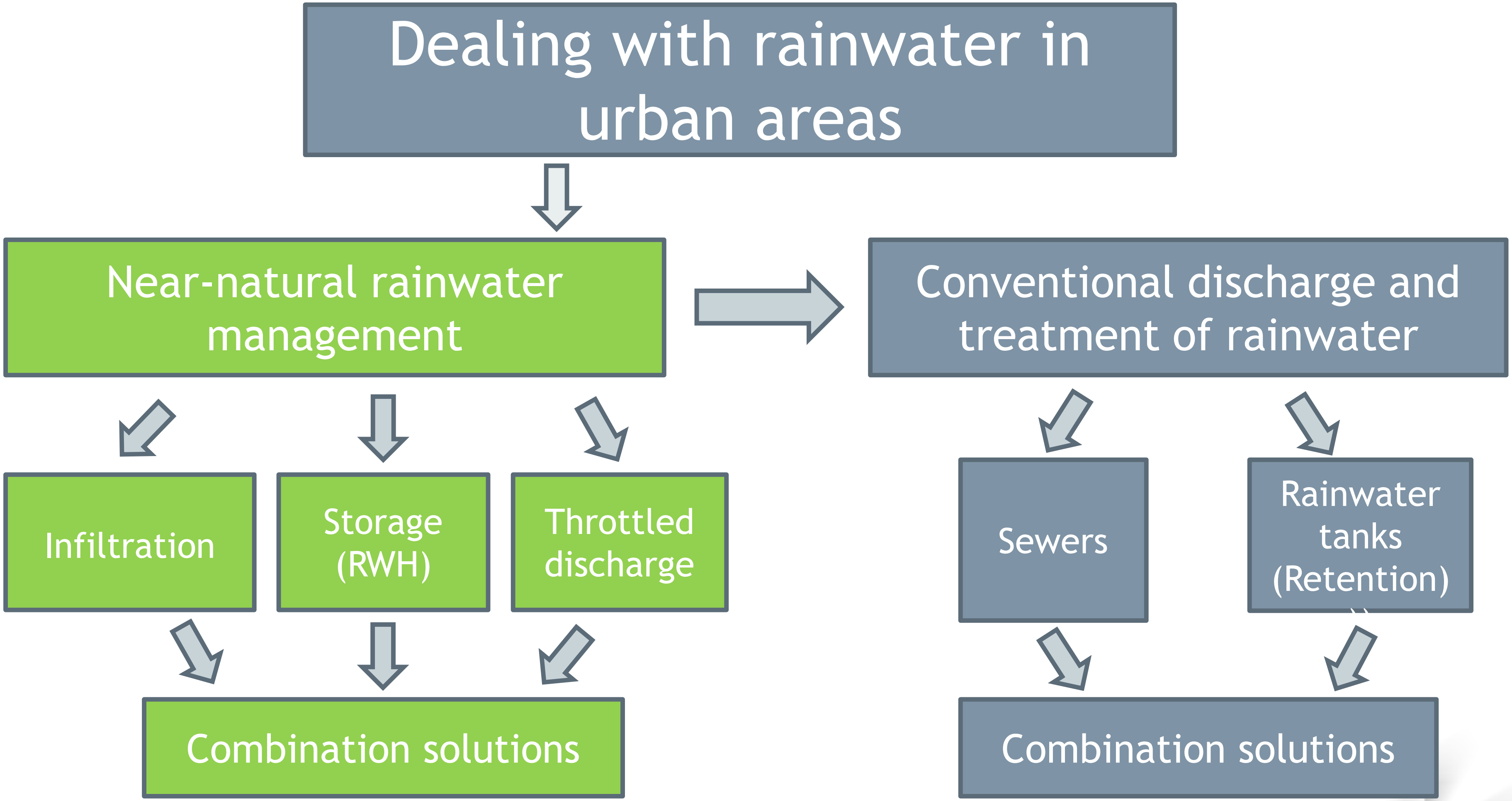
2) Rainwater

fbr, Association for Rainwater Harvesting and Water Utilization

INTRODUCTION



(Source: Adapted from Londong & Nothnagel)

Impacts of climate change on the conventional sewer system

Extreme rain and flood events

Flooded streets in Bonn in 2013 (Photo: Stephan Knopp GA/Bonn)

CONVENTIONAL

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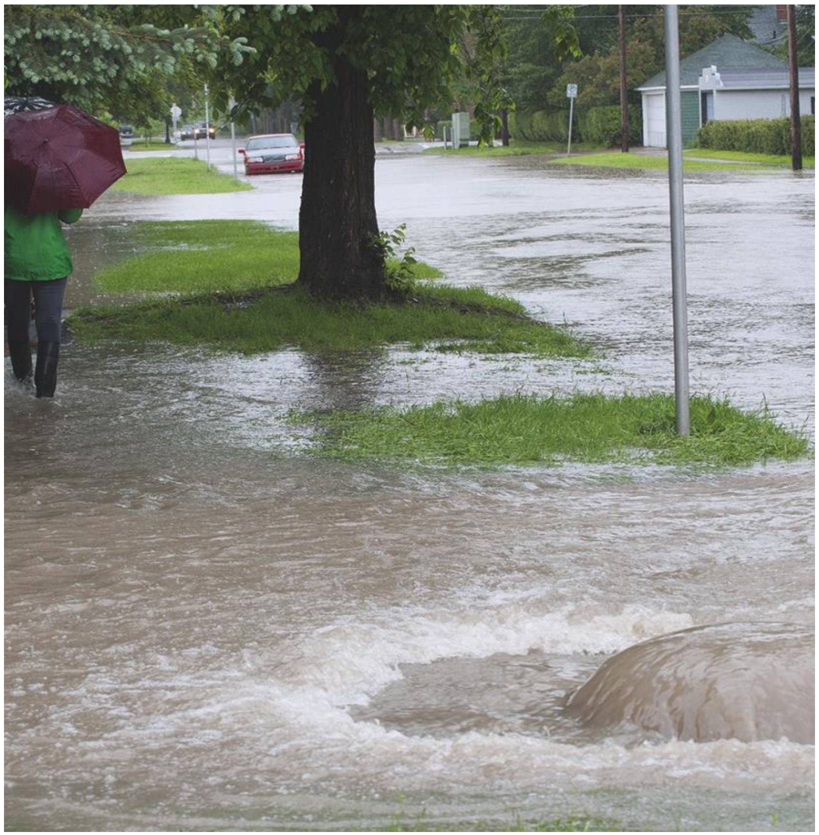
Increase in frequency of extreme weather events

Wet scenario



Dry scenario

CENTRALISED DISCHARGE

into **combined** sewer (without retention):

- Sewer overload due to increased frequency of heavy rainfall events
  e.g. in Berlin, ca. 40 sewer overflows/year
  → negative impacts on flora and fauna, fish mortality, etc.
- High pollutant load, especially from traffic surfaces, find ist way into water bodies (e.g. microplastics, heavy metals, …)
- Establishes unnatural water balances:
  reduces local evaporation process
  reduces local groundwater recharge
  Info: the natural water balance in Berlin is 80% evaporation, 20% groundwater recharge and 0% surface runoff.

CENTRALISED DISCHARGE

into **combined** sewer without treatment (retention):

Mixed water overflow basins in Berlin-Wedding (Photo: BWB)

- Construction of expensive underground rainwater retention basins (Berlin storage sewers approx. 3,000 €/m³)

Wall for storage space activation in Berlin-Wedding (Photo: BWB)

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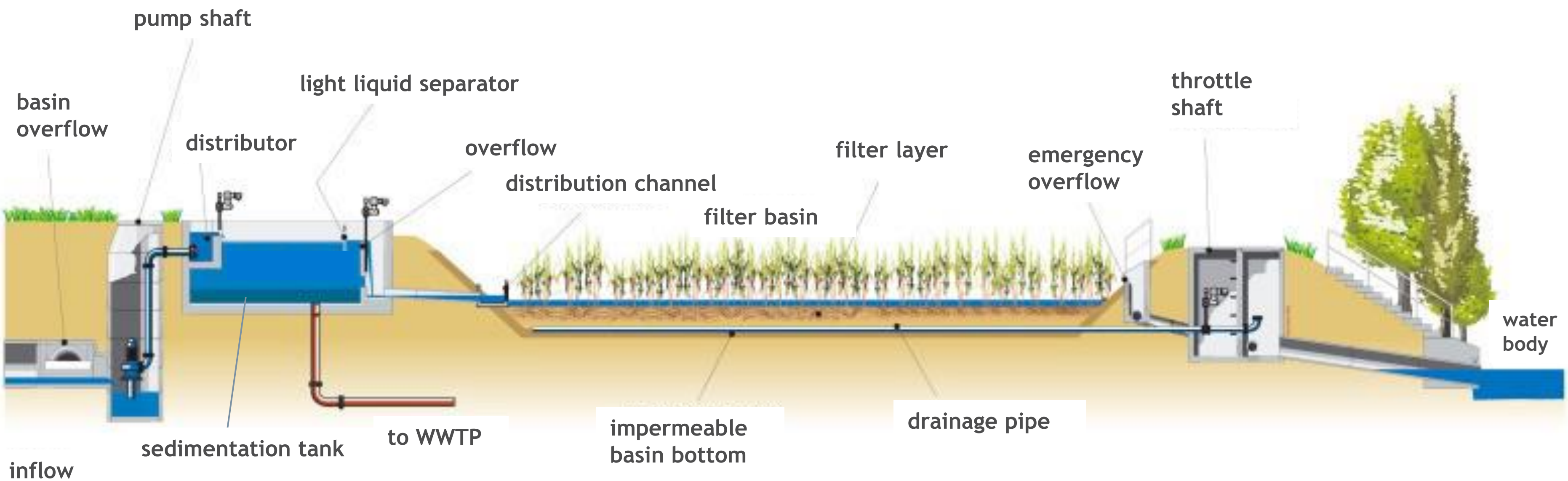
Schematic diagram of a retention soil filter



