Deterministic approach to managing floods and mitigating impact in Blantyre City

(Stormwater management)

2022 Engineering Conference

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09th September, 2022

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1.0 Introduction

1.1 Flooding Phenomenon

The covering or submerging of normally dry land with a large amount of water.

1.2 Flooding Conditions

- Flooding conditions vary from region to region.
- Flooding water levels ranging from 0.2 metres up to extreme cases of 5.0 metres.
- Major flooding can cover a few thousands hectares, Figure 1.

Figure 1: Comparison of Major Flooding against Flash Flooding	
❖ Major Flooding	❖ Flash flooding
❖ From river overtopping	❖ Localised short duration
❖ Causing widespread flooding of long duration	❖ Usually occur in urban areas from intense thunderstorms, with water rising immediately during the storm but receding within 6 hours after the rain

2.0 Background

2.1 Famous Global Flooding Events

- London Flooding Incidents on July 25, 2021 left people stranded, with streets turned into rivers and submerged train stations causing travel chaos.
- The British Columbia province of Canada where 18, 000 people were left stranded after landslides terrible disaster of November 17, 2021.
- A multiple of provinces across China were devastated by widespread series of flood events from heavy prolonged rains spanning from June to July, 2021 affecting quite a number of cities.

2.2 Public Perception

- World most rich cities are dangerously not prepared for extreme and severe weather events influenced by climate change.
- In Germany, the Associate Director of the Environmental Change Institute at the University of Oxford, Friederike Otto, bemoaned that even developed countries are not safe from severe impact of extreme weather events ever seen and known worse to be induced by climate change.

3.0 Objectives

- The devastating impact from surface run-off triggering justification for study into drainage technical system and capacity design procedure review.

- To explore alternative methodologies to avert similar future occurrences and consequences.

- To achieve optimum sustainable usage of surface water resources in an urban environmental set-up, mainly focusing on beneficial extraction of stormwater run-off.

4.0 Challenges in Blantyre City

4.1 General Experience

- Persistent flooding due to inadequate carrying capacity both in conduit size and network coverage.
- Restriction to traffic passage causing congestion and traffic jam.
- Environmental pollution from sewer spillage into open spaces.
- City residents and the surrounding society exposed to health risks, gradually affecting lives and economic productivity.

4.2 Zonal Flooding

- Post Office along Churchill road
- Fersson’s Transport in Limbe
- FDH Bank in Limbe
- Maselema
- Old DHL offices along Haile Selassie Street
- Clock Tower
- HHI along the Chileka Road via Magalasi
- Kwacha roundabout
- Residential township roads

4.3 Existing Stormwater System Design

- The stormwater system is separate from sanitary sewers.
- Originally constructed in the late 1950's with extensions constructed in 1968-9.
- Refurbishment was carried out in the 1980's with major works completed in 1990 (Government of Malawi, 1995).
- The artificial stormwater drainage collection systems generally still follow the city roads network.
- In form of open unlined ditches, masonry-lined channels and concrete circular pipe culverts, varying in diameter and installation depth.

5.0 Urban Stormwater Management

5.1 Resilient Stormwater Drainage Systems

- Sound drainage systems conserve fresh water.
- Industrialisation (Figure 2) results from successful investment in resilient and sustainable infrastructure, safe with provided resilient stormwater drainage systems.
- Resilient drainage systems therefore are necessary to prevent excessive flooding which generates negative sanitation impact and creates risk to collapse of structures for safe human settlement.

Figure 2 (a): Changes in Water Balance due to Urbanisation (Saraswat et al., 2016)

