

Case Histories of Failures in Geotechnical Engineering Practice

Richard Hwang

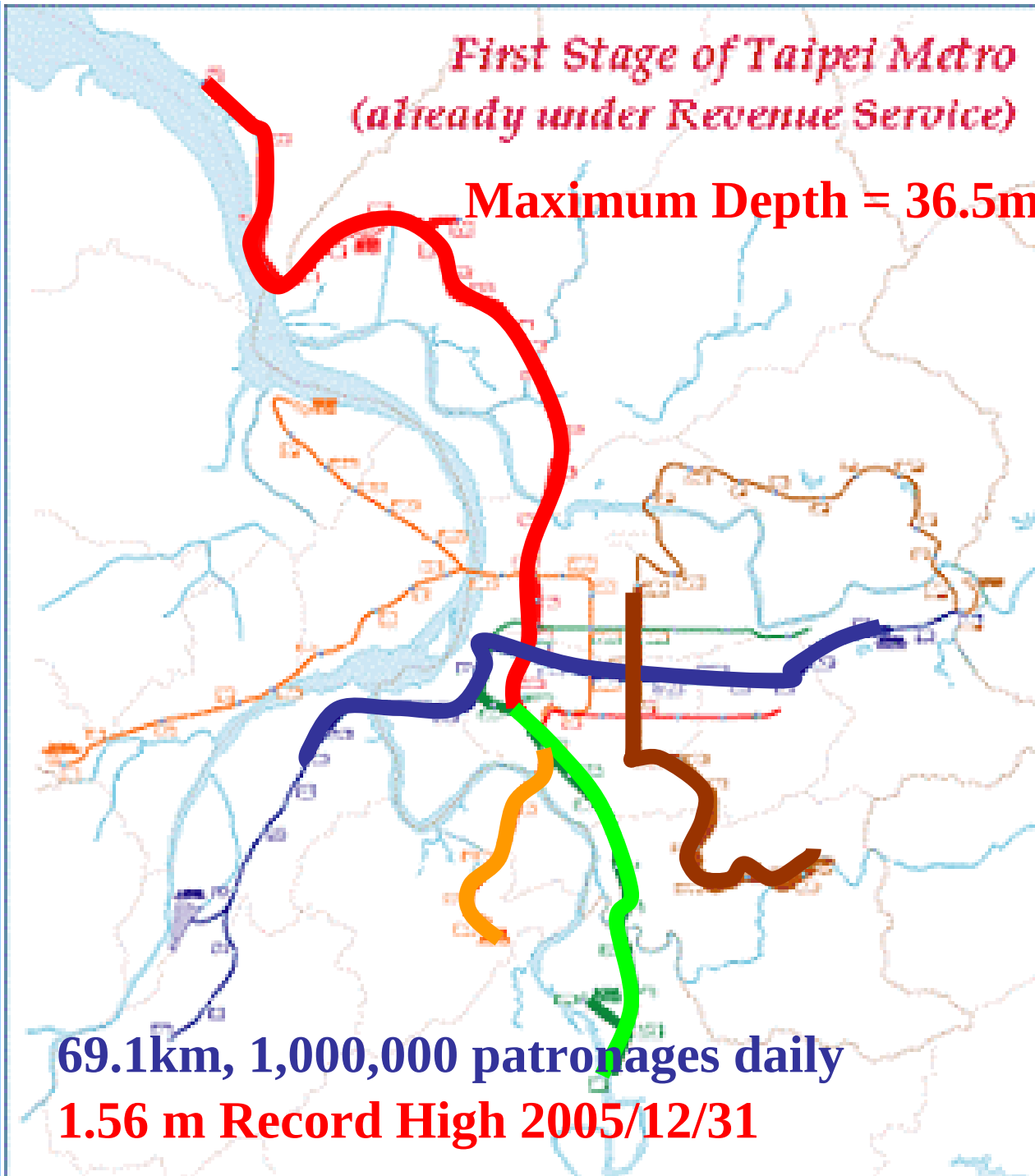
**Senior Vice President
MAA Group**

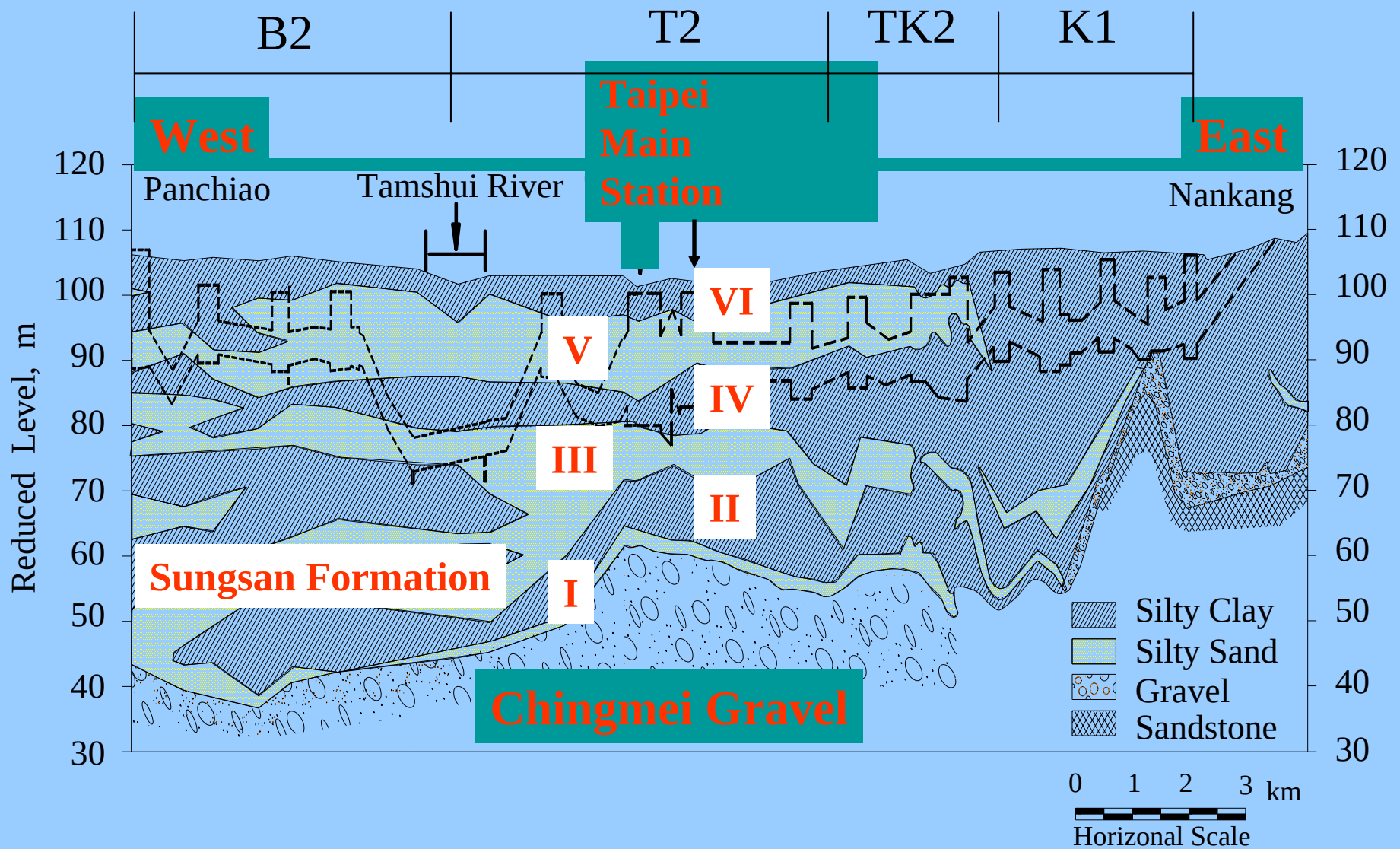
*First Stage of Taipei Metro
(already under Revenue Service)*

