

# Ecosystem-based Adaptation Measures for a CLIMATE RESILIENT CITY

handout | august 2019

**Deltares**  
Enabling Delta Life



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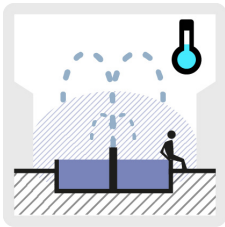


**WAGENINGEN**  
UNIVERSITY & RESEARCH



ASIAN DEVELOPMENT BANK

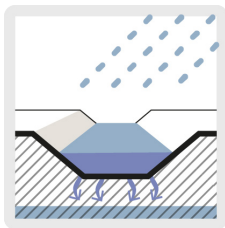
## Fountains, waterfalls, water facades



Standing water surfaces evaporate less water than green surfaces. Sprinkling water on surfaces serves to increase evaporation and lowers temperature. So moving water such as with fountains, waterfalls and water walls has a cooling effect on the surroundings. Surface water and rainwater can be used for this purpose.



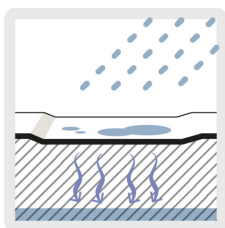
## Ditch or infiltration-strip



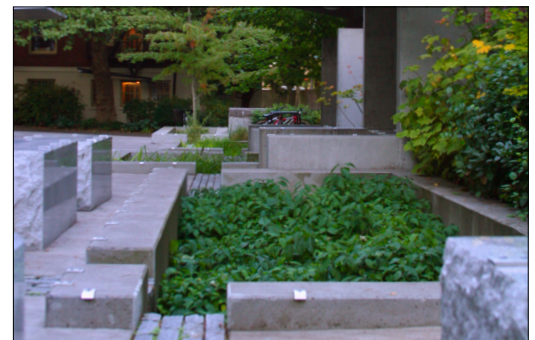
A ditch is a small channel and facilitates temporary rainwater retention, transportation, and infiltration. A ditch can contain water or can stand dry. Ditches can be integrated into green verges or the roadside. They look natural but they do need extra space and maintenance.



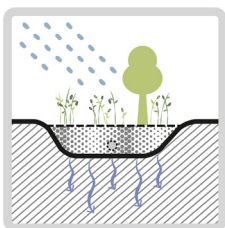
## Infiltration field



Adding fields next to paved surfaces to temporarily store runoff is a simple way to allow water to infiltrate from clean hard surfaces such as roofs and cycle paths. Besides the volume of precipitation that needs buffering, the permeability of the ground is another factor that determines the minimum dimensions.



## Gravel layers



A gravel layer is a subsurface facility packed with gravel for infiltration of runoff. Runoff is carried above or below the surface and led into the layer or shaft. Such systems are used next to paved surfaces or next to unpaved surfaces that do not offer sufficient room for infiltration ditches or where the ground has an insufficient permeability factor.



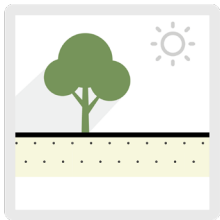
## Green facades



Green facades attract and lose less heat. The plants also cause evaporation, which helps keeping the town or city's climate cooler. An advantage is that it takes up little space in an already intensively used urban area, while providing many vertical metres of green.



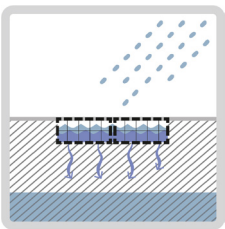
## Creating shade



Creating shade is important to prevent surfaces from heating up and to cool the surroundings. This can be accomplished by using trees, pergolas, overhangs, awnings and such. Arcades and covered walkways are urban elements commonly used in warm countries to create shade.



