



Sustainable Stormwater Management in Singapore: A Tropical Example

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Structure of the talk

About Singapore

Water situation in Singapore

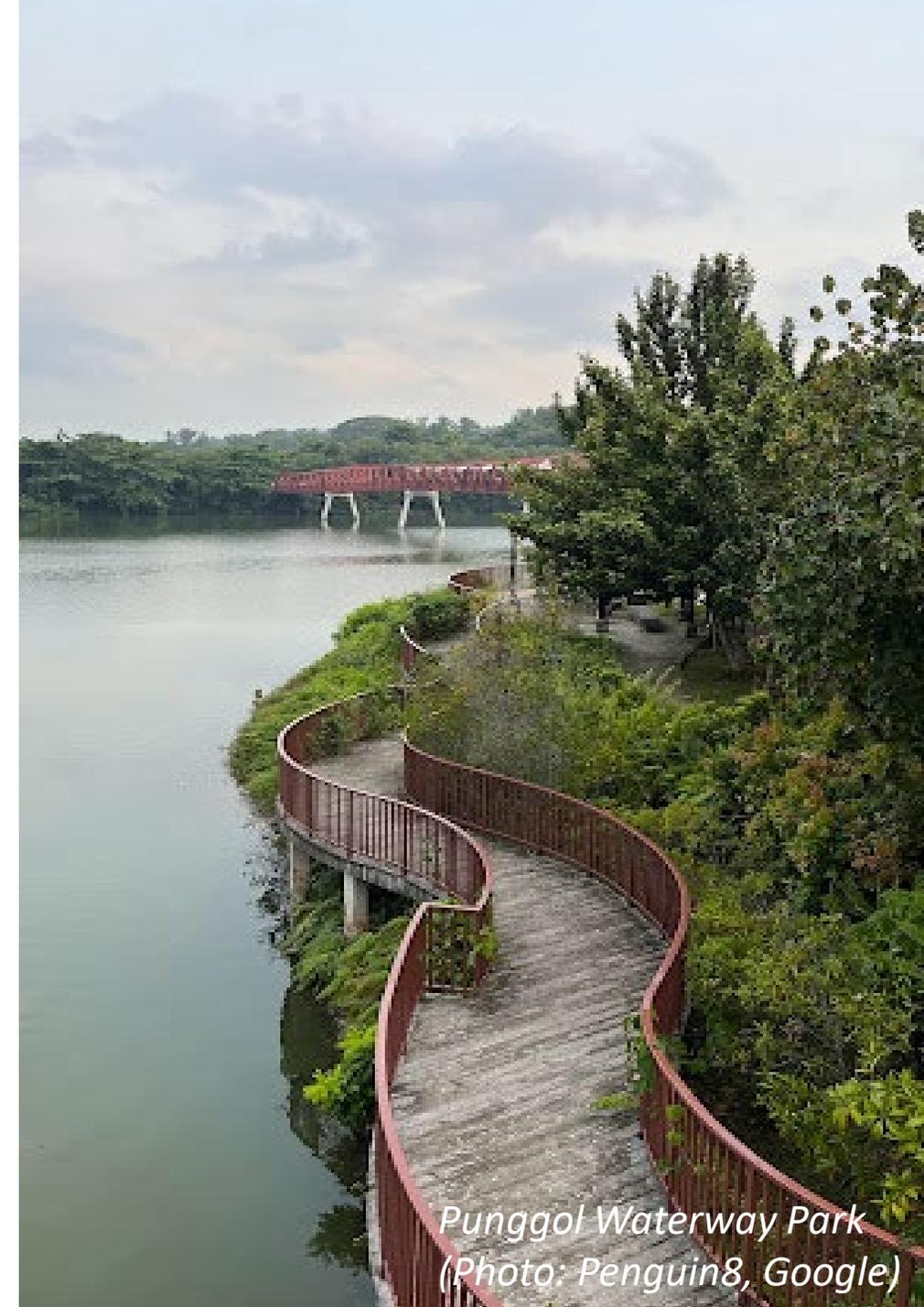
Stormwater management in Singapore

- Approaches
- Timeline
- ABC Waters Design elements

Why ABC Waters was successful

Tropical cities in Southeast Asia

Looking to the future



*Punggol Waterway Park
(Photo: Penguin8, Google)*

Welcome to Singapore

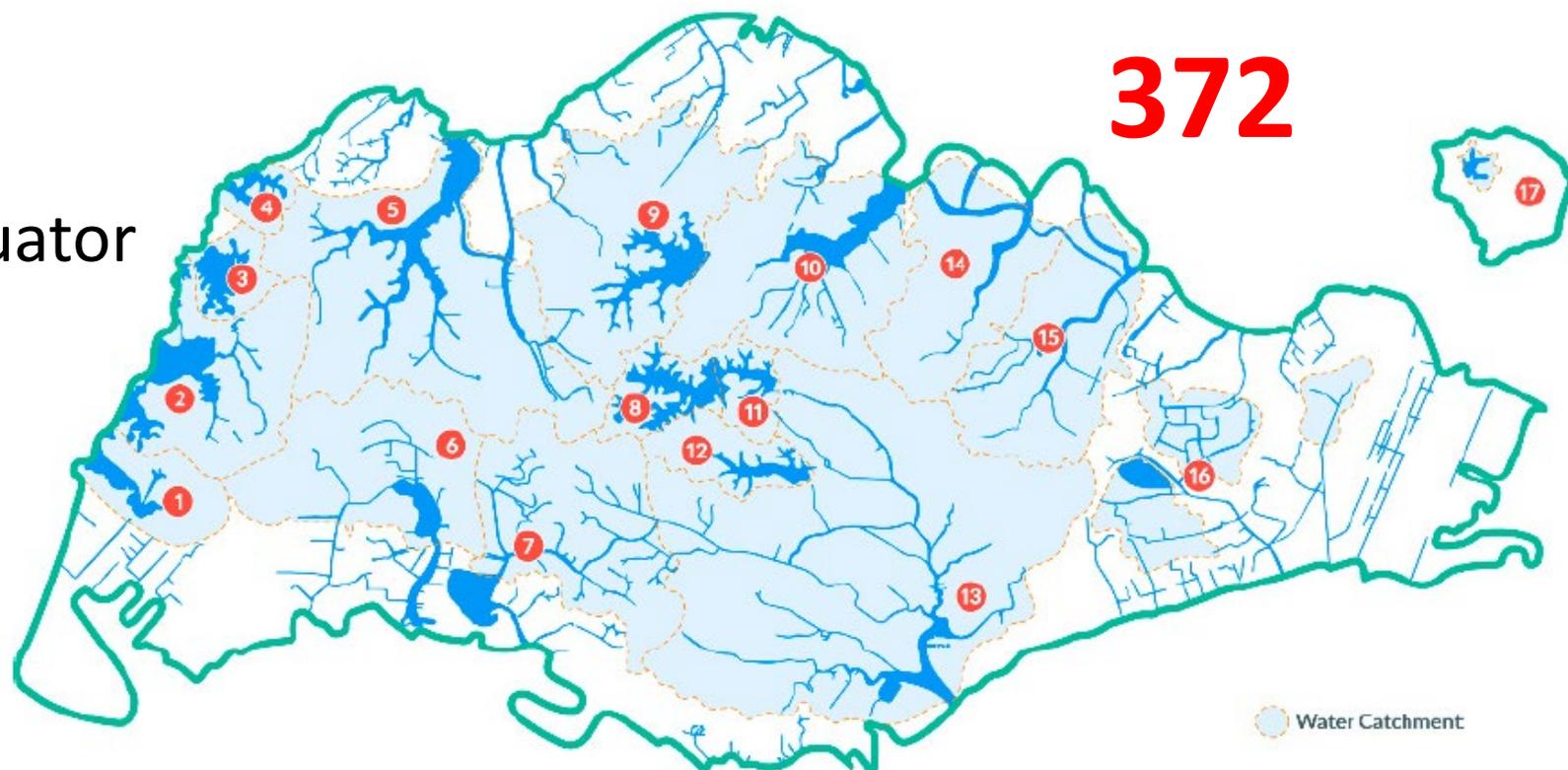
Population: 5.5 million

Location: 137 km N of Equator

Area: approx. 720 km²

Rainfall: 2400 mm/yr

Singapore is a water-stressed country



- | | | | | |
