HKIE THE HONG KONG INSTITUTION OF ENGINEERS 香港工程師學會

President Forum Series – Session No. 2

Climate Resilience for Infrastructure Development - How far should we go?

Climate Resilience for Infrastructure Development

Bruce Chong (11 Oct 2023)

Key Questions

ARUP

1. Do we need to further update our design assumptions?
2. What can be further improved in our drainage system?
3. What can be further improved in our coastal resilience?
4. How to address extreme case?
5. Do we have a holistic plan for climate risk and resilience?
6. How CIM (City Info Model) can further support weather forecast

Infrastructure design approach and assumptions

ARUP

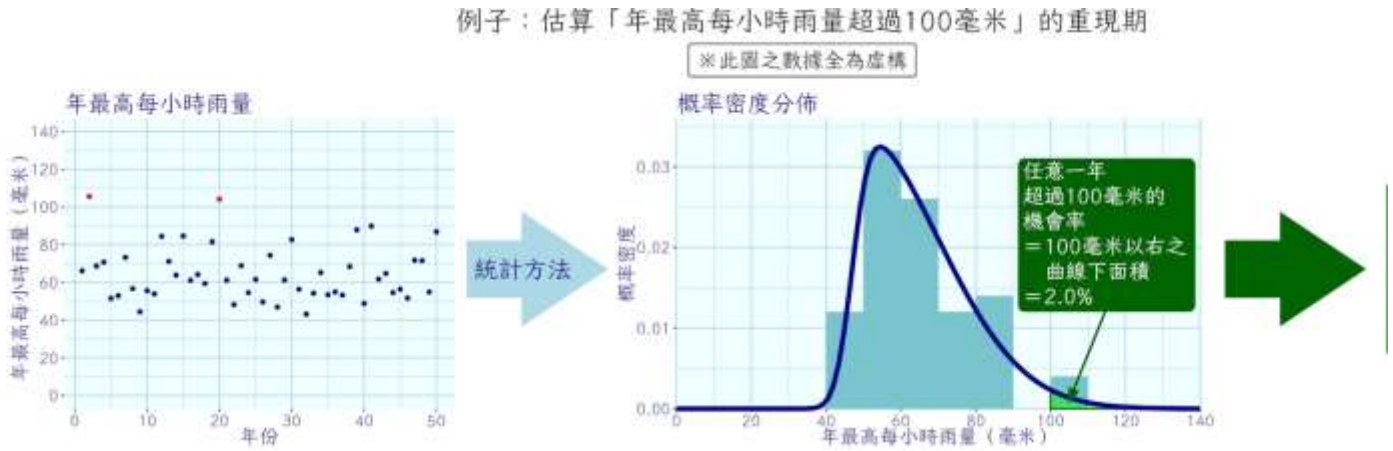
Past Events statistics (1 in X years)

+

Future Climate Scenario

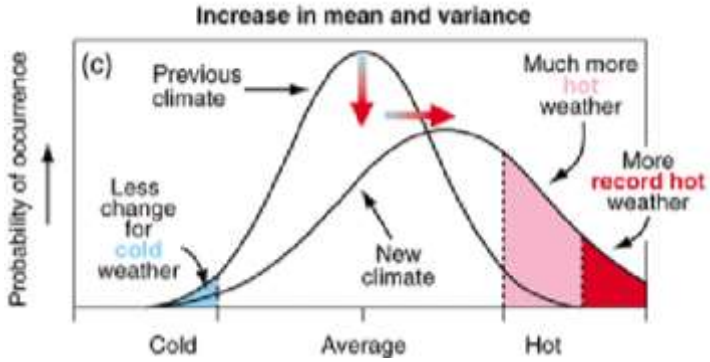
+

Extreme Hazard Scenario



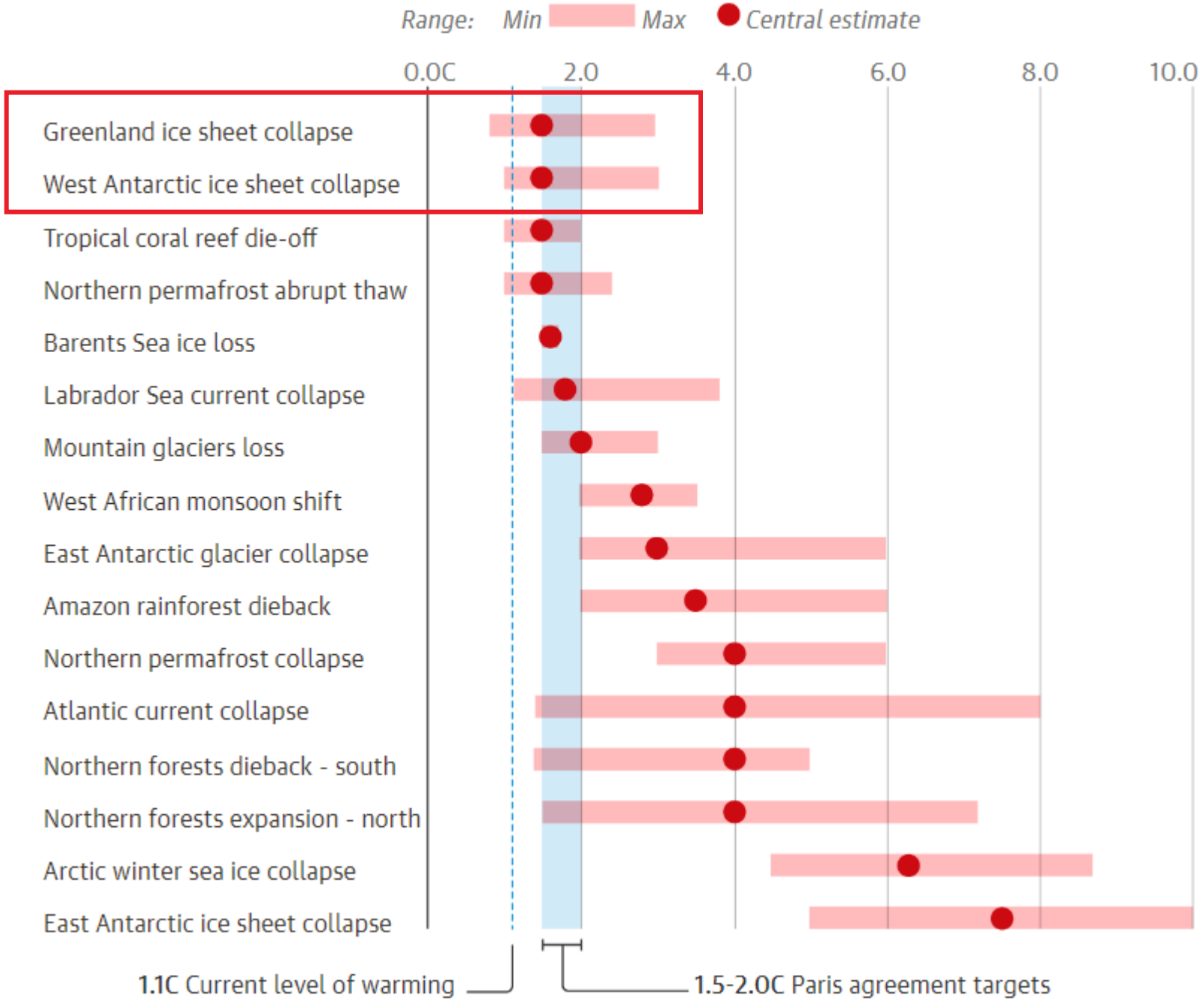
There are different forms of density function change for different weather parameters after considering the effect of climate change.