(Source: BWB)

CENTRALISED DISCHARGE

Retention soil filters

(Source: Retentionsbodenfilter : Handbuch für Planung, Bau und Betrieb, 2015)

CENTRALISED DISCHARGE

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with decentralised on-site pre-treatment (in street gullies):



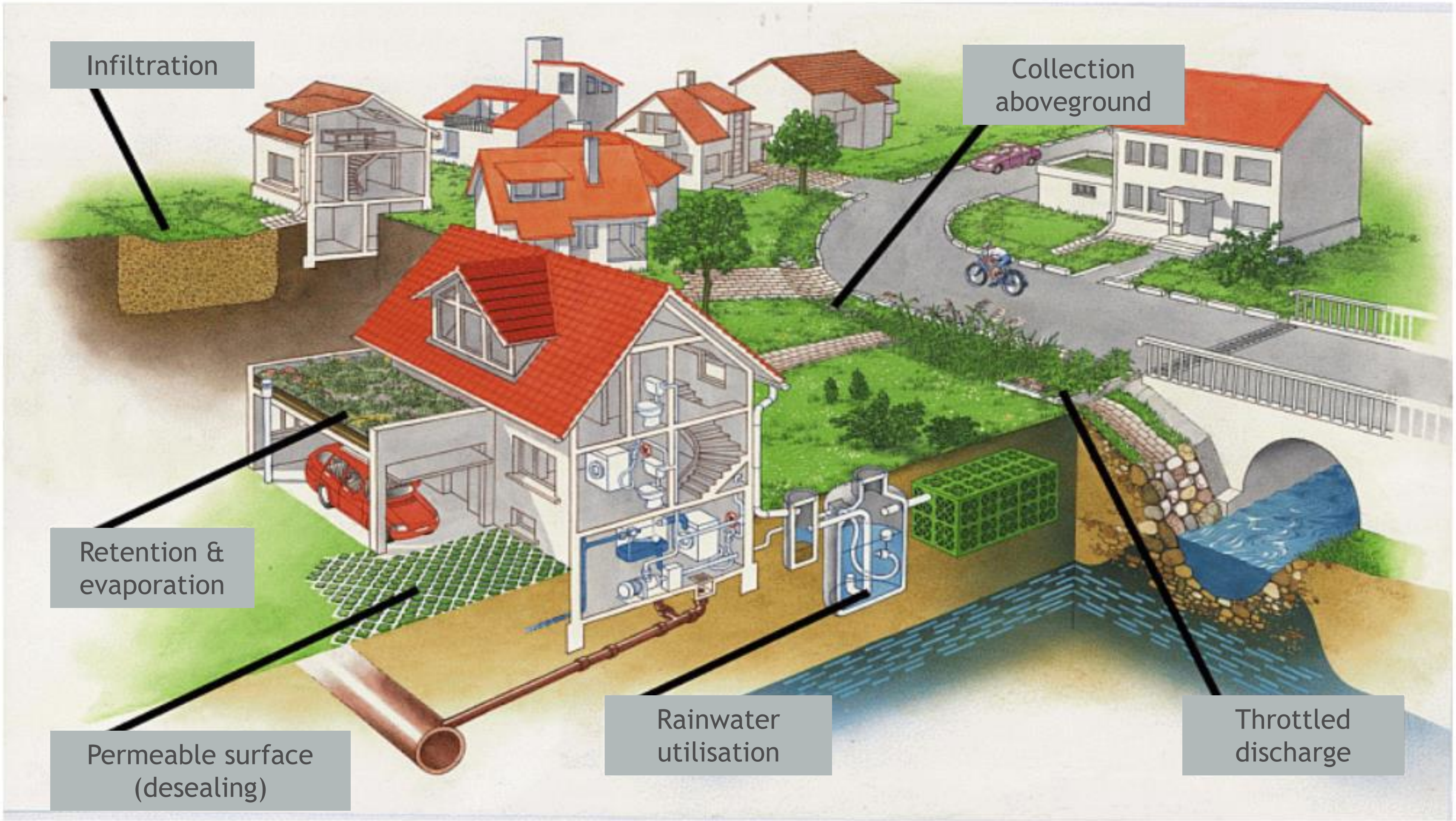
Different systems of decentralised rainwater pre-treatment at Clayallee, Berlin (Photo: KWB, Sieker)

Priorities in Rainwater (Stormwater)* Management

1. Avoiding new sealings and unsealing of urban areas
2. On-site rainwater harvesting and utilisation
3. Rainwater retention
4. Rainwater infiltration (groundwater recharge)
5. Throttled discharge into a water body or wastewater treatment plant

*Rainwater and stormwater are used here interchangeably

Decentralised rainwater management in urban areas



(Source: fbr)

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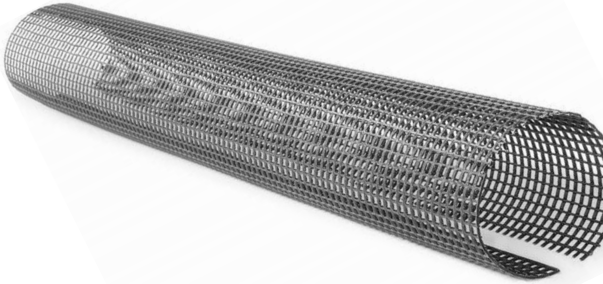
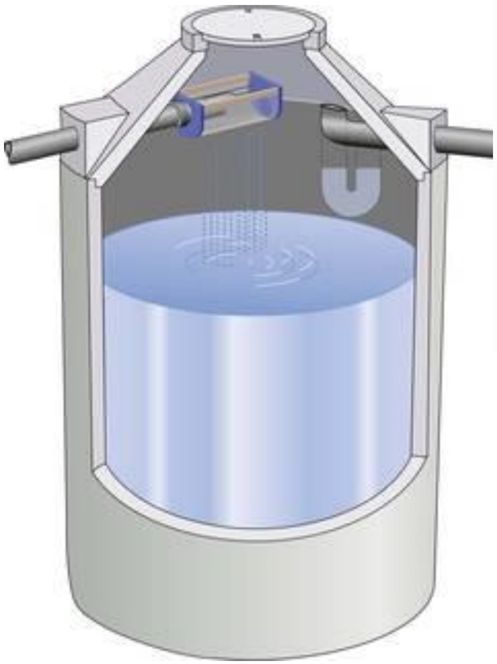
Leaves protective grating reduces maintenance



Rainwater tanks

Aboveground tanks preferred for garden irrigation (Graf)



Concrete underground (Mall)

Underground plastic tank (GreenLife)

Rainwater tanks for small-scale RWH

Underground tank (Mall)

RAINWATER HARVESTING

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Rainwater tanks for large-scale RWH

Conventional

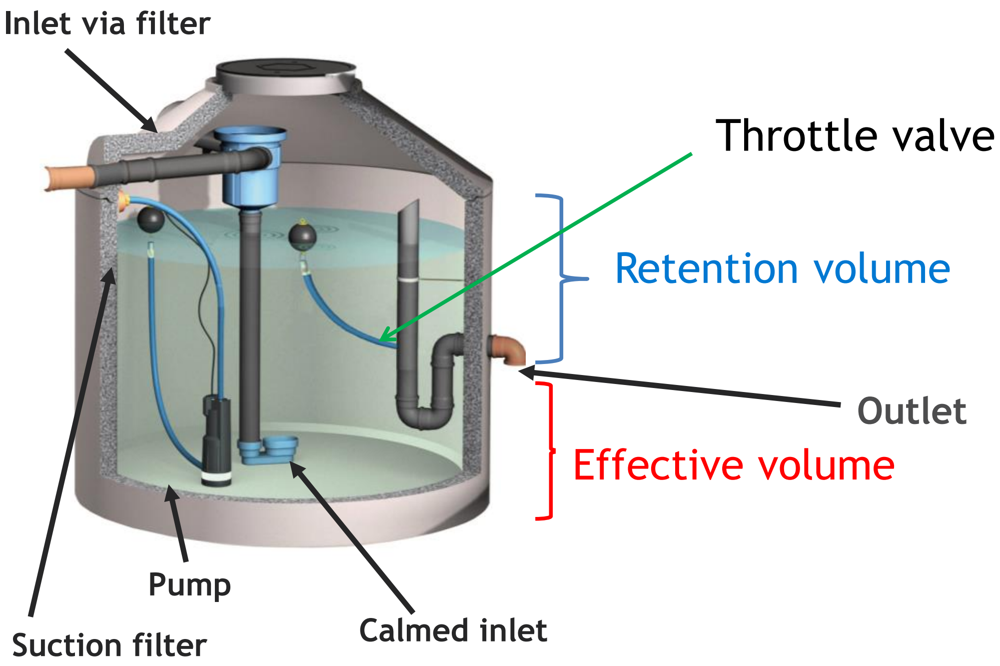
Office building

Airport Charles de Gaulle

(Source: fbr)

