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53 NWRM illustrated

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Environment

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Notes to the reader

Note 1:

The ID codes used in this document partly originate from the NWRM Concept Note and, in order to keep a clear understanding of the catalogue evolution, follow the same logic. As a consequence, the ID codes do not always reflect the multi-sector characteristics of some measures.

Note 2:

All definitions used in this document originate from literature and the past studies carried for DG ENV (http://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm) and were further developed in this pilot project.

Introduction

This catalogue gathers all the individual NWRMs identified by the NWRM project.

Each fiche comprises a small set of information that is the ID and name, Actions, Benefits, the definition and some illustrations of the measure or its action.

This document allows gathering in a small fiche a **short description of each NWRM for non experts** to have a quick vision of the list of existing NWRMs.
It is **completed by the online catalogue** that provide a full description of each NWRM in a standard format.

The document is currently split in **four so-called sectors** (**Agriculture**, **Nature**, **Urban**, **Forestry**) that were primarily defined in the terms of reference of the project. When delineating the respective measures, experts identified that "nature" is not as such a sector and the project officer proposed to replace the term by **HYMO** (e.g. **hydromorphology**).
Overall the terms reflect more the place in the landscape (agriculture land, forest land, natural areas, urban area). Experts also found that many measures can be implemented in more than one area.

To keep the logic defined in the ToR, the current version of the document keeps these four groups but indicates the primary areas where the measure can be applied.

Agriculture

A01 – Meadows and pastures

Sector(s): Agriculture

Definition:

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.

The measure offers the potential for temporary flood storage, increased water retention in the landscape and runoff attenuation. Soil cover is maintained at all times with rooted vegetation, this reduces the surface flow of water and allows greater infiltration to the soil. Rates of soil erosion are considerably lower than arable land with potential benefits for water quality.

Illustration:

Illustration 1: flooded meadow, Scotland (UK)

Source: Chris Spray's presentation, NWRM Workshop 1 (Scotland)

A02 – Buffer strips and hedges

Sector(s): Agriculture, Urban, Hydromorphology

Definition:

Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margin of fields, arable land, transport infrastructures and water courses. They can have several different configurations of vegetation found on them varying from simply grass to combinations of grass, trees, and shrubs. Due to their permanent vegetation, buffer strips offer good conditions for effective water infiltration and slowing surface flow; they 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. Buffer strips can be sited in riparian zones, or away from water bodies as field margins, headlands or within fields (e.g. beetle banks). 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.
For the purpose of this catalogue, riparian buffer (see F1) are considered a separate NWRM as they generally have different design, implementation and management criteria.

Illustrations:

Illustration 2: hedgerow (UK)

Source: http://www.bbc.co.uk/nature/habitats/hedge

Illustration 3: beetle bank (UK)

Source: http://commons.wikimedia.org/wiki/File:On_Fox_Hill_-_geograph.org.uk_-_816223.jpg

A03 – Crop rotation

Sector(s): Agriculture

Definition:
Crop rotation is the practice of growing a series of dissimilar/different types of crops in the same area in sequential seasons. Judiciously applied (i.e. selecting a suitable crop) crop rotation can improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants. In turn this can reduce erosion and increase infiltration capacity, thereby reducing downstream flood risk. It gives various benefits to the soil. A traditional element of crop rotation is the replenishment of nitrogen through the use of green manure in sequence with cereals and other crops. Crop rotation also mitigates the build-up of pathogens and pests that often occurs when one species is continuously cropped. However, as crop rotation has been traditionally practiced for agronomic reasons rather than to achieve environmental and water objectives, new practices may be required to ensure water retention benefits can be achieved. Some crops such as potatoes carry greater risks of erosion due to formation of ridges and the greater area of bare soil (see for example: http://publications.naturalengland.org.uk/file/5925127770341376). Crop rotation can be used in combination with other measures when these are compatible with crop choice.

Illustration:

Illustration 4: fields in crop rotation (USA)

Source: http://www.conewagoinitiative.net/practices/farm/1296-2

A04 – Strip cropping along contours

Sector(s): Agriculture

Definition:
Strip cropping is a method of farming used when a slope is too steep or too long, or otherwise, when one does not have an alternative method of preventing soil erosion. It alternates strips of closely sown crops such as hay, wheat, or other small grains with strips of row crops, such as corn, soybeans, cotton, or sugar beets. Strip cropping helps to stop soil erosion by creating natural dams for water, helping to preserve the strength of the soil. Certain layers of plants will absorb minerals and water from the soil more effectively than others. When water reaches the weaker soil that lacks the minerals needed to make it stronger, it normally washes it away. When strips of soil are strong enough to slow down water from moving through them, the weaker soil can't wash away like it normally would. Because of this, farmland stays fertile much longer. There is no available information on the extent of strip cropping in Europe. The practice has been widespread in North America as a means of mitigating soil erosion from wind and water.

Illustration:

Illustration 5: strip cropping along contour lines (UK)

Source: http://www.britannica.com/EBchecked/media/149126/Contour-farming-and-strip-cropping-on-sloping-farmland

A05 – Intercropping

Sector(s): Agriculture

Definition:

Intercropping is the practice of growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop, or planting a tall crop with a shorter crop that requires partial shade. Numerous types of intercropping, all of which vary the temporal and spatial mixture to some degree, have been identified: mixed intercropping, row cropping, relay cropping, etc.

Illustration:

Illustration 6: intercropped cereals with soybeans

Source: http://environmental.lilithezine.com/images/Intercropping-02.jpg

A06 – No till agriculture

Sector(s): Agriculture

Definition:
Tillage is a mechanical modification of the soil. Intensive tillage can disturb the soil structure, thus increasing erosion, decreasing water retention capacity, reducing soil organic matter through the compaction and transformation of pores. No-till farming (also called zero tillage or direct drilling) is a way of growing crops or pasture from year to year without disturbing the soil through tillage. No-till is an agricultural technique which increases the amount of water that infiltrates into the soil and increases organic matter retention and cycling of nutrients in the soil. In many agricultural regions it can eliminate soil erosion. The most powerful benefit of no-tillage is improvement in soil biological fertility, making soils more resilient.

Illustrations:

Illustration 7: no-till seeder

Source: http://www.livinghistoryfarm.org/farminginthe30s/media/crops09_0101.jpg

Illustration 8: maize planted without tillage

Source: http://www.commodityonline.com/news/zero-tilling--a-popular-alternative-farming-method-35479-3-35480.html

A07 – Low till agriculture

Sector(s): Agriculture

Definition:

Low till agriculture, also known as conservation or reduced till applies to arable land. It consists of a combination of a crop harvest which leaves at least 30% of crop residue on the soil surface, during the critical soil erosion period and some surface work (low till). This slows water movement, which reduces the amount of soil erosion and potentially leads to greater infiltration.

Illustrations:

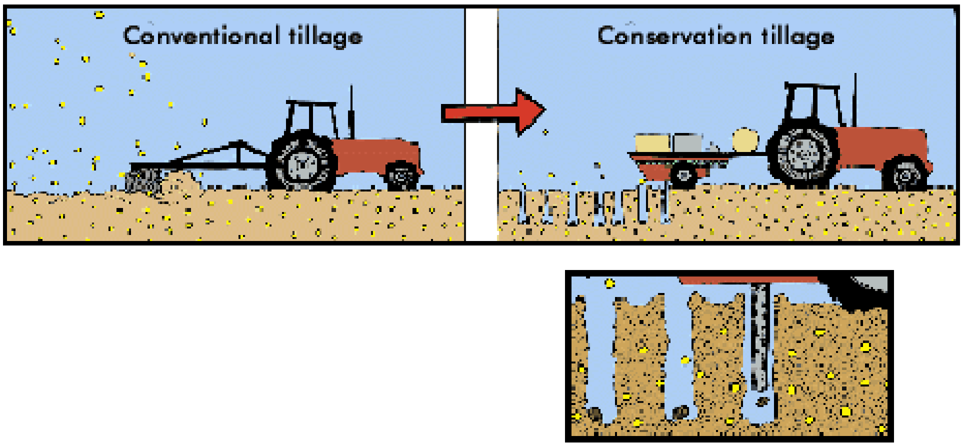

Illustration 9: ridge-till farming system

Source: Why Files, 2011 http://climatetechwiki.org/technology/conservation-tillage

Illustration 10: crop planted in conservation tillage

Source: http://luirig.altervista.org/naturaitaliana/viewpics.php?title=Contour+farming+and+conservation+tillage+protect+highly+erodi

A08 – Green cover

Sector(s): Agriculture

Definition:
Green cover (including cover crops or catch crops) 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.

