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Some thoughts on geotechnical challenges in Northern Metropolis

Ir James Sze

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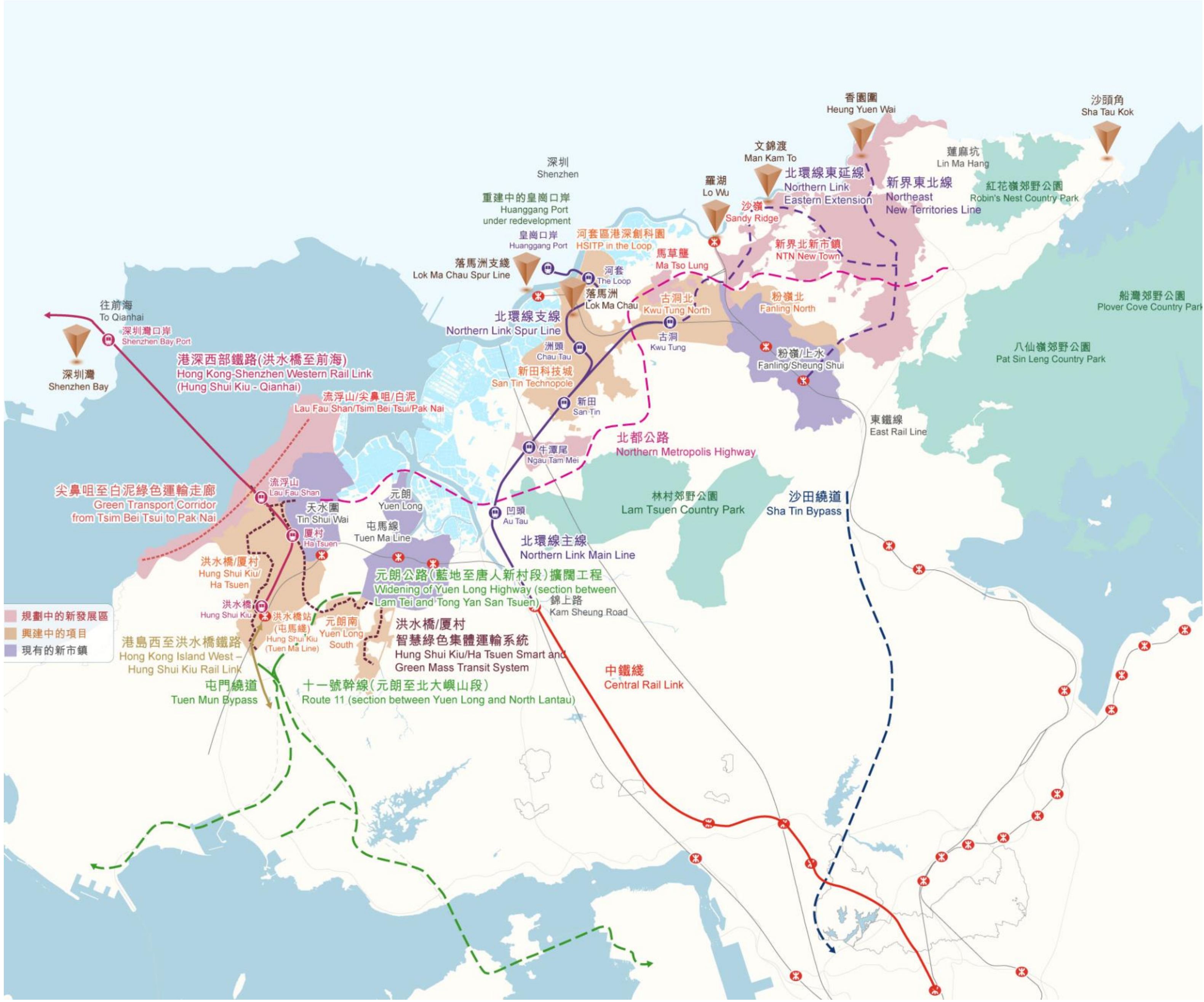
Northern Metropolis

- a total area of 30,000 ha
- 3,000 ha new development lands for various types of developments in four zones
- basic infrastructures and key transportation infrastructures - roads and underground railway lines



Soft superficial deposits

Geogenic Arsenic-rich ground

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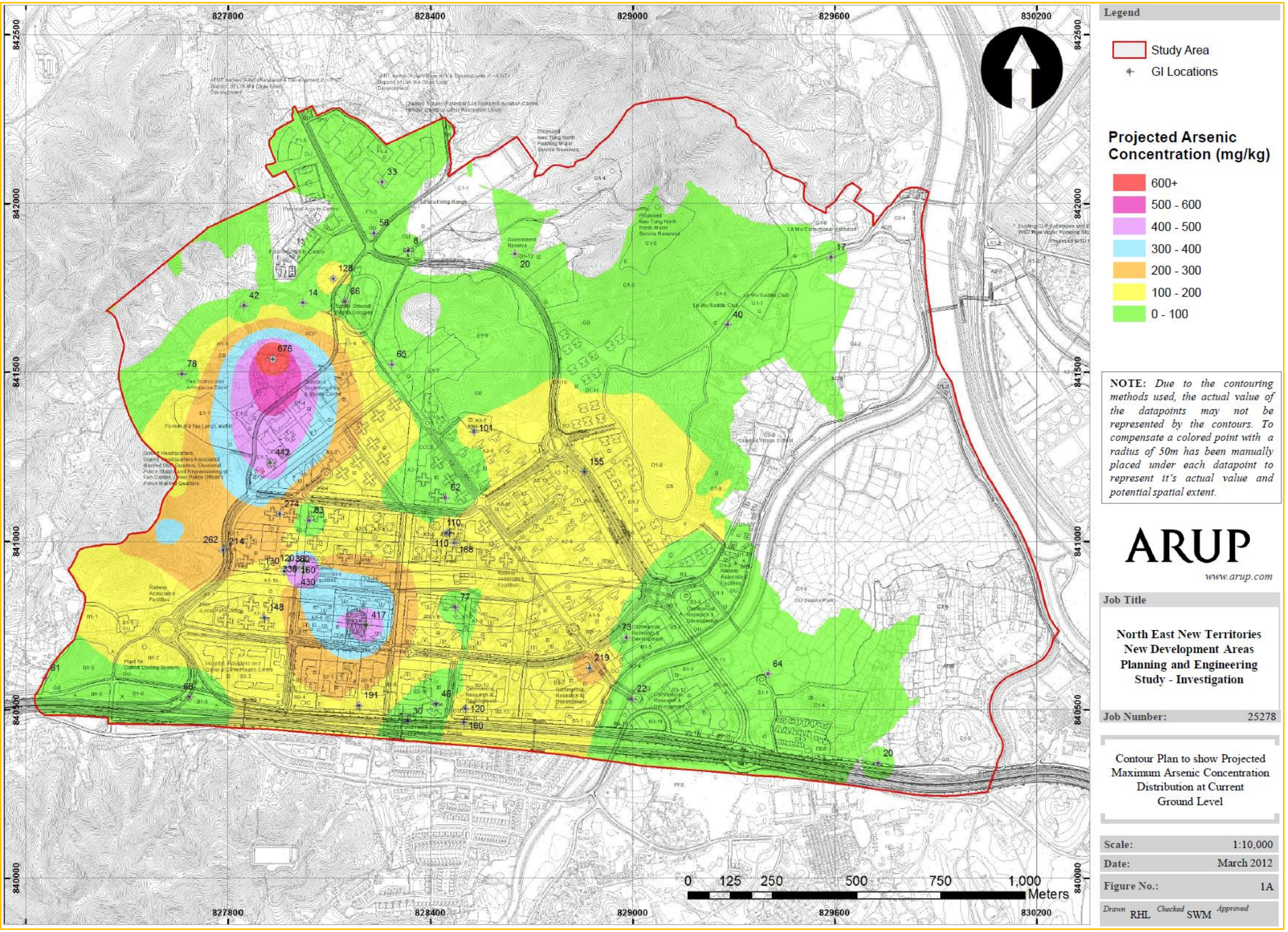