|----------------------|--------------------------|----------------------------|------------------------|---------------------|
| 1 Tengeh Reservoir | 5 Kranji Reservoir | 9 Upper Seletar Reservoir | 13 Marina Reservoir | 16 Bedok Reservoir |
| 2 Poyan Reservoir | 6 Jurong Lake | 10 Lower Seletar Reservoir | 14 Punggol Reservoir | 17 Tekong Reservoir |
| 3 Murai Reservoir | 7 Pandan Reservoir | 11 Lower Peirce Reservoir | 15 Serangoon Reservoir | |
| 4 Sarimbun Reservoir | 8 Upper Peirce Reservoir | 12 MacRitchie Reservoir | | |

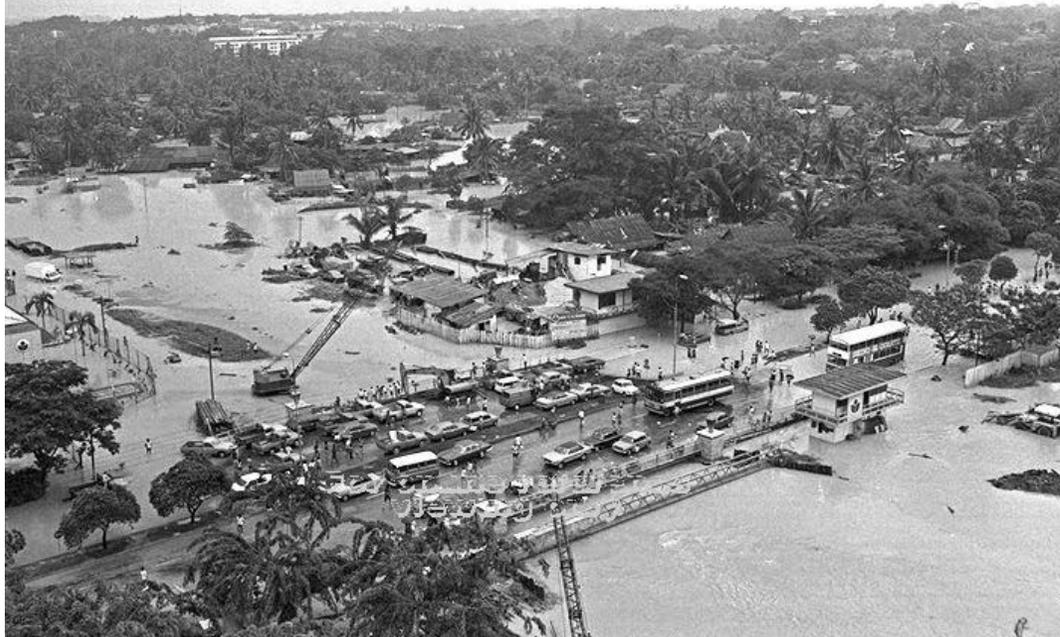
Water issues in Singapore

Flooding

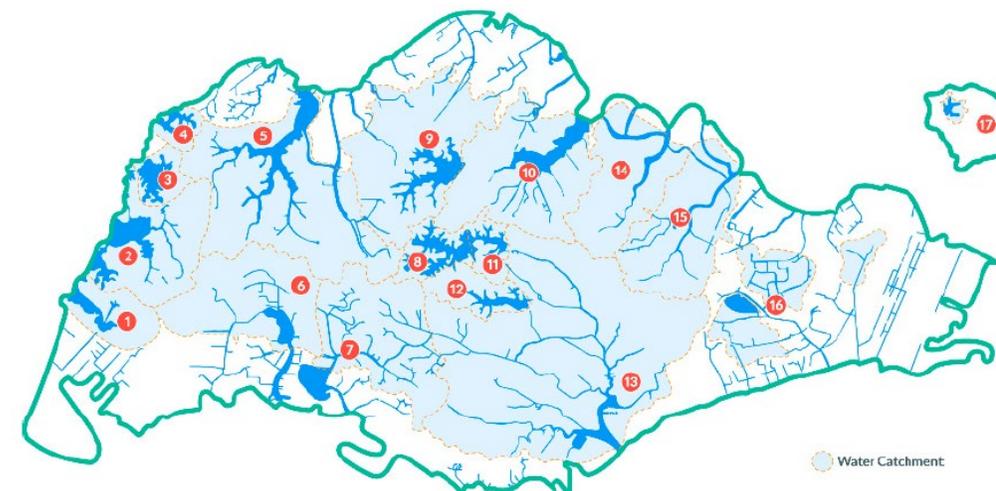
Poor water quality

Sea level rise

Water availability



(Singapore River, 1970)



