INNOVATIVE STORMWATER MANAGEMENT

IR AZMAN ABU BAKAR

PERUNDING AZMAN, OOI & RAO SDN BHD

ISSUES

URBANISATION

- Agricultural advances
- Industrial Revolution
- Rise of MEGACITIES

EXTREME WEATHER

- Greenhouse effect
- A warmer world
- An extreme world

URBANISATION

URBANISATION

- Economic growth
- Job opportunities
- Wealth creation
- Migration of people into cities.

Rise of MEGACITIES

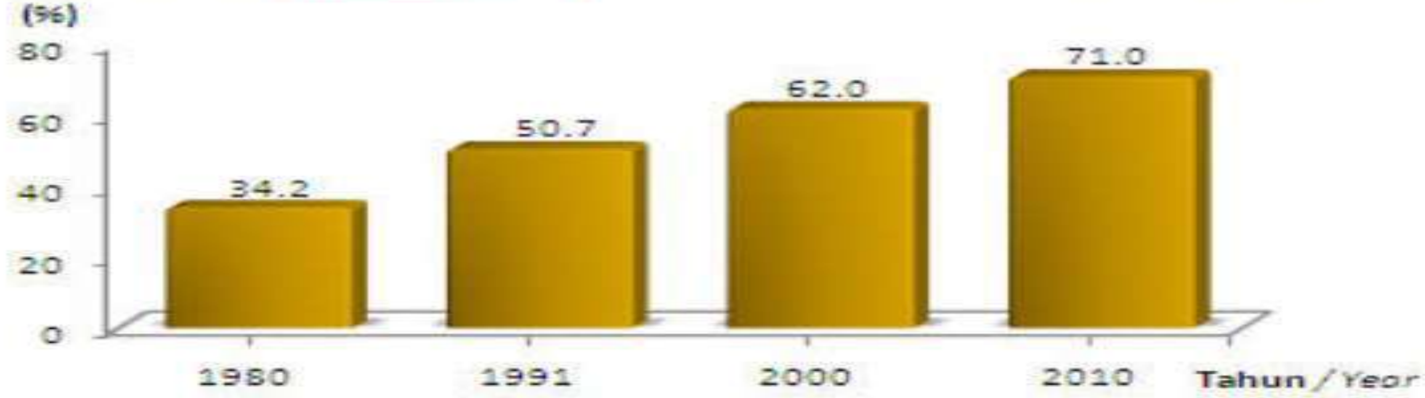
- Population of 10 millions and above
- Requires more food, H_2O & energy
- Increases usage of private and public transportation.
- Higher consumption lifestyles

ISSUES

- Destruction of natural habitats.
- Increases demand for natural resources.
- Produce more pollution
- Damage the environment.

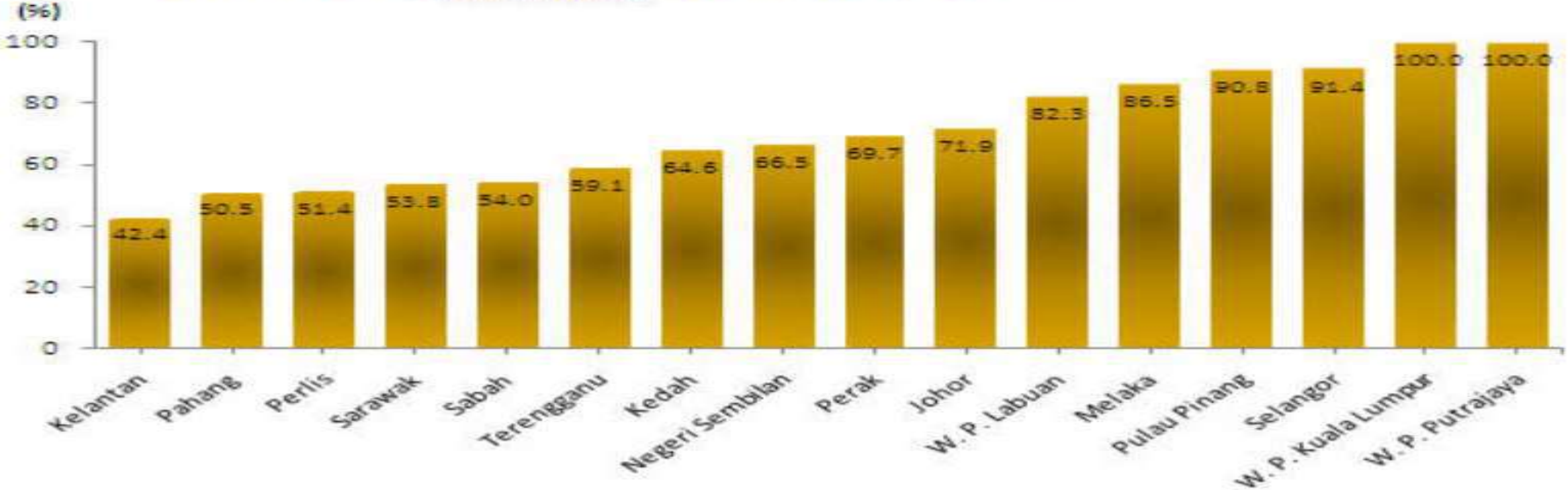
Carta 5: Paras urbanisasi, Malaysia, 1980, 1991, 2000 dan 2010

Chart 5: Level of urbanisation, Malaysia, 1980, 1991, 2000 and 2010



Carta 6: Paras urbanisasi mengikut negeri, Malaysia, 2010

Chart 6: Level of urbanisation by state, Malaysia, 2010



“MALAYSIA IS CONSUMING THE RESOURCES OF 2.4 PLANETS… THIS IS NOT GOOD AND IT MEANS WE ARE SHORTCHANGING FUTURE GENERATIONS FROM THEIR FAIR SHARE OF RESOURCES. IF WE KEEP GOING LIKE THIS, WE WILL HAVE MORE WATER STRESSES, AIR POLLUTION, EXTREME WEATHER EVENTS, FLOODING, AND IT IS NOT GOING TO END WELL.”

Nithi Nesadurai
President of the Environmental Protection Society Malaysia (EPSM)

ECOLOGICAL FOOTPRINTS

- Measures the impact of human activities on the natural environment.
- Basically an area measurement, represented in global acres (hectares).
- Places value on how much biologically productive land and water is needed to produce the resources we consume and to dispose the resulted waste.

Country Trends

Select Country or Region:

Malaysia

Select Type:

- ○ Ecological Footprint vs Biocapacity (gha per person)
- ○ Ecological Footprint vs Biocapacity (gha)
- ◉ Ecological Footprint (Number of Earths)

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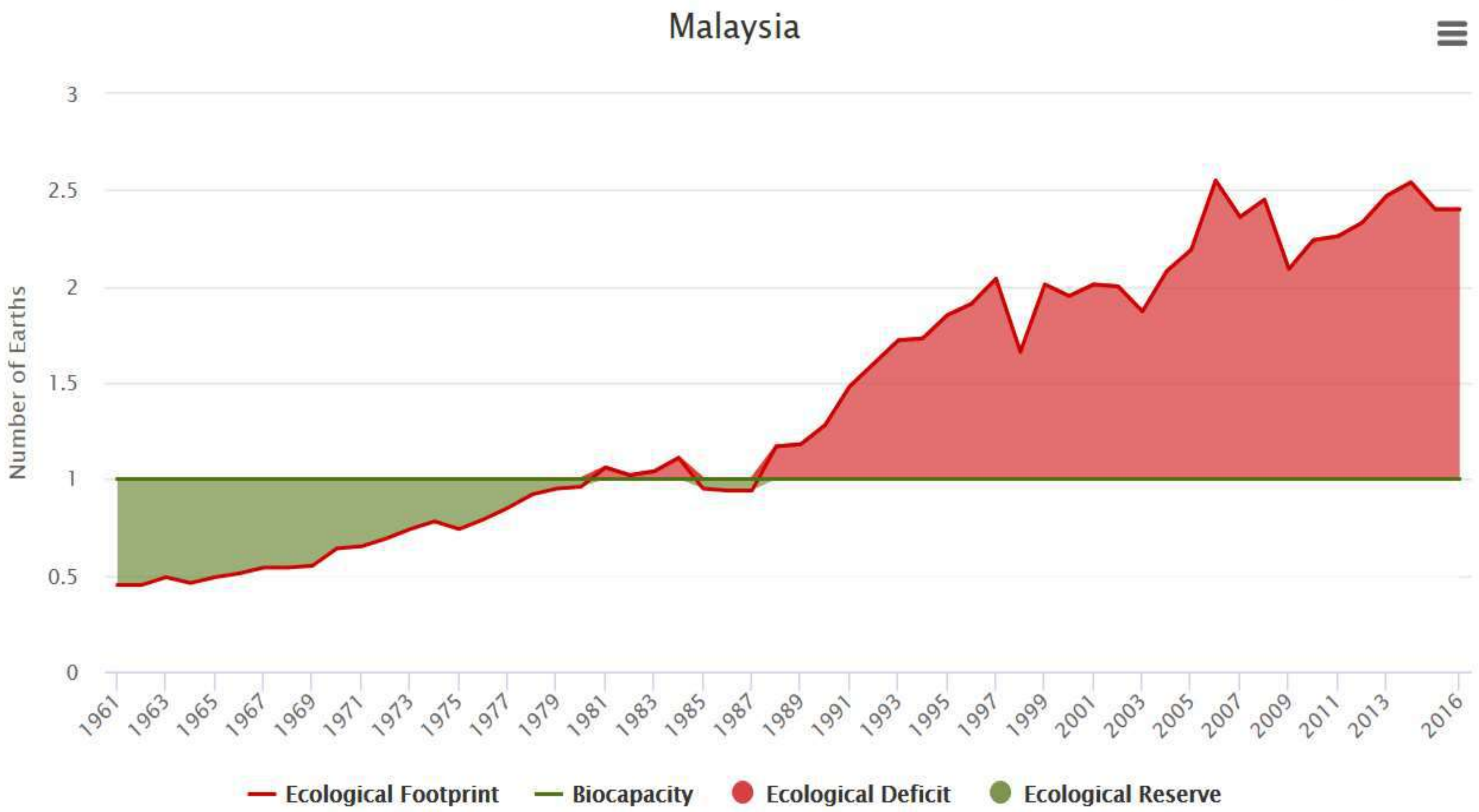
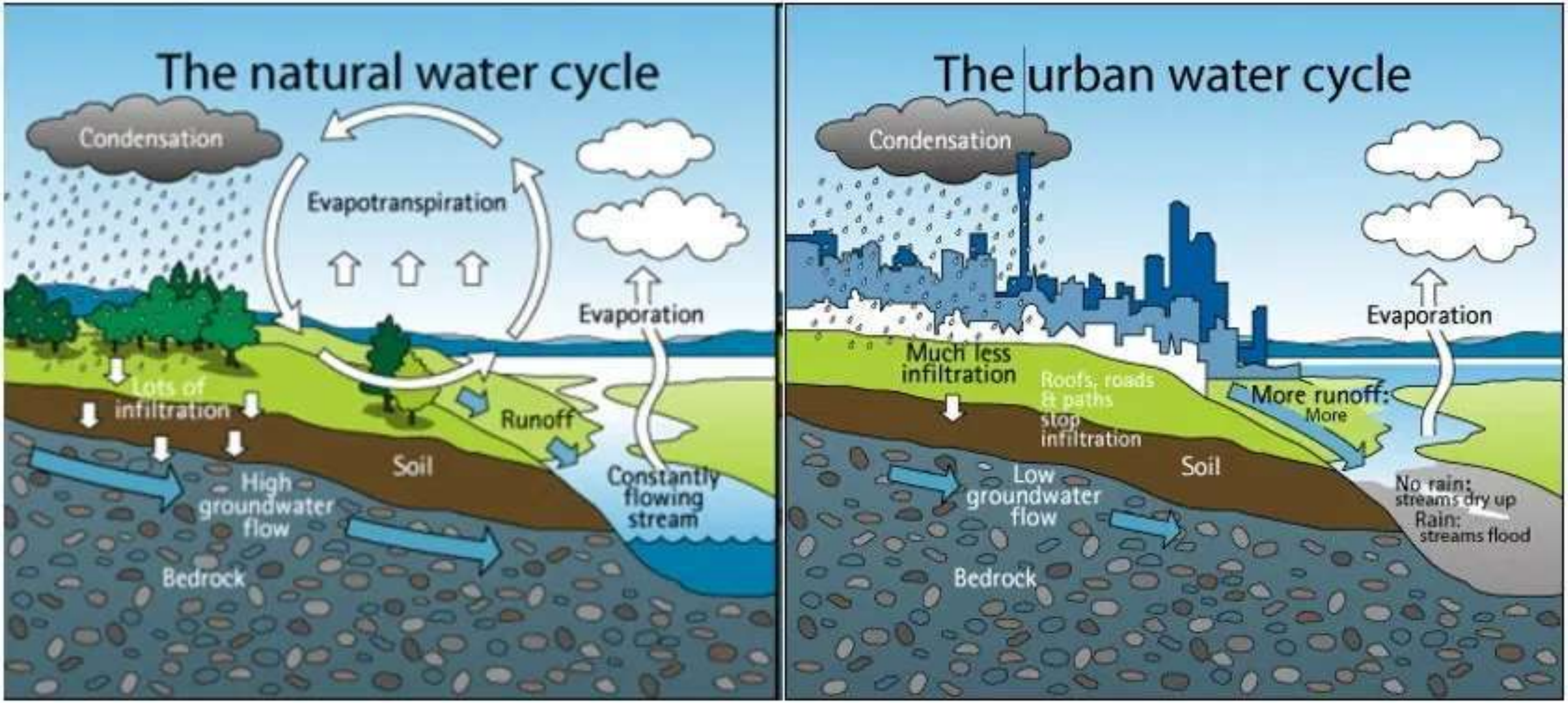
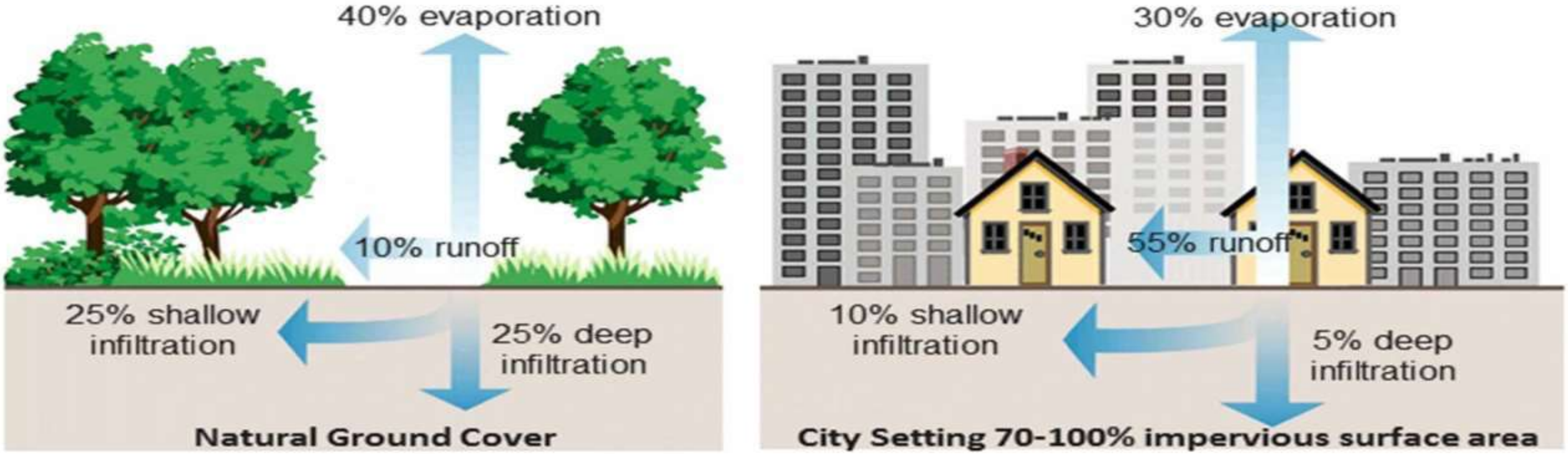




The natural water cycle
Condensation
Evapotranspiration
Evaporation
Lots of infiltration
Runoff
Soil
High groundwater flow
Constantly flowing stream
Bedrock
The urban water cycle
Condensation
Evaporation
Much less infiltration
Roofs, roads & paths stop infiltration
More runoff:
Soil
Low groundwater flow
No rain: streams dry up
Rain: streams flood
Bedrock