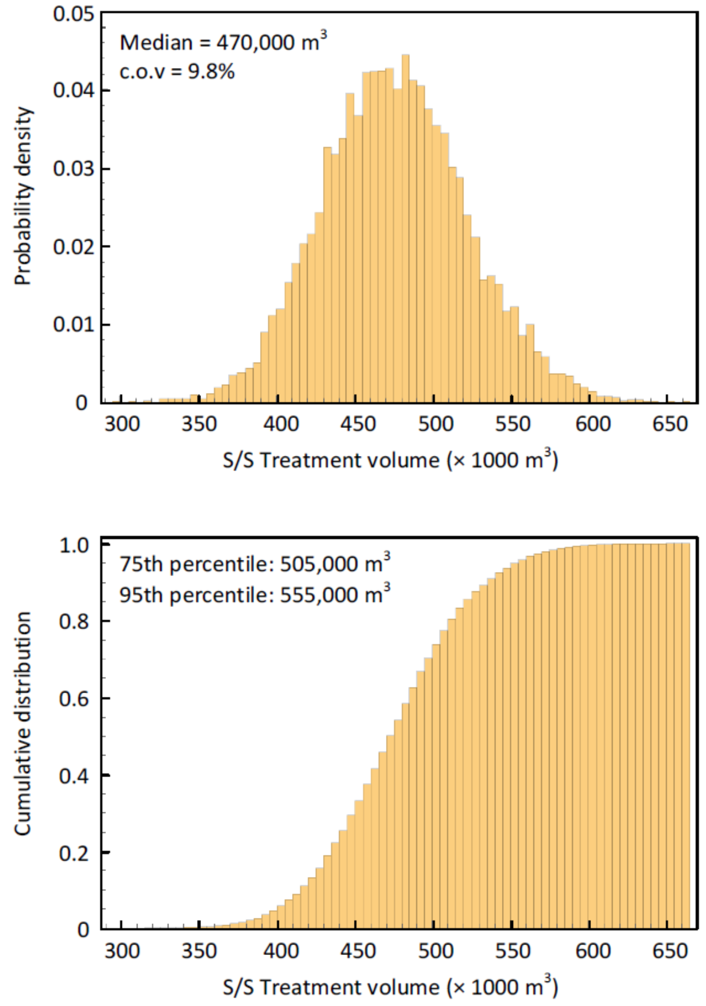

Figure 8. Probability density and cumulative distribution of estimated S/S treatment volumes (with arsenic concentration > 571 mg/kg).

Extracted from joint research by CEDD & PolyU

Remediation Procedures for HAC Soil

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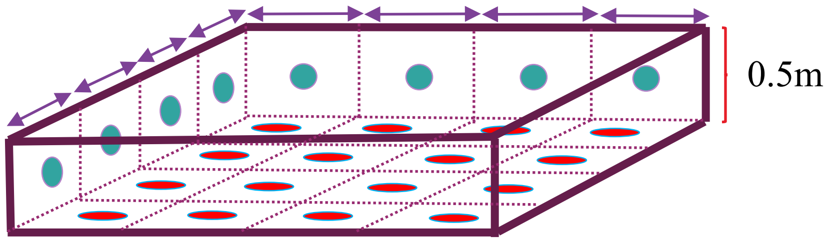
Excavate the HAC soil at Site
(Extent to be confirmed by **Closure Assessment**)



Remediation at **HAC Soil Treatment Facility**

Excavated Soil

1a Stockpiling of **non-HAC soil** / surplus soil

1b Temporary Storage for **HAC soil** requiring treatment

Handle as usual

Crushed and returned for retreatment

4b Temporary Storage for retreatment

2 Cement Stabilisation / Solidification Mixing Area

3 Temporary Storage for treated soil **pending** laboratory results (7 days curing)

TCLP & UCS lab test around 10-14 days

Sample passed

200m^3	200m^3	200m^3	200m^3	200m^3

1 sample per 200m^3

Sample failed

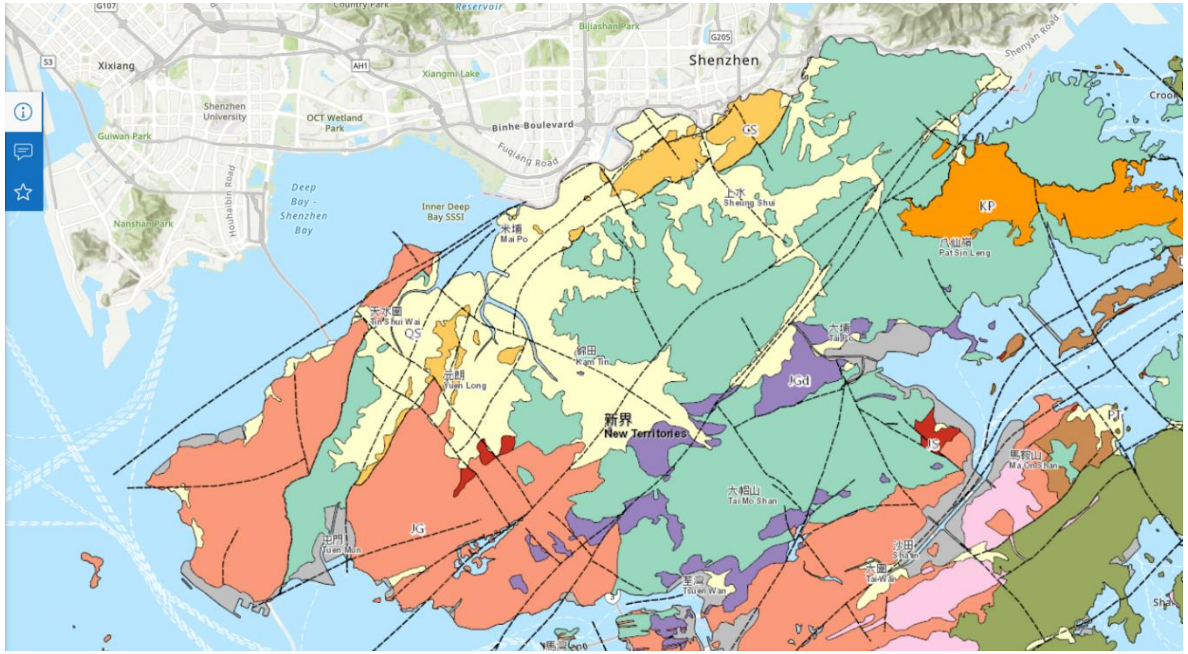
Acceptance Criteria:
TCLP-As: ≤5mg/L
UCS: ≧ 1MPa

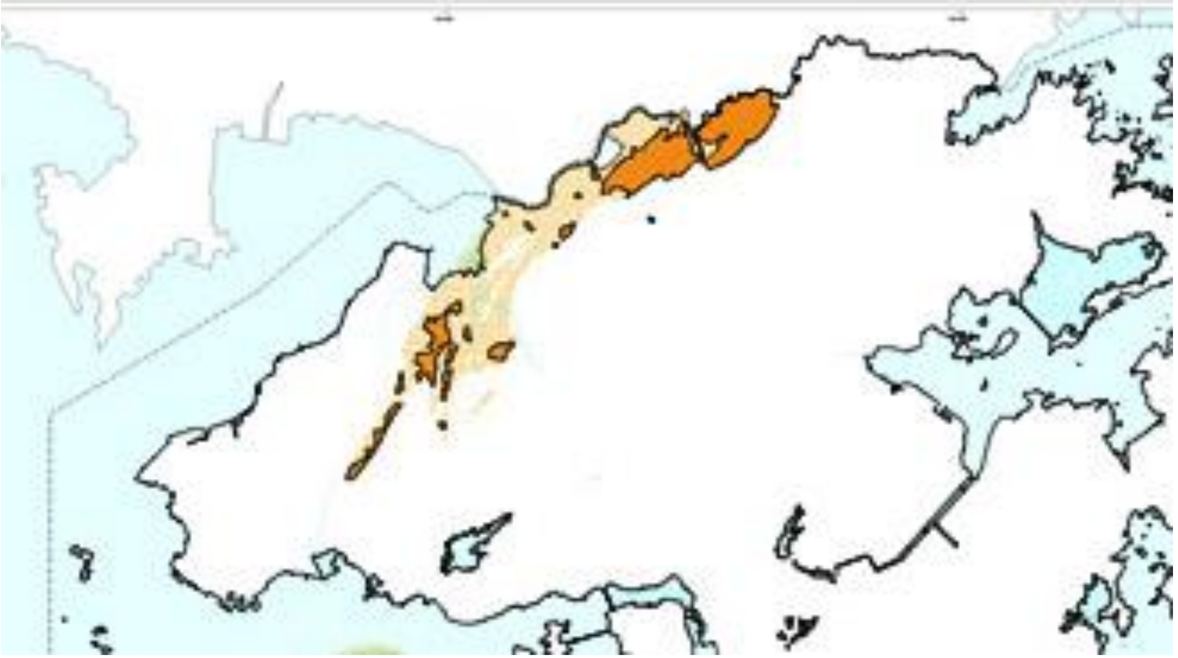
4a Temporary Storage for treated soil **passed** laboratory results

