CRC for
Water Sensitive Cities

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Biofilters:
Design, performance and O&M requirements

Kerrie Burge

watersensitivecities.org.au

Biofilters

- Biofilters are filters for stormwater that utilize vegetation to clean water and maintain the infiltration capacity of the soil.
- Biofilters can manage both water quality and flow impacts of urbanisation.
- Biofilters also have many other benefits.

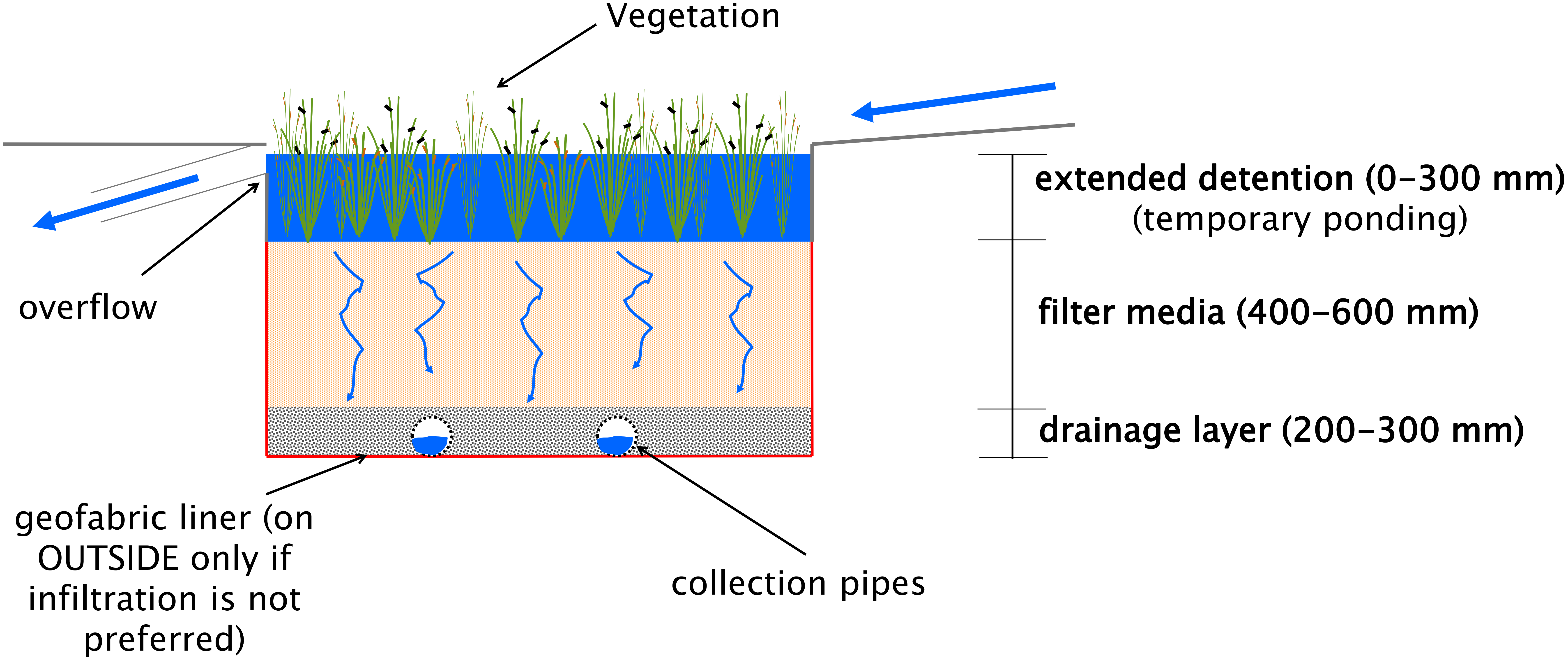
Vegetation in biofilters

1. Double the growth rate (Grey, V. et.al 2018)
2. Canopy 8 -10 x larger (Hitchmough, J. 1994)
3. Increased lifespan from 13 to 50 years (Skiera, B. and G. Moll. 1992)
4. Economic Benefit - Leafy Streets 3% Premium House Price (Lyndal Plant, Uni of Qld & Urban Forester)
5. Achieve or exceed WQ objectives (E2Designlab & Healthy Land and Water, 2018)
6. Microclimate – Urban Cooling (Coutts, A and Tapper, N. 2017, CRC WSC)
7. Frequent flow & potential flooding benefits (TBC)

Biofilters

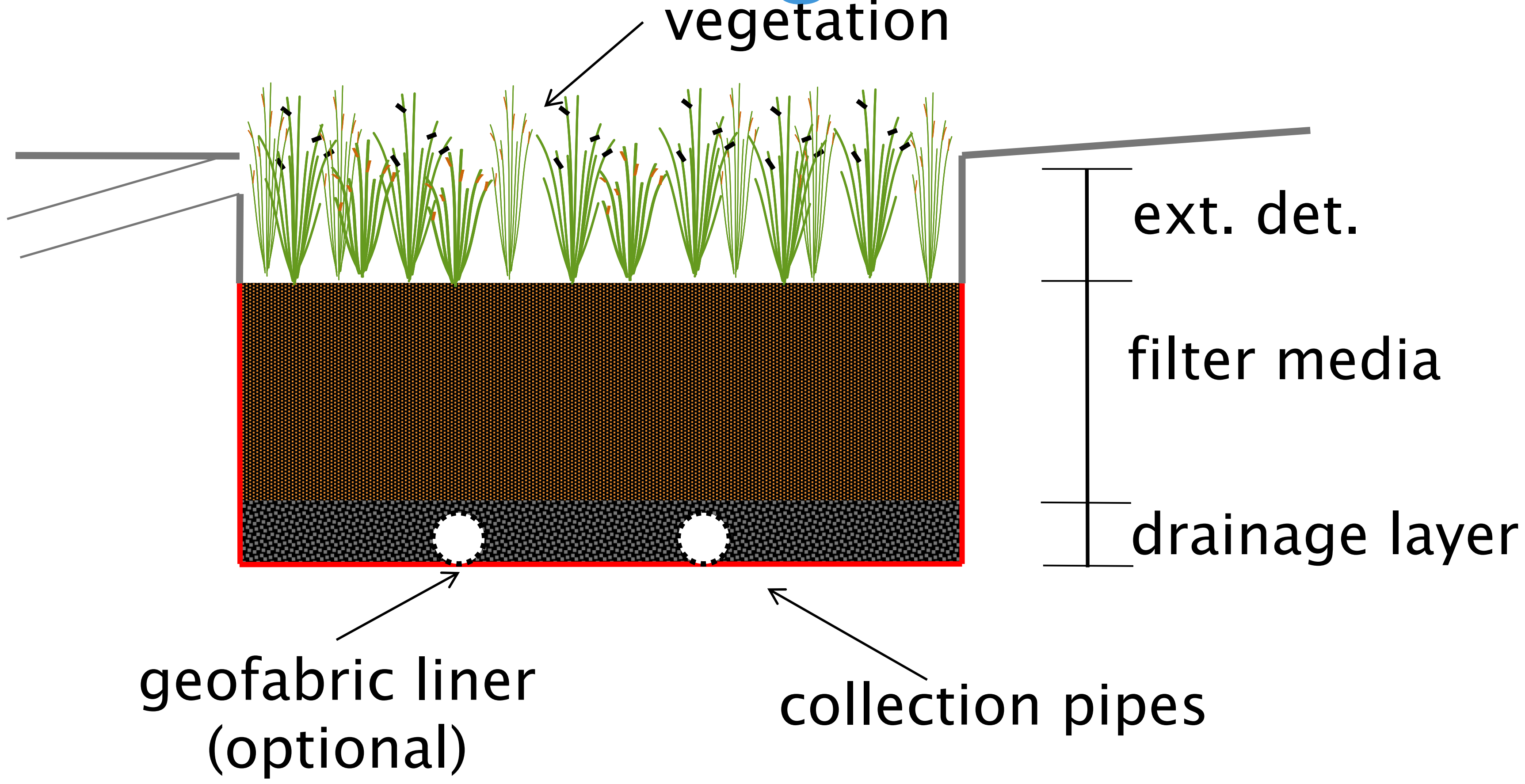
Also referred to as:

- Bioretention systems
- Biofiltration systems
- Raingardens

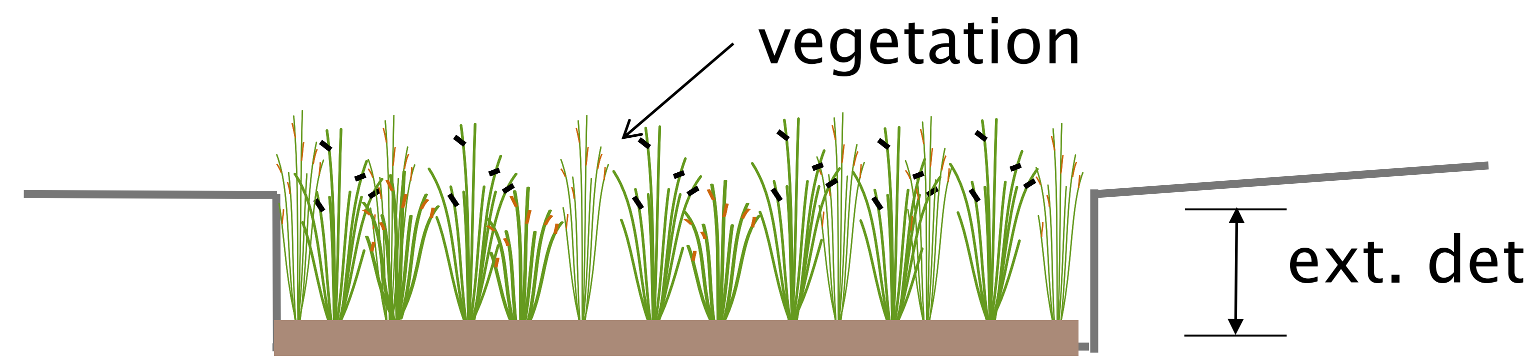


Different treatment types

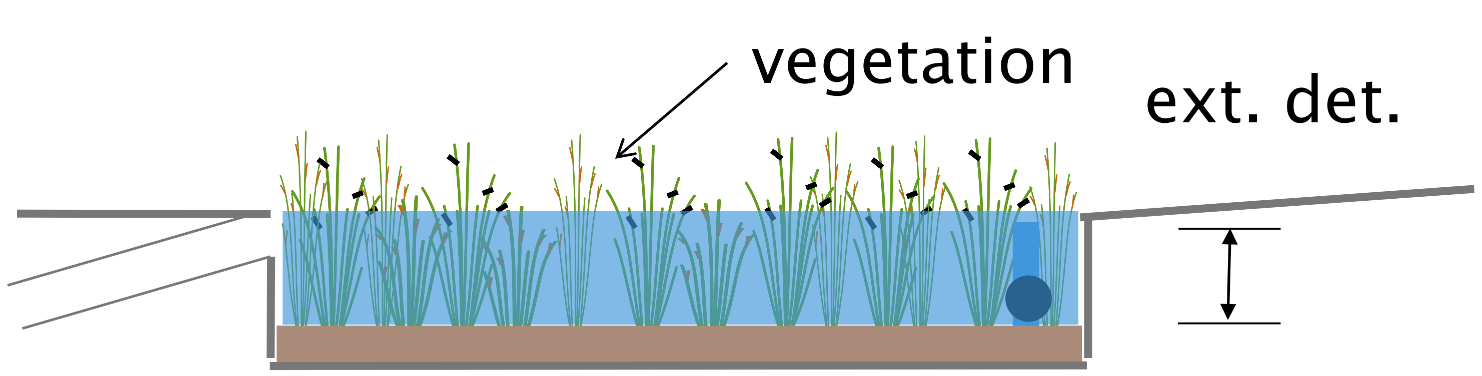
Biofilter / raingarden



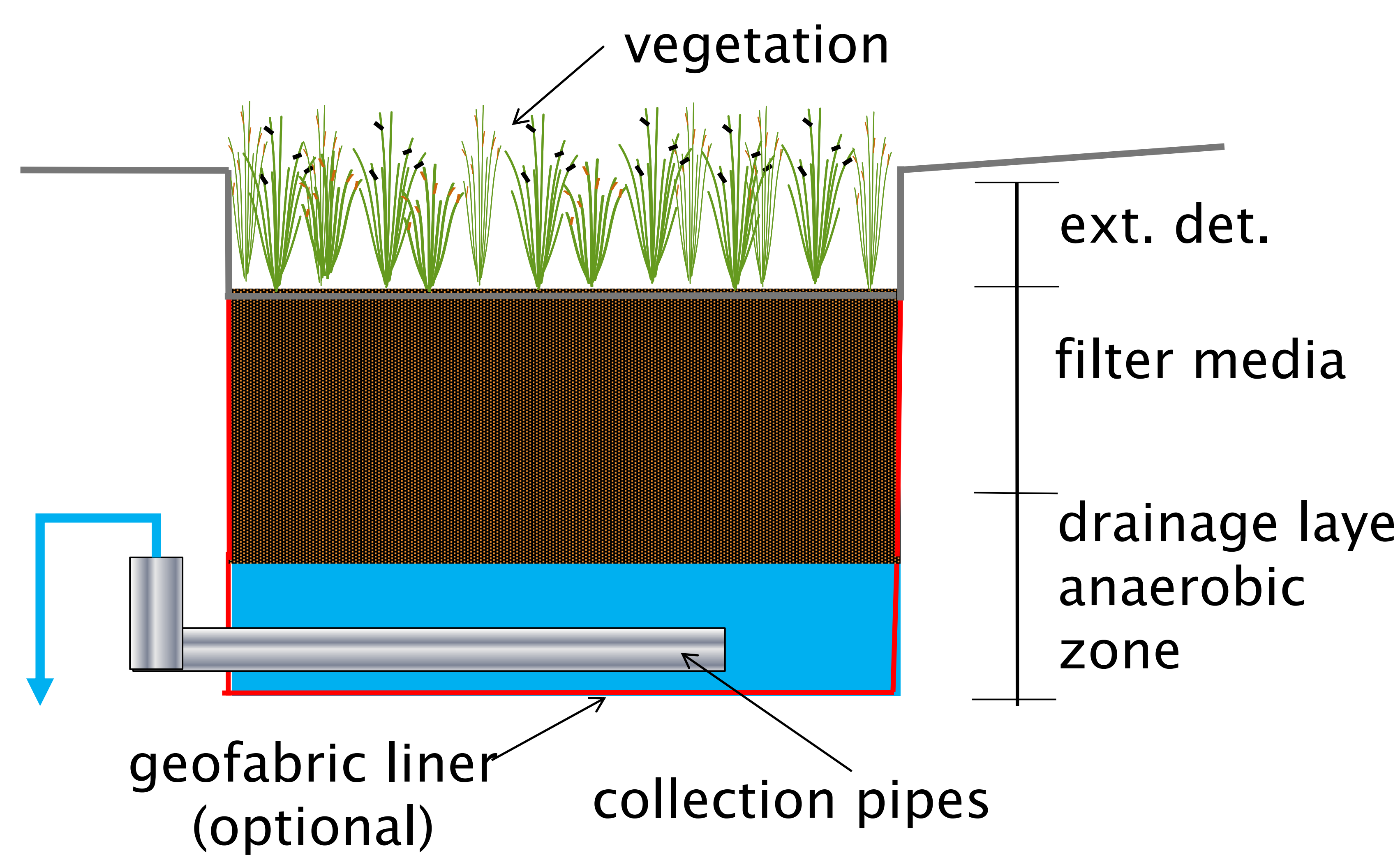
Swale



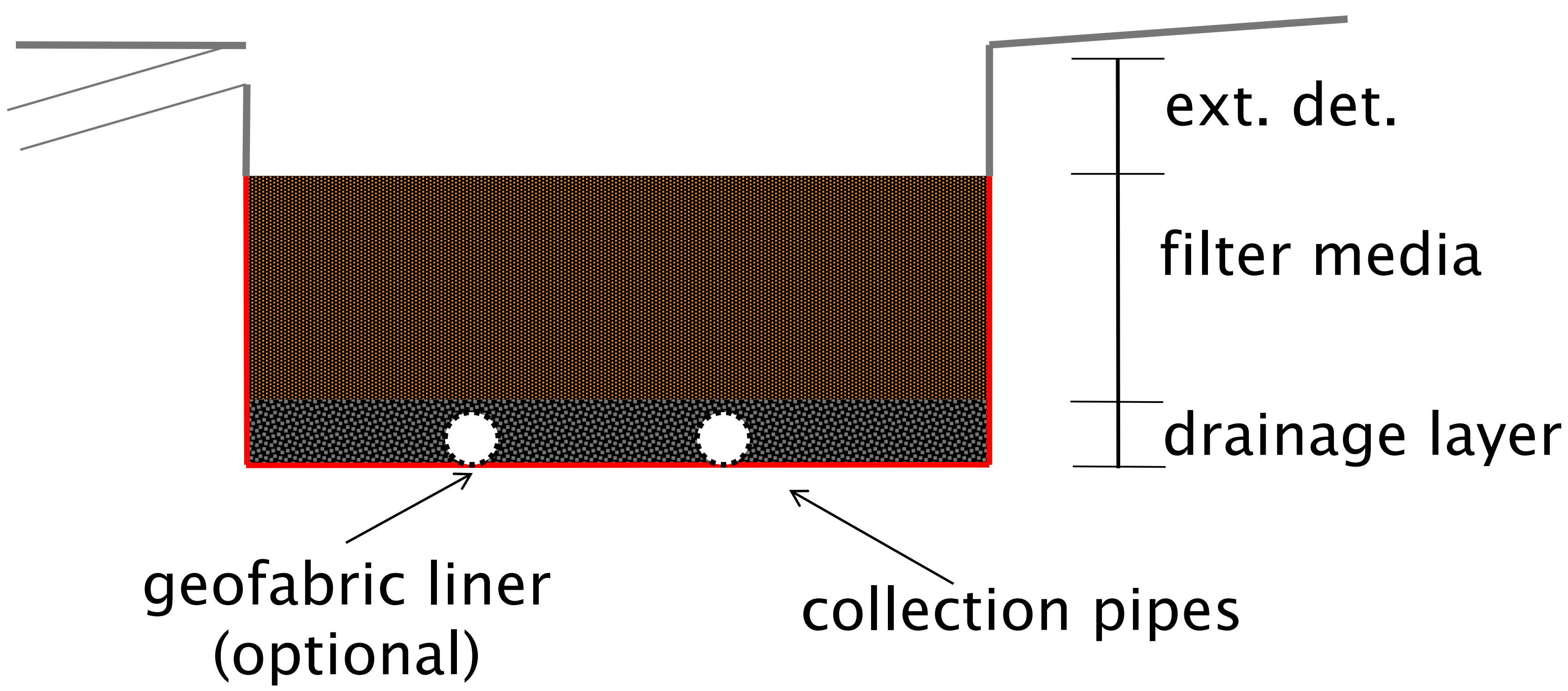
Wetland



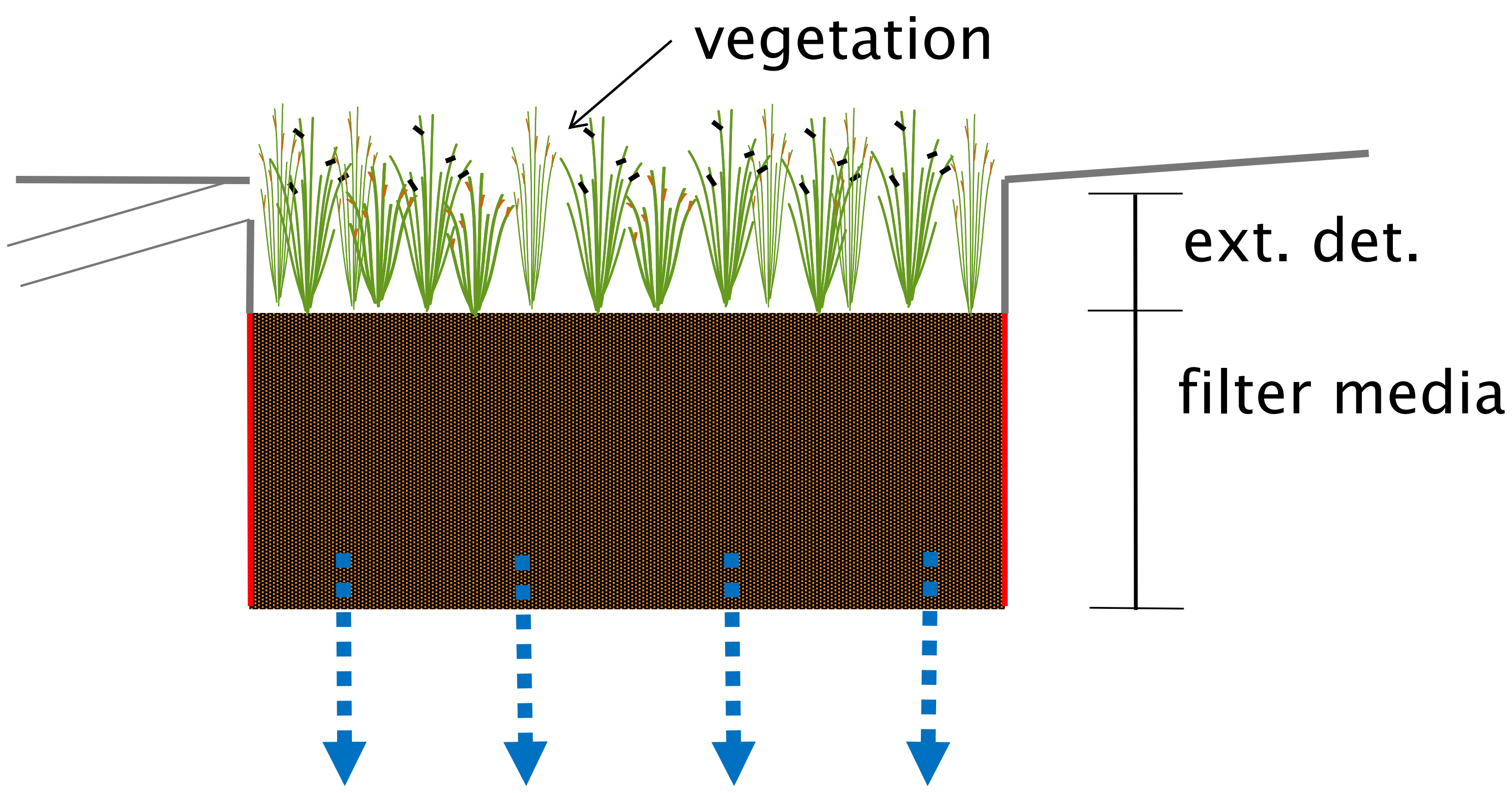
Biofilter with saturated zone



Sand Filter



Infiltration



Integration of scale for biofilters

Regional Scale

Hoyland St
(Brisbane)

Ascot Waters
(WA)

Lynbrook Blvd
(Lynbrook)

Batman Drv
(Melbourne Docklands)

Allotment Scale

Adelaide Museum
(SA)

Lt Bourke St
(Melbourne CBD)

Mernda Villages (Mernda)

Baltusrol Estate
(Melbourne)

What performance can we expect?

If designed properly vegetated, soil-based biofilters can reduce:

- > 95% of suspended solids,
- > 85% of total phosphorus,
- > 50% of total nitrogen (> 70% for some configurations)
- > 90% of heavy metals
- up to 80% pathogen removal

Combining WQ & flow management

Design features to help flow management:

- unlined wherever possible
- maximise opportunity for infiltration and evapotranspiration
- elevated outlet or no overflow only (infiltration)

Biofilter Design

Design will depend primarily on:

1. System objectives
   - ❖ Pollution control
   - ❖ Runoff reduction (volume, frequency)
   - ❖ Stormwater harvesting, etc

2. Site characteristics
   - ❖ Climate
   - ❖ Available size
   - ❖ Opportunities & constraints

Key findings from field studies

- Effective communication between designers and construction contractors is essential

- Maintenance requirements initially higher but reduce as vegetation grows (higher planting density helps)

CRC for Water Sensitive Cities

Australian Government
Department of Industry, Innovation and Science

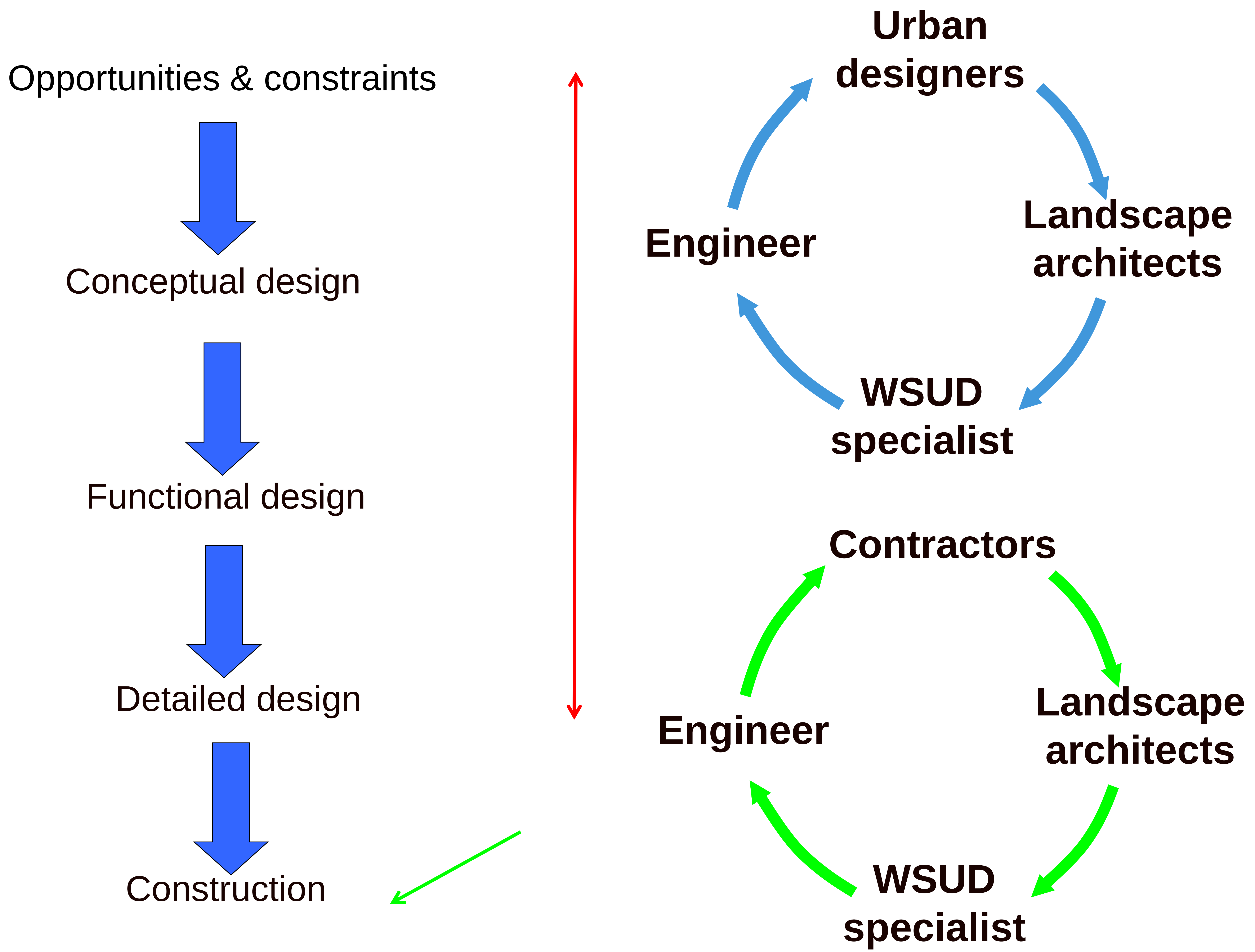
Business Cooperative Research Centres Programme

Biofilters:

Selection, sizing and functional design

watersensitivecities.org.au

Design Process



Opportunities and Constraints

- Landscape/urban design theme
- Treatment targets
- Water demands
- Catchment properties (size, flow rates, landuse)
- Site levels
- Existing drainage
- Space
- Soil properties (salinity, acidity)
- Urban design (e.g. solar orientation)

Opportunities and Constraints

Concept Design

STEP ONE: Select stormwater treatment measure(s)

- Biofilter / raingardens
- Wetlands
- Swales
- Ponds




Why might we choose a biofilter / raingarden?

- Attractive landscape features
- Self irrigating (and fertilising) gardens
- Habitat creation
- Potential source of water for reuse
- Not restricted by scale
- Integration with urban design (streetscape)
- Reduce impacts of urbanisation on hydrology
- Remove stormwater pollutants (protect receiving waters)

