Green infrastructure BMPs: from home to LA River

ENE510 - Water Quality Management and Practice (term project)

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This site is currently under construction.

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Introduction & Background

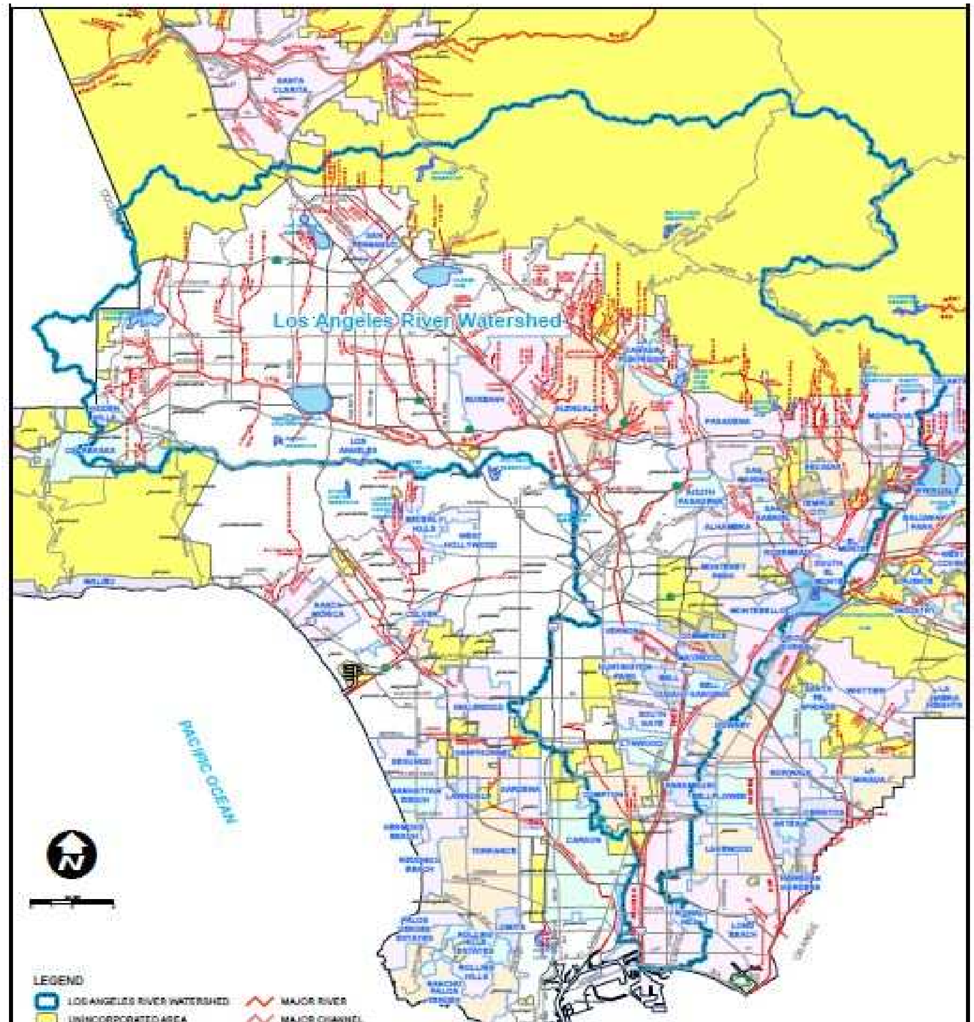
LA River watershed

LA River watershed basic information

Watershed Size:	834 square miles
Cities within watershed:	44 + other unincorporated communities
Land Use	37% residential 8% commercial 11% industrial 44% open space
Total Population:	Approximately 9 million

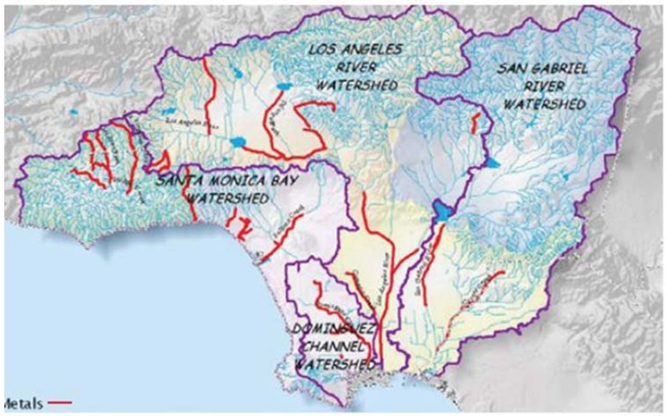
Types of pollutants that need to be removed:

Total suspended solid, nutrients (phosphorous and nitrogen), metals, oil & grease, bacteria & viruses

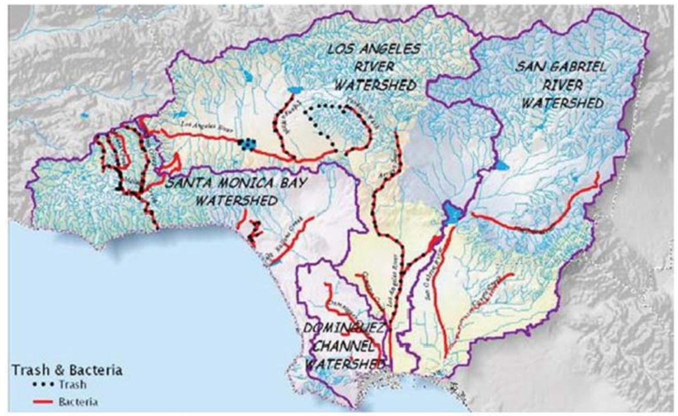


https://dpw.lacounty.gov/wmd/watershed/la/

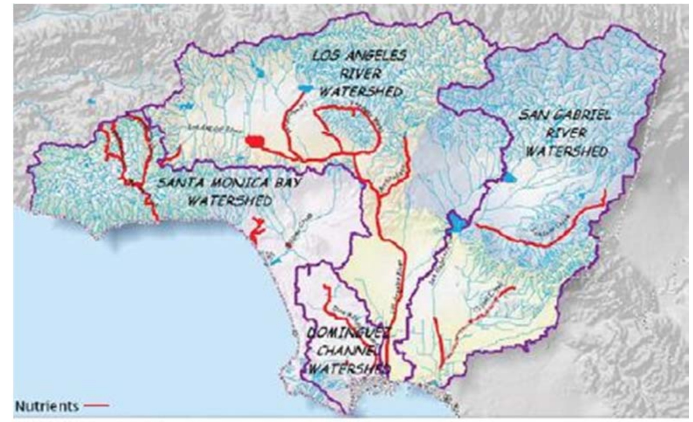
Introduction & Background (cont'd) Major water contaminant sources in LA River



Impaired reaches: Metals
(Integrated Regional Water Management Plan, 2006)



Impaired reaches: Trash and bacteria
(Integrated Regional Water Management Plan, 2006)



Impaired reaches: Nutrients
(Integrated Regional Water Management Project, 2006)

http://lariver.org/master-plan, page 41,42

Metals of concern include lead, zinc, cadmium, copper, chromium and nickel. They can be toxic to all forms of wildlife if allowed to build up to significant levels. A metals TMDL was imposed in 2005. Because of the number and types of metals identified, impairment tends to vary by reach.

Bacteria and viruses are often found in urban runoff and have been linked to the presence of trash. Results of monitoring undertaken in 2003-2004 for three organisms at monitoring stations along the River, indicate that established standards were exceeded in between 44% and 100% of the test results.

Nutrients, particularly nitrogen and phosphorus, are commonly found in lawn fertilizers, human and animal waste, and effluent from wastewater treatment facilities. In large concentrations, nutrients can cause algae and reduce dissolved oxygen, which are harmful to aquatic life and the River's environment.

Green infrastructure

Green infrastructure is a term used to refer to strategies for handling storm precipitation where it falls rather than after it has run off into a sewer system.

Goals

- ✓ Remove the pollutants & Enhance water quality
- ✓ Delay the peak time of the stormwater runoff
- ✓ Reduce the city runoff & restore the water into the ground water

Stormwater BMPs

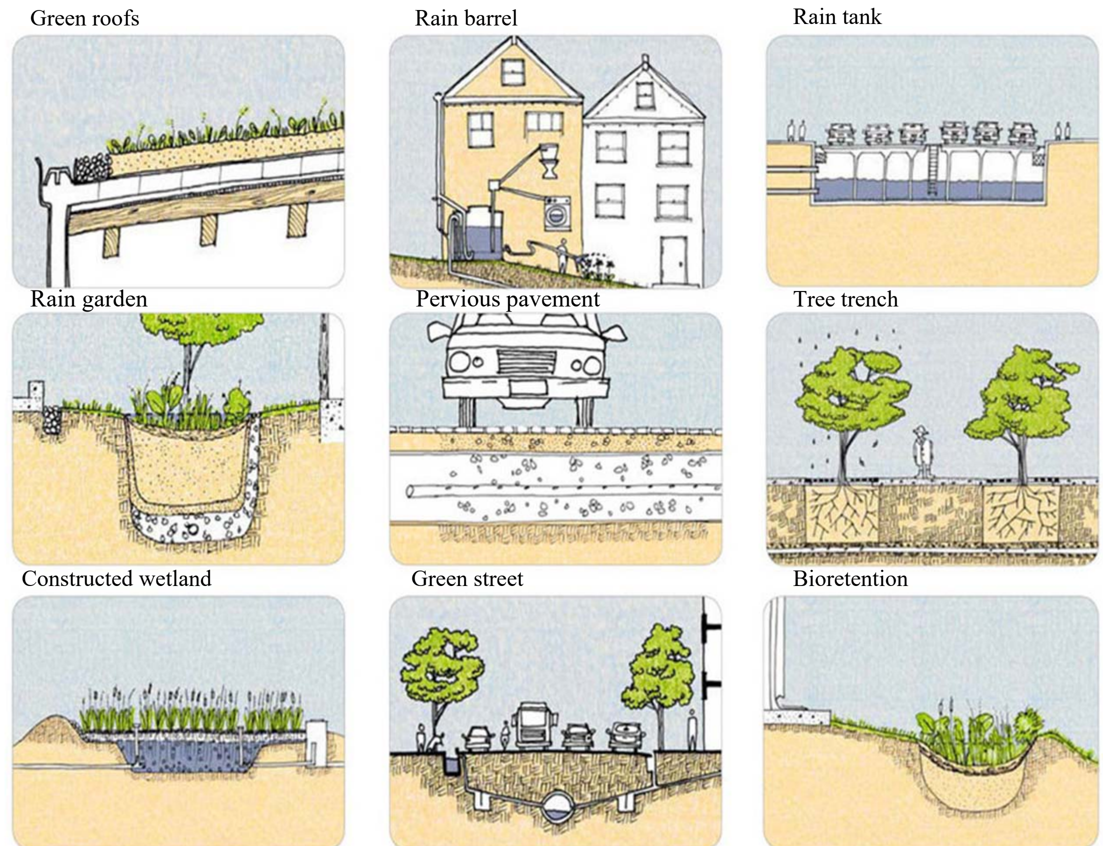
BMPs are structural, vegetative or managerial practices used to treat, prevent or reduce water pollution.

Selection of BMPs is based on:

- The type of pollutants to be treated
- The suitability of the site to the BMP
- Cost
- Effectiveness of the BMP in eliminating/reducing pollutants

Four categories of BMPs are used:

- Pollution prevention BMPs
- Pollution treatment BMPs
- Construction BMPs
- Maintenance BMPs



http://www.greencitiescalifornia.org/water-1/san-francisco-stormwater-management-ordinance

Introduction & Background (cont'd)

- Why do we need green infrastructure?
- How does green infrastructure improve the water quality in LA River?
- Why do we focus on residential area?

Source: http://news.wef.org/projects-win-dc-waters-2013-green-infrastructu
challenge/

Introduction & Background (cont'd)

Why do we need green infrastructure?

http://chuansong.me/n/960812841615

https://urgitaipei.wordpress.com/2014/02/17/green-infrastructure/

Green infrastructure

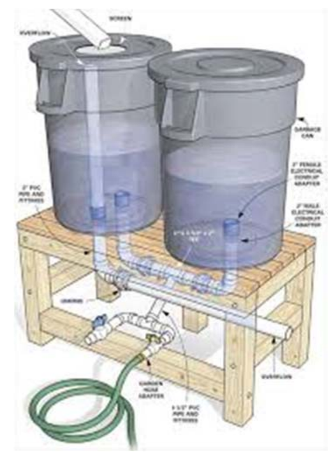
Buildings
- Green roofs
- Green walls

Landscape
- Bioretention
- Green streets
- Rain Gardens

Hardscape
- Pervious pavement
- Perforated pipe & overflow inlets

Water
- Condensate harvesting
- Grey water harvesting
- Passive irrigation

http://www.pavementinteractive.org/2013/07/22/porous-on-purpose-permeable-pavements/



https://www.familyhandyman.com/smart-homeowner/how-to-build-a-rain-barrel/view-all

Why do we need green infrastructure?

Benefits

- **Environmental:**
  - Uses trees and vegetation, provide multiple environmental benefits
  - Decrease water loss in the region
- **Economic:**
  - Defers or even replaces costly large grey stormwater infrastructure projects
  - Reduces the costs for treatment at water reclamation plants
- **Social:**
  - Increases the quality of neighborhoods and adds community amenities

http://www.raincommunitysolutions.ca/en/roads_and_runoff_webinar/

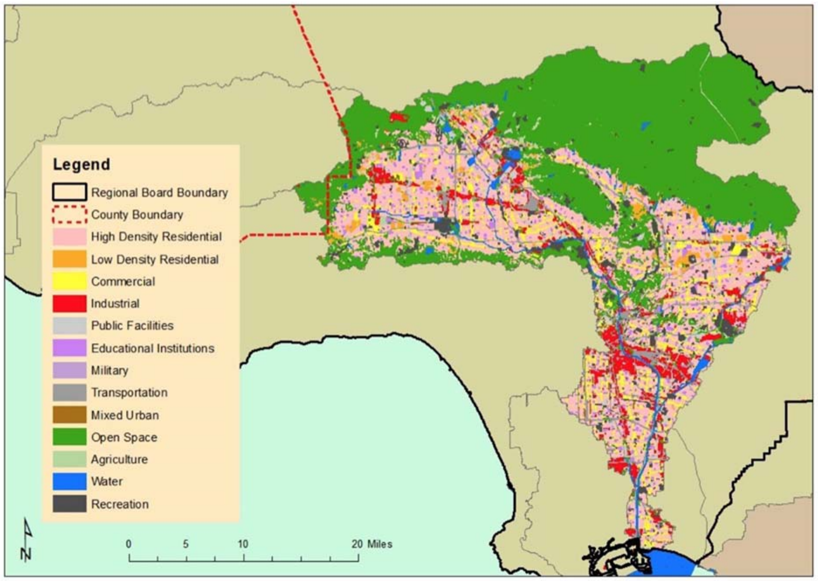
Introduction & Background (cont'd) How does it improve water quality in LA River?

Pollutants	Removal mechanisms	BMPs
• Pesticide • Nutrient • Pharmaceutical • Oil & grease • Heavy medals • Bacteria & virus • Suspended Solid	• **Biological** Biodegradation • **Physical** Adsorption and precipitation • **Chemical** Ions exchange	• Permeable Pavements • Stormwater tree trench • Rain barrel • Rain garden • Drywell

Introduction & Background (cont'd)

Why do we focus on residential area?

Land Use in the Los Angeles River Watershed



http://www.waterboards.ca.gov/rwqcb4/water_issues/programs/regional_program/Water_Quality_and_Watersheds/los_angeles_river_watershed/la_summary.shtml

http://www.willmarmn.gov/departments/stormwater_management_same.php

- Besides open space, most of the land use is residential area
- Residential area is the major source of pollutants: pesticides, fertilizer, oil, suspended solid and etc.
- Stormwater runoff in residential area contains a broad spectrum of pollutants.

