradation, and preserving soil biodiversity. Crop rotation, for example, involves cultivating different crops in temporal succession on the same land. This enhances soil structure, improves nutrient cycles, and increases microbiological diversity.
		A5	Soil conservation crop practices: strip cropping	Various soil conservation crop practices (e.g., crop rotation, strip cropping, intercropping, interlayer crops) can ensure that the soil retains water by maintaining good soil characteristics. These practices minimise the alteration of the composition and structure of the soil, thereby safeguarding it against erosion and degradation, and preserving soil biodiversity. Crop rotation, for example, involves cultivating different crops in temporal succession on the same land. This enhances soil structure, improves nutrient cycles, and increases microbiological diversity.
		A6	Soil conservation crop practices: intercropping	Various soil conservation crop practices (e.g., crop rotation, strip cropping, intercropping, interlayer crops) can ensure that the soil retains water by maintaining good soil characteristics. These practices minimise the alteration of the composition and structure of the soil, thereby safeguarding it against erosion and degradation, and preserving soil biodiversity. Crop rotation, for example, involves cultivating different crops in temporal succession on the same land. This enhances soil structure, improves nutrient cycles, and increases microbiological diversity.
		A7	No tillage	Tillage is a mechanical modification of the soil. Intensive tillage can disturb the soil structure, thus increasing erosion, decreasing water retention capacity, and reducing soil organic matter through the compaction and transformation of pores.
		A8	Reduced/conservation tillage	Tillage is a mechanical modification of the soil. Intensive tillage can disturb the soil structure, thus increasing erosion, decreasing water retention capacity, and reducing soil organic matter through the compaction and transformation of pores.
		A9	Green cover	Green cover refers to crops planted in late summer or autumn, usually on arable land, to protect the soil, which would otherwise lie bare during the winter, against wind and water erosion. Green cover crops also improve the structure of the soil, diversify the cropping system, and mitigate the loss of soluble nutrients.

		A10	Early sowing	Early sowing refers to sowing up to six weeks before the normal sowing season. This allows for an earlier and quicker development of crops and of a root network that leads to soil protection. The period in which the soil lies bare is shorter and, therefore, erosion and run-off are less significant and water infiltration is improved. Early sowing can also help to mitigate the extreme ETP rates typical of Mediterranean summers. However, early sown plants are frost sensitive; therefore farmers run the risk of losing the crops because of the low temperatures. In northern countries, temperature in spring (March) can be adequate but the risk of frost is still serious until May. Therefore, early sowing requires specific tools (plastic tunnel covers, onsite green house, etc.) and cannot be applied by any farmers for any crops.
		A11	Traditional terracing	Traditional terraces consist of nearly level platforms built along contour lines of slopes, mostly sustained by stone walls, used for farming on hilly terrain. When properly built and well maintained, terraces can reduce erosion and surface run-off by slowing rainwater to a non-erosive velocity. So-called traditional terracing involves less disturbance of the terrain than modern terracing, as it does not involve significant levelling or cutting using heavy machinery.
		A12	Beetle banks	Beetle banks are tussock grass ridges, generally about 2 m wide, which run from one side of a field to the other, while still allowing the field to be farmed. They provide habitat for ground-nesting birds, small mammals and insects (including those that feed on crop pests). When carefully placed across the slope, such banks can help reduce run-off and erosion. However, you must ensure that they do not channel water instead and make existing problems worse.
		A13	Hedgerows	Field boundaries are important elements of the countryside as landscape and historic features; for wildlife habitat; and for stock management and shelter. Hedges across long, steep slopes may reduce soil erosion as they intercept and slow surface run-off water before it builds into damaging flow, particularly where there is a margin or buffer strip alongside.
		A14	Controlled traffic farming	Controlled traffic farming is a system which confines all machinery loads to the least possible area of permanent traffic lanes. Current farming systems allow machines to run at random over the land, compacting around 75% of the area within one season and at least the whole area by the second season. Soils don't recover quickly, taking as much as a few years. A proper CTF system on the other hand can reduce tracking to just 15% and this is always in the same place. CTF is a tool; it does not include a prescription for tillage although most growers adopting CTF use little or none because soil structure does not need to be repaired. The permanent traffic lanes are normally parallel to each other and this is the most efficient way of achieving CTF, but the definition does not preclude tracking at an angle. The permanent traffic lanes may be cropped or non-cropped depending on a wide range of variables and local constraints.
	Forestry and pastures	F1	Afforestation of riparian areas	Planting forests in near-stream areas can have multiple benefits including erosion and nutrient leaching control. They will also slow the stream velocity during high flow flood events and may have beneficial effects on stream temperature.