- Increase in mean
- Increase in variance
- Increase in mean and variance



Scenario ID	Scenario	RCP	Wind Intensity	Track	SLR	Tide	Rainfall
Very High	Climate-powered TC follows shifted Mangkhut's path + high tide in high scenario hit by highest extreme rain						
High-1	Climate-powered TC follows shifted Mangkhut's path + high tide in high scenario						
High-2	Climate-powered TC follows historic Mangkhut's path + high tide in high scenario						

Tipping Points



Guardian graphics. Source: Armstrong McKay et al, Science, 2022. Note: Current global heating temperature rise 1.1C Paris agreement targets 1.5-2.0C

Infrastructure design approach and assumptions

ARUP

Source: DSD Storm Drain Manual

Table 1. Rainfall increase due to climate change in **SSP2-4.5 scenario** (Source: DSD SDM)

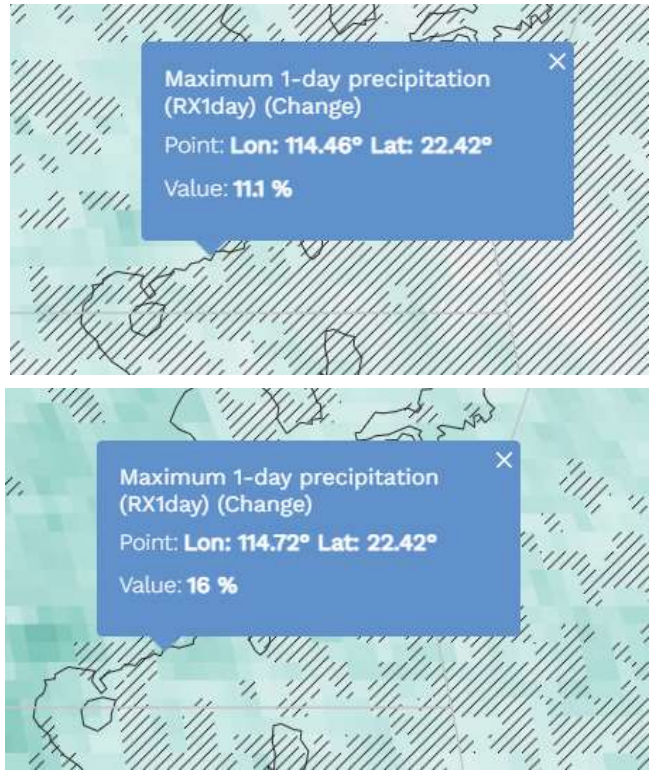
	Rainfall Increase
Mid 21st Century	11.1%
End of 21st Century	16.0%

Table 2. Design allowance (**Difference between SSP5-8.5 and SSP2-4.5**) (Source: DSD SDM)

Design allowance for rainfall increase
12.1%

28.1%

Source: IPCC AR6 Interactive Atlas

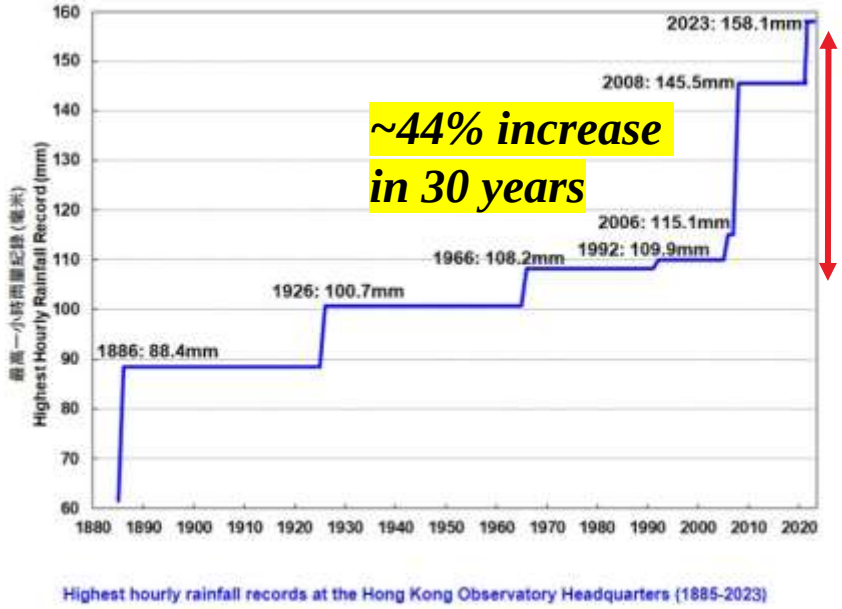


200-years rainfall intensity at the end of century based on historic rainfall in SDM

185.7 mm/hr

2021 Zhengzhou extreme rainfall intensity

201.9 mm/hr



Three key notes:

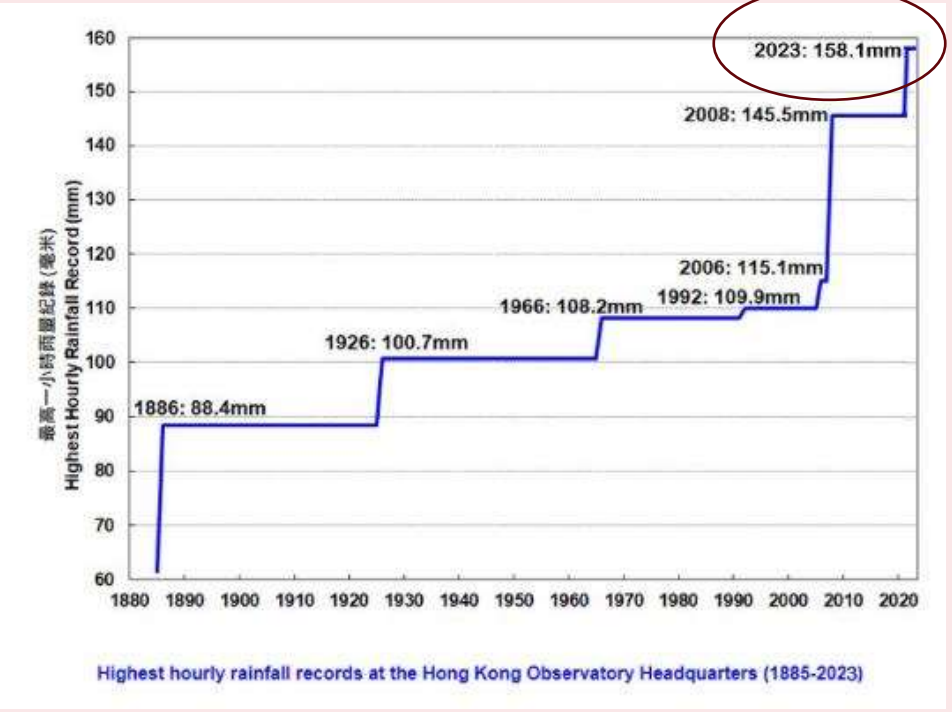
- Based on change in RX1day, but how about short duration high intensity rainfall?
- **28.1%** in future 80 years vs **44%** in past 30 years, **is it adequate?**

Beyond Code Consideration?