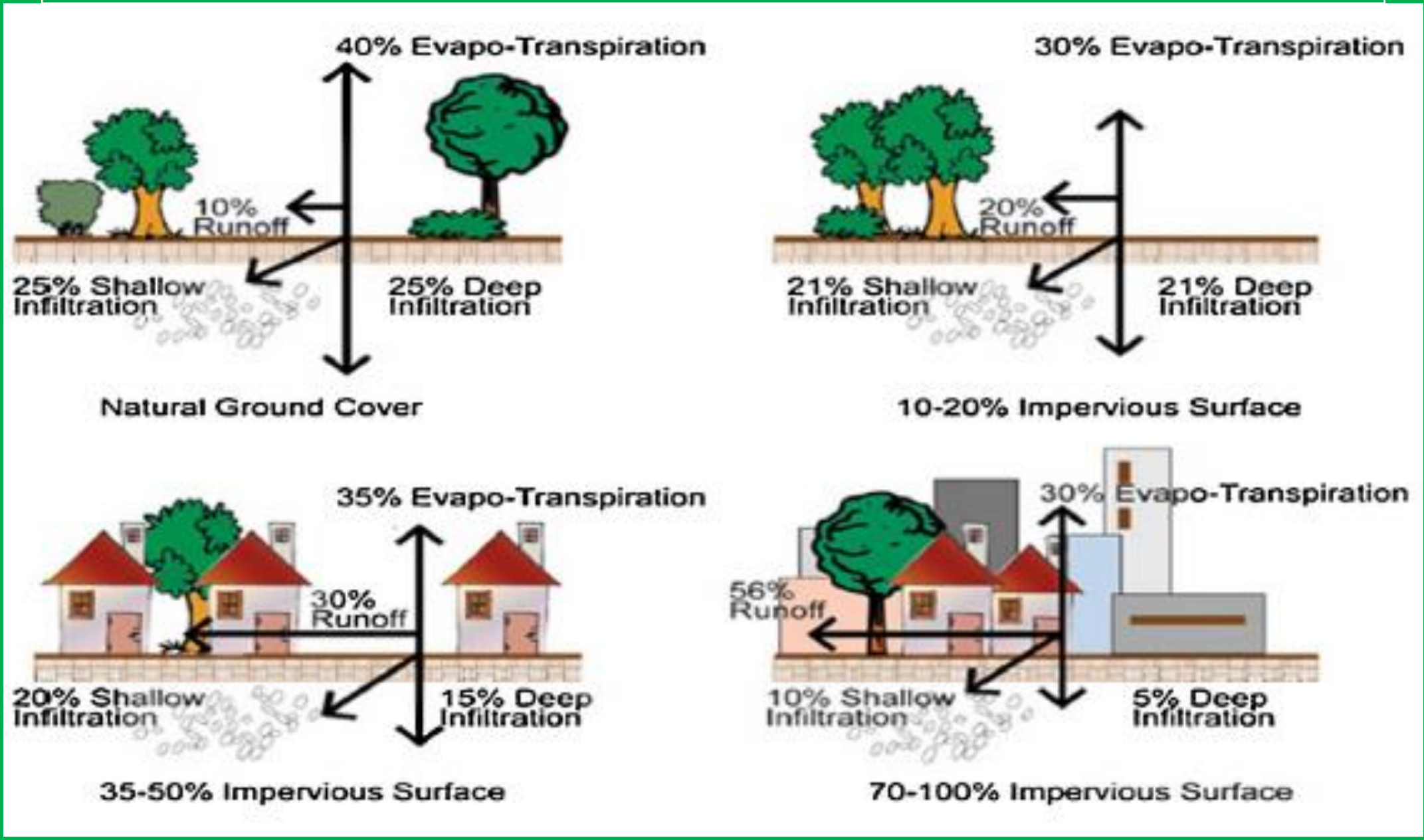
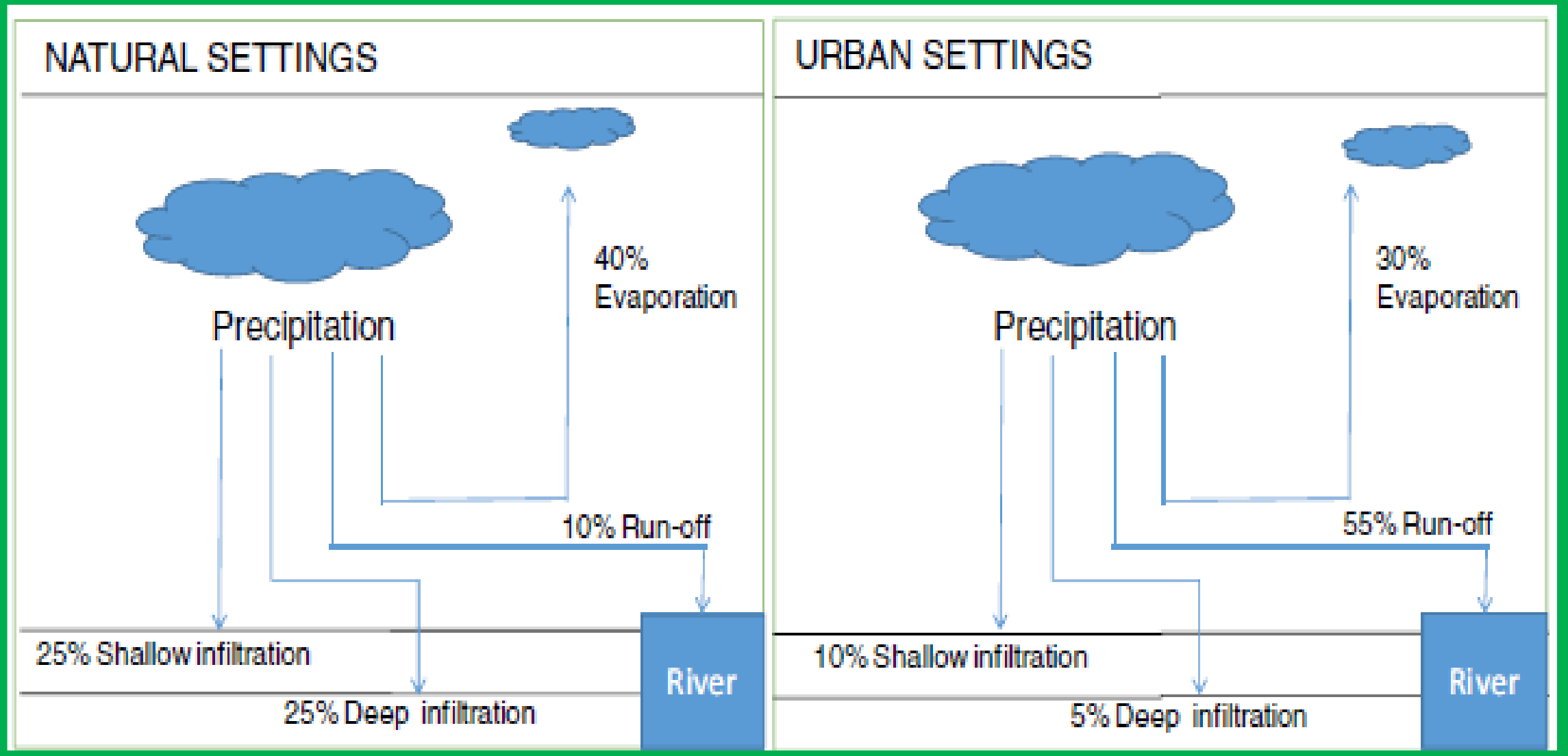