Maximum Depth = 36.5m

69.1km, 1,000,000 patronages daily

1.56 m Record High 2005/12/31

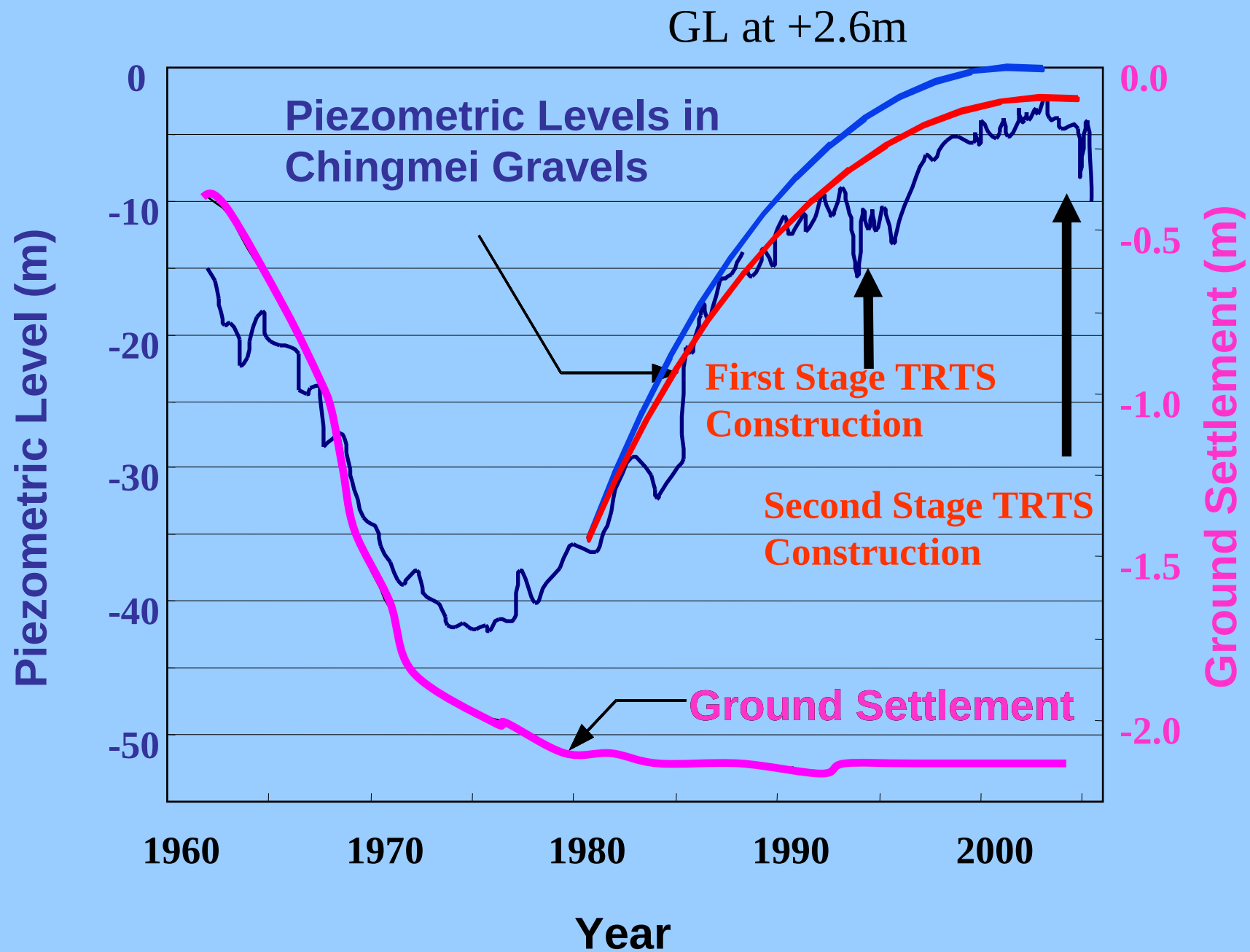


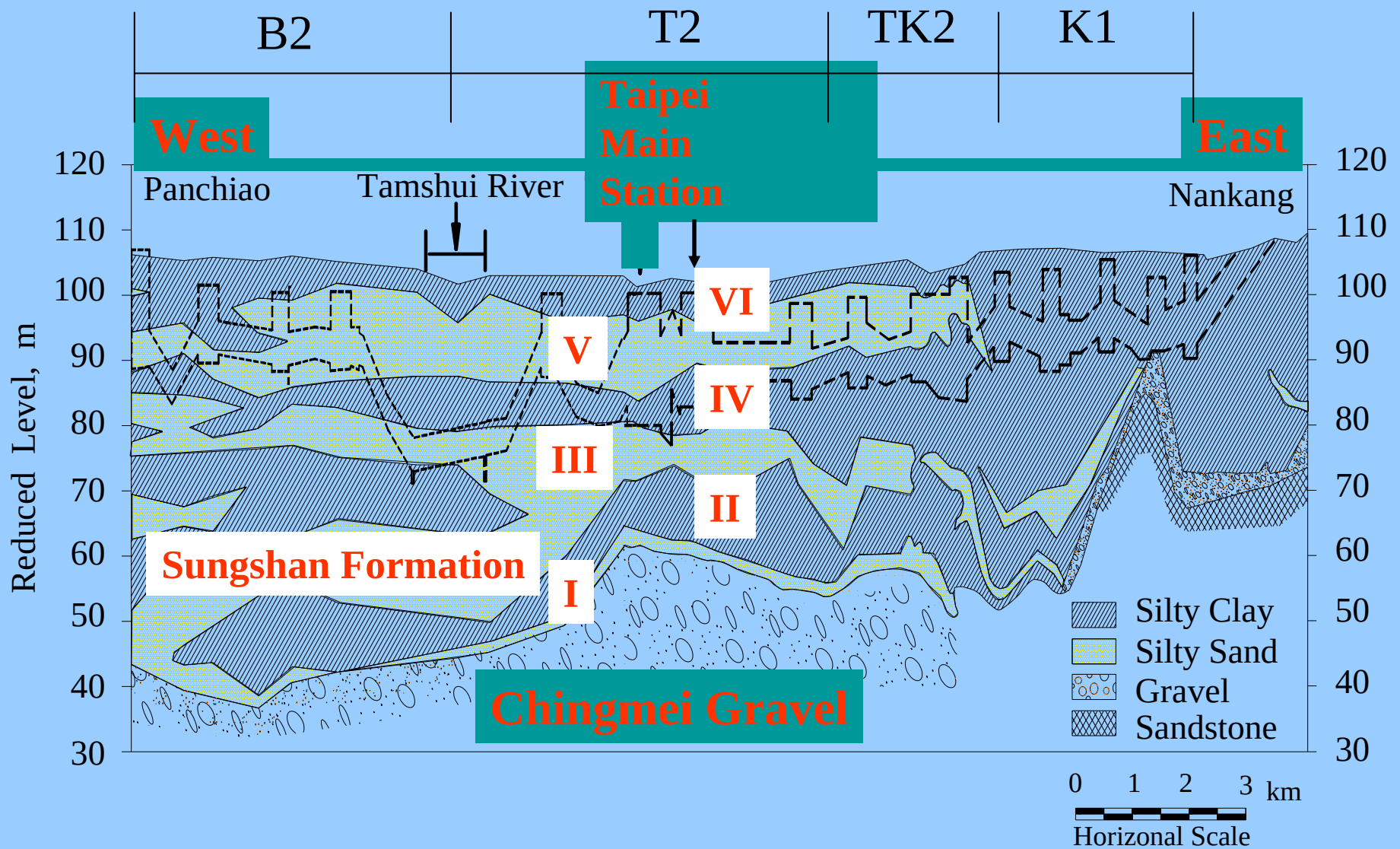


E-W Geological Profile of the Taipei Basin



**Chingmei Gravels
Ventilation Shaft GL-43m**





E-W Geological Profile of the Taipei Basin

RL 102.6 m

Year of 1970

RL 60.0 m

RL 53.0 m

7 m

40 m

**Chingmei
Gravels**

$$\text{Uplift} = 10 \times (88.0 - 53.0) = 350 \text{ kPa}$$

$$\text{Soil Weight} = 19 \times (76.0 - 53.0) = 437 \text{ kPa}$$

$$\text{Safety Factor} = 437 / 350 = 1.25$$

Analysis for blow-in

RL 102.6 m

Year of 1990

RL 88.0 m

26.6 m

GL -14.6 m

35.0 m

23.0 m

GL -26.6 m

W

RL 53.0 m

GL -49.6 m

**Chingmei
Gravels**

Uplift = $10 \times (88.0 - 53.0) = 350 \text{ kPa}$

Soil Weight = $19 \times (76.0 - 53.0) = 437 \text{ kPa}$

Safety Factor = $437 / 350 = 1.25$

Analysis for blow-in

RL 102.6 m

RL 53.0 m

GL -1 m

GL -17.6 m

GL -49.6 m

17.6 m

32 m

W

Chingmei
Gravels

Uplift = $10 \times (49.6 - 1.0) = 486 \text{ kPa}$

Soil Weight = $19 \times (49.6 - 17.6) = 608 \text{ kPa}$

Safety Factor = $608 / 486 = 1.25$

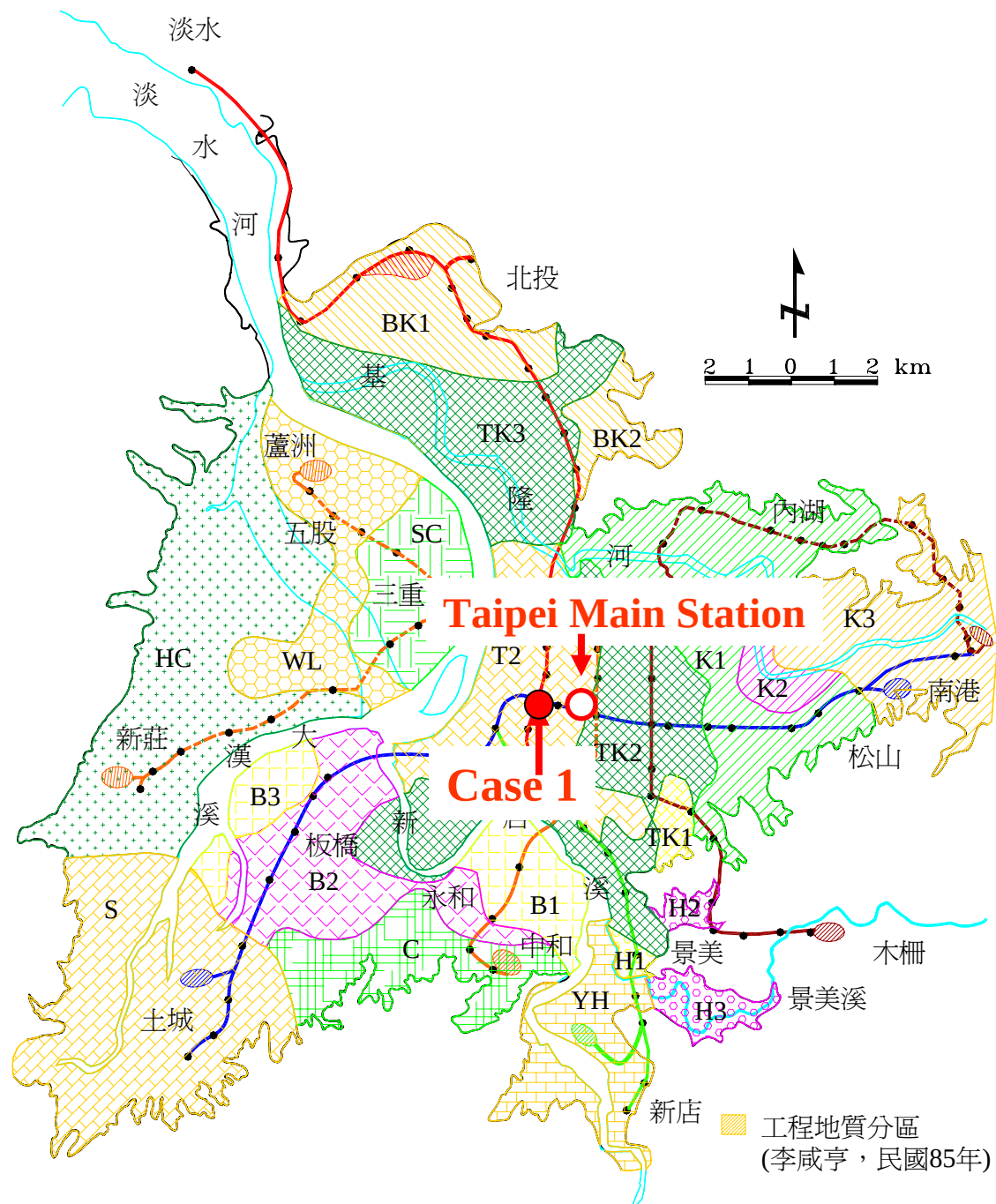
Analysis for blow-in

Contents

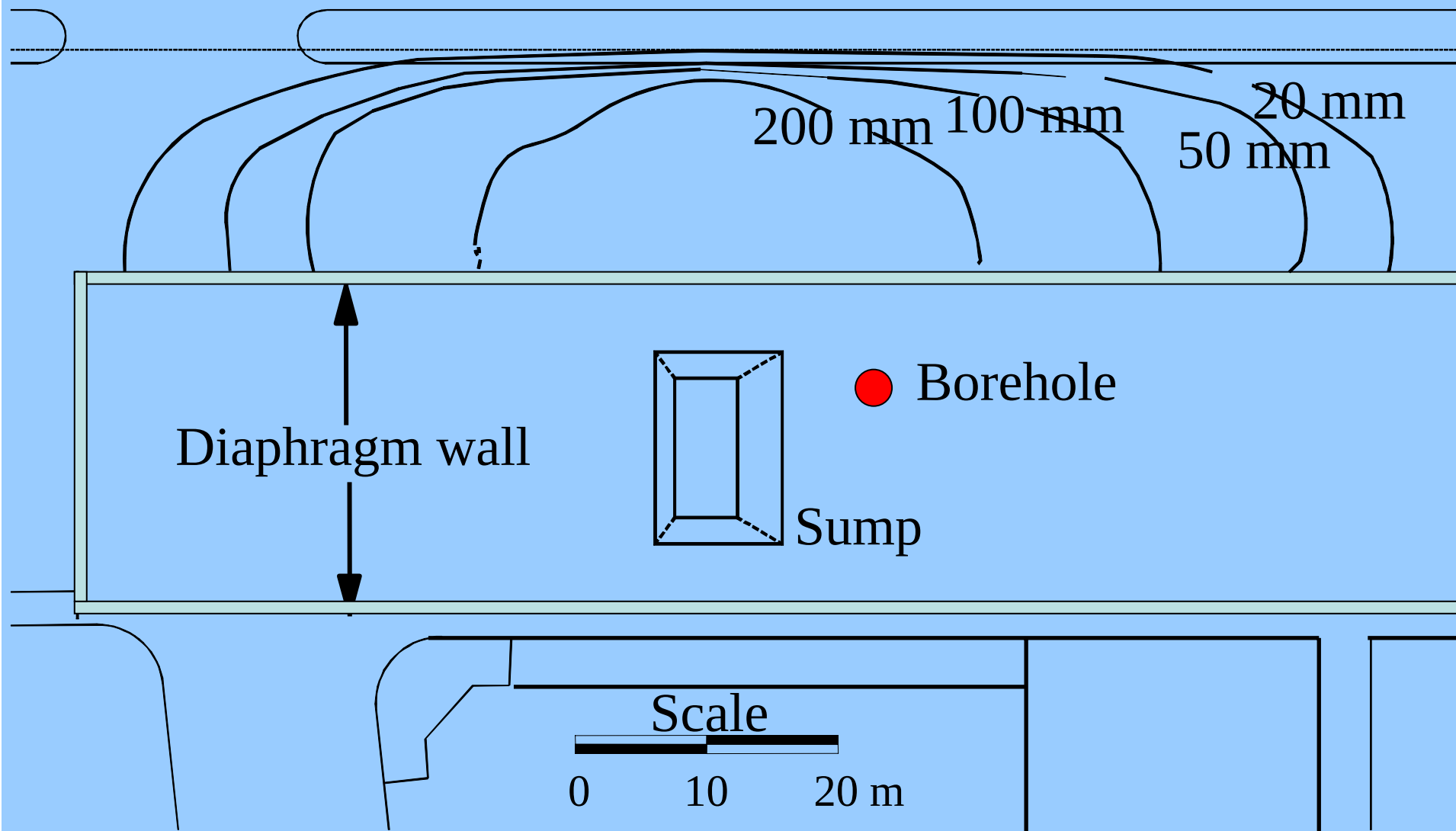
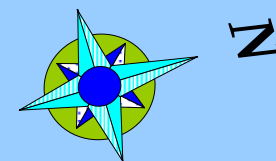
- Failure due to human errors
- Failure due to poor workmanship
- Failures due to Unforeseen Conditions

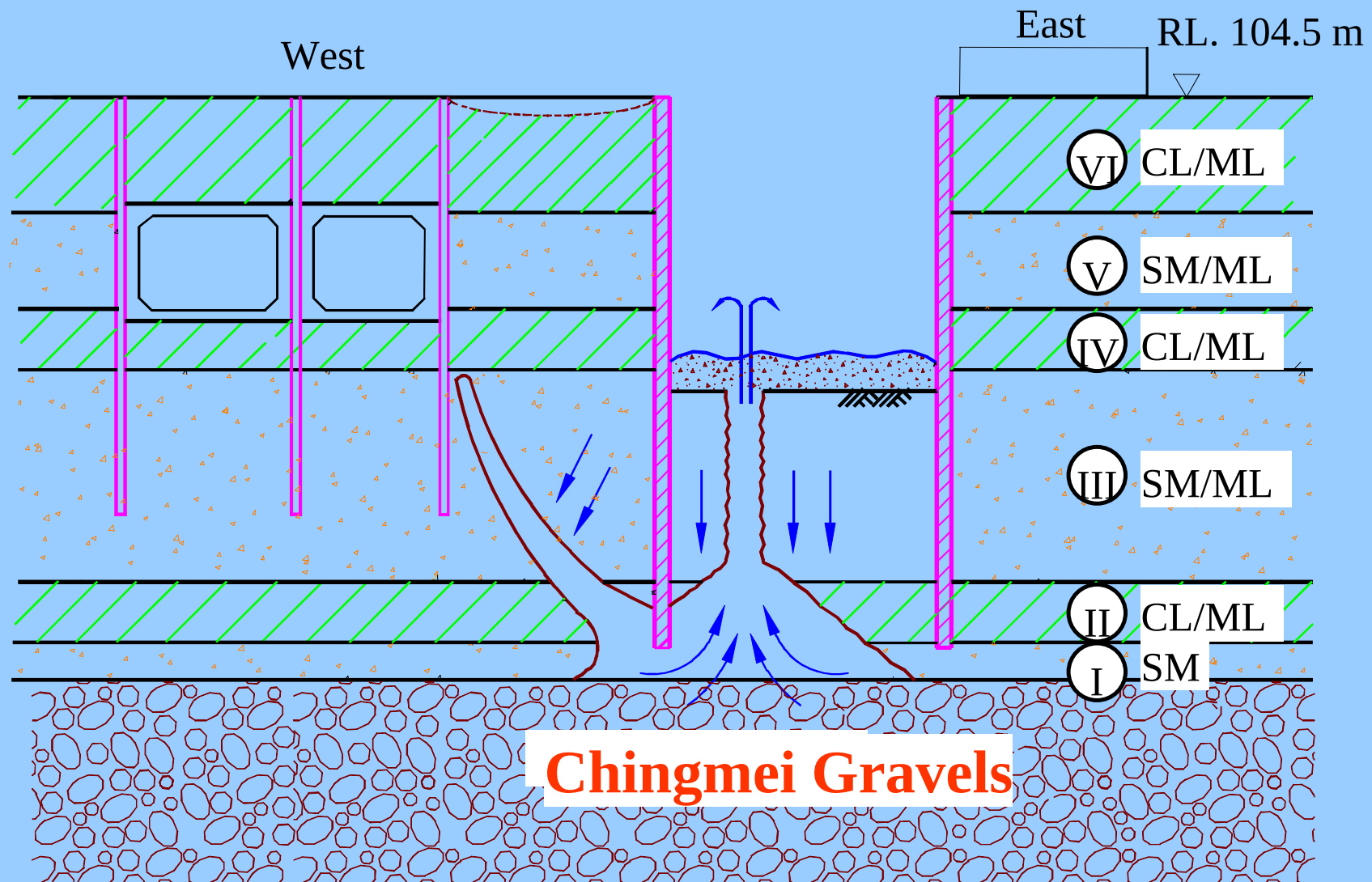
Case 1 – Human Error (Negligence)

- Nankang Line
- Station Excavation to GL-24.5 m



Geological Zoning of the Taipei Basin





Scenario of the Incident

700m to diaphragm Wall (500m excavated)