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Stormwater BMPs for residential area

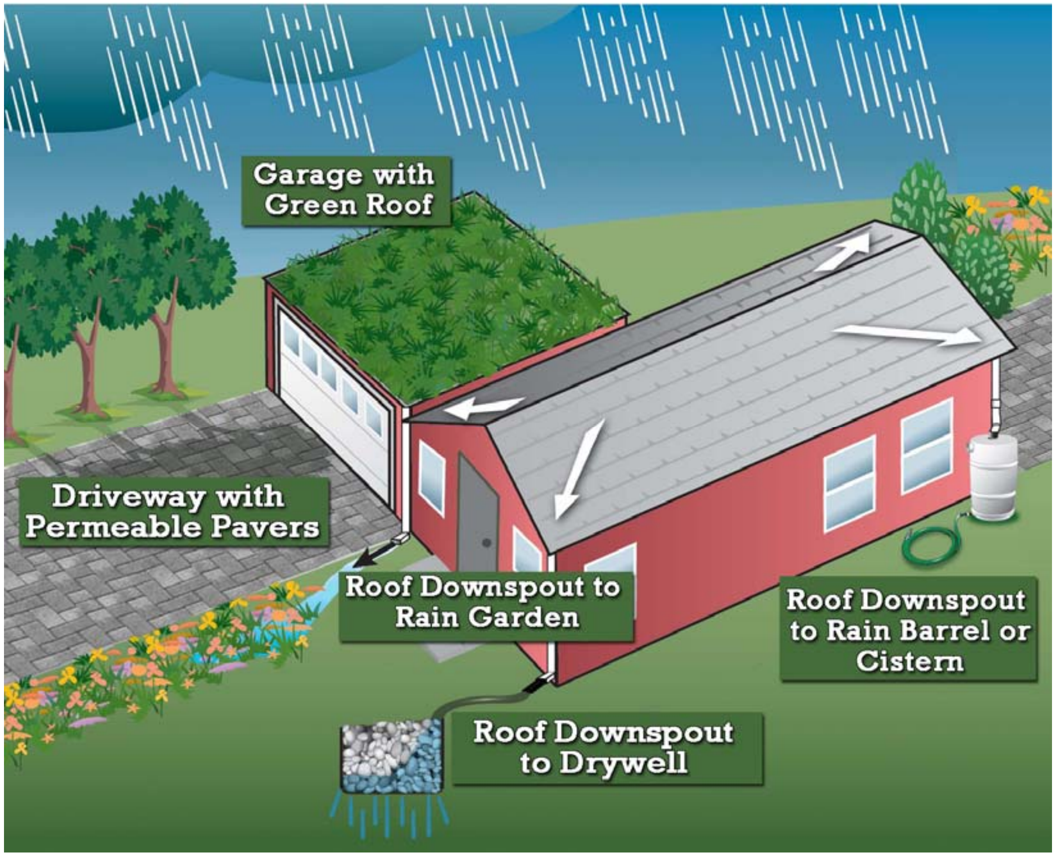
Green home

Goal:

- ✓ Pollutants removal for stormwater
- ✓ Infiltration and retention of storm water
- ✓ Limit pollutant conveyance
- ✓ Reduce runoff peak and Delay peak time
- ✓ Use stormwater for irrigation

Implementing BMPs measures:

- ✓ Green roof
- ✓ Downspout Planter
- ✓ Pervious pavement
- ✓ Rain barrel
- ✓ Rain garden
- ✓ Dry well



http://www.mymcmedia.org/water-quality-protection-charge-credit-deadline-is-september-30/

Sketch of green home

Stormwater BMPs for residential area

Green street

Goal:

- ✓ Pollutants removal for stormwater
- ✓ Infiltration and retention of stormwater
- ✓ Limit pollutant conveyance
- ✓ Reduce runoff peak and delay peak time
- ✓ Use stormwater for irrigation

Implementing BMPs measures:

- ✓ Pervious Pavements
- ✓ Stormwater tree trench
- ✓ Stormwater planter
- ✓ Bump out
- ✓ Rain garden
- ✓ Drywell

https://www.epa.gov/green-infrastructure/what-green-infrastructure

https://www.epa.gov/green-infrastructure/what-green-infrastructure

Stormwater BMPs for residential area

Green roof

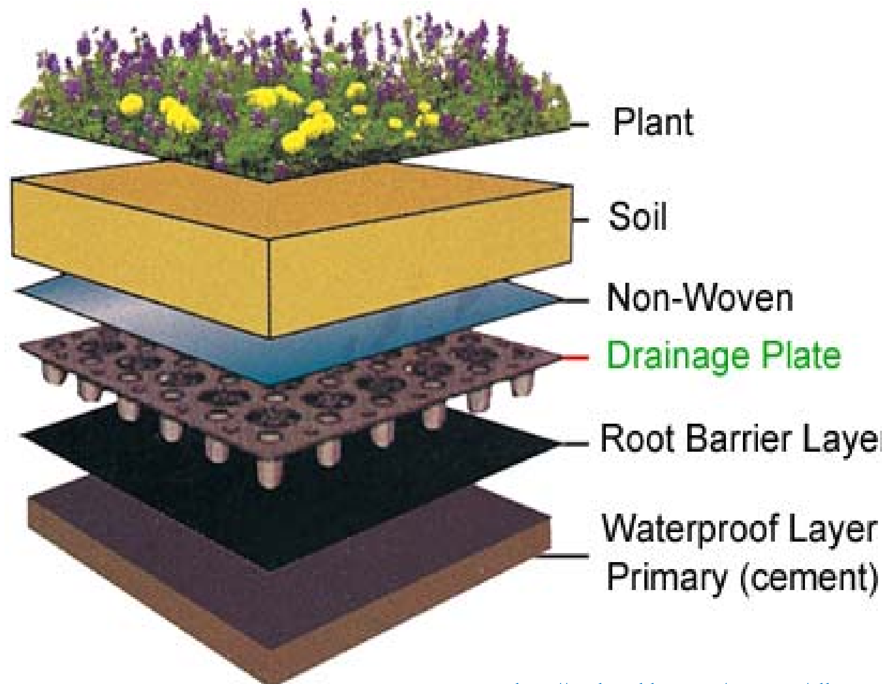
A **green roof** is a multi-layered rooftop system designed for filtering, absorbing, and retaining stormwater runoff.

Benefits for stormwater management:

- ✓ Reduces roof runoff (30% - 100%)
- ✓ Increases concentration time for stormwater
- ✓ Retains stormwater runoff by infiltrating into soil
- ✓ Improves stormwater quality

Pollutant removal:

- ✓ Suspended solid: filtered by soil, efficiency can be as high as 85%
- ✓ Metals: absorbed by soil or took up by plants
- ✓ Nutrients: removed by metabolism of bacteria or taken up by plants



http://ecobrooklyn.com/category/all-posts/

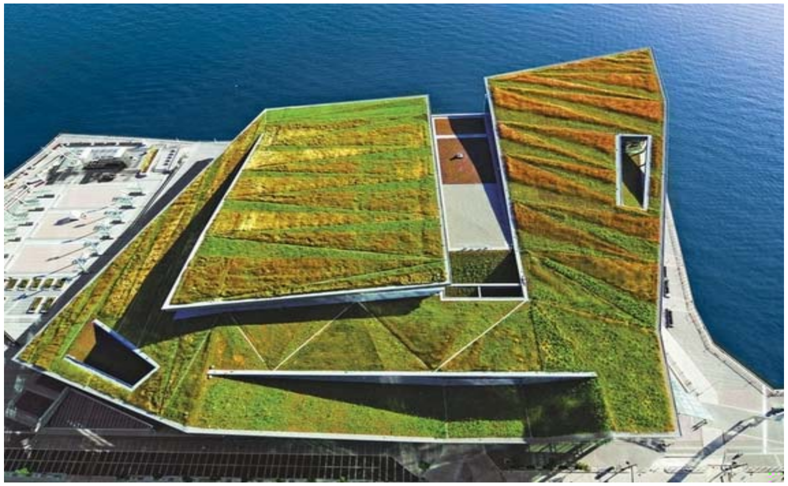
Structure of green roof

Green roof (cont'd)

Non-stormwater benefits:

- ✓ Reduces amount of airborne pollutants
- ✓ No addition space is required
- ✓ Provides habitat for wildlife
- ✓ Provides thermal insulation and sound insulation
- ✓ Site aesthetics

http://www.goodnet.org/articles/5-impressive-green-roofs-from-across-globe



http://www.goodnet.org/articles/5-impressive-green-roofs-from-across-globe

Disadvantages:

- It should be retrofitted for existing buildings
- Increases capital cost of building due to special structure
- Requires appropriate vegetation (drought-tolerant vegetation), maintenance and irrigation since the drought climate in LA

Stormwater BMPs for residential area

Rain barrel

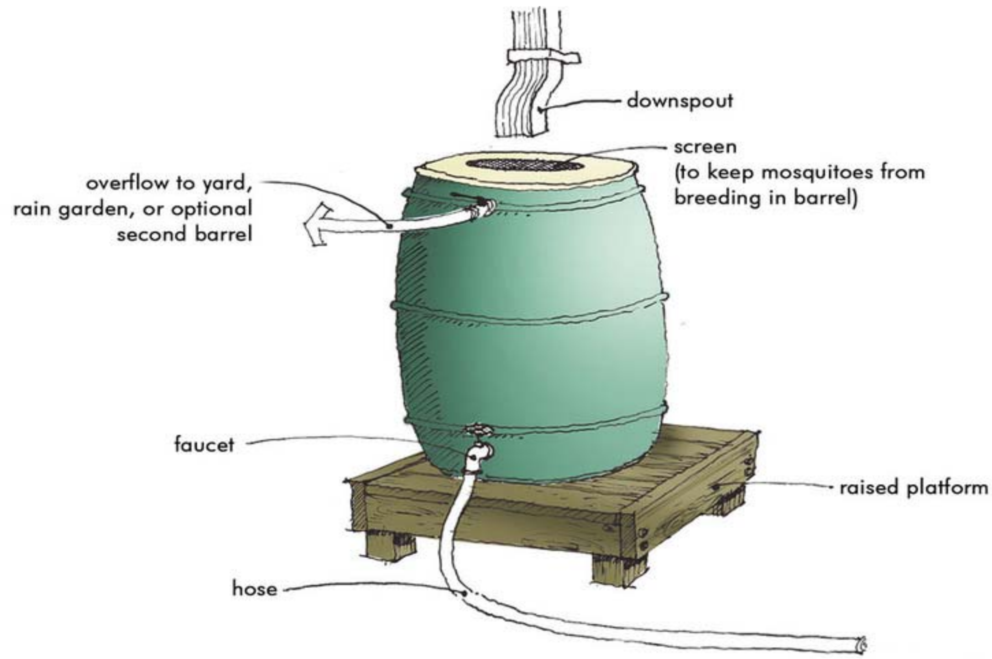
A **rain barrel** is a container that collects and stores exceed roof stormwater runoff that can be used to irrigate rain garden or wash. It should be placed above ground beneath a downspout next to a home.

Components:

- ✓ Removable cover with screen
- ✓ Outlet with valve and garden hose attachment
- ✓ Overflow outlet with discharge pipe or hose
- ✓ Storage: range in size from 50 to 180 gallons

Pollutant removal:

- ✓ Traps debris and exclude vectors by screen
- ✓ Sediment will occur in barrels
- ✓ Reduces mobilize pollutants into sewer system



https://www.watershedcouncil.org/rain-barrels.html

Sketch of rain barrel

Stormwater BMPs for residential area

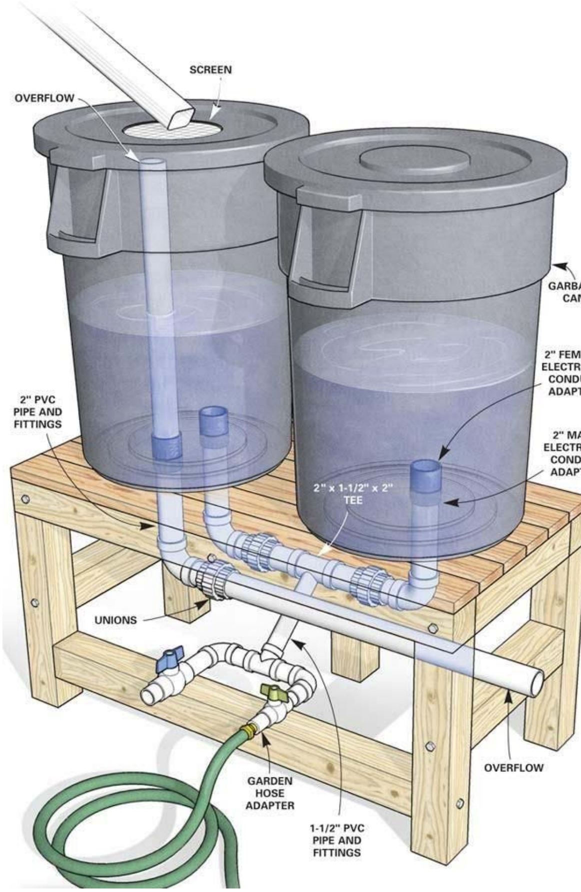
Rain barrel (cont'd)

Benefits:

- ✓ Collects exceed roof runoff
- ✓ Reduces runoff and pollutant discharge
- ✓ Potential water conservation & short-term storage
- ✓ Low installation cost
- ✓ Easy to maintain

Limitations:

- May have little storage (could be modified like figure)
- Water collected is not suitable for human or pet consumption or contact with fruits/vegetables
- May not be compatible with site aesthetics
- May allow vector breeding if not properly maintained
- Requires owners to maintain and empty them between storms



https://www.familyhandyman.com/smart-homeowner/how-to-build-a-rain-barrel/view-all

Sketch of rain barrel

Stormwater BMPs for residential area

Downspout planter

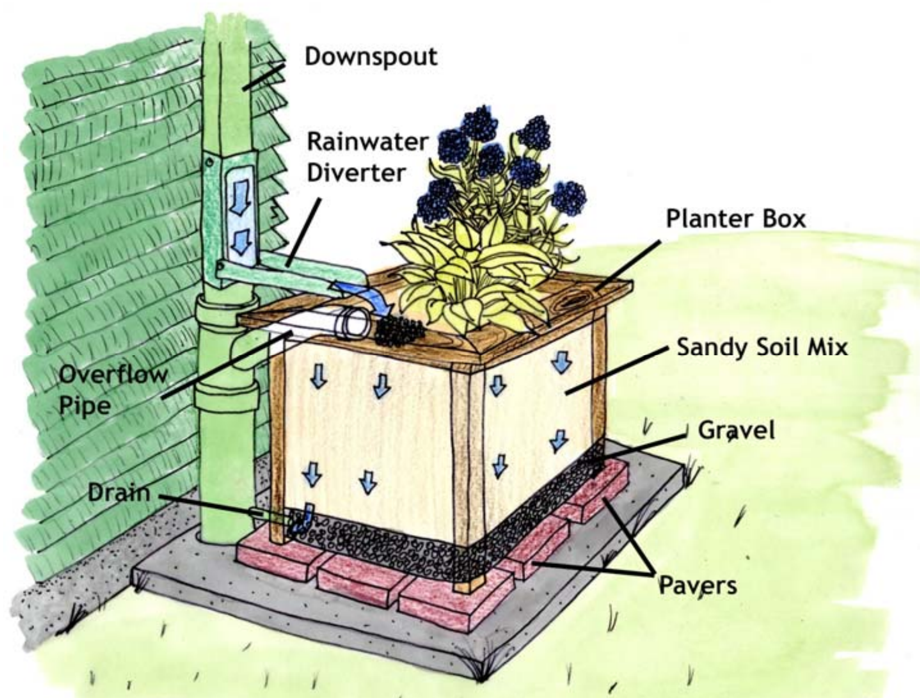
A **downspout planter** **(**for single home**)** is a structure that is designed to allow exceed roof stormwater runoff flow through and be used by plants.