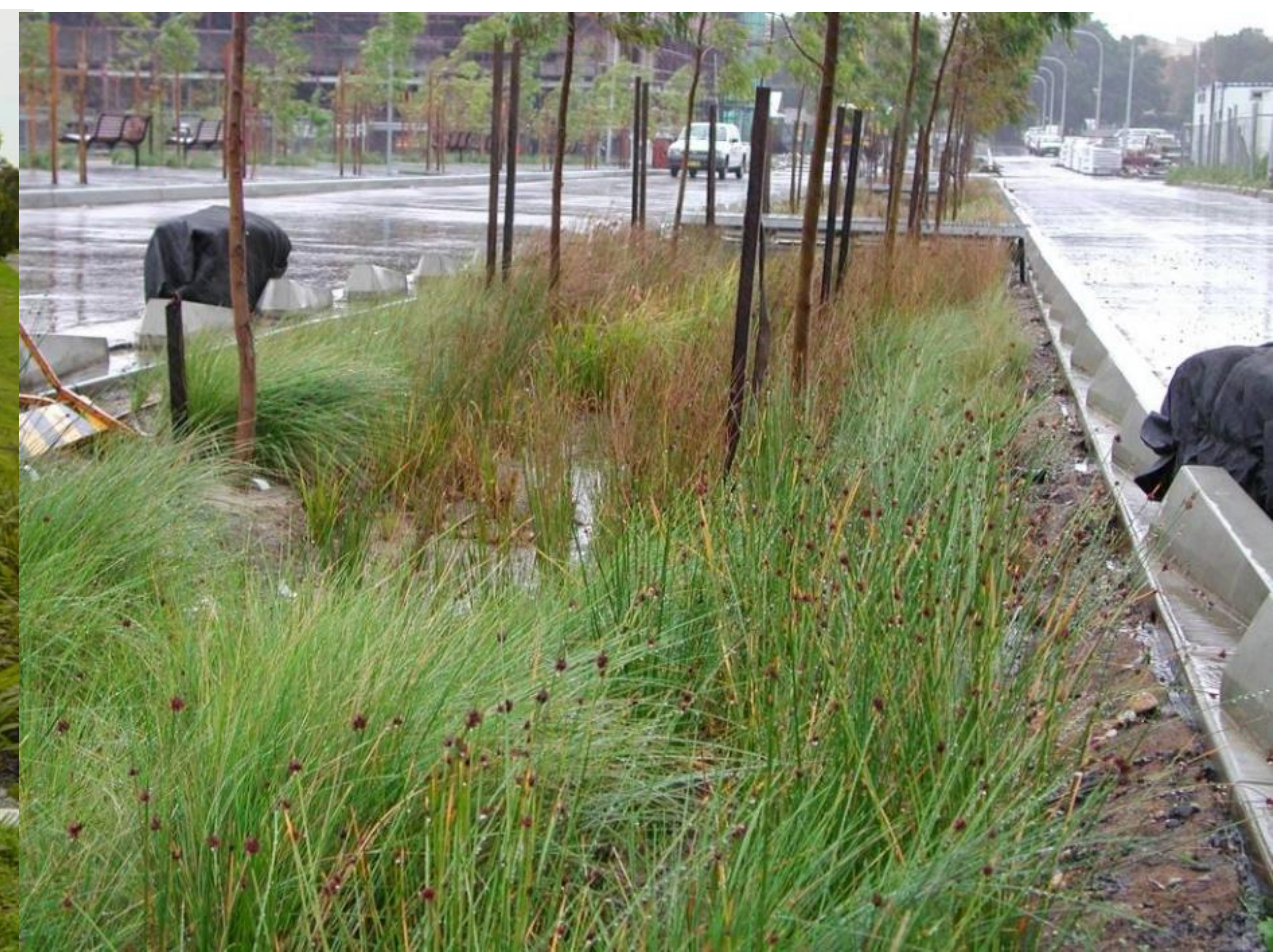


Treatment Measure	Potential benefits	Suitable site conditions	Unsuitable conditions	Application to small sites (<1000m^2)
Gross pollutant traps	Reduces litter and debris Can reduce sediment Pre-treatment for other measures	Conventional drainage systems	Sites larger than 100 ha Natural channels	Not suited due to need for periodic cleaning to maintain performance. Grated entry to drainage system can prevent gross pollutant contamination.
On-site infiltration	Reduced runoff Pollutant removal Passive irrigation	Sandy to sandy-clay soils (saturated hydraulic conductivity >36 mm/hr) Flat terrain (<2%) Deep groundwater table	Silty clay to clay soils Steep terrain Shallow groundwater table Saline groundwater Highly polluted runoff	Depends on soil drainage characteristics. Need to ensure that infiltration is below any footings in the vicinity.
Sediment basins	Coarse sediment capture Temporary installations Pre-treatment for other measures	Available land area	Proximity to airports, landfill	Unlikely that occupied site will generate suficient sediment to warrant sediment basin.
Rainwater tanks	Storage for reuse Sediment removal in tank Flood retardation	Proximity to roof Suitable site for gravity feed Incorporate to urban design	Non-roof runoff treatment	Particularly suited. Benefits increase if harvested water used for regular consumptive use – eg toilet flushing.
Vegetated swales	Medium and fine particulate removal Streetscape/landscape amenity Passive irrigation	Mild slopes (<4%)	Steep slopes	Potential landscape element as replacement/ substitute for other forms of drainage.
Buffer strips	Pre-treatment of runoff for sediment removal Streetscape/landscape amenity	Flat terrain	Steep terrain	Potential landscape element. Can make grassed areas environmentally beneficial.
Rain gardens	Fine and soluble pollutants removal Streetscape/landscape amenity Attenuate flows Passive irrigation	Flat terrain	Steep terrain High groundwater table	Potential landscape element as garden bed or planter box.
Ponds	Storage for reuse Fine sediment settling Flood retardation Community & wildlife asset	Steep terrain with confined valleys	Proximity to airports, landfill	Some scope as landscape element (eg incorporation of treatment pond with ornamental water feature). See also rainwater tanks.
Wetlands	Community asset Medium to fine particulate and Some soluble pollutant removal Flood retardation Storage for reuse Wildlife habitat	Flat terrain	Steep terrain High groundwater table Acid sulphate soils	Some scope as landscape element (eg incorporation of wetland treatment within ornamental water feature).
Retarding basins	Flood retardation Community asset	Available space	Limited available space Very flat terrain	See rainwater tanks.

CONCEPT DESIGN

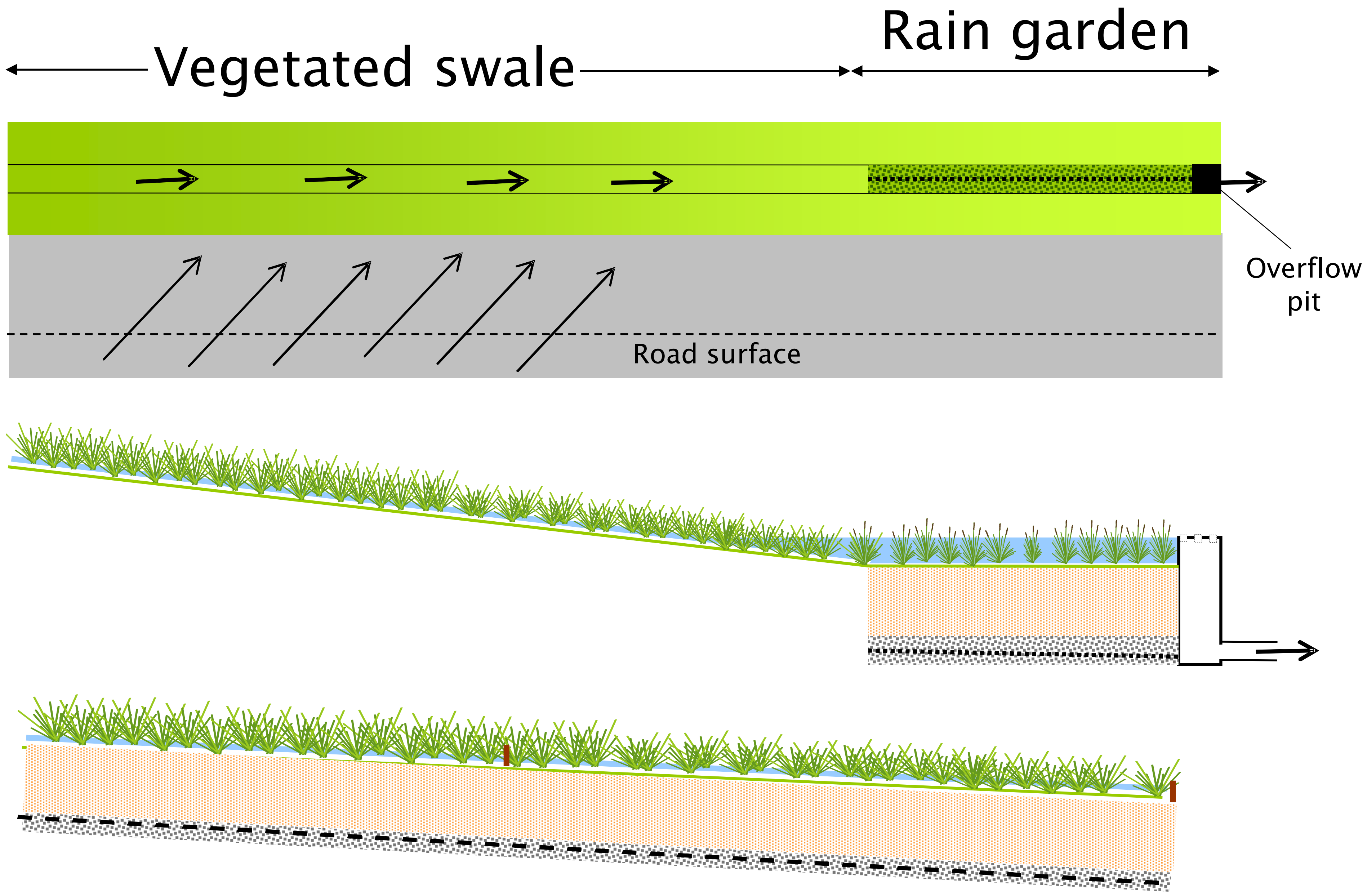
STEP TWO: Determine how treatment elements will be integrated with urban design

- Streetscape vs end of pipe
- Basins vs swales



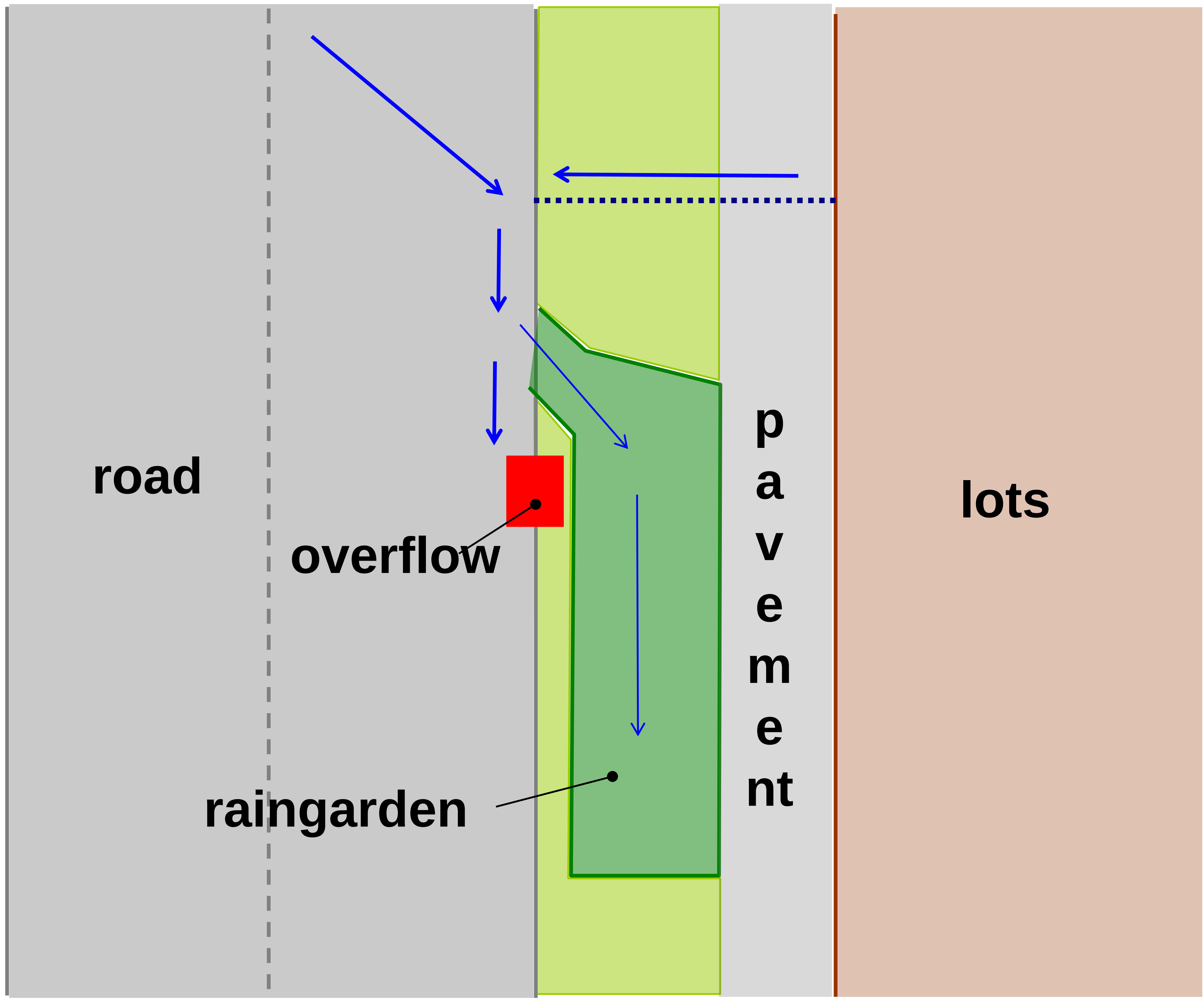
Bioswales

- Online (treatment and conveyance)
- Part or full length of swale
- Slope 1-4% (or check dams)



Raingarden basins

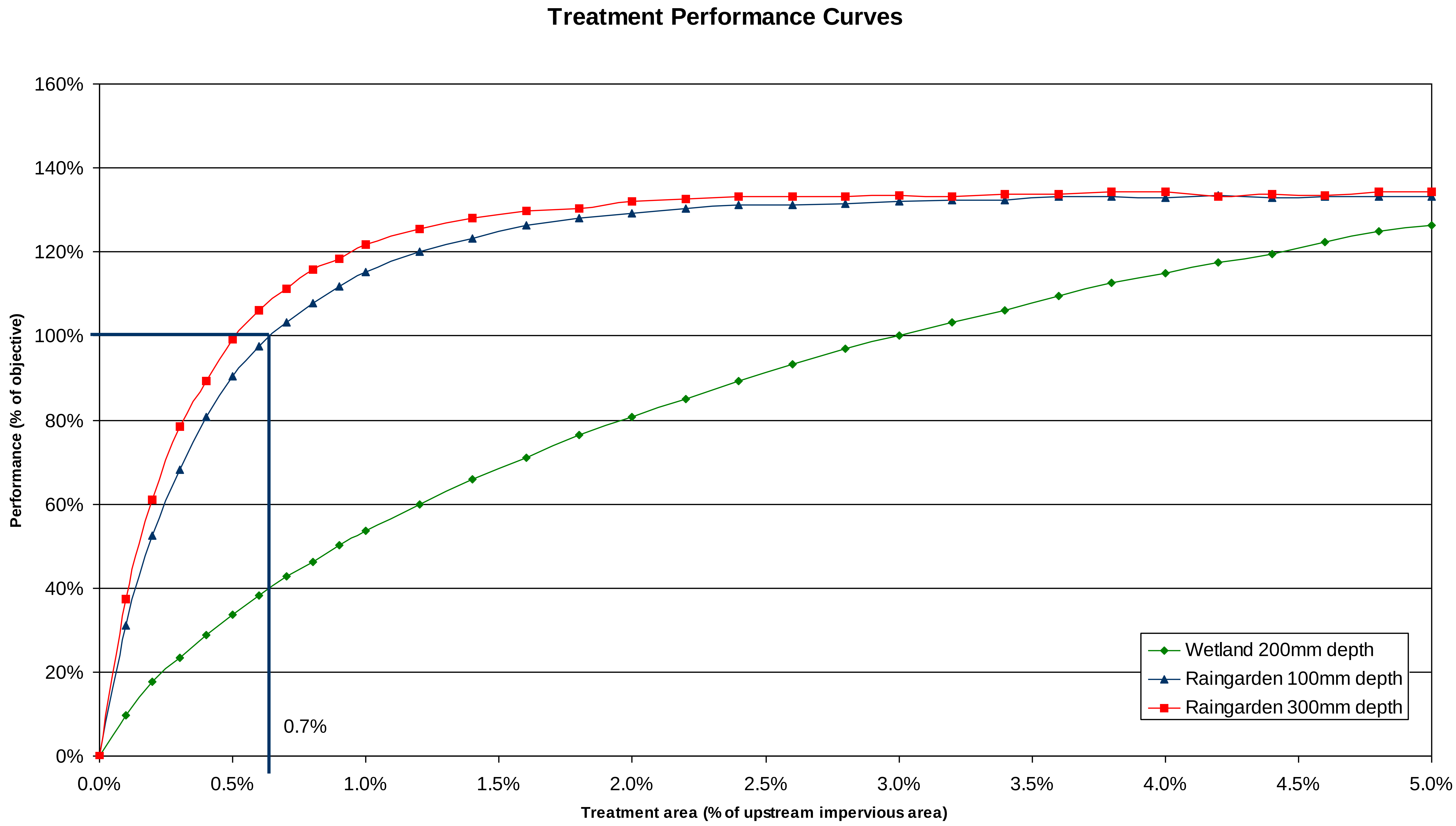
- Offline
- Less likely to scour
- Various scales
- Can provide a distributed retention or retarding function