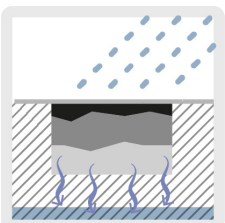
## Infiltration boxes



Infiltration boxes buffer rainwater underground and allow using a single area for two purposes. In general they offer more storage capacity than above-ground infiltration installations. More rainwater can be buffered temporarily and gradually released into the groundwater. The extra infiltration leads to less drought damage, subsidence and salinization.



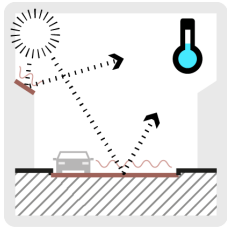
## Rain garden



These are sandy soil or aggregate filled depressions that treat stormwater runoff to improve water quality. Stormwater is captured and allowed to percolate through the soil/aggregate layer, where pollutants are removed, prior to being released through an underdrain located at the bottom of the depression.



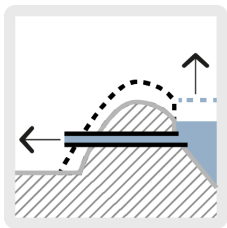
## Cool building materials (high albedo) / cool roof



The properties of surface materials concerning the power to reflect sunlight and the capacity to absorb heat influence the surface temperature. In general, light materials heat up less than dark materials. By choosing materials with less mass, such as wood and other porous materials that absorb less heat, the surface and the immediate surroundings will stay cooler.



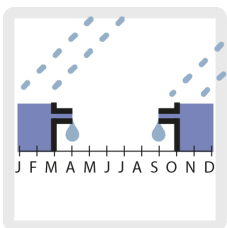
## Create extra surface water (m<sup>2</sup>)



Realising additional surface area for storage can serve to create additional storage volume while the fluctuation in water level remains unchanged. Part of the standard fluctuation of 30 cm, for example, is then earmarked for seasonal storage, while the other part is reserved for peak storage. The advantage to this method of seasonal storage is that the fluctuations are limited, which is good for flora along the banks.



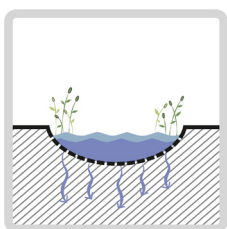
## Storage by creating extra freeboard



Designing the surface area for storage to handle greater fluctuations in water levels is a way of realising storage capacity without requiring additional surface area. In many locations, however, the height required cannot simply be created by a high groundwater level. Greater fluctuations in water levels will place demands on how the banks are designed and planted, since those banks will be exposed to more extreme conditions.



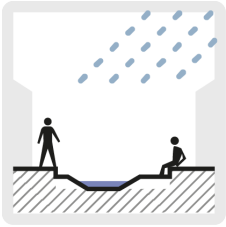
## Rainwater detention pond (wet pond)



Buffer ponds temporarily capture precipitation and allow it to drain off slowly. During rainfall, the rainwater is captured in the pond and subsequently drained off to create room for the next precipitation. Buffer ponds can be designed to have a mostly stony or a mostly natural appearance.



## Water square



Various towns and cities have designed systems to achieve rainwater retention in public spaces. These systems, known as water squares, are linked to other urban functions such as playing areas, green areas and residential functions. Water squares are generally used in inner-city areas with little room for water buffers and where high groundwater levels make infiltration impossible.



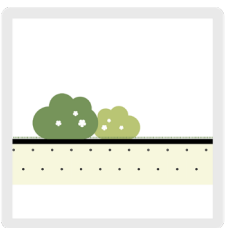
## Drainage-Infiltration-Transport (DIT) drains



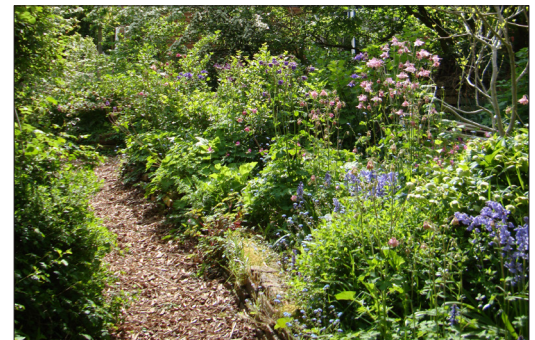
A sewage system using a perforated horizontal pipe wrapped with geotextile, drains the ground, allows water to infiltrate and transports it. Such systems are used next to paved surfaces or next to unpaved surfaces that do not offer sufficient room for infiltration ditches or where the ground has an insufficient permeability factor.