Figure 2 (b): Surface Run-Off Comparison between Natural and Urban Settings (Saraswat et al., 2016)



- Appropriate surface run-off conservation practices promote land restoration from degradation, protecting the ecosystem with sustainable management approaches in safeguarding biodiversity (United Nations, 2018).
- Excessive urban stormwater pose threat to urban infrastructure, economy and the ecosystem when not properly planned and managed (Jusic et al., 2019).
- Urban stormwater management controls both flow quantity and run-off quality, requiring understanding thereof in both structural and non-structural measures.

- National Research Council (2008) identified urban stormwater being the leading source of water quality problems and principal contributor to receiving water bodies in the United States posing great challenges in pollution control.

5.2 Stormwater Management with Government Urbanisation Agenda

- Provision of resilient infrastructure is in tandem with commitment strategies embraced by the Government towards attainment of MW 2063 urbanisation agenda.
- Run-off conservation is of paramount importance if Blantyre City is to be kept clean to deserved urban sanitary status associated with elite and the tidy business environment.
- As technocrats, are we ready to advise Government on such appropriate modern stormwater management practices?

5.3 Integrated Water Cycle Management

- Crucial for appropriate conservation practices in the urban water cycle, Figure 2.
- Knowledge and understanding of hydrologic principles and basics of hydraulic concepts is fundamental in the design of stormwater drainage systems.
- The fundamental objectives of stormwater management is to control: flooding; soil erosion and sedimentation; and pollution.