Reuse as backfill material / disposal

Geological condition at NM

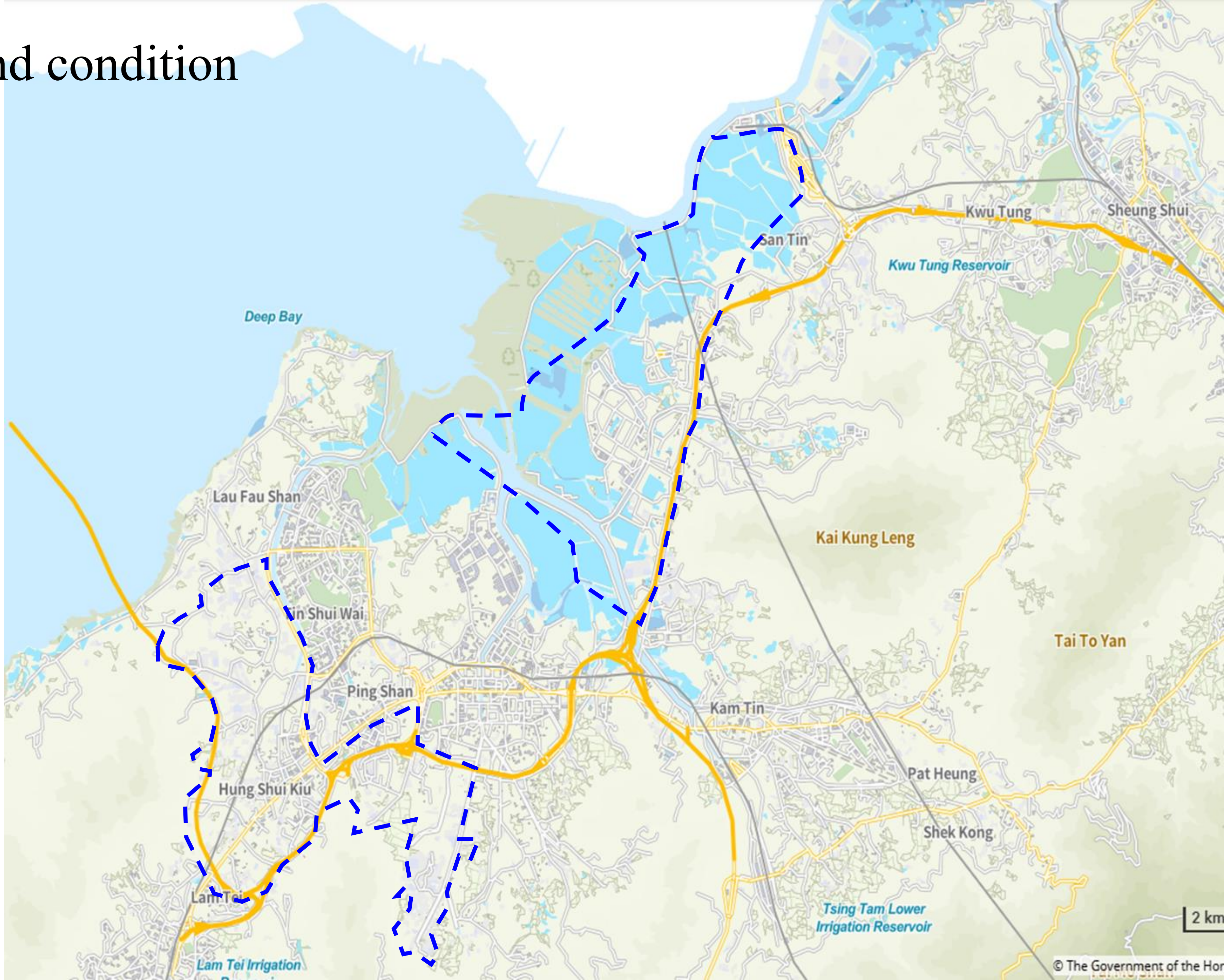
- Substantial area underlain by Carboniferous metamorphosed Sedimentary Rock (~300M years) :-
- Lo Ma Chau Formation - metamorphosed sandstone and carbonaceous siltstone with graphitic interbeds and conglomerate
- Yuen Long Formation - calcite & dolomite Marble





Geological model/ground condition

- Lack of comprehensive understanding due to limited existing GI information
- GEO commissioned "Regional Geological Study at Northwest New Territories"
- Conventional GI stations for defined development areas
- Geophysical surveys as supplement in area of interest:-
  - ✓ Micro-gravity survey
  - ✓ Ground penetration radar
  - ✓ Land seismic refraction
  - ✓ Land resistivity survey
  - ✓ Horizontal-vertical spectral ratio (HVSR)



Lack of Confidence on Rocks in NM

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Meta-sandstone

Meta-siltstone

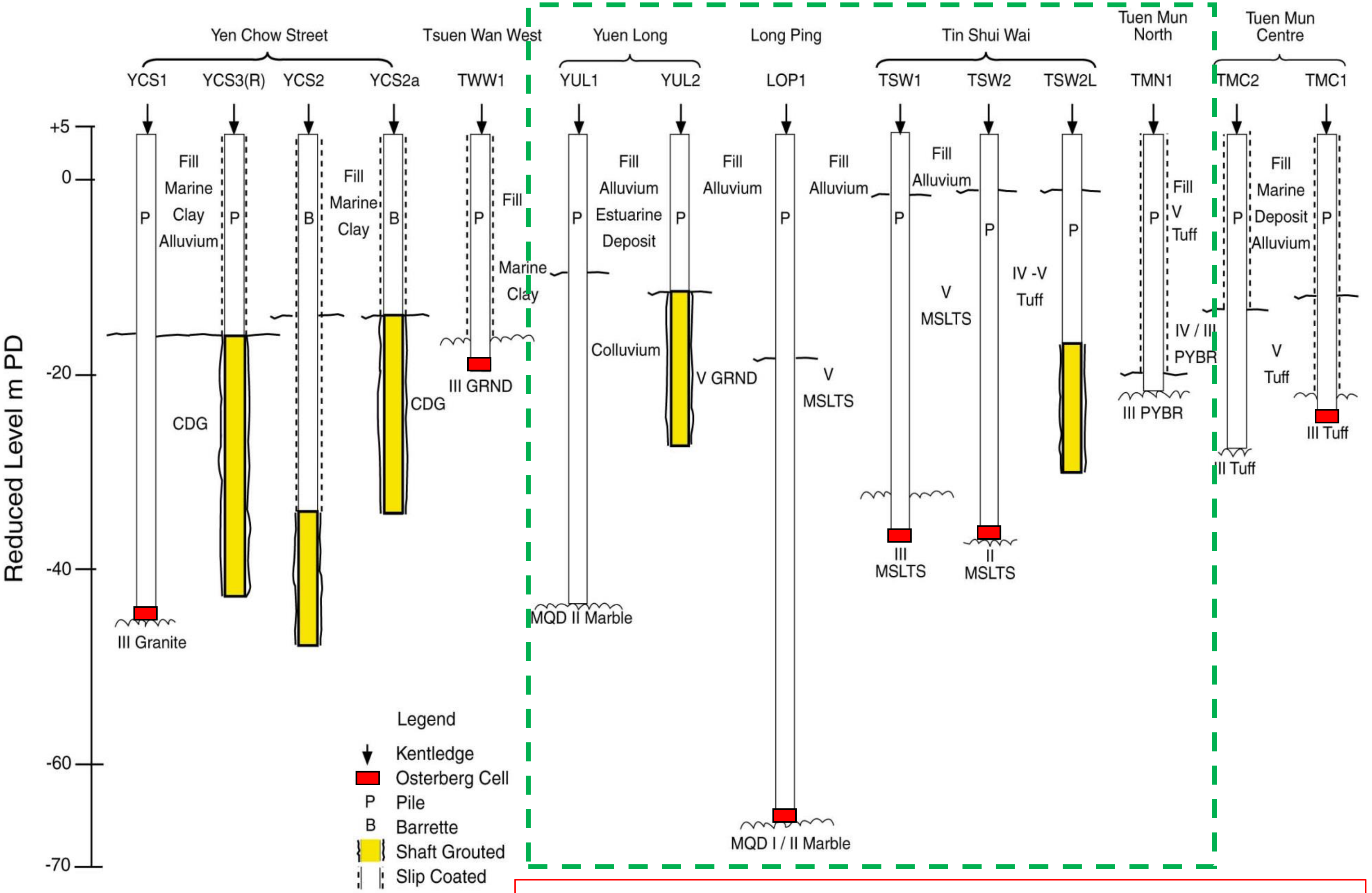
No prescriptive design guideline if the rock not metamorphosed !