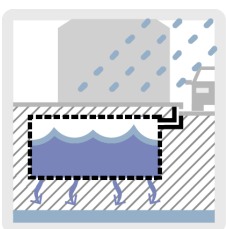
## Remove pavement to plant green



Less paving in the garden and in urban areas has many advantages: the rainwater is absorbed into the ground, replenishing the groundwater. Paved surfaces get warmer in the summer than green space; removing paving creates more room for planting and the plants keep the area cooler on hot summer days. Removing paving offers animals, plants and soil life more space.



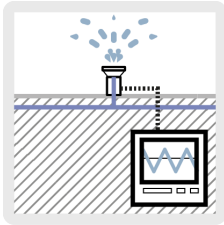
## Rain barrel



Rainwater tanks are the simplest systems for homes, and the easiest to install. In most cases, the precipitation is used for irrigating plants: the tank is already located outside. Commonly used rainwater tanks are not overly large (a common size is 224 litres), meaning that they require an overflow if the roof surface to which they are connected is too large.



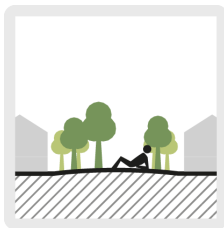
## Smart irrigation



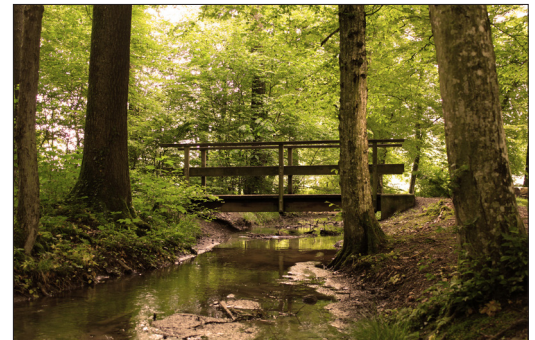
If in times of prolonged drought there is a chance of damage to the vegetation, it must be irrigated. If this is done periodically (weekly), plants will become accustomed that this does not occur daily and will take root deeper in the soil. If irrigation is done late in the day there is also less loss through evaporation.



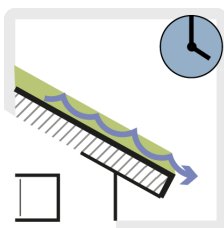
## Urban forest



Urban forests have many functions. Besides providing recreational space and contributing to a reduction in heat stress, they can create islands of relatively clean air in a city and improve the biodiversity. In addition, they contribute to limiting flooding, desiccation and salinization by infiltrating rainwater, and creating buffer and infiltration areas in the urban forests.



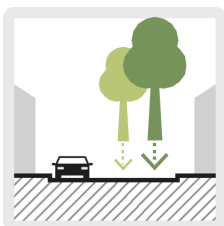
## Green roof with drainage delay



Green roofs with drainage delay are also called retention roofs. It is a green roof that can store extra water in a substrate layer under the green planted layer and is drained delayed with a pinched drain. A polder roof is a retention roof where the control system is linked to the weather forecast.



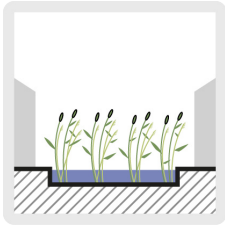
## Adding trees to streetscape



Planting trees on streets, squares and car parks creates shade and evapotranspiration and therefore has a cooling effect. Dense foliage over busy roads is not beneficial, since the emissions from the vehicles tend to become trapped under the foliage. The type of tree should be chosen to suit the local moisture system.