Rainwater harvesting in combination with retention

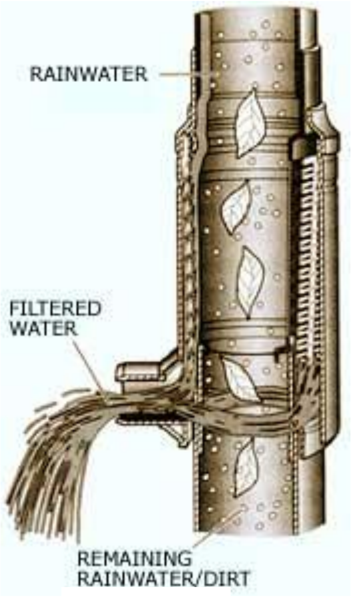
Cistern with throttle valve



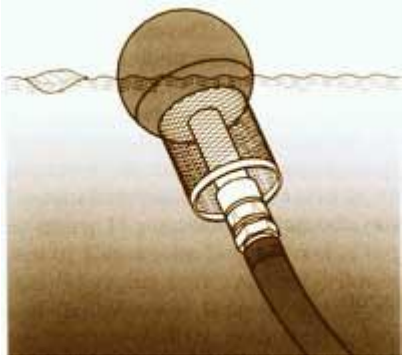
A conflict exists between rainwater utilisation (cistern should be full at all times) and the hydraulic relief of sewer (cistern should preferably be always empty, in order to collect new runoff). Retention cisterns are constructed as a combination structure to fulfill both demands. They have a specific **retention volume**, which can be throttled discharged into sewer and an additional fixed **effective volume** for reuse.

Rainwater filters

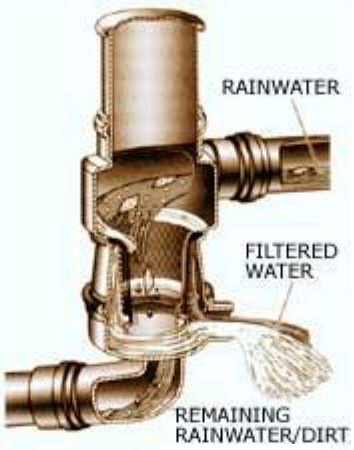
Various types of mechanical filters for different reuse scale (downpipes, in-tank, pre-tank, post-tank filters, …)



A downpipe filter collector diverts 90% of the rainwater to a storage tank through a 0.17 mm stainless steel mesh filter



A floating fine suction filter ensures that rainwater is pumped from cleanest level of the tank and is free of particulates



A large vortex fine filter diverts 90% of rainwater runoff from roof areas of up to 500 m²

(WISY AG filters. Source: John Gould and Erik Nissen-Petersen (1999) Rainwater Catchment Systems for Domestic Supply - Design, Construction and Implementation)

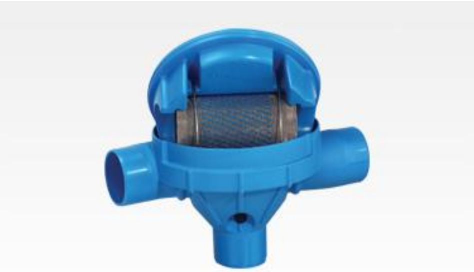
Rainwater filters

Rainwater filter for roof areas up to 500 m² (Source: Otto Graf GmbH)

Rainwater filter for roof areas up to 6000 m² (Source: INTEWA GmbH)

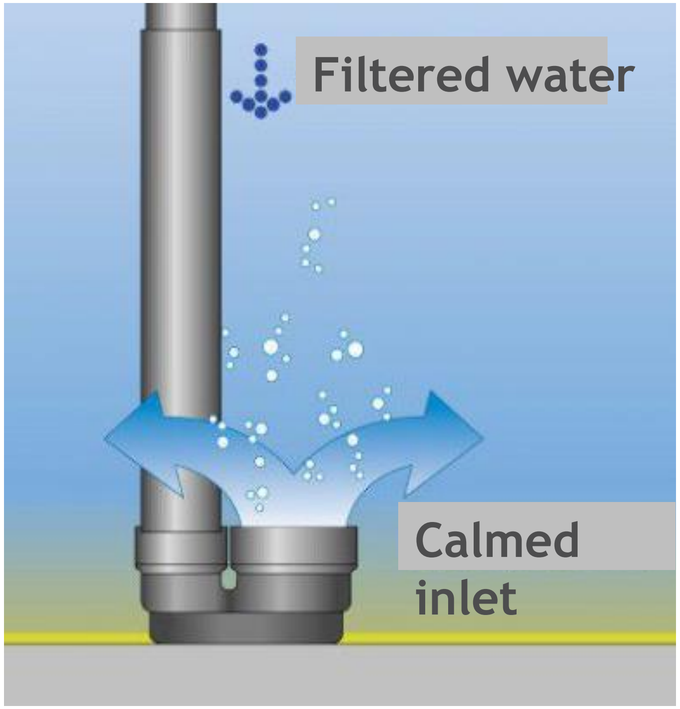
Downpipe filter

(Source: Wisy, AG)

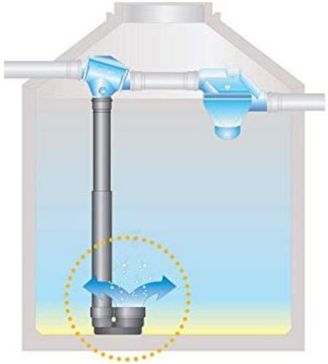


Integrated filter for rainwater tanks
(Source: 3P Technik Filtersysteme GmbH)

Calmed inlet



(Source: 3P Technik Filtersysteme GmbH)



A calmed inlet prevents whirl up of sediment at the bottom of the rainwater tank

Suction filter

A floating fine suction filter ensures that rainwater is pumped from cleanest level of the tank and is free of particulates

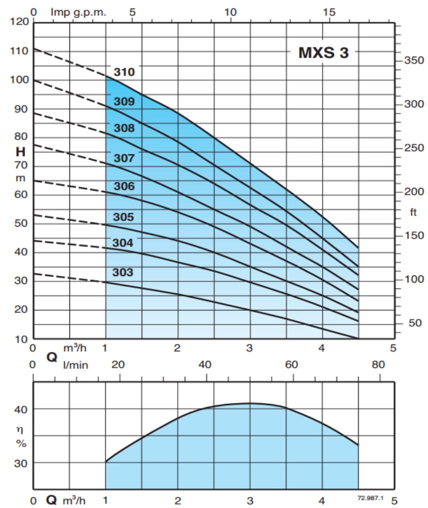
Pumps

ESPA

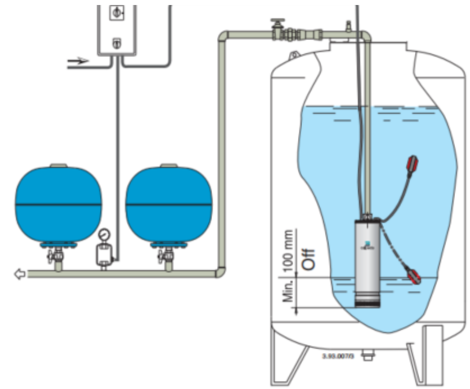
GreenLife

Intewa Rainmaster

Calpeda



Characteristic curve



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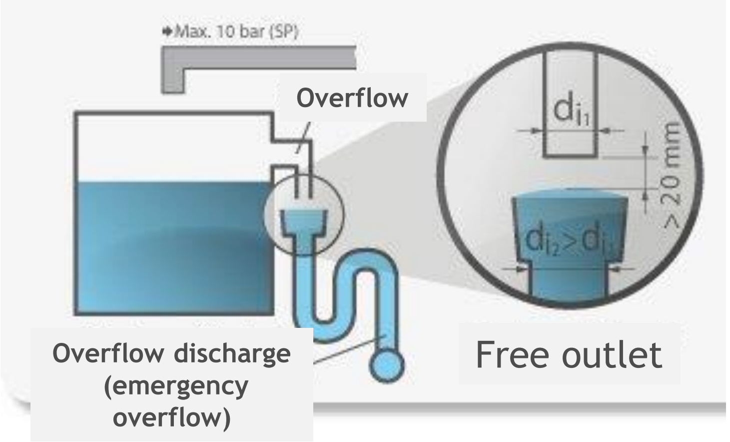
Installation example

Avoid cross connections (with drinking water network)



RAINWATER HARVESTING

Rainwater to potable water (and beer)

Clear water tank with Rainmaster Favorit SC, AQUALOOP control system and UV disinfection