		F2	Afforestation of montane areas	Targeted planting of forests in montane areas can help to stabilize hill slopes, thereby reducing erosion and potentially leading to greater water retention in mountain areas. Afforestation may have beneficial effects on the hydrograph by reducing peak flows and helping to maintain base flows. The potential for water retention must be balanced against the increased ET and pollutant trapping that may be associated with forests.
		F3	Afforestation of reservoir catchments	Afforestation of reservoir catchments can have multiple benefits. It can reduce sediment inputs from the catchment, lengthening the life of the reservoir, and may also have beneficial effects on water quality in some cases when peat lands are afforested. Afforestation can reduce peak flows and help to maintain base flows. The benefits of afforestation must be balanced against the potential for increased evapotranspiration from a rapidly growing forest.
		F4	Targeted planting in Mediterranean areas for “catching” precipitation	There is some evidence that planting trees on some Mediterranean hill slopes can assist in cloud formation and precipitation. The forests assist in "trapping" rising air and condensing atmospheric water vapour. This work has been pursued by Milan Milan, amongst others.
		F5	Forests as large-scale water pumps	Much of the evapotranspiration from forests falls elsewhere as rain, Ellison et al. (2012), amongst others, have shown that this large scale water pump can be a significant component of the annual precipitation in many continental areas. That is to say, many continental areas would receive a lot less rain if it were not for the moisture returned to the atmosphere by actively growing forests.
		F6	Land use conversion for water quality improvement	It is widely believed that forest soils can function as pollution filters. Afforestation is practiced in rural areas around many large cities as a means of improving the quality of the drinking water supply aquifer by filtering out pollutants. Afforestation may also reduce peak flows and help to maintain base flows. Such afforestation should reduce sediment loadings and may have other benefits including improved biodiversity and recreational value.
		F7	Continuous Cover forestry	Continuous cover forestry (CCF) is a broad term encompassing a wide variety of forest management practices. One key feature of is that biomass removal is based either on small clear-cuts or selective harvesting. Smaller clear-cuts may create less hydrological disturbance but some of the filtration benefits associated with forest soils may be lost as a result of the greater driving and road maintenance needed for continuous harvesting.
		F8	“Water sensitive” driving	"Water sensitive driving" requires an awareness of the wet areas (mires, peat lands, etc.) in the landscape and an ability to avoid them while conducting forestry operations. Water sensitive driving is focussed primarily on minimizing water quality impacts of forestry including nutrient leakage and an increased potential for methyl mercury formation.
		F9	Maintenance of riparian buffers	Riparian buffers are a key landscape feature for maintaining water quality. They can prevent sediment mobilization to streams, minimize nutrient leaching and reduce water flow rates. Maintaining treed forest buffers during clear-cutting can help to minimize the adverse effects of forestry on water quality and may have additional biodiversity benefits.

		F10	Appropriate design of roads and stream crossings	Inappropriate design of roads and stream crossings can cause some of the most negative effects of forestry on the landscape. Poorly designed roads can lead to excessive sediment mobilization. Poorly designed stream crossings may impede flow, leading to localized flooding, or act as a barrier to fish dispersal.
		F11	Sediment capture ponds	Sediment capture ponds are widely used to "slow down" water being drained from boreal forests. The main function of the sediment capture ponds is to remove prevent pollution of receiving waters downstream of a forest by removing suspended sediment and associated pollutants.
		F12	Coarse woody debris	Coarse woody debris is a key stream habitat feature used by fish and other organisms. Coarse woody debris can also help to lower flow velocity in streams.
		F13	Re-meandering of forestry-affected rivers	Historically, many rivers in northern Europe (and perhaps elsewhere) have been straightened and channelized to facilitate log floating. These straightened, channelized rivers have limited connection to the surrounding riparian floodplain and will have faster than natural flows. Re-meandering these rivers would slow flow velocities, potentially increase the water storage volume in the river, and improve connectivity between the river and surrounding floodplain.
		F14	Urban forests	Urban forests provide multiple benefits including increased water infiltration, pollutant filtration, reductions in peak flow and maintenance of base flows. Urban forests also have many other aesthetic, biodiversity and quality of life benefits.
		F15	Riparian trees in agricultural landscape	Riparian trees in agricultural landscapes can be an important component of the buffer between fields and streams. Riparian trees can aid in nutrient retention, shade streams and potentially moderate runoff.
	Urban development	U1	Green Roofs	Systems to cover the roof of a building or structure with vegetation cover and/or landscaping. Green roofs are designed to intercept and retain precipitation, reducing the volume of runoff and attenuating peak flows.
		U2	Rainwater Harvesting	Collecting and storing rainwater for subsequent use – for example, using water butts or larger storage tanks.
		U3	Permeable Paving	Pervious surfaces (either porous or permeable) designed to allow rainwater to infiltrate through the surface and into underlying layers (soils and aquifers).
		U4	Other Permeable Surfaces	Use of other permeable surfaces within the urban environment to promote infiltration into soils and aquifers – for example, grass or gravel areas.
		U5	Swales	Shallow, broad and vegetated channels designed to store and/or convey runoff.
		U6	Channels and Rills	‘Hard-edged’ conveyance channels to move water between components in a SuDS ‘train’. Typically narrower than swales, but may also include vegetated aspects.
		U7	Filter Strips	Gently sloping vegetated strips of land that provide opportunities for slow conveyance and infiltration. Designed to accept runoff as overland flow from upstream and to slow the progress of this runoff.