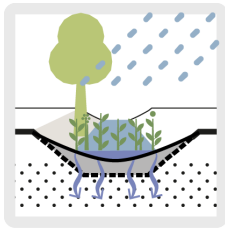
## Urban wetlands



Wetlands are water-rich natural areas that occur chiefly along rivers and in deltas. By their very nature, wetlands are overflow areas for rivers and as such are natural rainwater buffers. However, the urban expansions and the correspondingly lower groundwater levels put pressure on wetlands and wet nature around the world. In some cities, London for example, wetlands serve a function by developing greater biodiversity and natural and pleasant recreation areas for city dwellers.



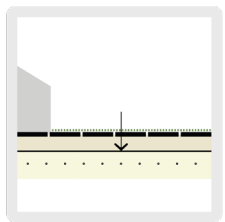
## Bioswale (with drainage)



A bioswale is a ditch with vegetation, a porous bottom and below that a layer of gravel, packed in geotextile with an infiltration pipe/drainpipe. It allows rainwater storage, infiltration and transport while helping to enhance biodiversity and quality of life.



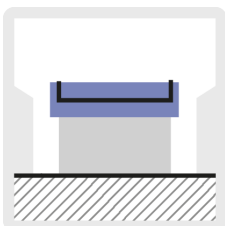
## Permeable pavement (infiltration & storage)



Permeable pavements consist of porous material that absorbs rainfall. Water can be stored either in the top layer (e.g. very open asphalt concrete) or in below the top layer in the foundation. Besides reducing runoff, permeable pavements can trap suspended solids and filter pollutants from the water.



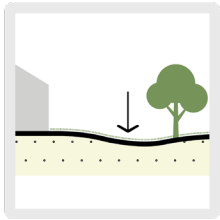
## Water roof



Flat roofs can be designed to buffer a degree of precipitation by situating the overflow at a slightly higher level. This needs to be taken into account in the roof's construction (greater load). The rainwater is drained off at a delayed pace using narrower drainpipes and only remains for a short period on the roof to create sufficient storage capacity in time for the next rainfall.



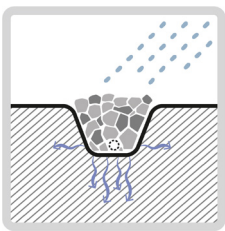
## Lowering of garden



By lowering a part of the garden it is possible to create systems to capture rainfall, such as infiltration ponds, that store stormwater and allow rainwater to infiltrate. Besides buffering precipitation, this measure can also lead to a decrease of the air temperature.



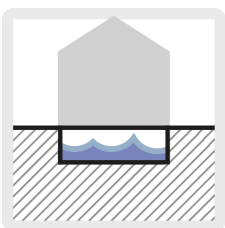
## Infiltration trench



An infiltration trench, also known as a French drain, is a linear feature used to reduce stormwater runoff and improve water quality. These shallow excavated trenches are filled with aggregate or crushed stone that is designed to allow for stormwater to infiltrate the ground plane and ultimately percolate through permeable soils into the groundwater. Their linear shape can also serve to convey stormwater from one area to another, or away from built structures, and typically contain a perforated pipe underdrain.



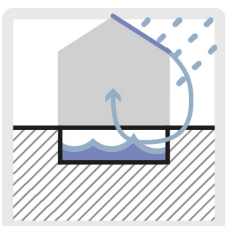
## Rainwater storage below buildings



While not always the case, this is most commonly achieved by directing stormwater from the roof of a building and collecting it in a cistern below the structure. The runoff can then be filtered and treated before being reused on site or discharged into the city drainage system. Cisterns below buildings do not provide for infiltration.



## Systems for rainwater harvesting



Rainwater harvesting is the collection and storage of stormwater for reuse on site. This is most commonly achieved by capturing runoff from the roof of a building, however, it can also include the collection of runoff from throughout the site or byproducts from systems such as air conditioning condensate. The collection structures can take on multiple forms and be installed either above ground or subsurface. Depending on its source and treatment, the harvested water can be reused on site for irrigation.