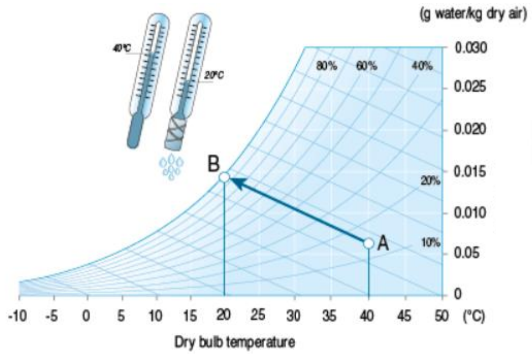
AQUALOOP Tap Comfort 1,600 l/d

AQUALOOP single-membrane station with membrane and control system

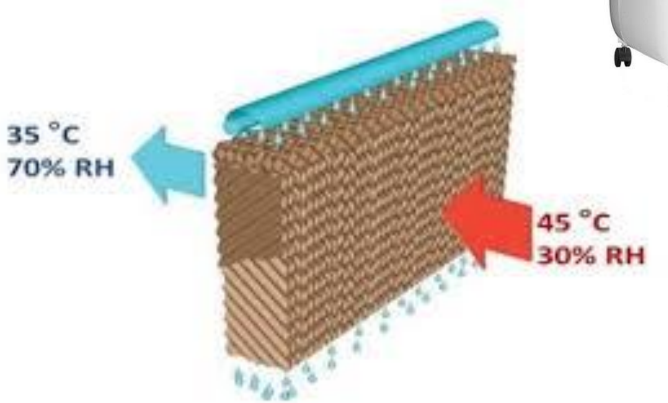
(Source: INTEWA GmbH; https://www.intewa.de/produkte/aqualoop/referenzen/projekte/ihre-haus-wasserquellen/)

Adiabatic cooling with rainwater

1 kW$_{elec.}$ + 100 litres of water has a cooling power of 70 kW

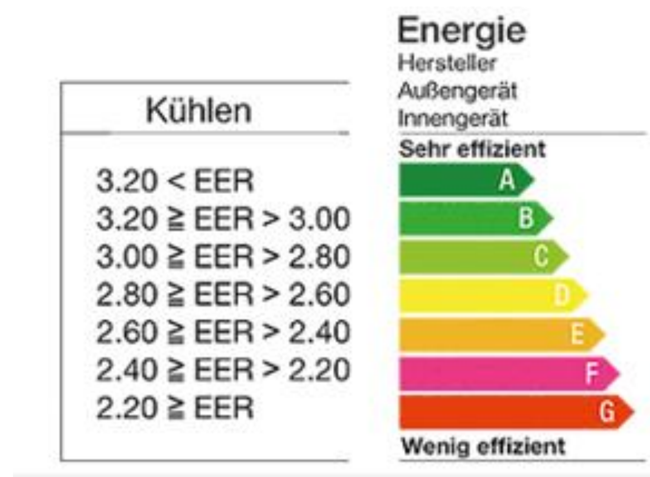


Adiabatic humidification



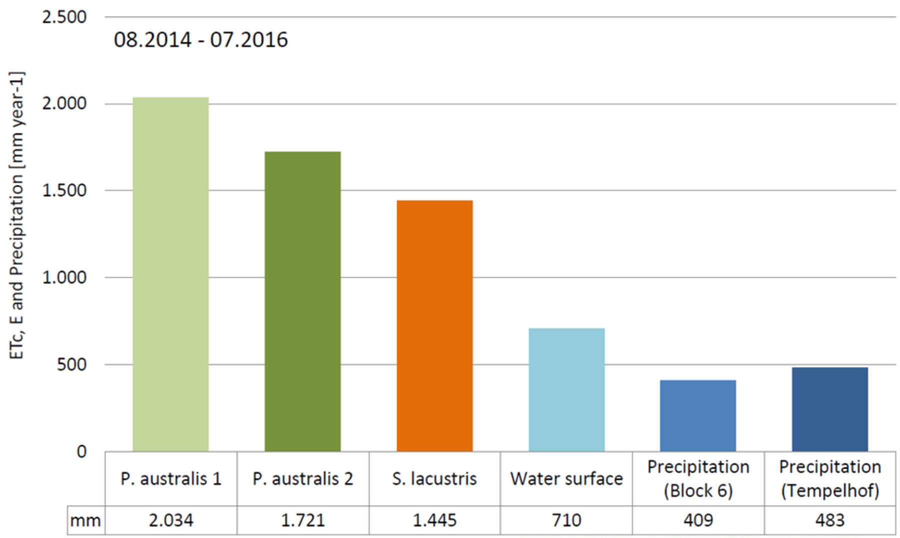
Cooling with electricity

1 kW$_{elec.}$ has max. 3.2 kW cooling power

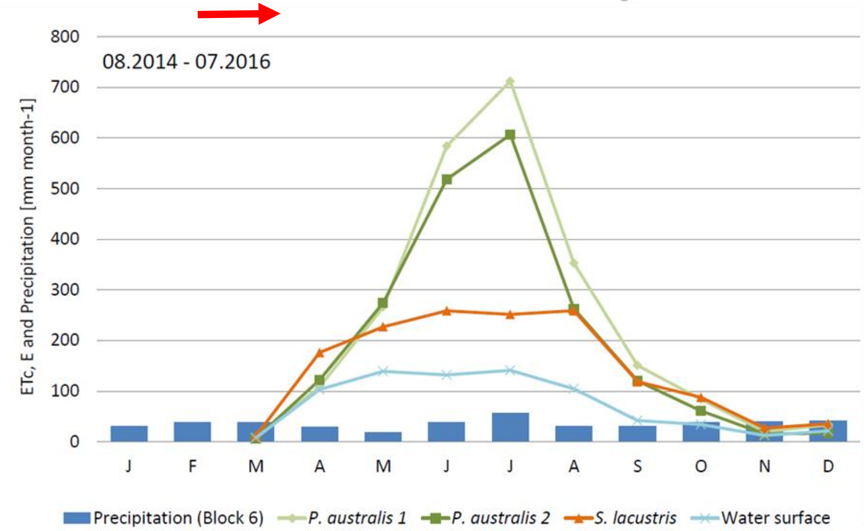


EVAPORATIVE COOLING

Evaporation of rainwater in densely populated urban areas



Evaporation in summer about 20 mm/d

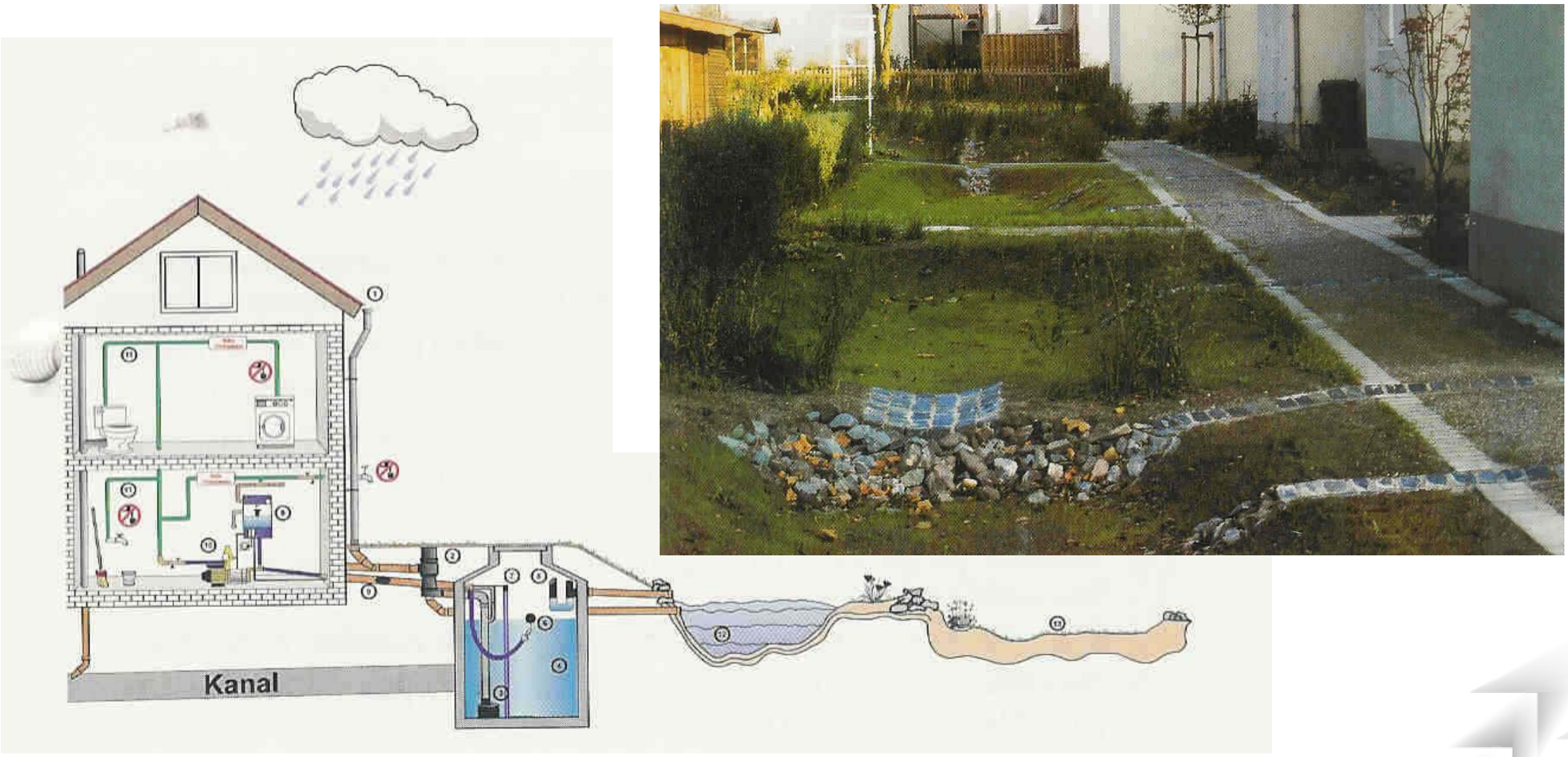


Reed evaporates during one single Summer month as much as a single tree does the whole year!