NATURAL vs. URBAN STORMWATER DRAINAGE



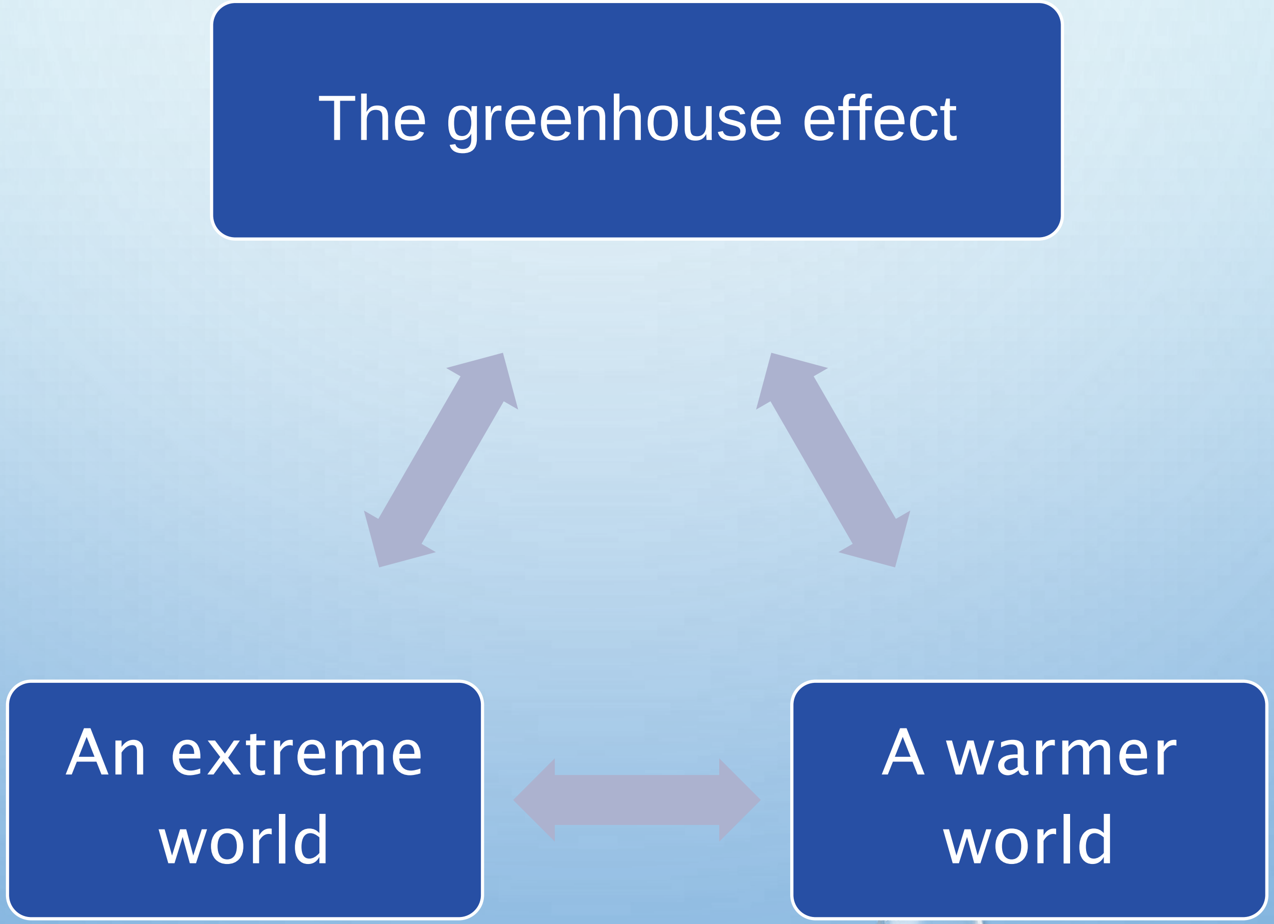
Stormwater infiltrates into the ground

Plants and trees work to absorb stormwater

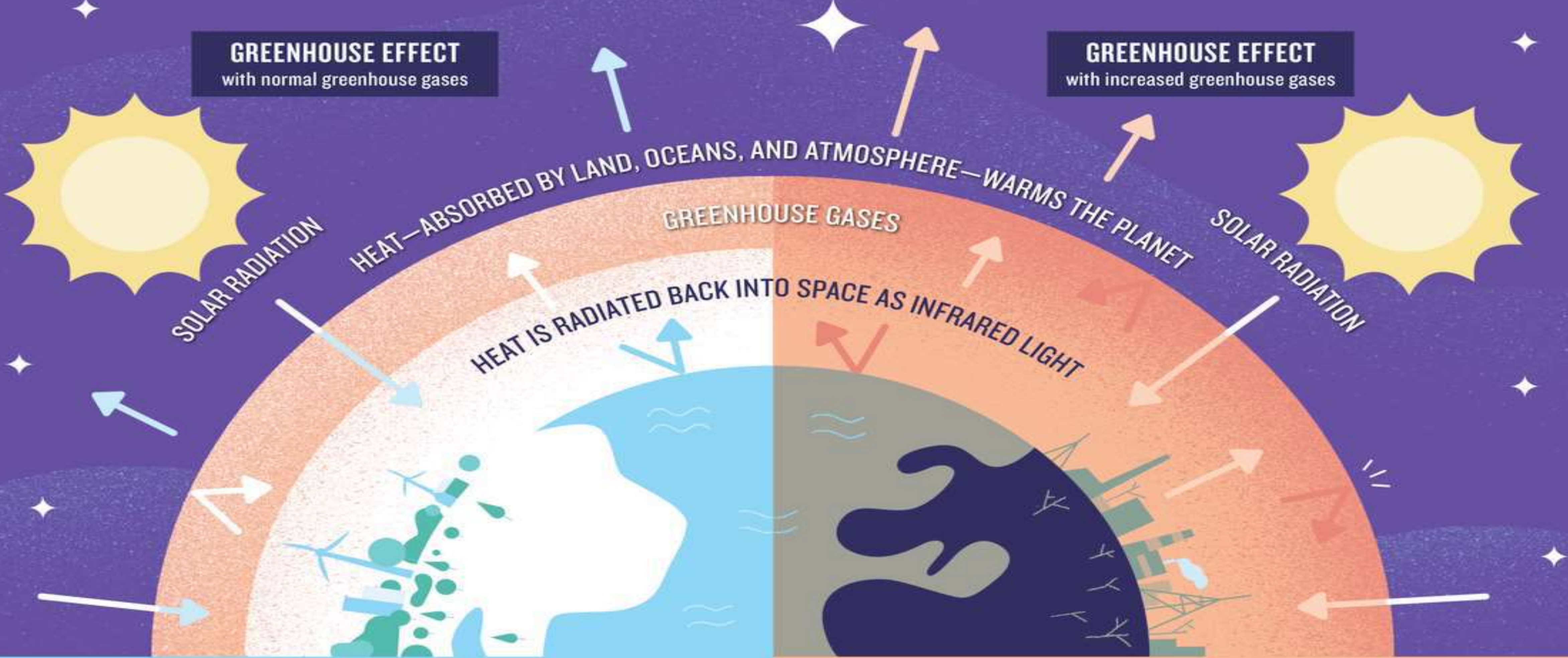
Water hits impervious surface and runs off roofs, streets, parking lots etc.

Runoff goes into the sewers

EXTREME WEATHER



In the last century, human activities such as burning fossil fuels and deforestation have caused a jump in the concentration of greenhouse gases in the atmosphere. The result: extra trapped heat and higher global temperatures.

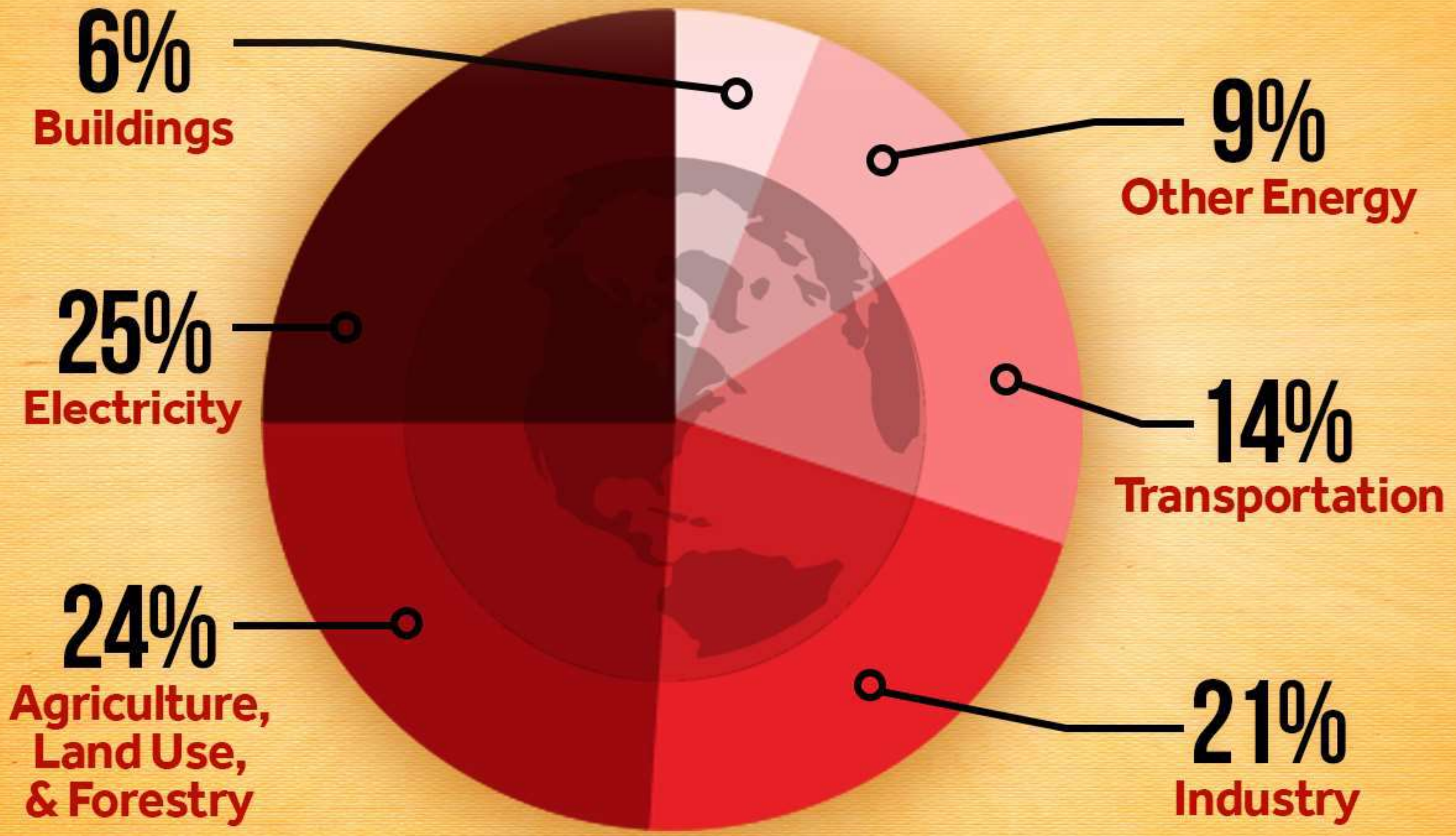


Some heat continues into space while the rest, trapped by greenhouse gases, help maintain the planet's relatively comfortable temperatures. Less gas = less heat trapped in the atmosphere.

Increased greenhouse gases means less heat escapes. Between preindustrial times and now, the earth's average temperature has risen 1.8 °F (1.0 °C).

GREENHOUSE GAS SOURCES

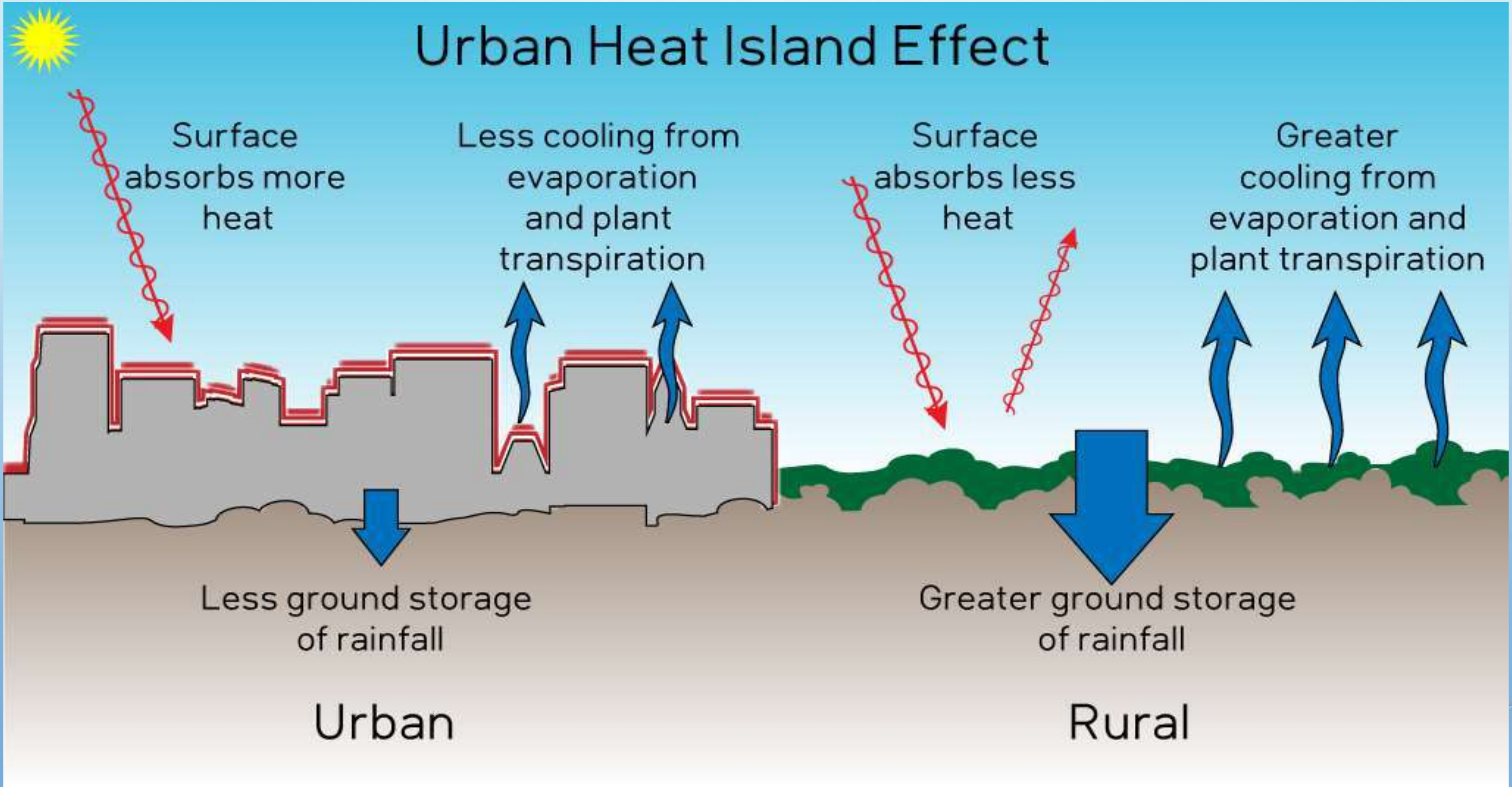
Global Greenhouse Gas Emissions by Sector