Illustration:

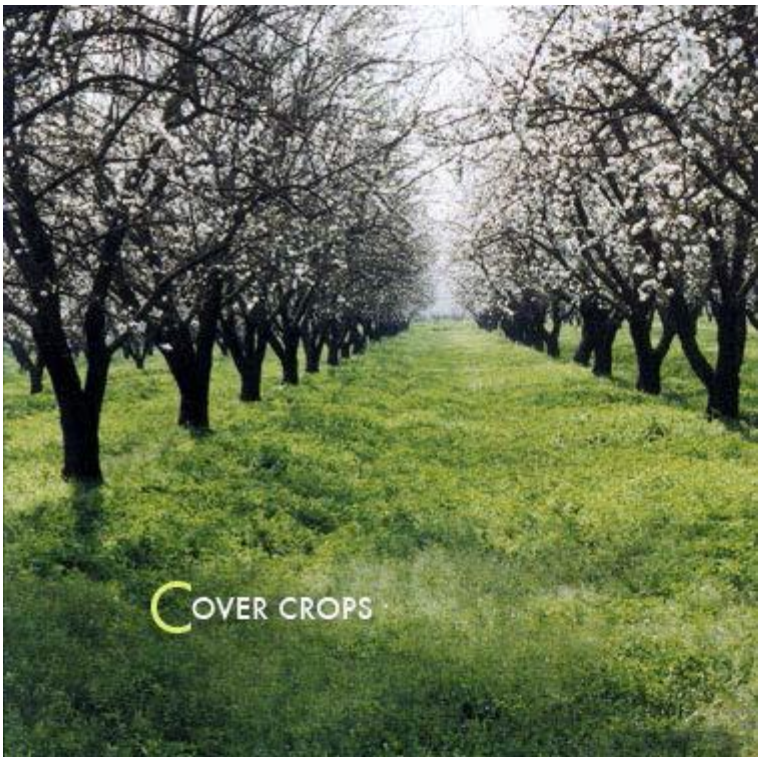

Illustration 11: orchard with green cover

Source: Gonzalo Delacámara's presentation, NWRM Workshop 1 (Spain)

A09 – Early sowing

Sector(s): Agriculture

Definition:

Early sowing refers to sowing up to six weeks before the normal sowing season. This allows for an earlier and quicker establishment of winter crops that can provide cover over winter 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 summer drought impacts on spring sown crops, in particular the extreme evapotranspiration rates of Mediterranean regions. 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. The low temperatures in northern countries may also delay crop establishment in spring crops resulting in an increased risk of soil erosion, avoiding cultivation and retaining residues from preceding crops may be preferable. Therefore, early sowing may require specific tools (plastic tunnel covers, onsite green house, etc.) and cannot be applied by all farmers for all crops. Early sowing of spring crops may also require different cultivation techniques (reduced tillage, controlled traffic farming) as soils are likely to be saturated before usual sowing times increasing the risk of soil compaction.
Restrictions on early sowing of winter crops include the harvest date of the preceding crop (particularly root crops) which may be later in northern Europe. For both spring and winter crops, early sowing involves a number of trade-offs. For example, different pest and disease risks arise that might require changes in management.

Illustration:

Illustration 12: early sowed barley (India)

Source: http://sowasia.org/sowing-seeds-early/

A10 – Traditional terracing

Sector(s): Agriculture

Definition:

Traditional terraces consist of nearly level platforms built along contour lines of slopes, mostly sustained by stone walls, used for farming on hilly terrain. By reducing the effective slope of land, terracing can reduce erosion and surface run-off by slowing rainwater to a non-erosive velocity. This also increases the degree if infiltration and improves soil moisture. However, abandonment of traditional terracing can result in high levels of erosion and run-off due to the lack of maintenance of stone walls. Abandonment can also change the nature of local flora and fauna; this may not be beneficial, for example the spontaneous regeneration of vegetation can present a risk of wild fire spread on sloping land.

This measure focuses on existing or traditional terracing as it involves less disturbance of the terrain than modern terracing such as significant levelling or cutting using heavy machinery. As the measure is highly labour intensive and costly to implement the focus of the measure would be in maintaining existing terracing rather than expansion.

Illustration:

Illustration 13: traditional terracing in montane area

Source: https://www.flickr.com/photos/75185667@N02/7848200480/

A11 – Controlled traffic farming

Sector(s): Agriculture

Definition:

Controlled traffic farming (CTF) 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.

Illustration:

Illustration 14: tractor applying the principle of CTF

Source: http://www.abc.net.au/landline/stories/s652276.htm

A12 – Reduced stocking density

Sector(s): Agriculture

Definition:

Livestock, particularly heavy species such as cattle, can have a number of damaging impacts on soil including compaction, destruction of soil structure (poaching) and loss of vegetation. These impacts can reduce infiltration of water into the soil, resulting in pooling and water logging with consequent impacts of denitrification and nitrous oxide emissions. Soil compaction will also increase the risk of run-off with consequent impacts on water quality and flood risks.

Reduced stocking density will limit soil compaction, thereby facilitating more rapid infiltration during precipitation events and potentially reducing peak flows and sediment runoff. There may also be issues due to management decisions which can increase risks due to livestock without changing stocking levels. For example increased out-wintering of cattle to avoid housing costs will exacerbate risks due to the increased vulnerability of soils during the winter months. The measure may be effectively achieved by moving grazing livestock from high risk areas or by increasing the use of housing. Whether the reduction in pressure is achieved through direct reductions in stocking density, movement from high risk areas or housing, there will be impacts on farm business in terms of direct or opportunity costs.

Illustration:

Illustration 15: sheep separated to reduce stocking density

Source: http://www.evergraze.com.au/library-content/long-term-phosphate-trial/

A13 – Mulching

Sector(s): Agriculture, Hydromorphology

Definition:

A mulch is a layer of material applied to the surface of an area of soil. Its purpose is any or all of the following:

- to conserve moisture
- to improve the fertility and health of the soil
- to reduce weed growth
- to enhance the visual appeal of the area

Mulching as NWRM is using organic material (e.g. bark, wood chips, grape pulp, shell nuts, green waste, leftover crops, compost, manure, straw, dry grass, leaves etc.) to cover the surface of the soil. It may be applied to bare soil, or around existing plants. Mulches of manure or compost will be incorporated naturally into the soil by the activity of worms and other organisms. The process is used both in commercial crop production and in gardening, and when applied correctly can dramatically improve the capacity of soil to store water.

Illustrations:

Illustration 16: mulching in urban garden

Source: https://en.wikipedia.org/wiki/Mulch

Illustration 17: Mulching in agriculture

Source: http://rrockyard.net/2012/10/04/proper-mulching-techniques/ & http://www.gov.mb.ca/agriculture/crops/production/fruit-crops/print,strawberry-management-of-runners.html

Forestry

F01 – Forest riparian buffers

Sector(s): Forest

Definition:
Riparian buffers are treed areas alongside streams and other water bodies. While most commonly associated with set asides following forest harvest, riparian buffers can also be found in urban, agricultural and wetland areas. By preserving a relatively undisturbed area adjacent to open water, riparian buffers can serve a number of functions related to water quality and flow moderation. The trees in riparian areas can efficiently take up excess nutrients and may also serve to increase infiltration. Riparian buffers serve to slow water as it moves off the land. This can decrease sediment inputs to surface waters.

Illustrations:

Illustration 18: Riparian buffer

Source: http://www.flatheadwatershed.org/watershed/floodplains.shtml

Illustration 19: Riparian buffer

Source: http://en.wikipedia.org/wiki/Riparian_buffer

F02 – Maintenance of forest cover in headwater areas

Sector(s): Forest

Definition:
Headwaters are the source areas for rivers and streams, crucial for sustaining the structure, function, productivity and complexity of downstream ecosystems. They are vital to hydrologic cycling as they are one of the main areas where precipitation contributes to surface and groundwater. Headwaters are typically less intensively used than downstream areas. In many headwater areas, extensive agriculture, forests or other semi-natural land cover types predominate. Forests in headwater areas have a beneficial role for water quantity and quality. Creating or maintaining forest cover in headwater catchments is a widely used practice in many major cities including New York, Istanbul and Singapore, as these cities are reliant on headwater forests for drinking water provisioning. Forest soils generally have better infiltration capacity than other land cover types and may act as a "sponge", slowly releasing rainfall. In areas of high relief, afforestation of headwater catchments can contribute to slope stabilization and may reduce the risks associated with landslides. On the other hand, afforestation of headwaters in dry areas may lead to reduction of water yield.