Urban stormwater management in Singapore



Bukit Timah Flood Alleviation scheme (1966)
(Source: CLC, 2017, *The Active, Beautiful, Clean Waters Programme: Water as an Environmental Asset*)



But it still flooded



A car near Maplewoods condominium at Bukit Timah Road gets toppled by the flash floods caused by heavy rains in Singapore on 17 July 2010



Paradigm shift with a holistic approach

Stormwater management - timeline

1965-1980 Post independence
1966 Bukit Timah flood alleviation scheme

1980s – 2000
1972 – Drainage Department set up
Mid-1970 – Drainage Master Plan

- Demarcation of drainage reserves
- Land along waterways were reserved for future expansion
- Singapore River banks stabilised
- Construction of concrete drainage network

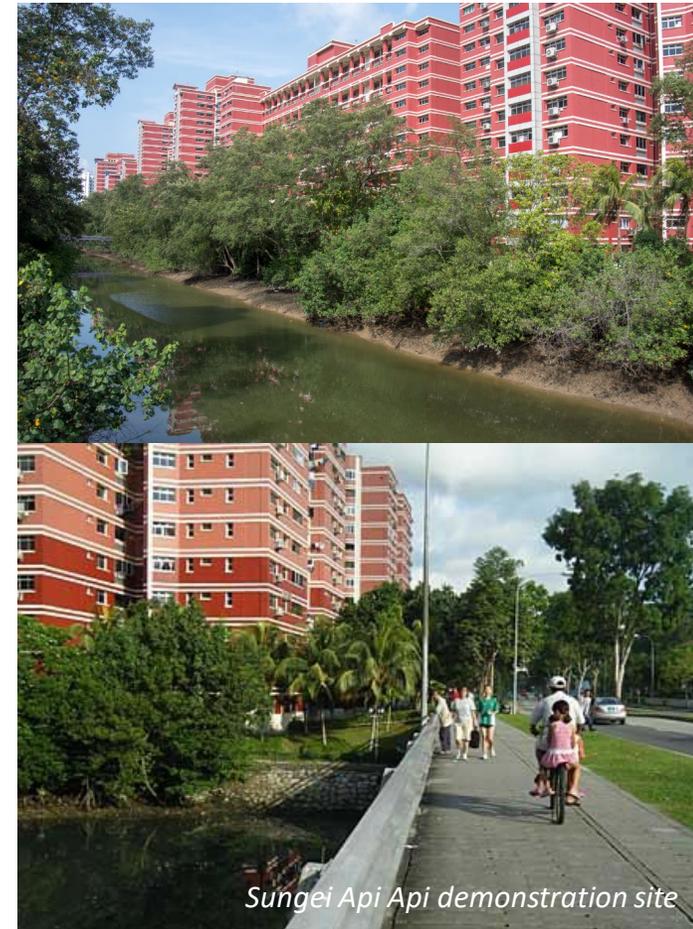
1980s – shift in thinking (integrate water with urban space)

1989 – Interagency panel set up, Waterbodies Design Panel (WDP)
Demonstration sites

1991 – 1991 Concept Plan
Waterbodies were included in urban plans

- Green and Blue Plan,
- Singapore River Development Guide Plan

Development Control Submission Guidelines (URA)



Sungei Api Api demonstration site

2000-
present

Institutional reorganisation
Changes in perception (public-centric approach)

2001 – reorganisation of the Public Utilities Board
Responsible for the entire water loop

2002 – Parks and Waterbodies Plan
(enhance Singapore’s living environment)
NEWater Programme launched

2004 – waterbodies opened to the public for recreational activities

2005 – Green Mark Certification Scheme

2006 – Active, Beautiful, Clean Waters Programme launched

- Demonstration sites
- Guidelines/handbooks
- Certification schemes

2009 - ABC Waters Design Guidelines
Engineering Procedures for ABC Waters Design Features

2007 – ABC Waters Master Plan unveiled

2009 – LUSH programme launched
(Landscaping for Urban Spaces and High Rises)

2010 - ABC Waters Certification Scheme

2011 - ABC Professional Program launched

2013 - ABC Professional Registry launched
Handbook of Managing Urban Runoff



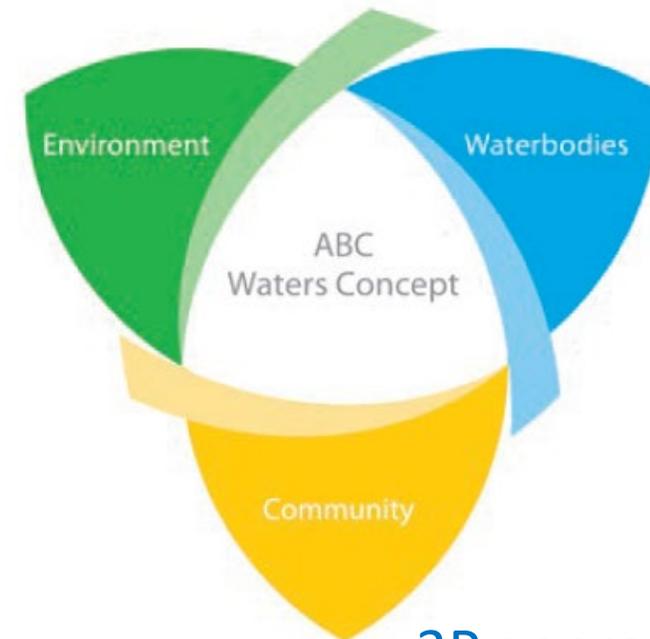
Key elements of the ABC Waters Program

Paradigm shift

Regulatory and administrative reform

Technical development and implementation

- Demonstration sites
- Field monitoring sites
- Guidelines
- Design plans
- Maintenance requirements
- Worked examples



3P approach

- People
- Public
- Private

<https://www.pub.gov.sg/Professionals/Working-on-ABC-Waterways/ABC-Waters-Design-Guidelines>

Key elements of the ABC Waters Program

Building capacity

- Training and certification programs

Building social capital



ABC Waters Learning Trail activities and teaching material



Using blue and green to manage stormwater in a holistic manner

SOURCE
The location where stormwater runoff is generated, i.e. origin of the stormwater flows

▷

SOLUTIONS AT THE SOURCE
refer to the slowing down and capturing of stormwater runoff on-site, e.g. via ABC Waters design features, detention tanks/ponds, etc.