70,000 tons/13 hours

RL 89m

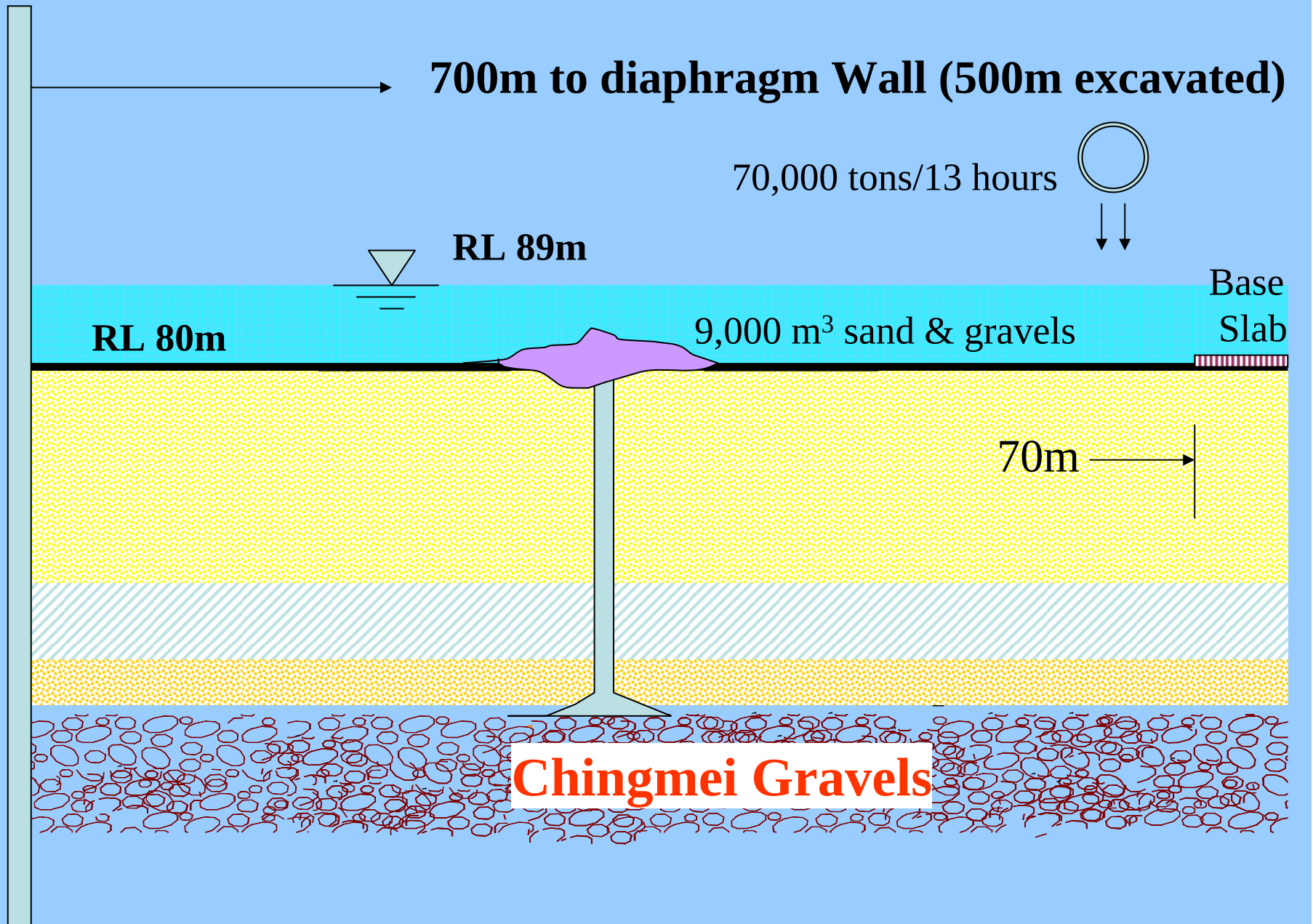
RL 80m

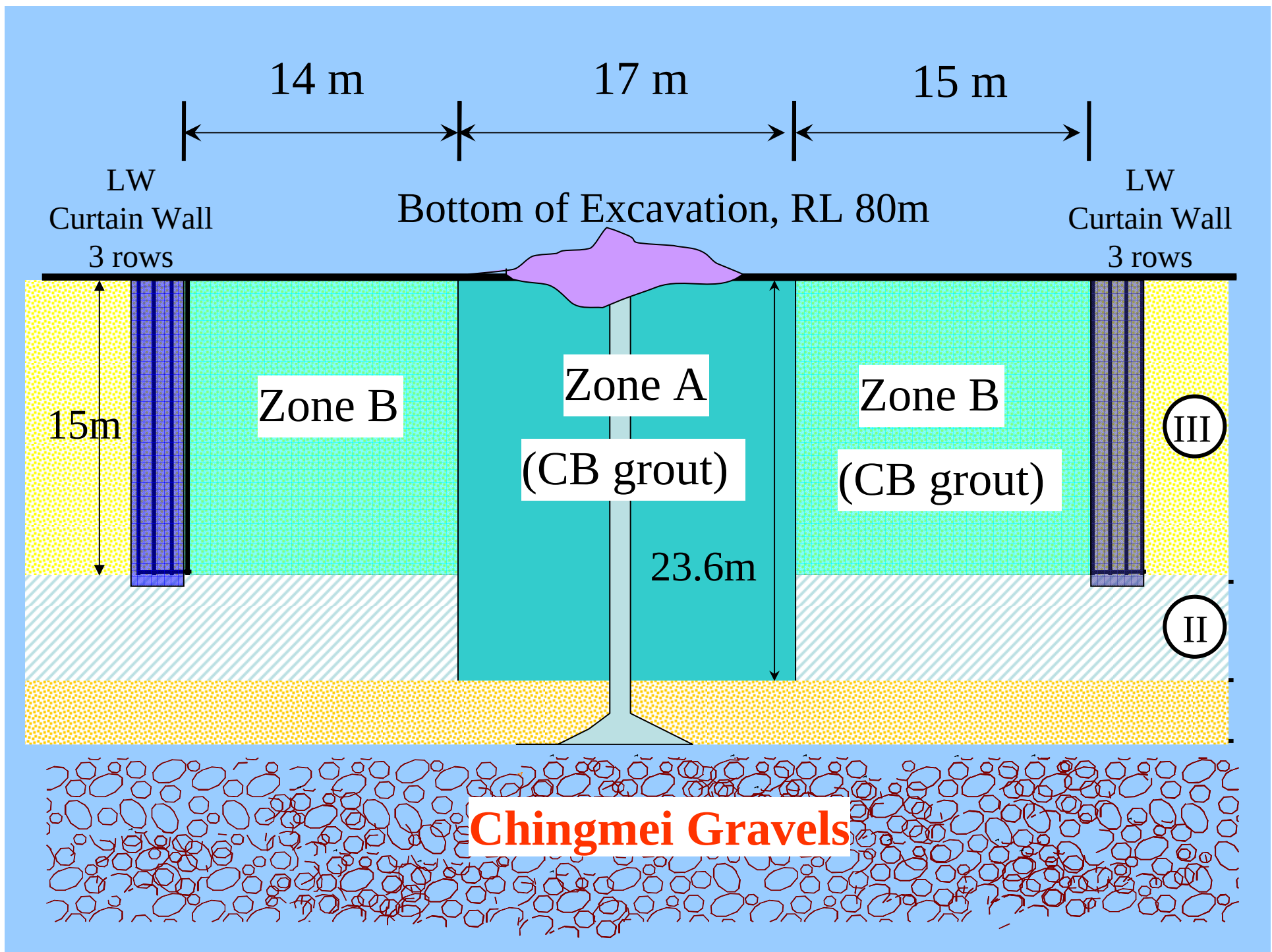
9,000 m³ sand & gravels

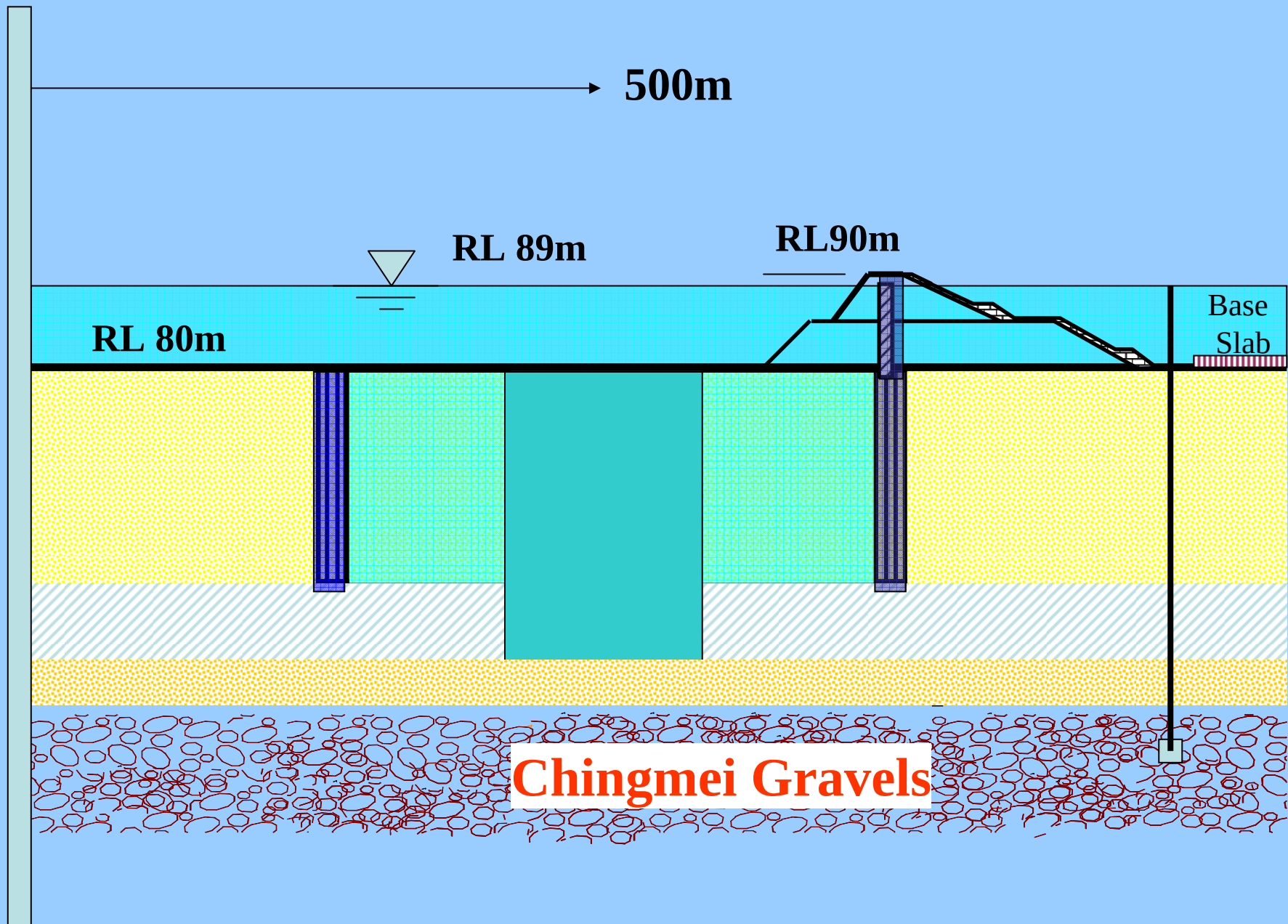
Base
Slab

70m

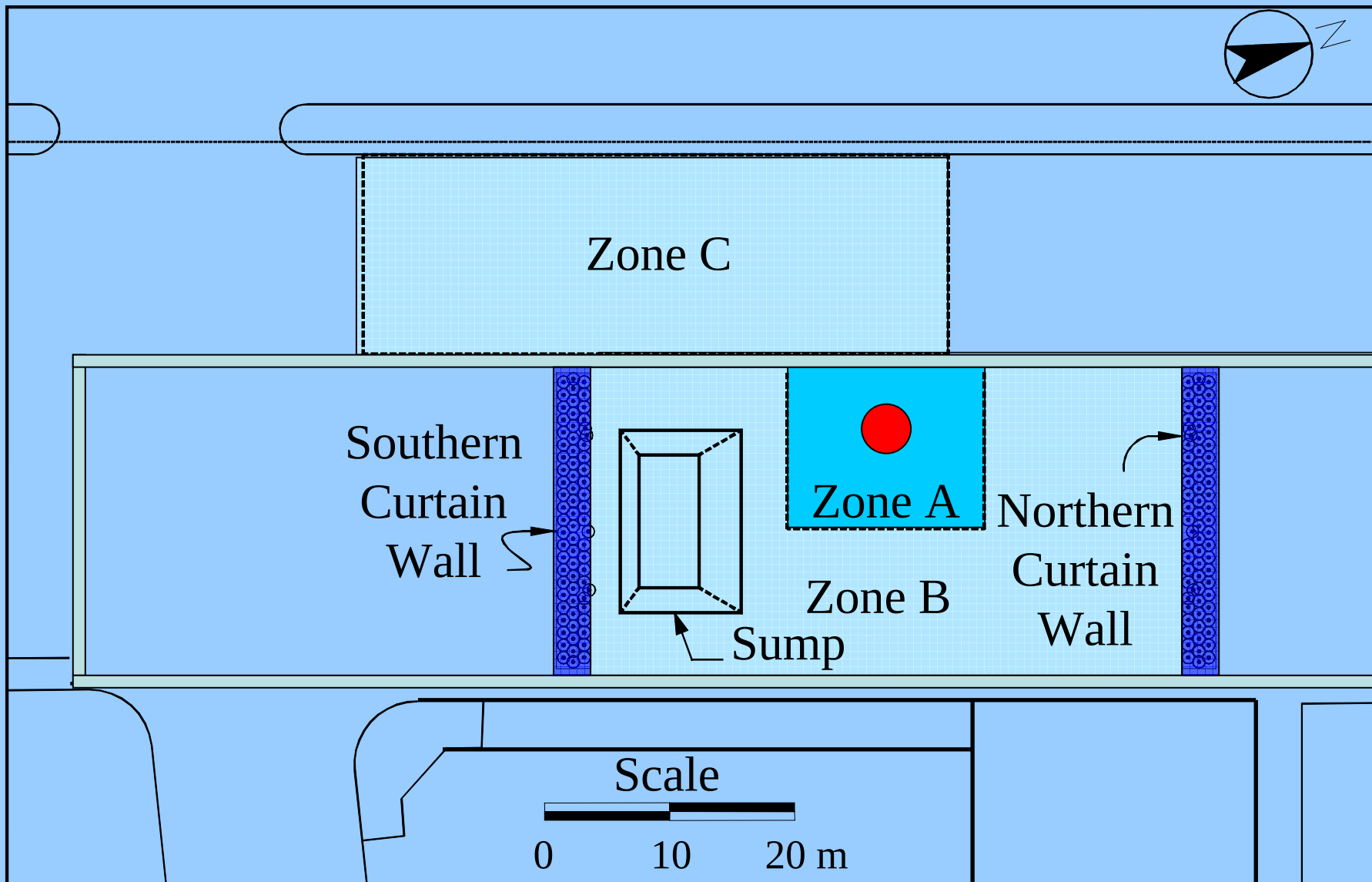