CONCEPT DESIGN

STEP THREE: Size treatment measures

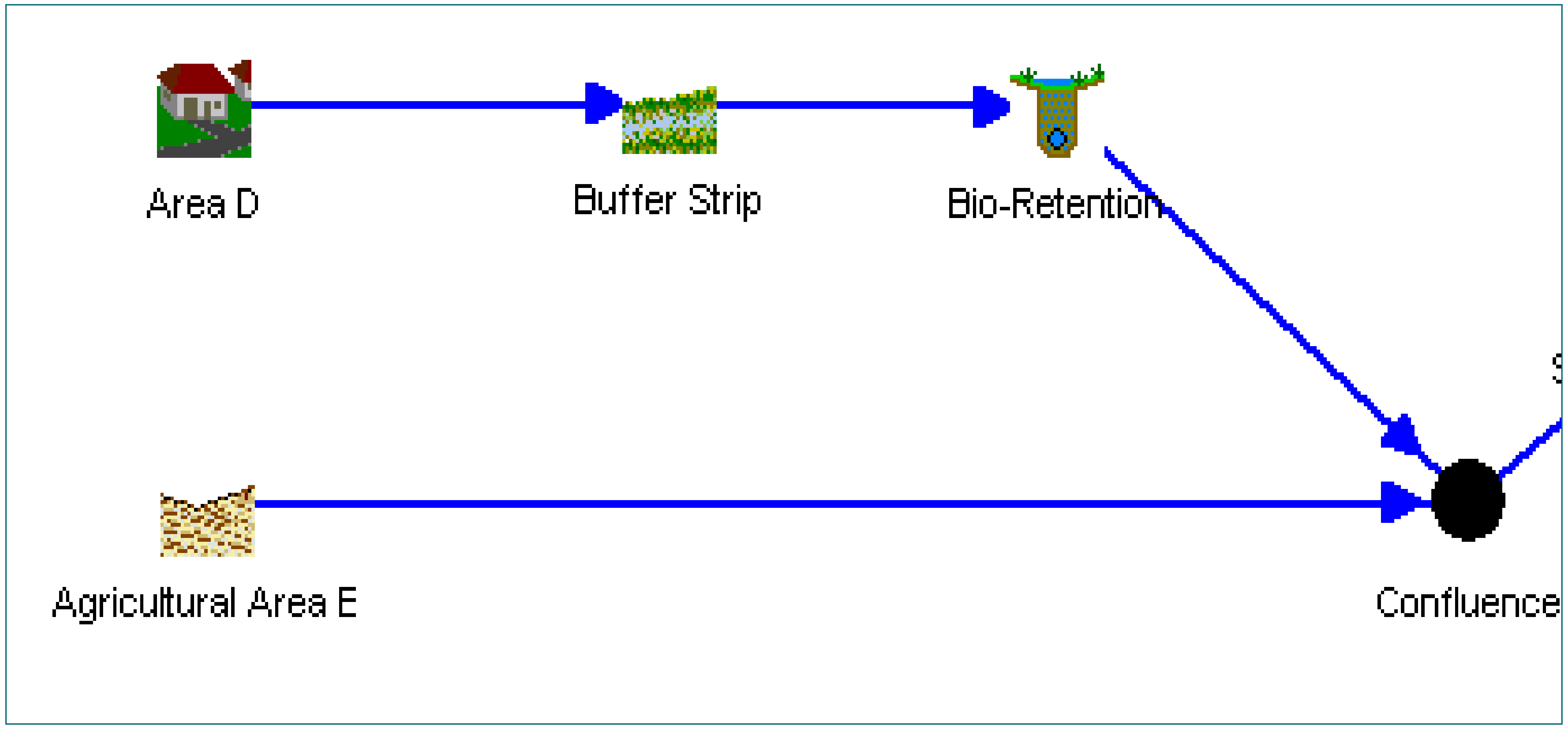
- Treatment Curves
- MUSIC

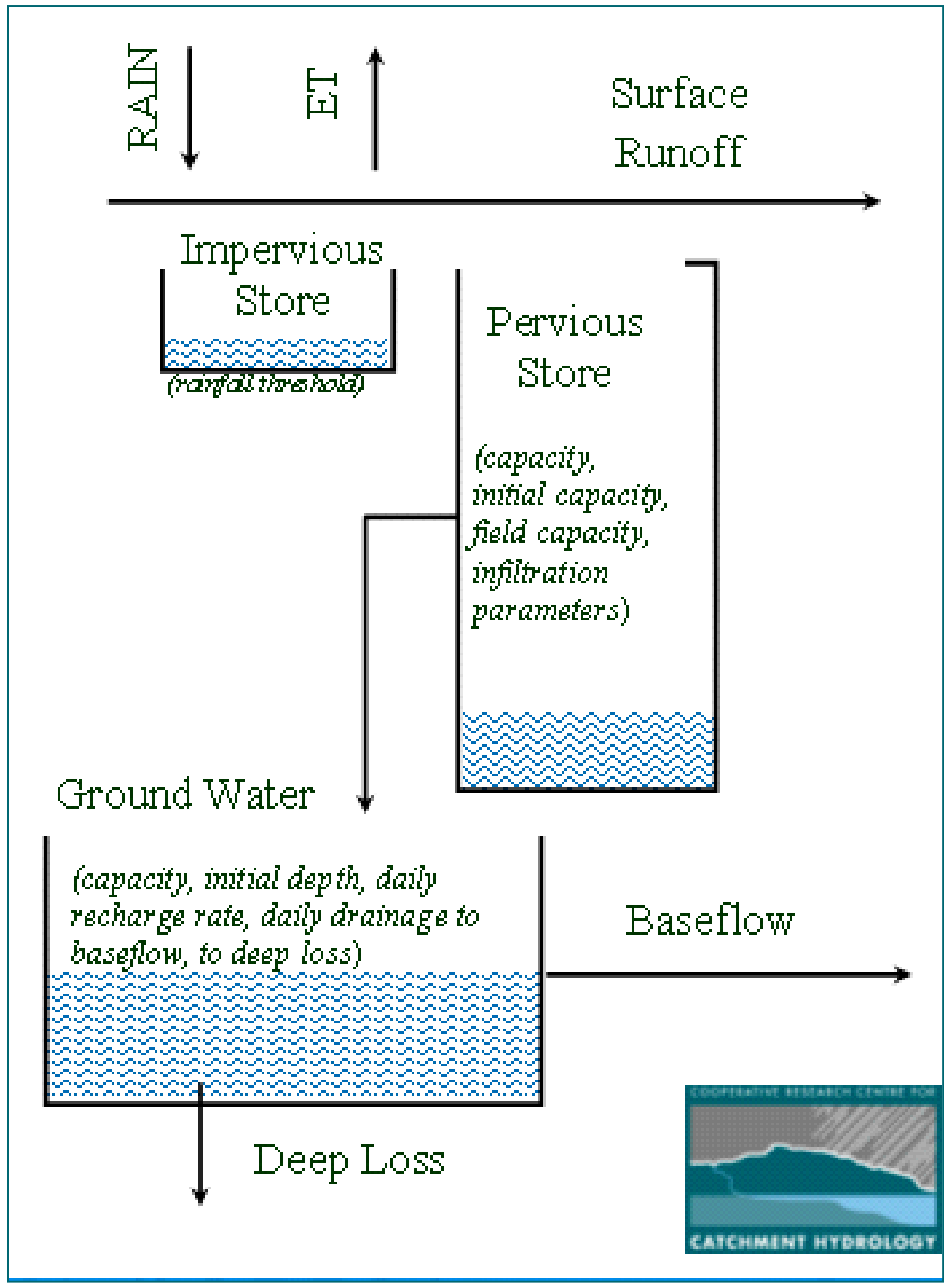


MUSIC

Stormwater quality model

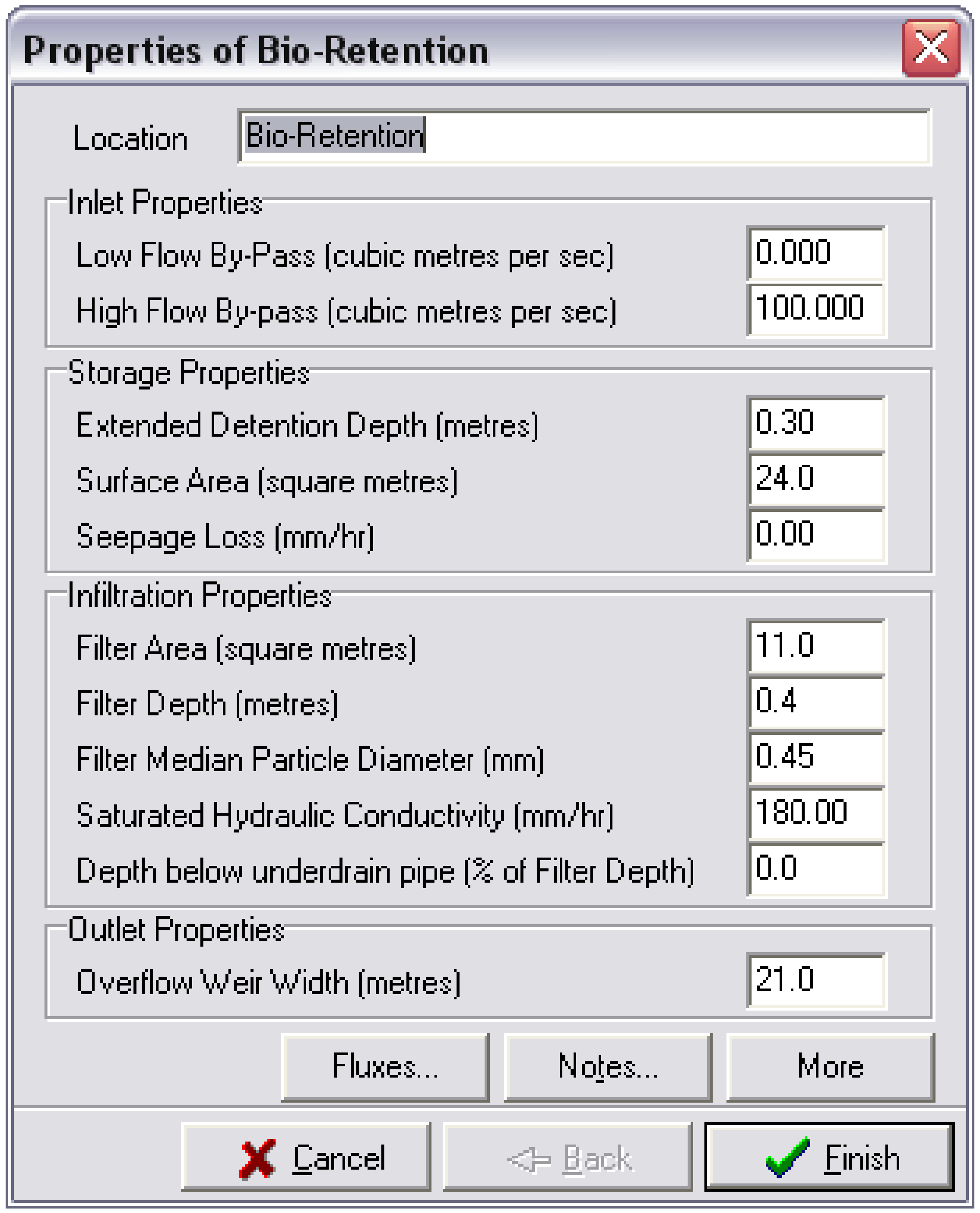
- Rainfall runoff
- Pollutant concentrations
- Storage and treatment