ARUP

Key Message

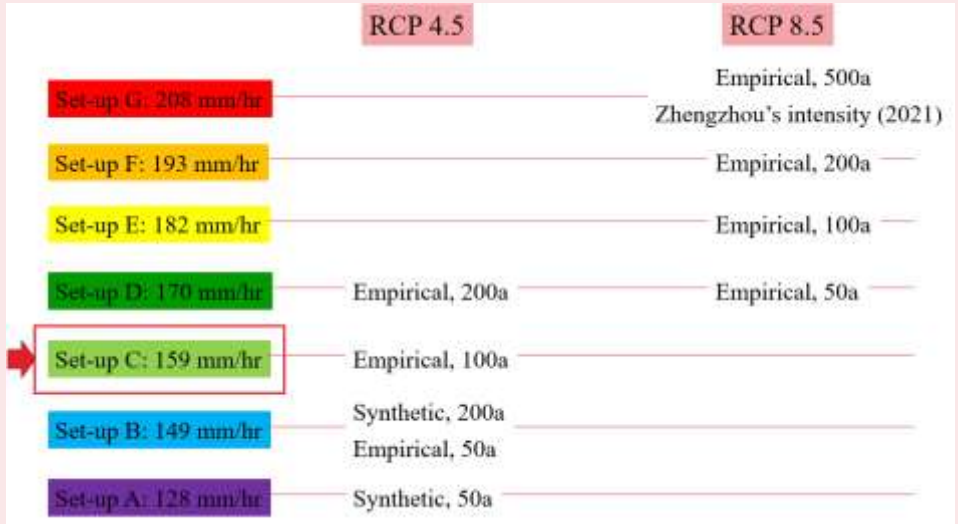
We live in an ever-increasing extreme rain world.



Highest hourly rainfall records at the Hong Kong Observatory Headquarters (1885-2023)

Key Reflection

Scenario should cover more



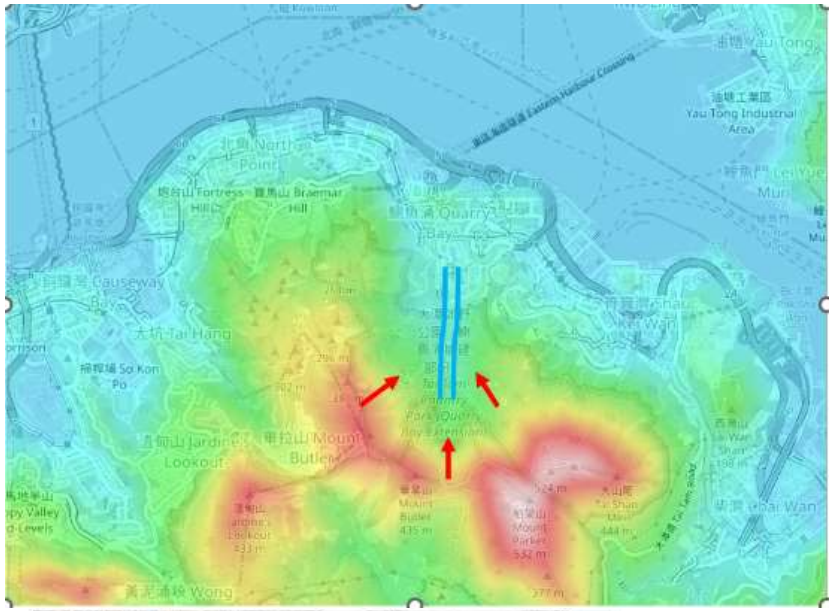
Urban Drainage System

ARUP


Sik Sik Yuen Wong
Tai Sin Temple
嗇色園黃大仙祠
SAN PO KONG
新蒲崗
Kowloon
Walled
City Park
九龍寨城公園

Urban Drainage System for existing urban areas – More Drainage Tunnels?

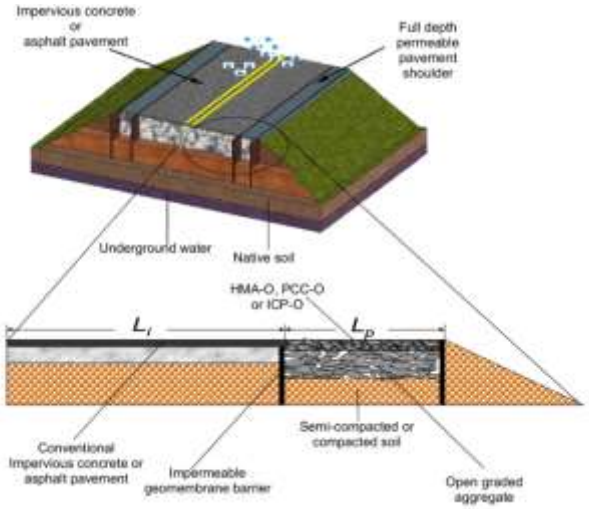
ARUP



Any more we can do?

Embed with more functions for next upgrade:

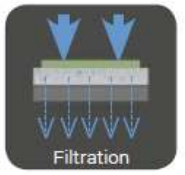
- Higher design requirements (current standard is 50 years return period)
- More permeability under road, parks etc)
- Road as part of the flood flow control
- Decentralized underground storage (e.g. road, open space)



Flow Control
-the regulation of stormwater runoff flow rates.

Detention
-the temporary storage of stormwater runoff in underground vaults, ponds, or depressed areas to allow for metered discharge that reduce peak flow rates.

Retention
-the storage of stormwater runoff on-site to allow for sedimentation of suspended solids.



Filtration
-the sequestration of sediment from stormwater runoff through a porous medium such as sand, a fibrous root system, or a human-made filter.

Infiltration
-the vertical movement of stormwater runoff through soil, recharging groundwater.

Treatment
-processes that use plant materials, natural phytoremediation and/or bacterial colonies to metabolize contaminants in stormwater runoff.

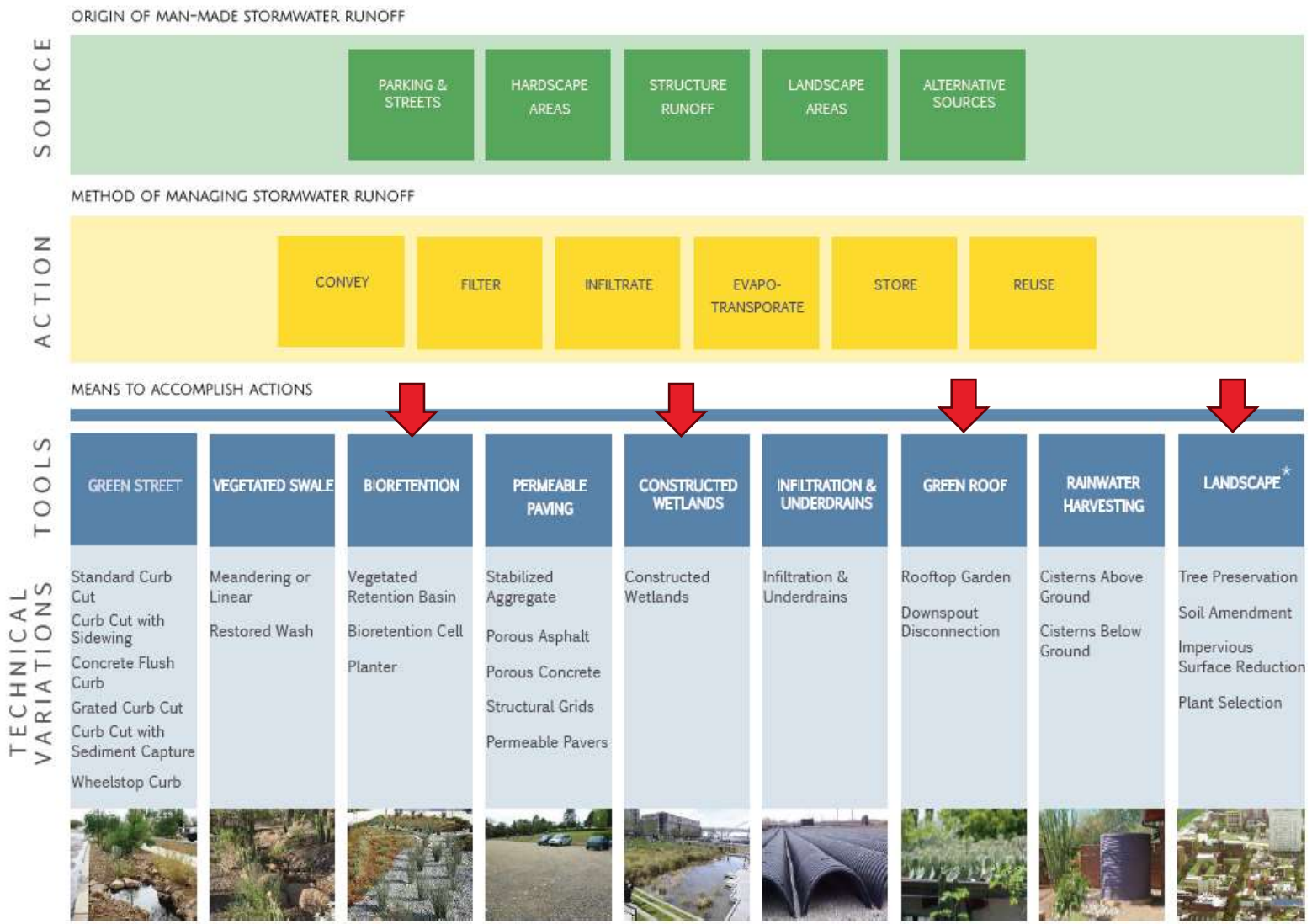
Sustainable Urban Drainage Implementation – System Level