Chingmei Gravels

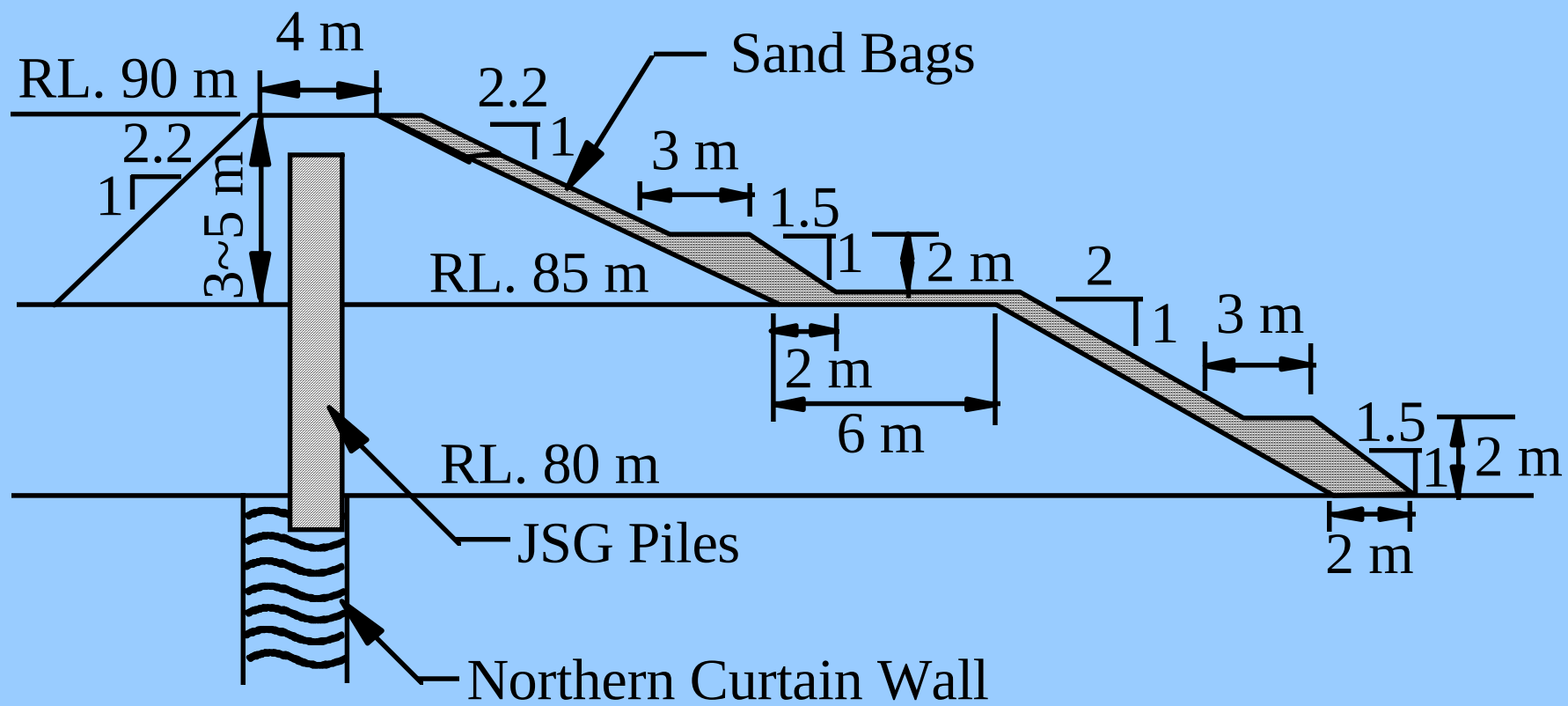






Chingmei Gravels

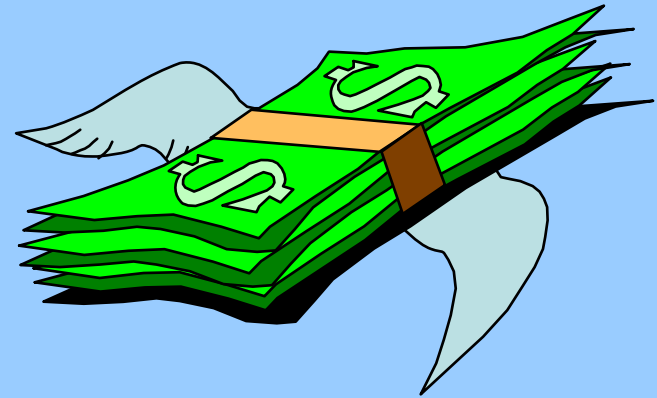


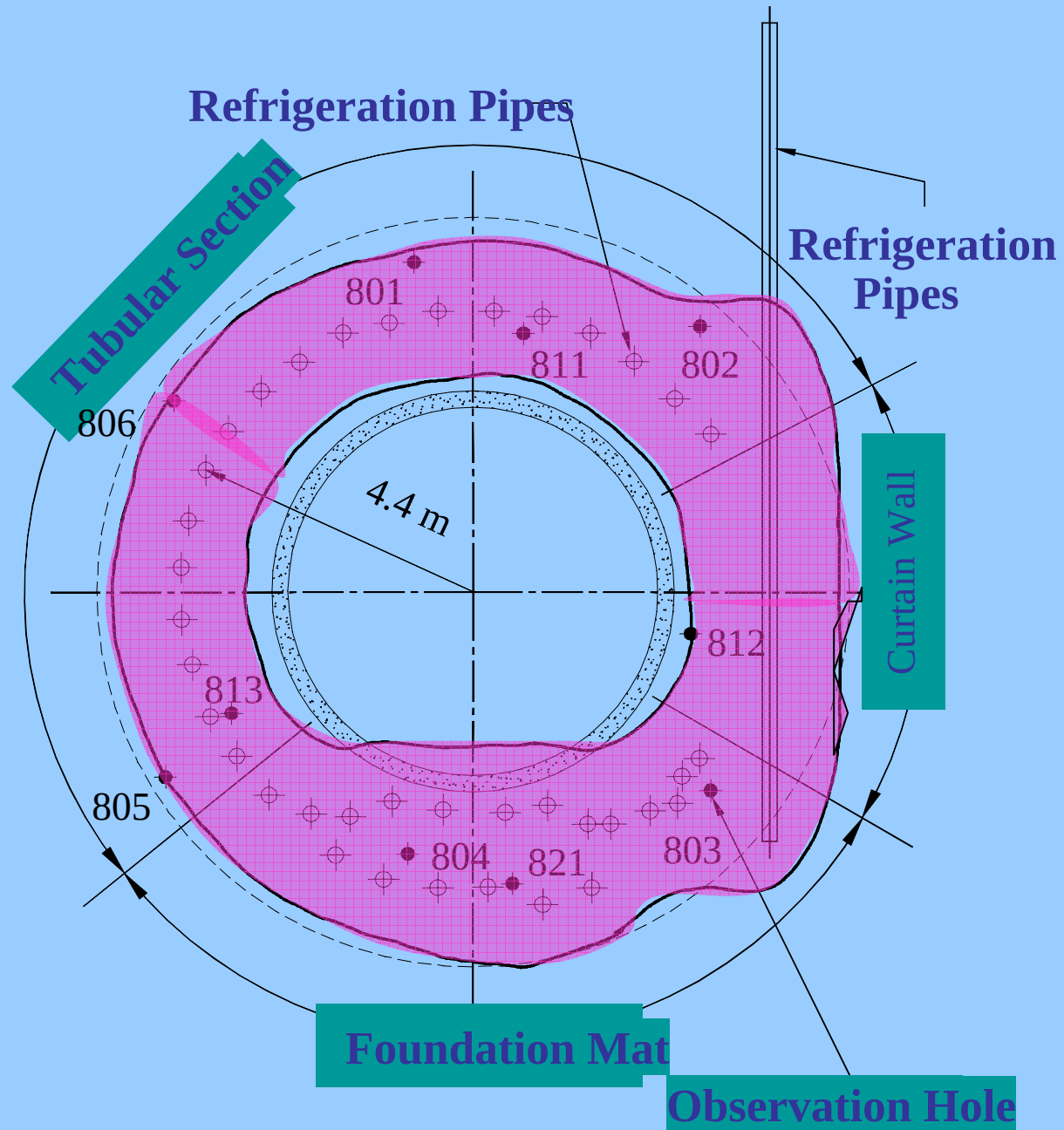


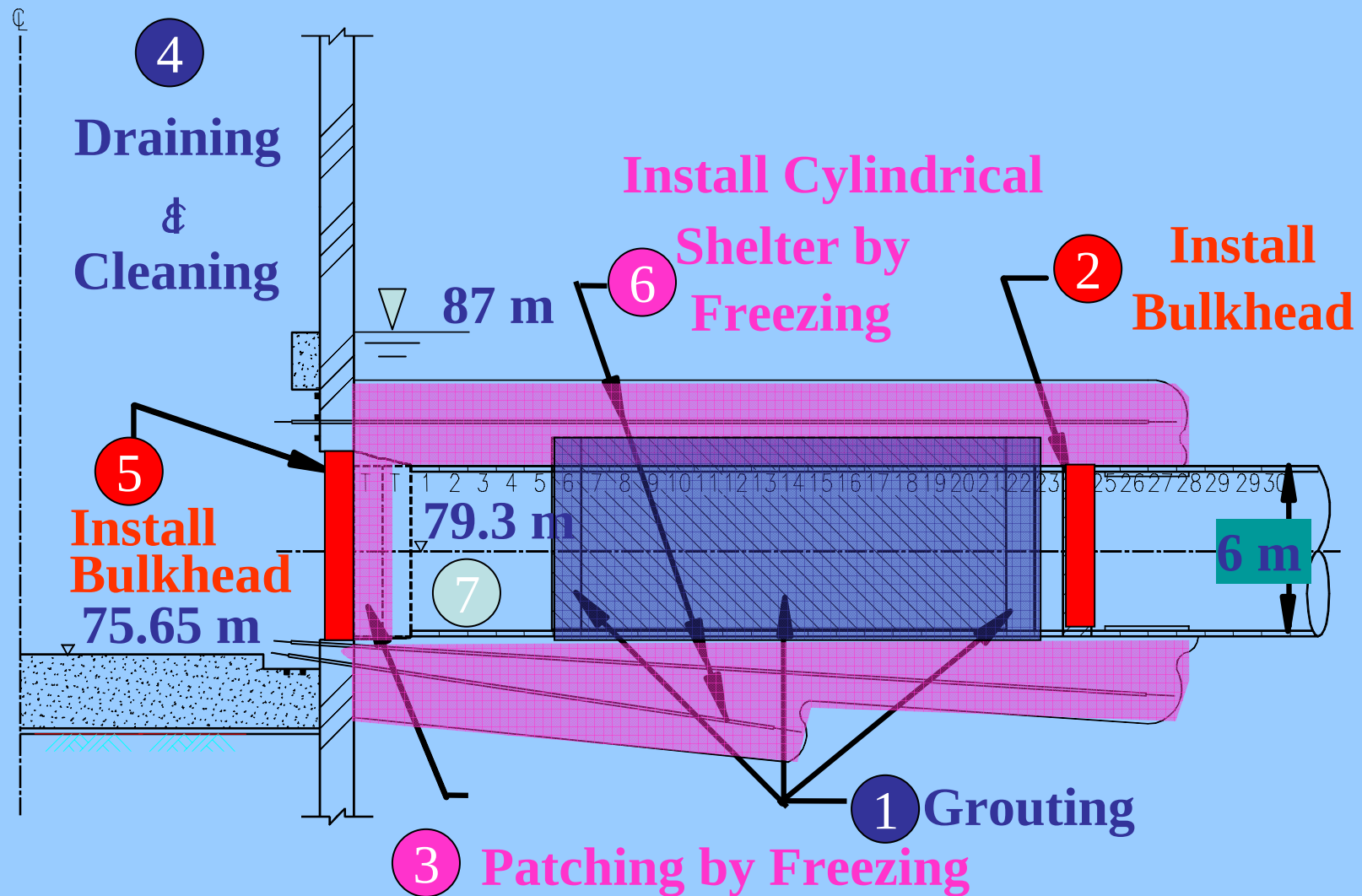
A Small Hole?