Benefits of rainwater harvesting

- Rainwater is relatively clean and its quality is usually sufficient for many applications with little or even no treatment
- Rainwater has a low salinity and can be reused in several applications where soft water is required such as for laundry, cooling and in industry (instead of RO, ion exchanger, etc.)
- Can save up to 50 % of the household water demand
- Reduces energy costs for cooling:
  1 m^3 of **evaporated** RW **releases 680 kWh of energy**
- Reduces drainage load on sewer and flooding in urban areas
- RWH is a flexible technology and can be designed to meet almost any requirement
- Contribute to self-sufficiency in water supply

Rainwater harvesting in combination with infiltration of the overflow water



RAINWATER RETENTION

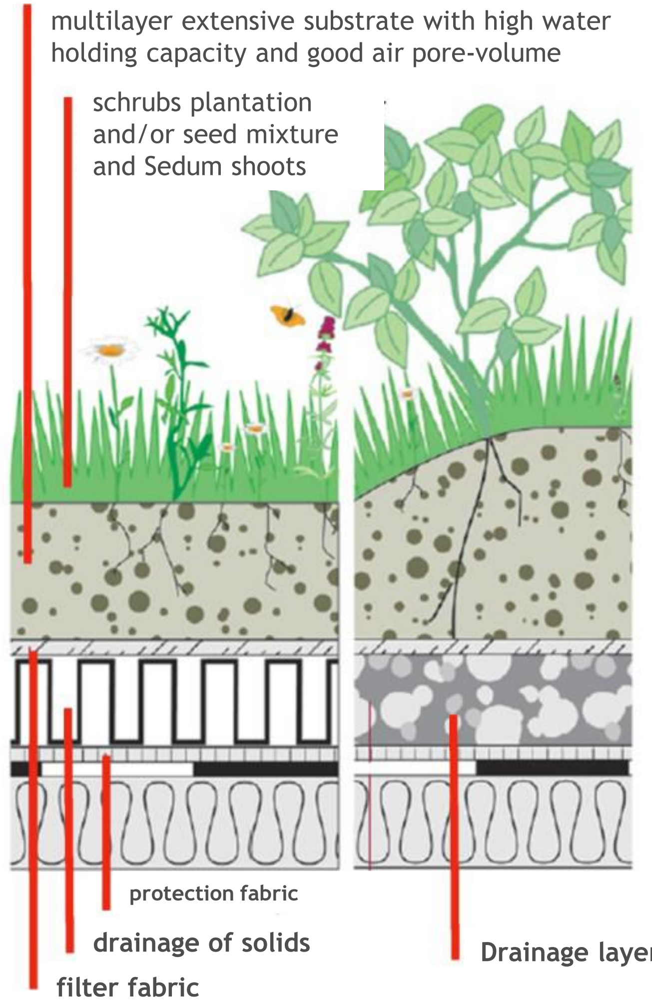
Extensive green roofs

(Source: Nolde & Partner)

RAINWATER RETENTION

Extensive green roofs

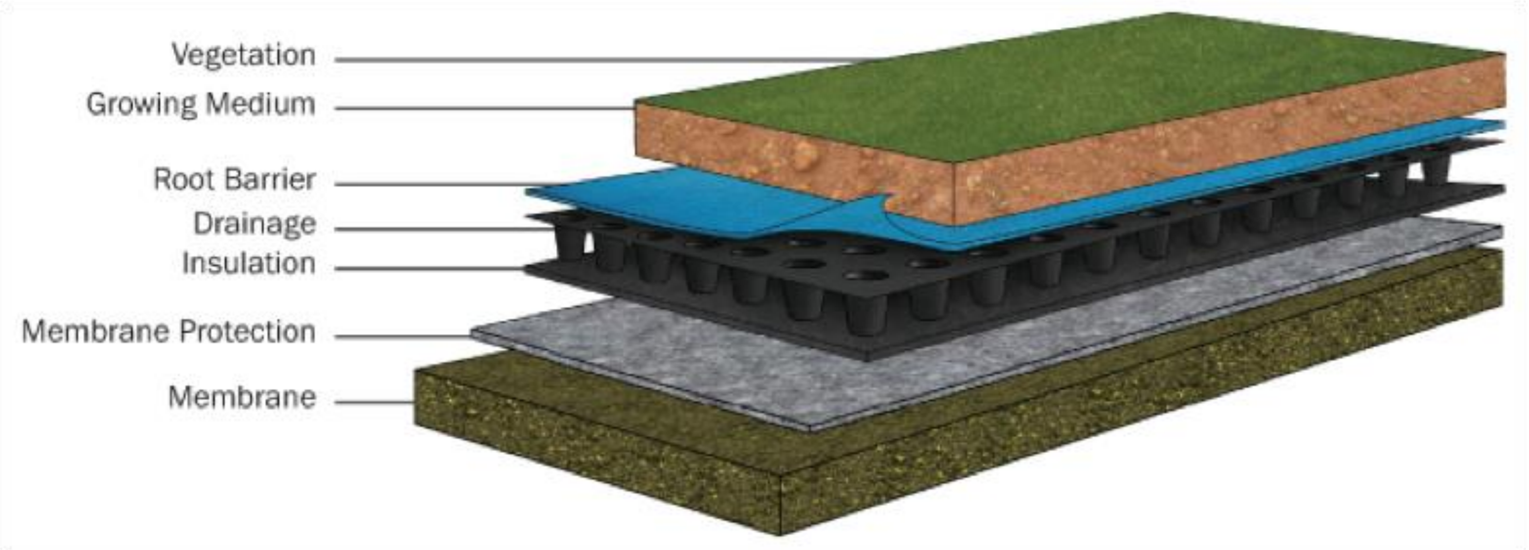
Extensive green roof, Alexa, Berlin (Photo: FBB, G. Mann)



Setup of an extensive green roof

(Source: Berlin Senate Department for Urban Development and Housing)

Schematic diagram of a multilayer system of a green roof



(Source green building alliance
https://www.go-gba.org/resources/green-building-methods/green-roofs/#lightbox/1/)

RAINWATER RETENTION

Intensive green roofs

(Source: Optigrün)

Facade and wall greening

Ground-bound facade greening with Virginia creeper in Berlin-Schöneberg (Photo: D. Kaiser)

System-bound facade greening in containers, Institute of Physics in Berlin Adlershof (Photo: M. Schmidt)

COMBINATION OF RAINWATER HARVESTING WITH GREEN ROOFS

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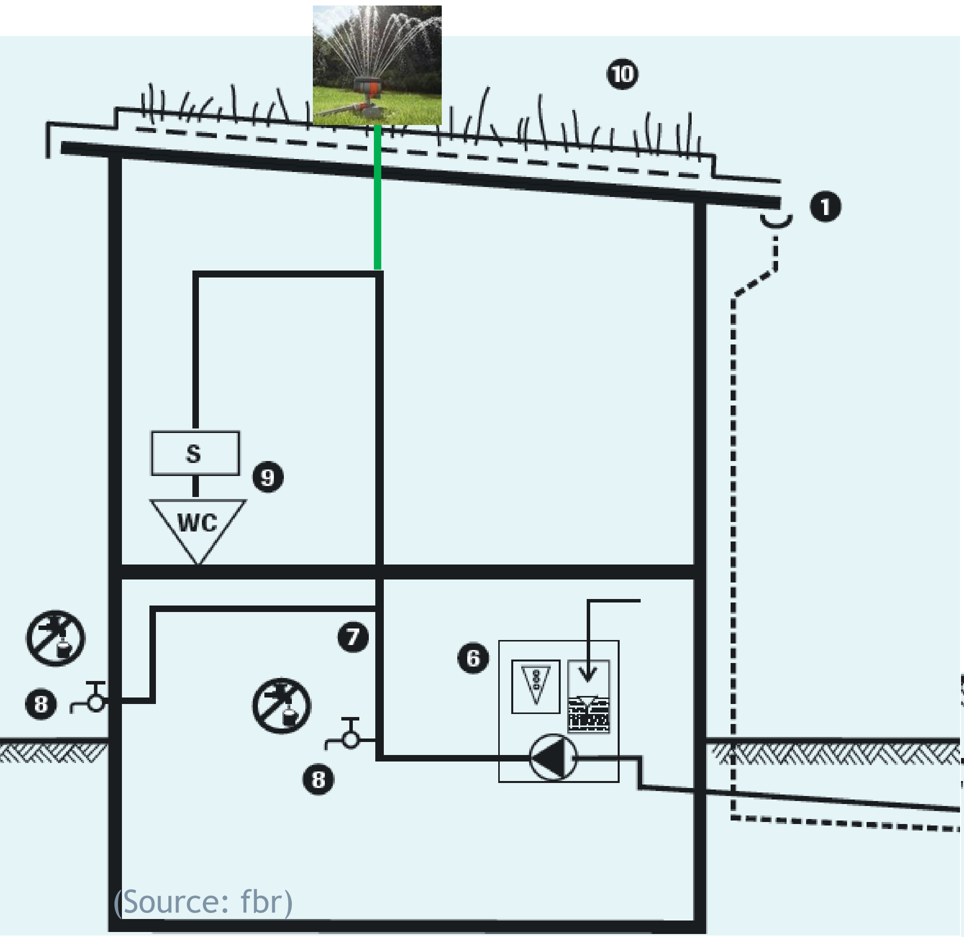
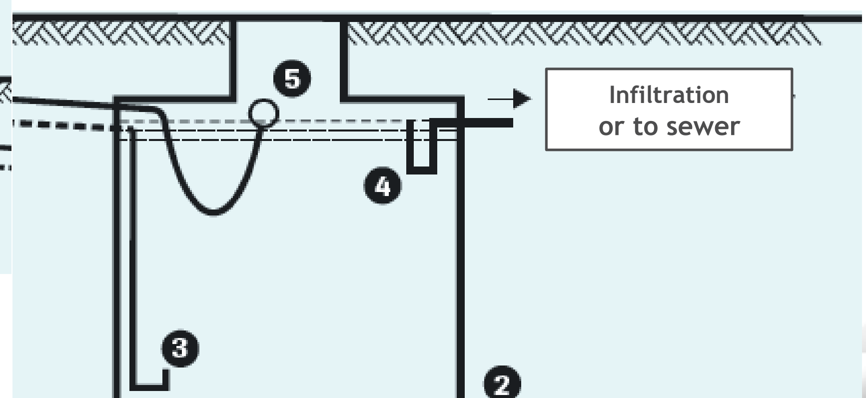