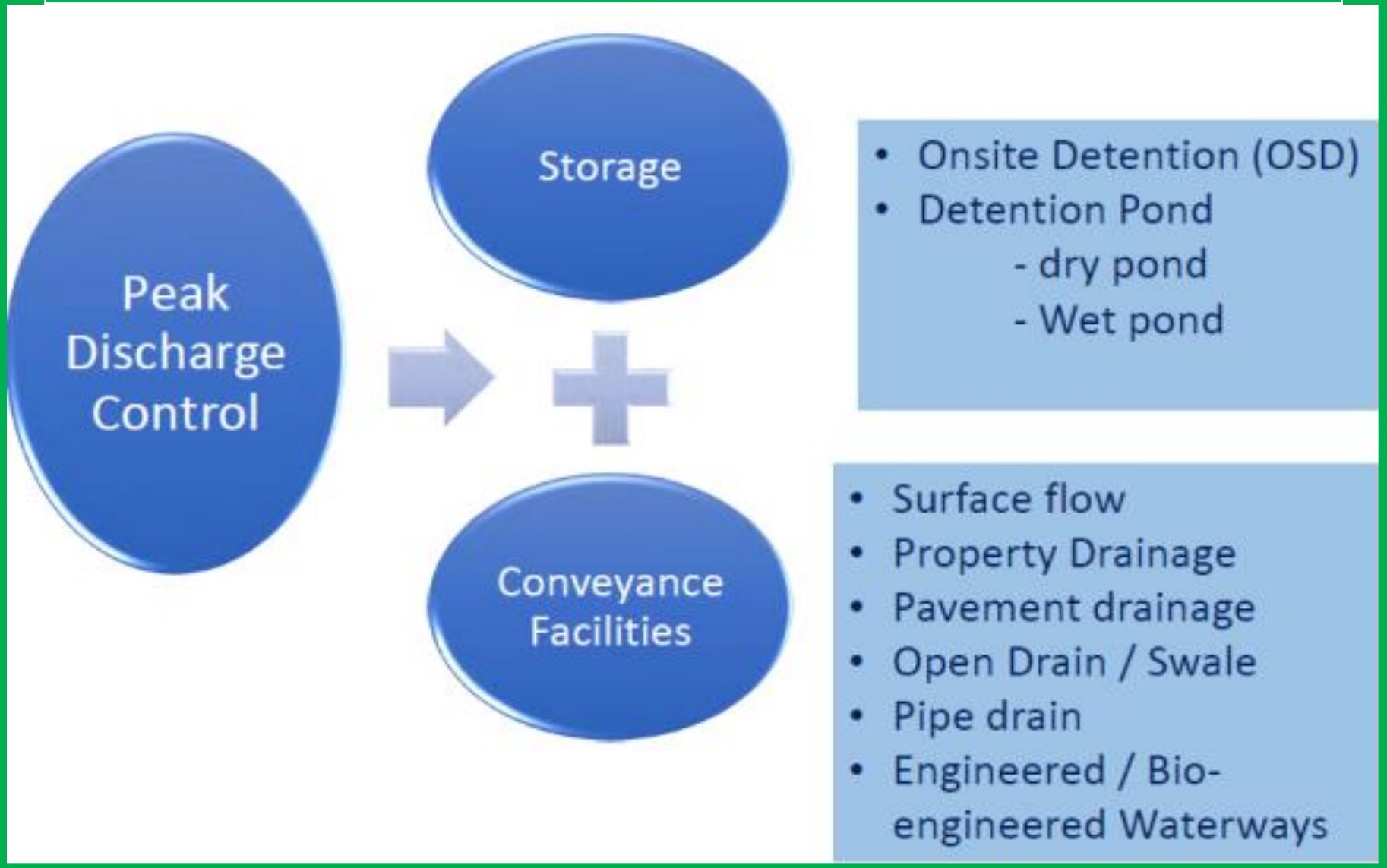
Urban Water Cycle

5.4 Modern Stormwater Management Approach

- Integrated techniques to achieve sustainable environmental and socio-economic balance form basis of modern stormwater management approach, incorporating both flood control and pollution control to restore the natural environment (Juiani et al., 2021).
- The techniques provide methodologies for run-off quantity (Figure 3) and quality control at source or nearby with effects of reduced stormwater and controlled flow rate to preserve groundwater in promoting the natural hydrologic cycle.

- In Malaysia, the Kwasa Damansara township development initiative unlocked land value in provision of 21st century high quality built-environment through coordinated input via the urban design guidelines.
- The infrastructure development strategy integrated urban stormwater management planning, landscape value and environmental consideration.

Figure 3: Modern Concepts on Quantity Control: (Urban Stormwater Management Manual for Malaysia, 2011)



5.5 System Design Balance

- Kleidorfer (2014) proposed on-site stormwater infiltration treatment facilities to protect pervasive contamination and flooding in receiving water bodies.
- Balanced drainage systems contribute to sustainable development in improving residential, work place, and leisure areas through balancing opportunities and challenges influenced by urban community infrastructure designs.
- Containment of flooding (quantity) and pollution (quality) to biodiversity (wildlife and plants) with heating protection, and safety to amenities is collectively referred to as Sustainable Drainage System (SuDS), which consist of nature-based solutions.
- Conventional system design paradigm focuses primarily on flood mitigation rather than preventive, it is not ideal for sustainable development pathway to curb combined negative physical and health impact to society, (Jusic et al., 2019).

6.0 SuDS Implementation Potential in Blantyre City

6.1 Landscape Potential

- Natural hillside landscape for imaginative designs and landscape planning as opposed to flat terrain.
- Radial rivers.