Code of Practice for Foundations 2017 Tables 2.1 & 2.2

Category	*Description of rock or soil*	*Presumed allowable bearing pressure (kPa)*
	Rock (granite and volcanic):	
1(a)	Fresh to slightly decomposed strong to very strong granite or volcanic rock of material weathering grade II or better, with 100% TCR of the designated grade which has a minimum UCS of rock material not less than 75 MPa (or an equivalent point load index strength PLI_{50} not less than 3 MPa)	10,000
1(b)	Fresh to slightly decomposed strong granite or volcanic rock of material weathering grade II or better, and with not less than 95% TCR of the designated grade, which has a minimum UCS of rock material not less than 50 MPa (or an equivalent point load index strength PLI_{50} not less than 2 MPa)	7,500
1(c)	Slightly to moderately decomposed moderately strong granite or volcanic rock of material weathering grade III or better, and with not less than 85% TCR of the designated grade, which has a minimum UCS of rock material not less than 25 MPa (or an equivalent point load index strength PLI_{50} not less than 1 MPa)	5,000
1(d)	Moderately decomposed, moderately strong to moderately weak granite or volcanic rock of material weathering grade III or better, and with not less than 50% TCR of the designated grade.	3,000
2	*Meta-Sedimentary rock:* Moderately decomposed, moderately strong to moderately weak meta-sedimentary rock of material weathering grade III or better, and with not less than 85% TCR of the designated grade.	3,000

Category of rock as defined in Table 2.1	*Presumed allowable bond or friction between rock and concrete or grout for piles (kPa)*	
	Under compression or transient tension	*Under permanent tension*
1(c) or better	700	350
1(d) or 2	300	150

West Rail Test Pile Programme (1998)



- 50% increase in presumed values is achievable
- Advocate Rock Mass Rating (RMR) approach

Design Guidelines in GEO Publication 1/2006

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Table 6.4 – Rating Assigned to Individual Parameters using RMR Classification System (Based on Bieniawski, 1989)

(A) Strength of Intact Rock

Uniaxial compressive strength, σ_c (MPa)	> 250	250 – 100	100 – 50	50 – 25	25 – 5	5 – 1	< 1
Point load strength index, PLI_{50} (MPa)	> 10	10 – 4	4 – 2	2 – 1	σ_c is preferred		
Rating	15	12	7	4	2	1	0

(B) Rock Quality Designation (RQD)

RQD (%)	100 – 90	90 – 75	75 – 50	50 – 25	< 25
Rating	20	17	13	8	3

(C) Spacing of Joints

Spacing	> 2 m	2 m – 0.6 m	0.6 m – 0.2 m	200 – 60 mm	< 60 mm
Rating	20	15	10	8	5

(D) Conditions of Joints

Discontinuity length[1]					
Rating	2				
Separation	None	< 0.1 mm	0.1 – 1 mm	1 – 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickenside
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Rating	6	5	3	1	0

(E) Groundwater

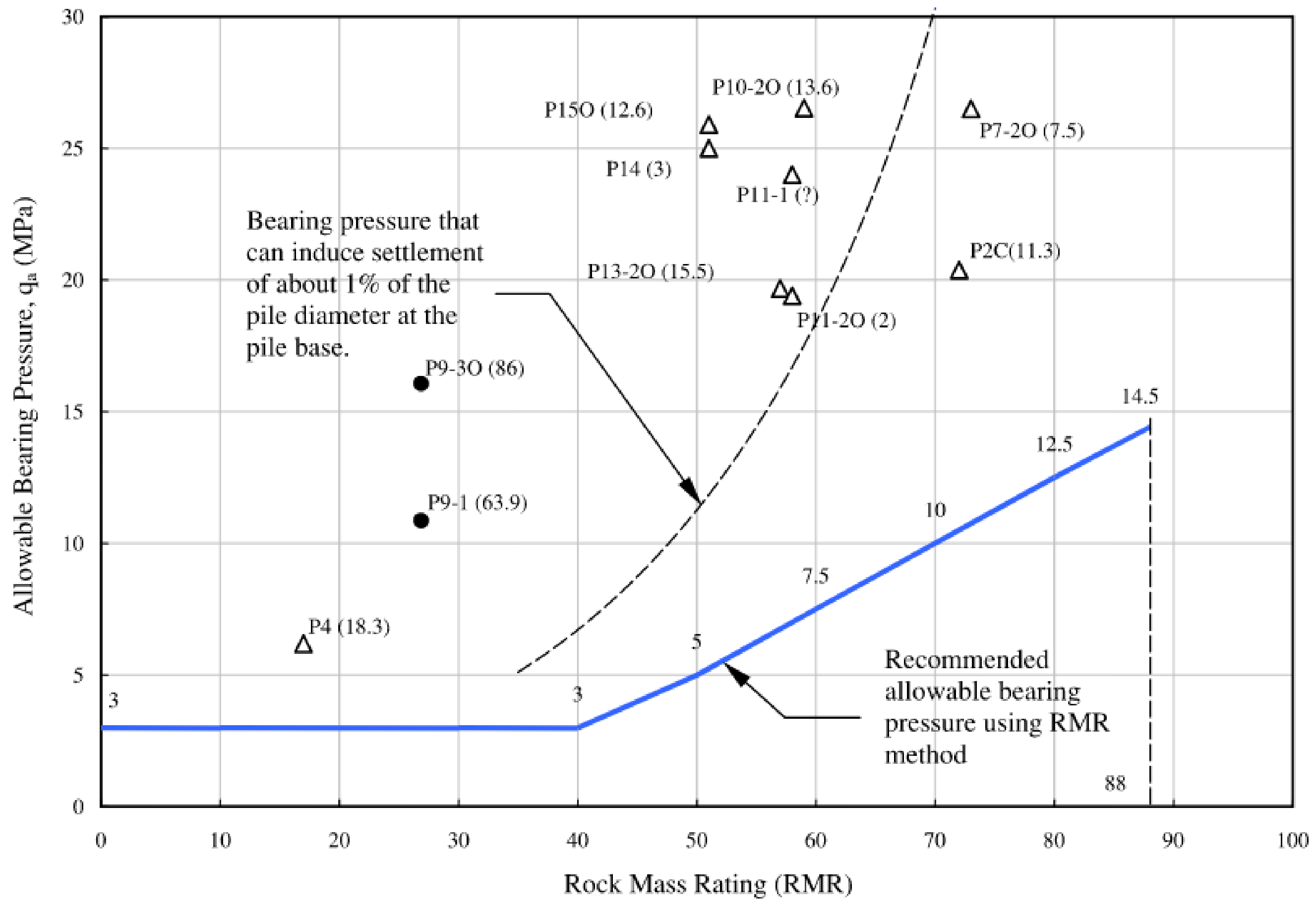
Rating[1]	7

Notes :

(1) Rating is fixed as the parameter is considered not relevant to the evaluation of allowable bearing pressure of rock mass.