1 Roof gutter
2 Rainwater reservoir (e.g. from concrete or plastic)
3 Calmed inlet
4 Overflow with odour trap
5 Suction filter (floating extraction)
6 Rainwater supply system incl. pump, control panel & drinking water backup system
7 Service water pipes
8 Tapping point
9 Toilet
10 Green roof



(Source: fbr)

3.2 Rain gardens

(Source: https://www.surfrider.org/coastal-blog/entry/cape-fear-chapter-installs-york-residential-rain-garden-in-north-carolina)

INFILTRATION

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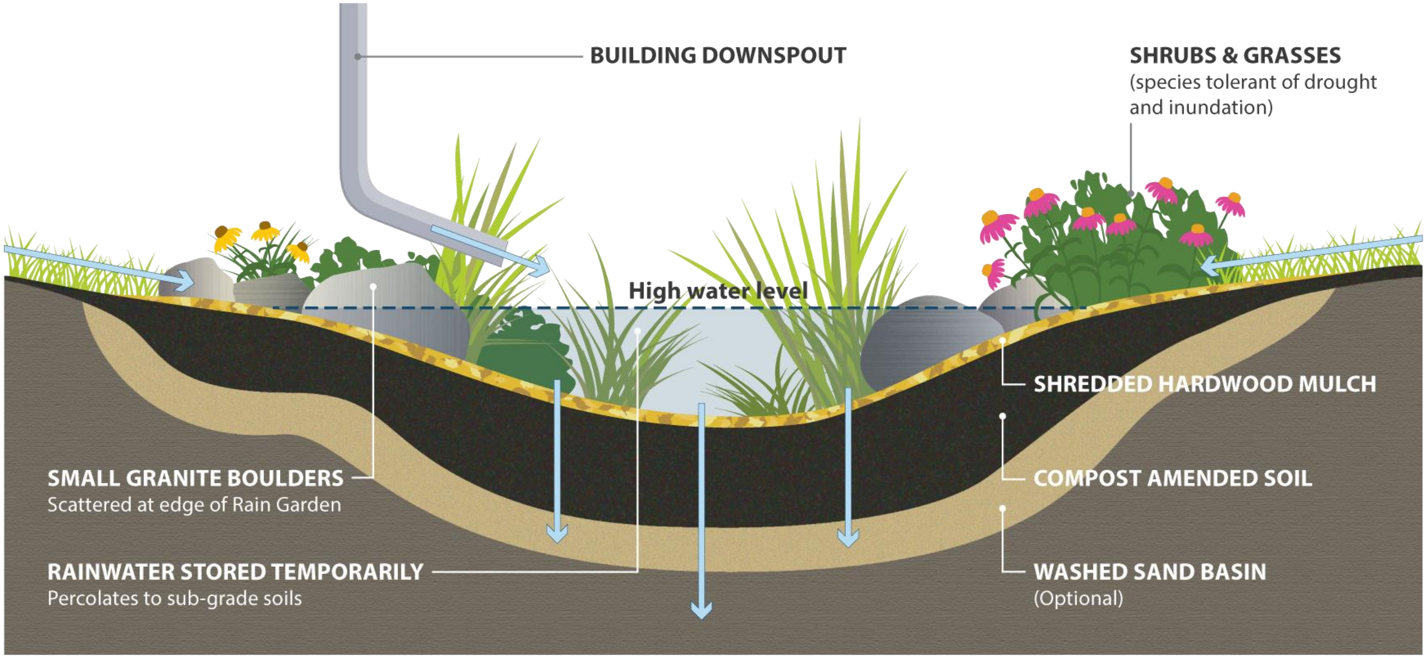
Cross section in a rain garden



(Source: Toronto and Region Conservation Authority; https://trca.ca/news/complete-guide-building-maintaining-rain-garden/)

Block 6 – Berlin: 100% disconnection from sewer

Green roofs, evaporation, infiltration and biodiversity

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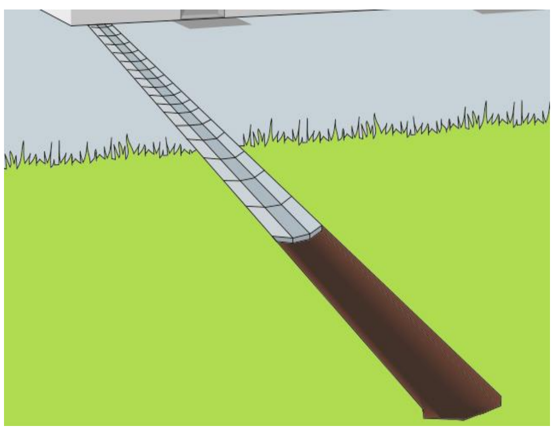
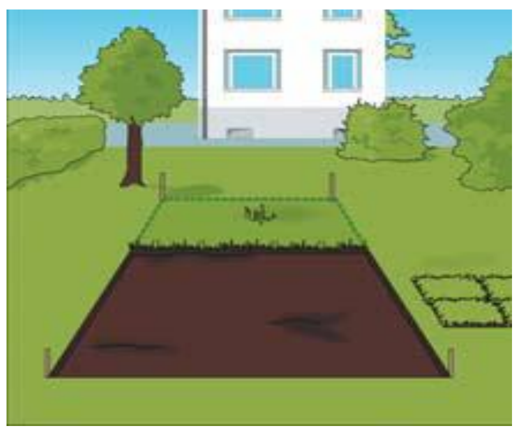
Constructed wetland in the centre of Berlin

3. Infiltration

Vegetated swales and surface infiltration





INFILTRATION

Selection of infiltration technologies under different soil and area conditions

Permeability				Selection procedure for rainwater management system	
Class	Permea-bility	k_f from	k_f to	Low area availability (1)	High area availability (2)
II	high	$1 \cdot 10^{-5}$	$5 \cdot 10^{-6}$	Swale infiltration	Swale infiltration 10 : 1
II	medium	$5 \cdot 10^{-6}$	$2 \cdot 10^{-6}$	Swale-trench infiltration without discharge	Swale infiltration 6: 1
III	moderate	$2 \cdot 10^{-6}$	$7 \cdot 10^{-7}$	Swale-trench infiltration with partly throttled discharge	Swale infiltration 4 : 1
IV	low	$7 \cdot 10^{-7}$	$2 \cdot 10^{-7}$	Swale-trench infiltration with throttled discharge (3)	Swale infiltration 2 : 1

(1) Ratio of connected sealed area to infiltration area is 10:1
(2) Ratio of connected sealed area to infiltration area as indicated
(3) K_f value without limitation downwards

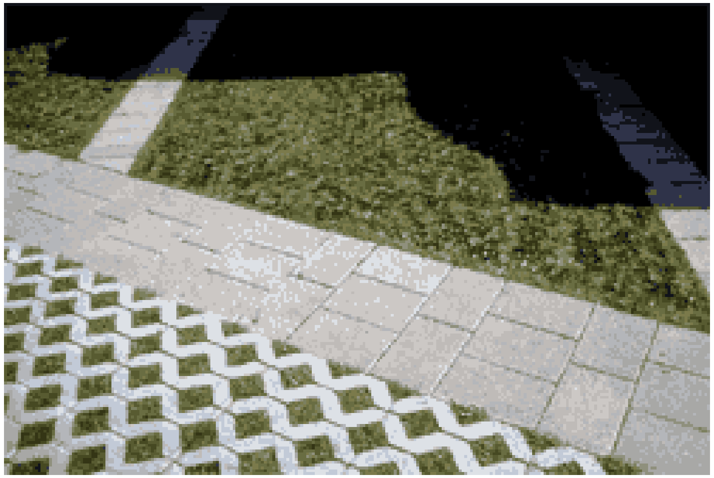
(Source: Adapted from Londong & Nothgnagel, 1999)

Soil permeability

- The permeability of the soil is the major influencing factor which determines whether rainwater infiltation is applicable at a specific site and it also affects the choice of technology
- The permeability of the soil is measured as the **filtration coefficient k_f**
- The technically relevant k_f range for rainwater infiltration lies between **1×10^{-3} (86 m/d)** and only **1×10^{-6}** m/s (86 **mm/d)**

For example, with k_f values larger than 10^{-3} rainwater infiltrates without it being sufficiently treated by physical/chemical and biolgoical processes in the topsoil layer. With k_f values smaller than 10^{-6}, rainwater will accumulate in the soil and flow very slowly into the ground.