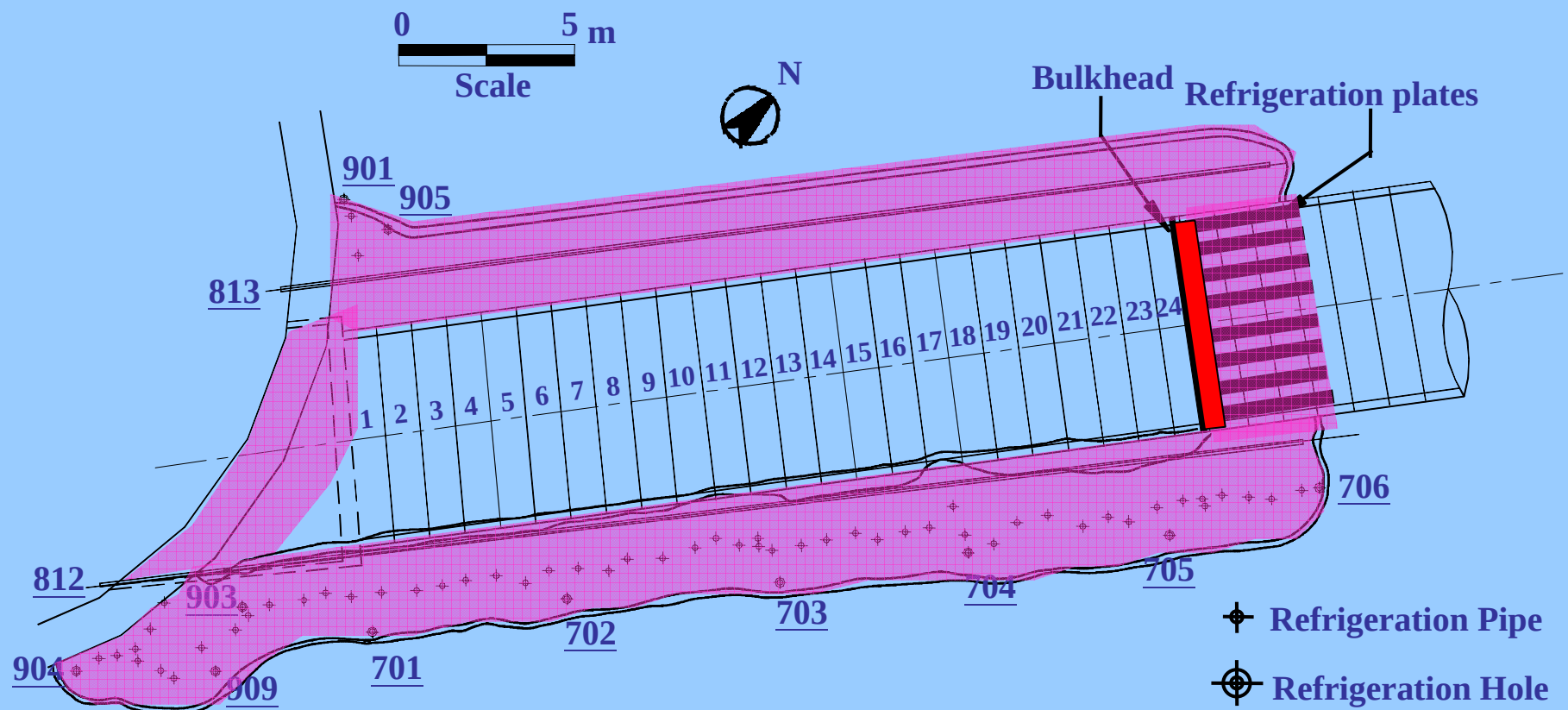
- 70,000 tonnes of water recharged
- 9,000 m³ of sands and gravels dumped
- 5,400 m³ of grout injected