Illustrations:

Illustration 20: before and after afforestation

Source: http://www.intechopen.com/books/advances-in-landscape-architecture/reclamation-of-degraded-landscapes-due-to-opencast-mining

F03 – Afforestation of reservoir catchments

Sector(s): Forest

Definition:

Planting trees in reservoir catchments can have both negative and positive effects. . Afforestation of previously bare or heavily eroded areas can control soil erosion, thereby extending the life of the reservoir and improving water quality. Water quality can also be improved if precipitation is able to infiltrate into forest soils before flowing to the reservoir. These potential improvements in water quality need to be balanced against the possibility that less precipitation will be available for reservoir recharge due to the potentially greater interception and evapotranspiration associated with forests. Studies have indicated decrease of water yield after afforestation of the catchment and with the increase of forest age. Forests in reservoir catchments should typically not be managed for timber production, but maintained in as close to a natural state as possible as the fertilization and ground disturbance associated with intensive forest management can have negative impacts on reservoir water quality. Increased acidification and eutrophication after afforestation with conifer species have also been reported. Use of long-lived native deciduous tree species for afforestation instead of fast growing conifers or eucalypts is likely to bring enhanced biodiversity benefits while minimizing water loss.

Illustrations:

Illustration 60: Reservoir catchment with forest

Source: http://www.surfat10.com/climate_care/Success%20Story%20of%20Afforestation

Illustration 21: reservoir catchment without forest

Source: http://www.iucnffsg.org/freshwater-fishes/major-threats/

F04 – Targeted planting for "catching" precipitation

Sector(s): Forest

Definition:
There is some evidence to suggest that loss of tree cover on Mediterranean hill slopes has altered weather patterns, which in turn have altered precipitation amount and timing. Modelling results suggest that Mediterranean precipitation regimes are very sensitive to variations in air temperature and moisture. Land use change and associated deforestation may have led to changes from and open monsoon-type regime with frequent summer storms over inland mountains to a regime dominated by closed vertical atmospheric recirculation where feedback mechanisms suppress storms over the coastal mountains and lead to increased summer time sea surface warming. This warming leads to torrential rains in autumn and winter. These rains can occur across the Mediterranean basin. This can be exacerbated by greenhouse heating associated with air pollutants. Targeted afforestation in some parts of the Mediterranean may be one means of combating drought and desertification. However, caution should be taken when choosing areas for afforestation to avoid possible adverse effects, as there is some evidence that afforestation in dry environments, especially in montane areas, may decrease water yield and cause water deficit in the downstream rivers. Local tree species should be used to reduce risks to biodiversity.

Illustration:

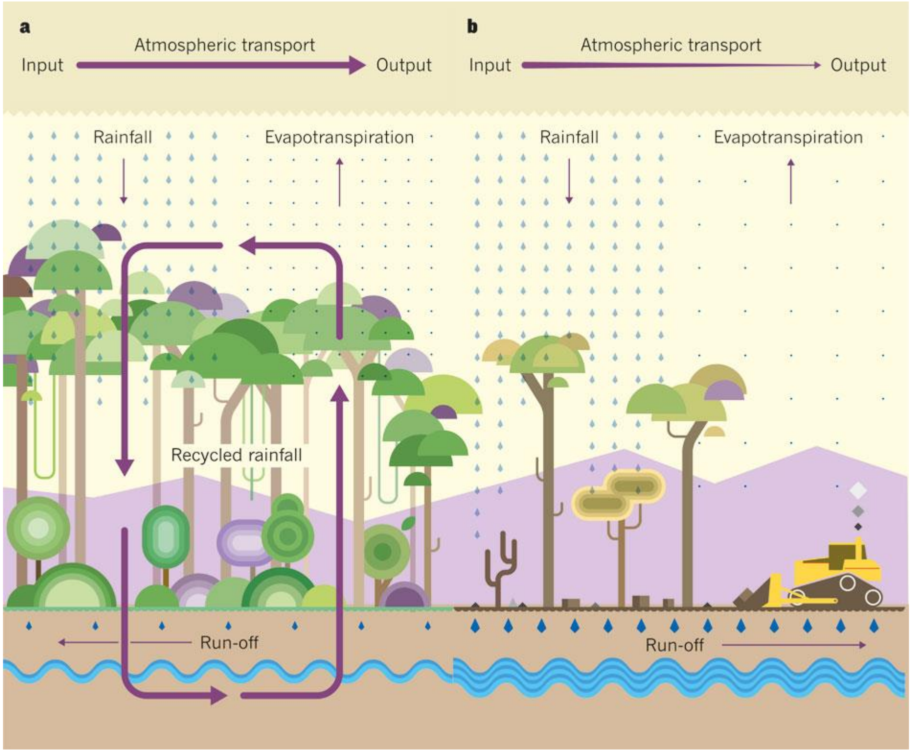

Illustration 22: functioning of the water cycle in forests

Source:
http://www.nature.com/nature/journal/v489/n7415/full/nature11485.html?WT.ec_id=NATURE-20120913

F05 – Land use conversion

Sector(s): Forest

Definition:

Land use conversion is a general term for large scale geographic change. Afforestation is one such land conversion in which trees are planted on previously non forested areas. Afforestation may occur deliberately or through the abandonment of marginal agricultural land. Depending on the tree species planted and the intensity of forest management, afforestation may have more or less environmental benefits. The NWRM related benefits include potentially enhanced evapotranspiration associated with growing forests and better water holding capacity associated with forest soils. The greatest environmental benefits are probably associated with planting of indigenous broadleaves and low intensity forestry. Plantation forestry with exotic species is likely to be less beneficial to the environment. It should be mentioned that afforestation in dry areas can cause or intensify water shortage. Even though afforestation may reduce available water supply at local scale, forest cover increases water supply regionally and globally, in particular through the intensification of the water cycle.

Illustration:

Illustration 23: afforestation of a hill

Source: Gebhard Schueler's presentation, NWRM Workshop 1

F06 – Continuous cover forestry

Sector(s): Forest

Definition:
Continuous cover forestry is a broad range of forest management practices which may have some beneficial hydrological effects. The main idea behind continuous cover forestry is a reduction in the number or size of clear-cuts. Some definitions of continuous cover forestry state that no clear-cuts shall be larger than 0.25 ha. Continuous cover forestry ensures that there is an uninterrupted tree canopy and that the soil surface in never exposed. An uninterrupted tree canopy will have higher interception than a site with discontinuous tree cover. Ensuring that soils are never exposed will limit sediment production.

Illustration:

Illustration 24: forest submitted to a continuous cover

Source: http://www.kyphilom.com/www/tmbr3.html

F07 – “Water sensitive” driving

Sector(s): Forest

Definition:

Off road driving has potentially severe negative consequences for water quality. Some of these damages can be minimized or mitigated if drivers of vehicles exercise a few simple precautions. Avoiding driving in wet areas whenever possible will limit soil compaction and rutting. Rutting can concentrate flow paths and lead to increased erosion. In colder regions of Europe, driving on frozen soils will also reduce the potential for compaction and damage. Driving parallel to contour lines of hill slopes will reduce the potential for rut formation and concentration of flow paths but may not always be feasible, especially in areas of high relief. Use of slash cover or specially designed logging mats in off road driving during forest logging operations may help to reduce soil compaction and rutting. Reduction of truck tire pressure on unpaved forest roads may also be considered as one aspect of this NWRM.

Illustration:

Illustration 25: water sensitive driving would avoid areas such as the one illustrated

Source: Gebhard Schueler’s presentation, NWRM Workshop 1

F08 – Appropriate design of roads and stream crossings

Sector(s): Forest

Definition:
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.