- Appropriate stormwater management practices therefore need to be engaged to mitigate impact of flooding from increased rate of run-off on hillside developments, such as energy dissipaters, to safeguard downstream settlements and receiving water bodies.

6.2 Available Amenities

- Recreation parks
- Wastewater treatment facilities
- Small-size earth dams

6.3 Run-Off Reduction Method

- Run-off Reduction Method (RRM) through LID strategies (Battiata, 2010; Saraswat et al., 2016).
- Can be utilized to intercept run-off huge volume from the watershed.
- Re-routing approach can be implemented in sequential combination of all capture, momentum retarder and storage techniques (Kellagher, 2013).
- Run-off can be circulated and detained in these recreation facilities and subsequently easily attenuated into adjacent stream ecosystems.
- The approach minimises run-off increase within developed land with capability of incorporating both conventional and innovative Best Management Practices in Table 1.

Table 1: Practices Included in the Run-Off Reduction Method

Step 1: Environmental Site Design (ESD)	Step 2: Runoff Reduction (RR) Practices	Step 3: Pollutant Removal (PR) Practices
Forest Conservation	Sheetflow to Conserved Open Space	Filtering Practice
Site Reforestation	Rooftop Disconnection: ▪ Simple ▪ To Soil Amendments ▪ To Rain Garden or Dry Well ▪ To Rain Tank or Cistern	Constructed Wetland
		Wet Swale
Soil Restoration (combined with or separate from rooftop disconnection)		Wet Pond
Site Design to Minimize Impervious Cover & Soil Disturbance	Green Roof	
	Grass Channels	
	Permeable Pavement	
	Bioretention	
	Dry Swale (Water Quality Swale)	
	Infiltration	
	Extended Detention (ED) Pond	

7.0 Findings

- Blantyre City Council need to invest in human capital to realise potential and value for government MW2063 urbanisation vision.
- Collaboration at different levels in governance is key to unleashing hidden aptitude.
- Authorities need to realise that time is changing, and practice of unusual methodologies in stormwater management is the only way towards sustainability.
- Paradigm shift from traditional practices to modern approaches in conservation of run-off is indispensable.