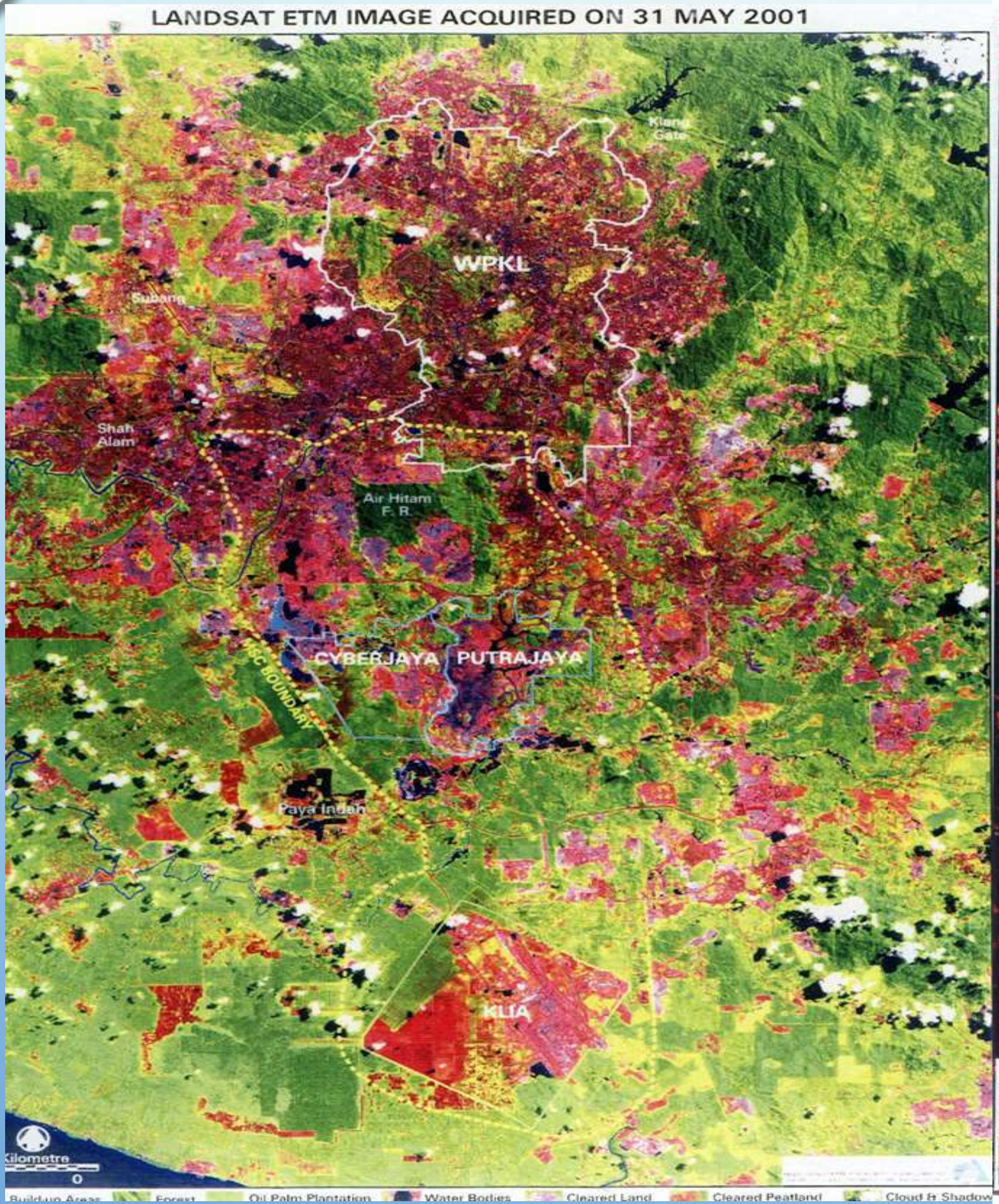
Source: US EPA

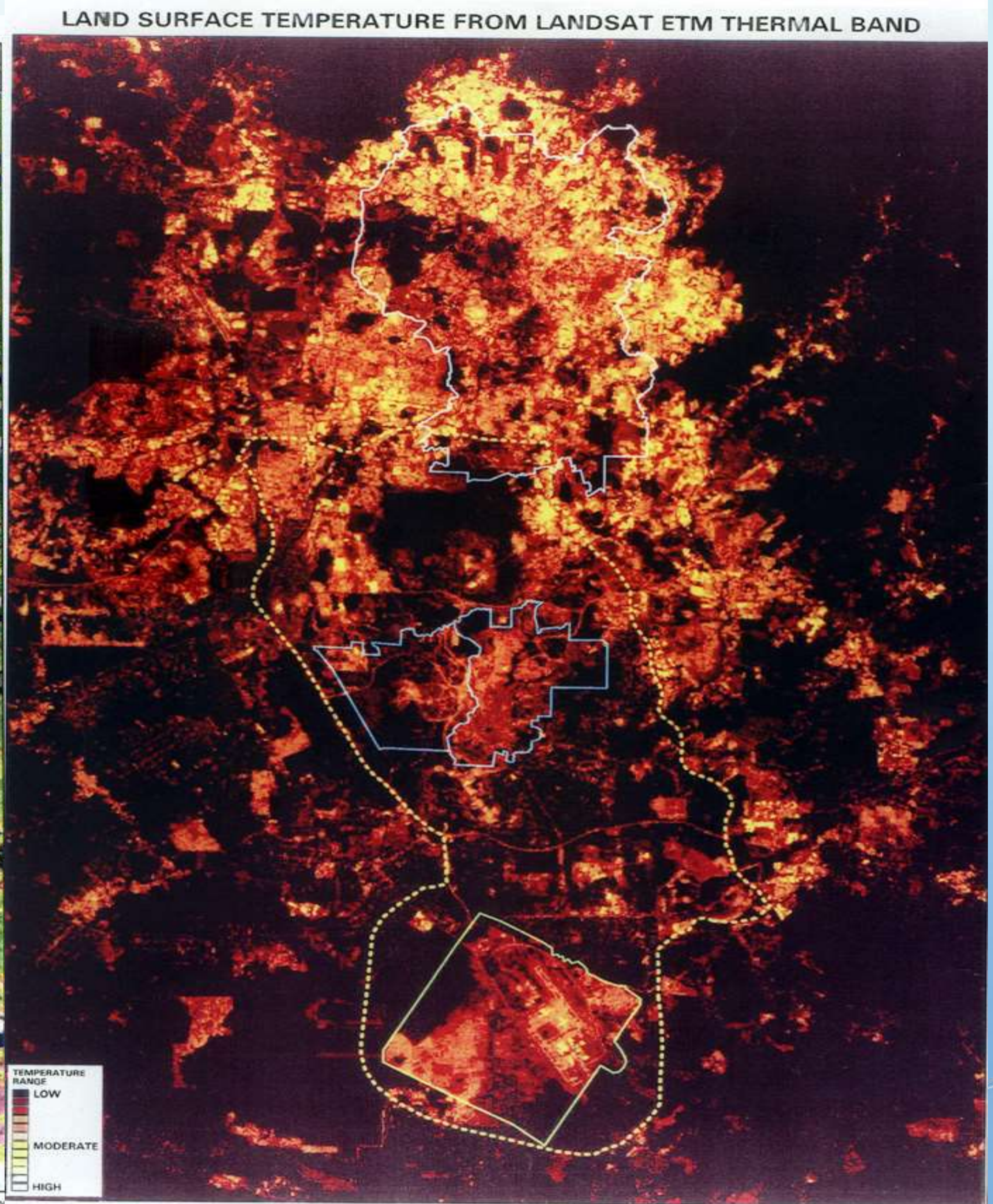
CLIMATE CENTRAL

A WARMER WORLD

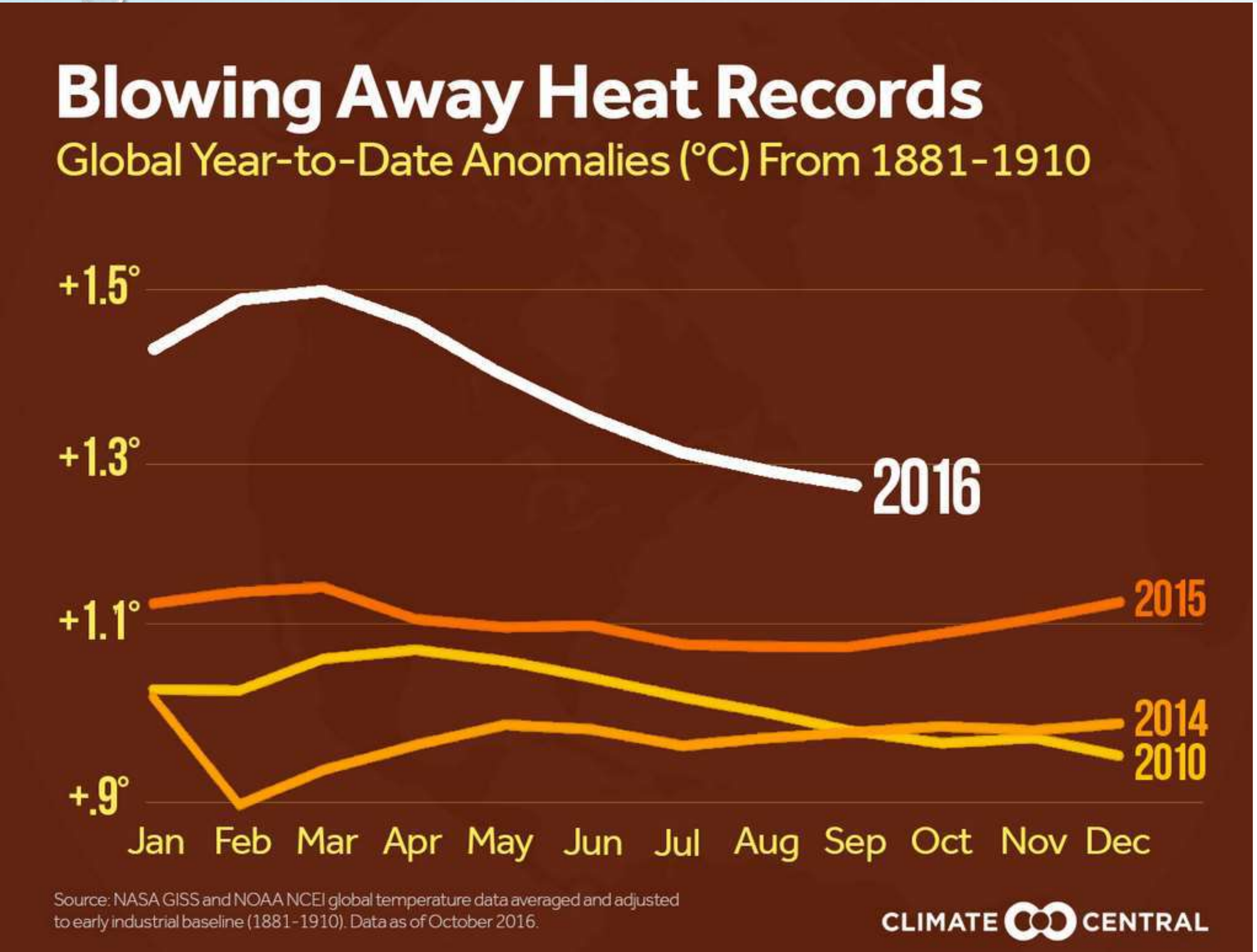


A WARMER WORLD





A WARMER WORLD



Top 10 warmest years (NOAA)

Rank	Year	Anomaly °C	Anomaly °F
1	2016	0.94	1.69
2	2015	0.90	1.62
3	2017	0.84	1.51
4	2018	0.77	1.39
5	2014	0.74	1.33
6	2010	0.70	1.26
7	2013	0.66	1.19
8	2005	0.65	1.17
9	2009	0.64	1.15
10	1998	0.63	1.13

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

“To keep global temperature increase "well below" 2°C and to pursue efforts to limit it to 1.5°C.”

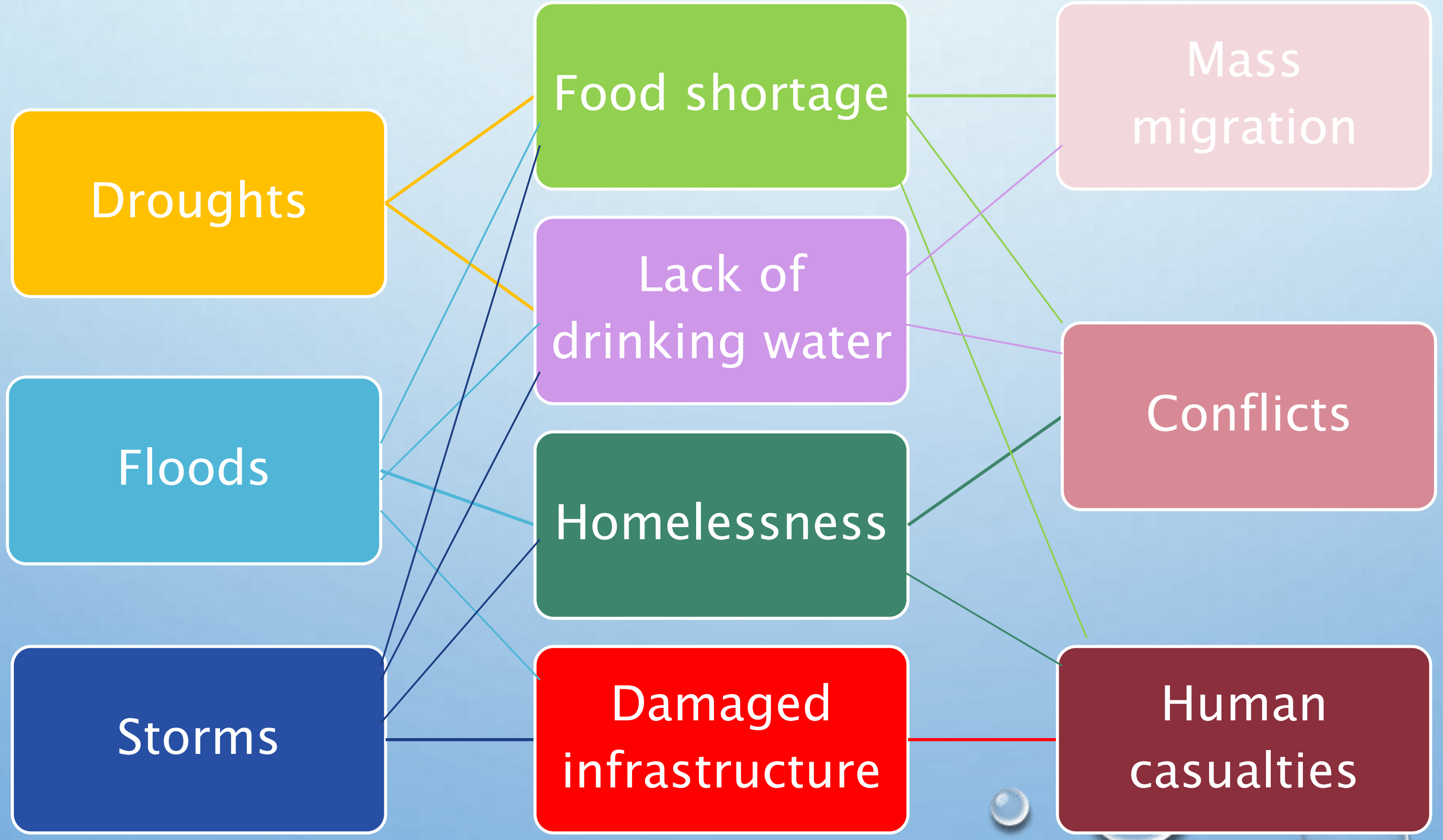
AN EXTREME WORLD


Draughts


Floods


Storms

AN EXTREME WORLD



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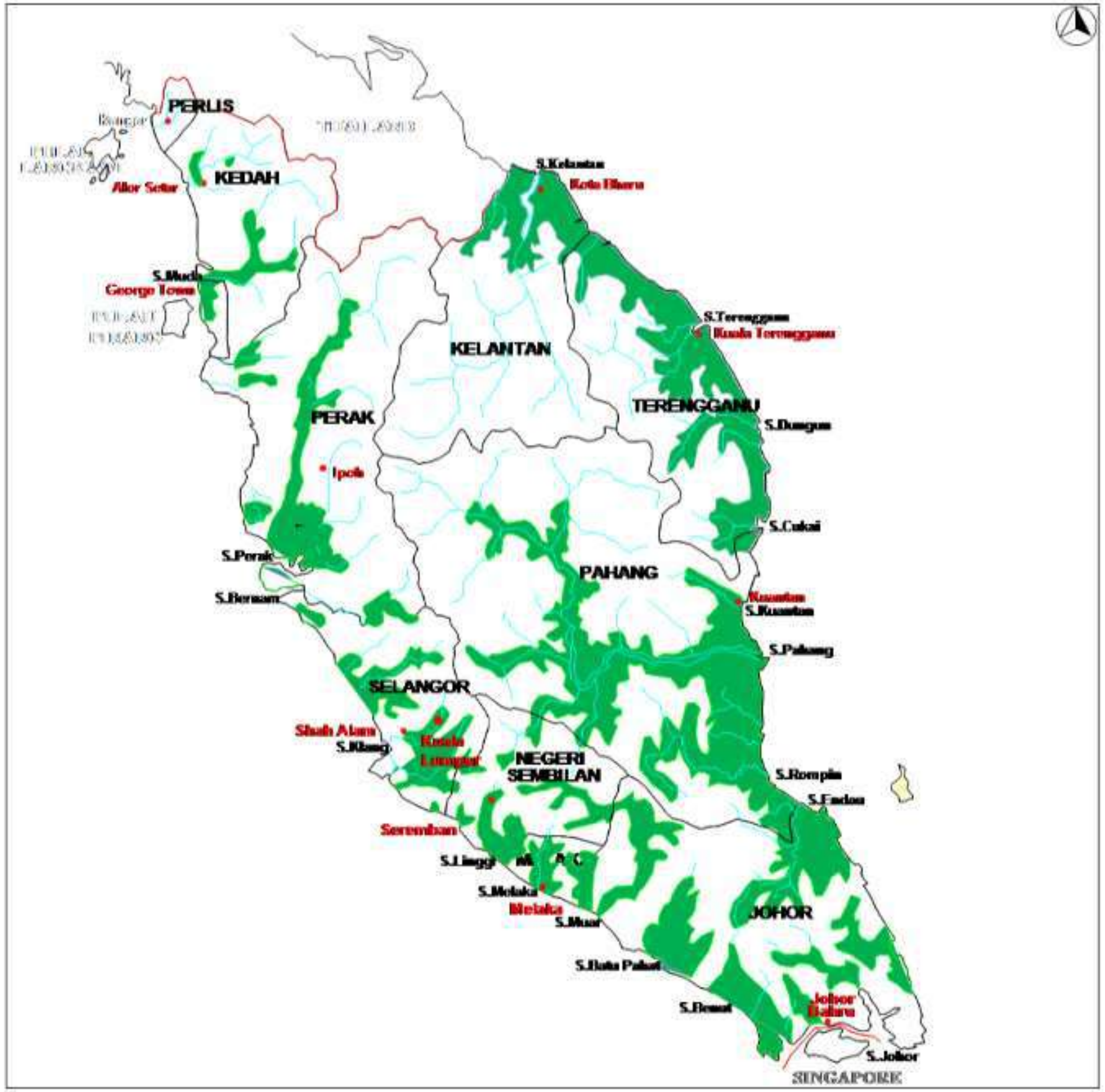


Figure 1: Green shaded areas indicate the flood prone areas in Peninsular Malaysia (Source: DID)

WE ARE A WATER-RICH COUNTRY

WE ARE A WATER-RICH COUNTRY – SUNGAI KLANG

1926
KL submerged to a depth of 900m.

1971
Torrential monsoon rains lasted for 5 days, causing massive flood and killed 32 people.

Post 1971
To mitigate flood occurrences, the river was 'changed' to resemble a big drain, its banks transformed from mud and natural vegetation to slabs of concrete.