Benefits:

- ✓ Collects exceed roof runoff
- ✓ Watering vegetation
- ✓ Potential water conservation & short-term storage
- ✓ Easy to maintain
- ✓ Low installation cost

Pollutant removal:

- ✓ Suspended solid: filtered by soil or filling
- ✓ Metals: absorbed by soil or taken up by plants
- ✓ Nutrients: removed by metabolism of bacteria or taken up by plants



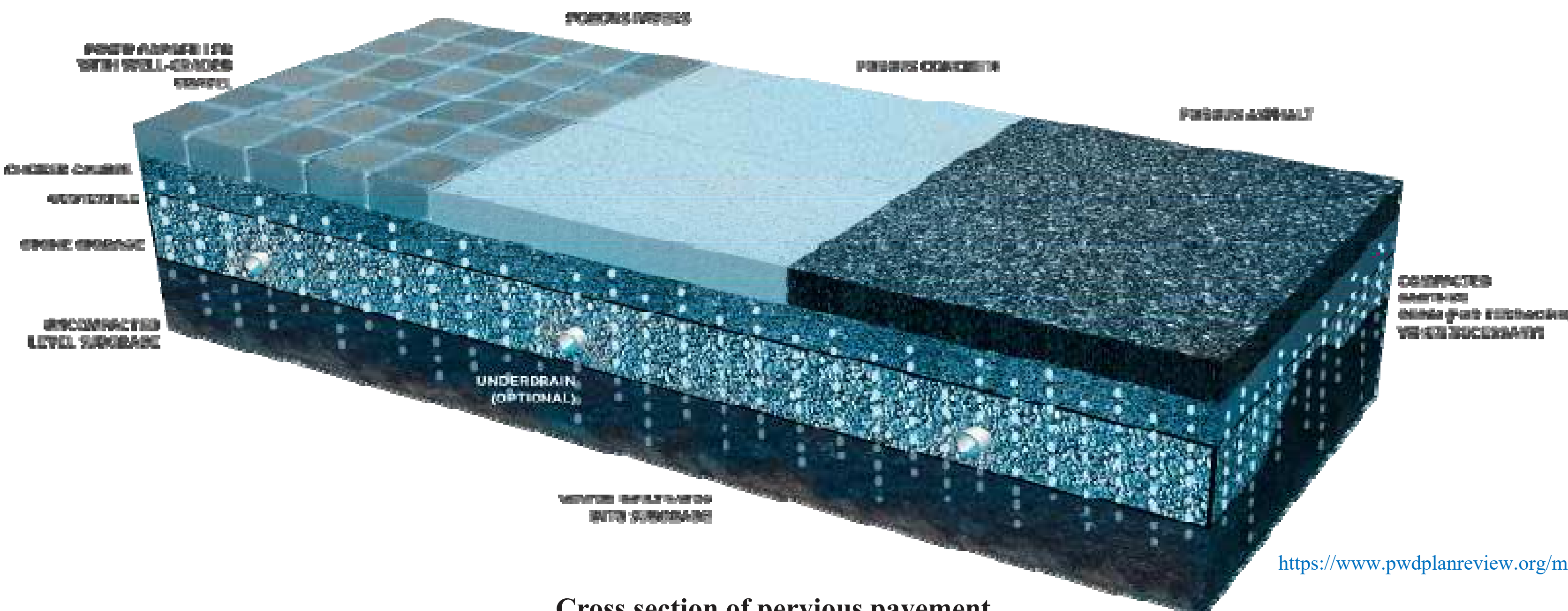
https://industryactionplan.wordpress.com/goals-and-initiatives/housing/sustainability/

Sketch of stormwater plant

Pervious pavement

Pervious pavement is a specially designed system that allows water to infiltrate through pavement and prevent it from becoming runoff.

Different types of pervious pavement: porous asphalt, pervious concrete and permeable interlocking concrete pavers (PICP)



https://www.pwdplanreview.org/manual/chapter-4

Cross section of pervious pavement

Pervious pavement (cont'd)

Summary of properties of permeable pavements

Properties	Pervious Concrete	Porous Asphalt	PICP
Pavement Thickness	5 to 8 inches	3 to 4 inches	3 inches
Bedding Layer	None	2 inches No. 57 stone	2 inches of No. 8 stone
Reservoir Layer	No. 57 stone	No. 2 stone	No. 2 stone 3-4 inches of No.57 stone
Design Permeability	10 feet/day	6 feet/day	2 feet/day
Construction Cost	$ 2.00 to $6.50/sq. ft.	$ 0.50 to $1.00/ sq. ft.	$ 5.00 to $ 10.00/ sq. ft.
Longevity	20 to 30 years	15 to 20 years	20 to 30 years
Temperature Reduction	Cooling in the reservoir layer	Cooling in the reservoir layer	Cooling at the pavement surface & reservoir layer
Colors/Texture	Limited range of colors and textures	Black or dark grey color	Wide range of colors, textures, and patterns

Sources: CWP and CSN (2008) and CWP (2007)

Stormwater BMPs for residential area

Pervious pavement (cont'd)

Benefits:

- ✓ Reduces stormwater runoff volume and peak flows
- ✓ Serves functional and aesthetic purposes
- ✓ Reduces space required for separate stormwater quality control measures
- ✓ Recharges groundwater

Metal removal efficiency (study from Germany):

Lead: 89% – 98%; Cadmium: 74% – 98%

Copper: 89% – 96%; Zinc 72% – 98%

Pollutant removal efficiency (study from Maryland and Virginia):

Sediment: 82% – 95%; TP:65%; TN: 80 – 85%;

High removal for Zinc and Lead

http://rdgusa.com/sites/discovery/2015/03/04/five-sustainable-site-practices/

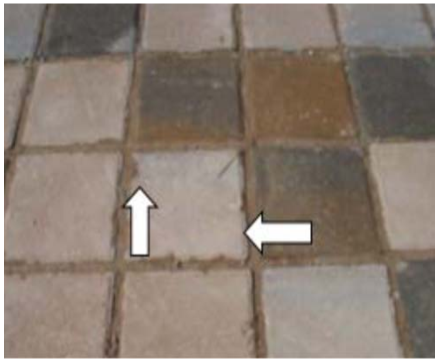
Structure of pervious pavement

Pervious pavement (cont'd)

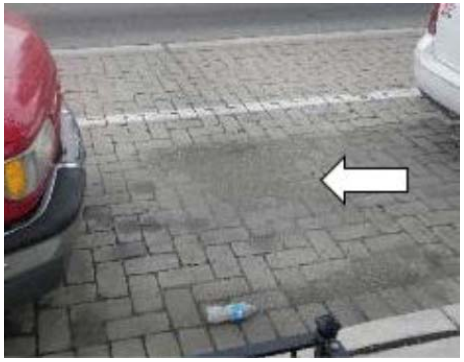
Common problems encountered in pervious pavement:

Excess sediment on permeable pavement

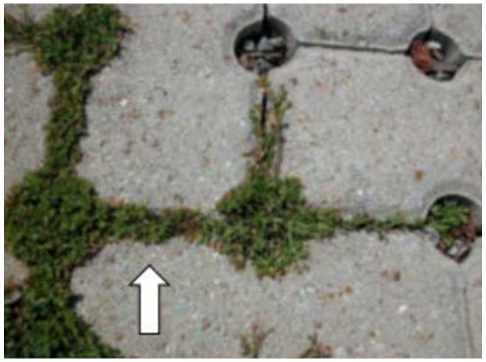
Sediment accumulation between paver blocks



Uneven distribution of sediment due to improper slope



Vegetative growth between paver blocks



https://www.epa.gov/sites/production/files/2017-03/documents/npdesinspect-chapter-14.pdf

Limitations:

- Cost of restorative maintenance can be somewhat high when the system seals with sediment and can no longer function properly as permeable pavement.
- Uneven driving surfaces and potential traps for high-heeled shoes are potential limitations.
- Not appropriate for industrial sites or locations with contaminated due to the potential threat to groundwater contamination.

Pervious pavement (cont'd)

Case study: Sand-based permeable brick (Beijing Olympic Stadium, China)

The **sand-based permeable brick** has good permeability, water conservation, abrasion resistance, aging resistance, anti-skid, anti-clogging, water purification, ecological conservation and economic benefits.

It is applied in Beijing Olympics Stadium and square in front of Chinese Pavilion of Shanghai World Exposition.

http://news.xinhuanet.com/tech/2009-05/05/content_11317431.html

Characteristics:

- ✓ Permeability: ≥ 1.5 ml/ (min·cm^2)
- ✓ Retention rate $>$ 0.06 g/cm^3
- ✓ Compression loss $\leq 20\%$
- ✓ No runoff when rain intensity $\leq$ 150 mm/d !!!

http://news.xinhuanet.com/tech/2009-05/05/content_11317431.html

Expectation

It is expected to have 3 billion m^2 permeable brick constructed to collect 1.8 billion m^3 stormwater annually, thereby recharging 0.97 billion m^3 stormwater into groundwater every year.

Bump out

A **bump out** is a vegetated curb extension that protrudes into the street either mid-block or at an intersection, creating a new curb some distance from the existing curb.

http://www.eastfallslocal.com/what-about-bumpouts/

Components:

A bump-out is composed of a layer of stone that is topped with soil, plants and an inlet or curb-cut directs runoff into the bump-out structure.

Functions:

- ✓ Reduces stormwater volume and control pollutant source
- ✓ Recharges groundwater
- ✓ Cleans stormwater runoff during infiltration through root zoon of vegetation and detention in the underlying layer

For video demonstration, you can consult the website below:
https://vimeo.com/85281101

http://www.eastfallslocal.com/what-about-bumpouts/

Sketch of bump out

Stormwater BMPs for residential area

Stormwater planter

A **stormwater planter** is a stormwater planter is a specialized planter installed into the sidewalk area containing an engineered soil matrix consisting of layers of topsoil, a sand/peat mixture, and gravel that is designed to capture and manage runoff from street and sidewalk.

Plants recommendation:

Native, drought-tolerant vegetation that does not require fertilization for at least 24 hours, like wildflowers, sedges, rushes, ferns, shrubs, etc.

Functions:

- ✓ Provides temporary storage for stormwater
- ✓ Recharges groundwater
- ✓ Purifies stormwater runoff during:
  - a) Infiltration through root zoon of vegetation
  - b) Detention in the underlying sand bed

Removal efficiency:

TSS: 66% – 98%
Metals: 26% – 100%
Nitrogen: 30% – 68%
Phosphorus: 4% – 85%

http://www.phillywatersheds.org/flowershow2011

Cross section of stormwater plant

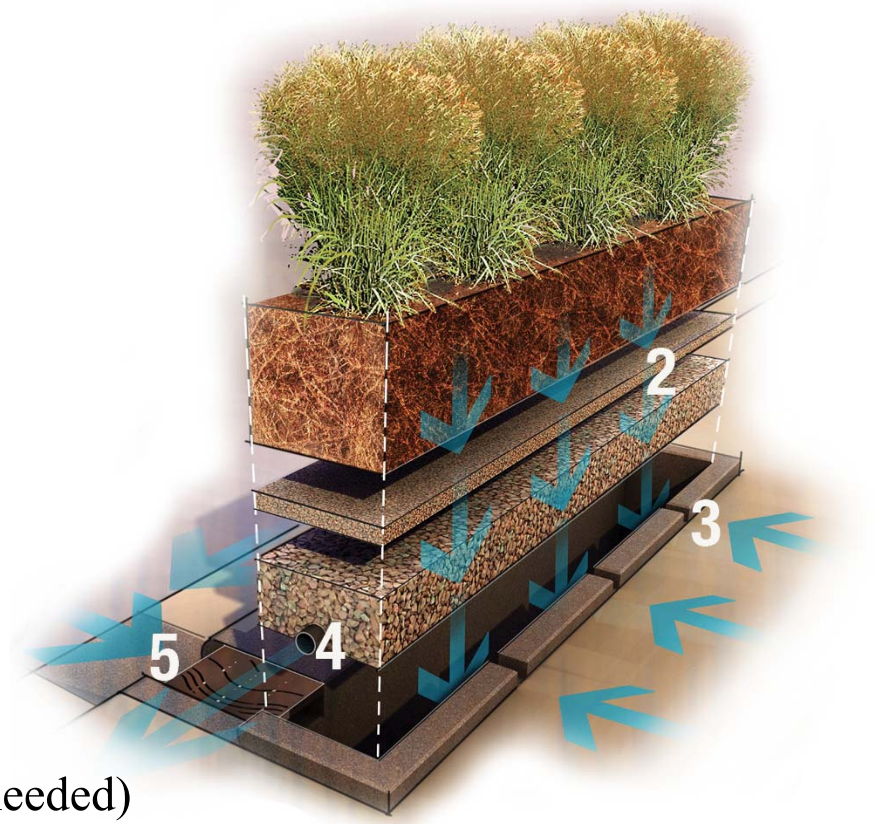
Stormwater planter (cont'd)

Advantages:

- ✓ Reduces peak flow during small storm events
- ✓ Low cost when integrated into site landscaping
- ✓ Recharges groundwater
- ✓ Requires little space (suitable for parking lot)
- ✓ Enhances site aesthetics
- ✓ Potential water conservation & short-term storage
- ✓ Easy to maintain

Disadvantages:

- Not suitable for industrial area
- Requires irrigation
- Not suitable for steep slope area
- Potential cost due to waterproofing building walls (if needed)



http://rdgusa.com/sites/discovery/2015/03/04/five-sustainable-site-practices/

Structure of stormwater plant

Stormwater BMPs for residential area

Stormwater tree trench

A **stormwater tree trench** is a system of trees that is connected by an underground infiltration structure. It consists of a trench lined with geotextile fabric with structural stone, gravel or soil boxes in which the trees are placed.

Functions:

- ✓ Reduces peak flow and delay peak time
- ✓ Recharges groundwater
- ✓ Cleans stormwater runoff during infiltration through plants and soil media

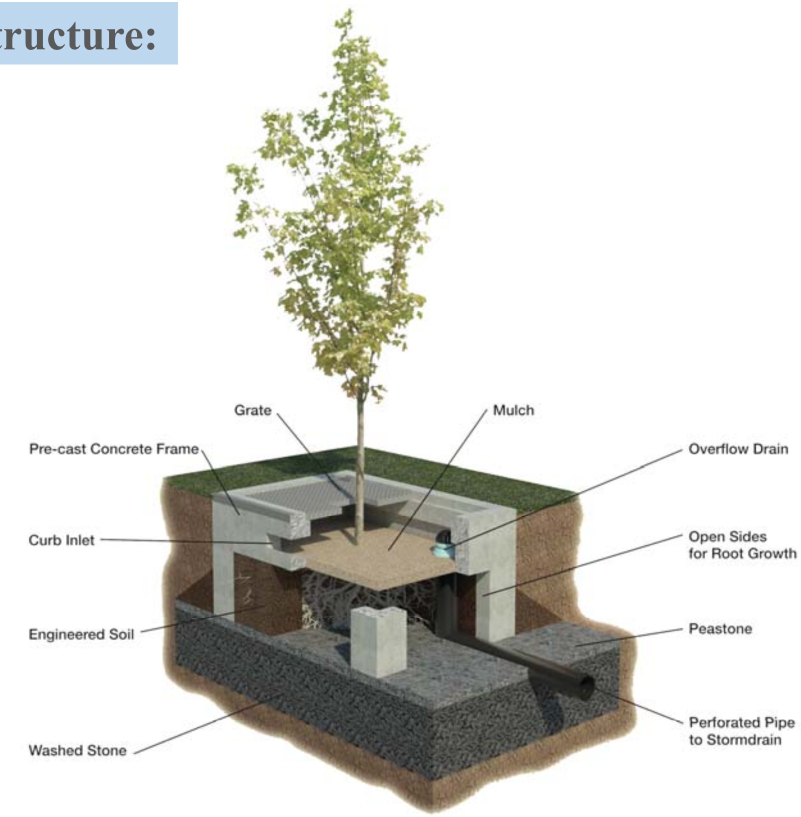
Disadvantages:

- Not suitable for industrial area
- Needs periodically maintenance (remove litters inside)
- Requires irrigation
- Media clogging

Recommended pollutant removal efficiency:

TSS: 85%
TN: 50%
Pathogen: high
Hydrocarbons: 80%
TP: medium – high(depend on engineered media)
Metals: 35%
Bacteria: 95%
Oils and grease: high

Structure:



http://www.nianticriverwatershed.org/our-programs/water-quality-management/stormwater-management/current/

Stormwater BMPs for residential area

Dry well

A dry well is a covered, porous-walled chamber that allows water to slowly soak into the ground, infiltrate into groundwater, its depth is greater than its width, and it can be used in conjunction with LID practice.