A\$4,000,000

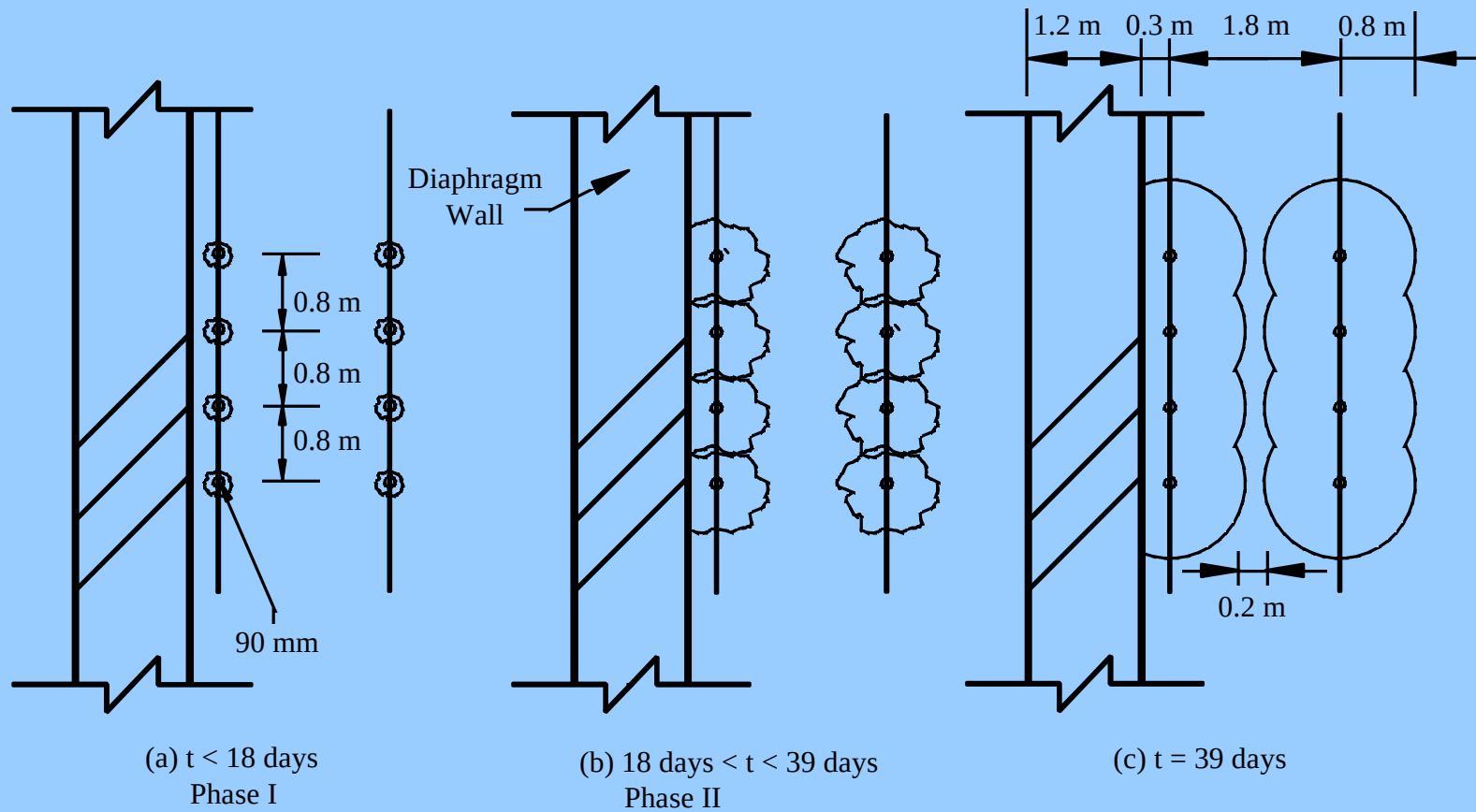








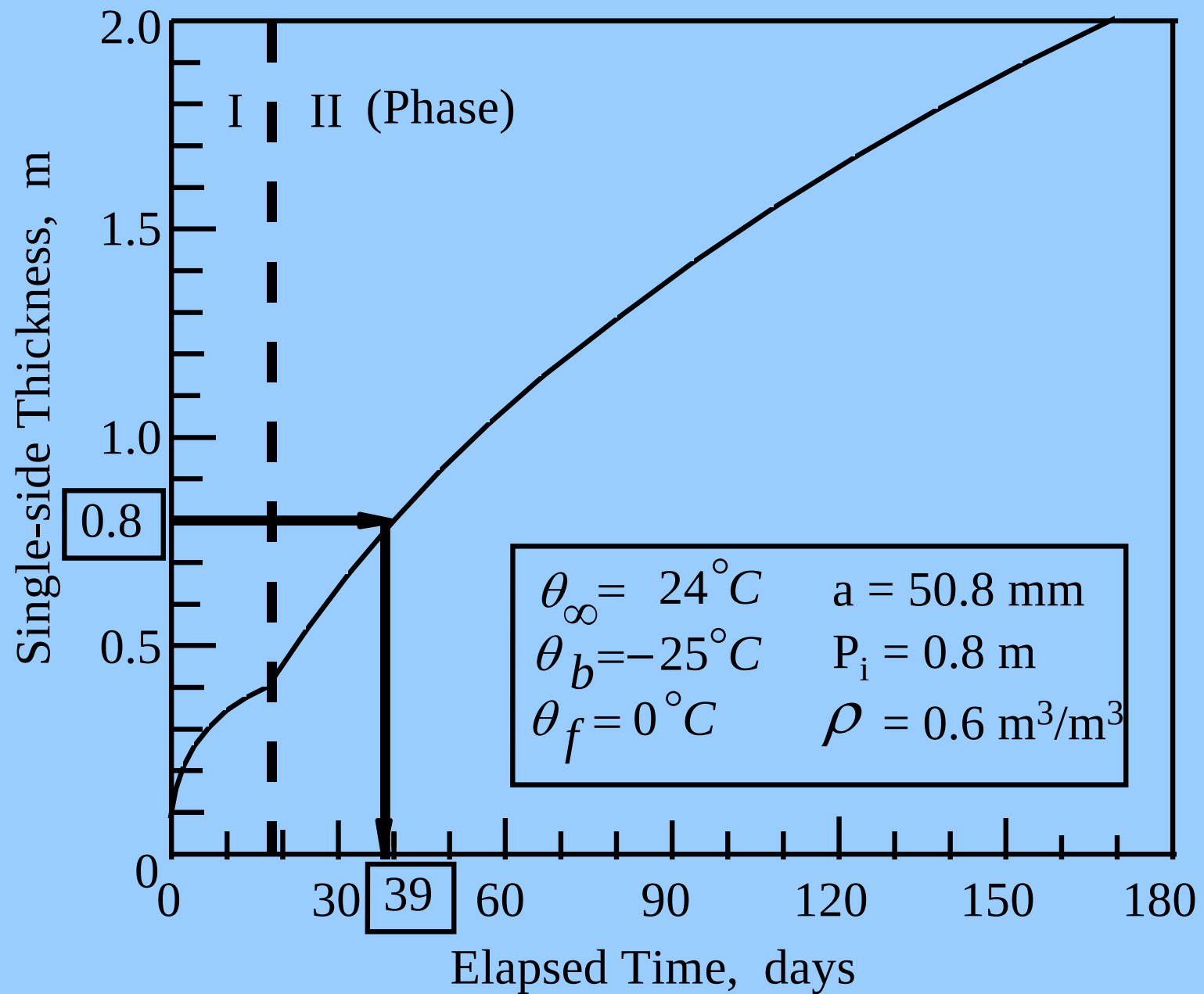
Ground Freezing

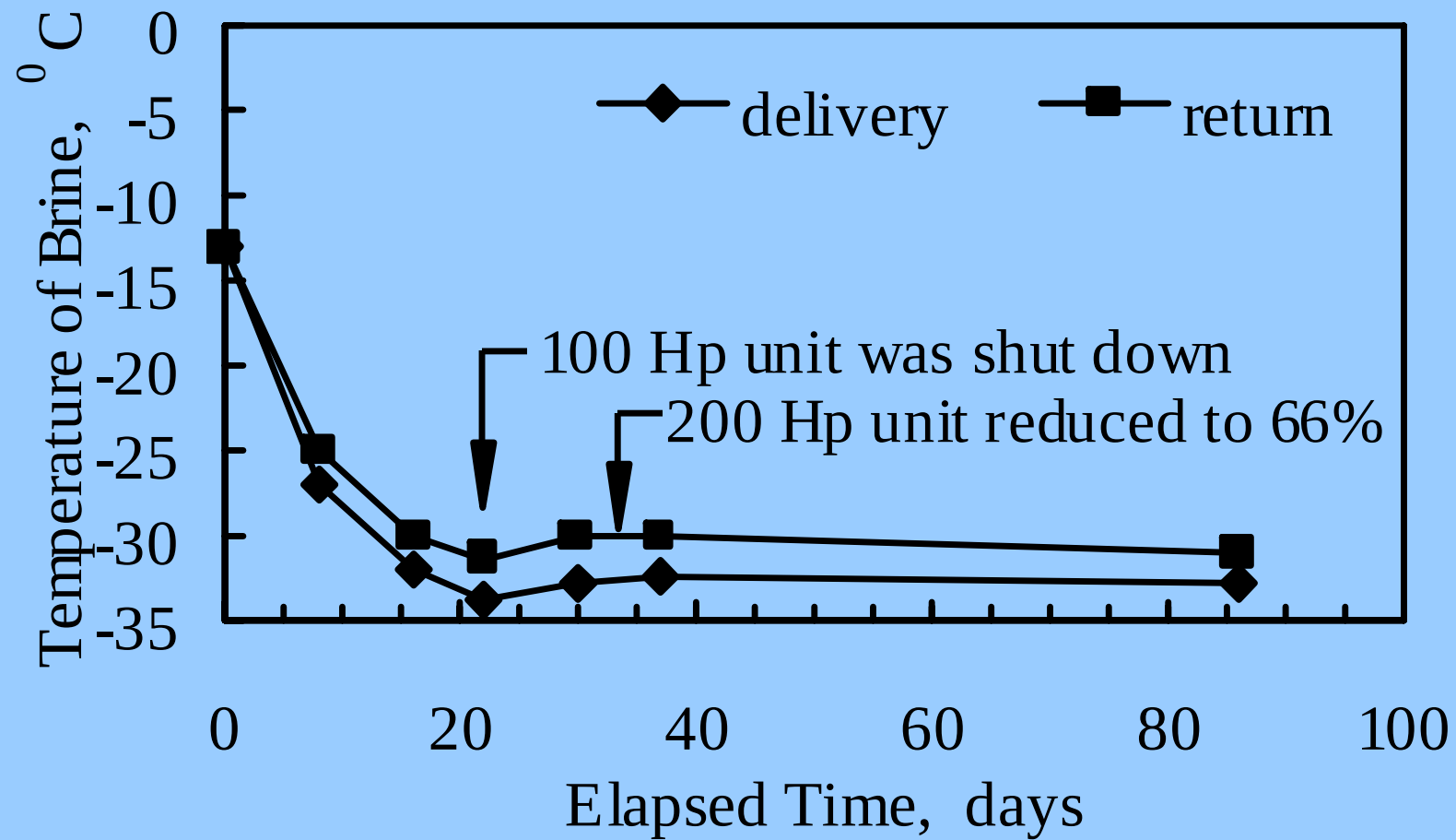


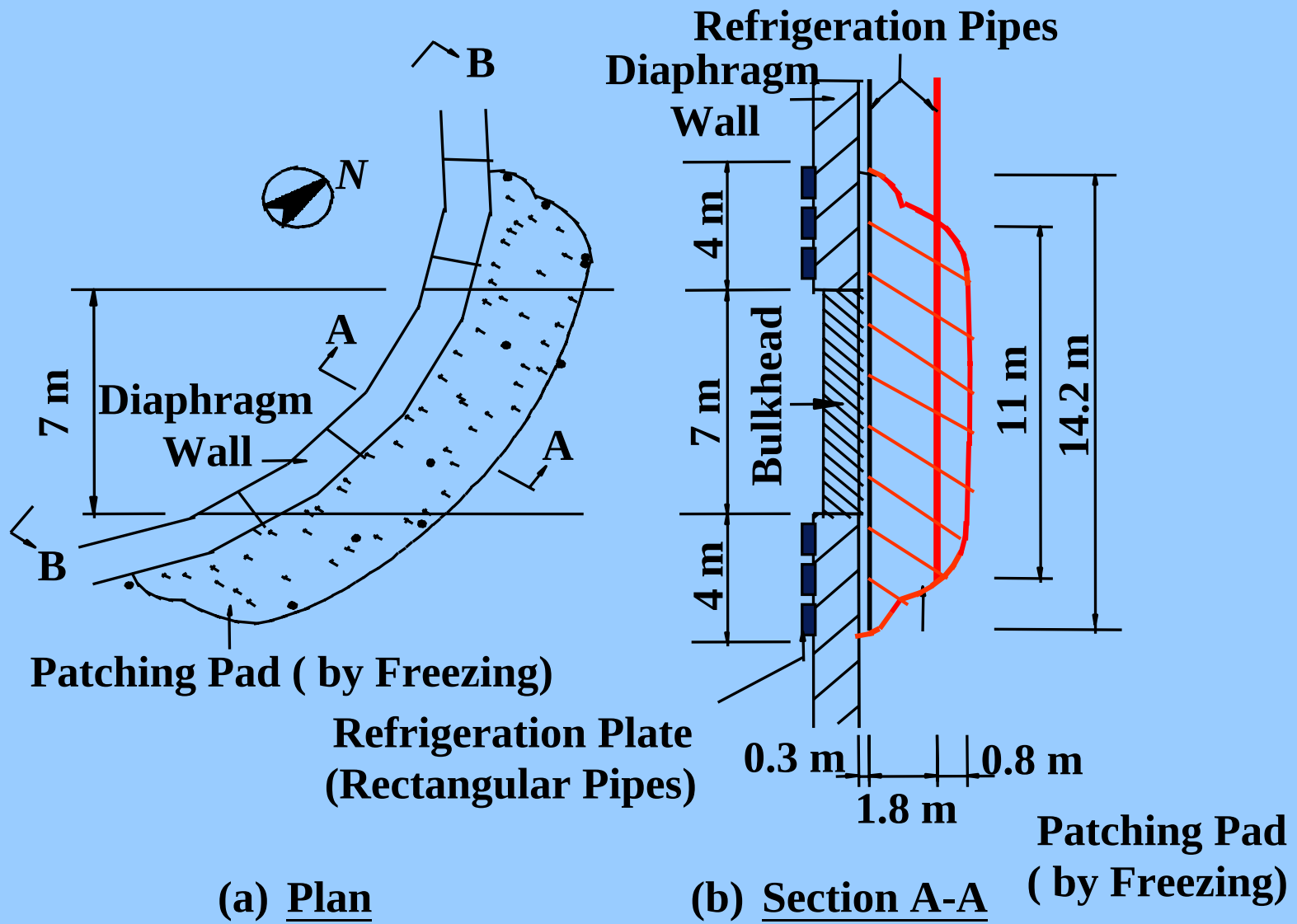
Rate of freezing for single pipe

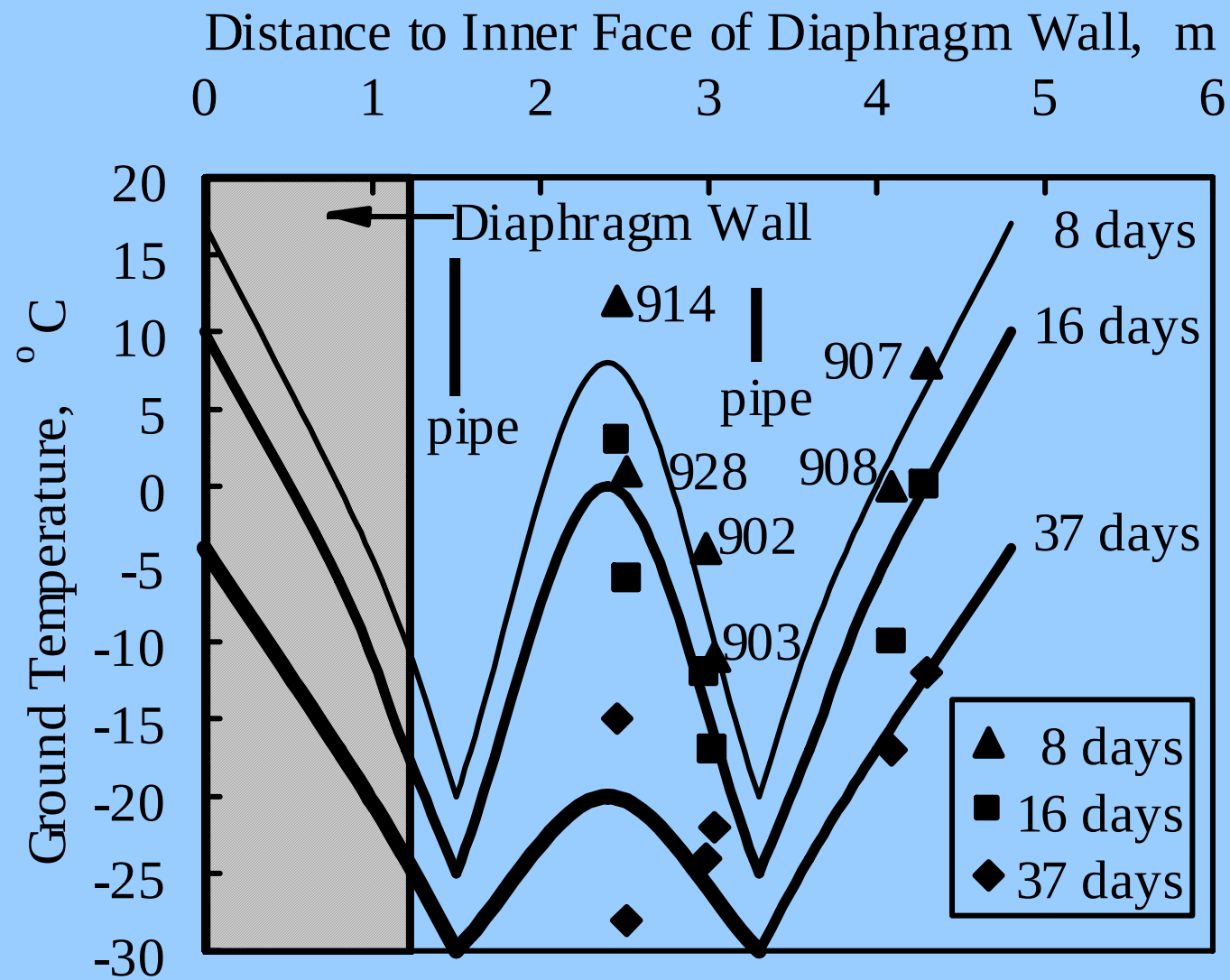
$$\lambda_1 \theta_c \left[\frac{\frac{\partial F(x_1, a: r, t)}{\partial r}}{F(x_1, a: r, t)} \right] + \lambda_2 \theta_\infty \left[\frac{\frac{\partial F(x_2, a: r, t)}{\partial r}}{1 - F(x_2, a: r, t)} \right] = L r_1 \left[\frac{\frac{\partial F(x_1, a: r, t)}{\partial t}}{\frac{\partial F(x_1, a: r, t)}{\partial r}} \right]$$

$$F(x, a: r, t) = -\frac{2}{\pi} \int_0^\infty e^{-x} \left(\frac{X}{a} \right)^2 t \frac{J_0(X \frac{r}{a}) Y_0(X) - J_0(X) Y_0(X \frac{r}{a})}{J_0^2(X) + Y_0^2(X)} \frac{dX}{X}$$