8.0 Case Studies

8.1 Hanoi City (Vietnam)

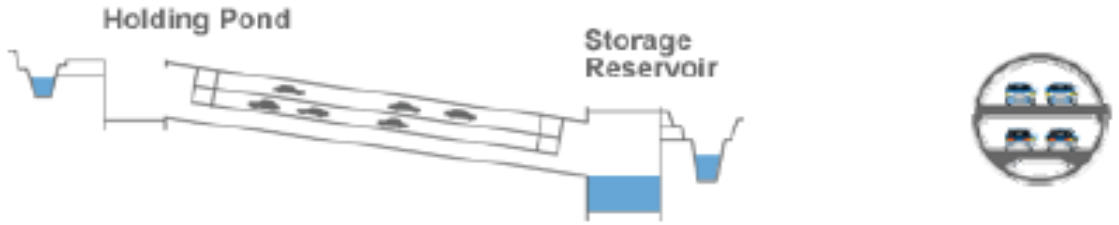
- Decentralised stormwater management measures are incorporated in the urban landscape design to handle the problem at source.
- Hanoi addresses excessive stormwater run-off through the urban aquaculture system, Figure 4.

Figure 4: Raw Wastewater and Stormwater Fish Pond in Hanoi City

8.2 Kuala Lumpur (Malaysia)

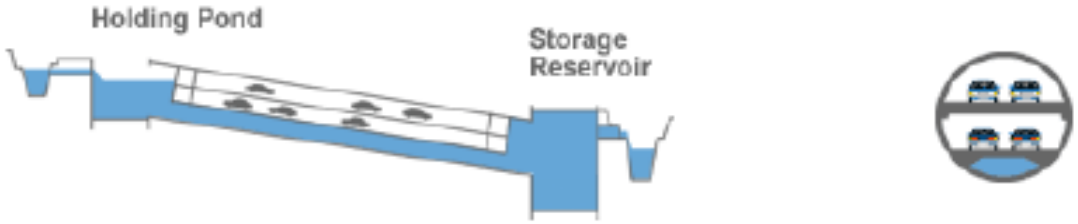
- Stormwater Management and Road Tunnel (SMART) project in Figure 5 testify modern cities safety from floods with sustainable urban planning.
- The SMART project has dual function sustainable solution concurrently operating as stormwater conveyance (diversion and storage) system, and road traffic carriageway.
- The project is similar in nature to Tokyo’s world largest underground flood and stormwater run-off diversion facility comprising five silos through tunnel channels, known as Metropolitan Area Outer Underground Discharge Channel or G-Cans project.

Figure 5: SMART System Project



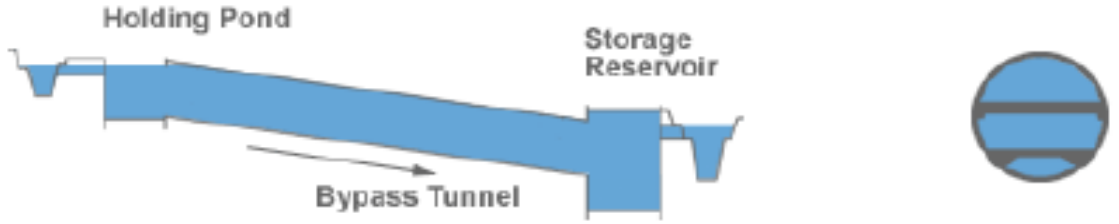
1. No storm, low rainfall

No flood water will be diverted into the SMART system.



2. Moderate storm

The SMART system will be activated and flood water will be diverted into the bypass tunnel in the lower channel of the motorway. Up to this point, the motorway will still be open to traffic.



3. Major storm

The SMART system will be activated and the motorway will be closed to traffic. Sufficient time will be allocated to allow the last vehicle to exit the motorway before the automated watertight gates are opened to allow flood water in. The motorway will be re-opened to traffic within 48 hours.