Illustrations:

Illustration 26: river with inappropriate design

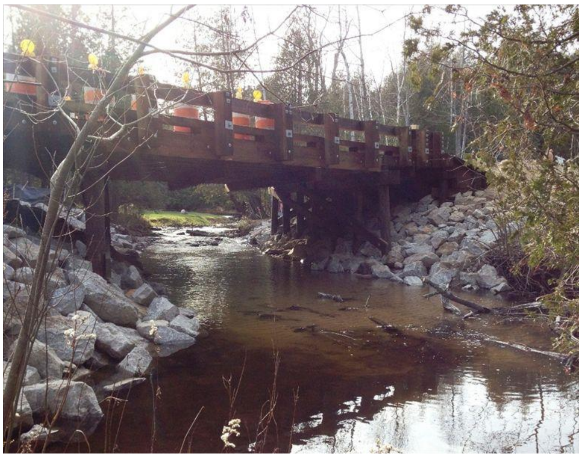

Illustration 27: river after designing a proper crossing

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

F09 – Sediment capture ponds

Sector(s): Forest

Definition:
Sediment capture ponds are engineered ponds placed in networks of forest ditches to slow the velocity of water and cause the deposition of suspended materials. Sediment capture ponds are most useful for managing the effects of ditch construction and maintenance, road work and final feeling. While used primarily in forests, sediment capture ponds may be a useful temporary measure for preserving water quality in and around construction sites or mines. They may also be useful for capturing sediment in agricultural runoff. Sediment capture ponds have a limited lifespan, depending on how much suspended material is in the inflowing water. However, ponds can be maintained by removal of accumulated sediment. As most water protection methods, sediment capture ponds function well during base and moderate flow events. Catchment area, hydraulic properties of ditches, discharge rate and soil characteristics are among factors influencing functioning of sedimentation capture ponds. Effective functioning largely depends also on expertise and skill of professionals designing and implementing this and also many other measures.

Illustration:

Illustration 28: sediment capture pond, Slovakia

Source: Michal Kravcík's presentation, NWRM Workshop 1 (Slovakia)

F10 – Coarse woody debris

Sector(s): Forest,

Definition:
Coarse woody debris in stream channels has multiple ecological and hydrologic benefits. Coarse woody debris consists of large sections of deadfall: tree stems or stumps that either fall into or are deliberately placed in streams. Coarse woody debris can be deployed with varying degrees of naturalness. At one extreme, coarse woody debris can be used to form coffer or placer dams which effectively limit water flow. At the other extreme, natural deadfall coarse woody debris is found when riparian trees are allowed to fall naturally into streams. Coarse woody debris will generally slow water flow velocity and can reduce the peak of flood hydrographs. In addition to its role in slowing streamflow and facilitating sediment accumulation, coarse woody debris can improve aquatic biodiversity by retaining food and providing additional habitat, such as refuges and spawning sites.

Illustration:

Illustration 29: river with coarse woody debris

Source: http://www.sitatrust.org.uk/projects/can-we-save-the-native-crayfish

F11 – Urban forest parks

Sector(s): Forest, Urban

Definition:
Urban forest parks can deliver a broad range of hydrology-related and other ecosystem services. Forests in urban areas have great amenity value, can improve air quality, moderate local microclimates, improve urban biodiversity and contribute to climate change mitigation as well as having ancillary hydrological benefits. Forest soils often have greater infiltration capacity than other urban land cover and can be an important location for aquifer recharge.

Illustration:

Illustration 30: aerial view of forest parks, France

Source: http://www.survoldefrance.fr/affichage2.php?img=3775&prev_suiv_link=1

F12 – Trees in urban areas

Sector(s): Urban

Definition:
Trees in urban areas can have multiple benefits related to aesthetics, microclimate regulation and urban hydrology. Trees in urban areas can also be important biodiversity refuges and can contribute to reducing particulate air pollution. Trees intercept precipitation, reducing the amount of rainfall which must be processed by sewers and other water transporting infrastructure. The area around urban trees may also have greater infiltration capacity than the impermeable surfaces often found in urban areas. Trees also transpire, which dries the soil and gives greater capacity for rainfall storage.

Illustration:

Illustration 31: trees in Fayetteville, USA

Source:
http://www.accessfayetteville.org/government/parks_and_recreation/park_planning_and_urban_forestry/urban_forest.cfm

F13 – Peak flow control structures in managed forests

Sector(s): Forest,

Definition:
Peak flow control structures are designed to reduce flow velocities in networks of forest ditches. Peak flow control structures are engineered ponds designed to limit the rate at which water flows out of a ditch network. Because the structures slow water flow, they will contribute to sediment control and can reduce the size of flood peaks. Peak flow control structures will have a limited lifespan as sediment will eventually fill in the upstream detention pond. However, ponds can be maintained by removal of accumulated sediment.

Illustration:

Illustration 32: peak flow control basin in forest, (Slovakia)

Source: Michal Kravcík's presentation, NWRM Workshop 1

F14 – Overland flow areas in peatland forests

Sector(s): Forest,

Definition:
Typically, overland flow areas are set asides used to minimize the negative impacts of forest management on water quality. They are most commonly associated with peatland forestry in Finland but could be applicable in other areas of Europe. Overland flow areas collect some of the excess sediment produced during ditch maintenance and other forest management operations such as road building or harvesting. Overland flow areas are created by building a semi-permeable dam in a forest ditch. Upstream of the dam, lateral ditches are constructed to transport water into the surrounding catchment. During periods of high flow, water will overflow the lateral ditches and travel across land to reach the receiving lake or stream. As the water travels across land, its velocity will be slowed and much of the sediment being carried will be deposited. At periods of low flows, the permeable dam will slow water flow and cause deposition of sediment. Existing wetlands may function as overland flow areas but the use of ecologically valuable and endangered mires should be avoided due to possible changes in vegetation composition. Overland flow areas can also be part of more complex system for water treatment from agricultural areas and landfills.

Illustration:

Illustration 33: ditch for overland flow (Slovakia)

Source: Michal Kravcík's presentation, NWRM Workshop

Hydromorphology

N01 – Basins and ponds

Sector(s): Hydromorphology, Urban, Agriculture, Forest

Definition:
Detention basins and ponds are water bodies storing surface run-off. A detention basin is free from water in dry weather flow conditions, whereas a pond (e.g. retention ponds, flood storage reservoirs, shallow impoundments) contains water during dry weather, and is designed to hold more when it rains.

Illustrations:

Illustration 34: a pond in forest

Source: Gebhard Schueler's presentation, NWRM Workshop 1

Illustration 35: a basin in the landscape (US)

Source: http://archive.inside.iastate.edu/2008/0703/rain.shtml

N02 – Wetland restoration and management

Sector(s): Hydromorphology, Urban, agriculture, forest

Definition:

According to the Convention on Wetlands (1971), a wetland is an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. It provides water retention, biodiversity enhancement or water quality improvement.

Wetland restoration and management 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; changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. They 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.

Illustration:

Illustration 36: wetland in a forest

Source: Gebhard Schueler's presentation, NWRM Workshop 1

N03 – Floodplain restoration and management

Sector(s): Hydromorphology

Definition:

A floodplain is the area bordering a river that naturally provides space for the retention of flood and rainwater. Floodplain soils are generally very fertile and they have often been dried-out to be used as agricultural land. Floodplains in many places have also been separated from the river by dikes, berms or other structures designed to control the flow of the river. They have also been covered by legacy sediments.

Major floodplains roles have thus been lost, due to land drainage, intensive urbanization and river channelization. The objective is to restore them, their retention capacity and ecosystem functions, by reconnecting them to the river.

Restoring the floodplain roles requires measures such as:

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

Illustrations:

Illustration 37: floodplain before flooding

Source: Thomas Borchers' presentation, NWRM Workshop *(from: Christian Damm)*

Illustration 38: floodplain during flooding

Source: Thomas Borchers' presentation, NWRM Workshop 1 *(from: Nora Künkler)*

N04 – Re-meandering

Sector(s): Hydromorphology

Definition:
A river meander is a U-form taken by the river, allowing it to decrease water velocity. In the past, rivers have been straightened by cutting off meanders. Many rivers in northern and Western Europe have been straightened and channelized to, for example, facilitate log floating and/or speed up the drainage of water and control/limit the river bed movements. Channelizing was also a way to gain land for cultivation. River re-meandering consists in creating a new meandering course or reconnecting cut-off meanders, therefore slowing down the river flow. The new form of the river channel creates new flow conditions and very often also has a positive impact on sedimentation and biodiversity. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals.