ARUP

Table 1: Hong Kong Land Utilization in 2015

Class		Approx. Area (km^2)	Percentage (%)
Residential	Private residential	26	2.3%
	Public housing	16	1.4%
	Rural settlement	35	3.2%
	Sub-total (a):	**77**	**6.9%**
Supporting Land Use and Infrastructure	Commercial/Business and office	4	0.4%
	Industrial land	7	0.6%
	Industrial estates	3	0.3%
	Warehouse and open storage	16	1.4%
	Government, institutional and community facilities	25	2.3%
	Open space	25	2.3%
	Regional roads *[assuming accounting for 50% of total road area]*	20	1.8%
	Sub-total (b):	**100**	**9.1%**
Other Developed Areas, including Strategic Infrastructure and Other Facilities	Territory-wide roads *[assuming accounting for 50% of total road area]*	20	1.8%
	Railways	3	0.3%
	Airport	13	1.2%
	Cemeteries and crematoriums	8	0.7%
	Utilities	8	0.7%
	Vacant land/ Construction in progress	17	1.5%
	Others	22	2.0%
	Sub-total (c):	**91**	**8.2%**
	Total Developed Land Area (a+b+c):	**268**	**24.1%**

~65km2



ARUP

Sustainable Urban Drainage Implementation – Decentralized approach?

- Open space
- Underflyover
- STA
- Large GIC site
- …

7 Sept 2023

黑雨生效時間及雨量同破紀錄　天文台：自1884年有紀錄以來最高

熱門文章

1 Sept 2023

蘇拉落波．總覽｜天文台以南30公里掠過　10號風球生效約7小時

熱門文章

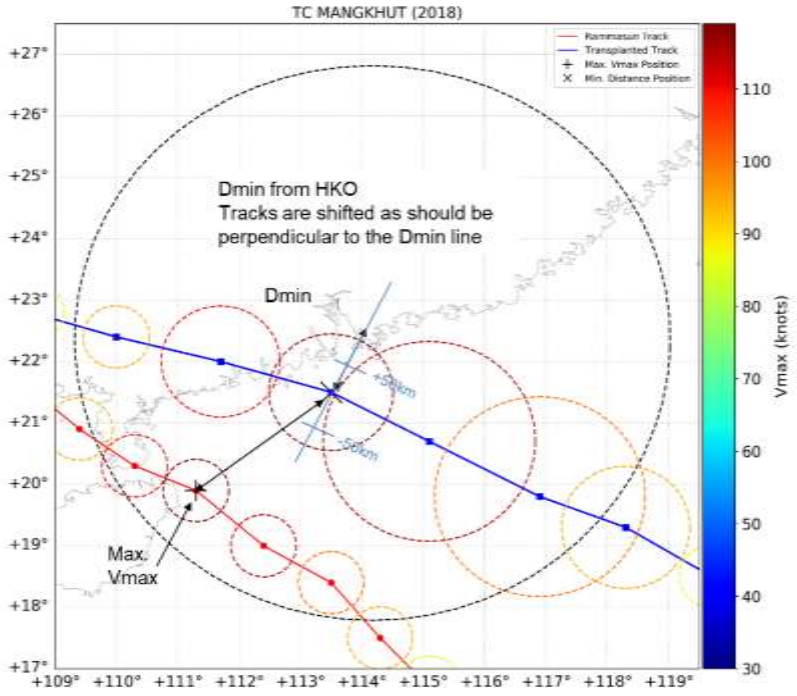
圓規風球｜風暴潮及天文潮疊加令多區水浸　程度直逼颱風黑格比

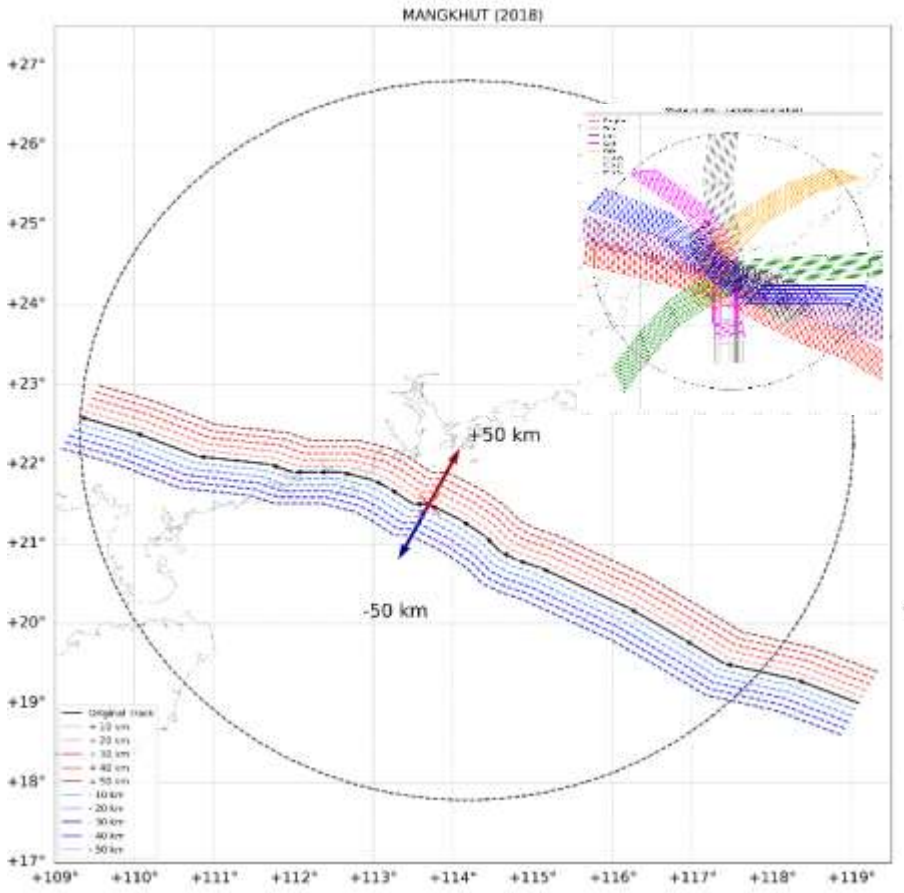
撰文：勞敏儀
出版：2021-10-13 12:57　更新：2021-10-13 14:49