Values of using dry well in California:

- ✓ Captures and stores urban stormwater runoff
- ✓ Facilitates stormwater infiltration even in clay soils
- ✓ Improves surface water quality
- ✓ Facilitates groundwater recharge
- ✓ Helps meet hydromodification management goal

Disadvantages:

- May not be appropriate for industrial sites
- Cannot receive untreated stormwater runoff
- Requires complete reconstruction for failed dry wells
- Is not suitable for fill sites or on steep slopes
- Is not appropriate for areas with low permeability soils or high groundwater levels

http://extension.oregonstate.edu/stormwater/sites/default/files/Drywells.pdf

Sketch of dry well

Dry well (cont'd)

Mechanism of dry well

1. Stormwater is pretreatment by other stormwater BMPs
2. Receives stormwater from one or more entry points
3. Screened by inlet grate
4. Sedimentation occurs in first chamber
5. Filtered by different layers
6. Stores stormwater
7. Discharge stormwater through small openings

Removal efficiency

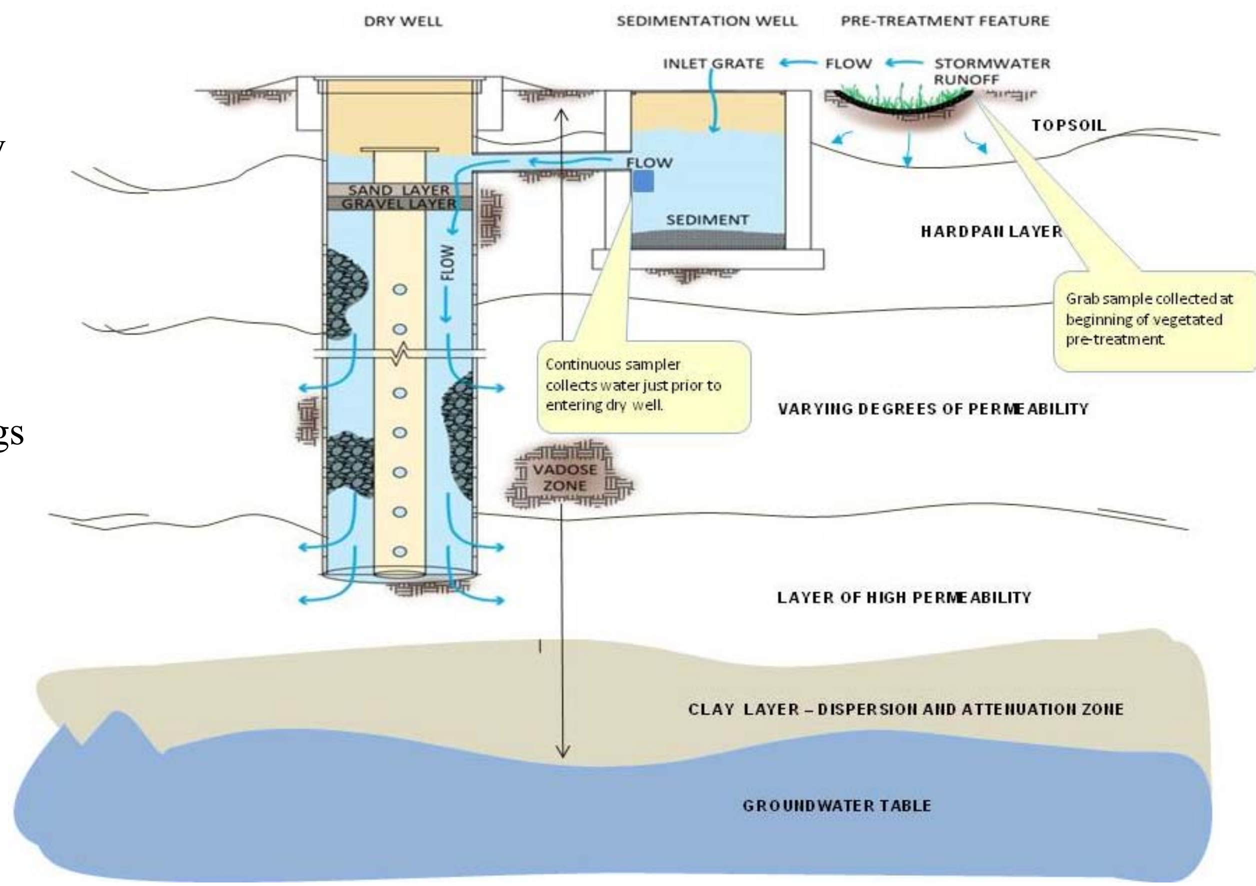
TSS: 71% – 87%

TP: 60% – 93%

TN: 57% – 92%

For video demonstration, you can consult the website below:
https://www.youtube.com/watch?v=uCFylYPXkCE&list=PLgn0YNmv0wYFTA5FaACTDEwaXKl1KPiKy

Cross section of dry well



http://www.elkgrovecity.org/city_hall/departments_divisions/public_works/dry_well_project___prop_84/elk_grove_dry_well_project/project_stormwater_and_groundwater_monitoring

Stormwater BMPs for residential area

Rain garden

A **rain garden** is a vegetated shallow depression that is designed to receive, retain, and infiltrate stormwater runoff from downspouts, piped inlets, or sheet flow from adjoining paved areas.

Advantages:

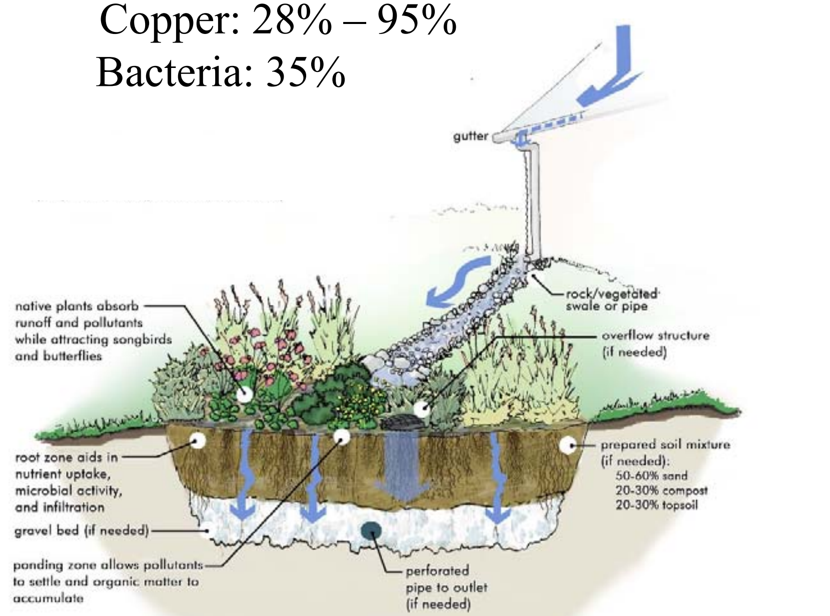
- ✓ Reduces stormwater runoff
- ✓ Recharges groundwater
- ✓ Eliminates pollutant discharge
- ✓ Water conservation
- ✓ Enhances site aesthetics
- ✓ Easy to maintain
- ✓ Provides habitat for wildlife

Disadvantages:

- Not suitable for industrial area
- Retention volume may be limited
- May result in standing water that allows vector breeding
- Requires relatively flat site and high hydraulic conductivity
- Requires maintenance

Removal efficiency for all kinds of rain garden:

TSS: 85%
Nitrogen: 17% – 65%
Zinc: 49% – 95%
Lead: 41% – 95%
Hydrocarbon: 80%
Ammonia: 95%
Phosphorus: 40% – 65%
Copper: 28% – 95%
Bacteria: 35%



http://www.greeningthegrey.org/gi-features/gi-features/bioretention-infiltration/

Sketch of rain garden

Stormwater BMPs for residential area

Rain garden (cont'd)

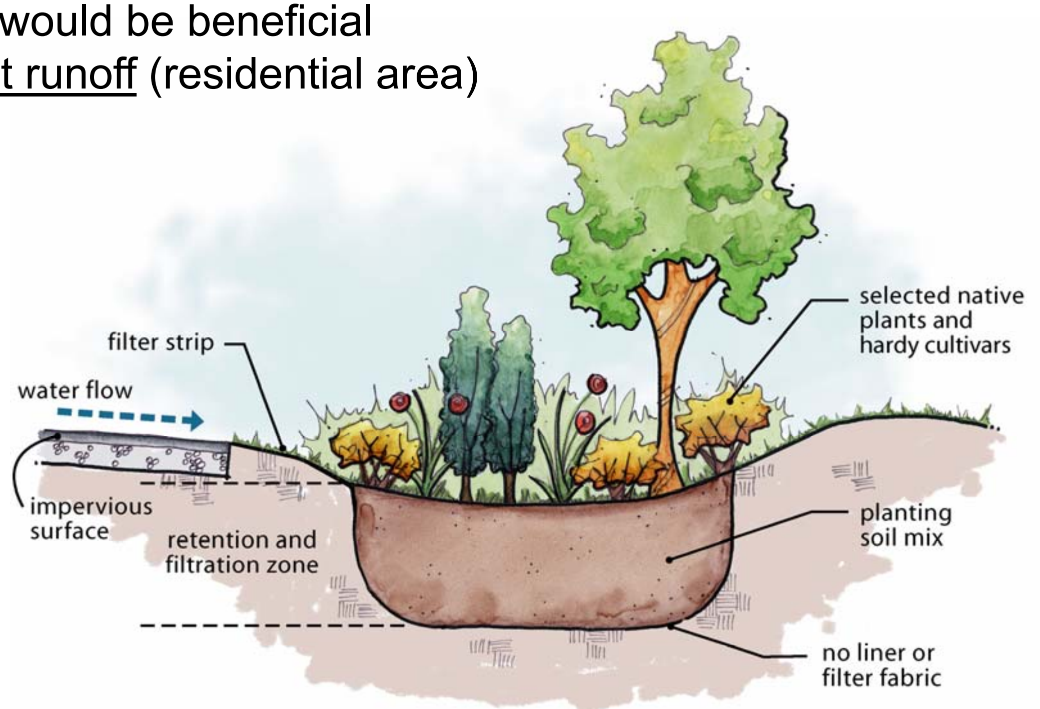
Different types of rain garden: Type#1

Recommended area:

- ✓ Areas where high recharge of groundwater would be beneficial
- ✓ Areas that are expected to generate nutrient runoff (residential area)
- ✓ Areas where visibility is not a concern

Characteristics:

- ✓ With no underdrain discharge pipe
- ✓ In-situ soil has high infiltration rate: (determined through proper soil testing) 1 inch/hour or greater
- ✓ At least 2.5 feet deep to allow adequate filtration processes to occur
- ✓ No liner or geotextile fabric
- ✓ Soil medium consisting of 50–60% sand, 20–30% top soil, and 20–30% leaf



http://msayla.com/permaculture-design-course-day-6-water-earthworks/

Cross section of rain garden

Rain garden (cont'd)

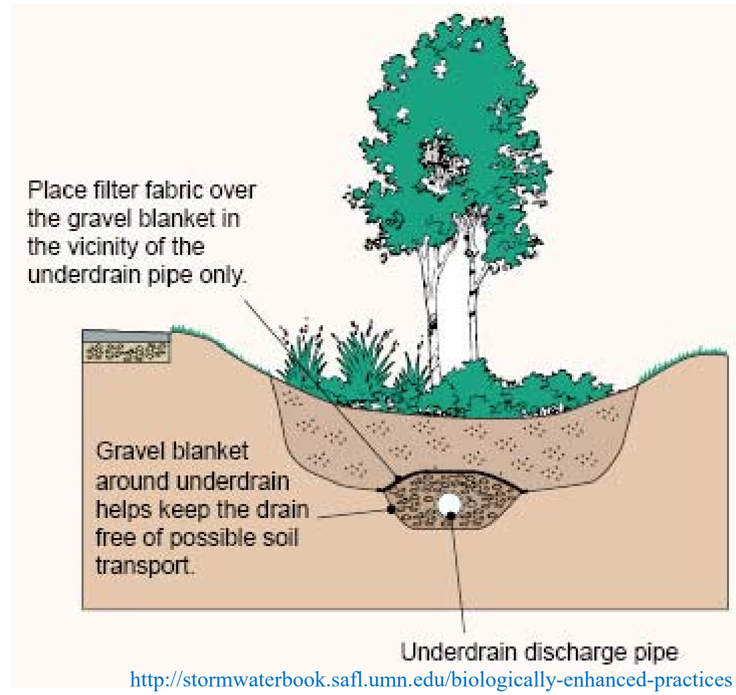
Different types of rain garden: Type#2

Recommended area:

- ✓ Areas where partial recharge of groundwater would be beneficial
- ✓ Areas that are expected to generate nutrient and metals loadings
- ✓ Visually prominent or gateway locations in a community

Characteristics:

- ✓ Uses an underdrain discharge pipe
- ✓ No impervious liner is used (partial recharge)
- ✓ Depth is shallow to allow high-capacity flows
- ✓ Place filter fabric (could be replaced by pea-gravel diaphragm) over the gravel blanket in the vicinity of the underdrain pipe only
- ✓ Use a gravel Blanket around underdrain helps keep the drain free of possible soil transport
- ✓ Provides a recharge zone



Cross section of rain garden

Stormwater BMPs for residential area

Rain garden (cont'd)

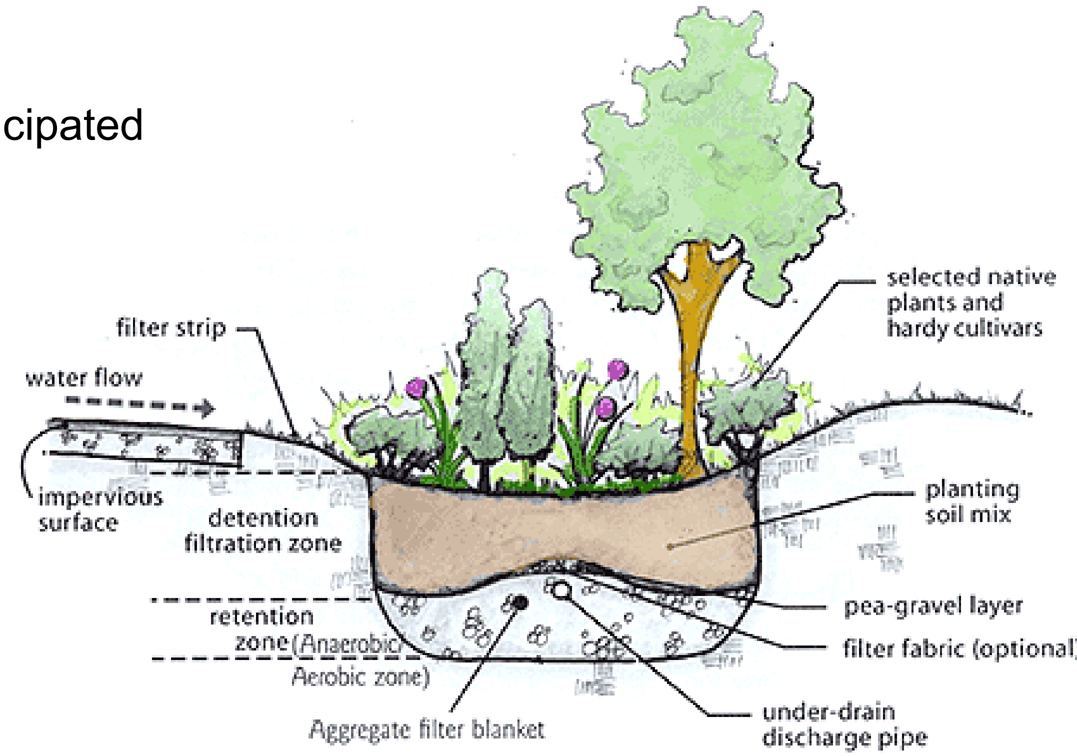
Different types of rain garden: Type#3

Recommended area:

- ✓ Areas where higher nutrient loading are anticipated

Characteristics:

- ✓ Uses an elevated underdrain discharge pipe
- ✓ incorporate a fluctuating aerobic/anaerobic zone below the raised underdrain discharge pipe
- ✓ Provides a storage area below the underdrain discharge pipe
- ✓ Provides a recharge zone
- ✓ No filter fabric is used on the side walls or at the invert of the facility discharge pipe



http://www.jkdirtworks.com/html/rain_gardens.html

Cross section of rain garden

Rain garden (cont'd)

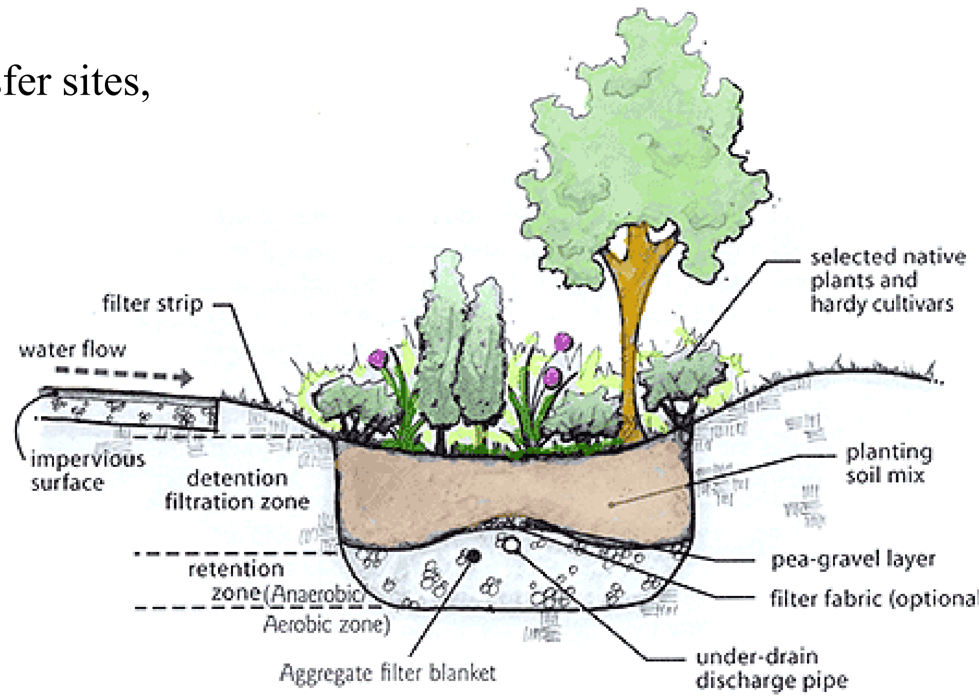
Different types of rain garden: Type#4

Recommended area:

- ✓ Areas that are known as hot- spots (gas stations, transfer sites, and transportation depots)

Characteristics:

- ✓ Uses an underdrain discharge pipe
- ✓ Impervious liner between in-situ soils and the planting soil medium is designed to reduce or eliminate the possibility of groundwater contamination
- ✓ Provides a level of treatment strictly through filtration processes that occur when the runoff moves through the soil material to the underdrain discharge point



http://www.jkdirtworks.com/html/rain_gardens.html

Cross section of rain garden

Stormwater BMPs for residential area

Rain garden (cont'd)

Mechanism of common contaminant removal in rain garden

1. Colloidal particles are removed are removed from stormwater by filtration.

2. Dissolved chemical and biological contaminants may be removed by sorption onto media surfaces during infiltration:
   a) Ion exchange: phosphate & metals
   b) Chemisoprtion: metals, phosphate, organics & pathogens
   c) Precipitation: metals & phosphate

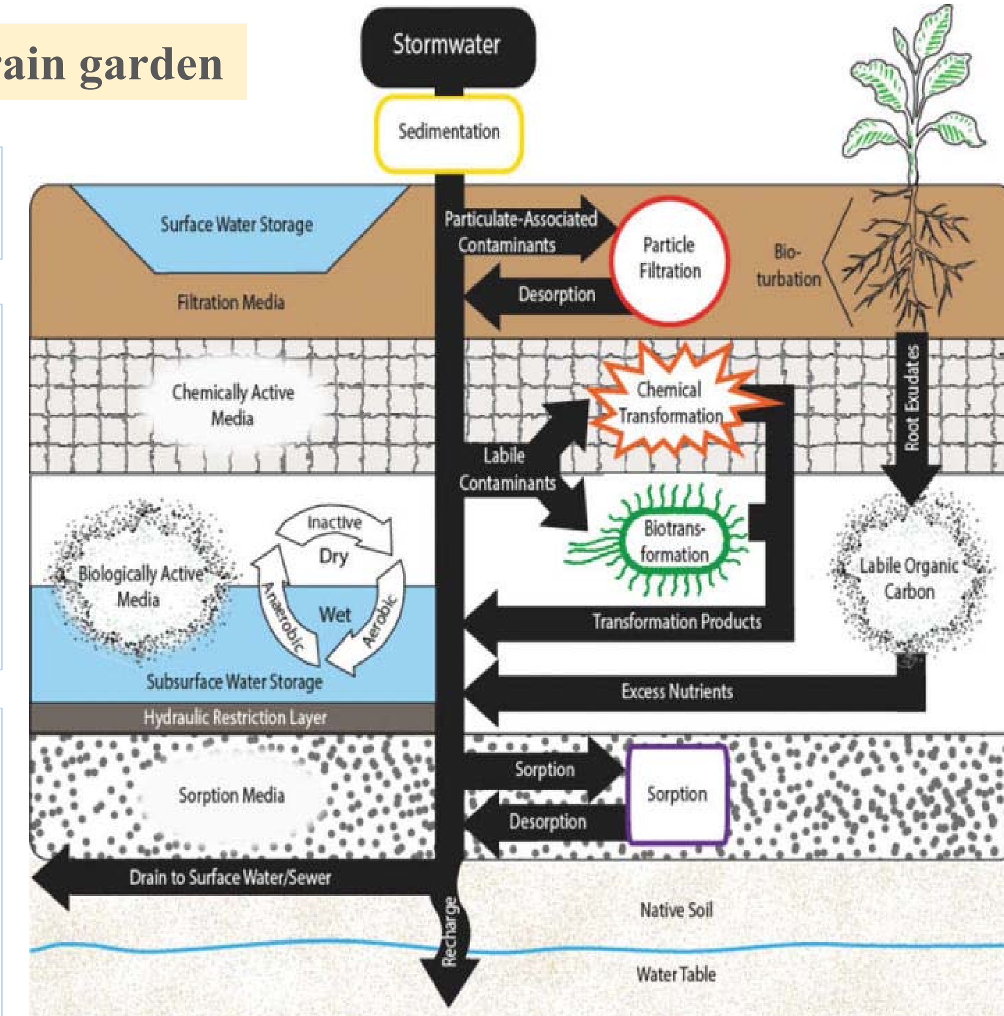
   Chemical contaminants may be transformed abiotically by hydrolysis, oxidation, or reduction reactions on geomedia.

3. Biotransformation: the diverse microbial communities interact with dissolved and sorbed compounds.

   Heterotrophic bacteria decompose pollutants to gain energy for synthesis of new cell and for respiration and motility.

   Autotrophic bacteria oxidize inorganic pollutants for energy.

   Plant uptakes dissolved nutrients and metals.



https://waterclimate.files.wordpress.com/2015/10/janel-et-al-2013-ees.pdf

Rain garden (cont'd)

Strategies for enhancing pollutant removal

Strategy 1: Media amendments

1. Media amendments to enhance sorption

- ✓ Metals removal can be enhanced by a variety of media with high cation exchange capacity (CEC) like zeolites and GAC.
- ✓ Media exhibiting good removal of phosphate include Al- or Fe-oxide–coated sand, fly ash, shale, cementious media, and limestone.
- ✓ Fe- and Al-oxide-coated sands exhibit better removal of silica colloids, bacteria, and protozoa than uncoated sand due to the electrostatic attraction between negatively charged pathogens and positively charged metal oxides .
- ✓ Sorption of most uncharged organic contaminants can be improved by media capable of hydrophobic interactions like GAC or biochars.

Potential Stormwater Infiltration Media: Representative Properties

Material	Sand	Kaolinite clay	Natural zeolites	Limestone	Fe-oxide	Mn-oxide	Al-oxide	GAC	Mulch/ compost
Specific surface area (m^2/g)	0.1	5-20	30-180	7	Variable	Variable	Variable	350-1000	11-26
Cation exchange capacity (cmol/kg)	1	1–15	20–100	23	Variable	Variable	Variable	240	11–70

Rain garden (cont'd)

Strategies for enhancing pollutant removal

Strategy 1: Media amendments (cont'd)

2. Media amendments to enhance contaminant transformation

- ✓ chemical and biological transformation reactions could result in mineralization of organic contaminants, denitrification, or stable transformation products that pose potential risks to groundwater or surface waters

3. Media amendments to enhance abiotic reaction

- ✓ Reactions with geomedia: Mn- or Fe-containing minerals are capable of oxidizing a variety of contaminants like phenolic compounds, aromatic amines and aromatic thiols.
- ✓ Geomedia with a sufficiently low redox potential: zero-valent Fe (ZVI) has been employed to reduce halogenated organic compounds and metals.
- ✓ Positively charged surfaces may enhance inactivation of pathogen indicators.

4. Media amendments to enhance biotransformation

- ✓ Addition of labile organic carbon enhances biological activity.
  Biofilms increase uptake of dissolved metals and removal of hydrophobic contaminants, such as PAHs.
- ✓ Additives to infiltration media may impact the structure and behavior of the microbial community.

Potential drawbacks:

- Sand filters (d_m = 0.2 mm) clogs while GAC and anthracite (d_m ~1 mm) filters does not.
- carbon and nutrients may be released by the media.

Rain garden (cont'd)

Strategies for enhancing pollutant removal

Strategy 2: Control of hydraulics and saturation

- ✓ Particle deposition will form a cake layer over time, it will act as a filter, which may enhance removal, but will reduce water infiltration rates.
- ✓ Moisture content within the infiltration system also influences microbial activity present within the infiltration media.
- ✓ Increased water retention times and promotion of saturation zones may be beneficial for contaminant removal, however, it require either greater storage volume or treatment system volume.
- ✓ Surface of ponded zones in bioretention systems should not provide habitat for disease.

Strategy 3: Manipulation of redox conditions

- ✓ Microbial communities responsible for transformation by controlling the concentrations of terminal electron acceptors.
- ✓ Forcing extended saturated conditions to enhance denitrification rates by creating a shift in conditions of microaerophilic, anoxic, or anaerobic conditions. (achieved by raised underdrains or low permeability media)

Potential drawback:

If contaminants are not fully mineralized, the products of aerobic and anaerobic degradation may differ. For example, intermediate metabolites of diuron (herbicide) are considerably more toxic than their parent compound.

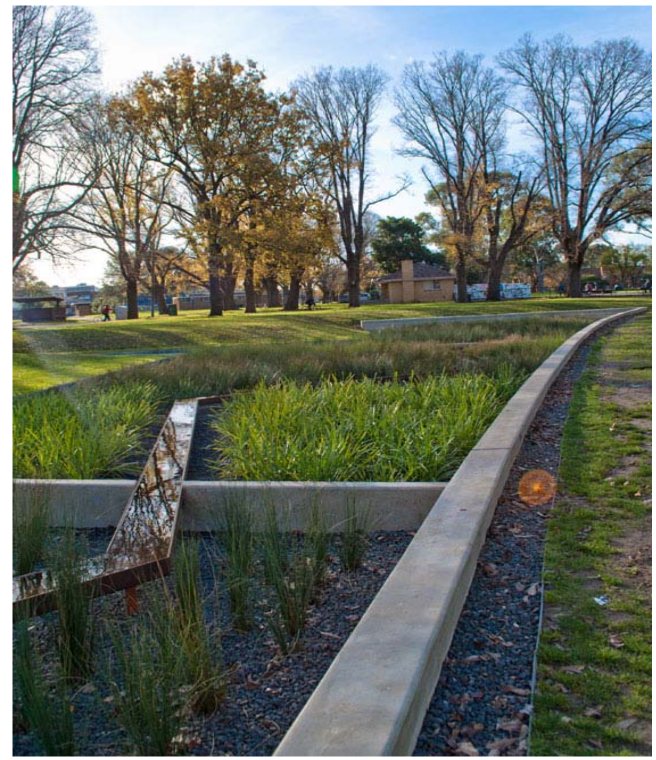
Rain garden (cont'd)

CASE STUDY: Edinburgh Gardens Rain garden (Melbourne, Australia)

The project involved sourcing stormwater from the North Fitzroy Main Drain and diverting it to a newly designed terraced rain garden within the Edinburgh Gardens, with the treated water being harvested for storage and irrigation of the trees within the park and local precinct.

Background information:

Name: Edinburgh Gardens Raingarden
Location: St Georges Road-Fitzroy North, Melbourne, Australia
Design Year: 2010
Year of Construction: 2011-2012
Area: 700 m^2
Budget: $1,000,000.00
Image credits: all GHD owned



Edinburgh Garden

http://www.landezine.com/index.php/2012/10/edinburgh-gardens-raingarden-by-ghd-pty-ltd/

Rain garden (cont'd)

CASE STUDY: Edinburgh Gardens Rain garden (cont'd)

Main components of project:

- Diversion pipe from North Fitzroy Main Drain with gross pollutant trap.
- Surcharge pit into 700 m^2 rain garden.
- Terraced rain garden with appropriate planting and filter media to treat stormwater.
- Overflow pit with underground pipe are connected to a 200 kiloliter underground storage facility with pump to irrigation distribution system.

Main design features:

- Filter media and appropriate plants that help to treat the stormwater through uptake of excessive nutrients and filtering fine sediments.
- "Zig zagging" features, which maintain the flow at a low velocity, connected to the surcharge pit that delivers water to all four terraces in

Stormwater management:

- Removes 16,000 kg total suspended solids annually.
- Removes 160 kg nutrients, phosphorus and nitrogen annually.
- Provides around 60% of their irrigation needs for Edinburgh Gardens.
- Reduces potable water use for irrigation by 4 million liters per year.

http://www.landezine.com/index.php/2012/10/edinburgh-gardens-raingarden-by-ghd-pty-ltd/

Edinburgh Garden

Rain garden (cont'd)

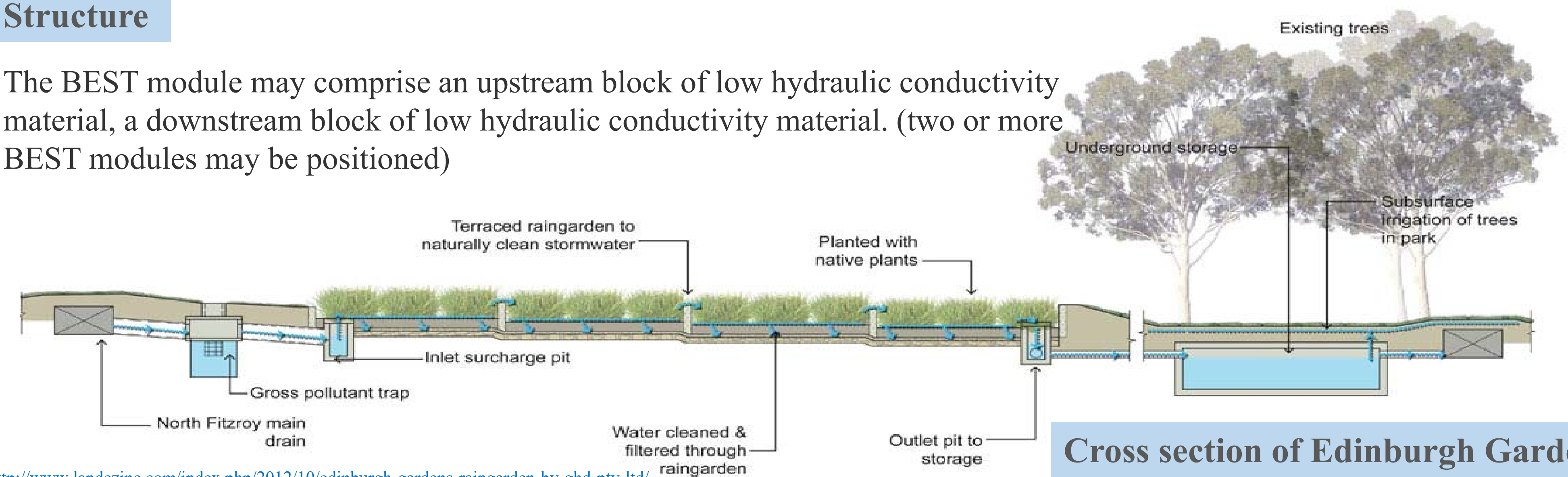
Innovative technology: biohydrochemically enhanced streamwater treatment (BEST)

Definition

Modifications to streambed hydraulic conductivity to improve circulation between surface water and hyporheic sediments, which is known as hyporheic exchange. Hyporheic exchange is a topic of growing interest for stream restoration and biogeochemistry because of the hyporheic zone's (HZ) potential role in improving water quality and mitigating temperature fluctuations.