PATHWAY
The means or routes through which stormwater is conveyed

▷

SOLUTIONS AT PATHWAYS
refer to enhancing the capacity of conveyance systems and includes drain widening, deepening, catchment level detention systems etc.



RECEPTOR
Where stormwater flows may propagate to and affect infrastructure

▷

SOLUTIONS AT RECEPTORS
refer to measures to protect areas where the stormwater flows may end up, e.g. flood barriers for buildings, etc.



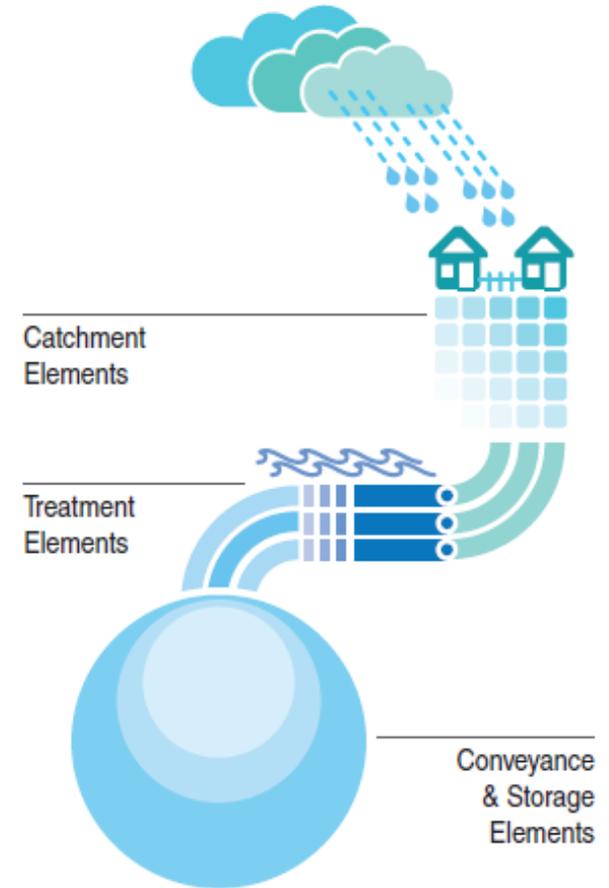


Fig. 2.2 Source-Pathway-Receptor Approach

(Source: PUB, 2018, *Active, Beautiful, Clean Waters, Design Guidelines*)

Using blue and green to manage stormwater



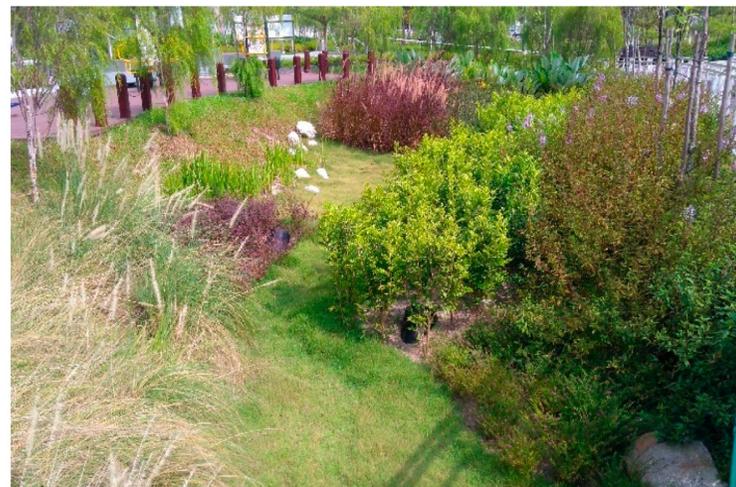
Bioretention swale (Liao 2019)



Re-designed urban waterways, Alexandra Canal (Liao, 2019)



Vegetated swale, Waterway Ridges (Yau et al., 2017)



Bioretention lawn, Waterway Ridges (Yau et al. 2017)



Rooftop greenery, Oasis Terraces (Alarmy stock photos)