2003
9.7km long submerged SMART Tunnel was built to carry stormwater runoff.

But things have only gotten worse. Flooding problems are increasing from year to year and they are no longer limited to the rainy season. Numerous possible contributing causes have been highlighted, including increasing siltation due to heavy construction along the riverbanks and unsustainable rubbish disposal practices.

STORMWATER MANAGEMENT IN MALAYSIA

Before 1975

- Rapid disposal concept.
- Developers normally channel all drainage to one or large trunk drains.
- All drains to trunk drains are normally concrete-lined and of the open channel type to minimize the land area required for the drains and maximise the greatest number of housing unit allowable in the area.

1975

- DID Planning and Design Procedure No.1: Urban Drainage Design Standard For Peninsular Malaysia.
- Maintaining the rapid disposal concept.
- Increased the occurrence of flash floods as the result of the increase in surface runoff, peak discharges, shorter flow duration and others.
- Also problems with polluted water, garbage and floating litters and increased of sedimentation in the river system.
- Widening and channeling rivers and drain to cater for increased discharges as the urban area develops were also bad for the environment.

2001

- DID New Urban Drainage Manual known as Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA).
- To manage the stormwater instead of draining it away as fast as possible, to a more environmentally approach known as control as source approach.
- This approach utilizes detention/retention, infiltration and purification process.

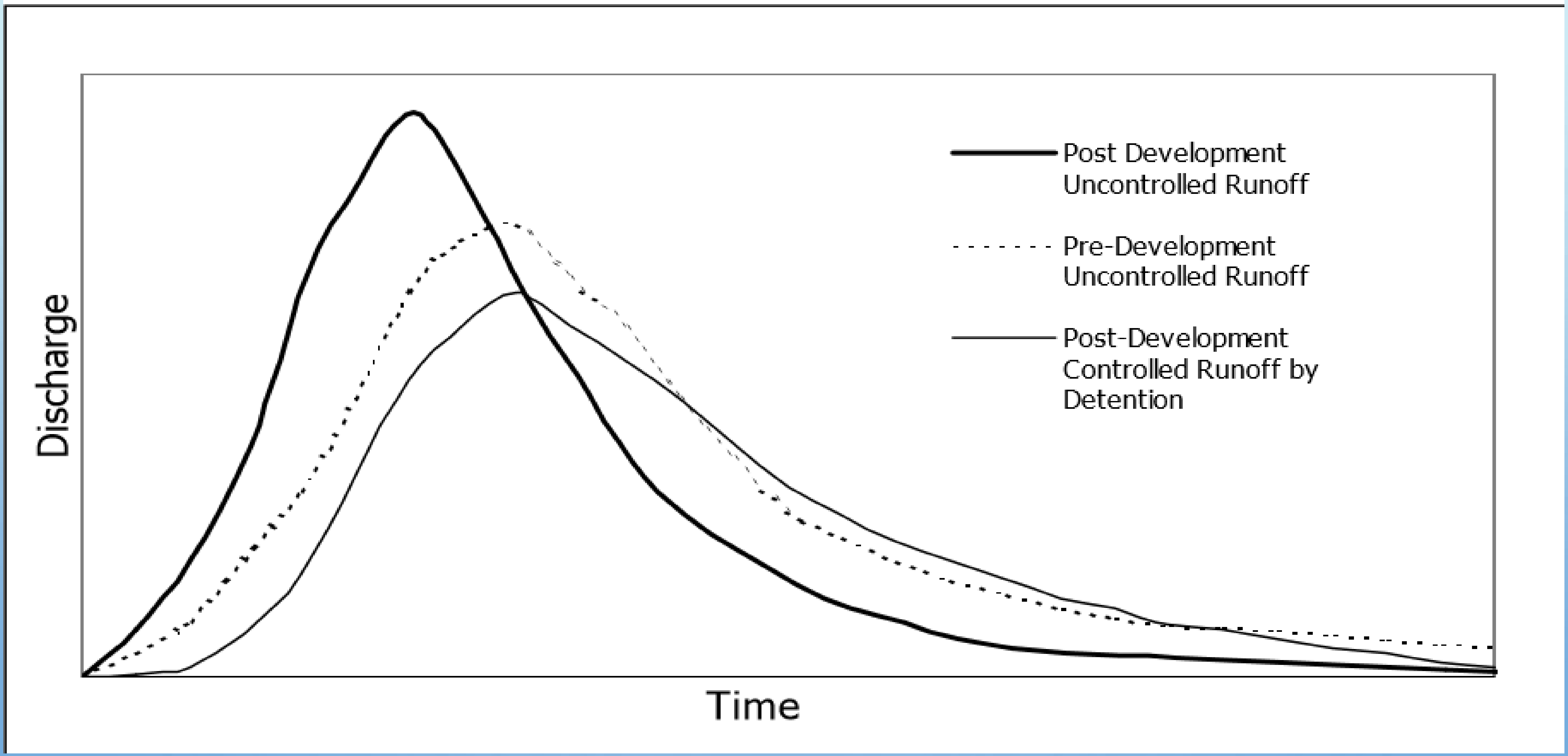
BEST MANAGEMENT PRACTICES

Structural	Non-structural
• Pipes (drains) • End-of-pipe treatment ❿Detention/retention basins. ❿Infiltration basins.	• Reduce runoff volume and pollutant generation. • Reduce imperviousness. • Avoid excessive use of chemicals on runoff surfaces. • Increase awareness.

Problem : INCREASED URBANIZATION		
Many drains are poorly maintained/encroached with other structures&cables.	Increases risks of flooding and environmental damage.	Runoff water carries contaminants into end-sources (lake,river,sea).

Usual site of drains/rivers in the city.

RUNOFF ISSUE



WATER SENSITIVE COMMUNITY

- A shift in the focus of stormwater management

Removing/Disposing stormwater	
ASAP	Via built infrastructures

↓

Recognising the value of stormwater	
Its close interrelationship with natural freshwater systems	How it can enhance the livability of cities

MOVING FORWARD

"To control runoff at its sources rather than collecting and conveying it to detention/retention basins."

LOW-IMPACT DEVELOPMENT (LID)

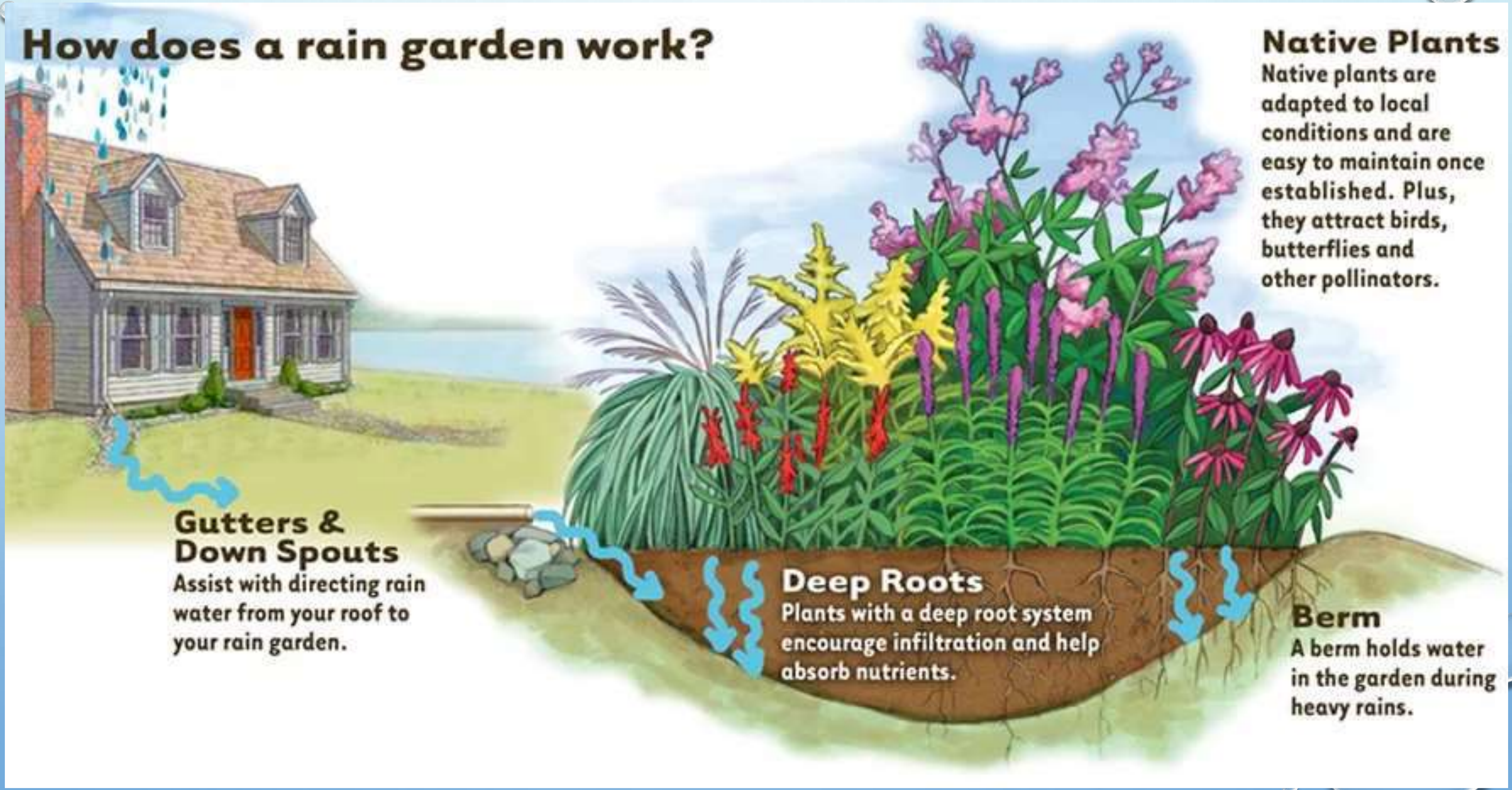
- Systems and practices (land planning, engineering designs etc) that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat.
- Works with nature to manage stormwater as close to its source as possible.
- Aim to preserve, restore and create green space using soils, vegetation, and rainwater harvest techniques.

AND THIS IS WHERE THE TREES COME INTO THE PICTURE…

WHY TREES???

- INFILTRATION - Absorb rainwater runoff, rather than directing it into sewers – roots penetrate through typically impermeable surfaces in the urban settings.
- INTERCEPTION - Tree canopies, branches and trunks.
- EVOTRANSPIRATION - Soil and plant surfaces.
- ABSORB POLLUTANTS - Especially woody plants, are very good at removing nutrients (nitrates and phosphates) and contaminates (such as metals, pesticides, solvents, oils and hydrocarbons) from soil and water.
- Offer HABITATS for all sort of animals.
- COUNTERACTING URBAN HEAT ISLAND EFFECTS in the cities – improve people's physical, mental and emotional health.

RAIN GARDEN



How does a rain garden work?
Native Plants
Native plants are adapted to local conditions and are easy to maintain once established. Plus, they attract birds, butterflies and other pollinators.
Gutters & Down Spouts
Assist with directing rain water from your roof to your rain garden.
Deep Roots
Plants with a deep root system encourage infiltration and help absorb nutrients.
Berm
A berm holds water in the garden during heavy rains.

RAIN GARDEN & STORMWATER MANAGEMENT

- A rain garden is a garden of native shrubs, perennials, and flowers (therefore, no fertilizer is needed and after the first year, maintenance is usually minimal) planted in a small depression (typically six to twelve inches of soil is removed and altered with tillage, compost and sand to increase water infiltration.)
- It is designed to temporarily hold and soak in rainwater runoff that flows from roofs, driveways, patios or lawns.
- It is dry most of the time. It typically holds water only during and following a rainfall event. Because rain gardens will drain within 12-48 hours, they prevent the breeding of mosquitoes.
- Rain gardens are effective in removing up to 90% of nutrients and chemicals and up to 80% of sediments from the rainwater runoff. Compared to a conventional lawn, rain gardens allow for 30% more water to soak into the ground.

SUSPENDED RAIN GARDENS

An Artist's vision of a suspended raingarden under a bridge

SUSPENDED RAIN GARDENS

- The concept of a suspended garden not really a new one – Made famous by the 'Hanging Gardens of Babylon.'
- So why not include stormwater treatment into a conventional hanging garden that can be suspended from building or structures or between two buildings/ structures?

SUSPENDED RAIN GARDENS & STORMWATER MANAGEMENT

Key components		
Planting media	Plants	Structure of the suspended raingarden
• Able to remove pollutants for a range of flow regimes.	• Ideally native species that can encourage local biodiversity.	• Must suit a range of site conditions. • Fulfil aesthetic design requirements.

SUSPENDED RAIN GARDENS & STORMWATER MANAGEMENT

- A study conducted at the University of Auckland in New Zealand that involved running synthetic stormwater through selected media and testing for removal rathes of suspended solids and dissolved heavy metals (copper, zinc and lead) revealed that:

- The containers and fasteners used to ‘hang the garden’ are comparable to other hanging gardens currently being used. (So, no additional cost just to manage stormwater!)
- Local plants could grow well over 6 weeks under artificial lightning for all media used. (Plants chosen Bird's Nest Fern, Devil's Ivy and Pak Choi are potentially suitable for growth in suspended raingardens stormwater to provide effective treatment.)
- But this novel lightweight media mix of coconut coir, zeolite, activated carbon and slow-releasing fertiliser, the combination of adsorption and filtration media was the most effective in treating stormwater contaminants of concern. These materials were relatively inexpensive and were locally available. (Hence this will make hanging raingardens be economically attractive for developers and owners to incorporate them as a stormwater management.)

SUSPENDED RAIN GARDENS & STORMWATER MANAGEMENT

Media 1	Media 2	Media 3
66.6% perlite, 33.4% vermiculite	90% coconut coir, 10% mixture of zeolite and activated carbon.	80% growstone, 20% biochar