Consideration of Worst Scenario

ARUP

Study: Projection of Tropical Cyclones & Potential Impact on Coastal Government Critical Infrastructure under Super Typhoon Direct Hit Scenarios





- Modelling to determine the change of TC parameters (i.e. Pc, Vmax, Rmw, Rainfall)
- Transplant and track shifting

Sensitivity Test – Emergency Preparedness for the Worst

ARUP

Tested Scenarios / Assumptions for Direct Heat Typhoon

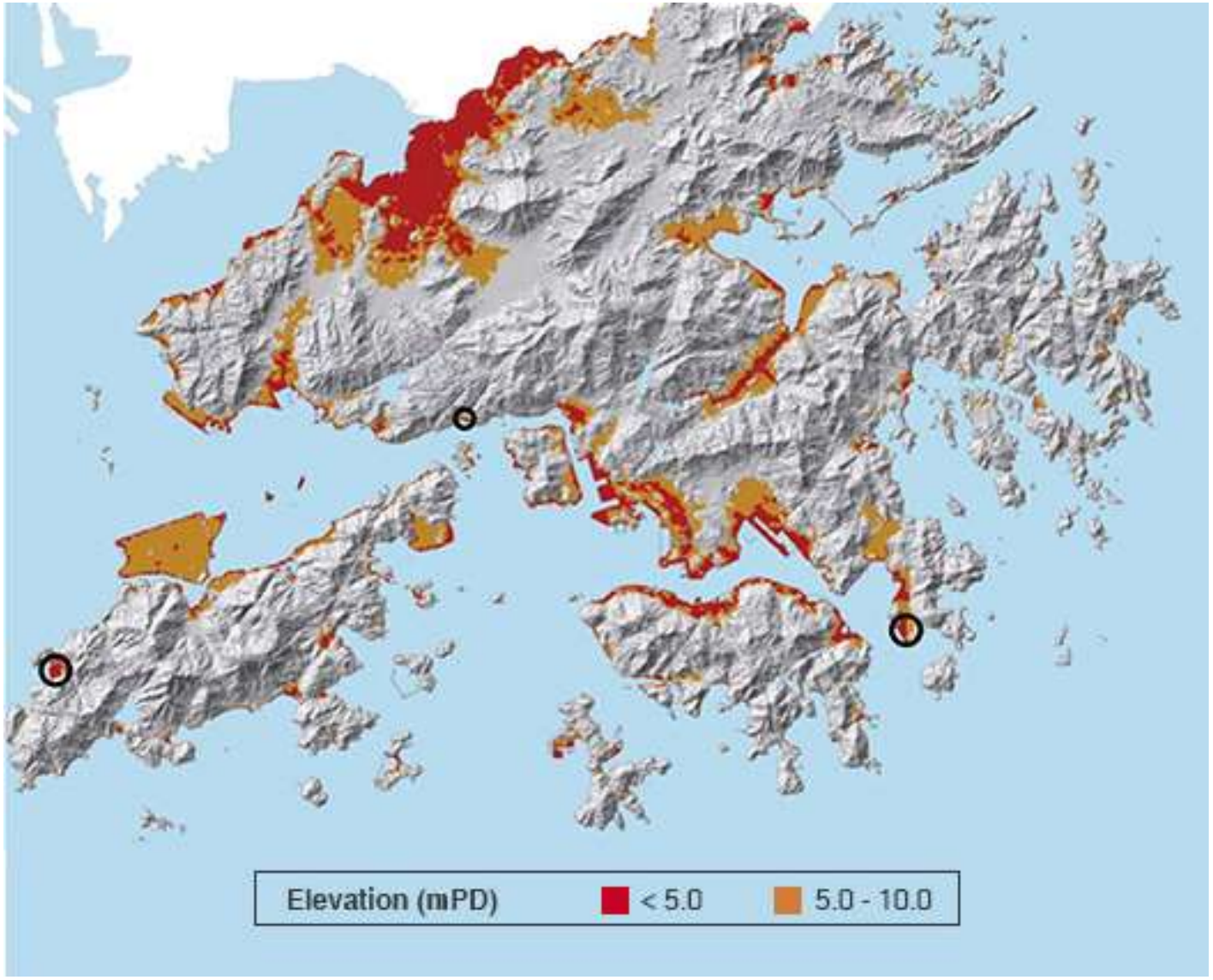
- **Relatively high tide level** (tide level + storm surge from super typhoon event + SLR)
- **Projected Changes of Tropical Cyclone Characteristics**
- **Tropical Cyclone-associated Rainfall**,

Station	Max Storm Tide level (mPD)						
	Present Day	Near-Future			Far-Future		
		RCP4.5/6.0#	RCP8.5	RCP8.5H	RCP4.5/6.0#	RCP8.5	RCP8.5H
Tsim Bei Tsui (TBT)							
Tai Po Kau (TPK)							
Quarry Bay (QUB)							
Shek Pik (SPW)							
Tai O (TAO)							
Waglan Island (WAG)							

- New Town: MaOnShan/TungChung/TseungKwanONewTown:about+5.5mPD
- Third Runway of HKIA: about+6.5mPD
- HZMB island: +6 to +6.5mPD