River restoration: Bishan Park- Kallang River

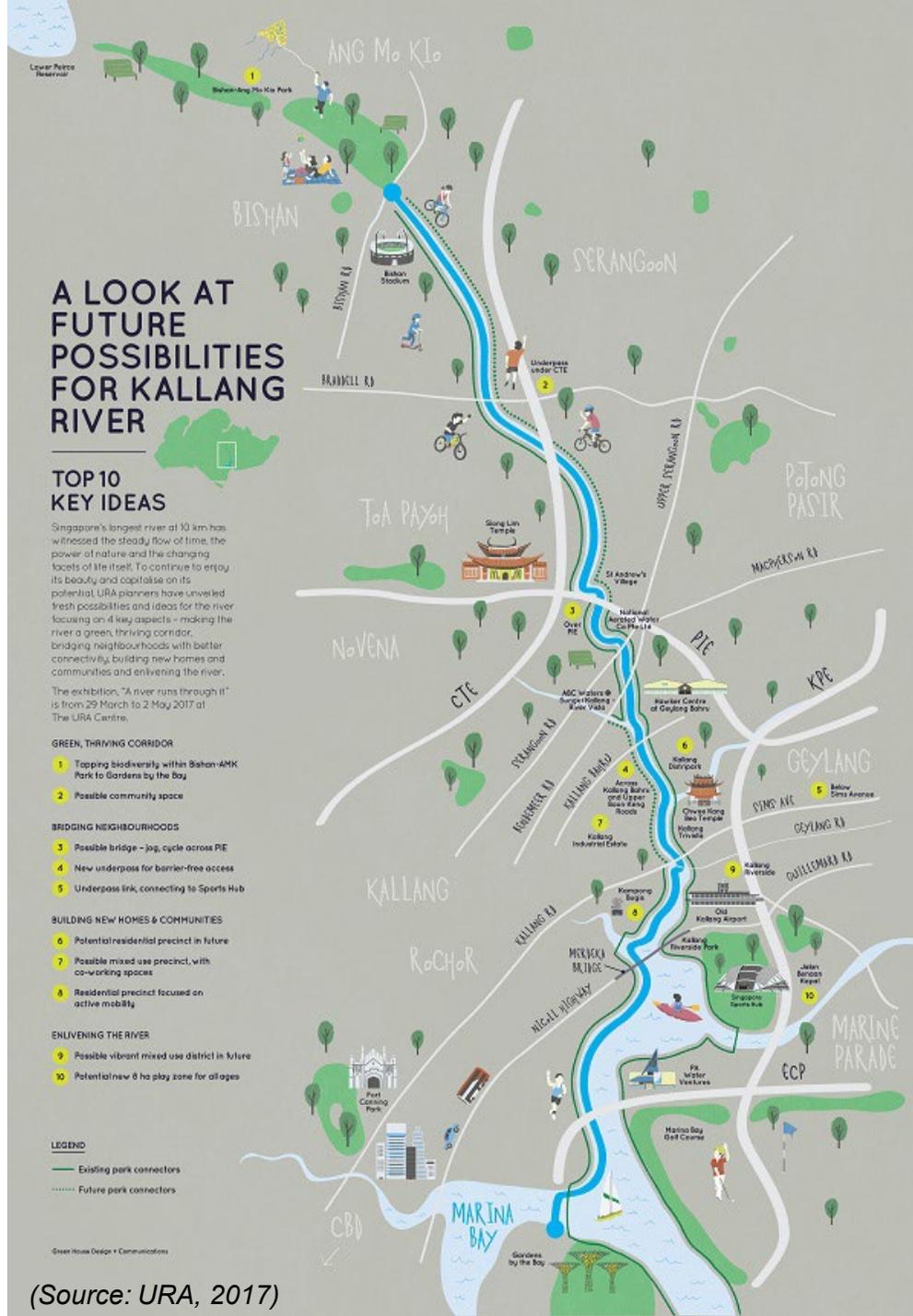


Kallang River overflows into adjacent floodplain (23/1/17)

(Source: <https://www.facebook.com/PUBsg/photos/pcb.1208420725915273/1208420425915303>, Ian Siah)

Future plans for the Kallang River

Blue-green infrastructure with multiple benefits



(Source: URA, 2017)



Kallang River at Potong Pasir
(The Straits Times)

Design elements of ABC Waters features

Location and siting

Minimise the use of land, integrate features within streetscapes

Size: usually 2% of catchment area (up to 5% of catchment area)

Growing media

Sandy loam mixture

Approved ASM soil mix:

clay 5-30%), silt (5-60%), sand (20-75%)

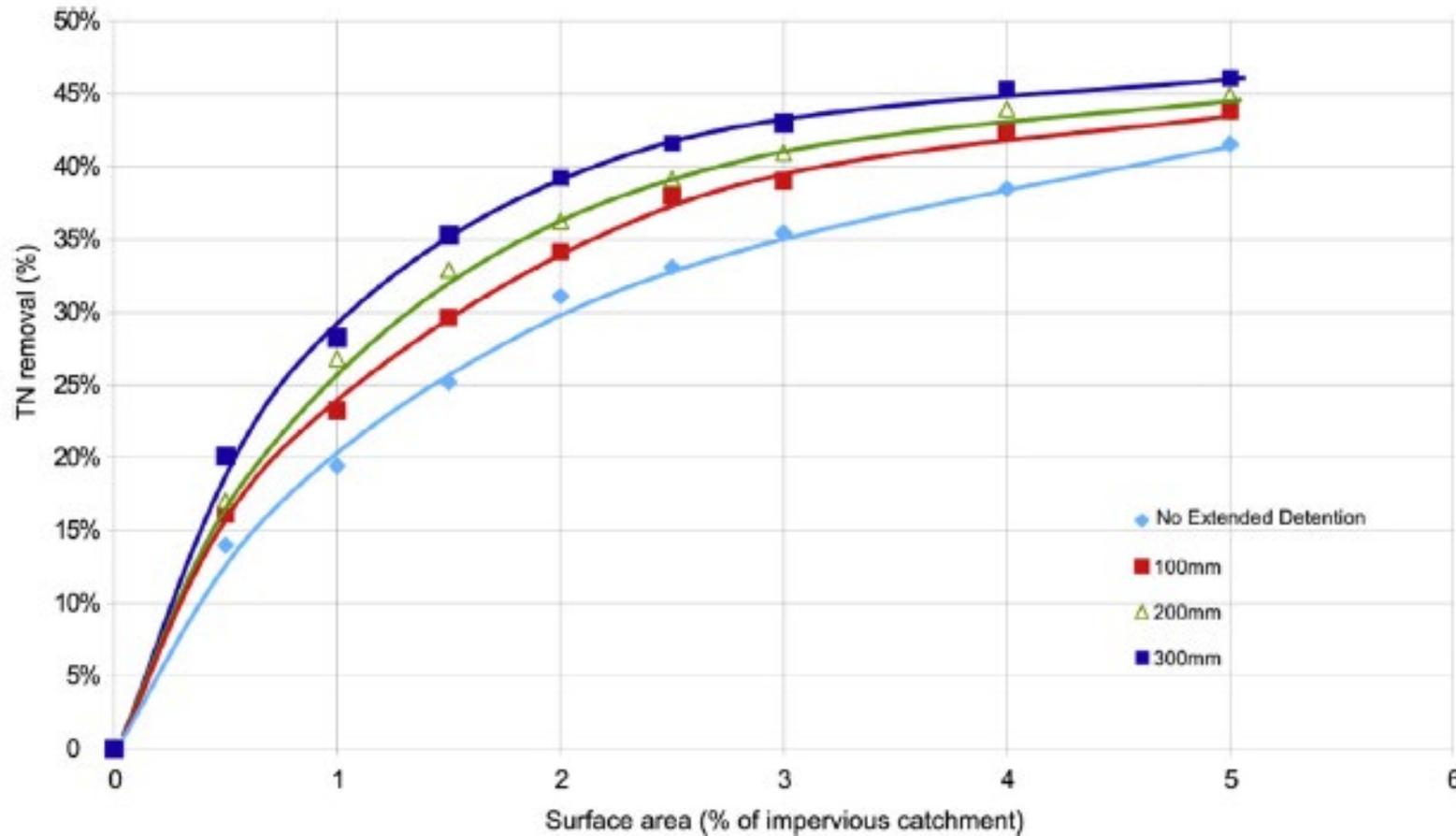
Plant selection

National Parks Board Centre for Urban Greenery and Ecology (CUGE)



(Source: National Parks Board, CUGE)

Sizing and performance curves for ABC design features



Performance targets:
Treat 1 in 3-month ARI
event

Water quality targets:
TSS (< 10 mg/L)
TN (< 1.2 mg/L)
TP (< 0.08 mg/L)

Sizing and performance curves for a bioretention system showing the relationship between bioretention surface area and total nitrogen (TN) removal for different ponding depths (no ponding, 100 mm, 200 mm, 300 mm ponding) when K_s of the filter media is 360 mm/hr Source: Fig. 6.6, [PUB \(2011\) Engineering Procedures for ABC Water Design Features](#).