(2) RMR is the sum of individual ratings assigned to parameters (A) to (E).

→ Consistent and detailed logging are needed !



Correlation between Allowable Bearing Capacity Rock and Rock Mass Rating

Opportunity to rationalise Foundation Design Capacity

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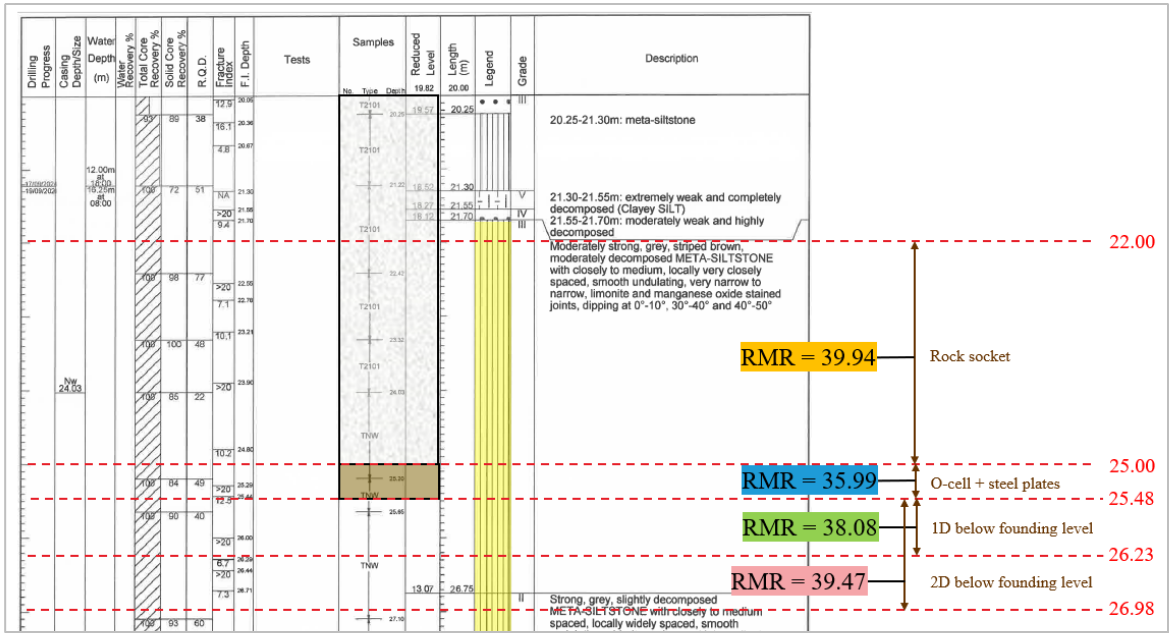
Foundation Bearing / Bond Capacity in Meta-sedimentary rock

Enhancing Foundation Design Guidelines for MS Rocks

If enhancing allowable bearing capacity from 3,000 to 5,000 kPa, cost & time saving could easily be 30-40%



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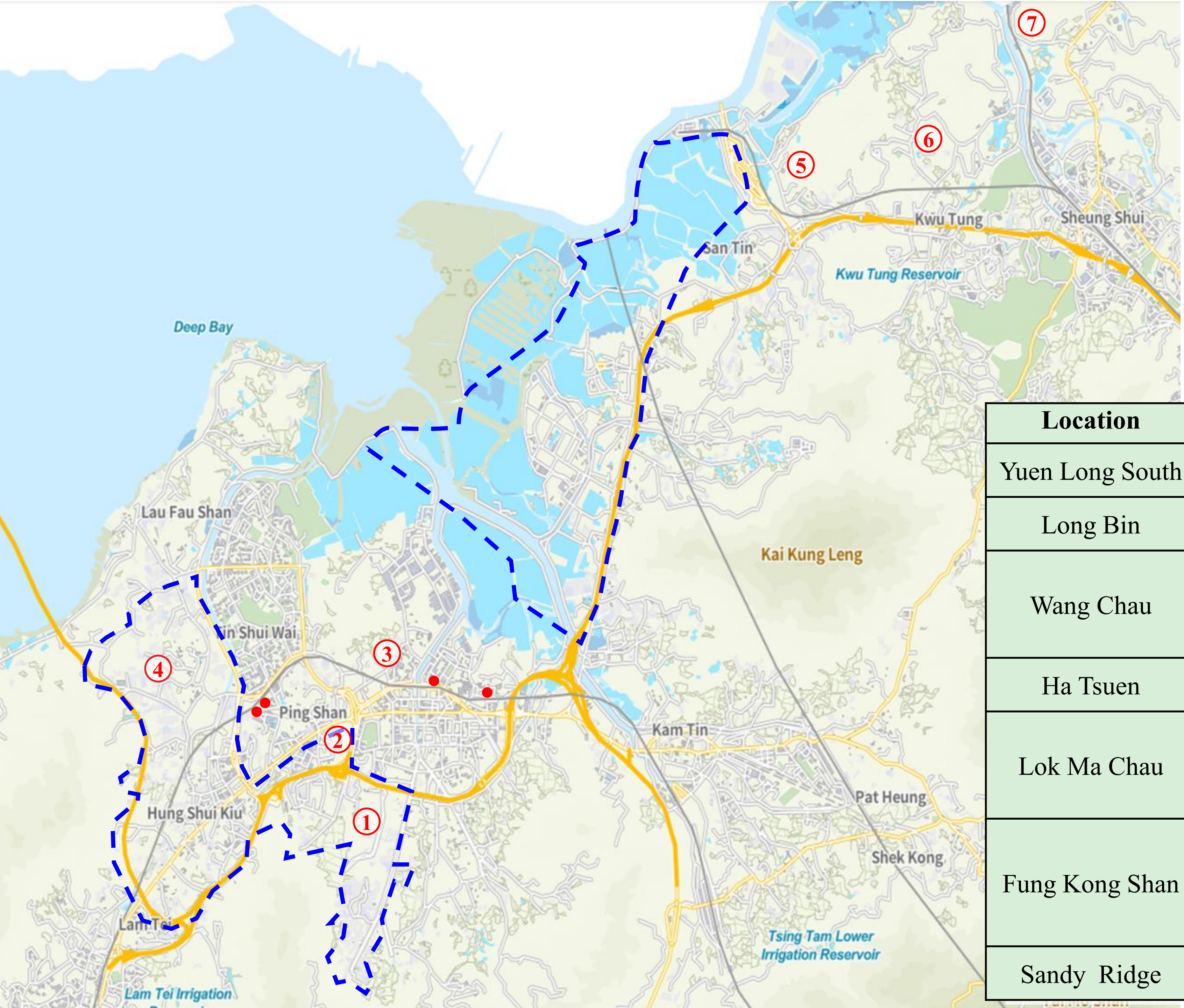
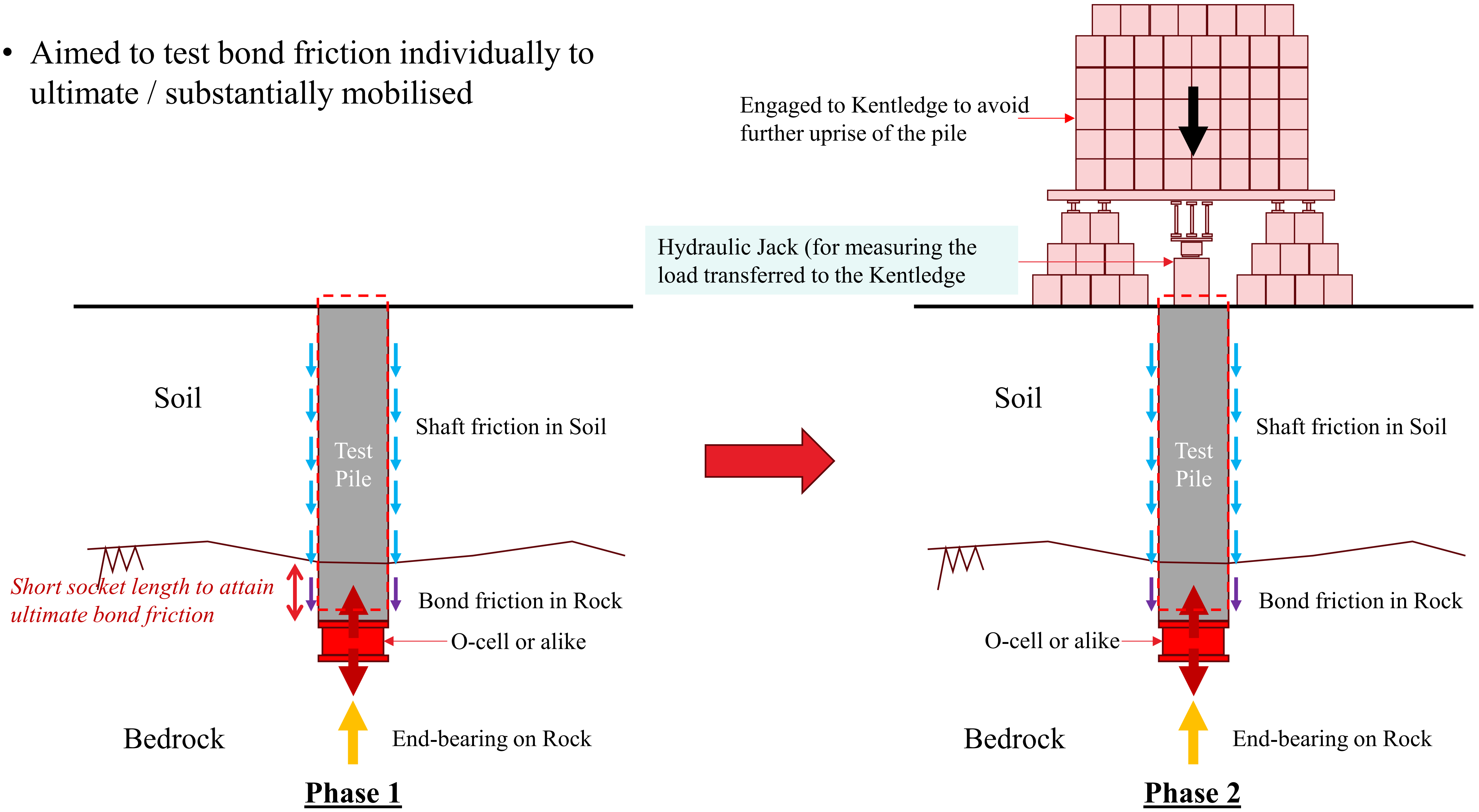
Pile testing programme in NM embarked by CEDD / GEO