Illustrations:

Illustration 39: river before re-meandering

Illustration 40: river after re-meandering

Source: http://riverwatch.eu/en/the-morava-anniversary-project-2014

N05 – Stream bed re-naturalization

Sector(s): Hydromorphology

Definition:

Streambed (or riverbed) represents the floor of the river, including each riverbank. In the past, riverbeds were artificially reconstructed with concrete or big stones, therefore modifying flows and decreasing fauna habitat and vegetation diversity. 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 of reducing travel time along the river. Streambed re-naturalization consists in removing some concrete or inert constructions in the riverbed and on riverbanks, then replacing them with vegetation structures, in order to avoid these damages and restore biodiversity.

The re-naturalization of river beds and banks could have a high impact on the erosion process. Stabilisation techniques are among the main measures to be implemented. The maximum impact is reached when the stabilisation technique restores the vegetation cover and the naturalness of the banks. Most of the time, techniques use plants for bank stabilization. According to their degree of complexity, these techniques can be grouped into two categories:

- bank re-naturalization
- plant engineering

Bank re-naturalization is a stabilisation technique used to correct mild erosion problems and that does not require a high degree of expertise to be implemented.

Plant engineering is defined as the techniques combining the principles of ecology and engineering to design and implement slope, bank and bank stabilisation works, using plants as raw materials for making vegetable frames.

Illustrations:

Illustration 41: river before renaturalization

Illustration 42: river after renaturalization

Source: http://chandrashekharasandprints.wordpress.com/2012/05/11/restoring-an-urban-river-bed-to-its-natural-eco-system-a-singapore-experiment/

N06 – Restoration and reconnection of seasonal streams

Sector(s): Hydromorphology

Definition:
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.
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.

Illustration:

Illustration 43: tributary useful during flooding, (Scotland, UK)

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

N07 – Reconnection of oxbow lakes and similar features

Sector(s): Hydromorphology

Definition:

An oxbow lake is an ancient meander that was cut off from the river, thus creating a small lake with a U form. Reconnecting it with the river consists in removing terrestrial lands between both water bodies, therefore favouring the overall functioning of the river by restoring lateral connectivity, diversifying flows and cleaning the river section of the present oxbow for a better water retention during floods.

Illustrations:

Illustration 28: Oxbow lake, (France)

Source: http://www.symbhi.fr/11256-les-travaux-en-riviere-durant-le-premier-semestre-2013.ht

Illustration 29: re-connected Oxbow lake, (France)

Source: http://nature.on-rev.com/2011/composants-du-paysage/

N08 – Riverbed material renaturalization

Sector(s): Hydromorphology

Definition:

Riverbed material represents the sediment eroded upstream, transported by the river and deposited on the river floor. It can be composed of coarse and/or fine material. Its re-naturalization consists in recovering the nature-like structure and composition of the bed load, in particular the equilibrium between coarse and fine sediment. In case of deficit of coarse sediment leading to river incision, the main objective is to level-up the riverbed with this type of sediment, by reactivating bank erosion in terrains contributing to this type of sediment. It should be noticed that in case of excess of fine sediment causing inundations, silting of hydro-electric dams or degradation of fish habitats, the main objective is to control erosion on slopes and riverbanks providing this type of sediment.

Illustrations:

Illustration 44: renaturalized riverbed, (France)

Source: http://www.onema.fr/les-jeudis-de-la-restauration,1432

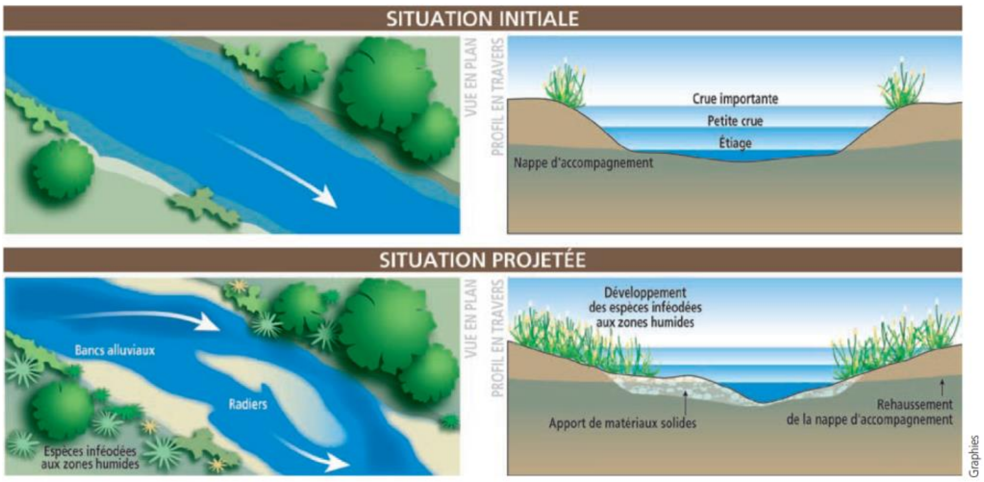

Illustration 45: explicative scheme for the principle of riverbed renaturalization (France)

Source: http://www.syndicatdelaseiche.fr/entretenir-et-restaurer-les-cours/restaurer-le-lit-des-cours-d-eau/

N09 – Removal of dams and other longitudinal barriers

Sector(s): Hydromorphology

Definition:

Dams and other transversal barriers are obstacles crossing the river section and causing discontinuities for sediment and fauna. Removing them consists in destroying all the obstacles, restoring the slope and the longitudinal profile of the river, therefore allowing re-establishment of fluvial dynamics, as well as sedimentary and ecological continuity.

Illustration:

Illustration 46: dam being removed for restoration of reference condition hydromorphology

Source: Ignacio Rodrigez's presentation, NWRM Workshop 1

N10 – Natural bank stabilisation

Sector(s): Hydromorphology, Urban

Definition:
Riverbank represents both natural and artificial terrain following the river flow. In the past, lots of artificial banks were built with concrete or other types of retention walls, therefore limiting rivers' natural movements, leading to degradation of the river, increased water flow, increased erosion and decreased biodiversity. River bank renaturalisation consists in recovering its ecological components, thus reversing such damages and especially allowing bank to be stabilized, as well as rivers to move more freely. Nature-based solutions such as bioengineering are preferable, but civil engineering has to be used in case of strong hydrological constraints.

Illustrations:

Illustration 33: bank stabilisation with stones (USA)

Source: http://www.goldenvalleymn.gov/surfacewater/stream-bank-stabilization.php

Illustration 34: bank stabilisation with wood weaving (France)

Source: http://www.siave.net/Protections_berges.html

N11 – Elimination of riverbank protection

Sector(s): Hydromorphology

Definition:

A riverbank protection is an inert or living construction providing bank fixation but also an obstacle for the lateral connection of the river. Eliminating it consists in removing some parts of the bank protection, especially the inert one, in order to enhance lateral connections of the river, diversify flows (depth, substrate, and speed) and habitats, but also cap floods in the mainstream. It is a prerequisite for many other measures like re-meandering or widening, as well as initiating later channel migration and dynamics.

This measure is appropriate and very efficient in impounded large gravel riverbeds where gravel bars are drowned and shallow low-velocity habitats are virtually absent. In these impounded rivers, spawning and nursery habitats like shallow near-bank gravel bars, side channels, and backwaters are often the bottleneck for stream-type specific fish species. River banks have been heavily fixed and the potential for river restoration is limited due to uses like navigation, hydropower or flood protection and mitigation measures are restricted to the river banks.

Illustration:

Illustration 47: destroyed artificial riverbank, (Brasil)

Source: http://echogeo.revues.org/13596?lang=en

N12 – Lake restoration

Sector(s): Hydromorphology

Definition:
A Lake is a water retention facility. It can store water (for flood control) and provide water for many purposes such as water supply, irrigation, fisheries, tourism, etc. In addition, it serves as a sink for carbon storage and provides 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 consists in enhancing their structure and functioning where they have been drained in former times.

Illustrations:

Illustration 36: Perch lake, (USA)

Source: http://giizis13.wordpress.com/page/3/

Illustration 37: lake George, (USA)

Source: http://www.lakegeorgeassociation.org/what-we-do/Lake-Saving-Projects/Reservoirs-and-Sediment-Basins.asp

N13 – Restoration of natural infiltration to Groundwater

Sector(s): Hydromorphology

Definition:
Groundwater is the part of infiltrated water which composes the water resource for population and human activities. Previous modifications of the landscape have reduced the infiltration capacity of many European soils, thereby limiting the rate at which precipitation is able to infiltrate and recharge groundwater aquifers. Restoration of natural infiltration to groundwater enables a lowering of run-off from surrounding land, and enhances the condition of groundwater aquifers and water availability. The natural cleaning processes associated with infiltration can improve water quality. This measure can also be known as "Artificial Groundwater Recharge" in the engineering literature.