		U8	Filter Trenches	Shallow excavations filled with gravel to create temporary subsurface storage of runoff. They may be designed to intercept overland flow or to accept point-source inflows (e.g. from roof drainage) and may be used to convey or infiltrate water (or both).
		U9	Bioretention Areas	Shallow landscaped depressions, typically under-drained, relying on engineered soils, vegetation and filtration to reduce runoff downstream and remove pollution. Aimed at managing and treating runoff from frequent rainfall events.
		U10	Soakaways	Excavations, typically filled with gravel, designed to store water and allow it to infiltrate into underlying soils or aquifers. Soakaways would typically receive point-source inflow (e.g. from roof drainage).
		U11	Infiltration Trenches	Shallow excavations filled with gravel or other material to create temporary storage and to enhance the natural capacity of the ground to infiltrate. Infiltration trenches would typically be used to intercept surface runoff drainage.
		U12	Infiltration Basins	Vegetated depressions designed to store runoff on the surface and allow it to gradually infiltrate into soil. Infiltration basins are dry except in periods of heavy rainfall.
		U13	Rain Gardens	Small-scale depressions used for storage and infiltration, typically at a property-level and close to buildings (e.g. to infiltrate roof drainage at a property level).
		U14	Detention Basins	Larger-scale surface storage basins to provide flow control through attenuation of runoff. Normally dry, and may serve other functions (e.g. recreation) when not inundated. Primary purpose is to provide storage of runoff at the end of a SuDS ‘chain’.
		U15	Retention Ponds	Ponds or pools with additional storage capacity to attenuate surface runoff during rainfall events. Retention time of runoff can provide the capacity to remove pollutants through sedimentation and opportunity for biological uptake of nutrients.
		U16	Wetlands	Wetlands provide both storm water attenuation and treatment, comprising shallow ponds and marshy areas covered in aquatic vegetation. Wetlands detain flows for an extended period to allow sediments to settle and to remove contaminants. The also provide runoff attenuation and can provide significant ecological benefits
		U17	Urban channel restoration	Working within engineered river channels to restore the operation of natural processes to improve water quality, sediment retention and slow down runoff conveyance. Utilising reaches where rivers pass through open space (parks) to restore more natural channels and manage flood risks
		U18	Floodplain restoration	Restoring a river's floodplain to its original conditions before having been affected by the construction of levees (dikes) and the draining of wetlands and marshes. This may reduce the incidence of floods, the provision of habitat and shelter, the improvement of water quality and the increased recharge rate of recharge of groundwater sources.

		U19	Managed Aquifer Recharge	MAR is the purposeful recharge of water to aquifers for subsequent recovery and environmental benefit. Within the context of urban environment, MAR covers the injection and infiltration of captured storm water – as such, it is linked to SuDS measures such as rainwater harvesting and infiltration techniques, but worth differentiating as a case where the primary purpose is to increase recharge to aquifers in addition to attenuating surface runoff

Source: Own elaboration from Stella Consulting (2012)

Table 2. Potential contribution of SUDS to improve water quantity and quality.

SUDS technique	Brief description	Water quantity	Water quality
Permeable paving	Infiltration through the surface into underlying layer	●	●
Filter drains	Drain filled with permeable material with a perforated pipe along the base.	●	●
Infiltration trenches	Similar to filter drains but allows infiltration through sides and base.	●	●
Soakaways	Underground structure used for store and infiltration.	●	●
Detention basins	Dry depressions outside of storm periods, provides temporary attenuation, treatment and possibly infiltration	●	●
Retention ponds	Designed to accommodate water at all times, provides attenuation, treatment and enhances site amenity value	●	●
Wetlands	Similar to ponds, but are designed to provide continuous flow through vegetation.	●	●
Rainwater harvesting	Capturing and reusing rainwater for domestic or irrigation uses.	●	○
Green roofs	Layer of vegetation or gravel on roof areas providing absorption and storage	●	●

Source: DEFRA, General SUDS Guidance.