Location	Test piles	Testing method
Yuen Long South	2 x ϕ813mm bored piles	O-cell
Long Bin	2 x ϕ1.5m bored piles	O-cell
Wang Chau	2 x ϕ813mm bored piles	Kentledge / O-cell
	1 x ϕ610mm socketed H-pile	O-cell
Ha Tsuen	1 x ϕ610mm socketed H-pile	O-cell
Lok Ma Chau	2 x ϕ1.5m bored pile	Kentledge / O-cell
	1 x ϕ610mm socketed H-pile	O-cell
Fung Kong Shan	2 x ϕ610mm socketed H-pile	Kentledge / O-cell
	1 x ϕ813mm socketed H-pile	Y-Jack x 3 layers
Sandy Ridge	2 x ϕ813mm bored piles	O-cell

Bi-directional Load Test

- Aimed to test bond friction individually to ultimate / substantially mobilised



Pile Load Tests by O-cell

<u>For ϕ610mm Socketed H-Pile</u>

O-cell
- 1 no. of 430mm dia.
- Capability = 6.3MN

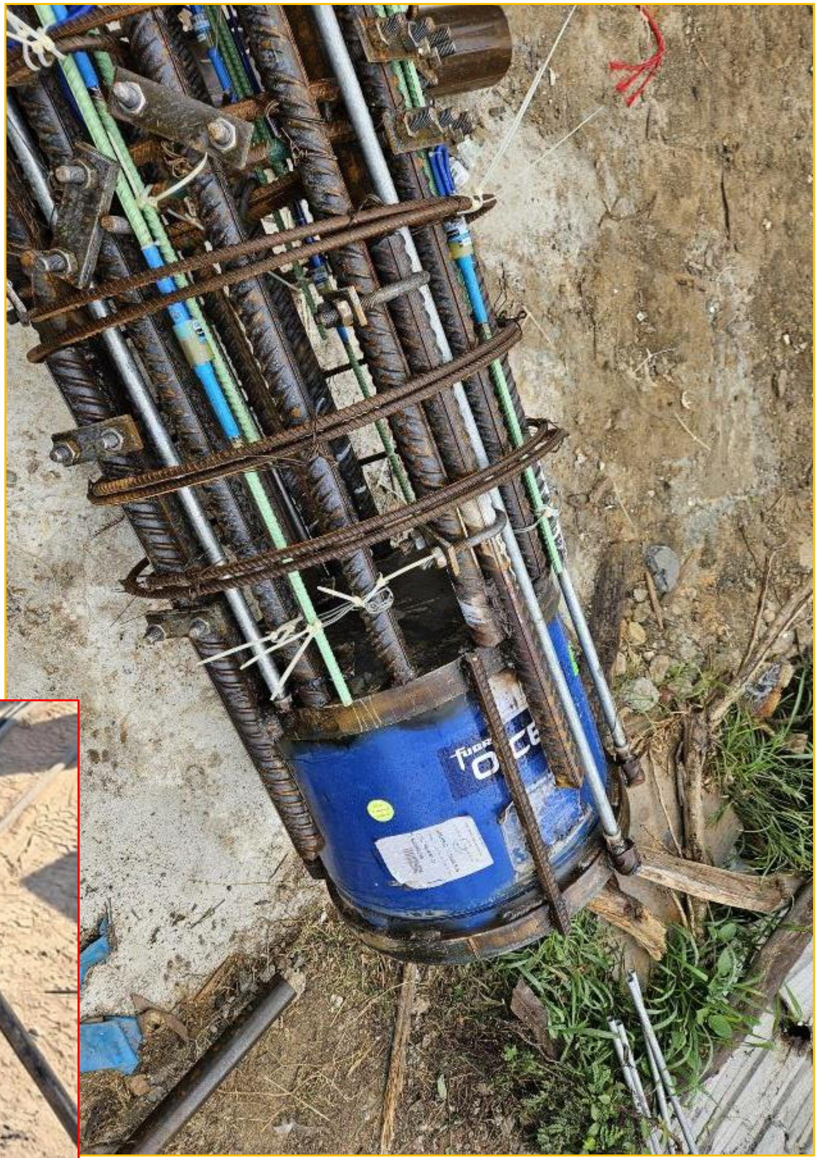
<u>For ϕ1.5m Bored Pile</u>

O-cell
- 5 nos. of 430mm dia.
- Capability = 5 x 6.37 = 31.8MN

<u>For ϕ813mm Bored Pile</u>

O-cell
- 1 no. of 530mm dia.
- Capability = 10.1MN

O-cell installation in test piles



Preliminary test results on end-bearing capacity

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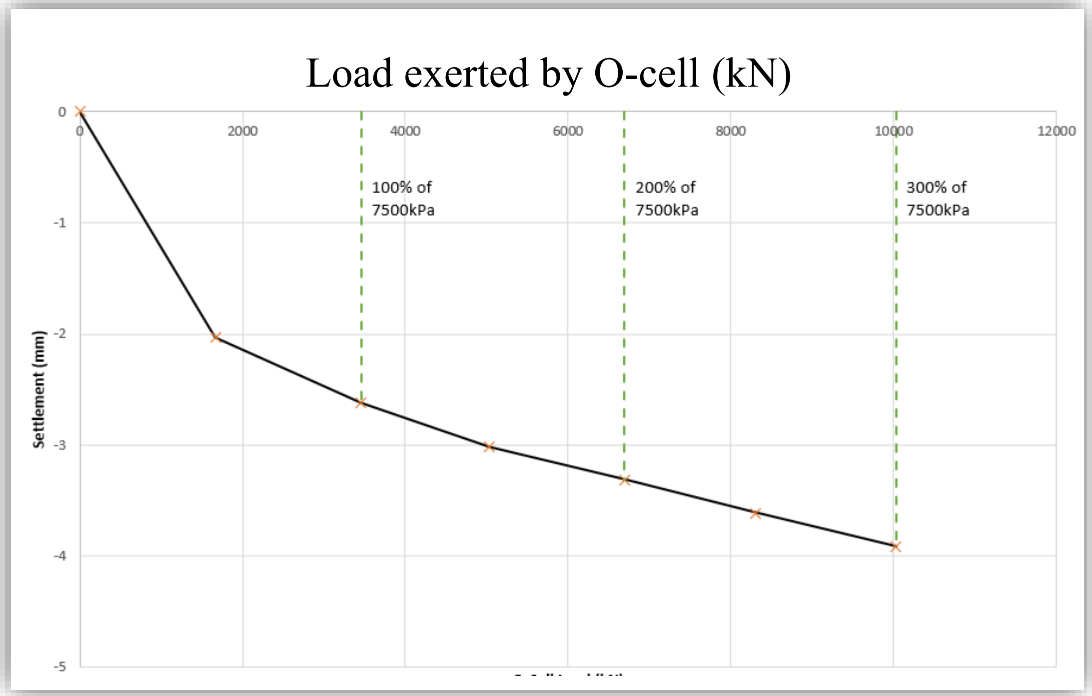
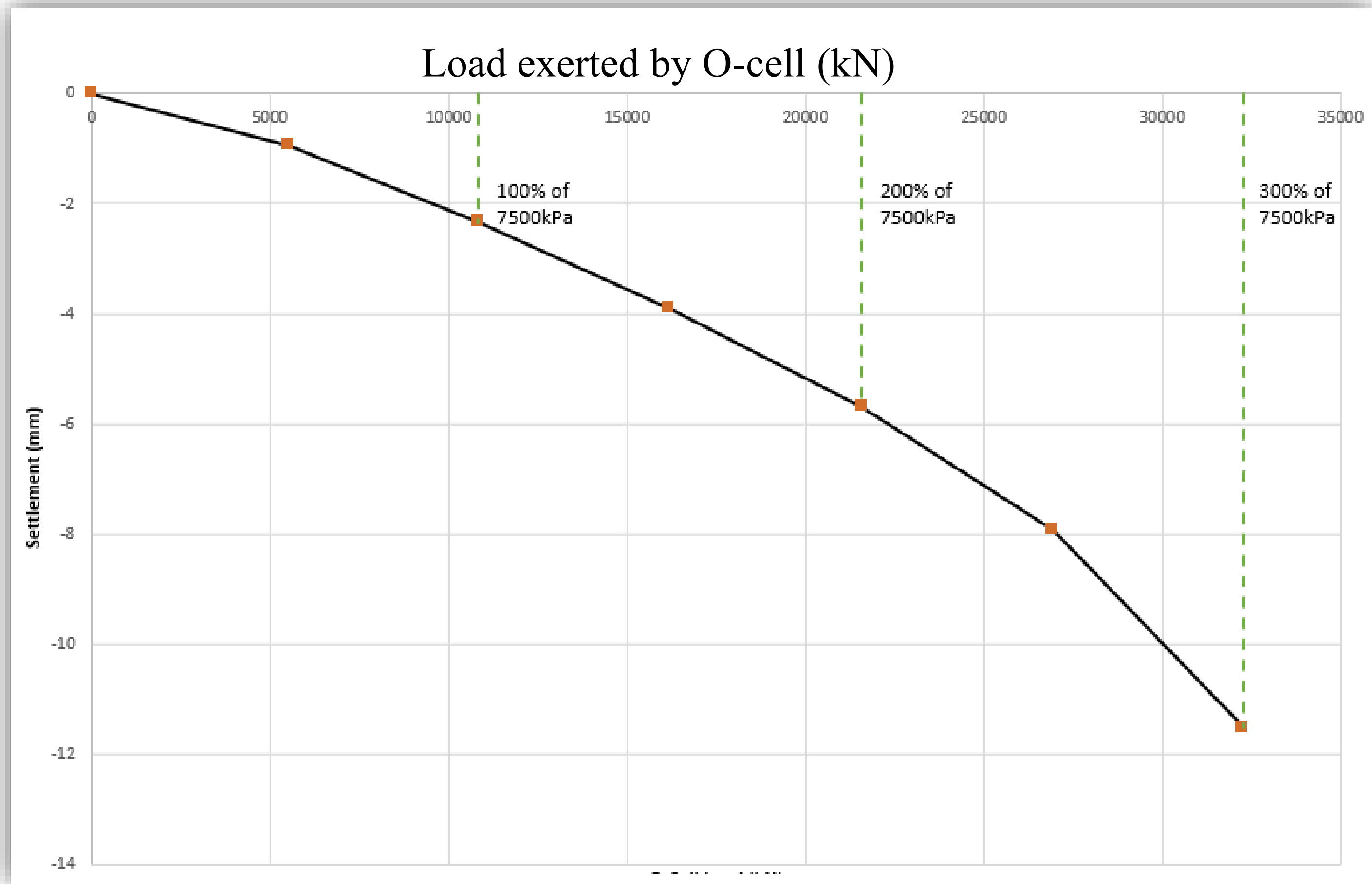
- YLS-P2 showed 2mm seating penetration then linear behavior, 2mm (tiny) settlement from 0.5WL to 3.0WL
- LB-P1 showed almost linear behaviour, 12mm at 3.0WL, far below fully moblised zone