Sensitivity Test – Emergency Preparedness for the Worst

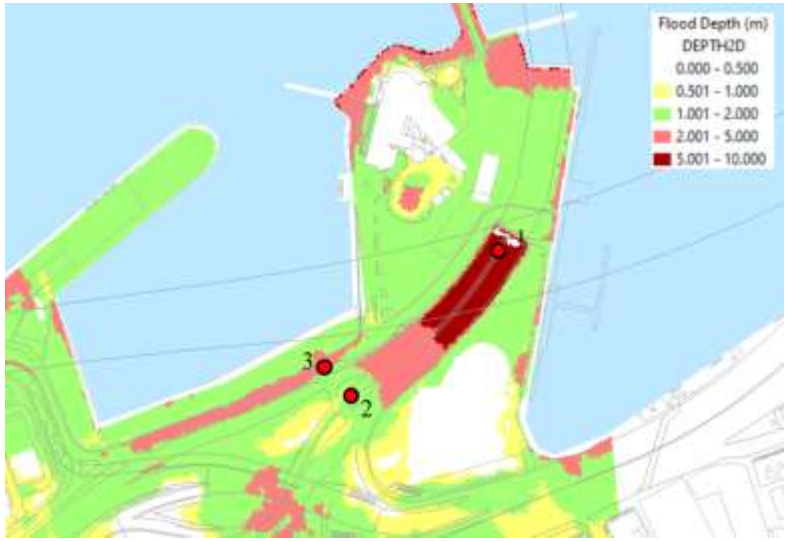
ARUP



Sensitivity Test – Emergency Preparedness for the Worst

ARUP

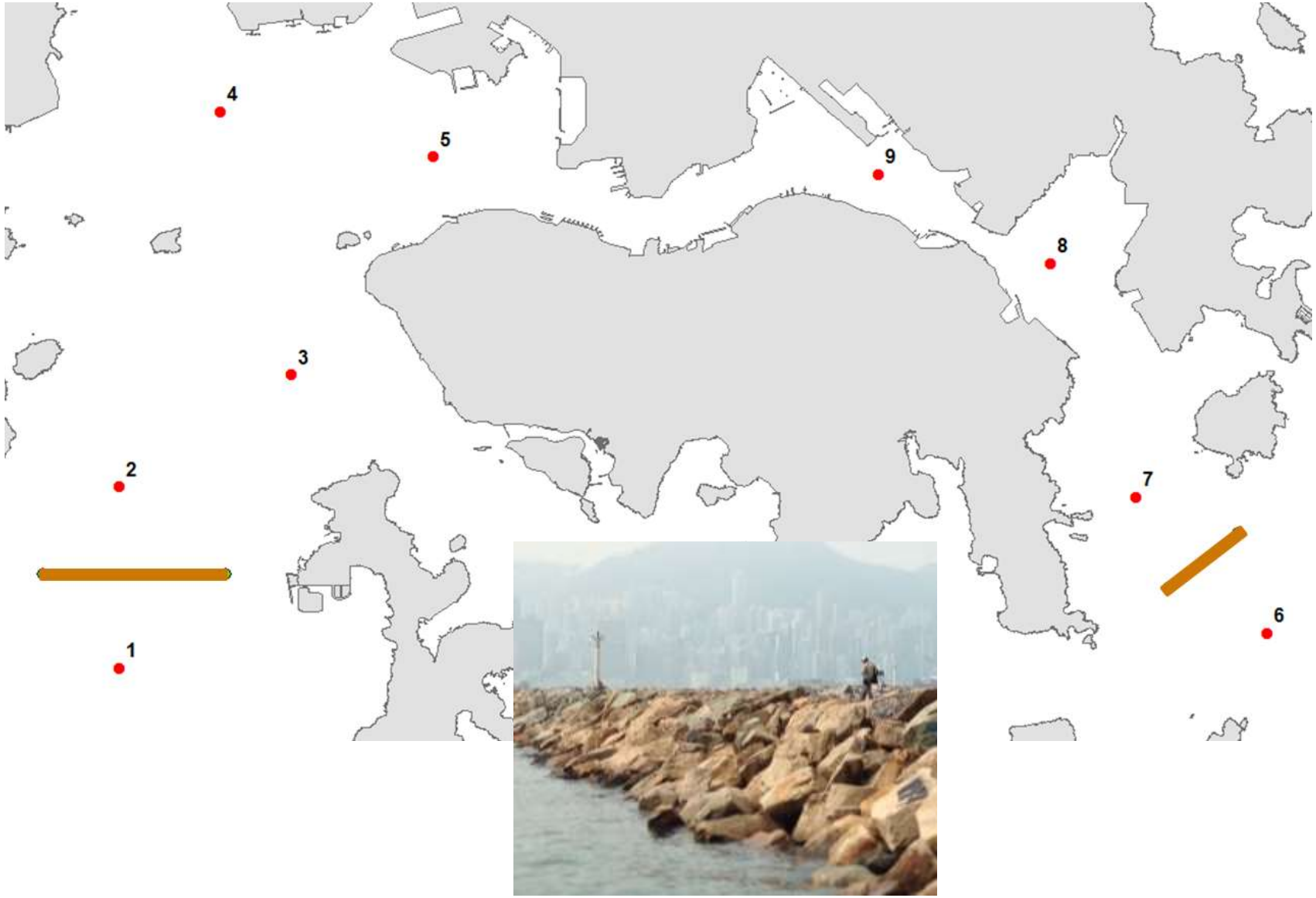
- Inconvenient Truth: It is NOT feasible to protect *all* critical facilities under Direct-Hit event
- Emergency Properness – Risk Management + Resilience + Public Communication + Education



Wave Barrier – now or long term?

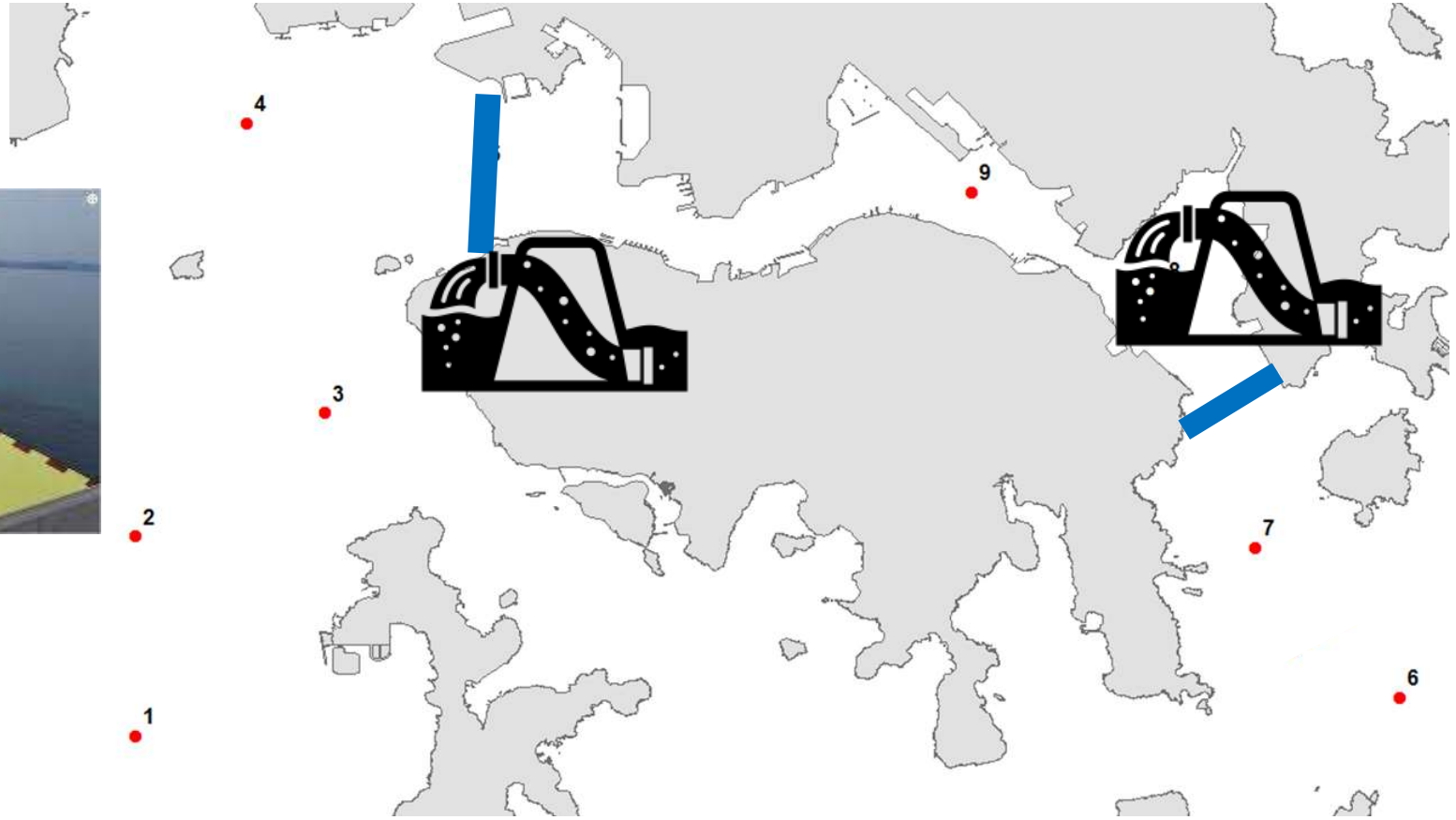
ARUP

Location	Wave Height (m)		% Change
	Existing	With BW	
1	2.55	2.55	0%
2	2.05	0.90	-56%
3	0.52	0.51	-1%
4	0.28	0.14	-49%
5	0.06	0.05	-5%
6	7.39	7.39	0%
7	6.01	2.71	-55%
8	1.91	0.98	-48%
9	0.19	0.09	-52%



Storm Surge Barrier with Pump Station – now or long term?