Table 3. Potential benefits of RBMPs

Freshwater for drinking
Water provision to deliver water services in the economy for both drinking and non-drinking purposes
Water security (reliability of supply and drought resilience)
Health security (control of waterborne diseases)
Flood protection
Storm protection
Regulation of the chemical condition of freshwaters
Biodiversity and gene-pool conservation in riparian zones
Commercial benefits associated to habitat protection (fish and plants, tourism, recreation and other activities)
Self regulation of water by filtration / sequestration / storage / accumulation by ecosystems
Natural assimilation (purification) of effluents by dilution, dispersion and physic-chemical processes
Mass stabilisation and control of erosion rates
Buffering and attenuation of mass flows
Regulation of hydrological cycle and water flow
Benefits of improved coastal water quality and ecological status for a sustainable commercial production of shellfish with human health and welfare values
Benefits of improved river quality and ecological status associated to better conditions for fish migration, spawning and rearing, support commercial food availability as well as recreational fishing with a commercial and human welfare value
Biomass production

Source: Own elaboration

Table 4. Potential additional benefits of adding NWRM to PoM

Type		Class
Provisioning (biotic / abiotic)	**Nutritional (biomass/abiotic)**	Rainfed cultivated crops
		Reared animals and their outputs
		Wild plants, algae and their outputs
		Wild animals and their outputs
		Plants and algae from in-situ aquaculture
		Animals from *in-situ* aquaculture
		Nutritional abiotic substances (mineral and non-mineral: e.g. salt, sunlight)
	Materials (biotic/abiotic)	Fibres and other materials from plants, algae and animals for direct use or processing
		Genetic materials from all biota
		Materials from plants, algae and animals for agricultural use
		Abiotic materials (e.g. metal ores, building materials)
	Energy (biomass-based / mechanical/abiotic)	Plant-based resources
		Animal-based resources
		Animal-based energy
Regulation & Maintenance (biotic/natural physical structures and processes)	**Mediation (by biota/ecosystems/natural abiotic structures) of waste, toxics and other nuisances and flows**	Bio-remediation by micro-organisms, algae, plants, animals
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, animals
		Filtration/sequestration/storage/accumulation by ecosystems
		Mediation of smell/noise/visual impacts
		By natural chemical and physical processes, e.g. atmospheric dispersion and dilution; adsorption and sequestration of waters in sediments; screening by natural physical structures.
		By solid (mass), liquid and gaseous (air) flows, e.g. protection by sand and mud flats; topographic control of wind erosion.
	Maintenance of physical, chemical, biological/abiotic conditions: lifecycle, habitat and gene pool protection; pest and disease control; soil formation and composition; atmospheric composition and climate regulation	Pollination and seed dispersal
		Maintaining nursery populations and habitats
		Pest control
		Disease control
		Weathering processes
		Decomposition and fixing processes
		Global climate regulation by reduction of greenhouse gas concentrations
		Micro and regional climate regulation
		By natural chemical and physical processes, e.g. atmospheric dispersion and dilution; adsorption and sequestration of waters in sediments; screening by natural physical structures.
depen dent on biotic and	**Cultural settings dependent on <u>biotic</u>**	Experiential use of plants, animals and land-/seascapes in different environmental settings

	structures: physical, intellectual, spiritual and symbolic interaction with biota, ecosystems and land/seascapes	Physical use of land-/seascapes in different environmental settings
		Scientific
		Educational
		Heritage, cultural
		Entertainment
		Aesthetic
		Symbolic
		Sacred and/or religious
	Cultural settings dependent on <u>abiotic structures</u> (physical settings)	Physical and intellectual interactions with land-/seascapes [physical settings] e.g. caves
		Spiritual, symbolic and other interactions with land-/seascapes [physical settings], e.g. sacred rocks or other physical structures or spaces

Source: Own elaboration from COWI *et al.* (2013)[9] – EGS typology based on CICES v4.3.

[9] COWI, 2013. Support Policy Development for Integration of Ecosystem Services Approach with WFD and FD Implementation. Towards practical guidelines to support RB Managers. Background document for expert workshop on 3-4 June 2013. *Yet unpublished – Ongoing project.*