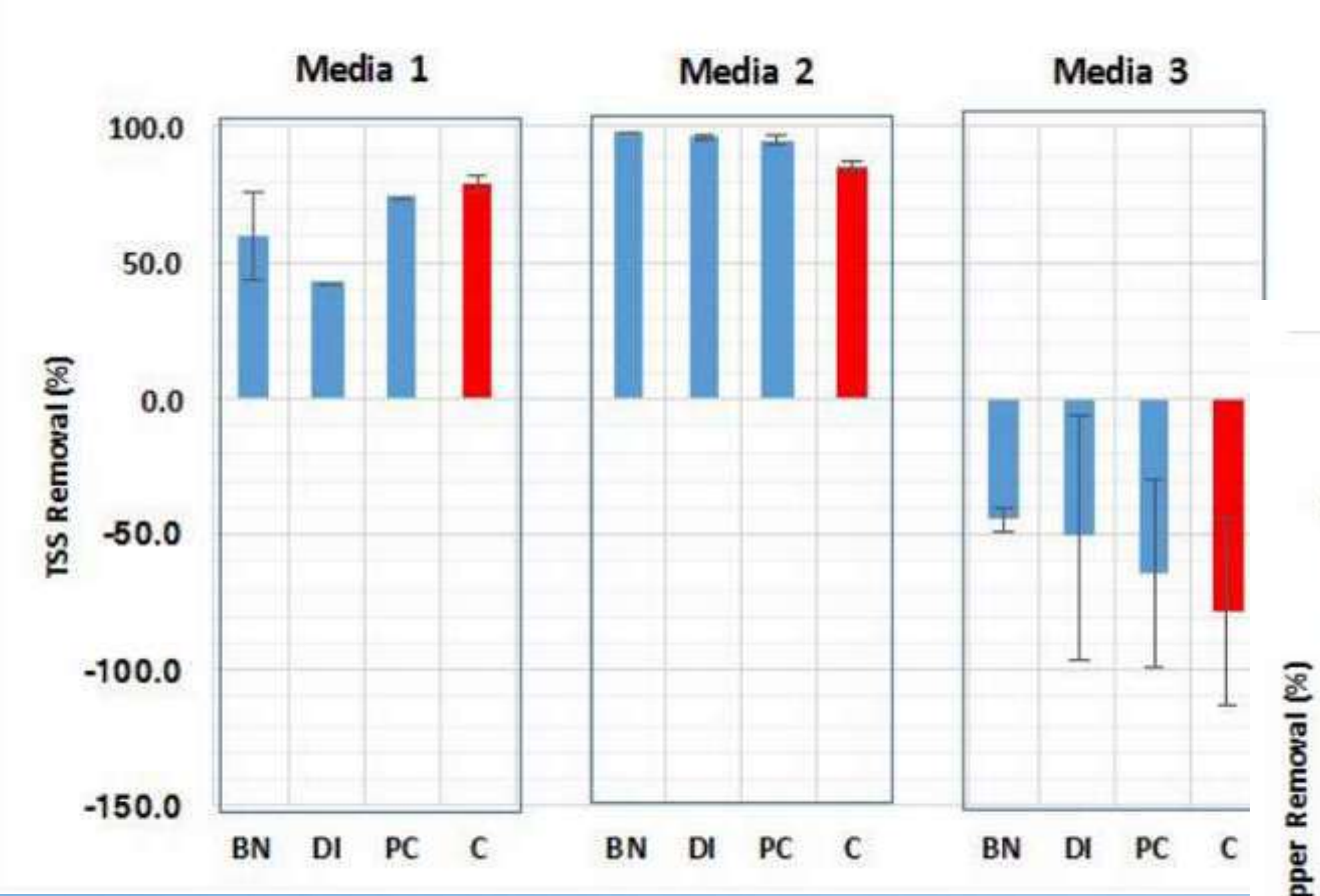


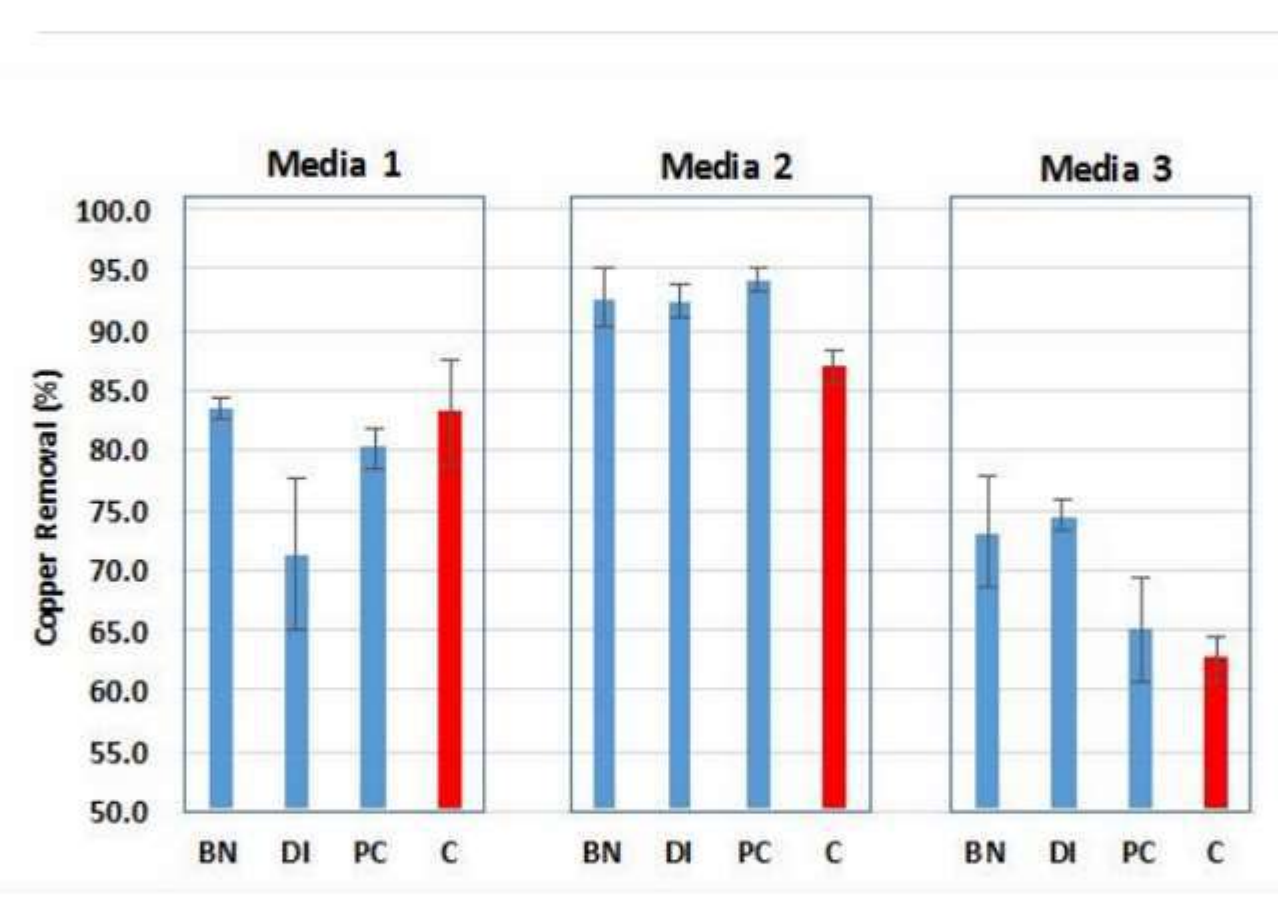
SUSPENDED RAIN GARDENS & STORMWATER MANAGEMENT

Plant 1	Plant 2	Plant 3
Bird’s nest fern (BN) - Highly aesthetic plant	Devil’s ivy (DI) - A drooping plant	Pak Choi (PC) - An edible plant

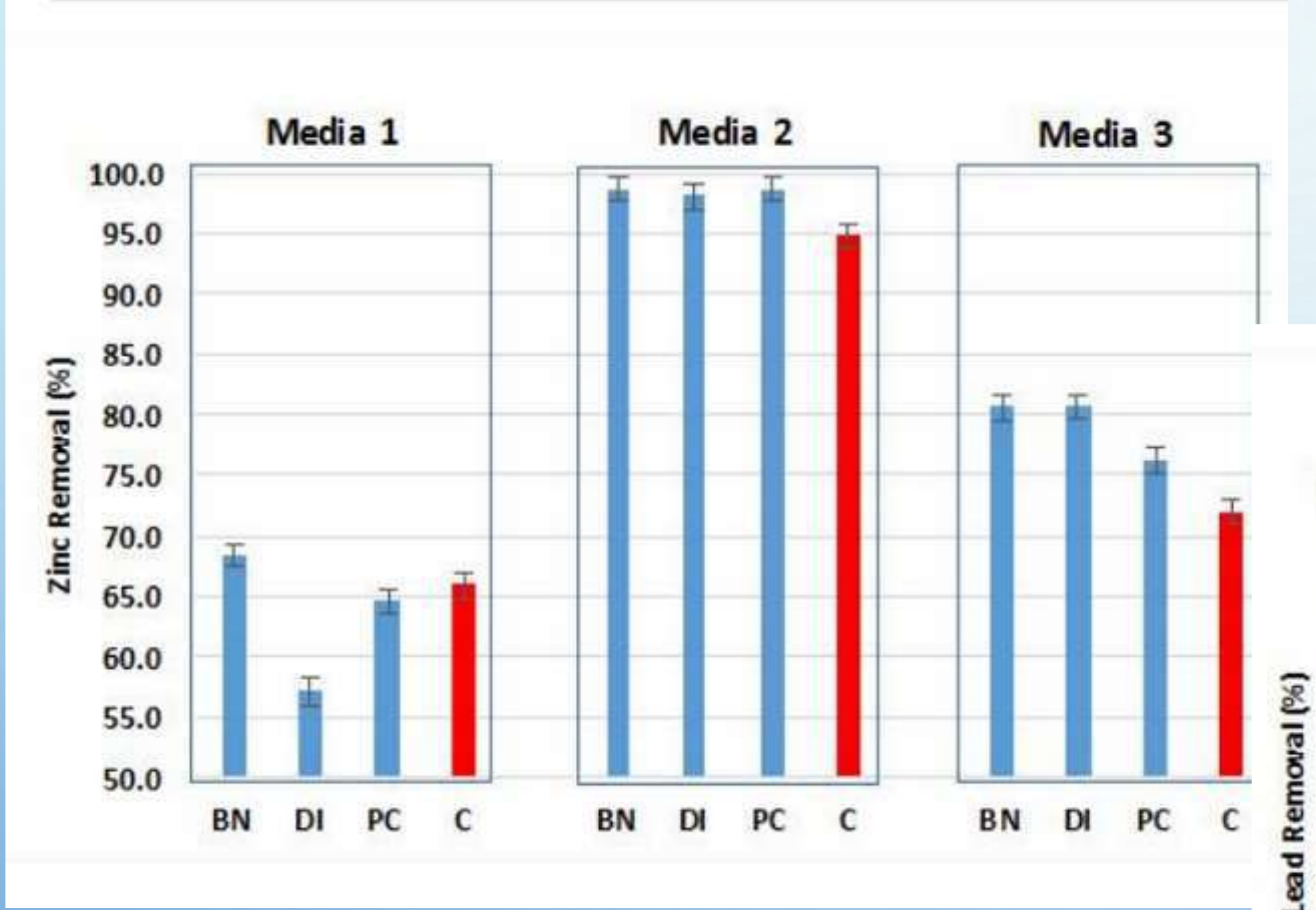


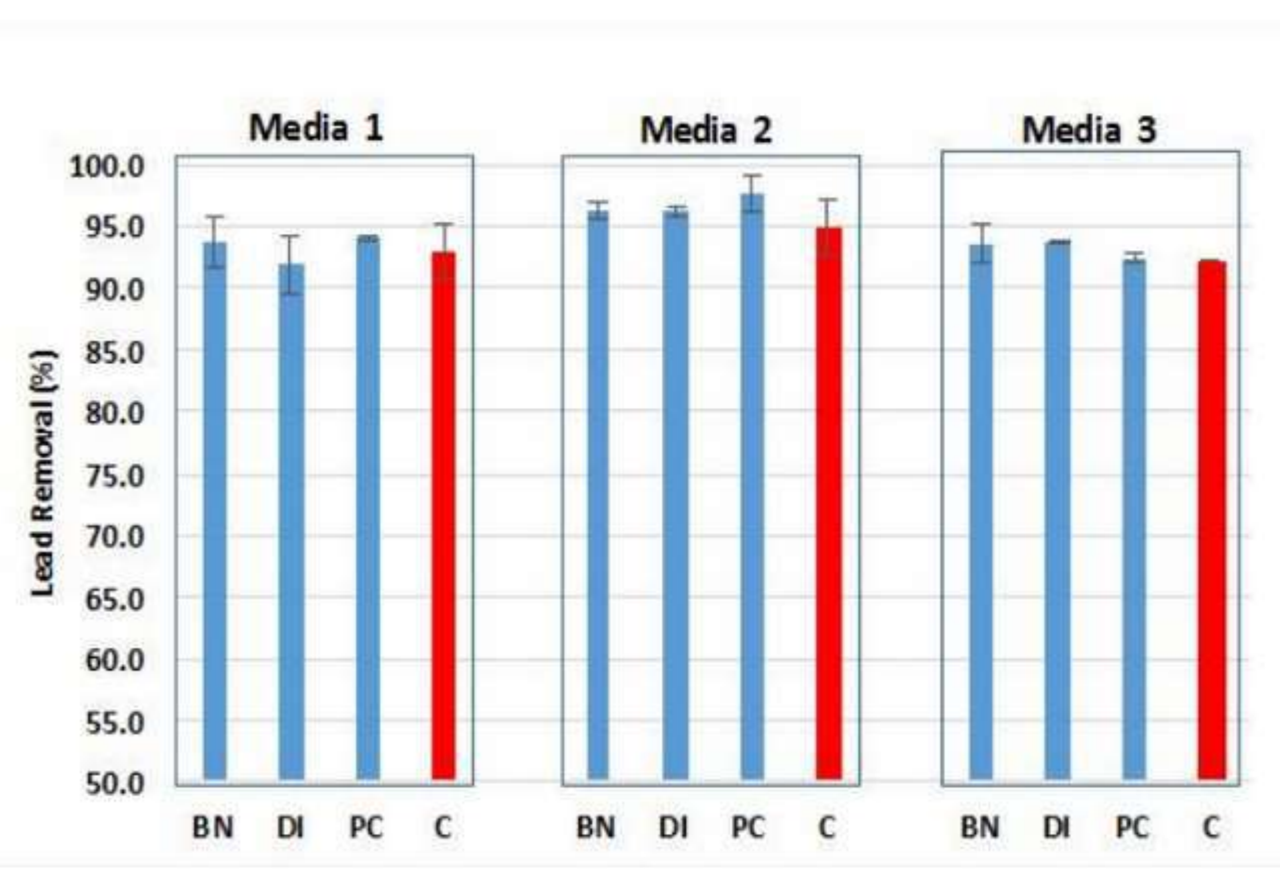
SUSPENDED RAIN GARDENS





SUSPENDED RAIN GARDENS





STORMWATER TREES-
THE HOWARD STREET PROJECT

STORMWATER TREES-
THE HOWARD STREET PROJECT

- Three London Plane trees were planted in a specially designed pavement, a 3 layers DeepRoot's Silva Cell system filled with a bioretention soil provided by British Sugar.
- That specialized pavement allows:

➢Roots to spread.

➢Water to move.

➢Soils to be protected from compression (compacted soil retains far less water!)

➢It to withstand heavy vehicle loads.

STORMWATER TREES-
THE HOWARD STREET PROJECT

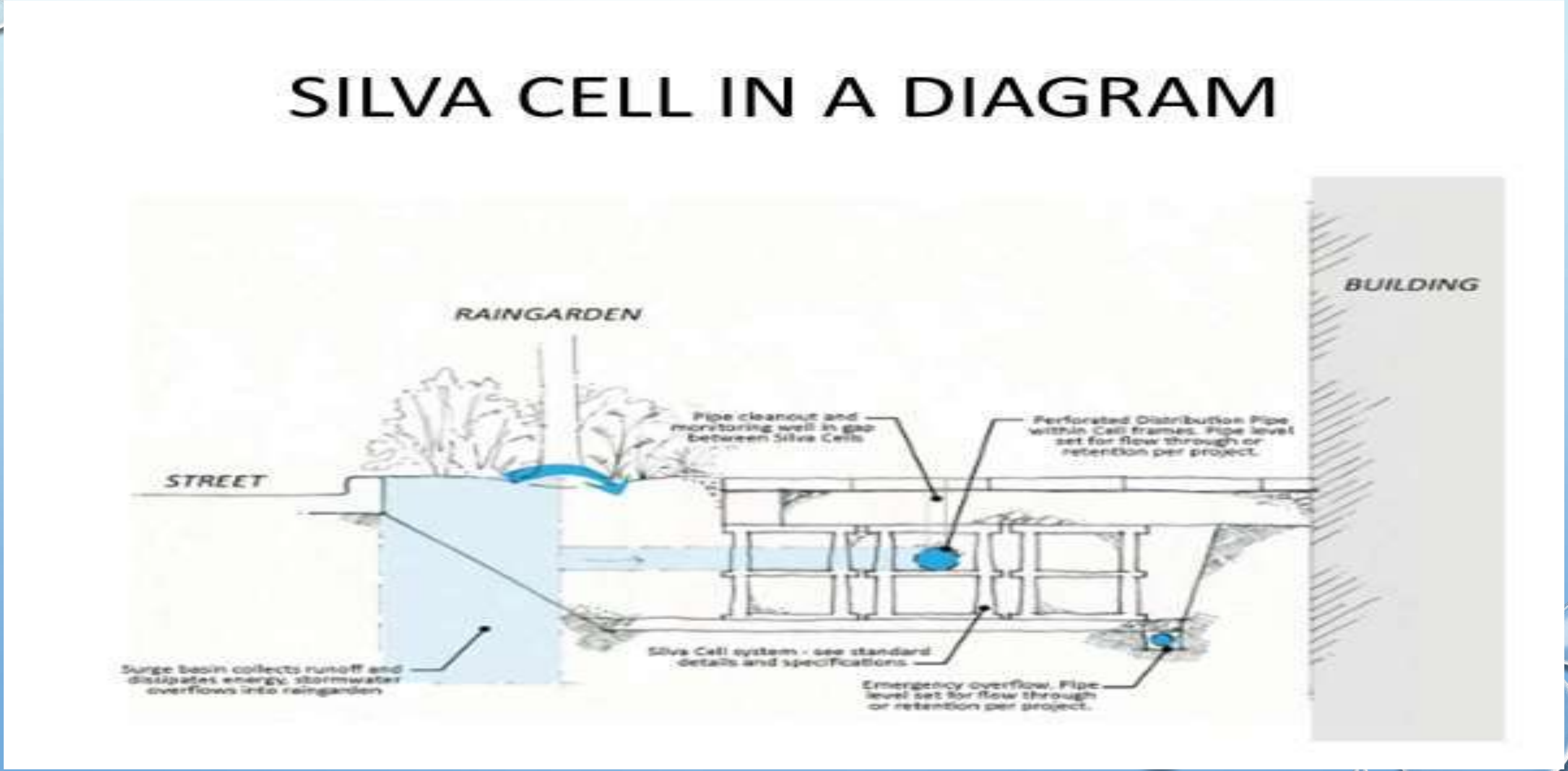
- The system has produced promising results between November 2015 and November 2017:

➢ Average peak flow attenuation was 81% - Reducing the rate at which rainfall enters into the sewer