Mechanisms to restore or enhance natural infiltration capacity include:

(i) surface structures to facilitate/augment recharge (such as soakaways and infiltration basins);

(ii) subsurface indirect recharge – infiltration capacity is enhanced through wells drilled within the unsaturated zone; and

(iii) subsurface direct recharge – infiltration and recharge of the groundwater aquifer is accomplished through wells reaching the saturated zone.

Illustration:

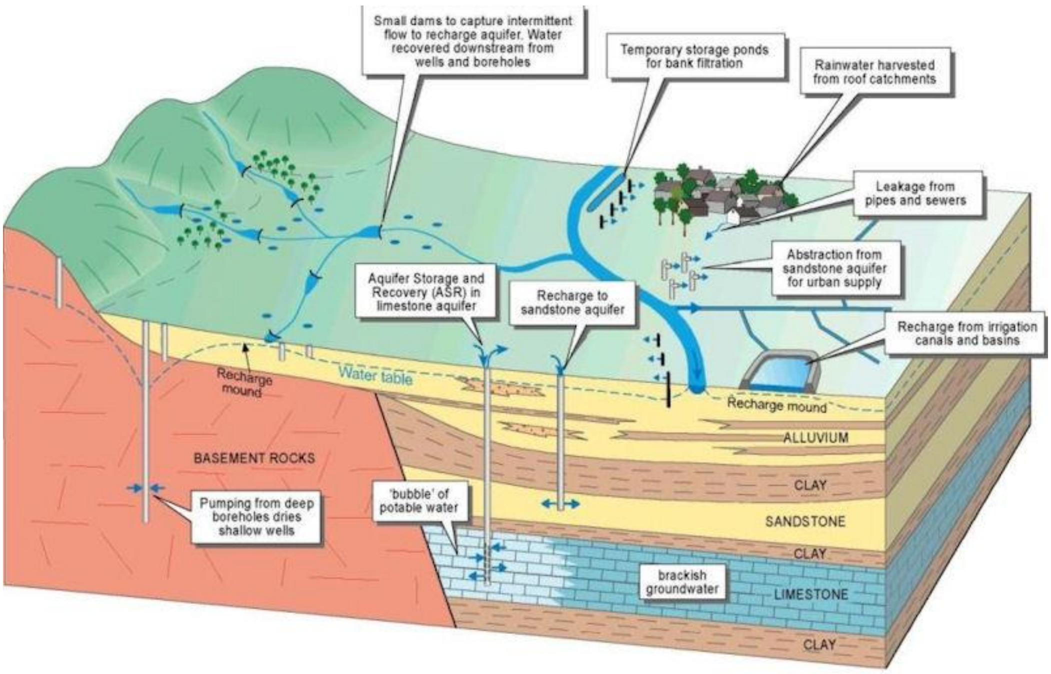

Illustration 48: explicative scheme of enhanced infiltration (UK)

Source: http://www.bgs.ac.uk/research/groundwater/agrar.html

N14 – Re-naturalization of polder areas

Sector(s): Hydromorphology

Definition:
A polder is a low-lying tract of land enclosed by embankments (barriers) known as dikes that forms an artificial hydrological entity, meaning it has no connection with outside water other than through manually operated devices. Its re-naturalization consists in enhancing polders with sub-natural characteristics, allowing better water storage in watercourses inside the polder, as well as increased biodiversity

Illustration:

Illustration 49: polder of Juist (Germany)

Source: http://commons.wikimedia.org/wiki/File:2012-05-13_Nordsee-Luftbilder_DSCF8997.jpg

Urban

U01 – Green roofs

Sector(s): Urban

Definition:

Green roofs are multi-layered systems that cover the roof of a building with vegetation and/or green landscaping over a drainage layer. There are two types of green roof:

- **Extensive green roofs** cover the entire roof area with lightweight, low growing, self-sustaining, low maintenance planting. They are only accessed for maintenance. Vegetation normally consists of hardy, drought tolerant, succulents, herbs or grasses. Extensive green roofs are often known as sedum roofs, eco-roofs or living roofs.
- **Intensive green roofs** are landscaped environments with high amenity benefits including accessible planters or trees and water features. These impose a greater load on the roof structure and require significant ongoing maintenance including irrigation, feeding and cutting. Intensive roofs are also termed roof gardens.

A typical structure for a green roof includes a surface vegetation layer underlain by a substrate (growth medium), geotextile filter layer, and an aggregate or geo-composite drainage layer. The green roof materials are underlain by a waterproof membrane, with an additional layer of insulation between that and the roof itself.

Green roofs are designed to intercept rainfall, which is slowed as it flows through the vegetation and a drainage layer, mimicking the predevelopment state of the building footprint. Some of the rainwater is stored in the drainage layer and taken up by the vegetation, with the remainder discharged from the roof in the normal way (via gutters and downpipes). Flow rates from the green roof are reduced and attenuated compared to a normal roof, and the total volumes discharged from the roof are also reduced. Green roofs therefore intercept rainfall at source and provide the first component of a SuDS management train.

Illustration:

Illustration 50: green roof

Source: Andras Kis' presentation, NWRM Workshop 1

U02 – Rainwater harvesting

Sector(s): Urban

Definition:
Rainwater harvesting involves collecting and storing rainwater at source for subsequent use, for example, using water butts or larger storage tanks. Water butts are the most widely applied and simple rainwater harvesting technique, collecting rainwater runoff from roofs via a connection to the roof down-pipe. They are primarily designed for small scale use such as in household gardens, although a range of non-potable uses is possible.
A limitation of rainwater harvesting as an NWRM is that during wet periods, water butts are often full and water use may be low, resulting in little or no attenuation or reduction in outflow rates or volumes. As a result there are differing opinions about the role of rainwater harvesting in providing a water retention function. Tanks can be specifically designed and managed to accommodate storm water volumes, which is likely to be more effective when applied at a larger scale than individual properties. In general, however, rainwater harvesting should be considered only as a source-control component in a SuDS 'train' where, in combination with other measures, they will contribute to effective and sustainable water management.

Illustrations:

Illustration 51: rainwater harvesting (USA)

Source: http://www.clemson.edu/sustainableag/rainwater.html

Illustration 52: tank containing rainwater

Source: Andras Kis' presentation, NWRM Workshop 1

U03 – Permeable surfaces

Sector(s): Urban

Definition:

Permeable paving is designed to allow rainwater to infiltrate through the surface, either into underlying layers (soils and aquifers), or be stored below ground and released at a controlled rate to surface water. Permeable paving is used as a general term, but two types can be distinguished:

- Porous pavements, where water is infiltrated across the entire surface (e.g. reinforced grass or gravel, or porous concrete and cobblestones)
- Permeable pavements, where materials such as bricks are laid to provide void space through to the sub-base, by use of expanded or porous seals (rather than mortar or other fine particles).

It is most commonly used on roads and car parks, but the measure can also apply to broader use of permeable areas to promote greater infiltration. It can be used in most ground conditions and can be sited on waste, uncontrolled or non-engineered fill, providing the degree of compaction of the foundation material is high enough to prevent significant differential settlement. A liner may be required where infiltration is not appropriate, or where soil integrity would be compromised.

CIRIA (2007) and the "Centre des recherches routières" (Road Research Centre) of Brussels (2008) describes three different types of porous/permeable pavements:

A. All rainfall passes through sub-structure and in to soils beneath, with (normally) no surface discharge (i.e. fully infiltrating);
B. Perforated pipes lie between the sub-base and underlying sub-soil, to convey rainfall that exceeds the capacity of the sub-soil to a receiving drainage system (i.e. partially infiltrating);
C. Perforated pipes lie beneath the sub-base, over an impermeable membrane, so all rainfall, after filtering through the sub-base, is conveyed to the receiving drainage system (i.e. no infiltration).

All types provide attenuation of rainfall, and potentially can also store runoff from surrounding areas, if designed and sized appropriately. Types A and B provide infiltration to underlying groundwater, thereby contributing to increased groundwater levels and/or flows, and hence potentially to baseflow. Type C does not interact with groundwater, but stores rainfall (and potentially runoff) and releases it at a controlled rate, hence still contributes to regulating the rate of rainfall-runoff.