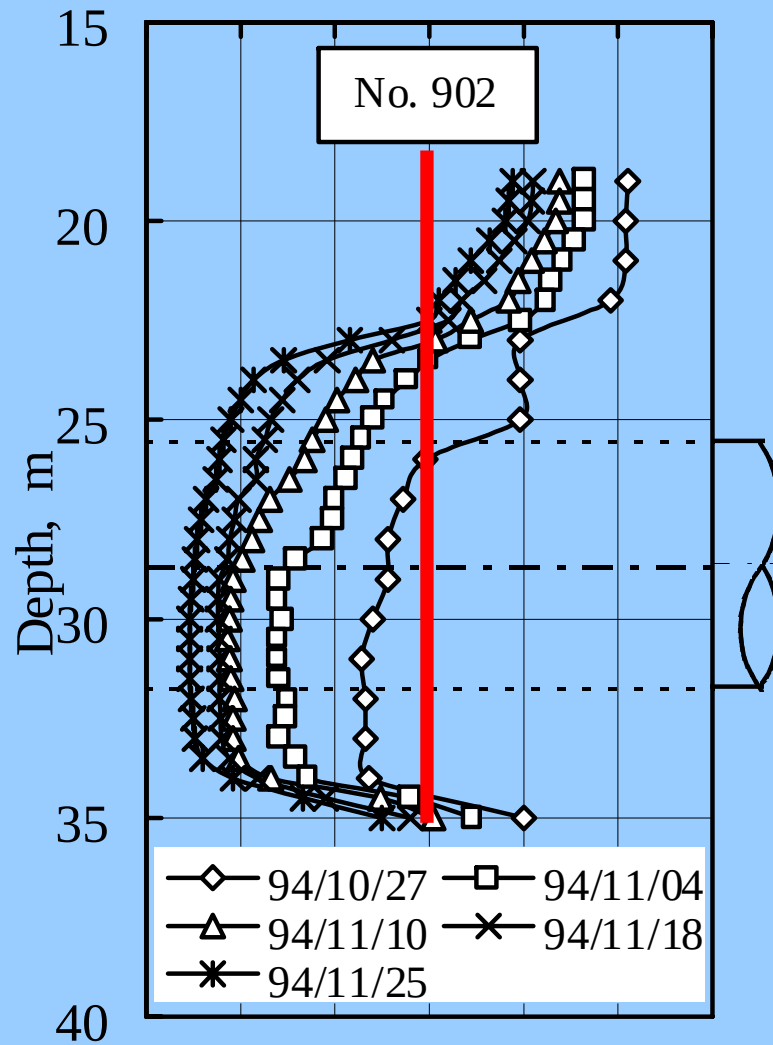




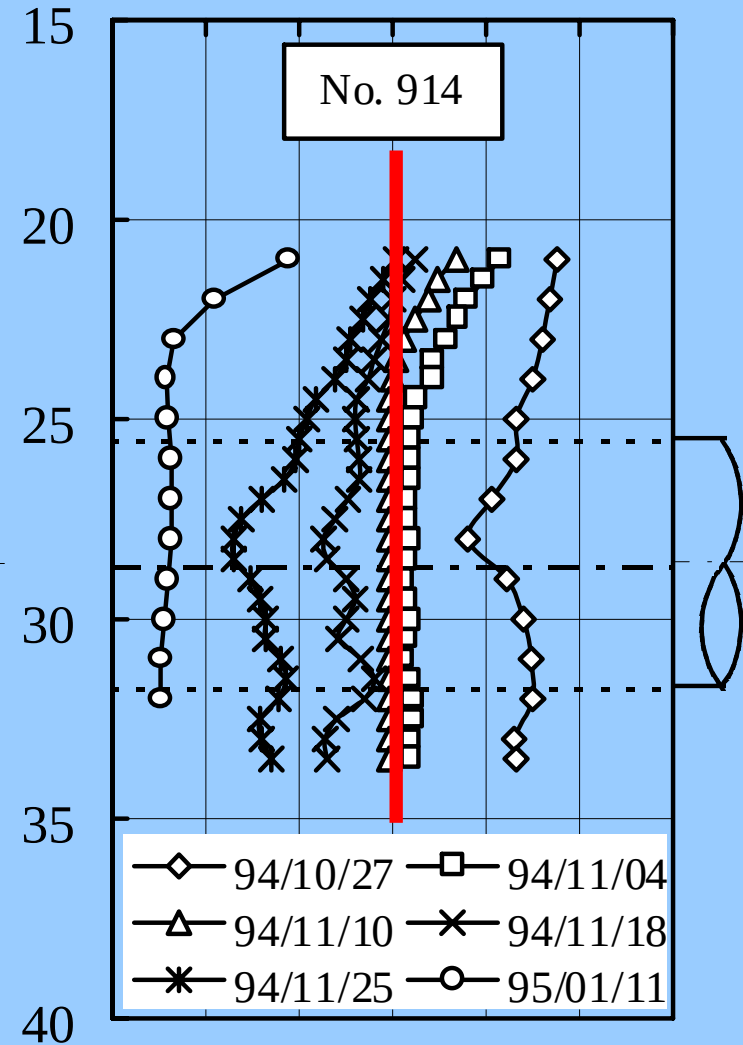


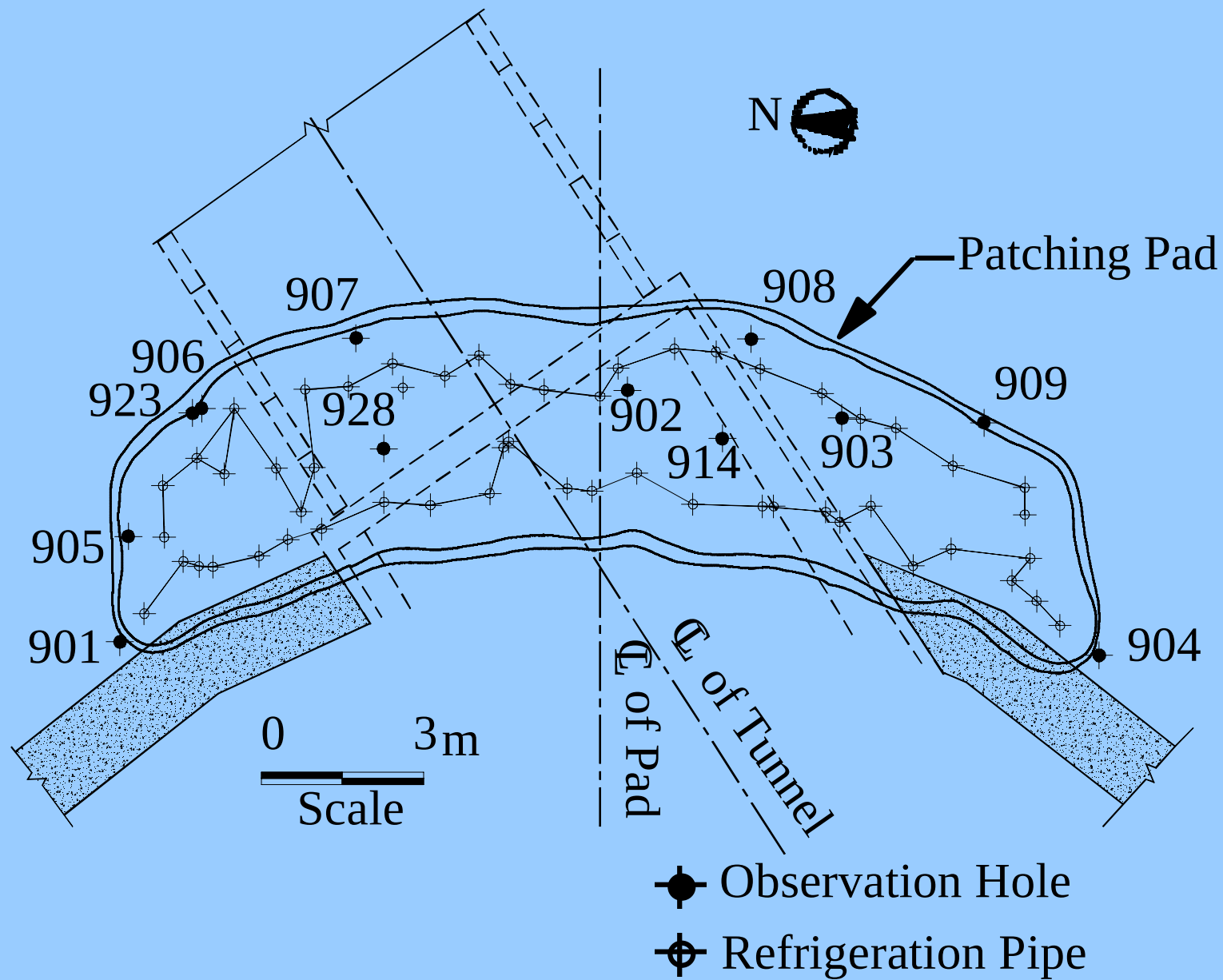


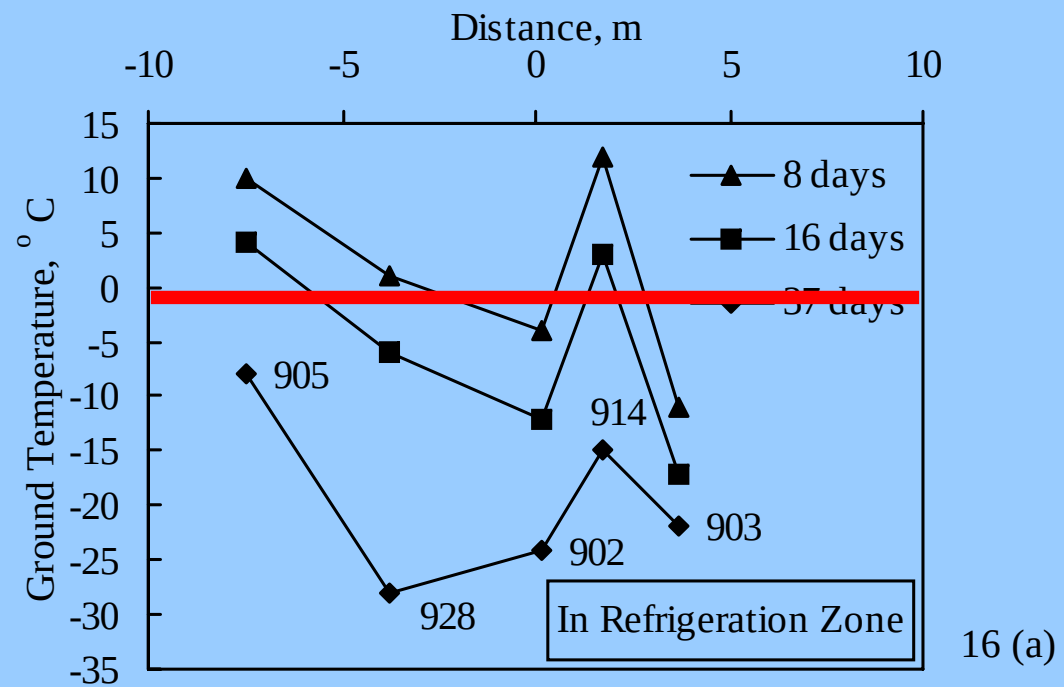
Ground Temperature, $^{\circ}\text{C}$
-30 -20 -10 0 10 20 30



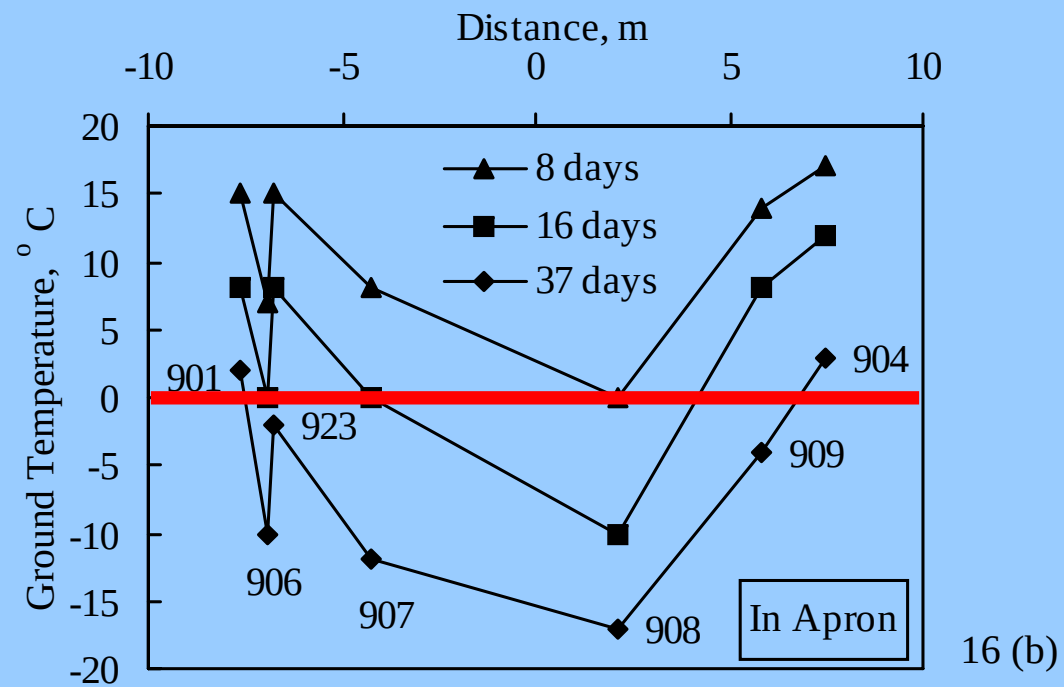
Ground Temperature, $^{\circ}\text{C}$
-30 -20 -10 0 10 20 30



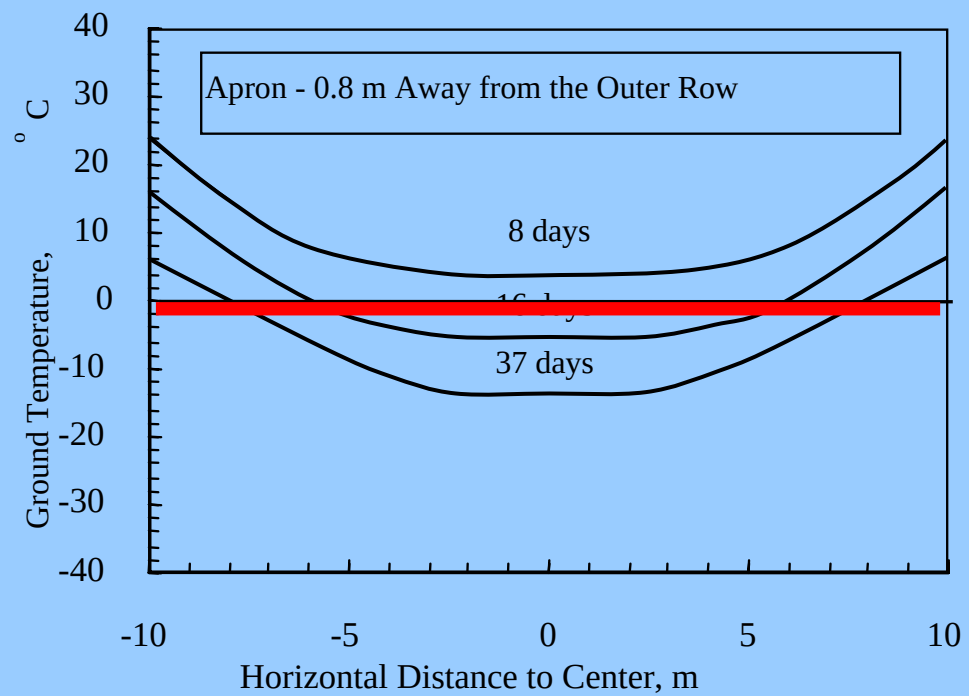
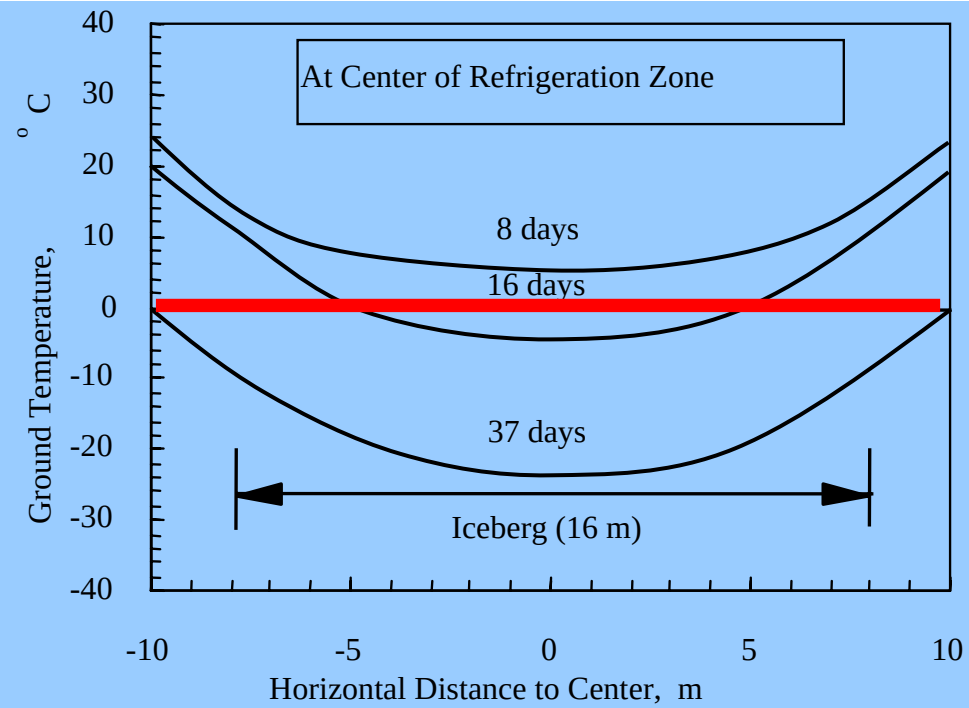


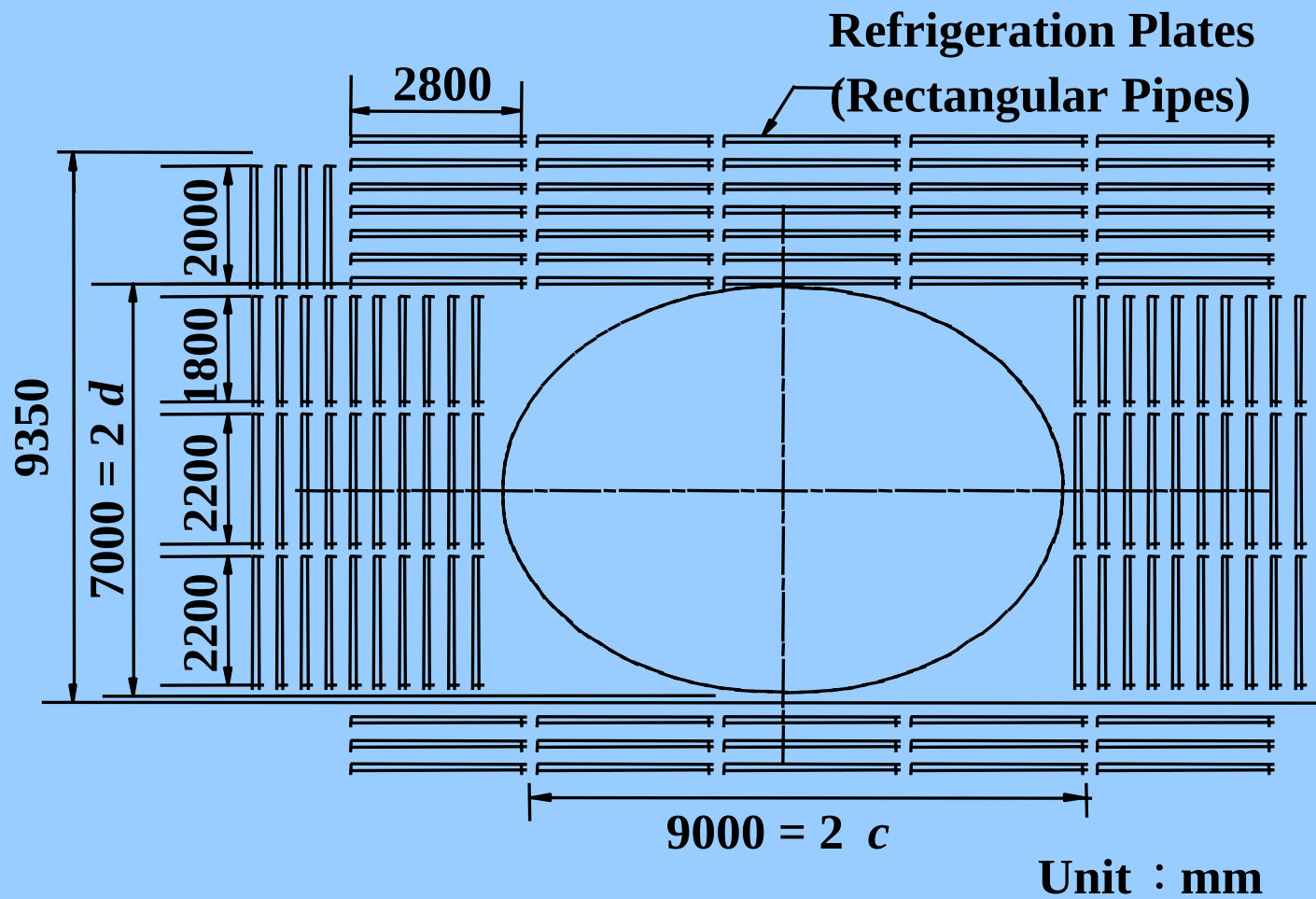


16 (a)