3.1 Permeable pavements



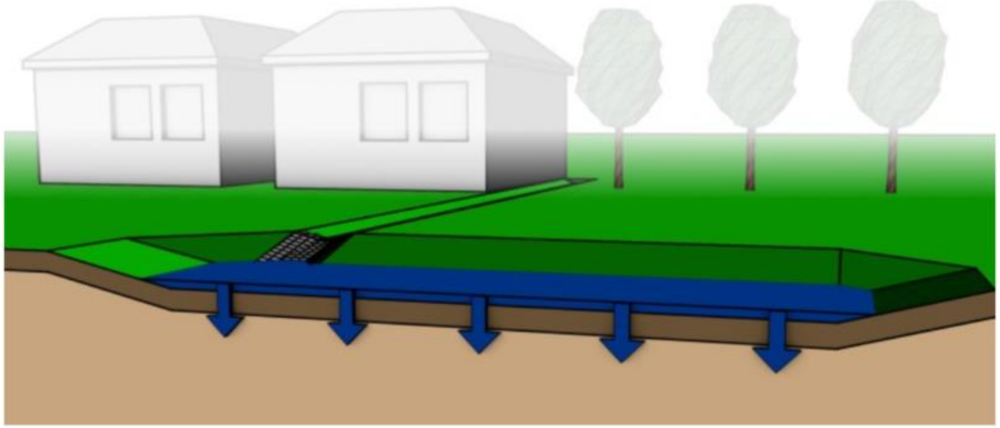
(Source: Sieker)

Permeable pavements

(Source: USGS Wisconsin Water Science Center)

3.3 Vegetated swales

Vegetated swale at Rummelsburger Bucht, Berlin (Photo: Sieker)



Schematic diagram of an infiltration swale: with inflow, aboveground retention space and infiltration (Source: Sieker)

Vegetated swales

(Source: Sieker)

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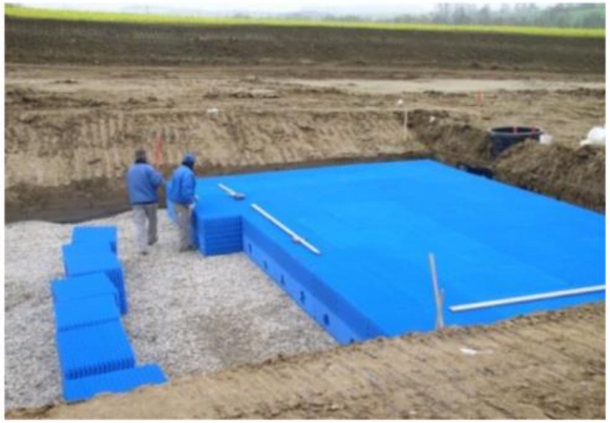
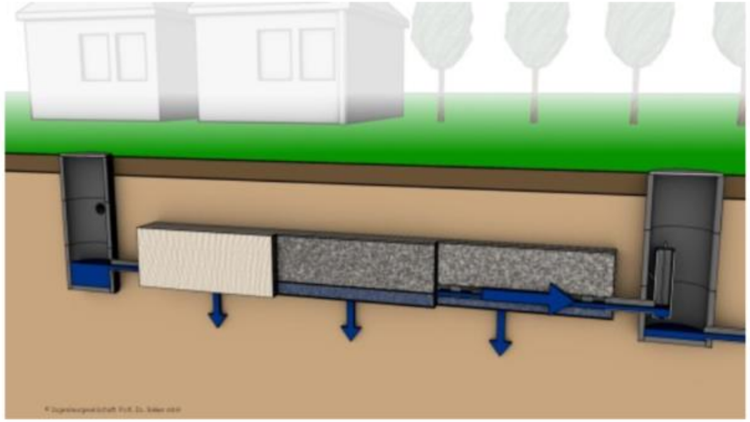
3.5 Infiltration trenches

View of the bottom of a soakaway (Photo: Sieker)



Setup of an infiltration trench with filling material (Photo: Sieker)



Schematic diagram of an infiltration trench with a sedimentation chamber at inflow and throttled outflow (Source: Sieker)

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Infiltration trenches

(Source: https://sustainablestormwater.org/2007/05/23/infiltration-trenches/)

(Source: Minnesota Stormwater Manual)

INFILTRATION

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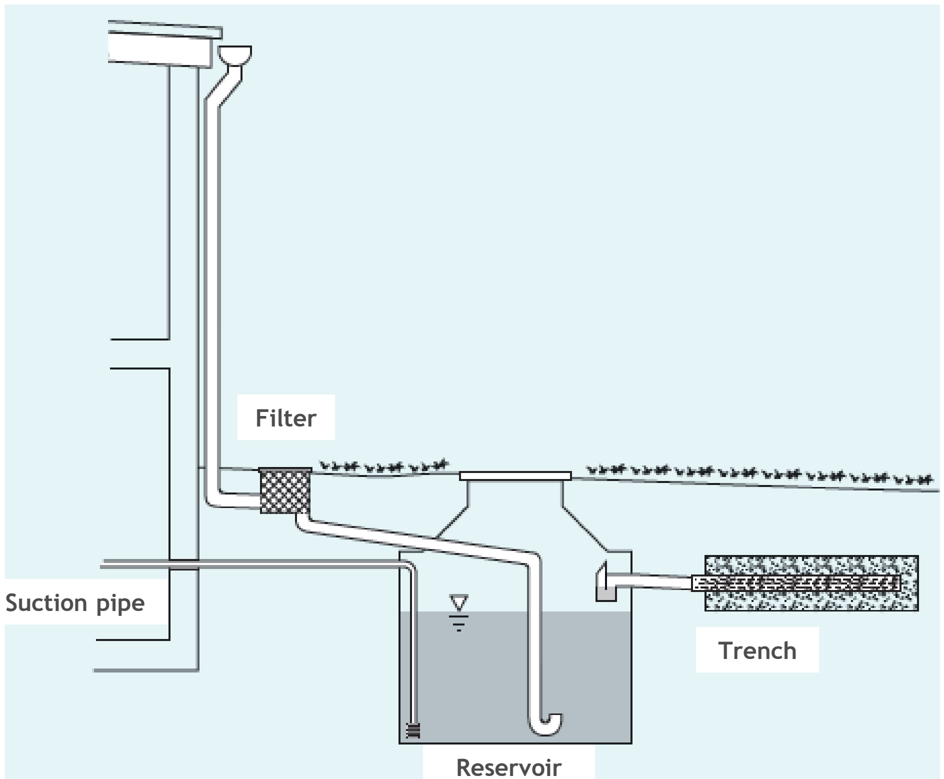
Rainwater harvesting combined to an infiltration trench



(Source: fbr)

Filling material for swale-trench infiltration system

(Source: ENREGIS)

Combination systems

Irrigation, evaporation and infiltarion combined

Swale-trench-deep bed system in Birkenstein, Brandenburg
(Photo: Sieker)

Schematic diagram of a tree-trench system
(Source: Sieker)

Rainwater harvesting in Berlin-Lankwitz

CASE STUDY 5:
RAINWATR HARVESTING (INCLUDING STREET RUNOFFS)