ARUP



- Floatable and extendable storm surge barrier
- Pumping station

Don’t forget other climate hazards

ARUP

US workplace injuries caused by heat severely undercounted, study shows

By using a narrow definition of heat-related injuries federal and state agencies miss thousands of others

NEWS LIVE: ISRAEL AT WAR POLITICS U.S. NEWS WORLD BUSINESS NBC NEWS TIPLINE PRIME DAY DEALS WATCH LIVE

SCIENCE NEWS

As temperatures spike, so do cases of second- and third-degree burns

The burns typically occur when people fall or pass out on sun-scorched pavement and other hot surfaces, which can exceed 160 degrees.

Don’t forget other climate hazards

ARUP

Expansion cracking of asphalt concrete pavement on a bridge

Rubber Cracking

Rutting

Will it happen in HK?

WORLD ›

Extreme heat in UK adds further air travel disruption as it melts airport runway

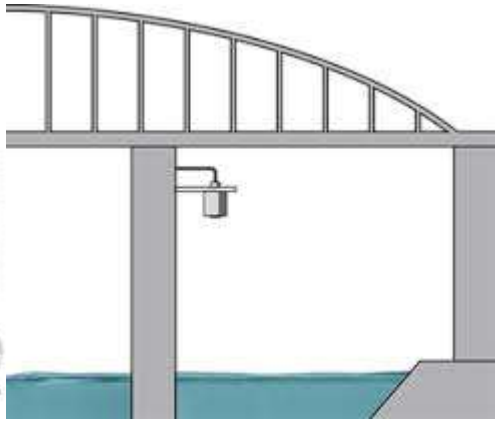
Don’t forget other climate hazards

ARUP

Surface could be 20°C hotter than the air temperature !

Cooling track & pavement

High performance asphalt pavement

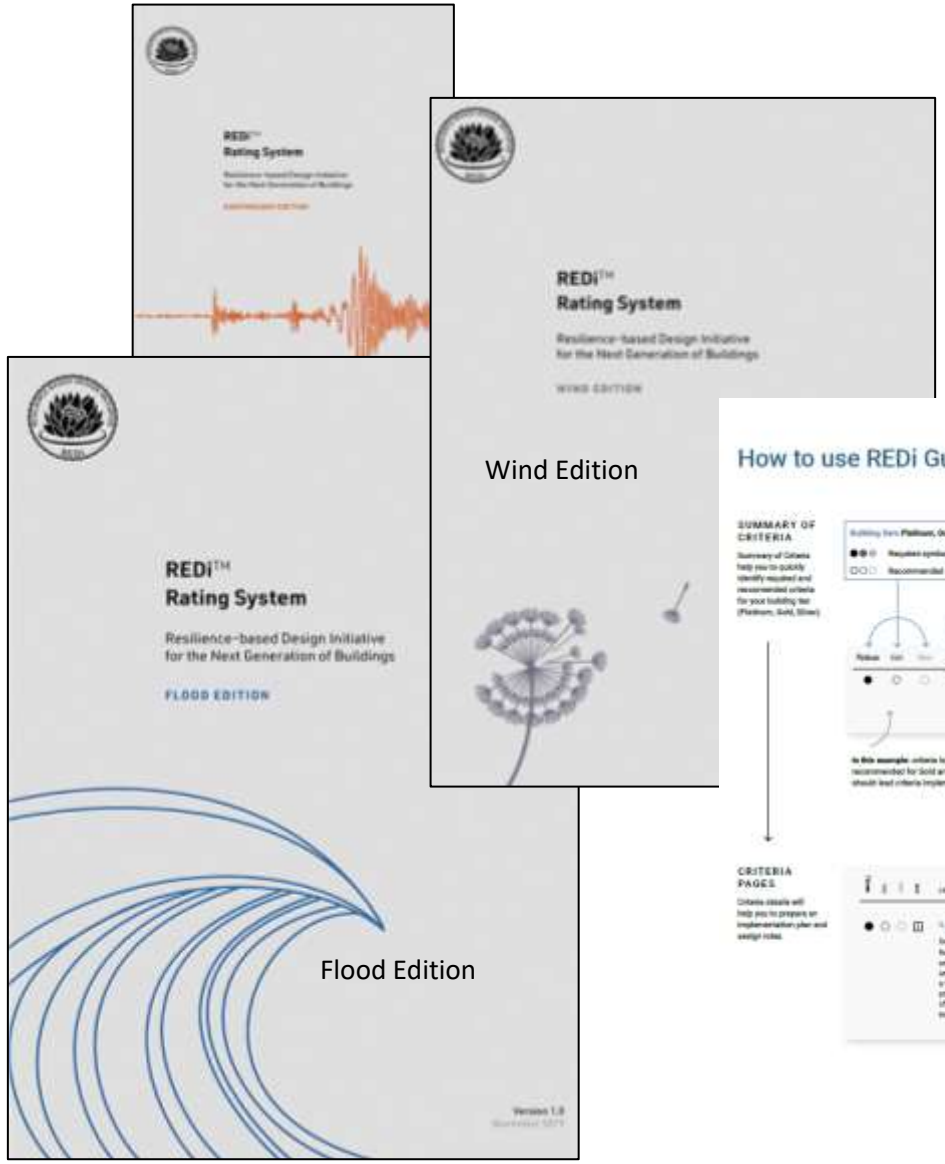


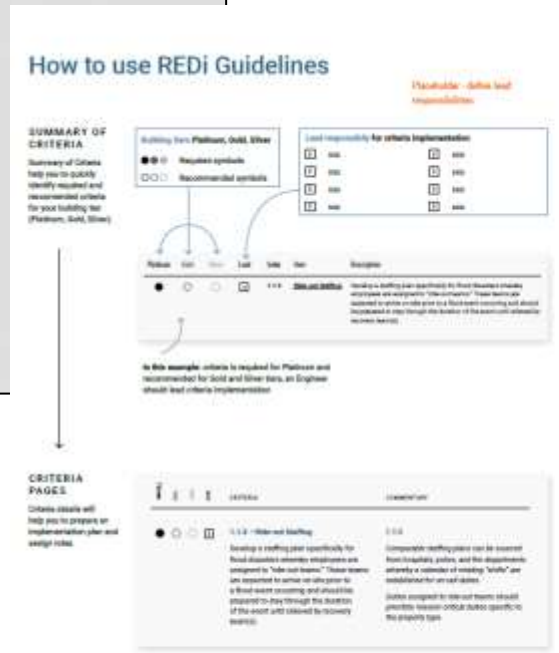
Smart highway to detect flooding situation on road sections