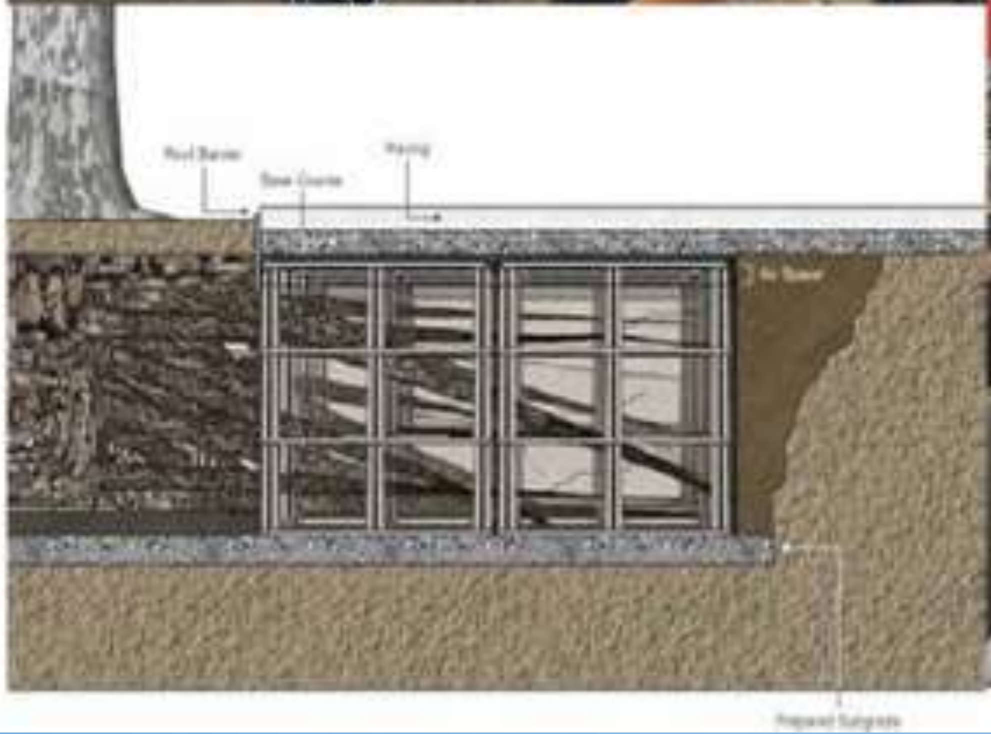
➢ Average volume reduction was 78% - The actual volume/amount of water that will end up in the sewer

➢ Average delay of storm water peak flow was 68 minutes - The amount of time it took for rainwater entering the system and then leaving via the sewer

STORMWATER TREES-
THE HOWARD STREET PROJECT



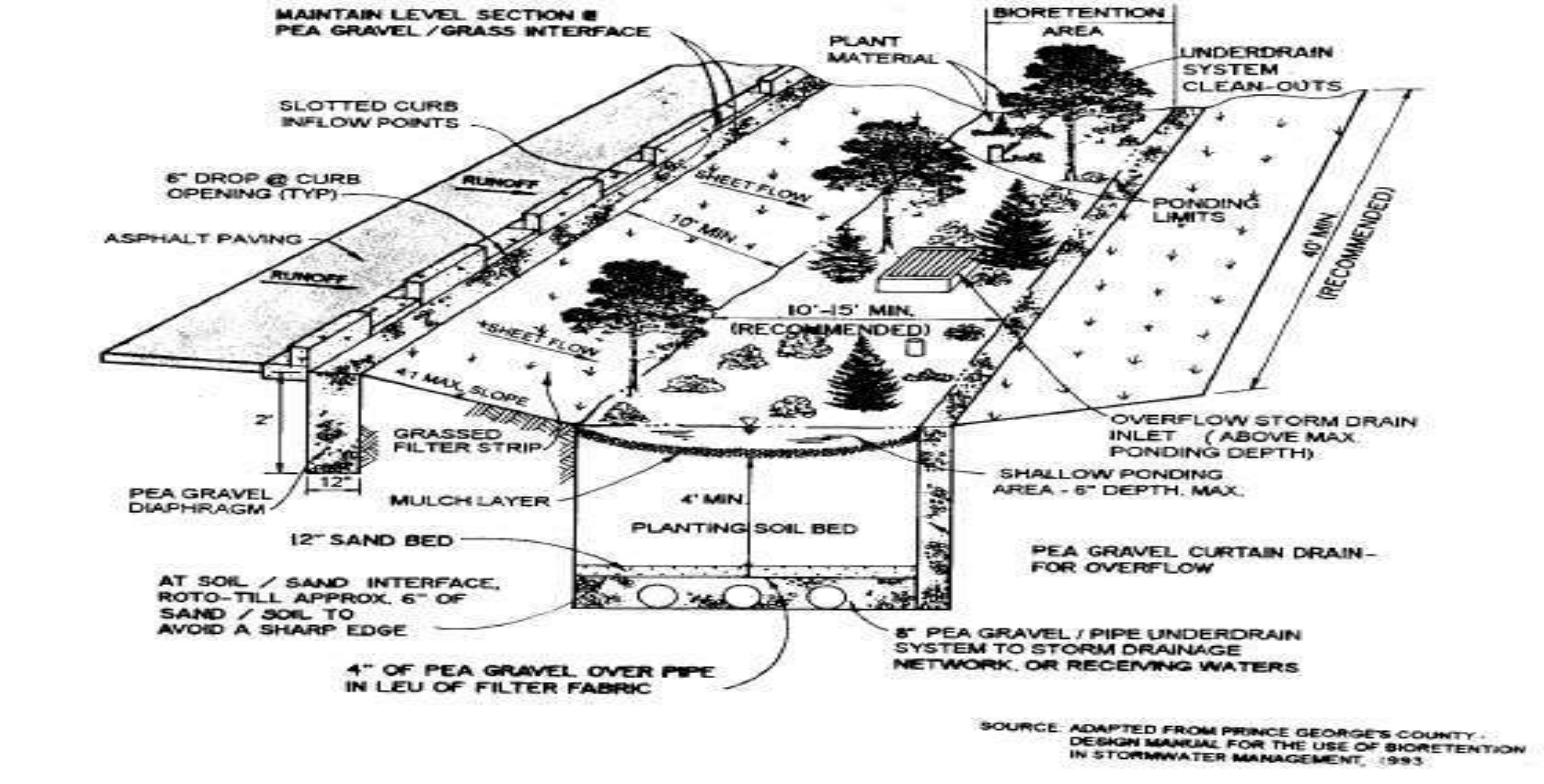





BIORETENTION PONDS

- Landscaped depressions or shallow ponds used to slow and treat on-site stormwater runoff.
- Stormwater is directed to the basin and then percolates through the system where it is treated by several physical, chemical and biological processes.
- The slowed, cleaned water is allowed to infiltrate native soils or directed to nearby stormwater drains or receiving waters.
- Typically associated within small areas of land with residential usage or with parking lots

BIORETENTION PONDS



BIORETENTION PONDS & STORMWATER MANAGEMENT

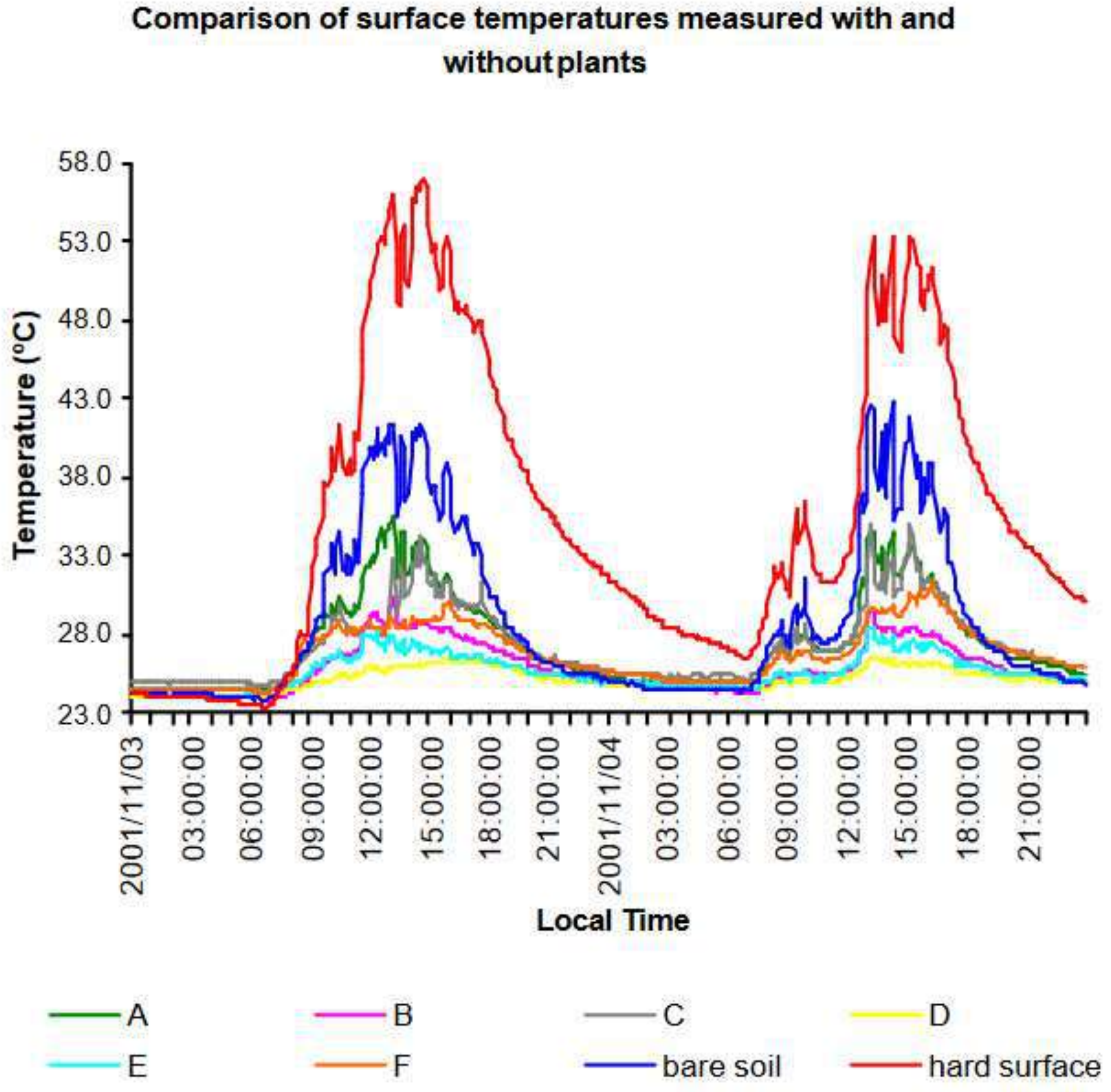
- These systems normally are composed of seven elements, each element with a different function:

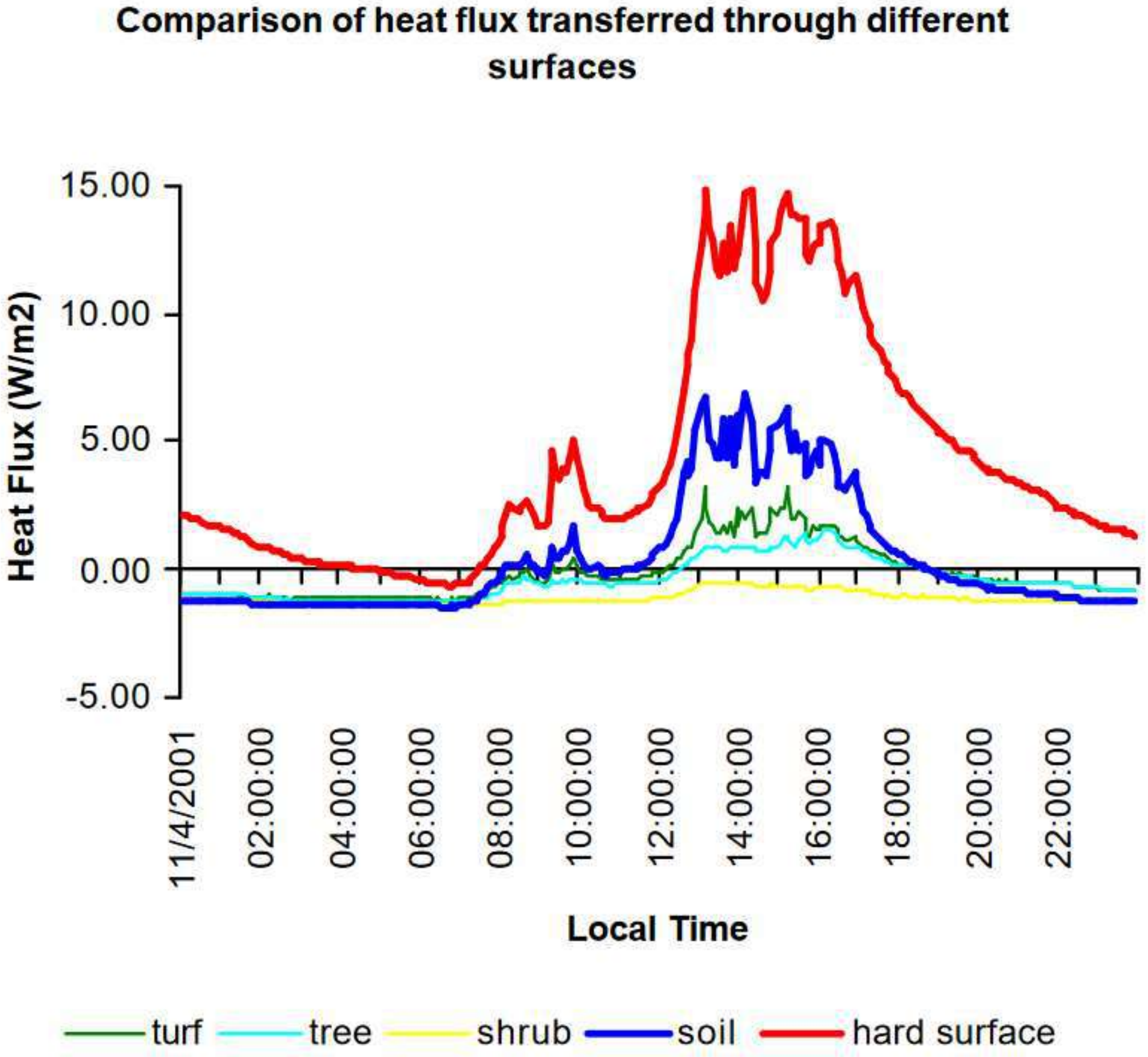
- ➢ Grass buffer strip- reduces runoff velocity and removes suspended solids.
- ➢ Vegetation –Help remove water through process of evapotranspiration and remove excess nutrients through nutrient cycling.
- ➢ Shallow ponding area –provides storage of excess stormwater flows and its subsequent evaporation, also aids in the additional settlement of particulate matter.
- ➢ Mulch –an organic layer that encourages micro biological degradation of petroleum-based pollutants, aids in pollutant filtration and reduces soil erosion.
- ➢ Engineered soils –to support vegetation growth along with nutrient uptake and provision for water storage. Soils should include some clay to adsorb pollutants such as hydrocarbons, heavy metals and nutrients.
- ➢ Sand bed –provide drainage and aeration of planting soil as well as an aid in flushing pollutants.
- ➢ Underdrain system –removal of excess treated water to storm drain system or receiving waters.

ROOFTOP GREENERY

- Historically built in the countries of the Northern hemisphere for insulation from the extreme cold.
- The ‘modern’ green roofs most probably originated in German after a thin layer of sand and gravel mix naturally attracted a layer of spontaneous vegetation.
- Initially advocated after being proven to help reduce urban heat island effect by cooling the urban temperature.

A STUDY OF THE URBAN HEAT ISLAND URBAN HEAT ISLAND IN SINGAPORE (2002)





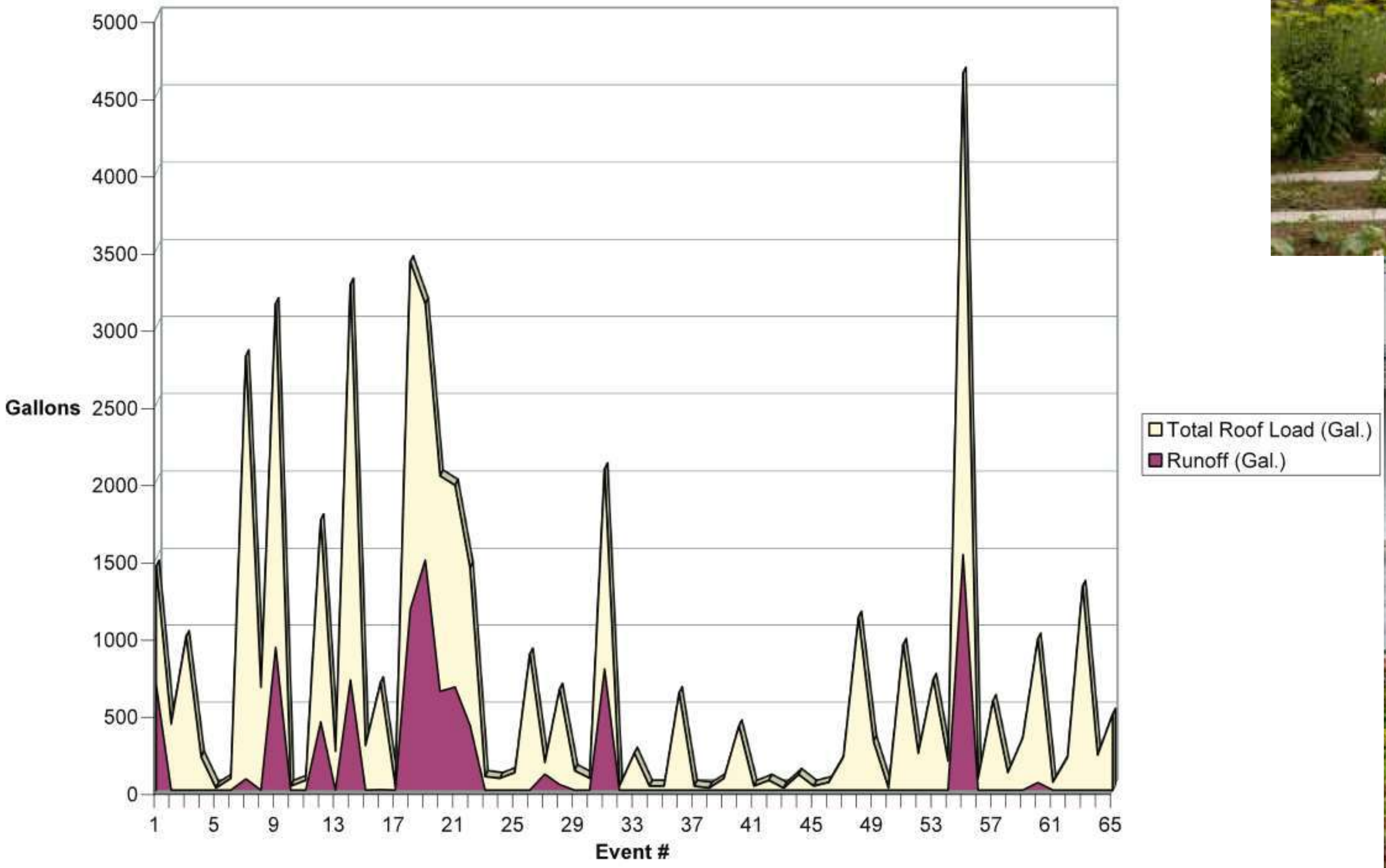
ROOFTOP GREENERY & STORMWATER MANAGEMENT

- Able to improve water quality in cities

Volume/Quantity	Quality
1. Store certain amount of rainwater hence delaying runoff. 2. Helps storm drains cope with severe downpour, hence reducing flash floods. 3. Can reduce the extent of stormwater drainage infrastructure because of its ability to retain water and lower peak runoff (1).	1. Certain media are able to filter heavy metal in rainwater hence resulting in cleaner runoff.