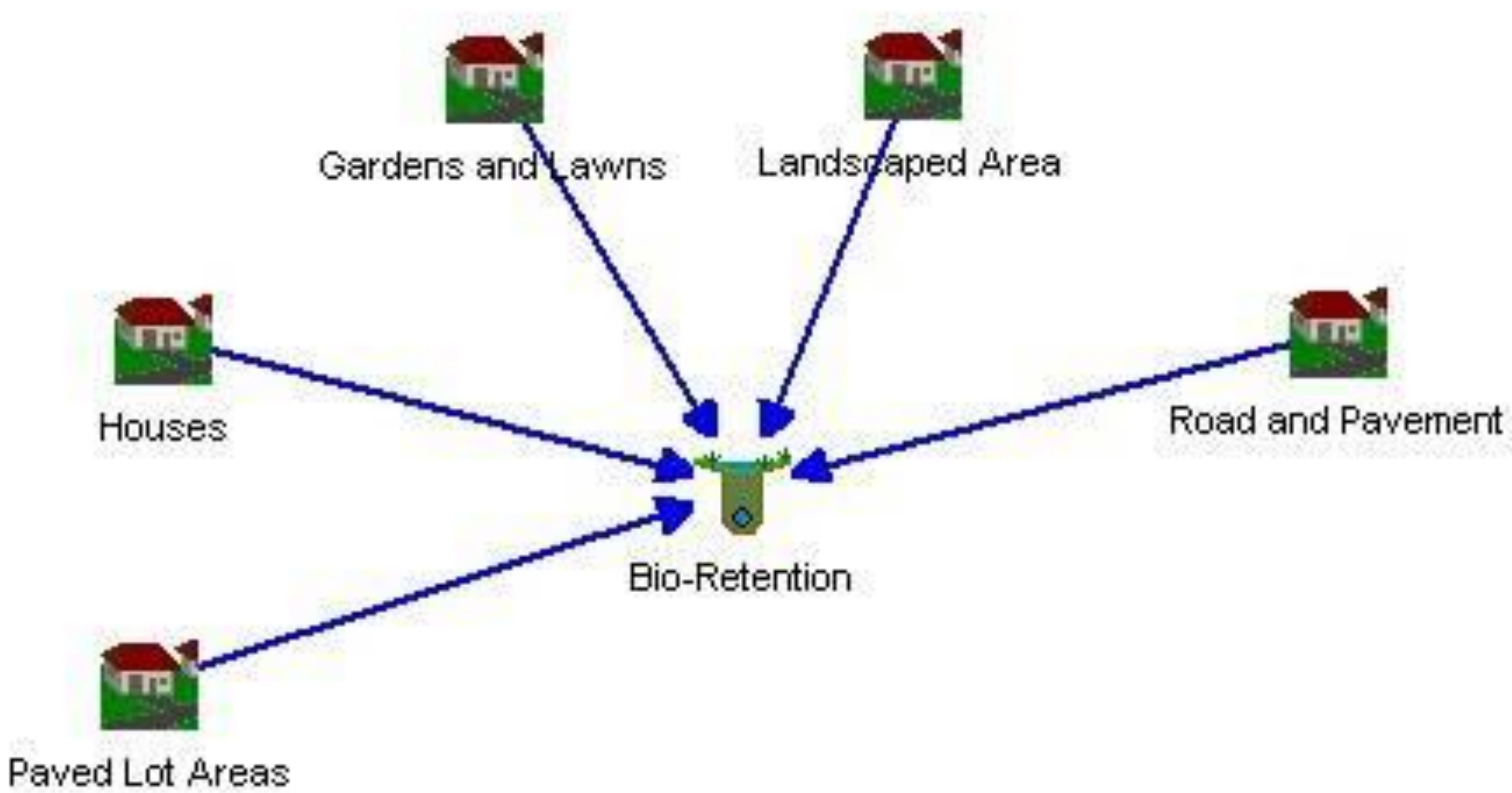


MUSIC - Inputs

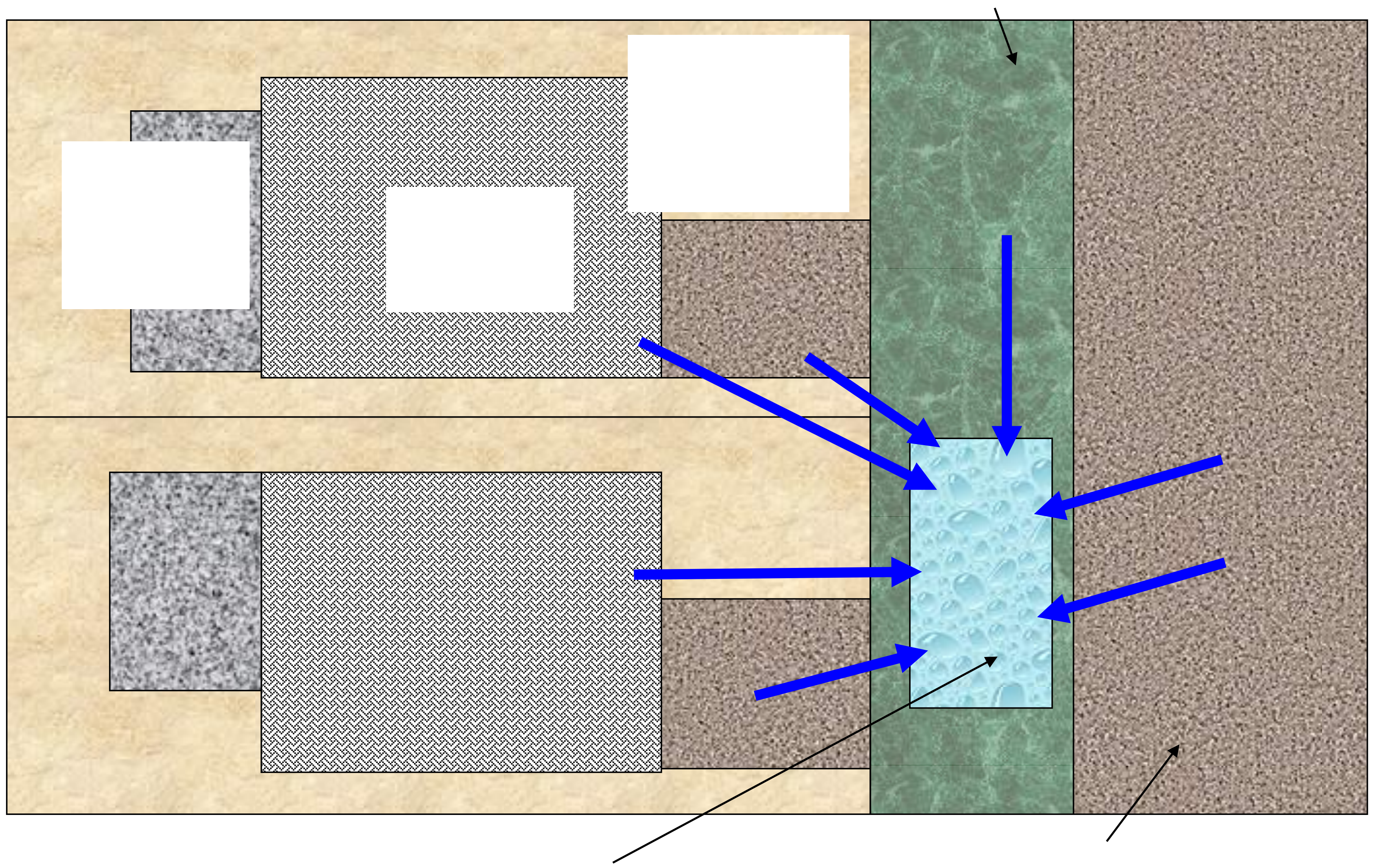
- Continuous rainfall data
- Catchment details
  - (area, impervious fraction, soils)
- Treatment system dimensions and characteristics



Sizing using MUSIC

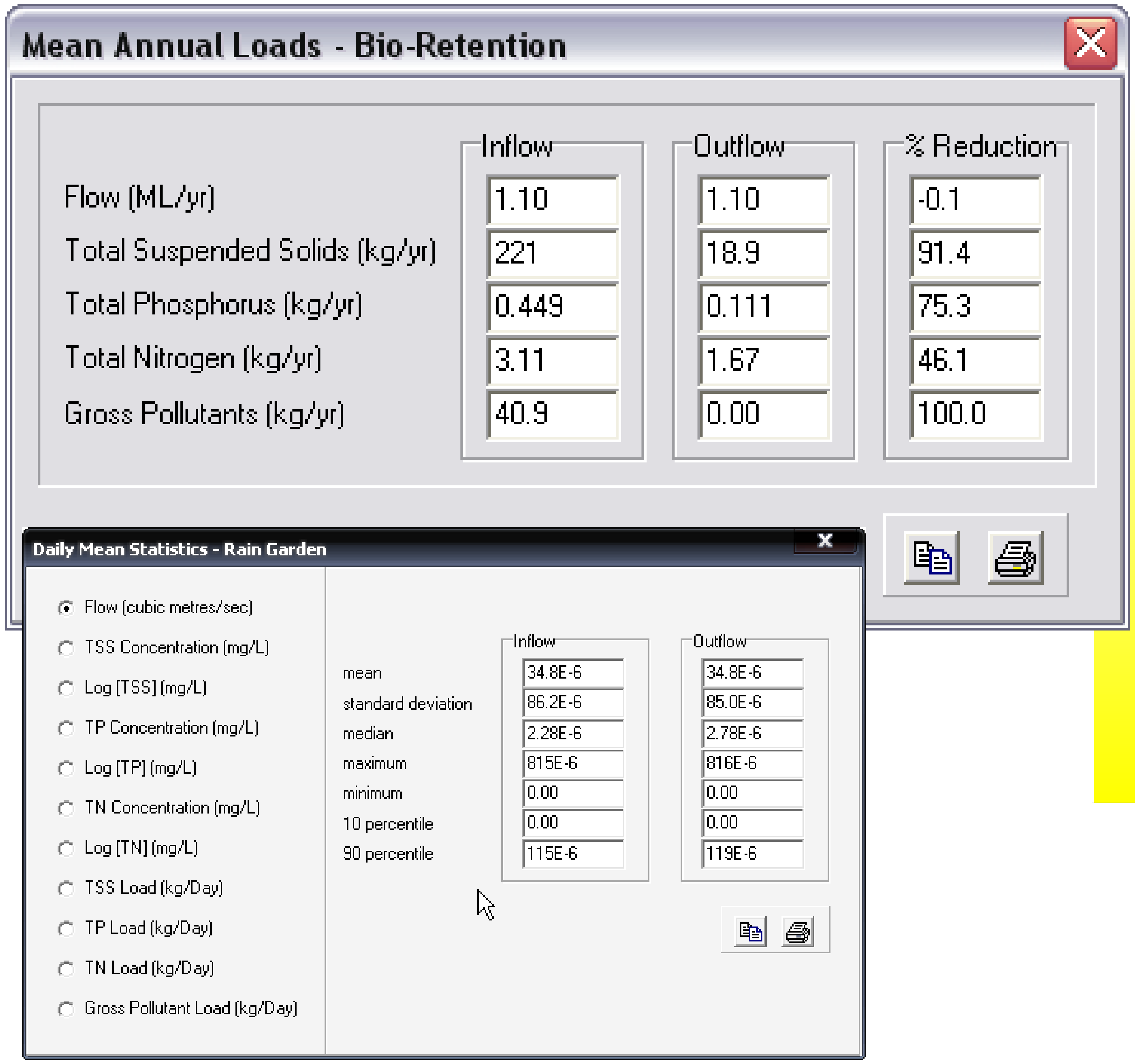


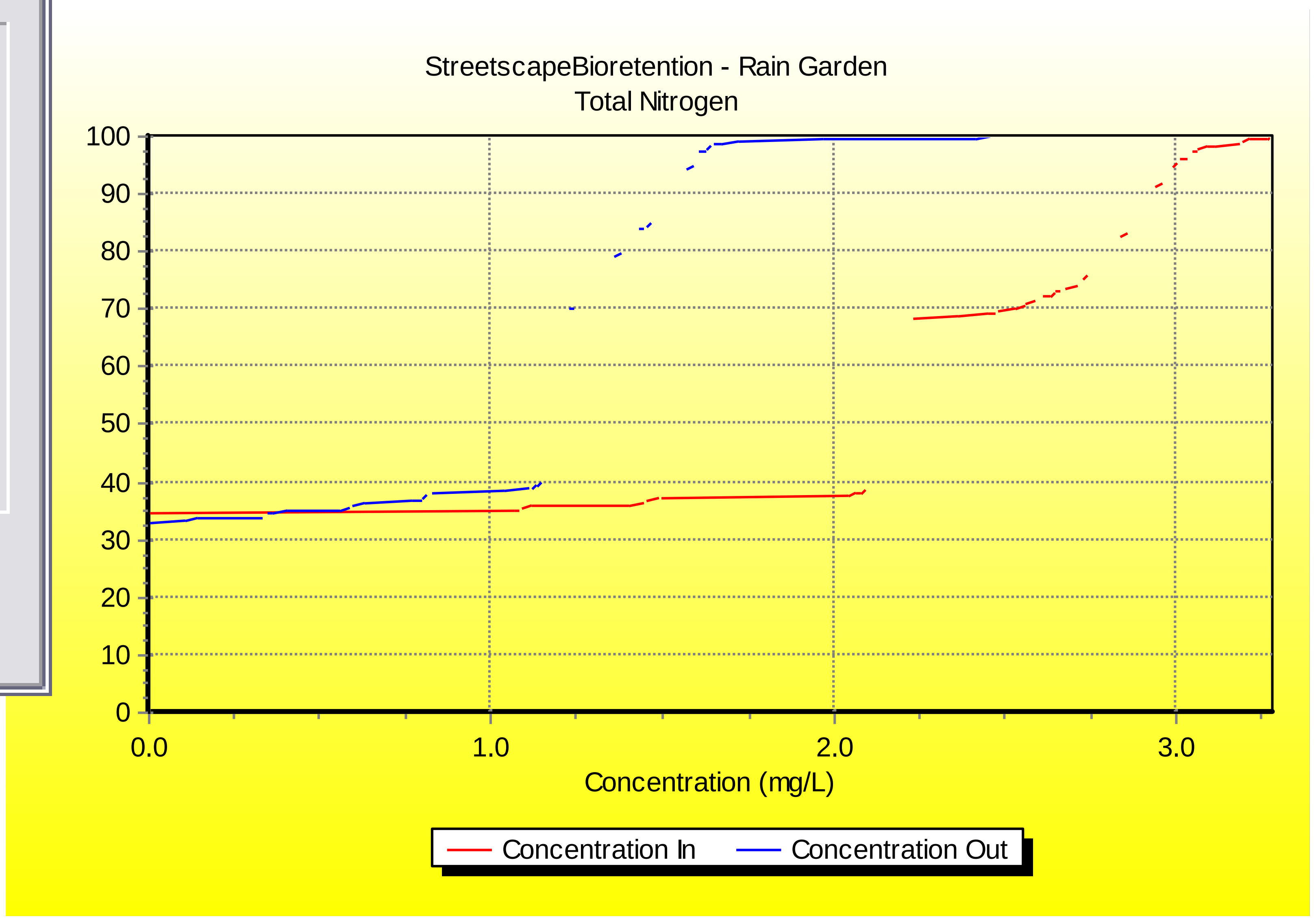
Stawell St, Melbourne, Browne 2005



MUSIC - Outputs

Predicts treatment performance for reducing pollutant concentrations and loads

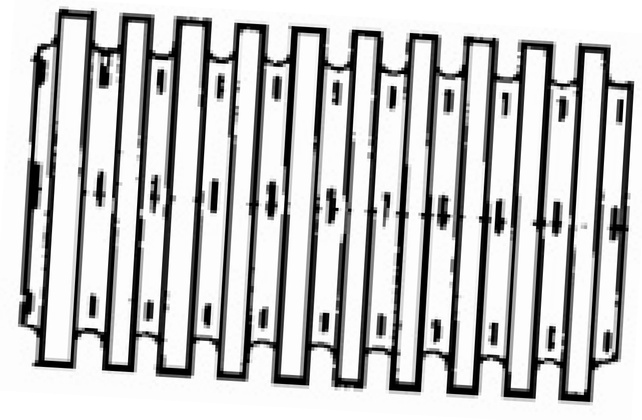




FUNCTIONAL DESIGN

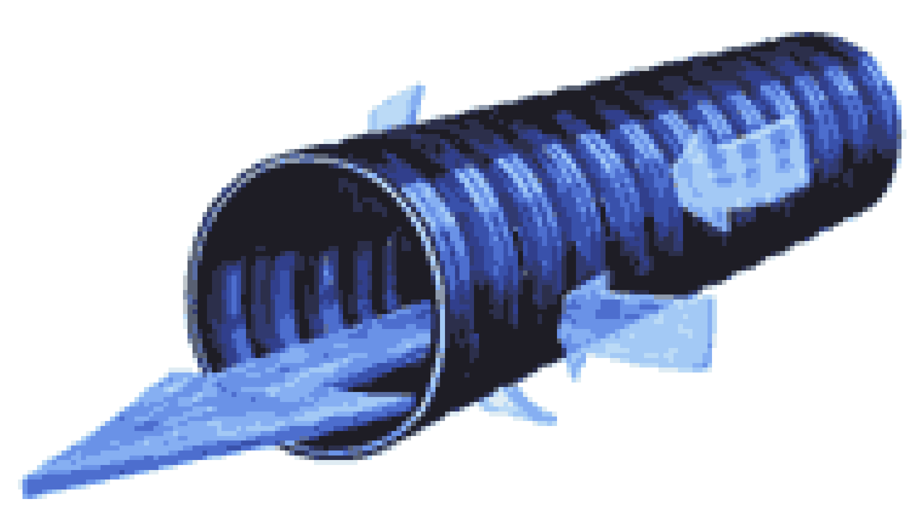
- Entry provision
- Overflow provision
- Edge treatments
- Drainage pipes

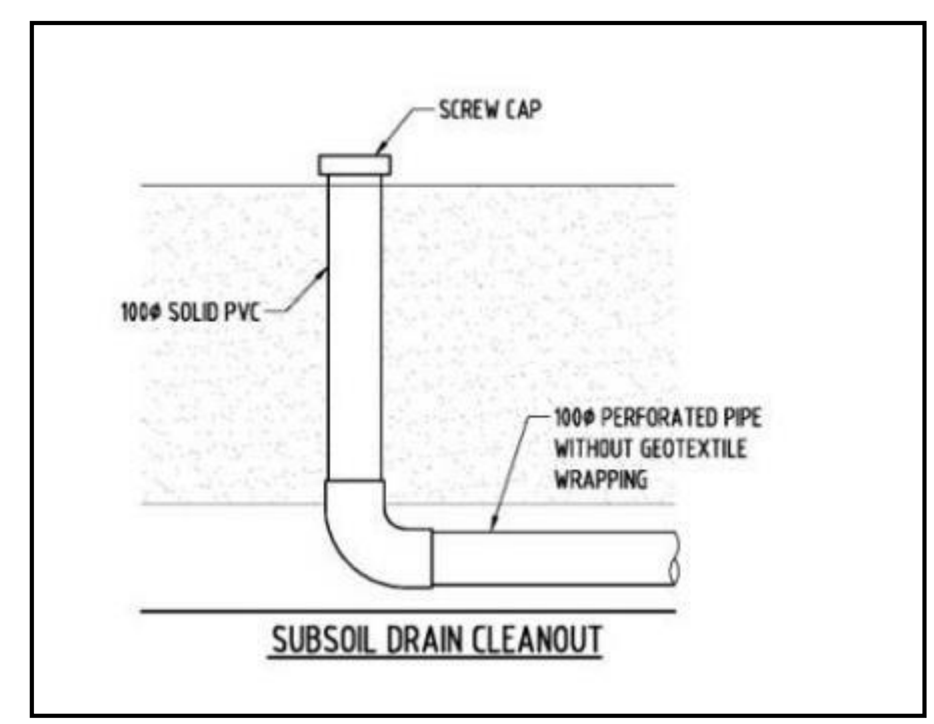
Drainage Layer



Pipes

- Capacity of perforations AND pipe must be higher than maximum infiltration rate through filter media (freely draining)
- Slotted pipes must have transition layer (slots bigger than perforations)
- Geofabric sock not recommended (clogging risk)
- Each pipe should extend to surface with inspection opening
- Maximum 1.5 m spacing





Tools in WSUD Engineering Procedures: Stormwater

Design assessment checklist example

Bioretention Basin Design Assessment Checklist					
Bioretention location:					
Hydraulics	Minor Flood: (m^3/s)		Major Flood: (m^3/s)		
Area	Catchment Area (ha):		Bioretention Area (ha)		
Treatment				Y	N
Treatment performance verified from curves?					
Inlet zone/hydraulics				Y	N
Station selected for IFD appropriate for location?					
Overall flow conveyance system sufficient for design flood event?					
Maximum upstream flood conveyance width does not impact on traffic amenity?					
Velocities at inlet and within bioretention system will not cause scour?					
Bypass sufficient for conveyance of design flood event?					
Bypass has set down of at least 100mm below kerb invert?					
Collection System				Y	N
Slotted pipe capacity > infiltration capacity of filter media?					
Maximum spacing of collection pipes <1.5m?					
Transition layer/geofabric barrier provided to prevent clogging of drainage layer?					
Basin				Y	N
Maximum ponding depth will not impact on public safety?					
Selected filter media hydraulic conductivity > 10x hydraulic conductivity of surrounding soil?					
Maintenance access provided to base of bioretention (where reach to any part of a basin >6m)?					
Protection from gross pollutants provided (for larger systems)?					
Vegetation				Y	N
Plant species selected can tolerate periodic inundation?					
Plant species selected integrate with surrounding landscape design?					
Detailed soil specification included in design?					