Structure

The BEST module may comprise an upstream block of low hydraulic conductivity material, a downstream block of low hydraulic conductivity material. (two or more BEST modules may be positioned)



Cross section of Edinburgh Garden

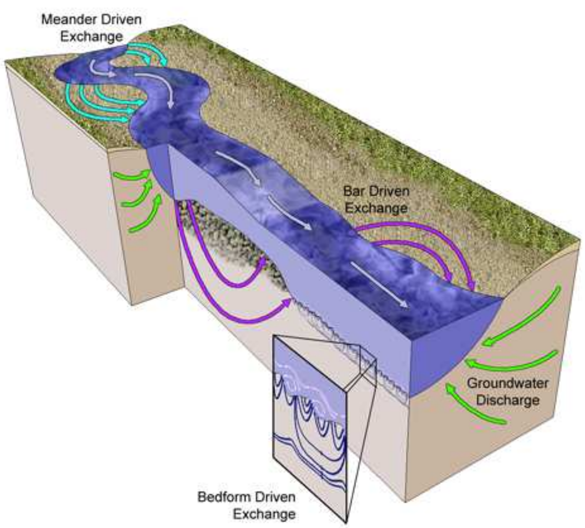
http://www.landezine.com/index.php/2012/10/edinburgh-gardens-raingarden-by-ghd-pty-ltd/

Rain garden (cont'd)

Innovative technology: biohydrochemically enhanced streamwater treatment (cont'd)

Advantages:

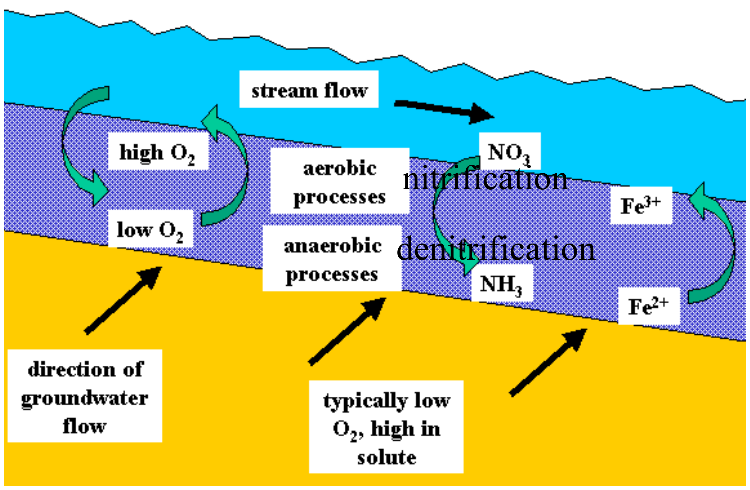
- ✓ Promotes hyporheic exchanges and corresponding hyporheic residence times, without disrupting surface flow.
- ✓ Enhances removal of various contaminants by setting several combinations of in-situ hydraulic conductivity and slope.
- ✓ Provides additional water quality and habitat enhancements, especially for nitrogen, coliform, and metals attenuation.
- ✓ With reactive geomedia may help in the removal, inactivation, or metabolism of a stream water contaminant.



http://susa.stonedahl.com/research.html

Drives of hyporheic exchange:

- Meanders
- Bedform
- In-channel obstacles
- Topography
- Hydraulic conductivity (K) heterogeneities



http://water.engr.psu.edu/gooseff/research.html

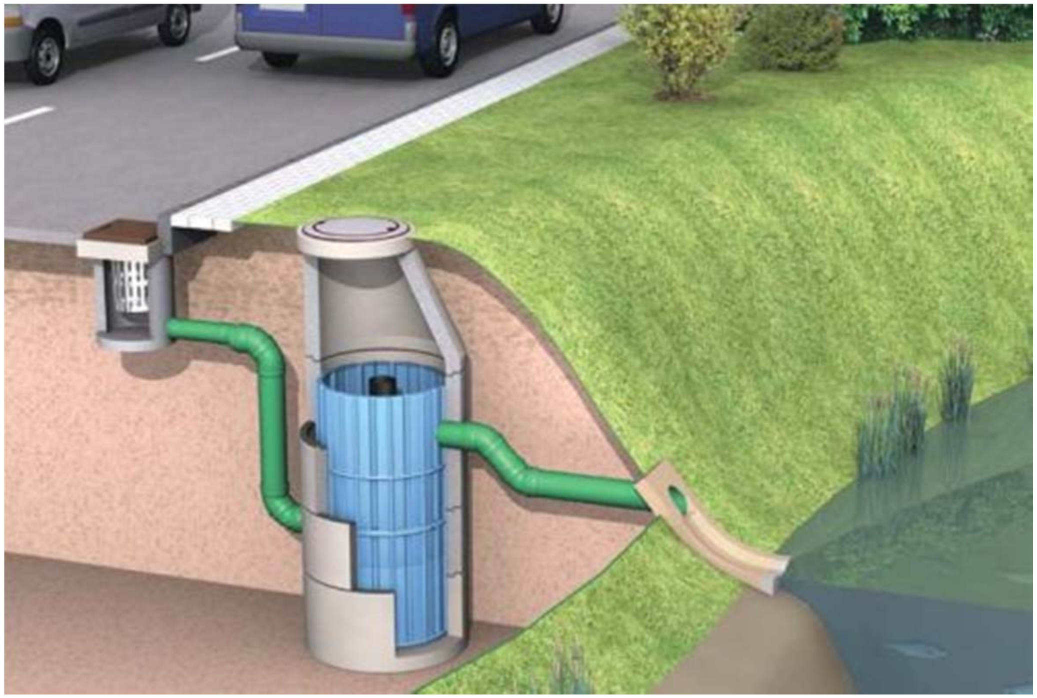
Mechanism of nitrogen removal

CONTENTS

Storm-filter

How does it work?

- ✓ Storm-water enters the inlet pipes and collection units and passes through the filter and fills the central cartridge.
- ✓ Upon filling the cartridge, the float valve is opened where the water is filtered and drained.
- ✓ A siphon is activated by the closing of a valve and then it draws polluted water into the drainage tube. Filter water is discharged out of the apparatus by an under drain system.
- ✓ Blowing the hood makes the water level rise up and air rushes in the regulators that breaks the siphon and releases the water column (see figure).

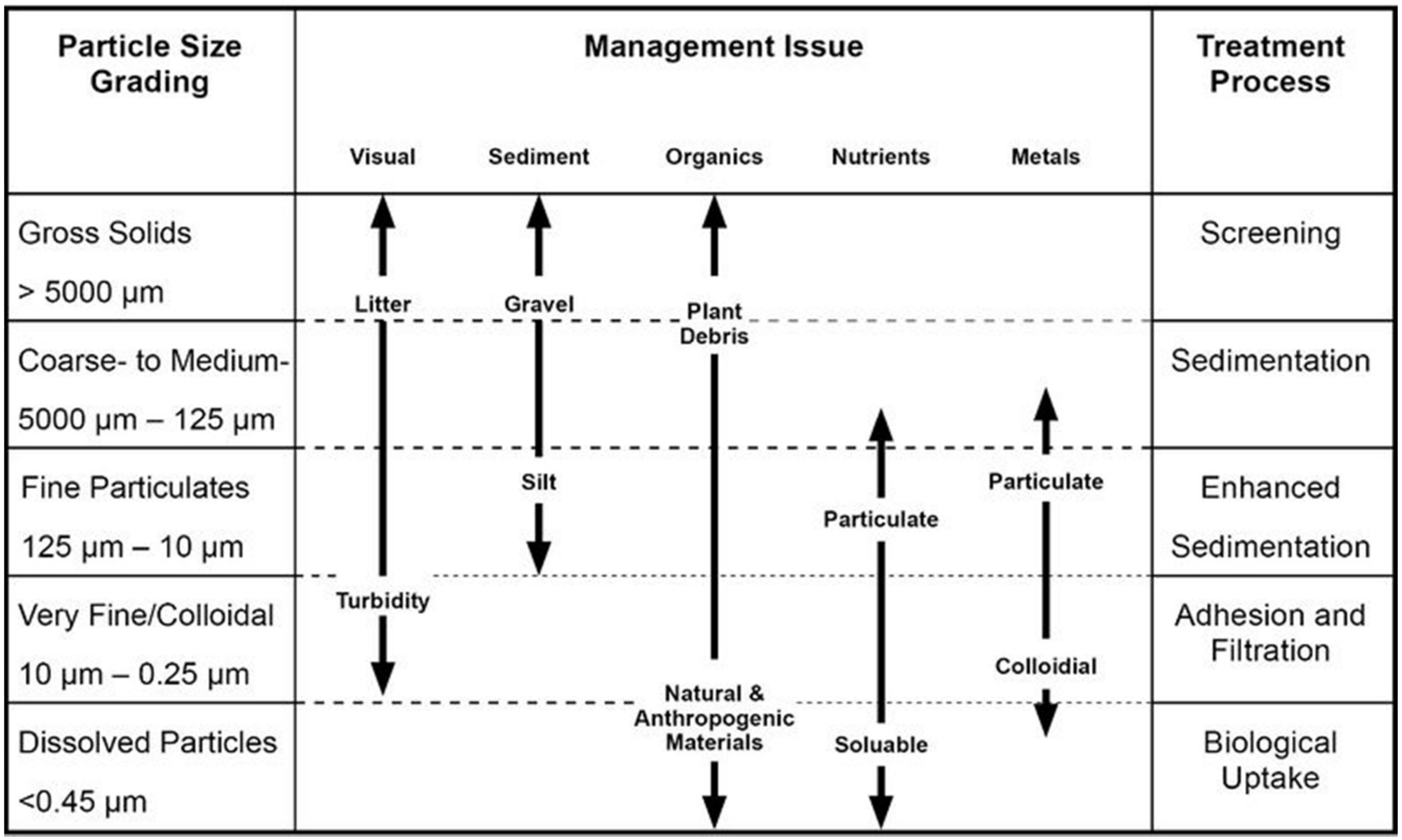


http://www.ngonline.net/stormwater-treatment-what-is-it-and-how-it-is-useful/

A Storm-filter in practice

Stormwater treatment technologies

Storm-filter (cont'd)



http://www.imbriumsystems.com/Portals/0/documents/sc/technical_docs/Particle%20Size%20Distributon.pdf

Nutrient separating baffle boxes (NSBB)

Pollutant removal

- Reduces the contaminant load in stormwater.
- Removes sediment, debris, litter, and organic matter.
- Removes hydrocarbons and bacteria.
- Decreases the biological oxygen demand of inflow.

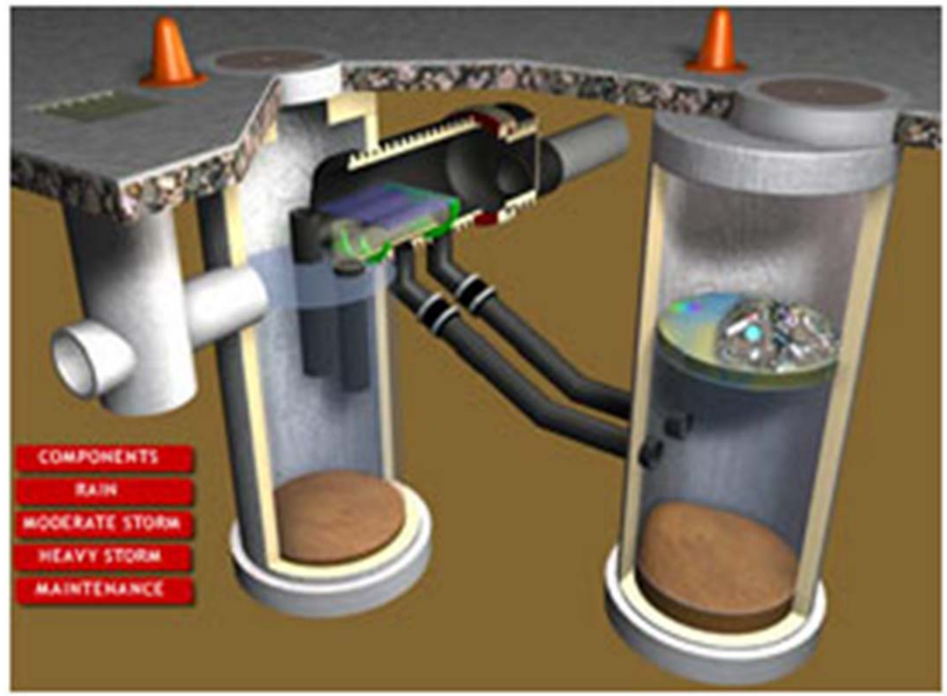
http://msu-water.msu.edu/managing-stormwater-on-the-msu-campus/

A NSBB in practice

Bay separator

How does it work?

- Initial inflow is treated through the series of manholes.
- During maximum flow rate, all of the runoff is treated in the primary manhole.
- Water containing sediments, oils and floatables is diverted to the storage manhole for a secondary treatment process.
- Suspended solids are removed by gravity in the primary manhole.



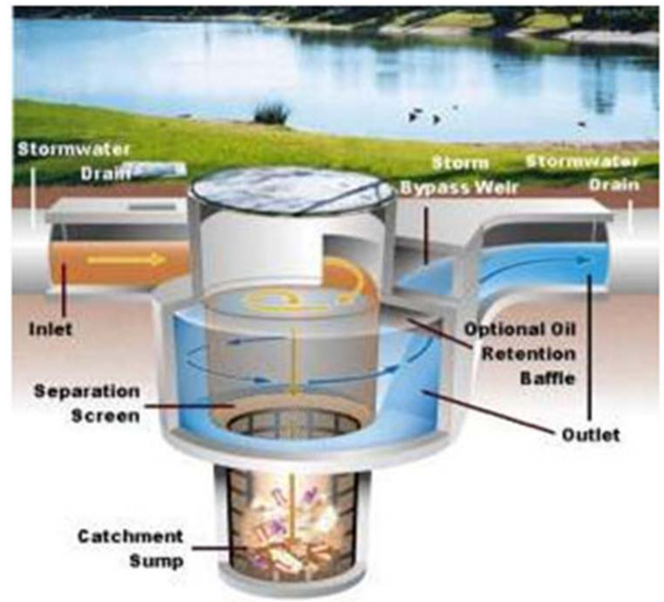
http://msu-water.msu.edu/managing-stormwater-on-the-msu-campus/

Schematic diagram of a bay separator

Continuous deflective separation (CDS) technology

How does it work?