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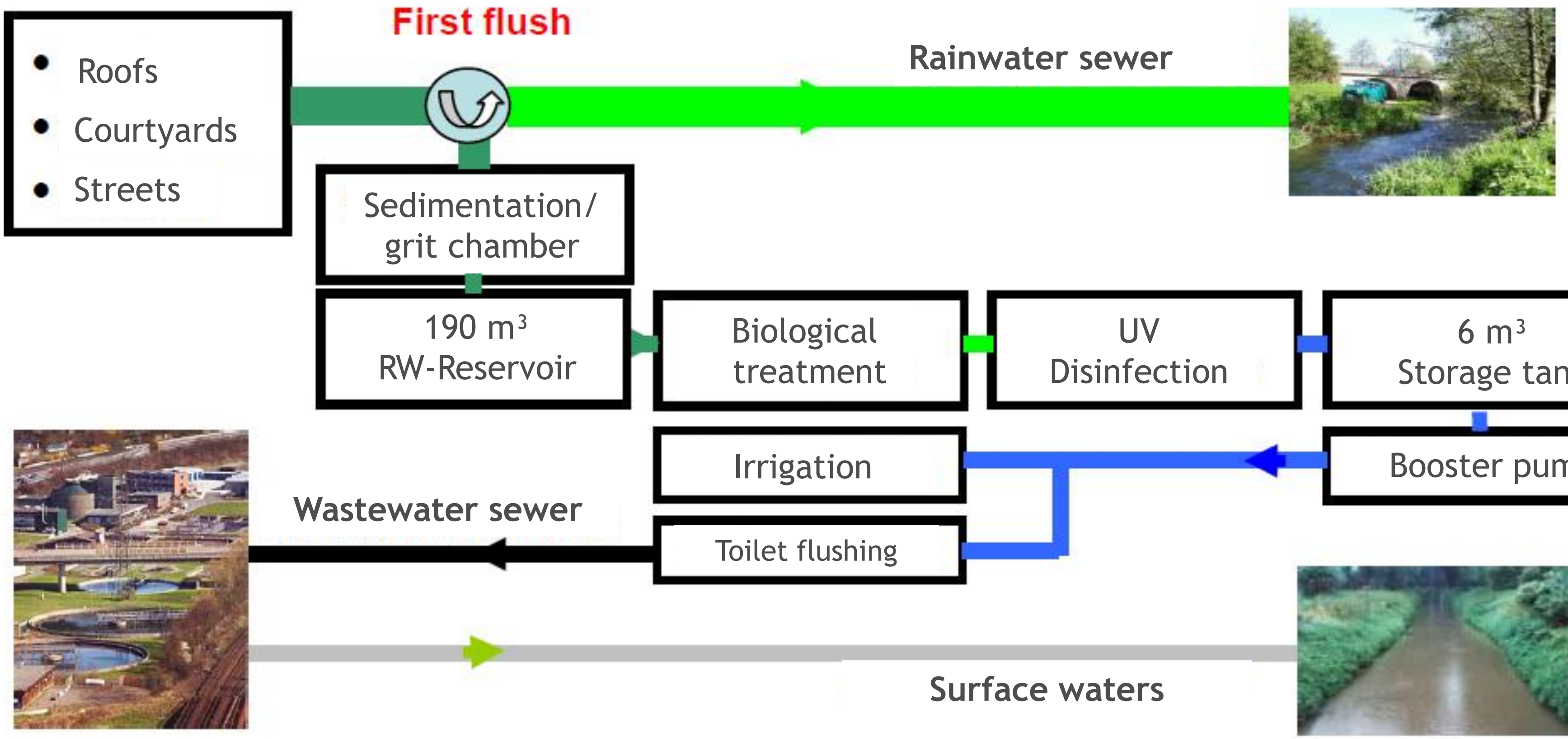
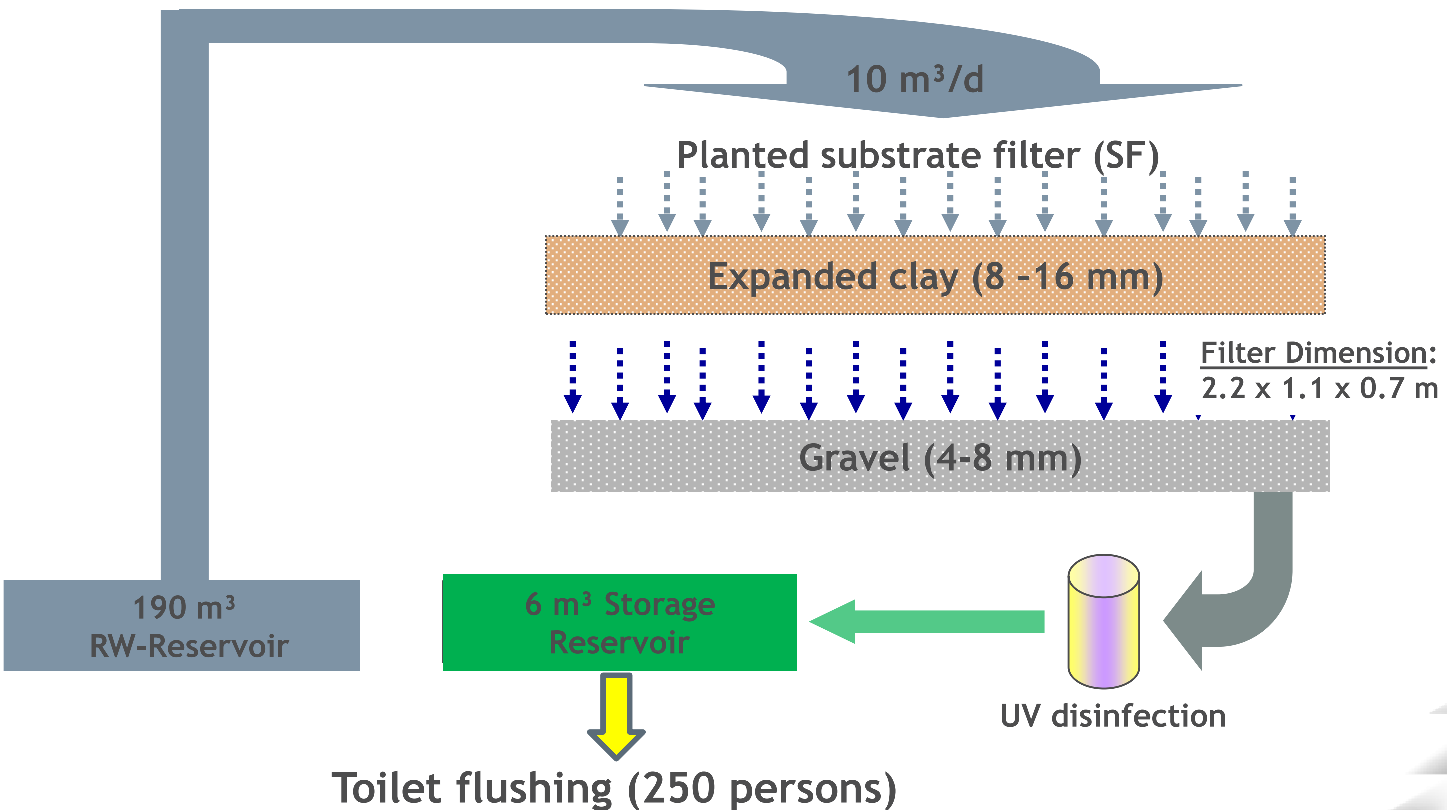
A flow diagram of the rainwater treatment design scheme



System design



CASE STUDY 5:
RAINWATR HARVESTING (INCLUDING STREET RUNOFFS)

Rainwater sewer with switch diversion

Planted soil filter inside the building

CASE STUDY 5: RAINWATR HARVESTING (INCLUDING STREET RUNOFFS)

Service water quality from the rainwater harvesting system compared to Berlin drinking water quality

Parameter		Ablauf Sandfilter Max	Min	Mittel	Berlin drinking water (typical concentrations)
LF [µS/cm]		199,00	60,00	103,38	Cond.: 813 µS/cm
Trans [%]		97,10	24,00	83,79	
TOC	[mg/l]	5,30	1,26	2,49	TOC: 4.5 mg/l
BSB_7	[mg/l]	3,00	0,59	0,86	
CSB	[mg/l]	15,80	4,56	6,82	
N_{ges}	[mg/l]	3,82	0,69	2,06	
P_{ges}	[mg/l]	0,174	0,014	0,089	
Cl	[mg/l]	17,22	0,81	4,05	
NO_2-N	[mg/l]	0,131	0,006	0,063	
NO_3-N	[mg/l]	3,512	0,364	1,726	
PO_4	[mg/l]	1,65	0,09	0,28	
SO_4	[mg/l]	19,51	2,72	7,09	SO_4: 180 mg/l
Na	[mg/l]	7,69	1,13	5,12	
Mg	[mg/l]	2,07	0,05	1,47	Mg: 13 mg/l
Ca	[mg/l]	19,76	6,68	15,74	Ca: 110 mg/l
HH_4-N	[mg/l]	6,61	0,47	3,54	

- **Drinking water saving potential:** 70% of the water demand for toilet flushing (80 apartments) = 2,500 m^3/a
- Hygiene requirements are met
- Only the unpolluted portion of the rainwater enters surface waters, ⇒ environmental relief

CASE STUDY 5:
RAINWATR HARVESTING (INCLUDING STREET RUNOFFS)

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Rainwater harvesting including street runoffs, Berlin	
Characteristics	The first project of its kind in Berlin including street runoffs for rainwater harvesting
Project start	2000
Collection area	Roof and courtyard surfaces including sealed street surfaces
Catchment area	12,000 m^2 sealed surfaces
Rainwater reservoir	190 m^3; rainwater is diverted from the rainwater sewer (including first flush)
Pre-treatment	Sedimentation and grit chamber (sand trap)
Biological treatment	Planted soil filter and UV disinfection
Treatment capacity	10 m^3/d
Reuse option	Toilet flushing (200 persons) and irrigation

Which rainwater management technolgy is most suitable for my project?

- Usually it is not a single measure, but a combination of several different measures to get best results under the given conditions
- Here, is an economic study useful, which besides the monetary goals also considers the non-monetary goals for a specific measure. Assessment of the economic efficiency should not be solely based on the size of the investment but should also include the future operating costs and savings made.