Design Process

Concept Design

» Opportunities and constraints

» Choose a system

» Integration with urban design

» Sizing

Functional Design

» Entry

» Overflow

» Edges

» Drainage pipes

» Checklists

Detailed Design

» Plans

» Follow through from functional design

Stringybark Creek infiltration

Construction activities can impact on maintenance requirements

Protect system during construction and establishment of landscaping features

Inspection before handover

Asset Handover Checklist		
Asset Location:		
Construction by:		
Defects and Liability Period		
Treatment	**Y**	**N**
Actual treatment performance equivalent to design?		
Maintentance	**Y**	**N**
Maintentance plans provided for each asset?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
Asset inspected for defects?		
Asset Information	**Y**	**N**
Design Assessment Checklist provided?		
As constructed plans provided?		
Copies of all required permits (both construction and operational) submitted?		
Proprietary information provided (if applicable)?		
Digital files (eg drawings, survey, models) provided?		
Asset listed on asset register or database?		

CONSTRUCTION TIPS

- The design can be counter-intuitive to contractors
- Brief contractors so they understand the concept of nature-based solutions
- Perform site visits by someone who understands functional intent and key points during construction phase
- Good construction will result in good performance and low maintenance







CRC for Water Sensitive Cities

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

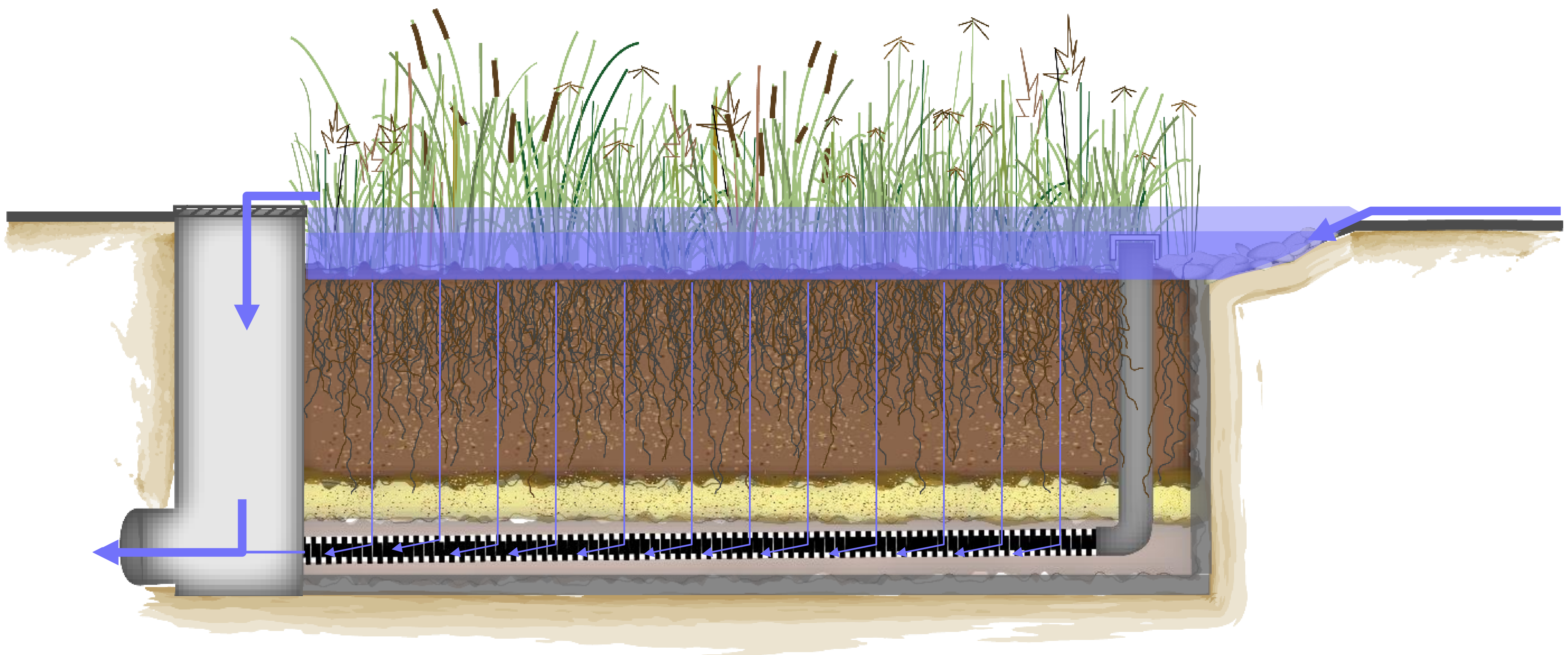
Biofilters:

Filter media, vegetation and maintenance

watersensitivecities.org.au

Drainage layers and filter media

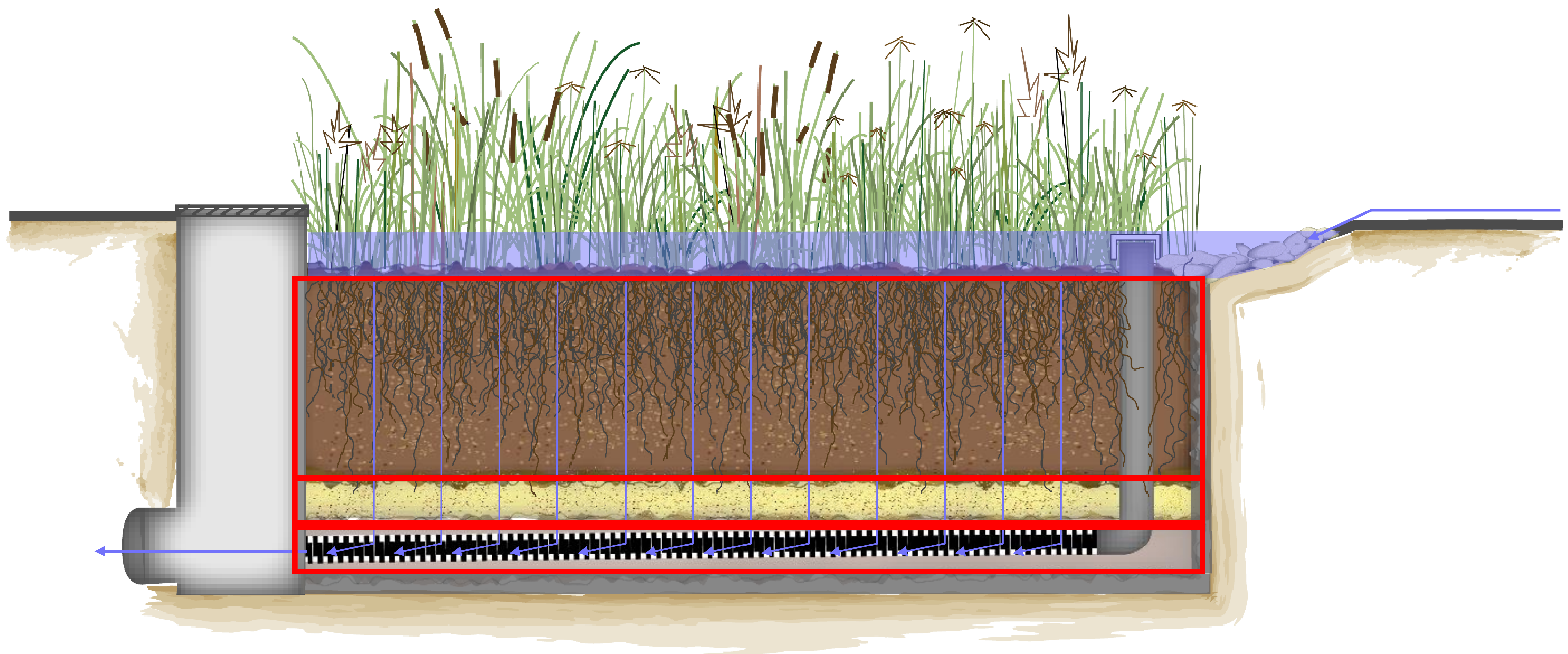
▸PRIMARY DESIGN OBJECTIVE: **Pollutant removal**



Filter media and drainage layers influence pollutant removal efficiency by:

- Maintain healthy plant growth
- Control hydraulic conductivity
- Prevent leaching of pollutants

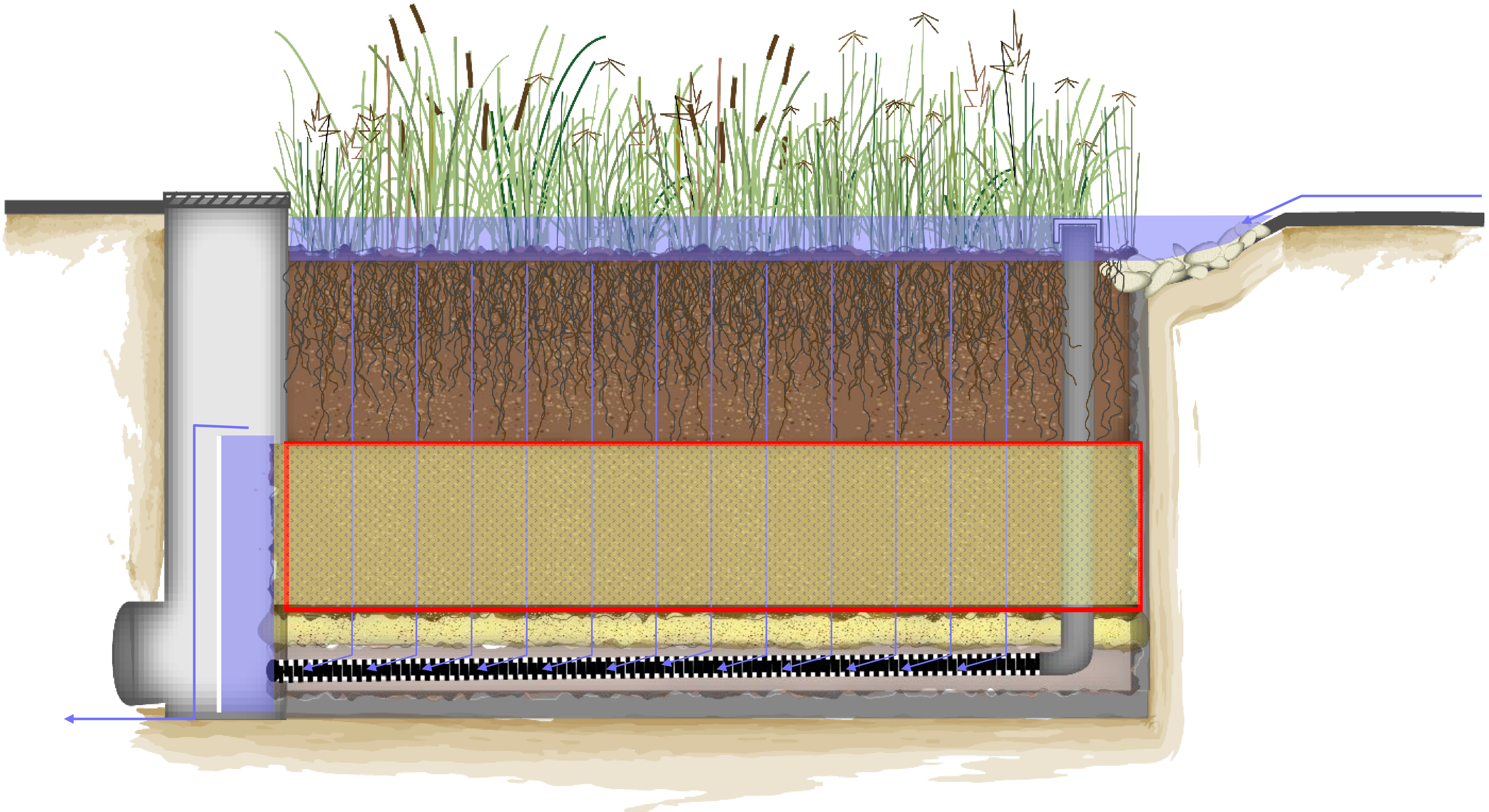
Drainage layers and filter media



For systems without a Saturate Zone (SZ), there are three important components:

1. Filter media
2. Transition layer
3. Drainage layer

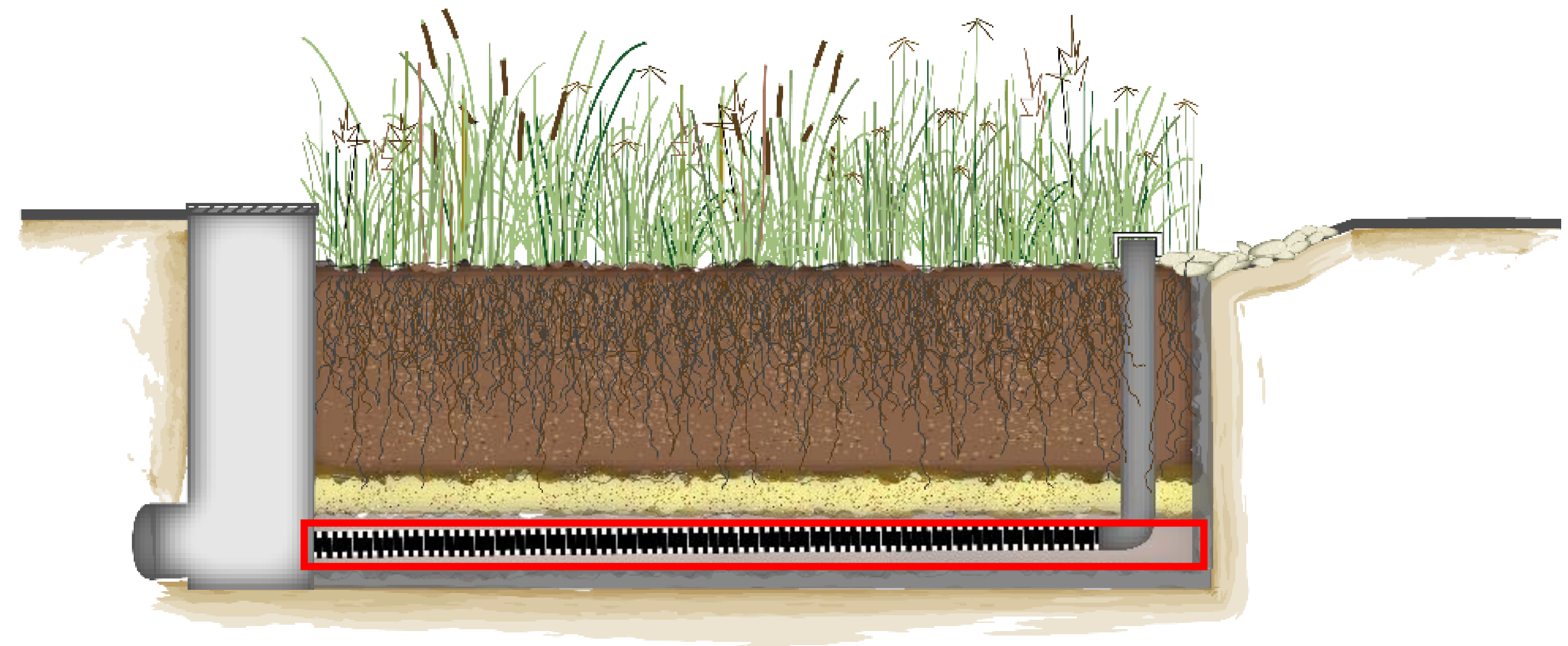
Drainage layers and filter media



For systems with a saturated zone (SZ), there is also:

4. SZ filter media

Drainage Layer



Important Functions

Prevent loss of filter media

Holds perforated drainage pipes

General Characteristics

2-5 mm screenings

Fine gravel, or

Future - crushed recycledconcrete
- more sustainable if available
- must be washed

Transition Layer

Important function

Prevents migration of filter media into drainage layer

General Characteristics

Sand/coarse sand

Indicative particle size (% passing)

1.4 mm	(100 %)
1.0 mm	(80 %)
0.7 mm	(44 %)
0.5 mm	(8.4 %)

CRC for
Water Sensitive Cities

Filter Media

KEY DESIGN OBJECTIVES:

Supporting healthy plant growth – and therefore good root growth

Maintaining hydraulic conductivity over time – and therefore maintain treatment efficiency

Reducing leaching potential – particularly nutrients

SAZ Filter Media

Course sand – (may not require additional transition layer)

Carbon source

- Short term – e.g. pea straw
- Long term – e.g. hardwood chips (approx. 6mm grading)

Volume of Carbon source calculated based on C:N ratio expected in stormwater

- Approx. 5% by volume

Typical Recipe

98 L sand (by volume)
500 g pea straw
1.5 kg red gum woodchips

Important design consideration - GEOFABRIC

Geotextile fabrics not recommended anywhere within the soil profile or around drainage pipes

Role of vegetation

Research to date has demonstrated the importance of vegetation for raingardens. Some of the important functions of plants include:

- Direct pollutant uptake
- Facilitation of other physical and chemical processes to remove nutrients
- Prevents erosion of the soil media
- Maintains hydraulic conductivity (Ksat) of the filter media

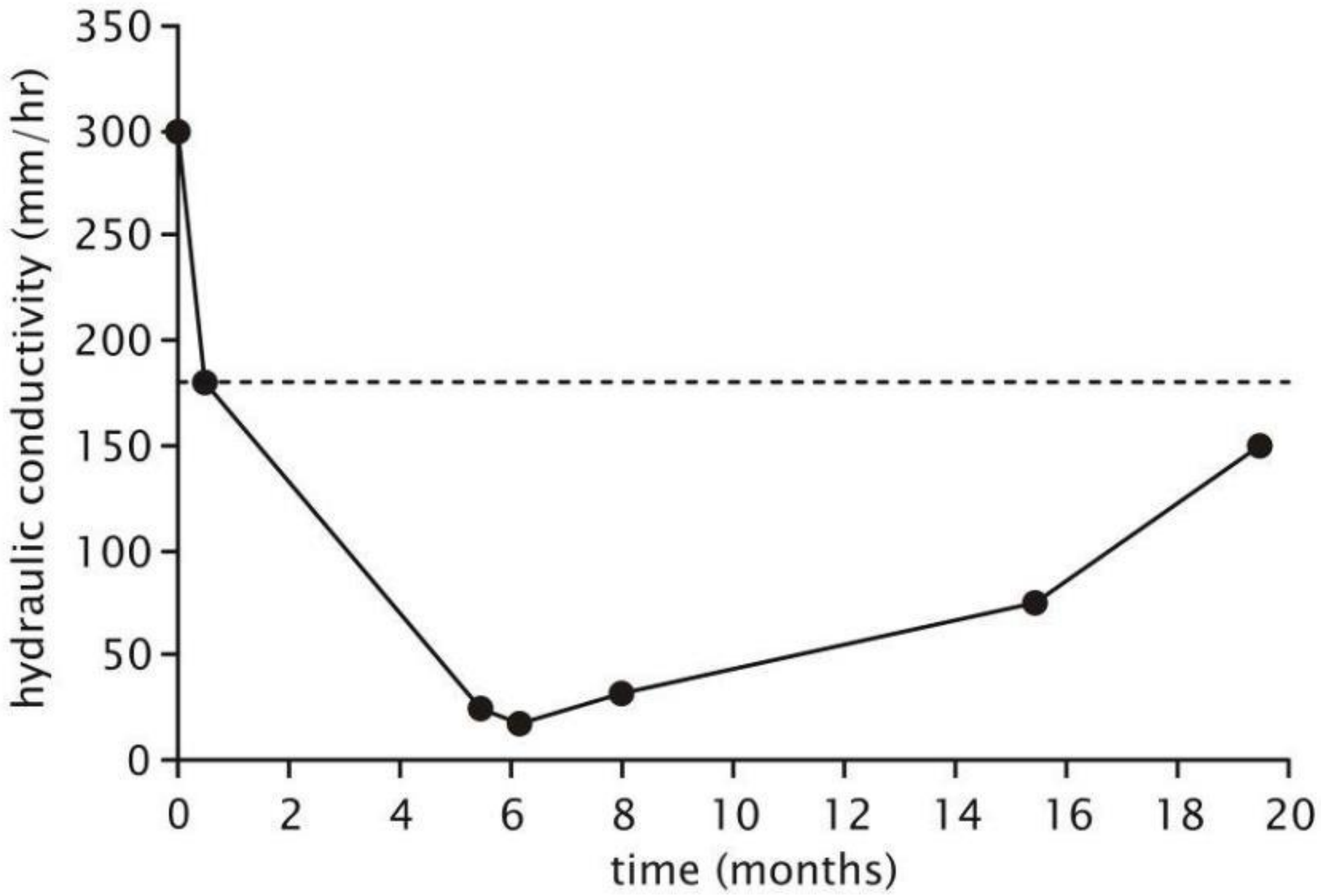


Figure A.1 Evolution of hydraulic conductivity during the first 20 months of a bioretention system

Selecting appropriate plant species

- Assess hydrologic requirements of the plants
- Drought tolerant – subject to extended dry periods
- Tolerant of freely draining sandy soil
- Tolerant of occasional inundation

Selecting appropriate plant species

- Growth form
- Extensive fibrous root structures
- Not shallow rooted
- Avoid clumping structures such as bulbs or large corms
- Dense linear foliage with spreading growth form rather than clumping

Dense planting (6-10 plants/m2)

High densities increase root densities, protect surface porosity, promote even distribution of flows, increases evaporative losses

Range of species

» increases robustness

» accounts for variability in nutrient removal other processes

Range of growth forms

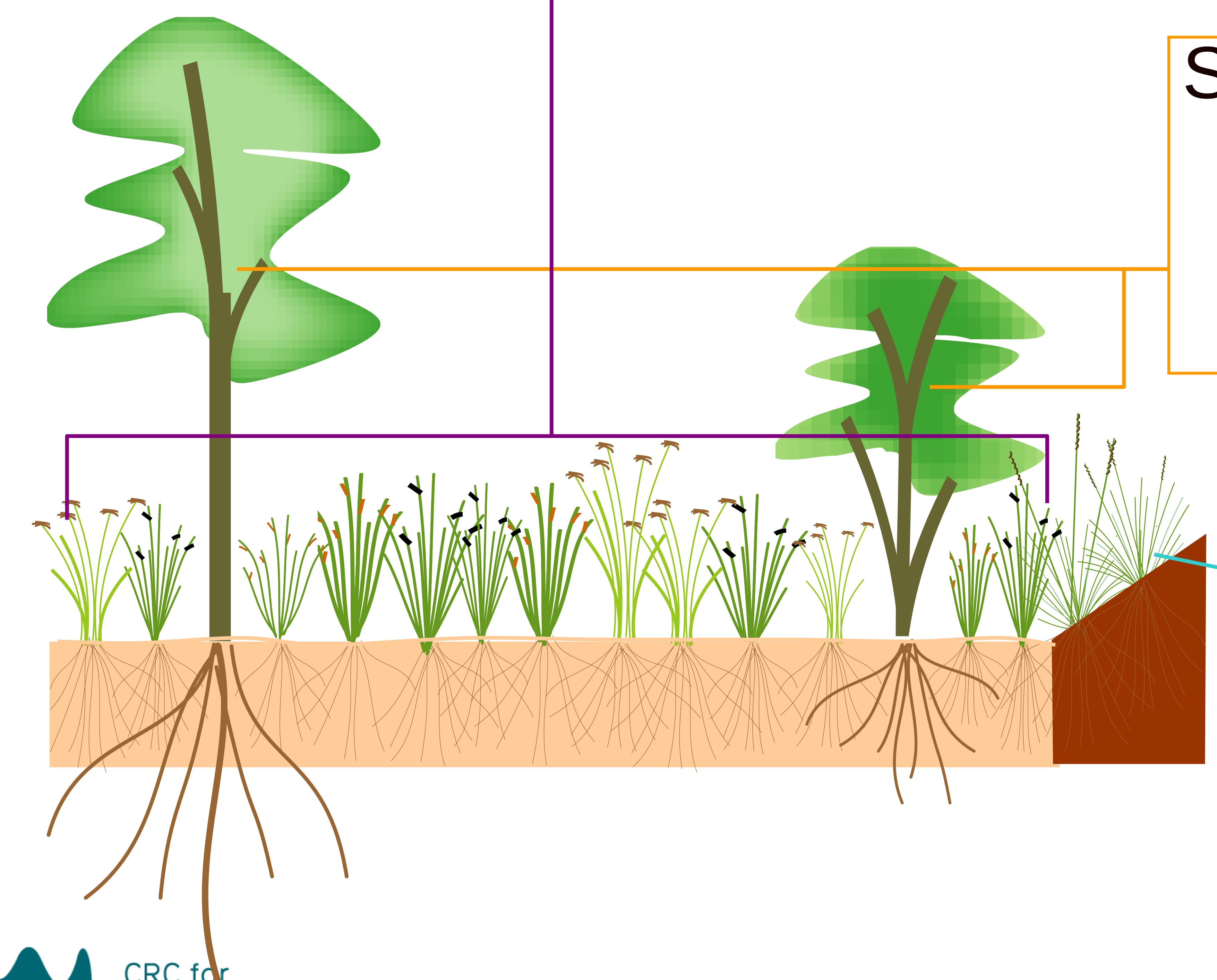
Layout of vegetation

Dominant Species

- Extensive planting
- 6-10 plants/m^2 depending on plant growth form

Shrubs and trees

- Occasional planting according to landscape requirements
- <1 plant/m^2



Batter planting

- Drier species


Raingarden
Typical garden bed

What is the objective of long term maintenance?

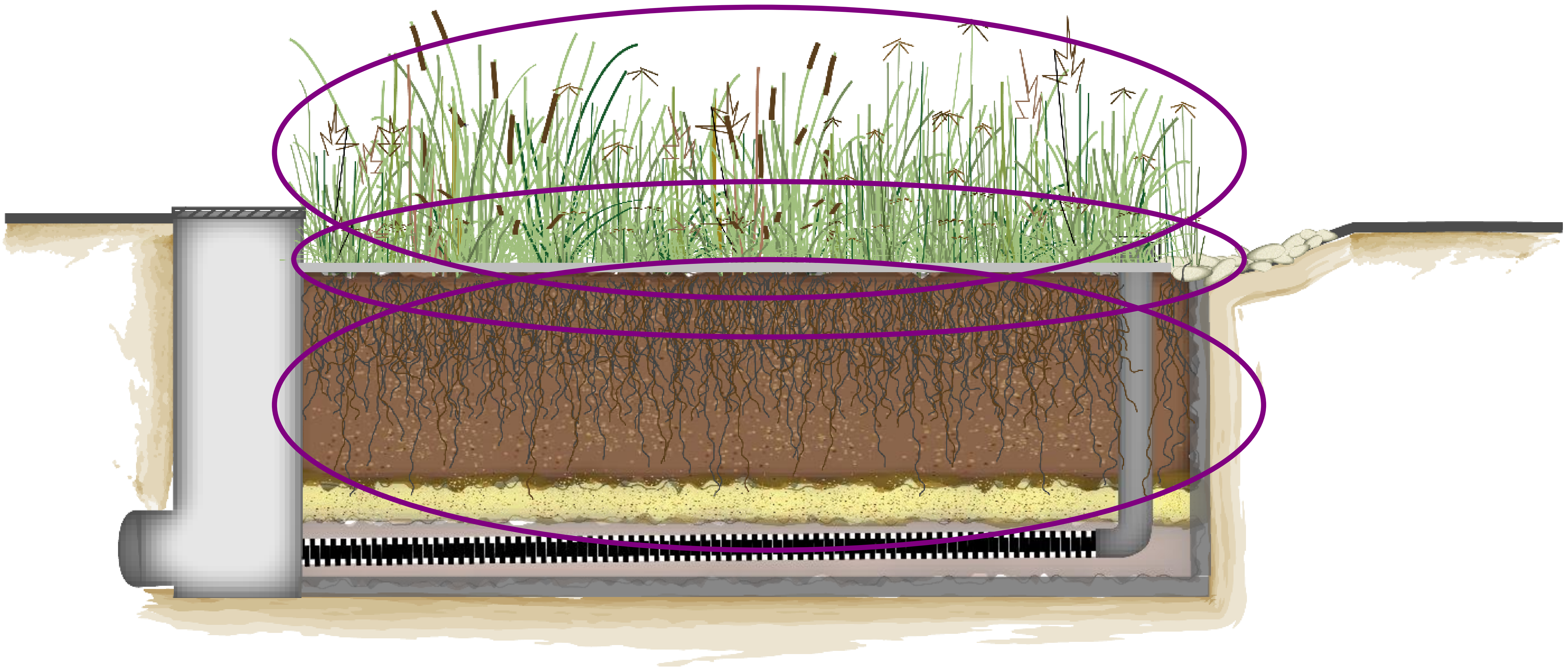
- To maintain treatment function
  - ✓ For pollutant removal efficiency
- To maintain aesthetics
  - ✓ Varies between sites, budgets etc