Illustration:

Illustration 53: permeable paving

Source: Andras Kis' presentation, NWRM Workshop 1

U04 – Swales

Sector(s): Urban, Agriculture

Definition:

Swales are broad, shallow, linear vegetated channels which can store or convey surface water (reducing runoff rates and volumes) and remove pollutants. They can be used as conveyance features to pass the runoff to the next stage of the SuDS treatment train and can be designed to promote infiltration where soil and groundwater conditions allow. Three kinds of swale give different surface water management capabilities:

- Standard conveyance swale – Generally used to convey runoff from the drainage catchment to another stage of a SuDS train. They may be lined or un-lined, depending on the suitability for infiltration.
- Enhanced dry swale – Includes an underdrain filter bed of soil beneath the vegetated conveyance channel to accommodate extra treatment and conveyance capacity above that of the standard swale. The underdrain leaves the main channel dry except for larger runoff events, and will prevent channels becoming waterlogged where the swale is situated on gentler slopes. A lining can also be incorporated into the underdrain if infiltration to underlying ground is not appropriate.
- Wet swale - Where prolonged treatment processes are required for the storm runoff, the swale's conveyance channel can be encouraged to maintain marshy conditions by using liners to control infiltration, or by siting in an area with high water table.

The promotion of settling is enhanced by the use of dense vegetation, usually grass, which promotes low flow velocities to trap particulate pollutants. In addition, check dams or berms can be installed across the swale channel to promote settling and infiltration. As a result, swales are effective in improving water quality of runoff, by removing sediment and particulate pollutants. In wet swales, the effectiveness is further enhanced by providing permanent wetland conditions on the base of the swale.

Swales are applicable to a wide range of situations. They are typically located next to roads, where they replace conventional gullies and drainage pipe systems, but examples can also be seen of swales being located in landscaped areas, adjacent to car parks, alongside fields, and in other open spaces. They are ideal for use as drainage systems on industrial sites because any pollution that occurs is visible and can be dealt with before it causes damage to the receiving watercourse.

Illustration:

Illustration 54: swale

Source: Andras Kis' presentation, NWRM Workshop 1

U05 – Channels and rills

Sector(s): Urban, Agriculture

Definition:

Channels and rills are shallow open surface water channels incorporated in to the start of a SuDS train. They collect water, slow it down and provide storage for silt deposited from runoff. They can have a variety of cross sections to suit the urban landscape, and can include the use of planting to provide both enhanced visual appeal and water treatment.

The main role of channels and rills are to capture runoff at the start of a SuDS train, allow deposition of sediment and convey the runoff to downstream SuDS features. They can also be used in between SuDS features as connectors. They collect water, slow it down and provide storage for silt and oil that is captured. The outlets are designed to act as a mini oil separator, making them effective at treating pollution and reducing treatment requirements downstream. Clearly channels can be included in many situations and settings, but would not always considered to be NWRMs unless specifically designed to perform these functions and used in conjunction with other measures.

Planting in channels and rills can visually enhance the urban landscape and offer biodiversity and amenity value. These features can be applied to all new developments and can be retrofitted to existing developments.

Illustrations:

Illustration 55: Channel in urban area

Source: http://www.susdrain.org/delivering-suds/using-suds/suds-components/swales-and-conveyance-channels/channels-and-rills.html

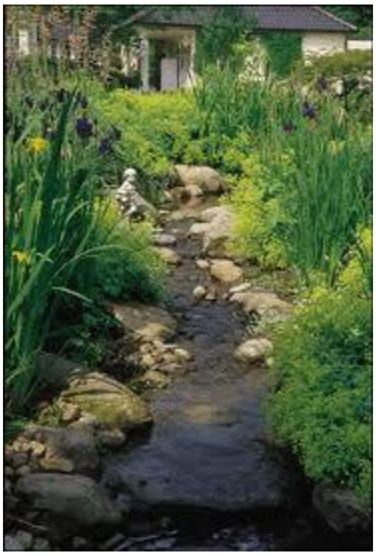

Illustration 56: Rill in urban area

Source: Andras Kis' presentation, NWRM Workshop 1

U06 – Filter strips

Sector(s): Urban, Agriculture

Definition:
Filter strips are uniformly graded, gently sloping, vegetated strips of land that provide opportunities for slow conveyance and (commonly) infiltration. They are designed to accept runoff as overland sheet flow from upstream development and often lie between a hard-surfaced area and a receiving stream, surface water collection, treatment or disposal system.

Filter strips are generally planted with grass or other dense vegetation to treat the runoff through vegetative filtering, sedimentation, and (where appropriate) infiltration. They are often used as a pre-treatment technique before other sustainable drainage techniques (e.g. swales, infiltration and filter trenches). Filter strips are best suited to treating runoff from relatively small drainage areas such as roads and highways, roof downspouts, small car parks, and pervious surfaces.

Filter strips can serve as a buffer between incompatible land uses, and can provide locations for groundwater recharge in areas with pervious soils. Filter strips are often integrated into the surrounding land use, for example public open space or road verges. Local wild grass and flower species can be introduced for visual interest and to provide a wildlife habitat.

Illustrations:

Illustration 57: small filter strip in urban area

Source: Andras Kis' presentation, NWRM Workshop 1

Illustration 58; filter strip in agriculture area

Source: http://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs144p2_021118.jpg

U07 – Soakaways

Sector(s): Urban, Agriculture

Definition:

Soakaways are buried chambers that store surface water and allow it to soak into the ground. They are typically square or circular excavations either filled with rubble or lined with brickwork, pre-cast concrete or polyethylene rings/perforated storage structures surrounded by granular backfill. The supporting structure and backfill can be substituted by modular, geocellular units.

Soakaways provide storm water attenuation, and storm water treatment. They also increase soil moisture content and help to recharge groundwater, thereby offering the potential to mitigate problems of low river flows. They store rapid runoff from a single house or from a development and allow its efficient infiltration into the surrounding soil. They can also be used to manage overflows from water butts and other rainwater collection systems, or can be linked together to drain larger areas including highways.

As a sub-surface infiltration device, a soakaway requires no net land take. They can be built in many shapes and can often be accommodated within high-density urban developments, and can also be retro-fitted. Soakaways are easy to integrate into a site, but offer very little amenity or biodiversity value as they are underground features and water should not appear on the surface.

Illustration:

Illustration 59: principle of a soakaway

Source: Andras Kis' presentation, NWRM Workshop 1

U08 – Infiltration trenches

Sector(s): Urban

Definition:

Infiltration trenches are shallow excavations filled with rubble or stone. They allow water to infiltrate into the surrounding soils from the bottom and sides of the trench, enhancing the natural ability of the soil to drain water. Ideally they should receive lateral inflow from an adjacent impermeable surface, but point source inflows may be acceptable with some design adaptation (effectively they are a form of soakaway). Infiltration trenches reduce runoff rates and volumes and can help replenish groundwater and preserve base flow in rivers. They treat runoff by filtration through the substrate in the trench and subsequently through soil. They are effective at removing pollutants and sediment through physical filtration, adsorption onto the material in the trench, or biochemical reactions in the fill or soil. However they are not intended to function as sediment traps and must always be designed with an effective pre-treatment system where sediment loading is high (e.g. filter strip). Unless very effective pre-treatment is included in the design, they are best located adjacent to impermeable surfaces such as car parks or roads/highways where there levels of particulates in the runoff are low. They work best as part of a larger sustainable drainage treatment train. Infiltration trenches are easy to integrate into a site and can be used for draining residential and non-residential runoff. Due to their narrow shape, they can be adapted to different sites, and can be easily retrofitted into the margin, perimeter or other unused areas of developed sites. Infiltration trenches are also ideal for use around playing fields, recreational areas or public open space. They can be effectively incorporated into the landscape and designed to require minimal land take.