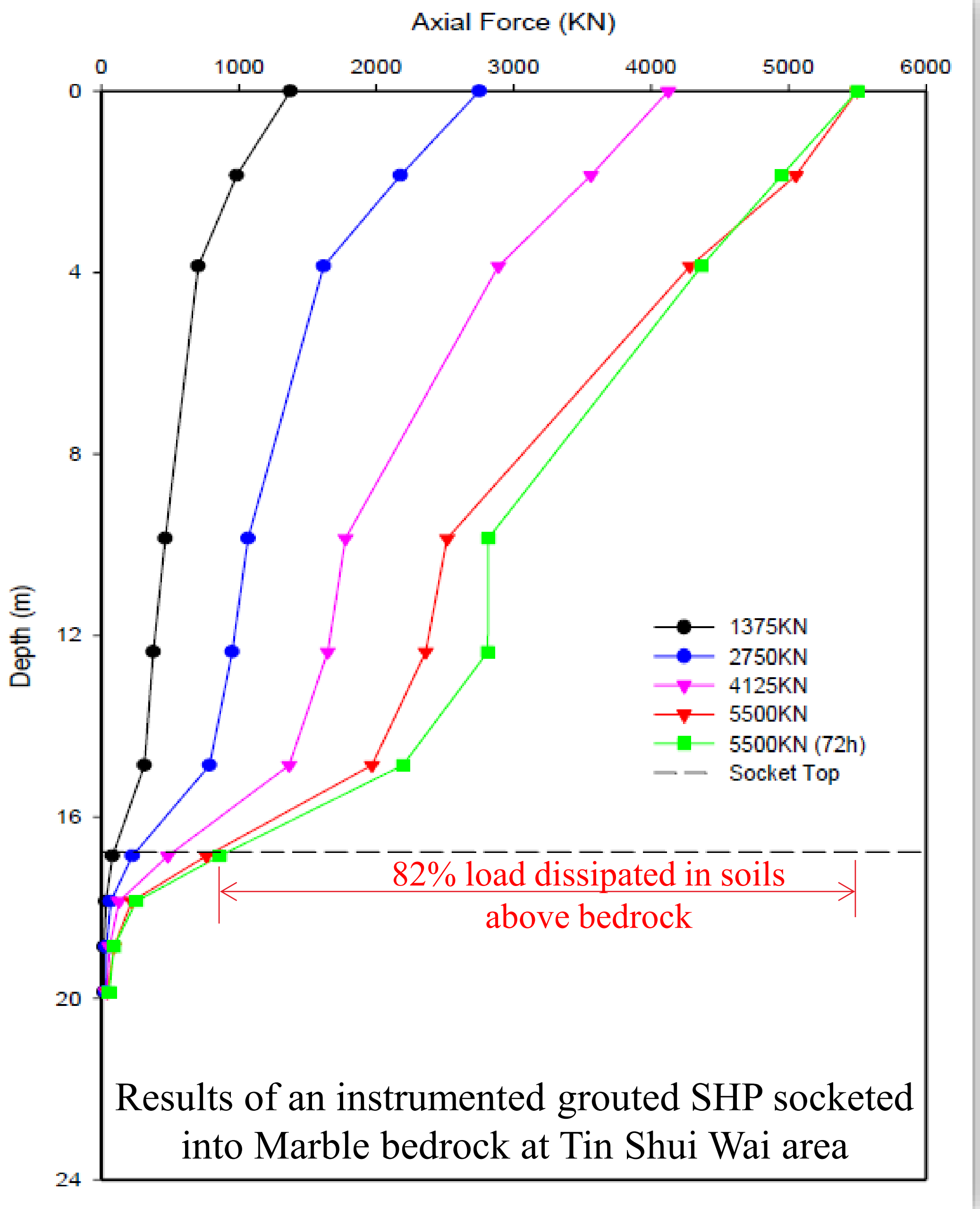
▲ YLS-P2 (ϕ813mm BP, RMR = ~ 67)



▲ LB-P1 (ϕ1.5m BP, RMR = ~47)

Further thought – frictional capacity in soils

- Frictional capacity along pile shaft, even in case of replacement piles, can have significant contribution
- Soil friction exhibits ductile behaviour, no need to worry about strain softening in combined use with rock socket friction / end-bearing



Results of an instrumented grouted SHP socketed into Marble bedrock at Tin Shui Wai area

Further thought - Piled Raft

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	Lotte World Tower, Seoul, South Korea	**Burj Khalifa, Dubai, UAE**
Height	555m	828m
No. of storey	123	162
Piled Raft foundation system	6.5m thick mat foundation with 108 nos. ϕ0.975m friction ground stiffening bored piles, net lengths = 20 nos. @20m, 88 nos. @30m	3.7m thick mat foundation and 194 nos. ϕ1.5m friction bored piles, average net length@43m
Estimated maximum tower settlement	**39mm**	80mm
Design stiffness of foundation system & underlying soil/rock masses	**172MN/mm**	61MN/mm
Actual recorded settlement	15mm under 100% dead load	30mm under 75% dead load(1)
Actual foundation stiffness	**~ 350MN/mm**	~ 98MN/mm

(1) Extracted from Poulos and Bunce (2008) "Foundation Design for the Burj Dubai – The World's Tallest Building"

Further thought - Piled Raft

- Ground condition and predicted settlement contour for Burj Khalifa

Piled raft of *Burj Khalifa*

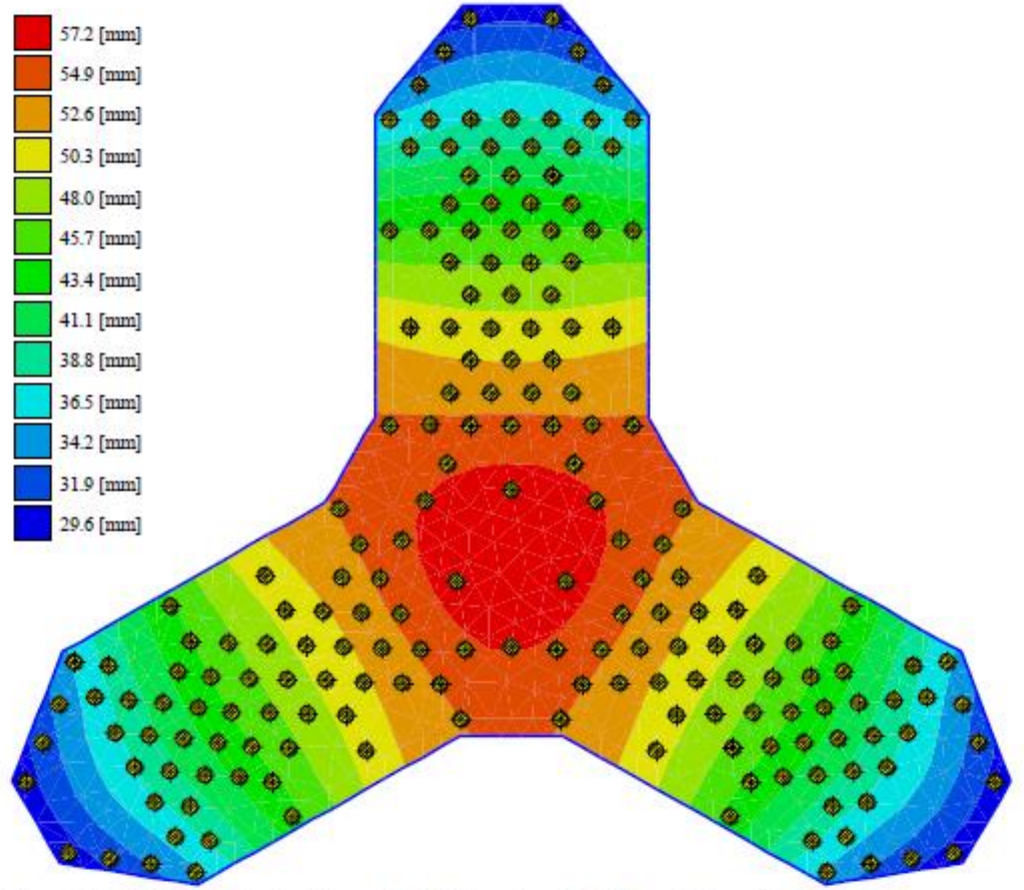

Figure 7-8 Settlement using the method "Given Load-Settlement Curve"

Extracted from O. El Gendy & M. El Gendy (2021) “Analysis of Piled raft of Burj Khalifa in Dubai by the program ELPLA”

Table 7-1 Summary of Geotechnical Profile and Parameters

Strata	Sub-Strata	Subsurface Material	Level at top of stratum [m DMD]	Thickness H [m]	UCS q_s [MPa]	Undrained Modulus E_u [MPa]	Ult. Comp. Shaft Frict. f_s [kPa]
1	1a	Medium dense silty Sand	+2.50	1.50	-	34.5	-
	1b	Loose to very loose silty Sand	+1.00	2.20	-	11.5	-
2	2	Very weak to moderately weak Calcarenite	-1.20	6.10	2.0	500	350
3	3a	Medium dense to very dense Sand/ Silt with frequent sandstone bands	-7.30	6.20	-	50	250
	3b	Very weak to weak Calcareous Sandstone	-13.50	7.50	1.0	250	250
	3c	Very weak to weak Calcareous Sandstone	-21.00	3.00	1.0	140	250
4	4	Very weak to weak gypsiferous Sandstone/ calcareous Sandstone	-24.00	4.50	2.0	140	250
5	5a	Very weak to moderately weak Calcisiltite/ Conglomeritic Calcisiltite	-28.50	21.50	1.30	310	285
	5b	Very weak to moderately weak Calcisiltite/ Conglomeritic Calcisiltite	-50.00	18.50	1.70	405	325
6	6	Very weak to weak Calcareous/ Conglomerate strata	-68.50	22.50	2.50	560	400
7	7	Weak to moderately weak Claystone/ Siltstone	-91.00	>46.79	1.70	405	325

Thanks