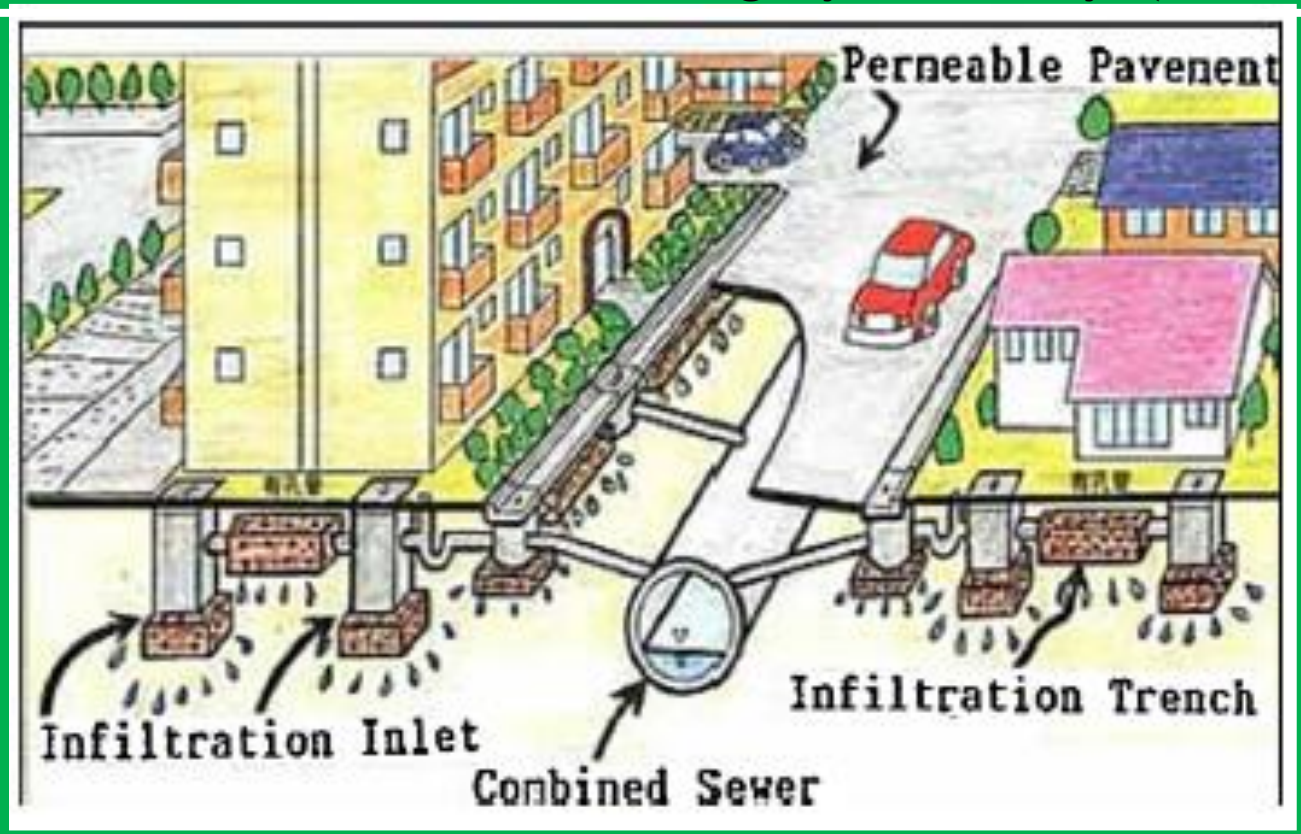
8.3 Bangkok (Thailand)

- Plans to build similar magnitude underground stormwater drainage facility below the existing 8 lane-100 Km long eastern outer ring road.

8.4 Tokyo (Japan)

- Combined sewer in Tokyo is the adopted design, Figure 6.

Figure 6: Infiltration Trench and Sewerage System in Tokyo (Sarawat et al., 2016)



9.0 Conclusion

- Lack of creativity towards adaptation to climate change obscures sustainable development innovations in local authorities besides financial constraints.
- Vast and rapid increase in development of urban areas is influenced by urbanisation trends resulting into increased stormwater peak run-off and corresponding high volumes outfalls threatening sustainability to infrastructure, property and life.
- Malawi Urban Stormwater Management Manual is required to guide needed design of Blantyre City Stormwater Master Plan.

Thank You