Why the ABC Waters Programme was so successful

Singapore's challenges

Focus on planning for the future

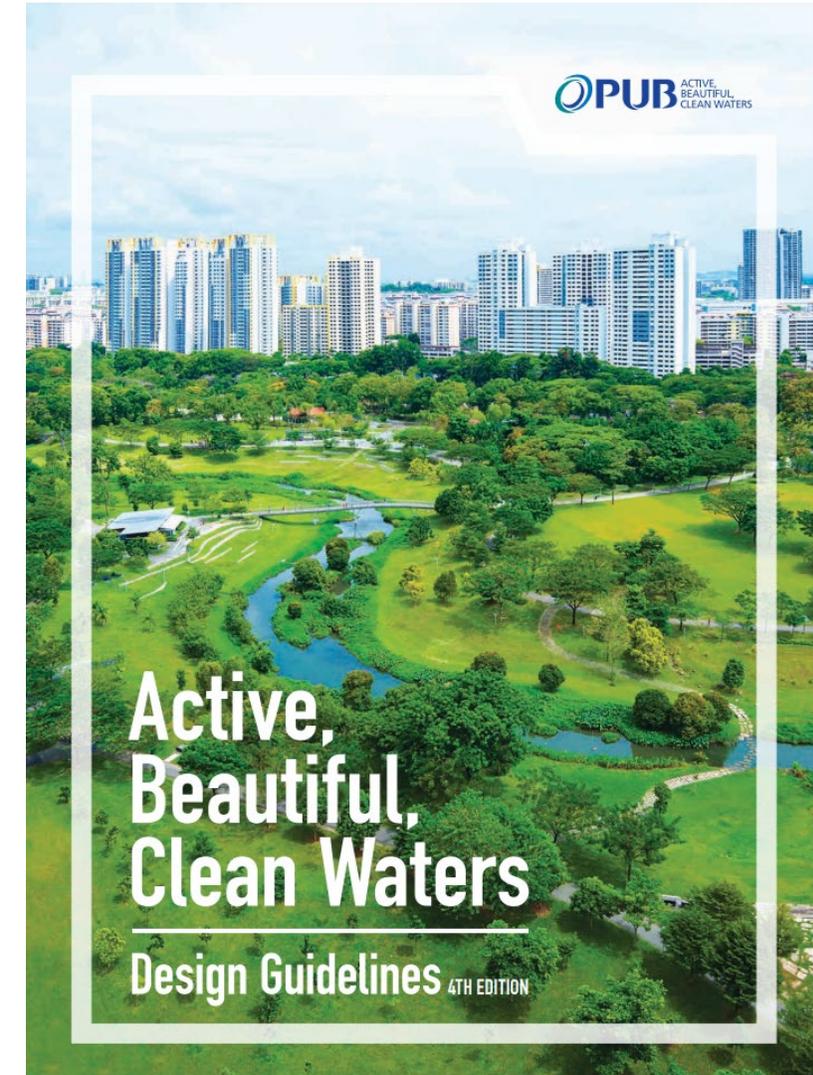
Holistic approach

Strong leadership

Institutionalisation and strong governance

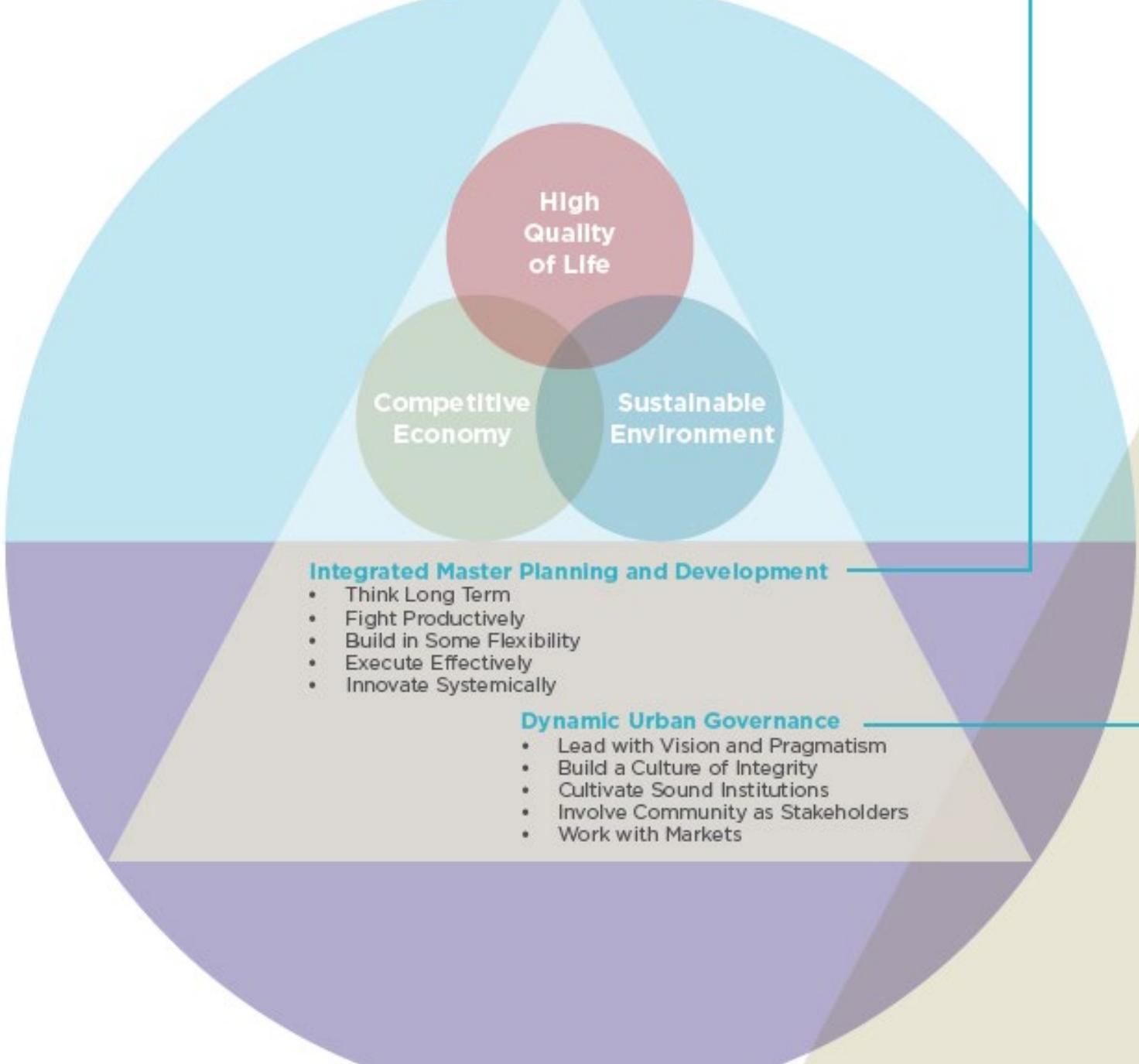
Collaborative spirit

- interagency, private, public



(Source: Public Utilities Board, PUB, Singapore)

Singapore Liveability Framework





(Source: https://bridges.monash.edu/articles/figure/Revitalisasi_Pulo_Geulis_2045_Pulo_Geulis_Revitalisation_2045/8052089)

Stormwater issues facing Southeast Asian cities



*Bangkok flooding
(Source: The Straits Times)*



*Jakarta floods and poor water quality
(Source: The Guardian)*

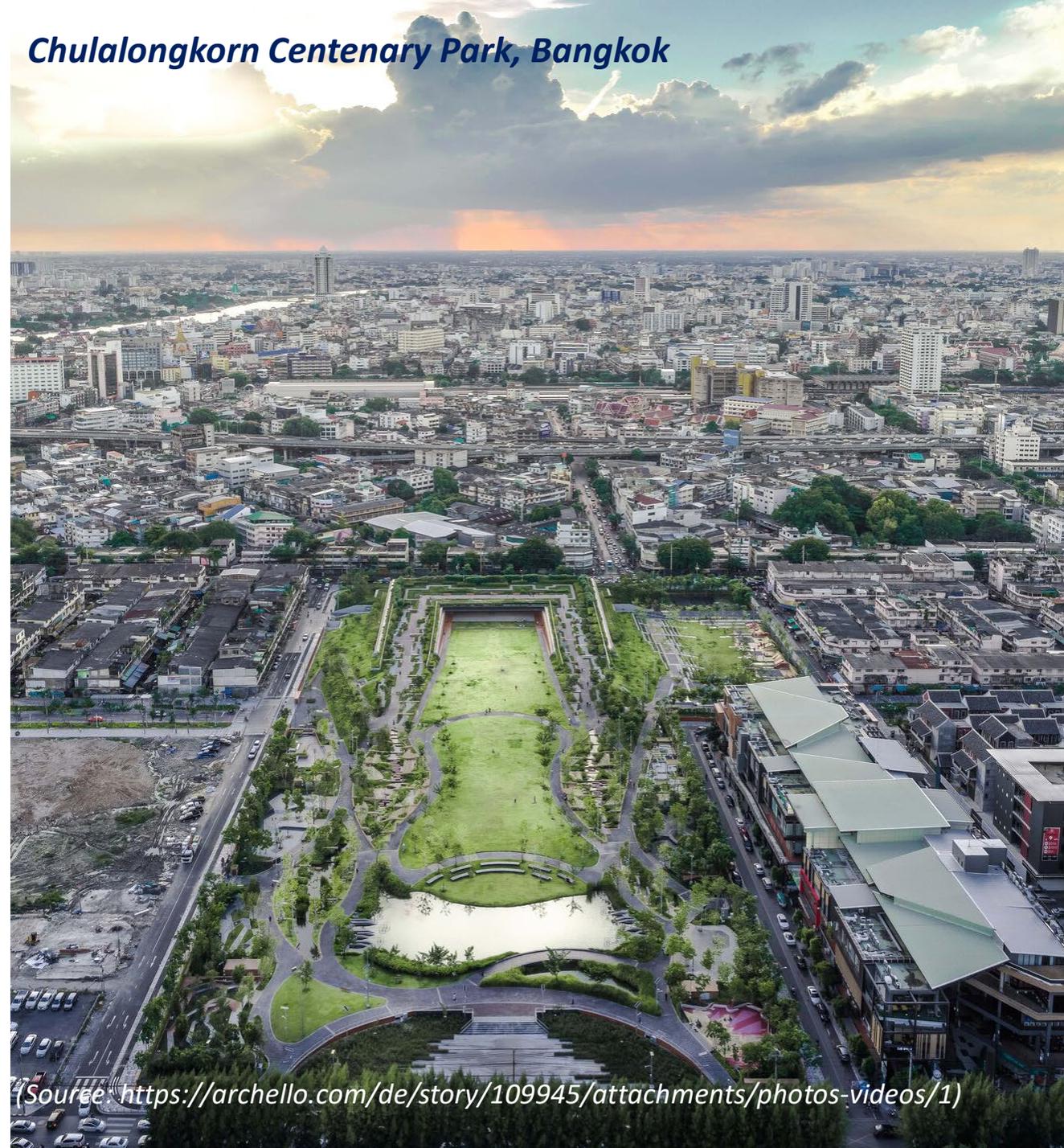
Stormwater management in Southeast Asian cities



*Sky Park Bangkok, Thailand
Recreational space
Ecological habitat connectivity*



Chulalongkorn Centenary Park, Bangkok



Grey infrastructure dominant

Ad hoc implementation

Externally driven

Importance of locally driven initiatives



Wetland, Bogor Indonesia

(Dr. Cynthia Henny, LIPI)

Recommendations from the ADB for nature-based solution implementation in Vietnam

Political Leadership and Planning

- A strong and committed political leadership and good coordination among relevant agencies will be indispensable to make WSUD work.
- Piecemeal implementation of WSUD leads to poor outcomes. A clear, city-wide vision and goal of WSUD should be set out.
- WSUD measures are multifunctional. A comprehensive and integrated strategy/master plan should be developed to explore social, economic, climate, and environmental benefits.
- Integrate nature-based solutions and the WSUD into urban planning guidelines and regulations.