## Extensive green roof



A green roof is a multi-layered roof system that is partially or entirely covered with vegetation. Extensive green roofs have a maximum depth of six (6) inches and are a layered system containing growing media, waterproofing membrane, drainage, and often irrigation components. Extensive green roofs can support groundcovers and shallow root plant material, and therefore require less structural support and reduced maintenance when compared to intensive green roofs.



## Intensive green roof



Intensive green roofs have a minimum depth of six (6) inches and are a layered system containing growing media, waterproofing membrane, drainage, and advanced irrigation components. Intensive green roofs can support groundcovers, bushes and even trees, and therefore require more structural support and maintenance when compared to extensive green roofs.



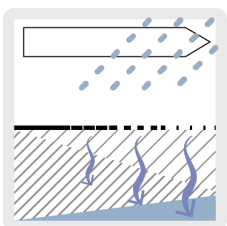
## Private green garden



A residential or private domestic garden, is the most common form of garden and is in proximity to a residence, such as the 'front garden' or 'back garden'. The front garden may be a formal and semi-public space and so subject to the constraints of convention and local laws. Residential gardens are typically designed at human scale, as they are most often intended for private use.



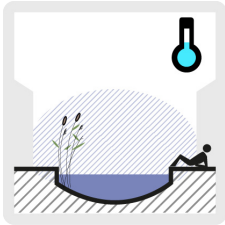
## Improve soil infiltration capacity



Amending soils improves the conductivity, or infiltration (in/hr) of the soil. This is achieved by increasing the permeability of the soil, allowing water to move through the spaces between soil particles more freely. Typically, native soils in the Greater New Orleans area consist primarily of compacted clays, which have small soil particles with little void space between. Replacing these clay soils with sandy soils, which exhibit large particles with a high void ratio, increases permeability.



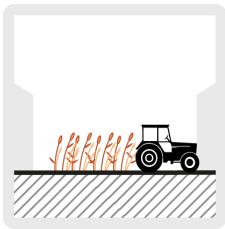
## Cooling with water elements: ponds



A body of standing water, either natural or man-made, that is usually smaller than a lake. They may arise naturally in floodplains as part of a river system, or they may be somewhat isolated depressions. Usually they contain shallow water with marsh and aquatic plants and animals.



## Urban agriculture



Urban agriculture is the practice of cultivating, processing, and distributing food in or around a community. Urban agriculture can also involve aquaculture, agroforestry, urban beekeeping, and horticulture. These activities can occur both in dense urban environments as well as within less dense, suburban areas.



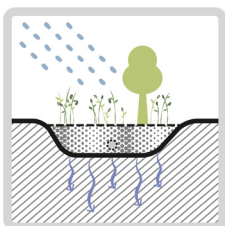
## Floating puri-plants (floatlands)



A floating wetland is a vegetated, artificial island typically used for small scale ecological intervention. These facilities are often used in canals and other surface waters to improve water quality. Floating wetlands also function as wildlife habitat.



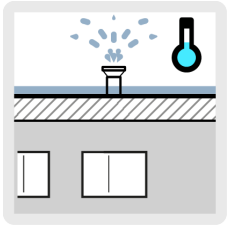
## Bioretention cell



Bioretention cells are stormwater detention features that collect, detain, infiltrate, and filter stormwater runoff prior to releasing it to a storm sewer system via an overflow or discharge mechanism. These facilities typically feature both surface level (freeboard) and subsurface stormwater detention. Starting from the surface, it is commonly composed by: planting (trees & native shrubs), mulch layer, bioretention soil, aggregate bridging course, aggregate subbase, pipe underdrain, and undisturbed native soil.



## Wetting surfaces (of gardens, roofs, roads)



A sprinkler system can wet areas like roofs, roads or gardens so it can evaporate and cool down the air temperature. Other examples are fountains and waterfalls. This measure can be used in densely populated urban areas where the urban heat island effect is severe.