Key elements to long term function

Three elements key elements in design and construction

1. Appropriate filter media
2. Dense vegetation cover
3. Protection from sediment during construction

Result - Long tem maintenance is predictable



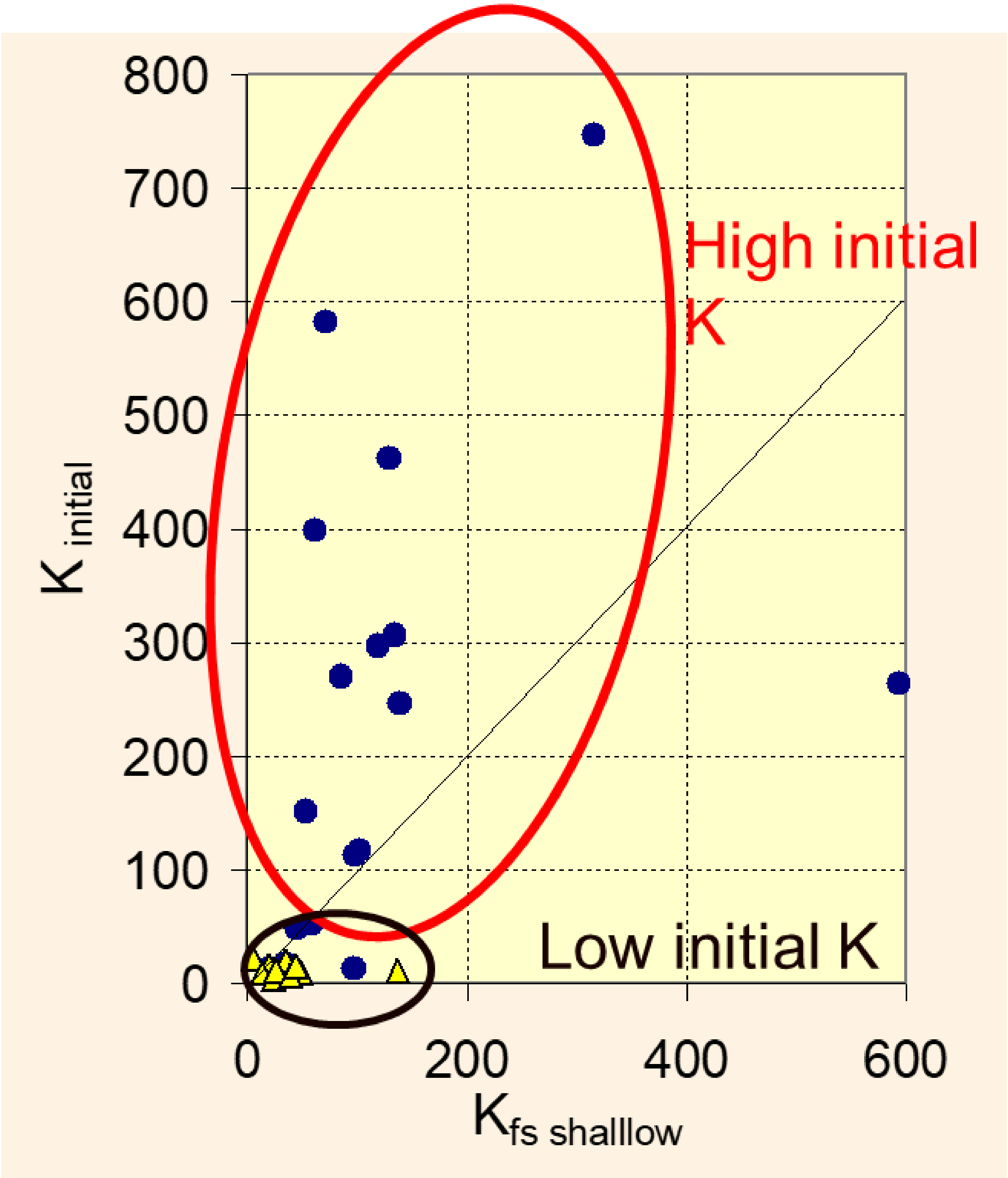
1. Filter media specification

Correct specification

- hydraulic conductivity
- PSD
- soil properties
- soil nutrition

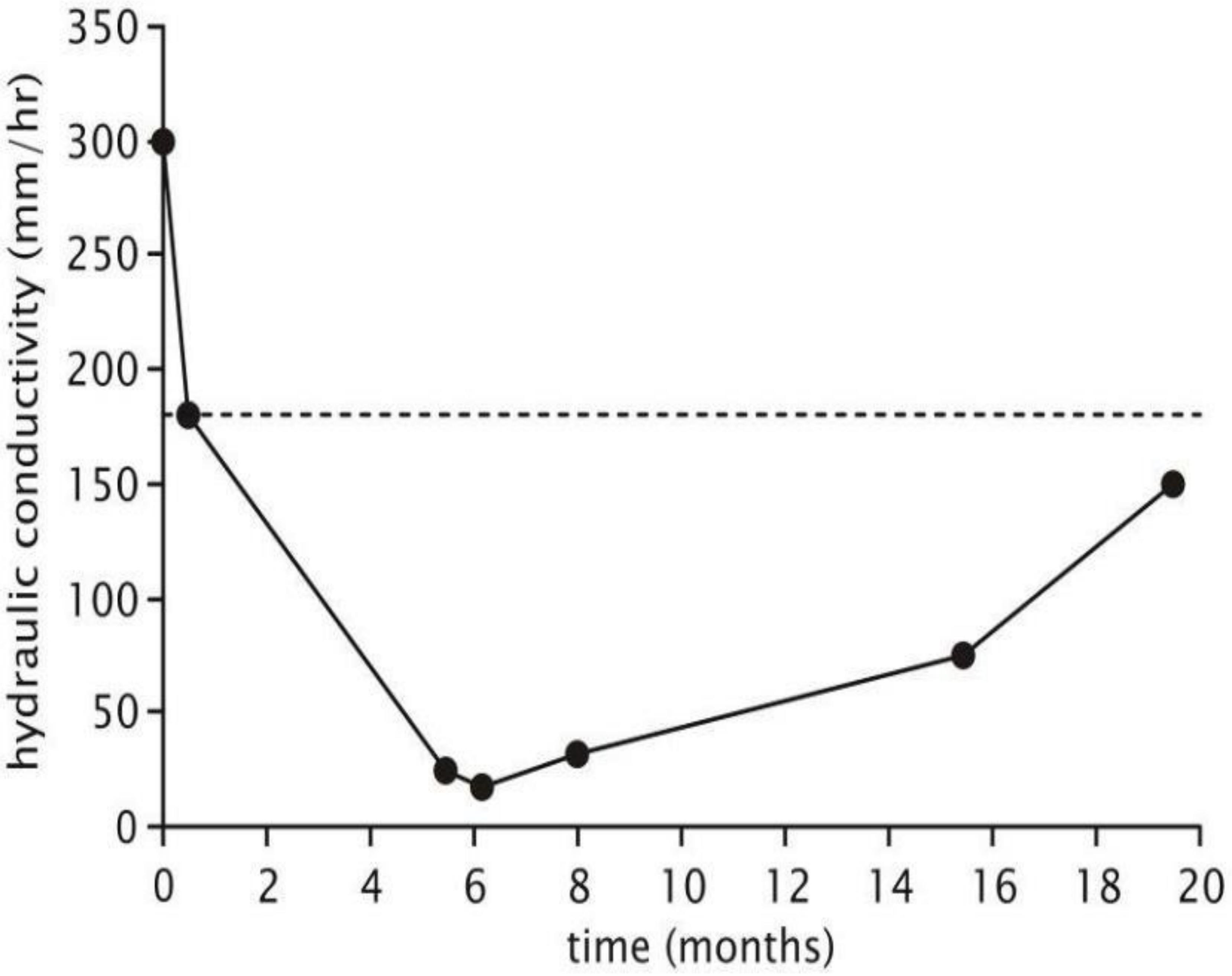
Correct installation

- light compaction



2. Dense vegetation cover

- Pollutant removal efficiency related to root structure and density
- Plants have a role in the recovery of infiltration capacity (hydraulic conductivity) as they mature



Long Term Maintenance Activities

Four areas of maintenance:

1. Horticultural
2. Drainage
3. Filter media
4. Observation after rainfall to check infiltration

Horticultural maintenance

1. Maintain high plant densities
    - *replacement of lost plants (large losses – check shade and frost tolerance)*
    - *limit trimming*
2. Control weeds (manual)
    - *manage/reduce herbicide use to prevent overspray*
3. Assess for and treat plant pests & disease

Drainage maintenance

1. Remove blockages from inlets, outlet and overflows
2. Check for structural integrity of pits and other civil works
3. Remove sediment from pits and entry sites etc. (likely to be irregular occurrence in mature catchment)



Filter media maintenance

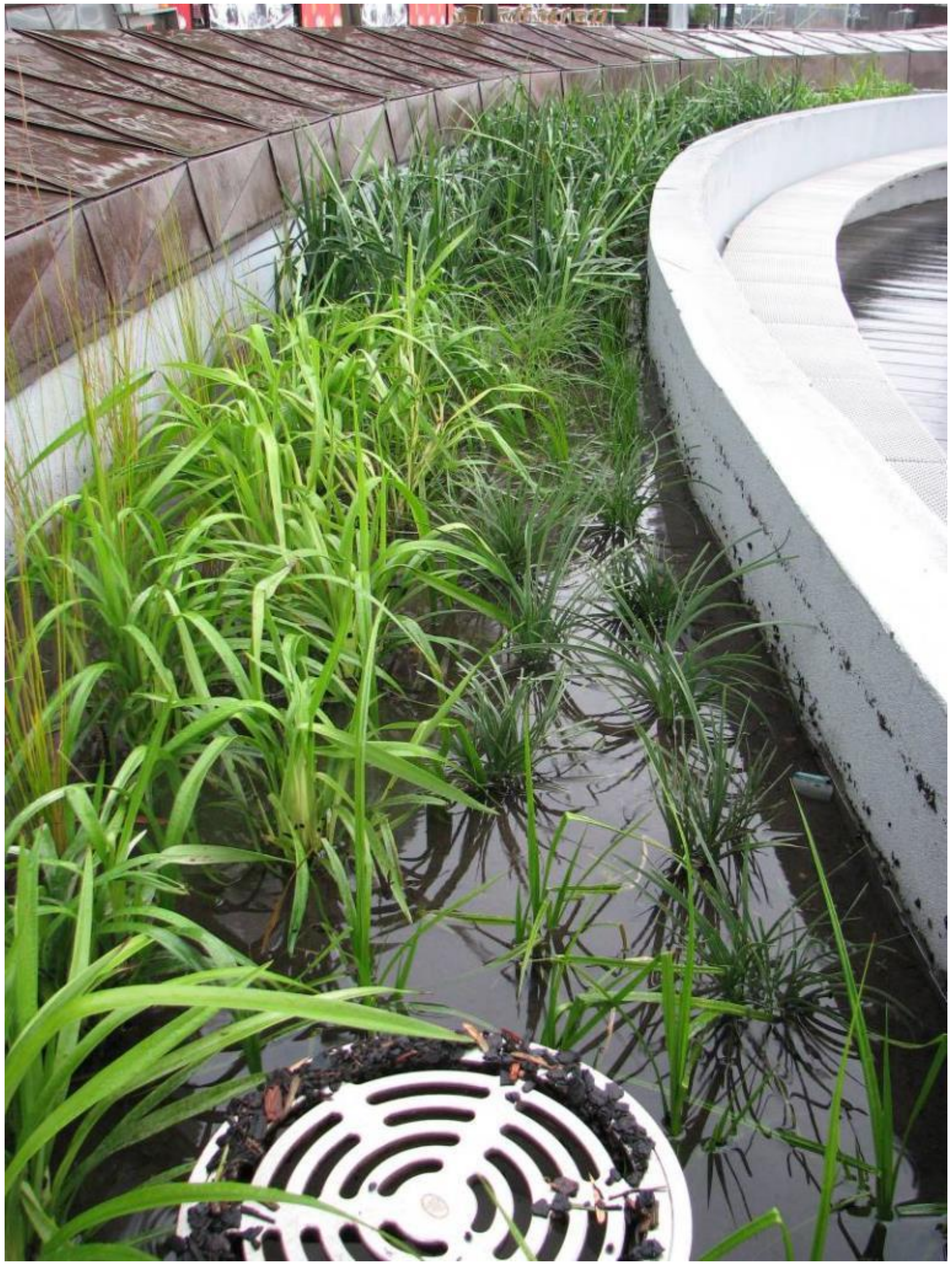
1. Remove sediment build up
2. Infill any holes in the filter media
3. Check for erosion or scour
4. Remove solid waste

CRC for
Water Sensitive Cities

Observations

Occasionally observe raingarden after a rainfall event to check infiltration. Check for poor drainage.

Has it altered or does it vary from design capacity (e.g. unusually high sediment loads may require installation of a sediment forebay)

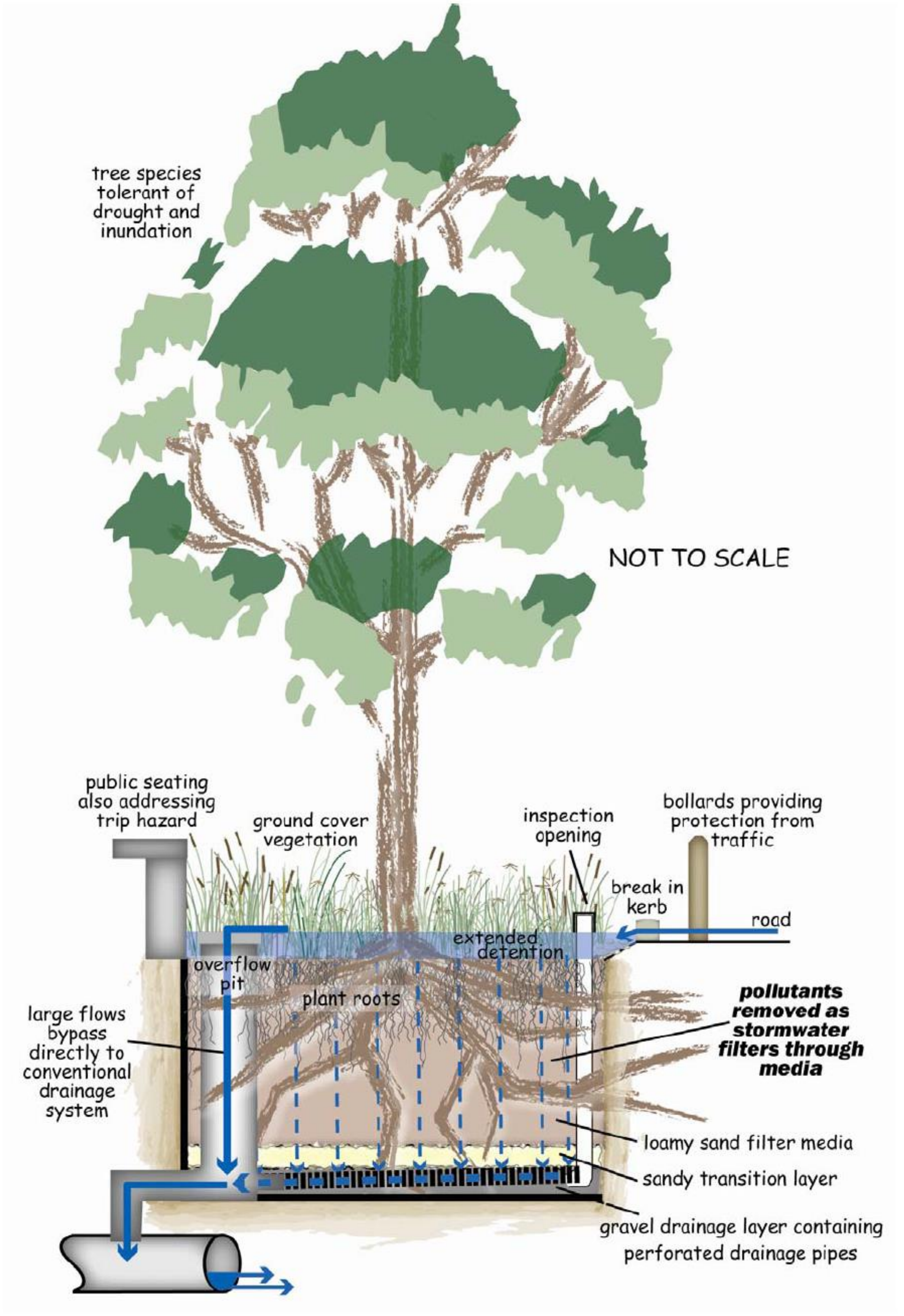


Other considerations for successful maintenance

1. Maintenance plan

   Include description and sketch of how the system operates

2. Identify maintenance jurisdiction



CRC for
Water Sensitive Cities

SUMMARY POINTS

Key elements during design and construction

- Correct filter media
- Dense vegetation cover
- Protection during construction

Predictable long term maintenance activities

- Horticultural
- Drainage
- Filter media
- Observation after rainfall event

Follow us on Twitter

@CRCWSC

Follow us on YouTube

/WaterSensitiveCities

Thank you.