Communication and Participation

- Community participation from the design to implementation of WSUD measures is a key factor in ensuring success.
- A consensus recognizing rehabilitating and expanding water systems in cities as an essential foundation for building urban resilience, is needed. Awareness on the advantages of WSUD should be communicated to the public.
- For widespread implementation, use of WSUD should be incentivized to the private sector and urban dwellers.

Knowledge and Design

- International knowledge and design should be leveraged for local context.
- Highly capable local consultants and contractors should be engaged to upscale local knowledge and capacity.
- Design should be kept simple so it is easy to maintain.
- Demonstration projects will help stakeholders and developers to see and experience WSUD benefits.



Traditional concepts of space in Bali

The *telajakan* is a profane space between the front wall and road.

This place functions as a garden where people plant vegetation such as flowers, foliage, and trees.



Traditional methods of water management: Subak system in Bali, Indonesia

- Diverse stakeholders
 - People-centric approach
 - Adaptive co-management
- e.g., community work with local government, decisions made after consensus reached



Sena district of Ayutthaya, Thailand

Re-design to suit local contexts/cultures

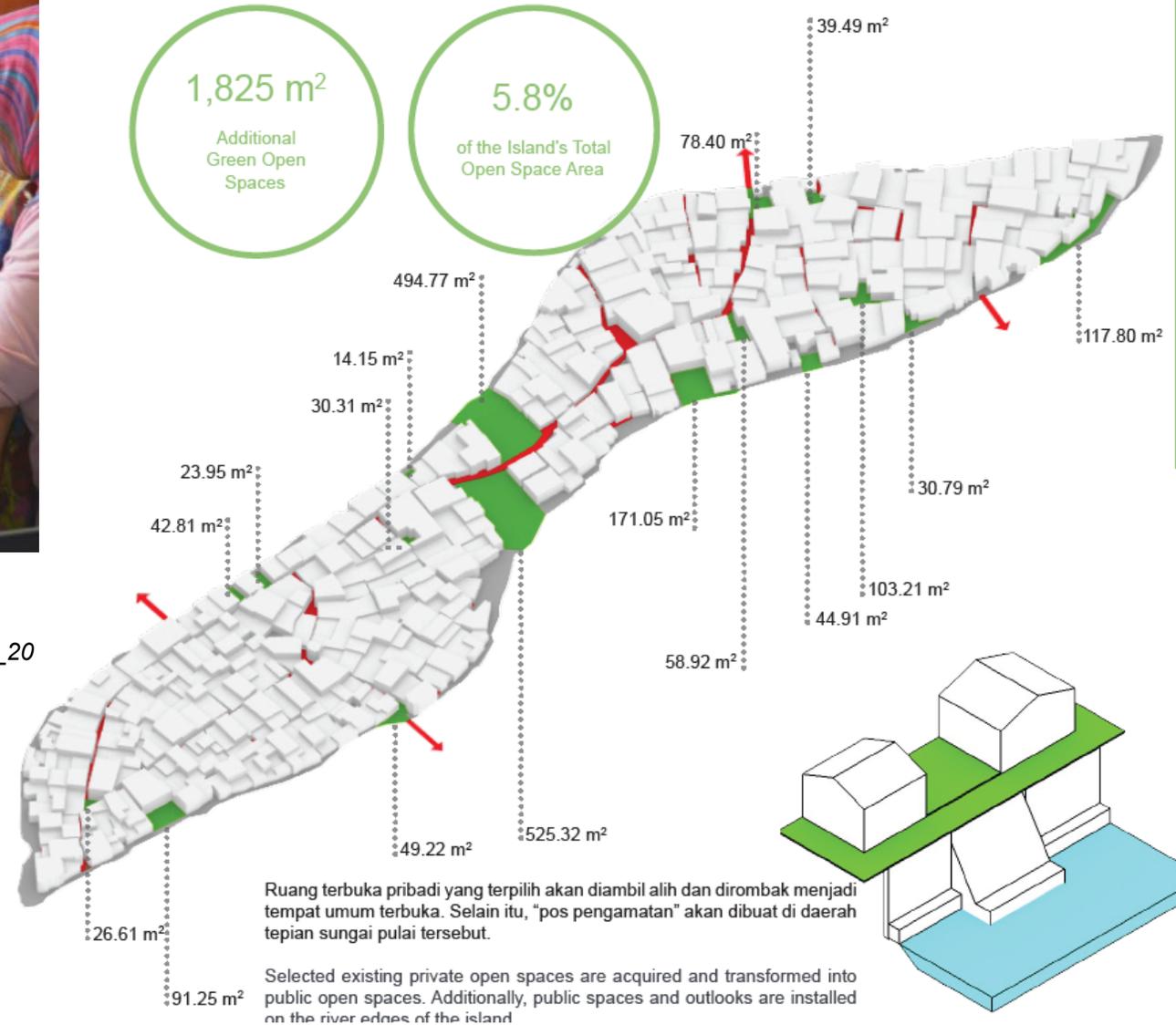
Temporary retention zones
(monkey cheeks, kaem ling)
Multipurpose use of land for flood mitigation



Scenario workshop focus group discussions

(Source: https://bridges.monash.edu/articles/figure/Revitalisasi_Pulo_Geulis_2045_Pulo_Geulis_Revitalisation_2045/8052089)

Co-development with the community



Looking to the future – key challenges facing Singapore

Climate change and sea level rise

Increasing population

Longevity of ABC Waters features

Performance for extreme events



(Source: <https://www.youtube.com/watch?v=2QKBvcZz6n4>)



Useful resources:

Centre for Liveable Cities (CLC) 2017. The Active Beautiful Clean Waters Programme: Water as an Environmental Asset.

Guidelines more suited for the tropics:

Singapore Active, Beautiful, Clean Waters Design Guidelines (PUB, 2018)

Darwin Water Sensitive Urban Design Practice Guide (McAuley, 2009)

Water Sensitive Urban Design for the Coastal Dry Tropics (Townsville): Technical Design Guidelines (AECOM, 2011, Creek to Coral, 2011)

<https://www.nparks.gov.sg/-/media/cuge/pdf/rtn-04-2012---a-selection-of-plants-for-in-the-tropics.pdf>

<https://www.pub.gov.sg/Professionals/Working-on-ABC-Waterways/ABC-Waters-Design-Guidelines>