ROOFTOP GREENERY & STORMWATER MANAGEMENT

Figure 1: Rainfall Load versus Roof Runoff

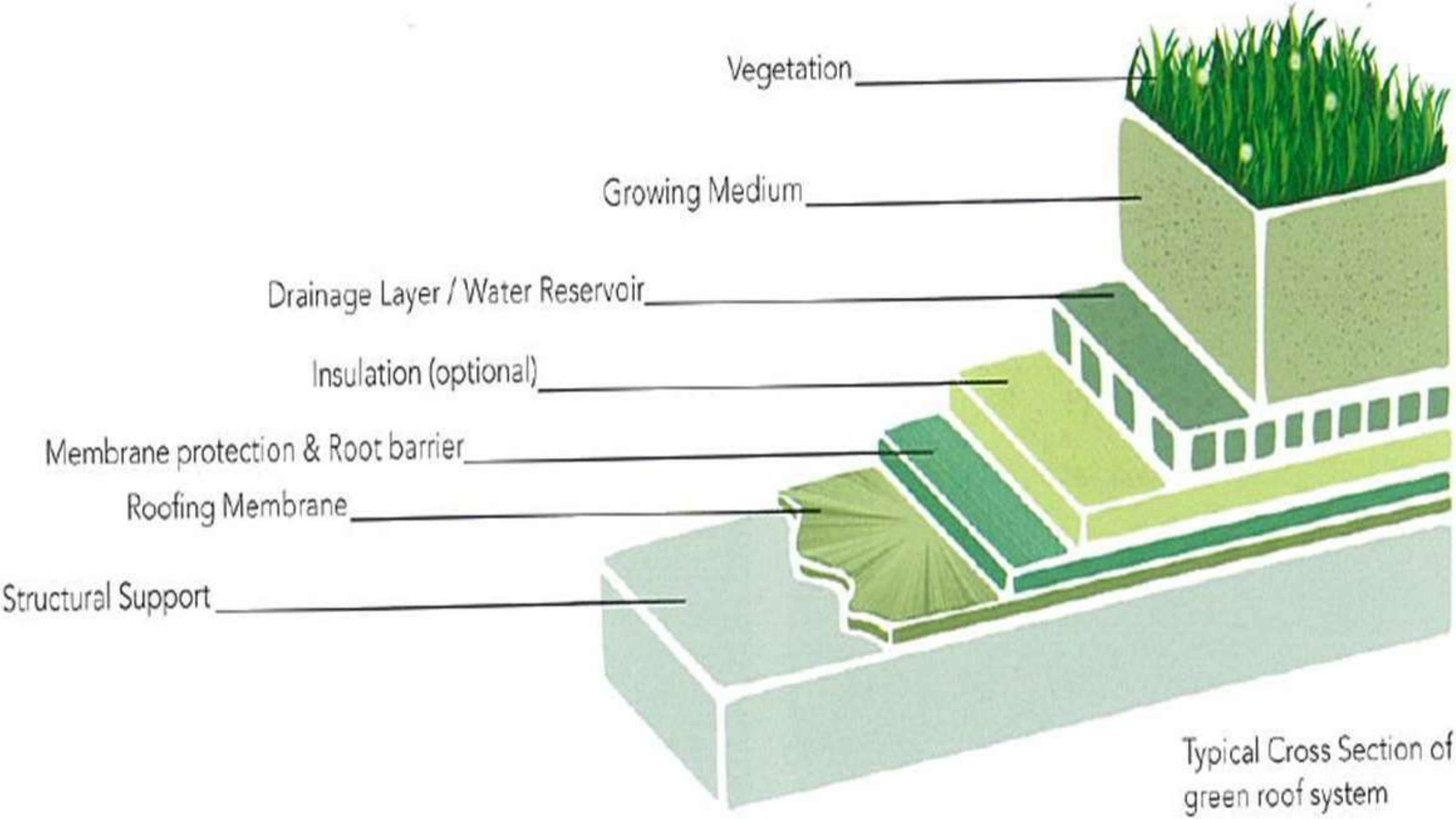


TYPES OF ROOFTOP GREENERY

	Green roofs	Hybrid gardens	Roof gardens
Plant group	Grasses and/or groundcovers	Grasses and/or groundcovers and low shrubs	Grasses, groundcovers, shrubs and trees.
System build-in height	Up to 150mm	Up to 250mm	Up to 1500mm
System build-up weight	≤ 150kg/m^2	≤ 300kg/m2	≤ 500kg/m2
Maintenance	Low	Periodic	High

Green roofs @ School of Art, Design and Media, Nanyang Technological University.

Roof gardens @ Kampung Admiralty housing complex



Typical Cross Section of a green roof system

Suggested Plant Species for Green Roofs

 **Name:** *Kalanchoe* 'Crenatodaigremontianum' **Family:** Crassulaceae **Biodiversity:** -	 **Name:** *Portulaca oleracea* **Family:** Portulacaceae **Biodiversity:** Attracts bees, small insect pollinators	 **Name:** *Kalanchoe pinnata* (Life Plant) **Family:** Crassulaceae **Biodiversity:** Attracts nectar feeding birds
		
 **Name:** *Portulaca grandiflora* (Ross Moss) **Family:** Portulacaceae **Biodiversity:** Attracts Bees, Small insect pollinators	 **Name:** *Pedilanthus tithymaloides* 'Nana' (Jacob's Ladder) **Family:** Euphorbiaceae **Biodiversity:** Attracts nector feeding birds	 **Name:** *Portulaca pilosa* (Native Portulaca) **Family:** Portulacaceae **Biodiversity:** Attracts Bees, small insect pollinators
		

"GARDEN ON THE MOVE"

GREEN WALLS

- All forms of vegetated wall surfaces.
- They are often treated as ornaments, but studies have proven that

➢ Temperatures behind green walls can be reduced by as much as 10°Celsius.

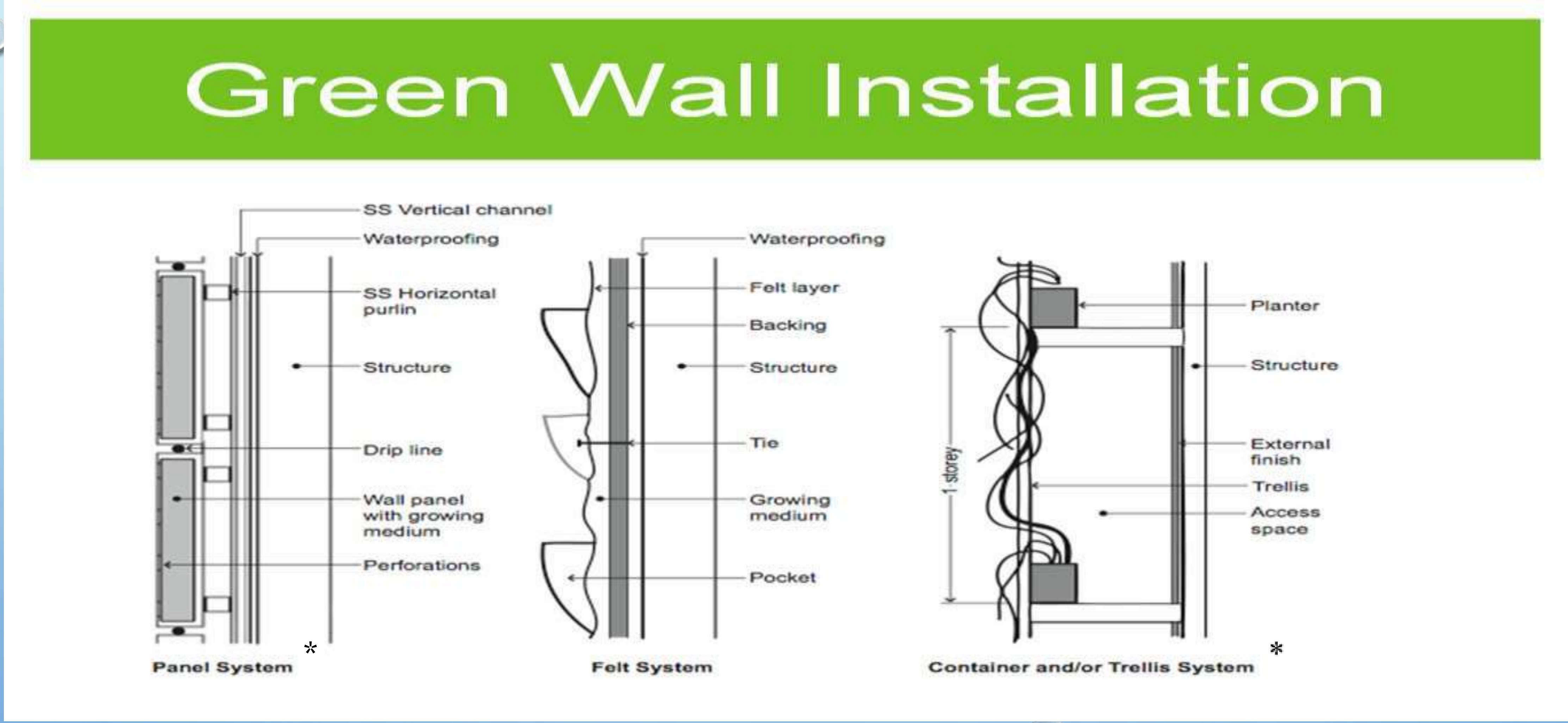
➢ Green walls can help reduce sound reflection.

➢ Through shading, green walls can reduce energy costs by 23 percent.

➢ Protect the underlying structure from frost, sun and rain and will extend the life of the building..

➢ In term of stormwater management, it reduces local flooding by absorbing rainwater, both at root level and by holding it in the canopy of foliage.

TYPES OF GREEN WALLS



* Allow the planting medium to be used for stormwater treatment.

GREEN WALLS & STORMWATER MANAGEMENT

- Exterior wall of the Rubens at the Palace hotel in Victoria.
- Covers 350 square metres with a range of different plants that are all recommended by The Royal Horticultural Society as the best pollinators to attract wildlife such as bees, butterflies and birds to the urban environment.
- Water collected by the tanks is channelled slowly through the wall, nourishing plant life and helping to reduce the risk of surface water flooding in the area by storing up to 10,000 litres at any time.

GREEN WALLS & STORMWATER MANAGEMENT

A female mallard duck had been photographed enjoying the Wall’s lush vegetation.

- Portland Expo Center Stormwater Green Wall.
- 30-foot tall and 60-foot long green wall that is adorned with soil and vegetation native to Oregon, particularly the Columbia River Gorge
- Constructed in 2014 as a freestanding custom metal structure with a **gravity water distribution system** that feeds stormwater to a series of vegetated channels that **filter pollutants** and **absorb stormwater.**
- No pumps are used - The water flows by gravity from the roof through different channels.
- Manages and treats 9,400 square feet of roof stormwater runoff.

HOW TO ENCOURAGE?

- SKYRISE GREENERY INCENTIVE SCHEME 2.0

➢ National Parks Board of Singapore

➢ Fund up to 50% of installation costs of rooftop greenery and vertical greenery.

➢ Open to both residential and non-residential types of development.

HOW TO ENCOURAGE?

- ENFORCING THROUGH LEGISLATION

- 2009 Toronto - Green roofs are required on new commercial, institutional and residential developments with a minimum gross floor area of 2,000 m^2.
- 2015 France - All new buildings constructed in commercial areas must accommodate a green roof, solar panels or both.

PERMEABLE PAVEMENT

Pavement Types from NCDEQ Stormwater Design Manual

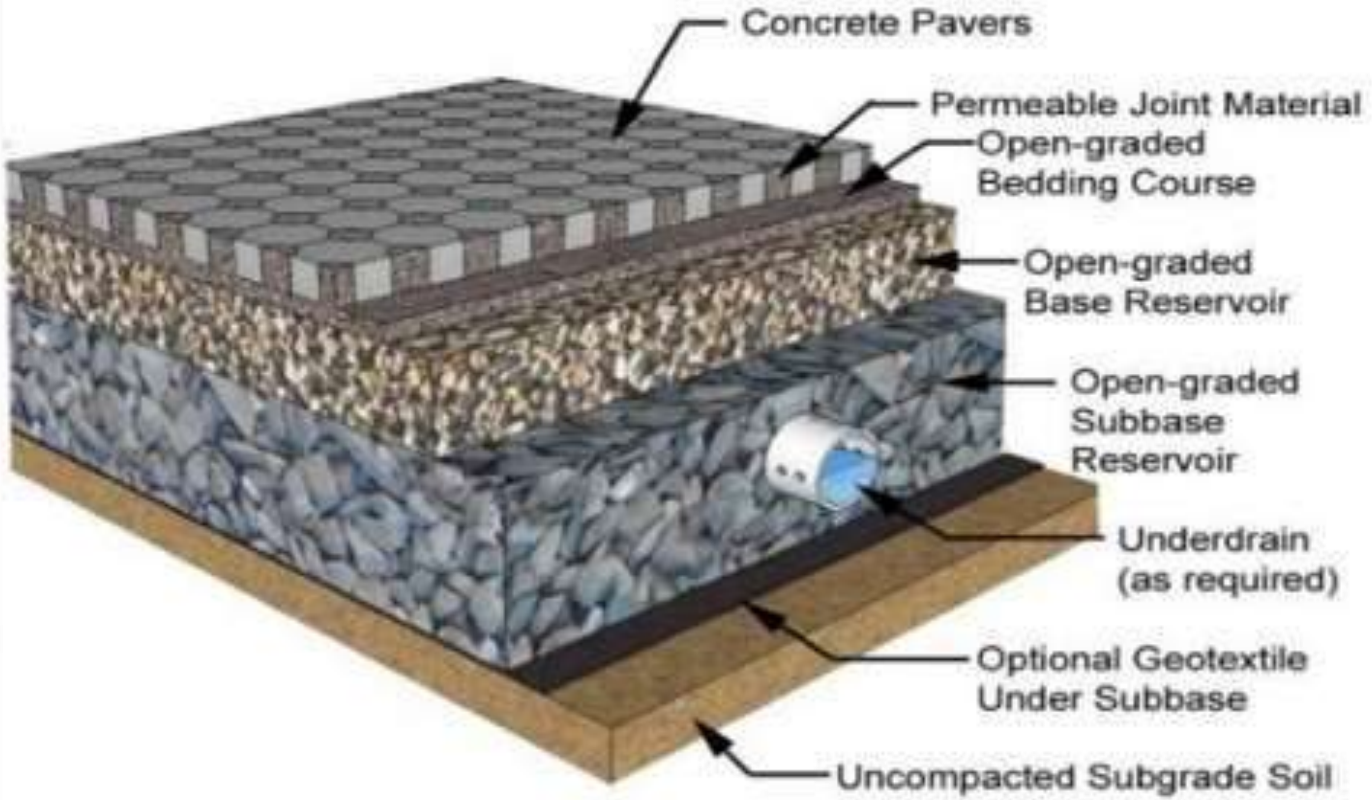
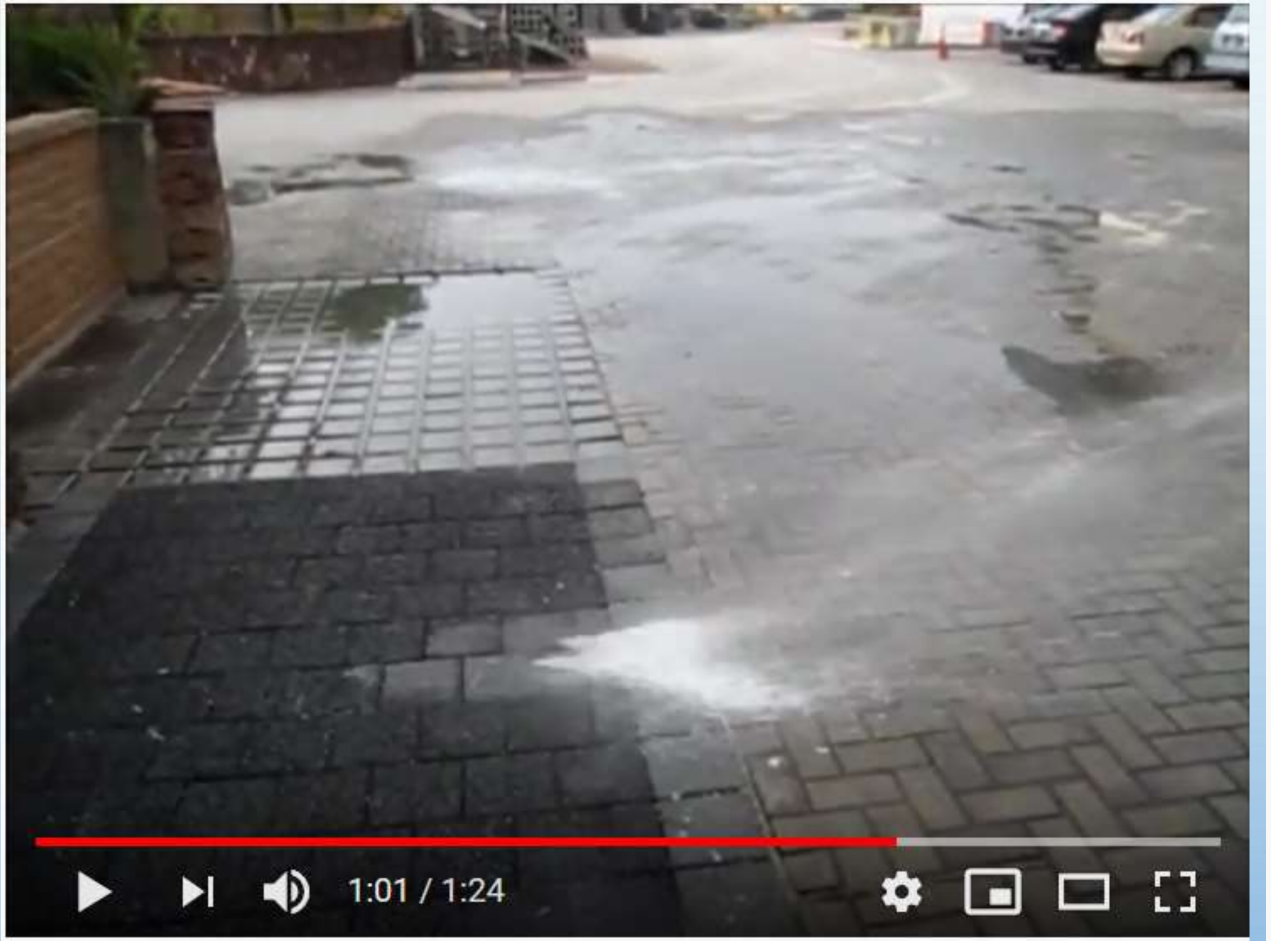