- Non-mechanical screening process that removes suspended solids and floatables from stormwater flow.
- Raw stormwater enters the unit's chamber; a diversion barrier guides the flow into the separation chamber where a vortex is formed, it spins the suspended solids and floatables to the center of the separation chamber and then to the catchment sump.
- The screened liquid then moves toward the outlet and the cleaned water then is free to move to the receiving waters.



http://msu-water.msu.edu/managing-stormwater-on-the-msu-campus/

Cross section of continuous deflective separator

Stormwater treatment technologies

Comparison of removal efficiency

Technology Type	TSS	TP
Nutrient Separating Baffle Boxes (NSBB)	**67%**	**79%**
Bay Separator	**87%**	**76%**
Continuous Deflective Separation (CDS) Technology	**69%**	**0.2%**

CONTENTS

Case studies

Geographical location of following case studies

Case studies 1. CII Sohrabji Godrej Green Business Centre in *Hyderabad, India*

Benefits:

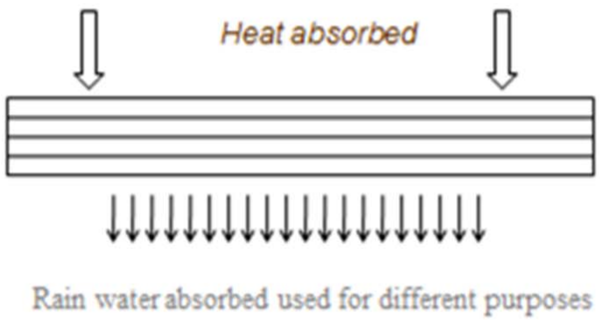
- ✓ A zero discharge building
- ✓ 100% rain water harvesting
- ✓ Water-less urinals in men's restrooms
- ✓ Roof garden covering 60% of roof area
- ✓ Utilizes Root Zone Treatment (RZWT)

http://www.greenbusinesscentre.com/site/ciigbc/index.jsp

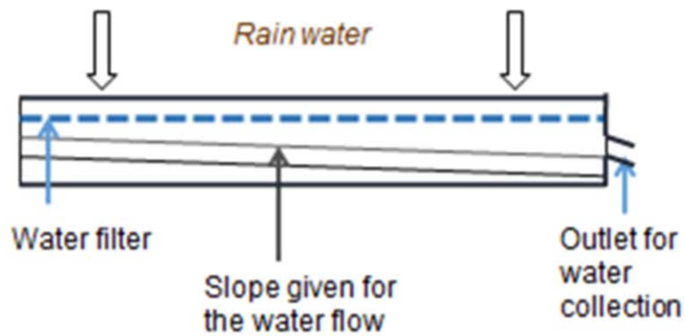
CII Sohrabji Green Buisness Center

Case studies 1. CII Sohrabji Godrej Green Business Centre in *Hyderabad, India* (cont'd)

Roof garden



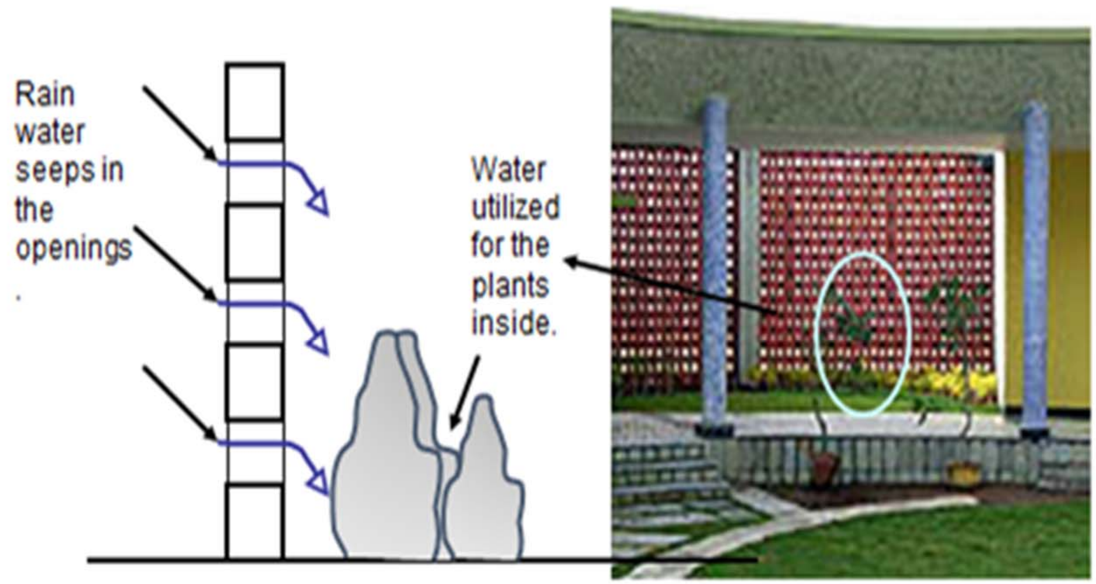
- Absorbing heat and radiating it into the building. This is minimized through the roof gardens covering 55% of the roof area.
- Rain water harvesting.
- Seepage into the ground has been installed in pedestrian areas and parking area.



https://image.slidesharecdn.com/hyderabadfinal-140427123054-phpapp02/95/sohrabji-godrej-green-business-centre-10-638.jpg?cb=1420164581

Case studies 1. CII Sohrabji Godrej Green Business Centre in *Hyderabad, India* (cont'd)

Function of a wall mesh (Jali)

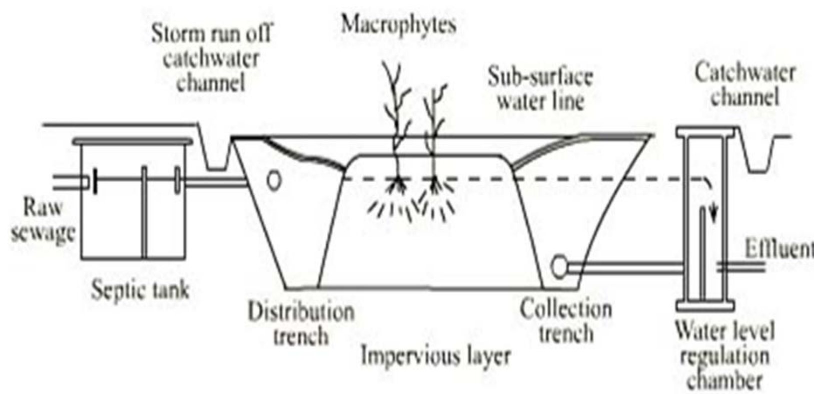


Section through the jali

https://www.slideshare.net/smitaranjansamantara/green-building-ppt-72908544

Root zone technology

- ✓ Root zone technology is a low energy, low maintenance and natural approach to treat domestic sewage.
- ✓ It is a wastewater treatment technique consisting of constructed wetland with subsurface flow of wastewater
- ✓ The wetland, a lined basin containing media and wetland plants, treats wastewater by a variety of physical, chemical and biological means.



http://nptel.ac.in/courses/105104102/41

Flow diagram of the root zone technology

2. ITC Gardenia in *Bengaluru, India*

- ✓ The Royal Gardenia is the worlds largest LEED platinum rated hotel.
- ✓ The hotel's Atrium lobby is not air-conditioned. There are no doors and the whole lobby is wind-cooled. Also, the lobby features vertical hanging gardens with a mix of plants that are watered using drip irrigation.
- ✓ The hotel, is one of the first hotels in India to create the concept of vertical hanging gardens These gardens rise towards the ceiling. Lighting is provided from natural sources or through an energy efficient lighting system.

http://www.starwoodhotels.com/luxury/property/overview/index.html?propertyID=3526

ITC Royal Gardenia (Bangalore, India)

2. ITC Gardenia in *Bengaluru, India* (cont'd)

Living walls

- ✓ Living walls (also called bio-walls, ìmurî vegetal, or vertical gardens) are composed of pre-vegetated panels or integrated fabric systems that are affixed to a structural wall or frame.
- ✓ Modular panels are comprised of polypropylene plastic containers, geo textiles, irrigation, and growing medium and vegetation.
- ✓ Living walls perform well in full sun, shade, and interior applications, and can be used in both tropical and temperate locations.

https://greenwall.wordpress.com/2014/10/21/sustainable-building/

Structure of living wall

Case studies

2. ITC Gardenia in *Bengaluru, India* (cont'd)

Living walls

Benefits:

- ✓ Improvement of Air Quality
- ✓ Reduction of Urban Heat Island Effect
- ✓ Moderate Building Temperatures
- ✓ Contribute to Carbon Dioxide/Oxygen Exchange
- ✓ Stormwater Management (absorbs 45-75% of rainfall)
- ✓ Habitat and Biodiversity

Inside of living wall

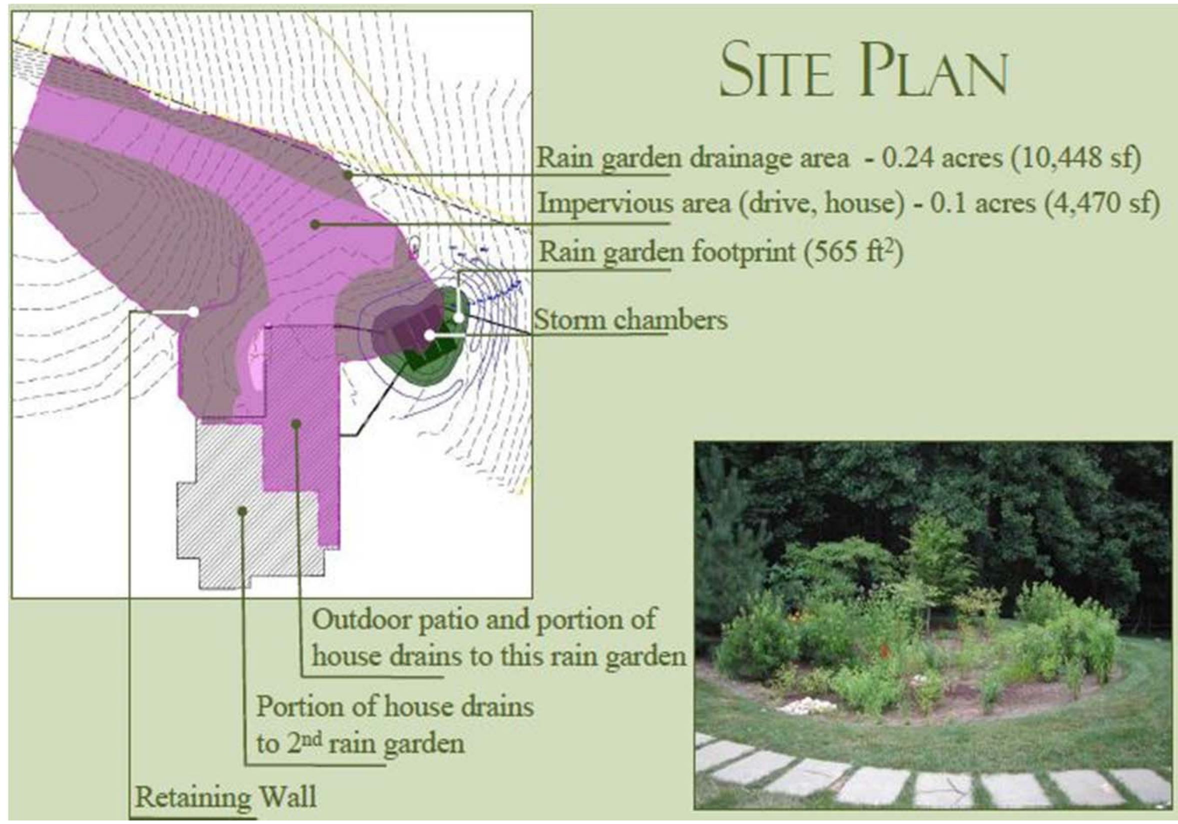
Outside of living wall

https://www.hotels.com/ho336231/itc-gardenia-a-luxury-collection-hotel-bengaluru-bengaluru-india/

3. Rain garden in *Fairfax County, Virginia, USA*

Watershed condition of the rain garden

- 0.24 acre (10,448 sf) drainage area
- 0.10 acre (4,470 sf) impervious area
- 565 ft^2 rain garden footprint

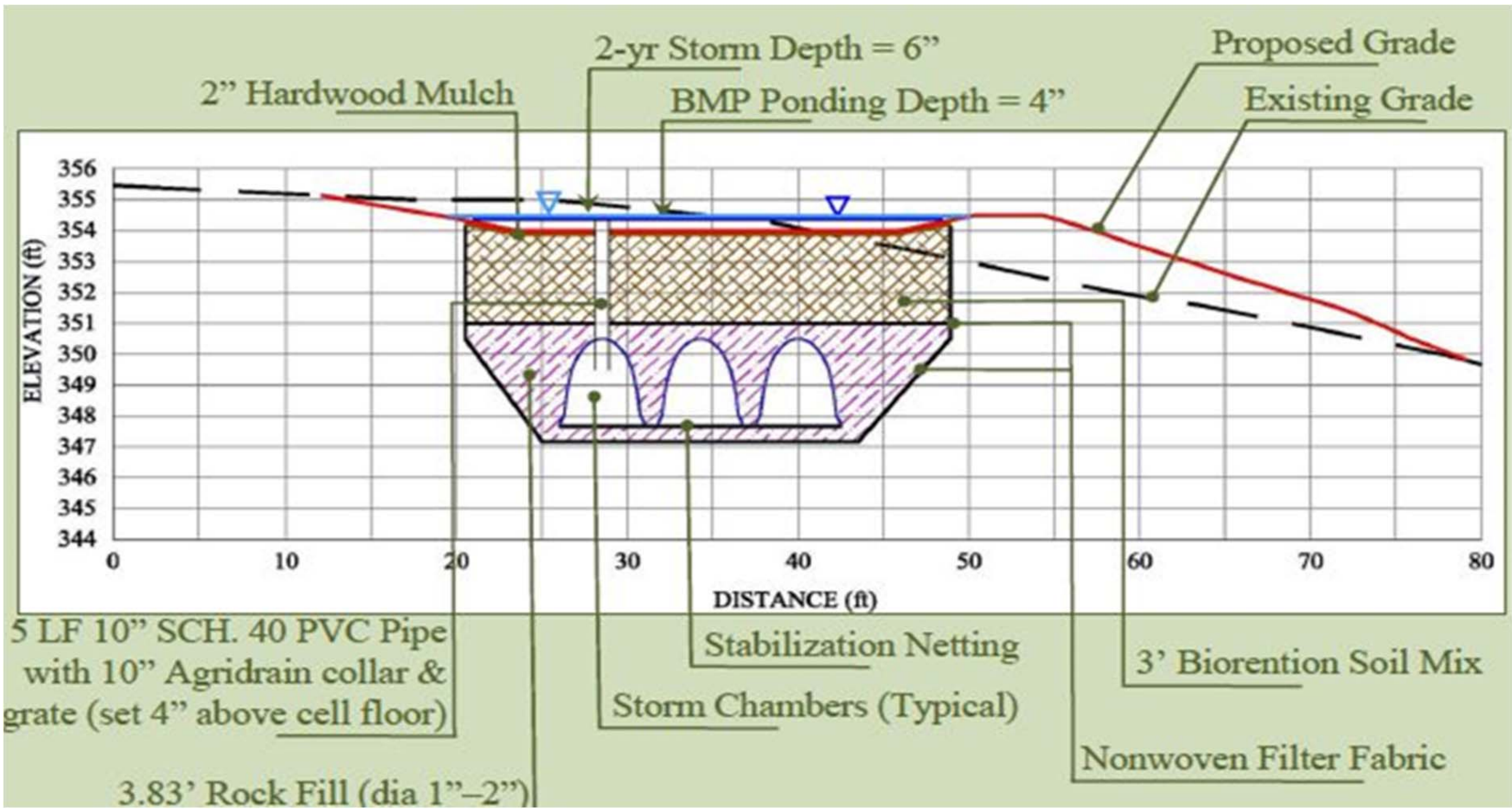


Source:https://static1.squarespace.com/static/55c211c8e4b06ea5799e6c03/t/561415e0e4b000464e33475b/1444156896162/Residential_Rain_Gardens.pdf

Case studies

3. Rain garden in *Fairfax County, Virginia, USA* (cont'd)

The rain garden cross section



Source:https://static1.squarespace.com/static/55c211c8e4b06ea5799e6c03/t/561415e0e4b000464e33475b/1444156896162/Residential_Rain_Gardens.pdf