Illustrations:

Illustration 60: infiltration trenches with stones in urban area

Source: Andras Kis' presentation, NWRM Workshop 1

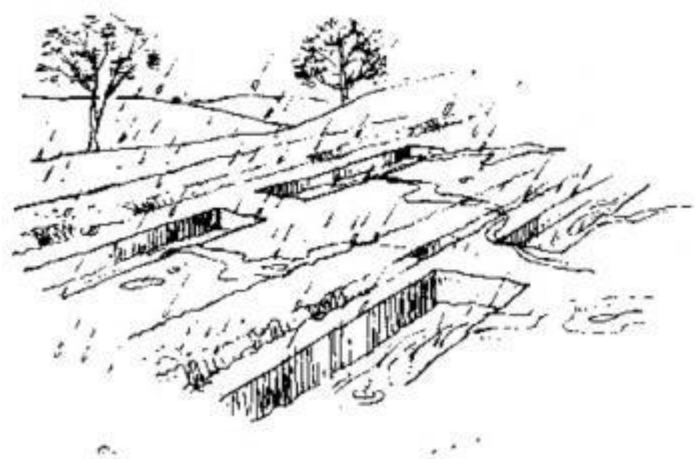

Illustration 61: infiltration trenches in agriculture area

Source: UNDP 2008 (http://www.sswm.info/category/implementation-tools/water-sources/hardware/precipitation-harvesting/field-trenches)

U09 – Rain gardens

Sector(s): Urban

Definition:
Rain gardens are small-scale vegetated gardens used for storage and infiltration. The term 'rain garden' is often used interchangeably with 'bioretention area' (although the latter could also be applied more loosely to other measures such as filter strips or swales).
Rain gardens are typically applied at a property level and close to buildings, for example to capture and infiltrate roof drainage. They use a range of components, typically incorporated into the garden landscape design as appropriate. These components may include:

- Grass filter strips to reduce incoming runoff flow velocities and to filter particulates. For example, these may be used at the base of roof drainage downspouts to slow and filter roof runoff as it enters the rain garden.
- Ponding areas for temporary storage of surface water prior to evaporation, infiltration or plant uptake. These areas will also promote additional settling of particulates.
- Organic/mulch areas for filtration and to create an environment conducive to the growth of micro-organisms that degrade hydrocarbons and organic matter. These may be particularly effective where rain gardens are used to treat excess highway runoff.
- Planting soil, for filtration and as a planting medium. The clay component of the soil can provide good adsorption for hydrocarbons, heavy metals and nutrients.
- Woody and herbaceous plants to intercept rainfall and encourage evaporation. Planting will also protect the mulch layer from erosion and provide vegetative uptake of pollutants.
- Sand beds to provide good drainage and aerobic conditions for the planting soil. Infiltration through the sand bed also provides a final treatment to runoff.

The filtered runoff is then either collected and returned to the conveyance system (using an underdrain) or, if site conditions allow, infiltrated into the surrounding ground. They aim to capture and treat stormwater runoff from frequent rainfall events, while excess runoff from extreme events is passed on to other drainage features as part of a SuDS 'train'. Rain gardens should be planted up with native vegetation that is happy with occasional inundations. Rain gardens are applicable to most types of development, and can be used in both residential and non-residential areas. They can have a flexible layout and should be planned as landscaping features, enhancing the amenity value.

Illustration:

Illustration 62: rain garden

Source: Andras Kis' presentation, NWRM Workshop 1

U10 – Detention basins

Sector(s): Urban

Definition:

Detention basins are vegetated depressions designed to hold runoff from impermeable surfaces and allow the settling of sediments and associated pollutants. Stored water may be slowly drained to a nearby watercourse, using an outlet control structure to control the flow rate. Detention basins do not generally allow infiltration: see U12 for infiltration basins.

Detention basins can provide water quality benefits through physical filtration to remove solids/trap sediment, adsorption to the surrounding soil or biochemical degradation of pollutants.

Detention basins are landscaped areas that are dry except in periods of heavy rainfall, and may serve other functions (e.g. recreation), hence have the potential to provide ancillary amenity benefits. They are ideal for use as playing fields, recreational areas or public open space. They can be planted with trees, shrubs and other plants, improving their visual appearance and providing habitats for wildlife.

Illustration:

Illustration 63: infiltration basin

Source: Andras Kis' presentation, NWRM Workshop 1

U11 – Retention ponds

Sector(s): Urban

Definition:
Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments. Existing natural water bodies should not be used due to the risk that pollution events and poorer water quality might disturb/damage the natural ecology of the system.
Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled rate. Ponds can be designed to control runoff from all storms by storing surface drainage and releasing it slowly once the risk of flooding has passed. Runoff from each rain event is detained and treated in the pond. The retention time and still water promotes pollutant removal through sedimentation, while aquatic vegetation and biological uptake mechanisms offer additional treatment. Retention ponds have good capacity to remove urban pollutants and improve the quality of surface runoff.
Ponds should contain the following zones:

- a sediment forebay or other form of upstream pre-treatment system (i.e. as part of an upstream management train of sustainable drainage components)
- a permanent pool which will remain wet throughout the year and is the main treatment zone
- a temporary storage volume for flood attenuation, created through landscaped banks to the permanent pool
- a shallow zone or aquatic bench which is a shallow area along the edge of the permanent pool to support wetland planting, providing ecology, amenity and safety benefits.

Additional pond design features should include an emergency spillway for safe overflow when storage capacity is exceeded, maintenance access, a safety bench, and appropriate landscaping.
Well-designed and maintained ponds can offer aesthetic, amenity and ecological benefits to the urban landscape, particularly as part of public open spaces. They are designed to support emergent and submerged aquatic vegetation along their shoreline. They can be effectively incorporated into parks through good landscape design.
(Ponds installed primarily for wildlife benefit, or for other purposes besides management of runoff, may also be classified as measure N1).

Illustration:

Illustration 64: retention pond

Source: http://winnipeg.ca/waterandwaste/drainageFlooding/ponds.stm

U12 – Infiltration basins

Sector(s): Urban

Definition:

Infiltration basins are vegetated depressions designed to hold runoff from impervious surfaces, allow the settling of sediments and associated pollutants, and allow water to infiltrate into underlying soils and groundwater. Infiltration basins are dry except in periods of heavy rainfall, and may serve other functions (e.g. recreation). They provide runoff storage and flow control as part of a SuDS 'train'. Storage is provided through landscaped areas that allow temporary ponding on the land surface, with the stored water allowed to infiltrate into the soil. The measure enhances the natural ability of the soil to drain water by providing a large surface area in contact with the surrounding soil, through which water can pass.

Infiltration basins may also act as "bioretention areas" of shallow landscaped depressions, typically under-drained and relying on engineered soils, vegetation and filtration to reduce runoff and remove pollution. They provide water quality benefits through physical filtration to remove solids/trap sediment, adsorption to the surrounding soil or biochemical degradation of pollutants. Water quality is, however, a key consideration with respect to infiltration basins as the potential for the infiltration to act as a vector for poor quality water to enter groundwater may be high. Pre-treatment may be required in certain areas before infiltration techniques are appropriate for use, for example swales or detention basins to reduce sediment loading and retain heavy metals and oils.

Infiltration basins have the potential to provide ancillary amenity benefits. They are idea for use as playing fields, recreational areas or public open space. They can be planted with trees, shrubs and other plants, improving their visual appearance and providing habitats for wildlife. They increase soil moisture content and help to recharge groundwater, thereby mitigating the problems of low river flows.

Illustration:

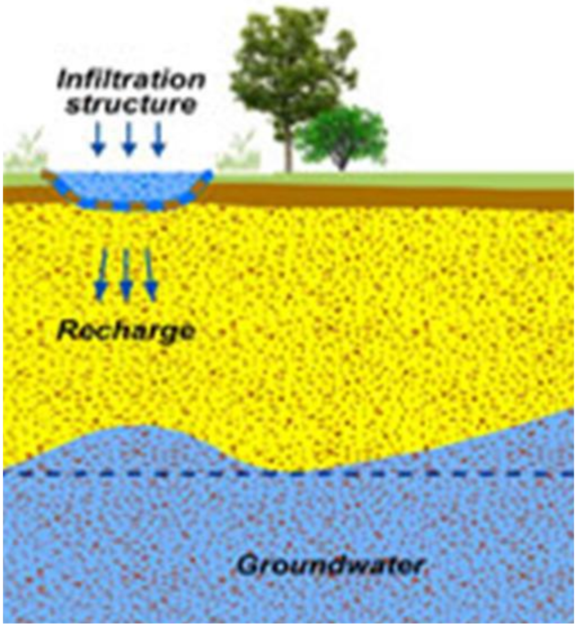

Illustration 65: explicative scheme of the MAR principle

Source: Andras Kis' presentation, NWRM Workshop