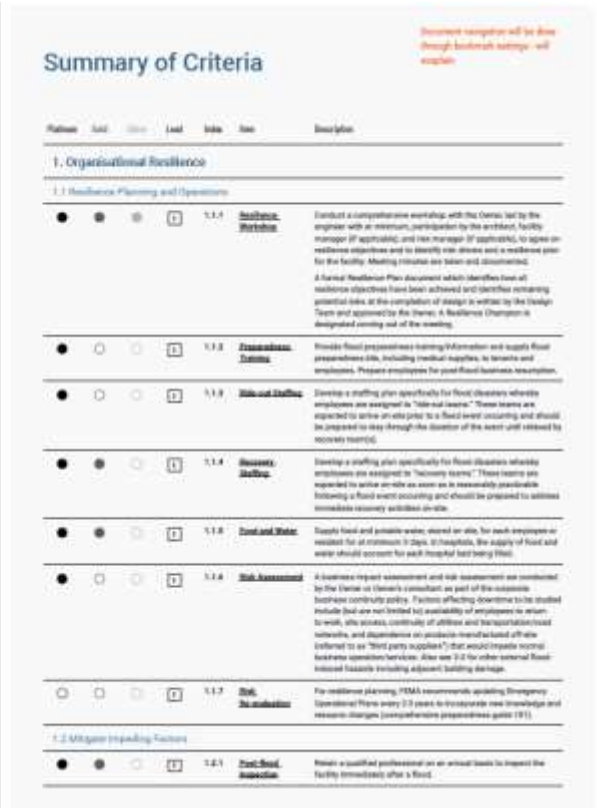
Climate Resilience Framework & Rating System

ARUP

Resilience-based Design Initiative
for the Next Generation of Buildings







https://www.redi.arup.com/

Climate Resilience Rating System

REDi Framework

- Building
- Organization
- Ambient / Site
- Loss Assessment

https://www.redi.arup.com/

City Information Collection to Enhance Weather Forecast

ARUP

- Combining with day-by-day Numerical Weathe Model forecasts, sub-km daily temperature extremes at asset level can be made
- In a recent study by HKO using ML techniques, 10-km numerical weather model forecast can be statistically downscaled into 50-m resolution across Hong Kong

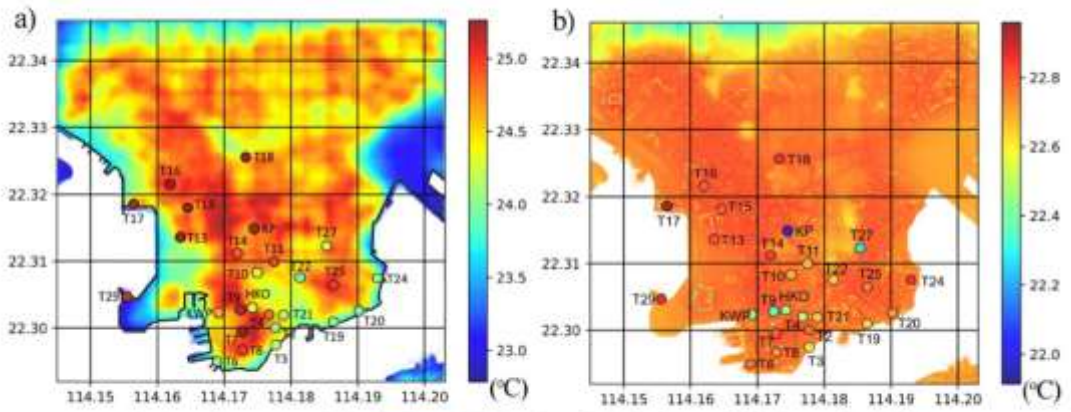


Fig. 8. Spatial temperature distribution from UMTF: a) MaxTmp on the 10th of May, and b) MinTmp on the 11th of May.

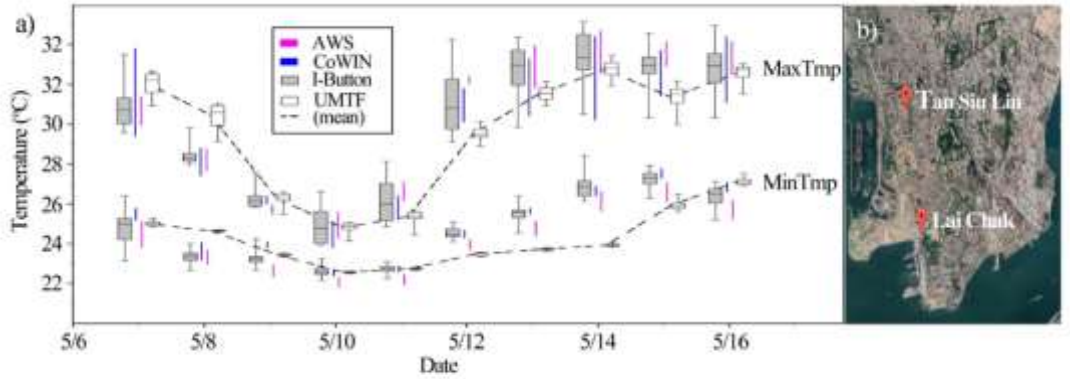
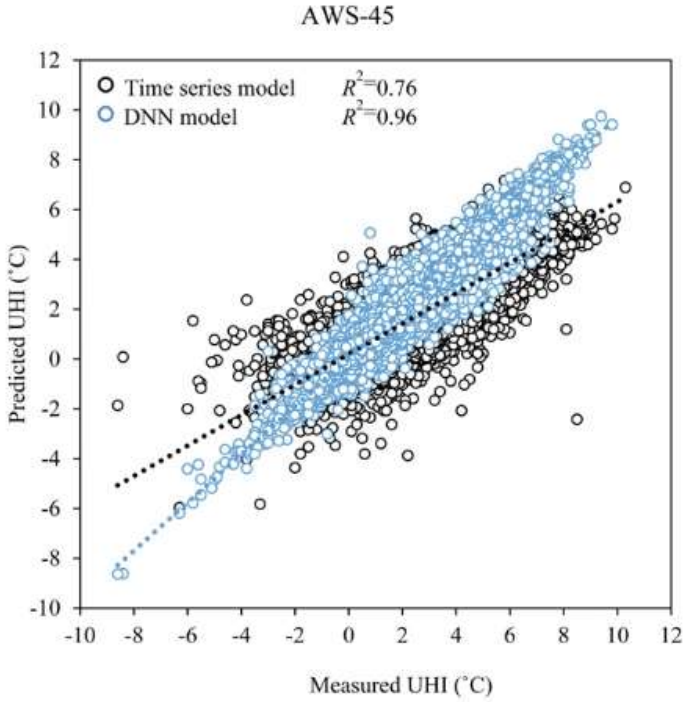


Fig. 7. a) Time-series of MaxTmp and MinTmp comparison with AWS, I-button and CoWIN from the 7th to 16th of May, the locations of CoWIN stations. Notes: the tips of the box represent the maximum and minimum values of the dataset, and the top, centre and bottom lines of the box reflect the 25% tile, medium, and 75% tile, respectively. The lines without box show the maximum and minimum values of the data.



Traditional Statistical model (black)

Deep learning ML model (blue)

[4] Chang, J. M. H., Lam, Y. F., Lau, S. P. W., & Wong, W. K. (2021). Development of fine-scale spatiotemporal temperature forecast model with urban climatology and geomorphometry in Hong Kong. Urban Climate, 37, 100816.

Oh, J. W., Ngarambe, J., Duhirwe, P. N., Yun, G. Y., & Santamouris, M. (2020). Using deep-learning to forecast the magnitude and characteristics of urban heat island in Seoul Korea. Scientific reports, 10(1), 3559.

Key Questions

ARUP

1. Do we need to further update our design assumptions?
2. What can be further improved in our drainage system?
3. What can be further improved in our coastal resilience?
4. How to address extreme case?
5. Do we have a holistic plan for climate risk and resilience?
6. How CIM (City Info Model) can further support weather forecast

ARUP

Thank you

bruce.chong@arup.com