Case studies

3. Rain garden in *Fairfax County, Virginia, USA* (cont'd)

Rain garden construction

Source:https://static1.squarespace.com/static/55c211c8e4b06ea5799e6c03/t/561415e0e4b000464e33475b/1444156896162/Residential_Rain_Gardens.pdf

1	2
3	4

1. Installing storm chambers
2. Bioretention soil mix
3. Landscaping
4. Outlet pipe & Erosion control

Case studies 3. Rain garden in *Fairfax County, Virginia, USA* (cont'd)

Rain garden cost estimates

ITEM	QTY	UNIT	UNIT COST	TOTAL COST
DESIGN & SURVEY	---	Lump Sum	$12,500.00	$12,500
CONSTRUCTION				
MATERIALS				
- E&S Controls	---	Lump Sum	$140.00	$140
- Storm Chambers	6	Each	$350.00	$2,100
- Pipe	---	Lump Sum	$1,100.00	$1,100
- Filter Fabric	1,460	Sq ft	$0.10	$150
- Stone	70	Tons	$15.00	$1,025
- Bioretention Soils	60	Cu yd	$50.00	$3,000
- Mulch	10	Cu yd	$33.00	$330
- Misc. Hardware	---	Lump Sum	$250.00	$250
LABOR	---	Lump Sum	$12,700.00	$12,700
BOBCAT	40	Hours	$27.50	$1,100
PLANTING				
Materials	---	Lump Sum	$1,650.00	$1,650
Labor	---	Lump Sum	$2,800.00	$2,800
TOTAL				$38,845

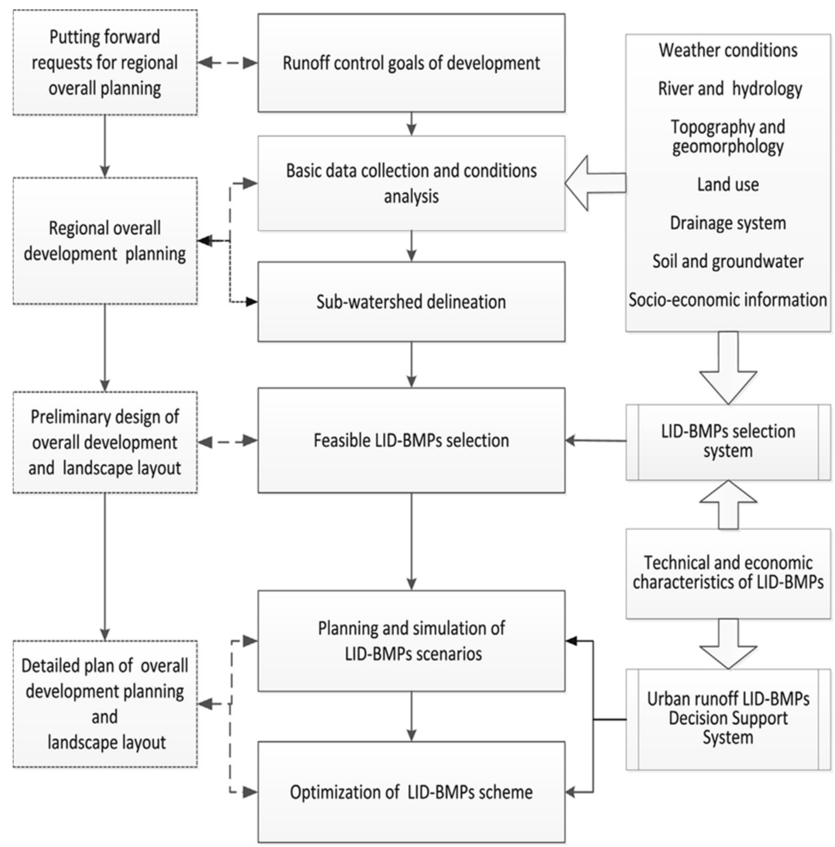
Source:https://static1.squarespace.com/static/55c211c8e4b06ea5799e6c03/t/561415e0e4b000464e33475b/1444156896162/Residential_Rain_Gardens.pdf

4. LID-BMPs simulation in *Guangdong, China*

The process of LID-BMPs' planning

1. Setting of runoff control goals
2. Basic data collection and site condition analysis
3. Subwatershed delineation
4. Selection of feasible LID-BMPs
5. LID-BMPs scenario planning and simulation

The flowchart of LID-BMPs' planning



Source: Haifeng Jia, Hairong Yao, Ying Tang, Shaw L. Yu, Richard Field, Anthony N. Tafuri. LID-BMPs planning for urban runoff control and the case study in China. Journal of Environmental Management 149 (2015) 65e76

4. LID-BMPs simulation in *Guangdong, China* (Cont'd)

Location of study site

Associated land use

Source: Haifeng Jia, Hairong Yao, Ying Tang, Shaw L. Yu, Richard Field, Anthony N. Tafuri. LID-BMPs planning for urban runoff control and the case study in China. Journal of Environmental Management 149 (2015) 65e76

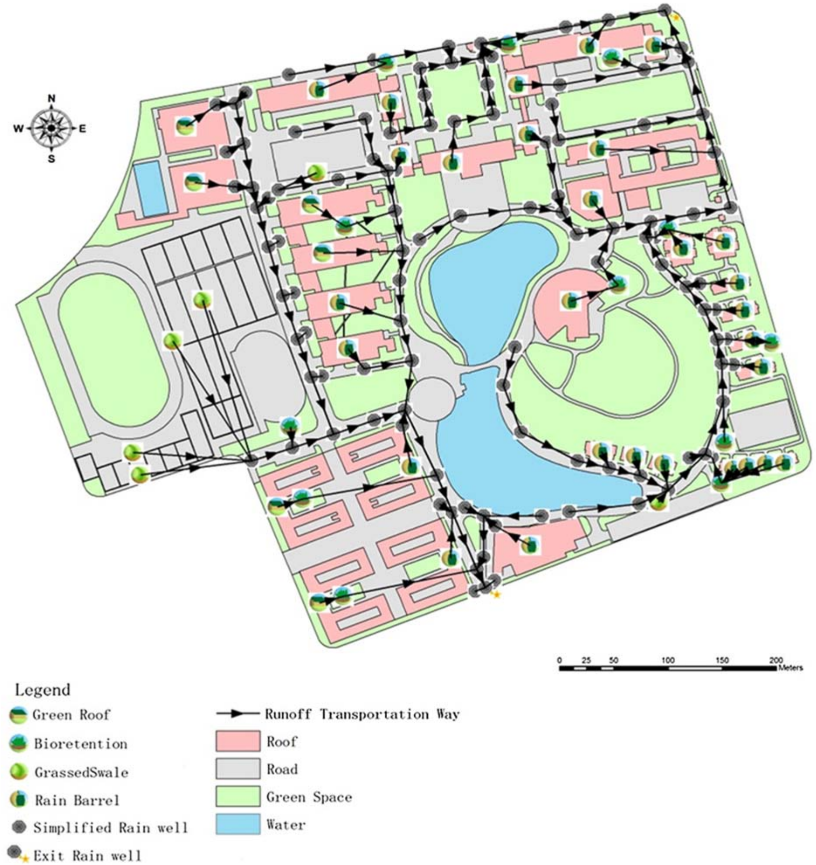
4. LID-BMPs simulation in *Guangdong, China* (Cont'd)

Information about different scenarios

- **Pre-development scenario**
  This scenario assumed the site conditions remain as before development. According to the survey data, the site was comprised of rural areas with crops, forest and ponds.
- **Basic scenario**
  The college administration had already drafted a college campus development plan without considering runoff LID-BMPs control. The existing college campus development plan was assumed as basic scenario.
- **Scenario 1- the least-cost BMPs implementation scenario**
  Under this scenario, the major consideration was the cost of implementation. The LID-BMPs would be mainly installed during the phase II campus construction period. The LID-BMPs considered included 11 bioretention units, 25 green roof units, 6 grassed swale units and 7 rain barrels.
- **Scenario 2 - the maximized BMPs performance scenario**
  Under this scenario, the primary consideration was to maximize the LID-BMPs effectiveness. LID-BMPs were considered for both phase I and phase II campus construction period. The LID-BMPs used included 17 bioretention units, 35 green roof units, 6 grassed swale units,18 rain barrels, 10 porous pavement units and 2 wet detention ponds.

4. LID-BMPs simulation in *Guangdong, China* (Cont'd)

Different scenarios layout maps



Scenario 1

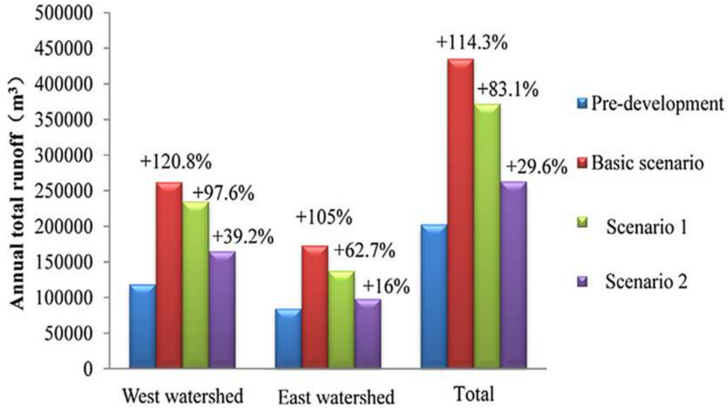
Scenario 2

Source: Haifeng Jia, Hairong Yao, Ying Tang, Shaw L. Yu, Richard Field, Anthony N. Tafuri. LID-BMPs planning for urban runoff control and the case study in China. Journal of Environmental Management 149 (2015) 65e76

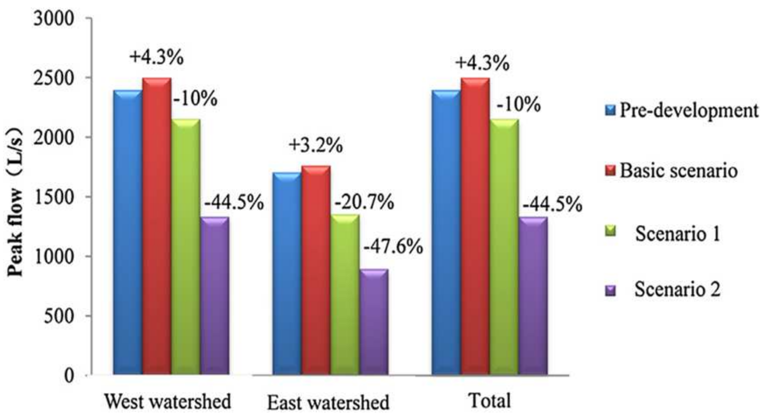
Case studies

4. LID-BMPs simulation in *Guangdong, China* (Cont'd)

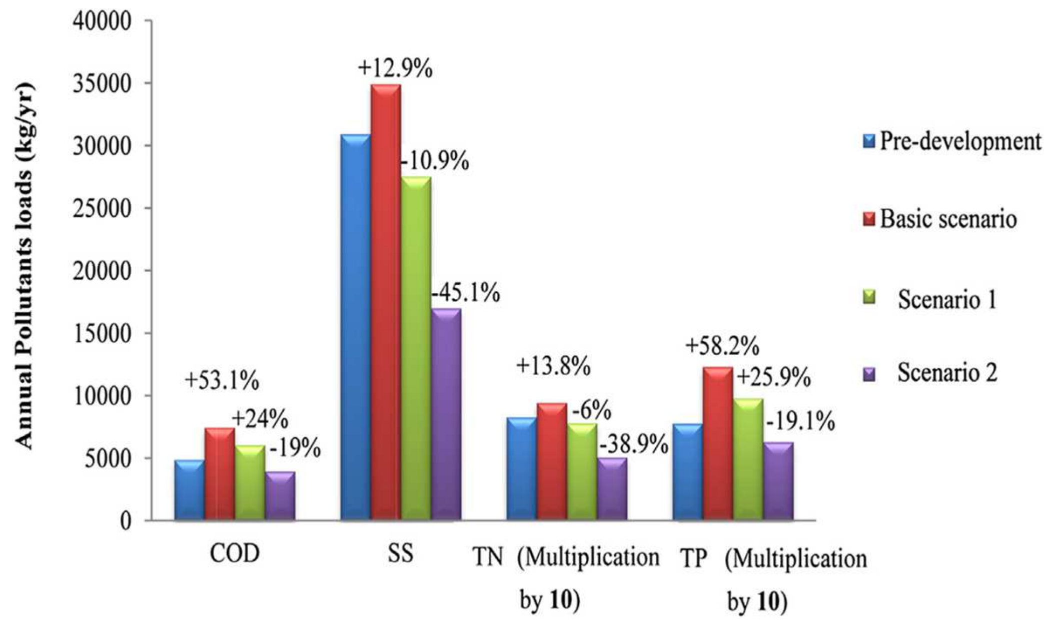
Comparisons of different scenarios



Comparison of annual runoff volume under different scenarios



Comparison of peak flows under different scenarios



Comparison of pollutant loads under different scenarios

Data from Haifeng Jia, Hairong Yao, Ying Tang, Shaw L. Yu, Richard Field, Anthony N. Tafuri. LID-BMPs planning for urban runoff control and the case study in China. Journal of Environmental Management 149 (2015) 65e76

4. LID-BMPs simulation in *Guangdong, China* (Cont'd)

Analysis of simulation results

The four scenarios described above were simulated using SUSTAIN. The results showed that the runoff volume, peak flow and the pollutant load were much larger under the basic scenario when compared to the pre-development scenario. These results illustrate clearly the negative impacts of urbanization. The results also show that the two LID-BMPs scenarios could effectively cut runoff quantity and pollutants loads. Under Scenario 1, total runoff volume, peak flow and pollutant loads were reduced by 14.5%, 13.8% and 17 - 21%, respectively, compared to those under the basic scenario. Under Scenario 2, total runoff volume, peak flow and pollutant loads were reduced by 40%, 46.8% and 46 - 51%, respectively.

A cost-effective urban runoff control LID-BMPs plan is essential for mitigating the negative impacts of urbanization. However, to find the best urban runoff control LID-BMPs planning, a thorough analysis of various planning-design scenarios is necessary. Many factors, need to be included in these analyses. such as site conditions, BMP effectiveness and costs, etc.

CONTENTS

Summary and Discussion

Stormwater BMPs for residential area

- **Green home BMPs**
  Consists of rain garden, dry well, rain barrel and so on. Each green home is a green neighborhood node.
- **Green street BMPs**
  Green streets use combinations of stormwater BMPs to improve water quality and reduce stormwater runoff.

Stormwater treatment technologies

- **Stormfilter**
  Removes pollutants such as dissolved metals, hydrocarbons, and nutrients from stormwater run-off runoff.
- **Nutrient separating baffle boxes (NSBB)**
  Utilizes a patented screening technology that consists of enhanced three chamber separation, and inline installation.
- **Bay separator**
  Efficiently and effectively treat storm water by separating debris and trapping pollutants.
- **Continuous deflective separation (CDS)**
  Uses the natural motion of the water to separate and trap pollutants.

Case studies

- **CII Sohrabii Green Business Centre (India)**
  A typical case which using green roof to utilize the stormwater. The wall Jali can also collect raindrops efficiently.
- **ITC Royal Gardenia (Bangalore, India)**
  Successful BMPs applied in the commercial area. Living wall not only manages stormwater but also increases landscaping.
- **Rain garden in Fairfax County (Virginia, America)**
  Provide the details of how rain garden is constructed and its cost. Rain garden with chambers can store considerable amount of stormwater.
- **Comparison of different types of LID-BMPs simulation (China)**
  The simulation of a campus under 4 scenarios shows that BMPs play an import role in reducing the runoff and mitigating pollutants.

Suggestions for future work

With the gowning population and the pressure of water problem, green infrastructure BMPs still is one of the efficient ways to improve water quality, reduce city runoff and mitigate pollution in the LA River. Green Garden will become a popular trend for individual houses to manage small scale runoff. Green roof and green wall can be an option for schools and hotels. It is recommended that government should invest more fundinncepg on the green streets and green neighborhoods to achieve multiple benefits.

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Conceptual vision of a future city

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Q & A

Thank you!