Figure from VADEQ Stormwater Design Specification No. 7 (Source: Smith, 2009)

PERMEABLE PAVEMENT & STORMWATER MANAGEMENT

Eliminates runoff	**Recharges groundwater**	**Traps suspended solids and pollutants**	**Eliminates the need for retention basins and water collection areas**	**Reduces surface temperatures and, therefore, the heat island effect**
Need maintenance due to the possibility that solids and particles may get trapped and clog pavement pores. If not, will assume the traits of impervious pavements.	By infiltration of rain/melted snow into the ground.	Pollutants are removed: total suspended solids are reduced by 85%, NO3 by 30%, and total phosphorous by 85%.	In-situ infiltration into the groundwater.	Evaporation of water at or below the surface produces surface cooling.

PERMEABLE PAVEMENT & STORMWATER MANAGEMENT



Sunway Neupave - No More Water Ponding Area

Porous Asphalt Demonstration

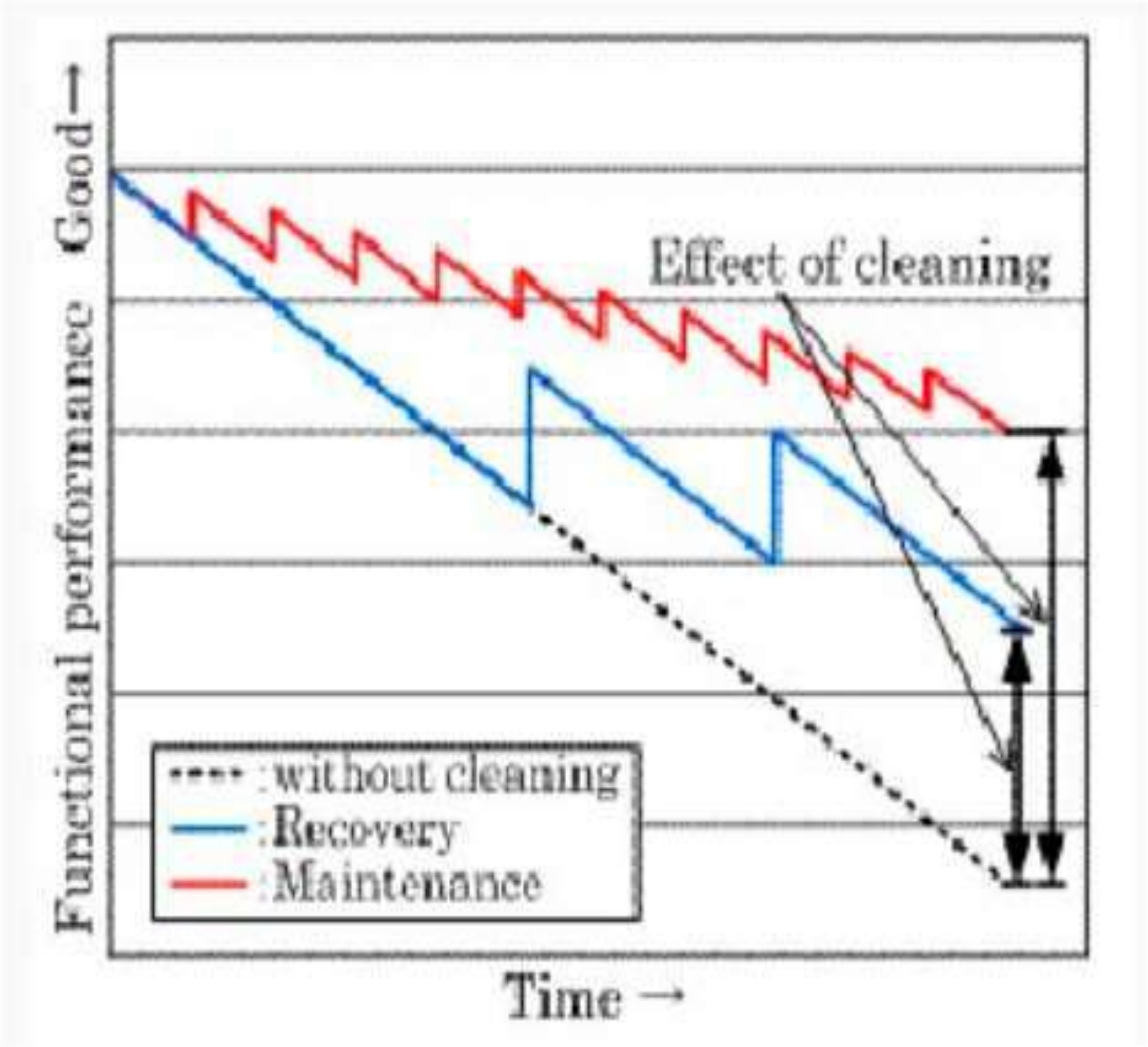


Image diagram of cleaning effect

Porous pavement cleaning machine

ISSUE THAT MAY ARISE FROM THESE INNOVATIVE MANAGEMENTS:

- Maintenance:

➢ Who’s paying?

➢ Unlike water, electricity or gas, stormwater could not be measured because of ‘lack of metering.’

➢ In the USA, many municipalities have established stormwater user fees (SUFs), commonly known as stormwater utilities, to raise revenue for stormwater management.

STORMWATER USER FEES (SUFS) IN USA

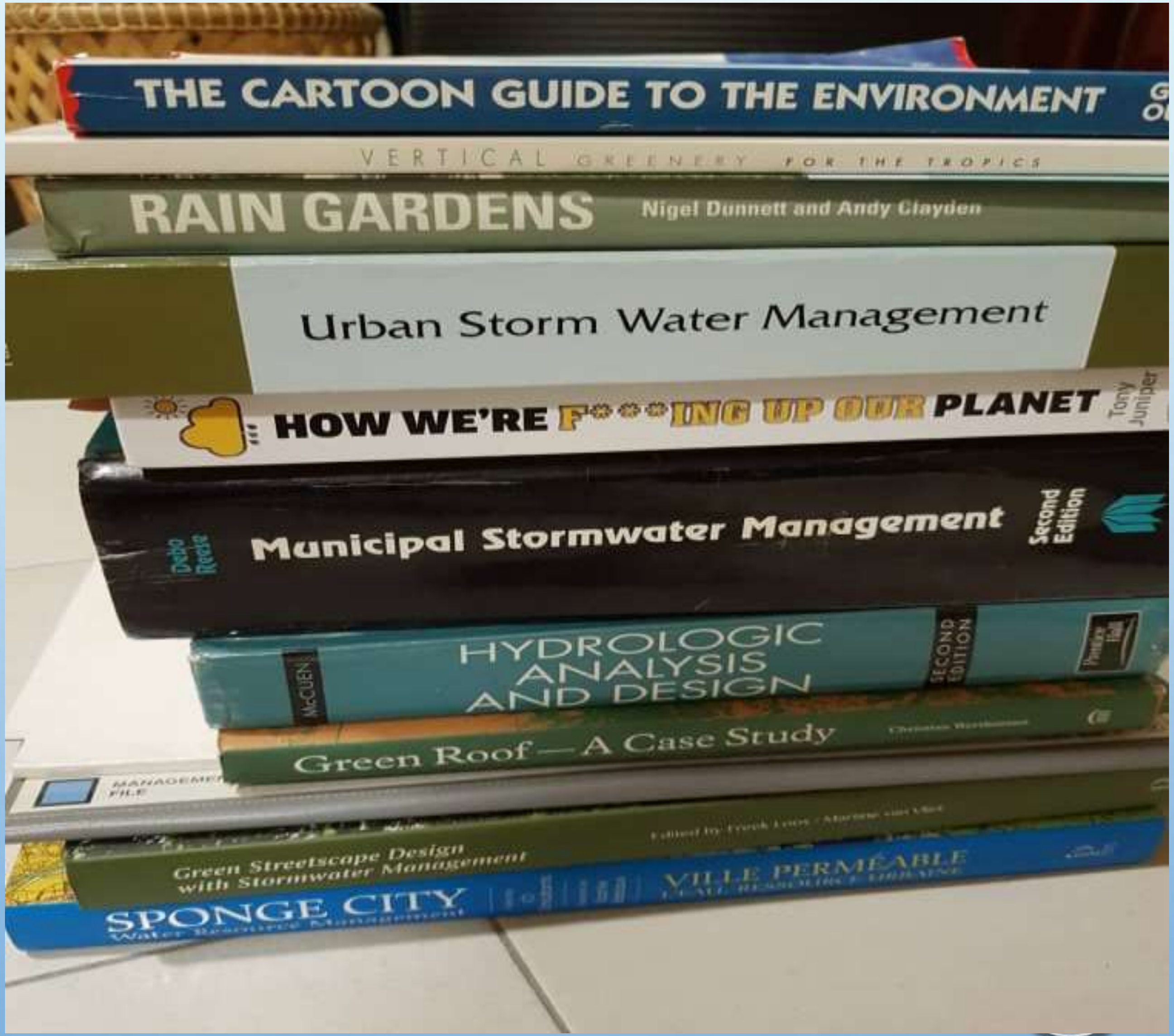
Method	Description
ERU	User fees that determine usage based upon impervious area. One ERU is equivalent to the average amount of impervious area on residential properties. Typically, a charge is assessed per ERU utilized.
Flat Fee	User fees that charge a flat rate to users of a stormwater conveyance system.
Tier	A system where consumers are categorized based upon a select variable and charged accordingly.
Residential Equivalence Factor (REF) (or similar)	User fees that determine usage using the NRCS runoff or Rational method.
Dual (Residential/Commercial)	User fees that assess different rates or use different methods (often Fixed Rate and ERU) for commercial and residential properties.
Per Parcel Square Foot (Sqft.)	User fees that charge a rate per parcel sqft. of imperviousness.
Per Parcel Acre	User fees that charge a rate per parcel acre of imperviousness.
Water Meter	User fees that charge based upon the size of a parcel's water meter. (Often exhibited in tier systems)
By Water Usage	User fees that charge according to parcel water usage.

A nation that fails to plan intelligently for the development and protection of its precious waters will be condemned to wither because of its shortsightedness. The hard lessons of history are clear, written on the deserted sands and ruins of once proud civilizations.

— *Lyndon B. Johnson* —

[redacted]

REFERENCES


THE CARTOON GUIDE TO THE ENVIRONMENT
VERTICAL GREENERY FOR THE TROPICS
RAIN GARDENS
Nigel Dunnett and Andy Clayden
Urban Storm Water Management
HOW WE'RE F***ING UP OUR PLANET
Tony Juniper
Debo Reese
Municipal Stormwater Management
Second Edition
HYDROLOGIC ANALYSIS AND DESIGN
McCUEN
SECOND EDITION
Prentice Hall
Green Roof — A Case Study
Green Streetscape Design with Stormwater Management
SPONGE CITY
Water Resource Management
VILLE PERMÉABLE

REFERENCES

- Department of Statistics Malaysia Official Website. Population Distribution and Basic Demographic Characteristic Report 2010 (Updated: 05/08/2011)
- Global Footprint Network http://data.footprintnetwork.org/#/
- https://www.star2.com/living/2017/12/13/living-within-our-planets-capacity/#GcSe1gvOXpe08sBc.99
- Johnson, Lyndon B. (1970). “Public Papers of the Presidents of the United States: Lyndon B. Johnson, 1968-1969”, p.1131
- https://www.greaterauckland.org.nz/2017/12/15/aucklands-urban-freshwater-historic-relationship/water-cycle/
- https://drnm.me/water-cycle-infographic/great-graphic-showing-how-urbanization-impacts-the-water-cycle/
- https://www.aalto.fi/en/news/how-can-we-conserve-the-natural-cycle-of-water-in-cities
- https://www.climatecentral.org/go/wmo-greenhouse-gas-bulletin-2015
- https://www.nst.com.my/news/2017/01/202751/rich-waters
- https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=162&bul_id=U3p3RVY0aGtGS08yTDY2cEpraDFlUT09&menu_id=NWVEZGhEVlNMeitaMHNzK2htRU05dz09
- http://redac.eng.usm.my/html/publish/2004_06.pdf
- Wong Nyuk H (2002) “A Study of Urban Heat Island in Singapore.”
- http://www.lakesuperiorstreams.org/stormwater/toolkit/bioretention.html
- https://www.groundwater.org/action/home/raingardens.html
- Kea Kandace M. (2015) “An Analysis of Trends in U.S. Stormwater Utility& Fee Systems”

REFERENCES

- National Parks, Centre for Urban Greenery and Ecology Singapore. “A Concise Guide to Rooftop Greening.”
- Glass Charles C. (2007) “Green Roof Water Quality and Quantity Monitoring”
- https://www.straitstimes.com/singapore/environment/moving-garden-as-singapores-first-public-bus-with-green-roof-hits-the-road
- https://www.straitstimes.com/singapore/green-thumbs-up-for-kampung-admiralty
- Lau J.T and Mah D. Y. S. (2018) “Green Wall for Retention of Stormwater.”
- https://greenworkspc.com/blog/2016/04/25/stormwater-green-wall-portland-expo-center-new-admirer
- https://www.oregonmetro.gov/news/portland-expo-center-debuts-unique-living-stormwater-green-wall
- https://www.telegraph.co.uk/gardening/howtogrow/11035106/Green-walls-how-to-grow-a-garden-vertically.html
- https://www.dezeen.com/2013/08/21/londons-largest-living-wall-will-combat-flooding/
- Eugene S, Khareedi S, Padhye L.P (2017) “Evaluating The Viability of Suspended Raingardens for Stormwater Treatment.”
- https://www.researchgate.net/publication/321337280_Effective_Stormwater_Runoff_Treatment_with_Lightweight_Media
- Pennsylvania Stormwater Management Manual (2005)
- https://www.pavementinteractive.org/reference-desk/pavement-types-and-history/pavement-types/permeable-pavements/
- https://www.go-gba.org/resources/green-building-methods/permeable-pavements/
- https://www.sunway.com.my/sunway-first-to-introduce-permeable-pavers-in-malaysia/
- https://hydropavers.ca/products/fake-vs-real/
- http://www.dohkenkyo.com/english/tc_clean.html


THANK YOU FOR LISTENING
ANY QUESTIONS?
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