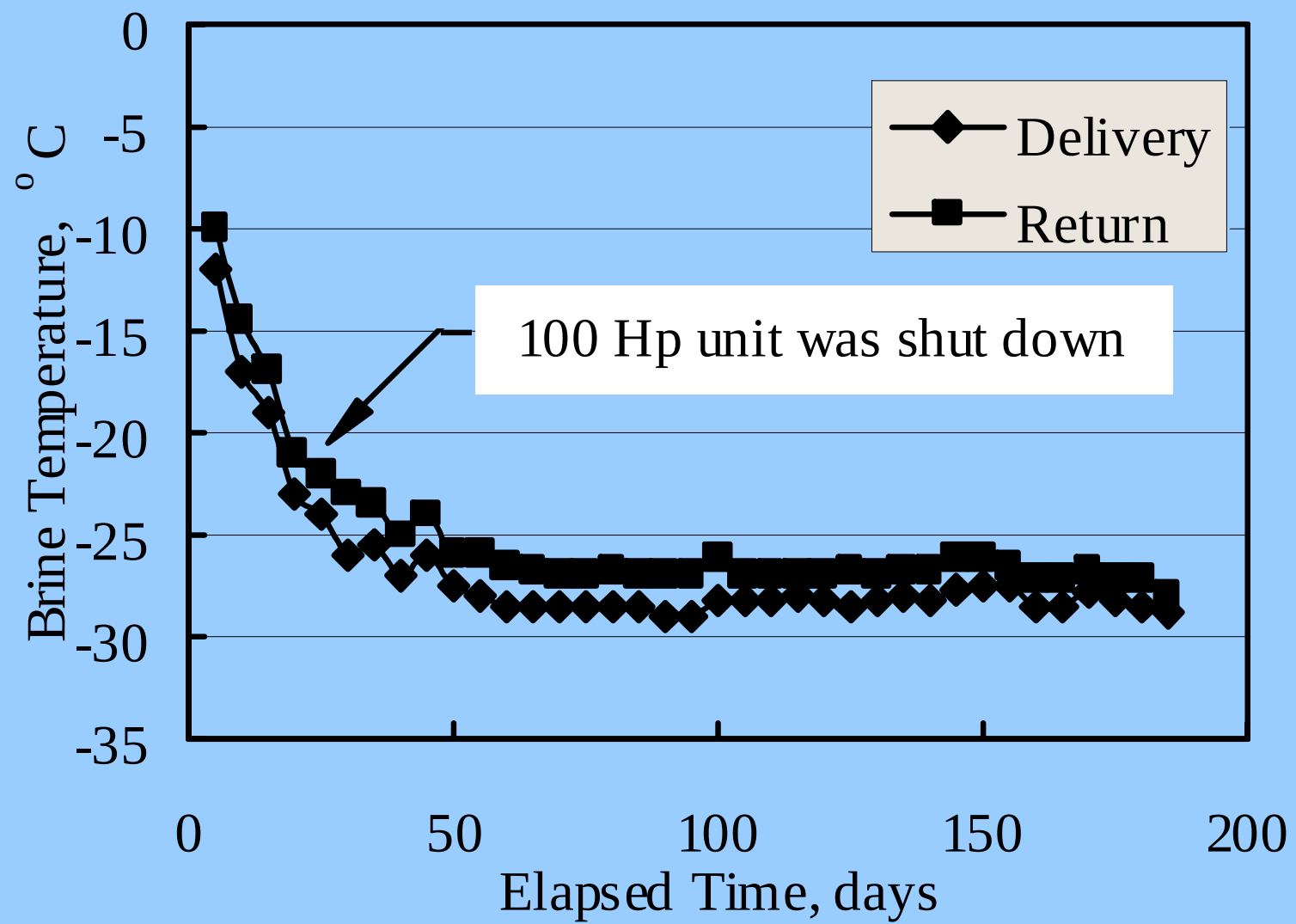


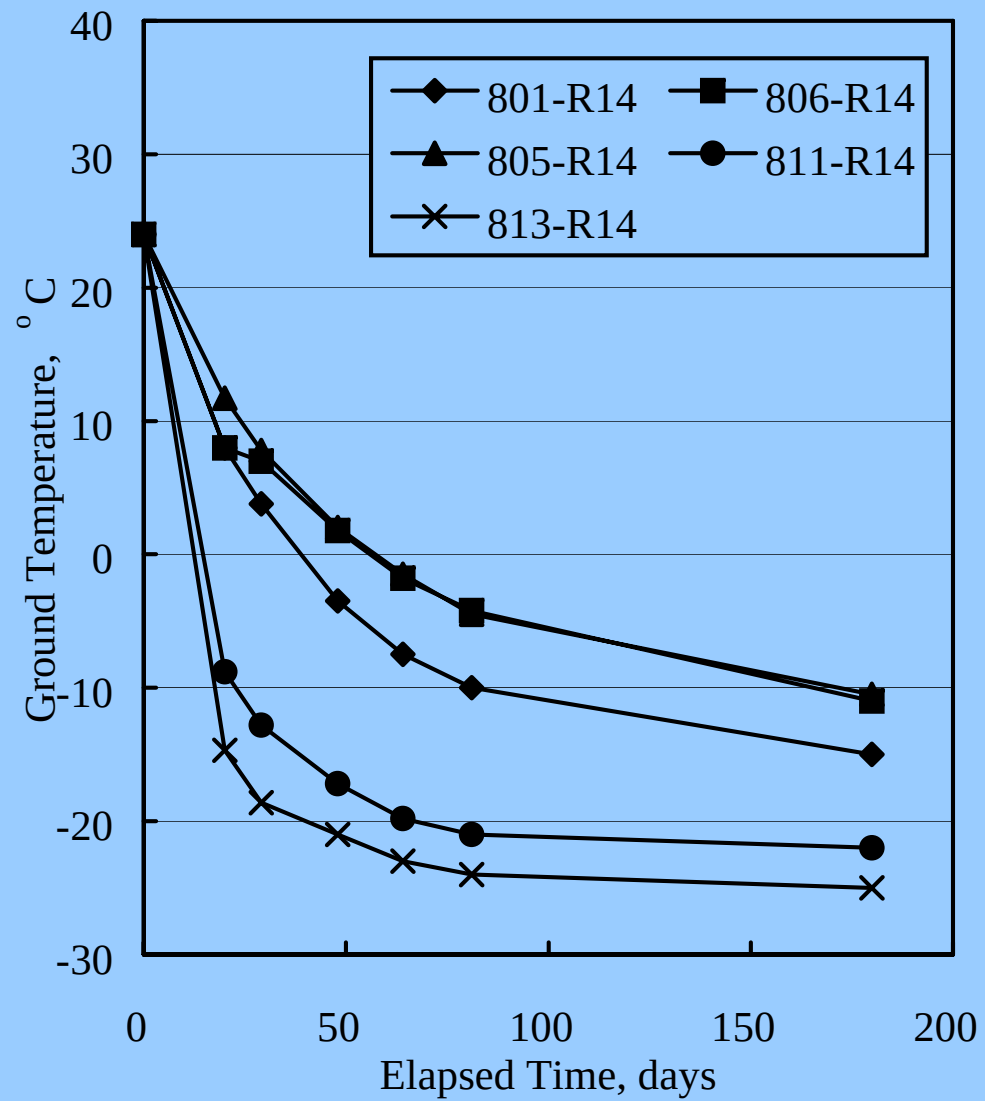
16 (b)

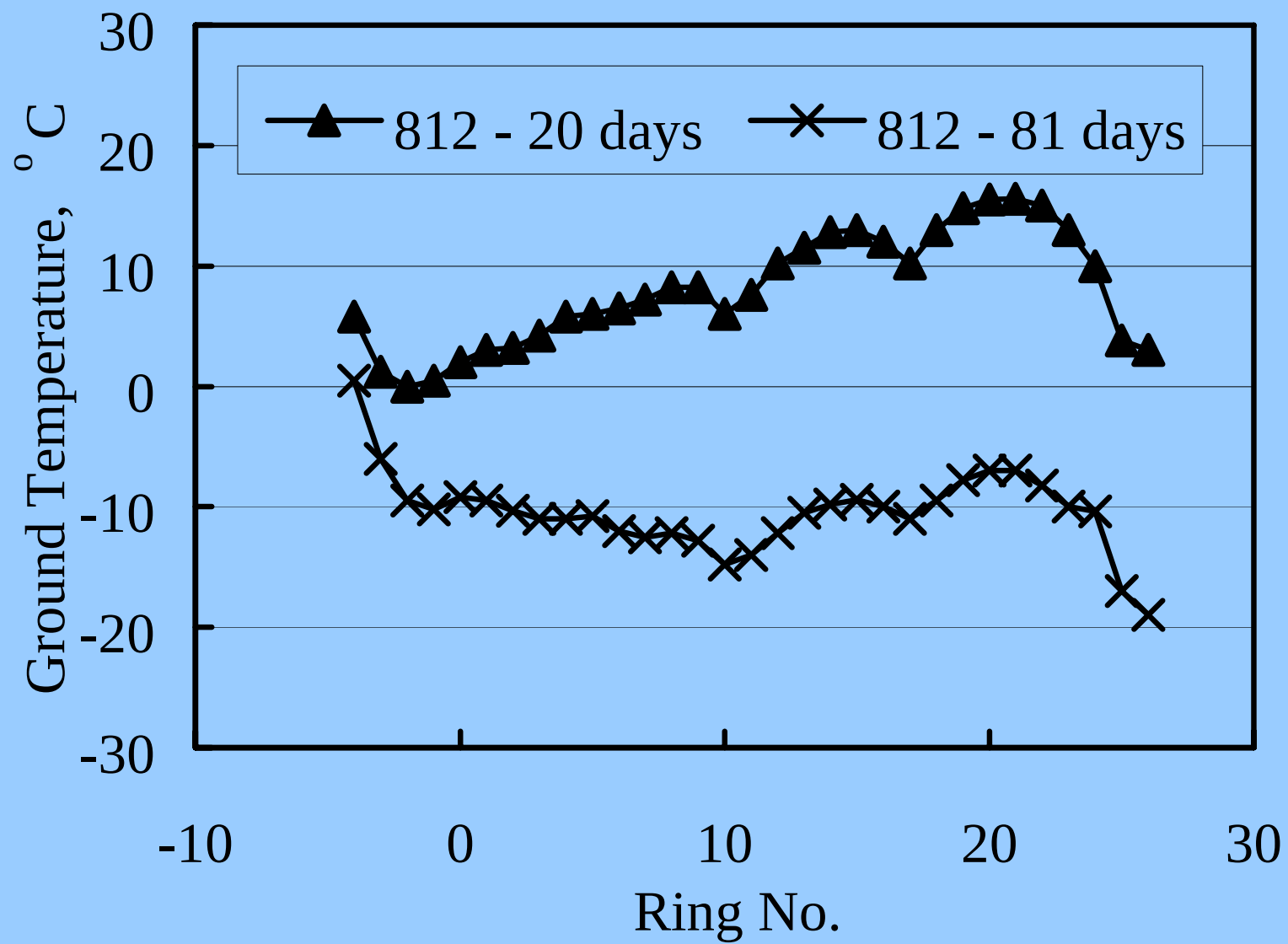


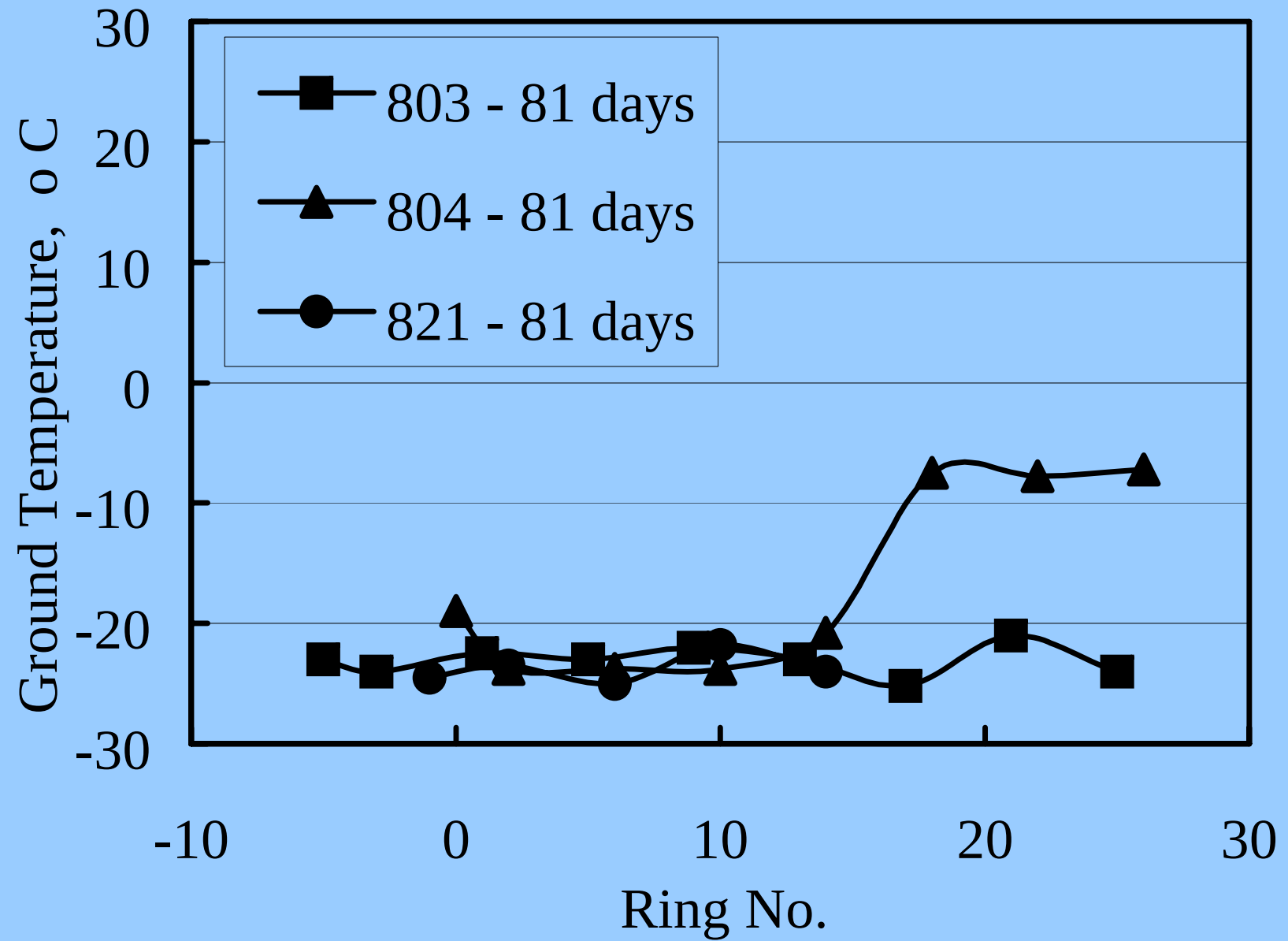


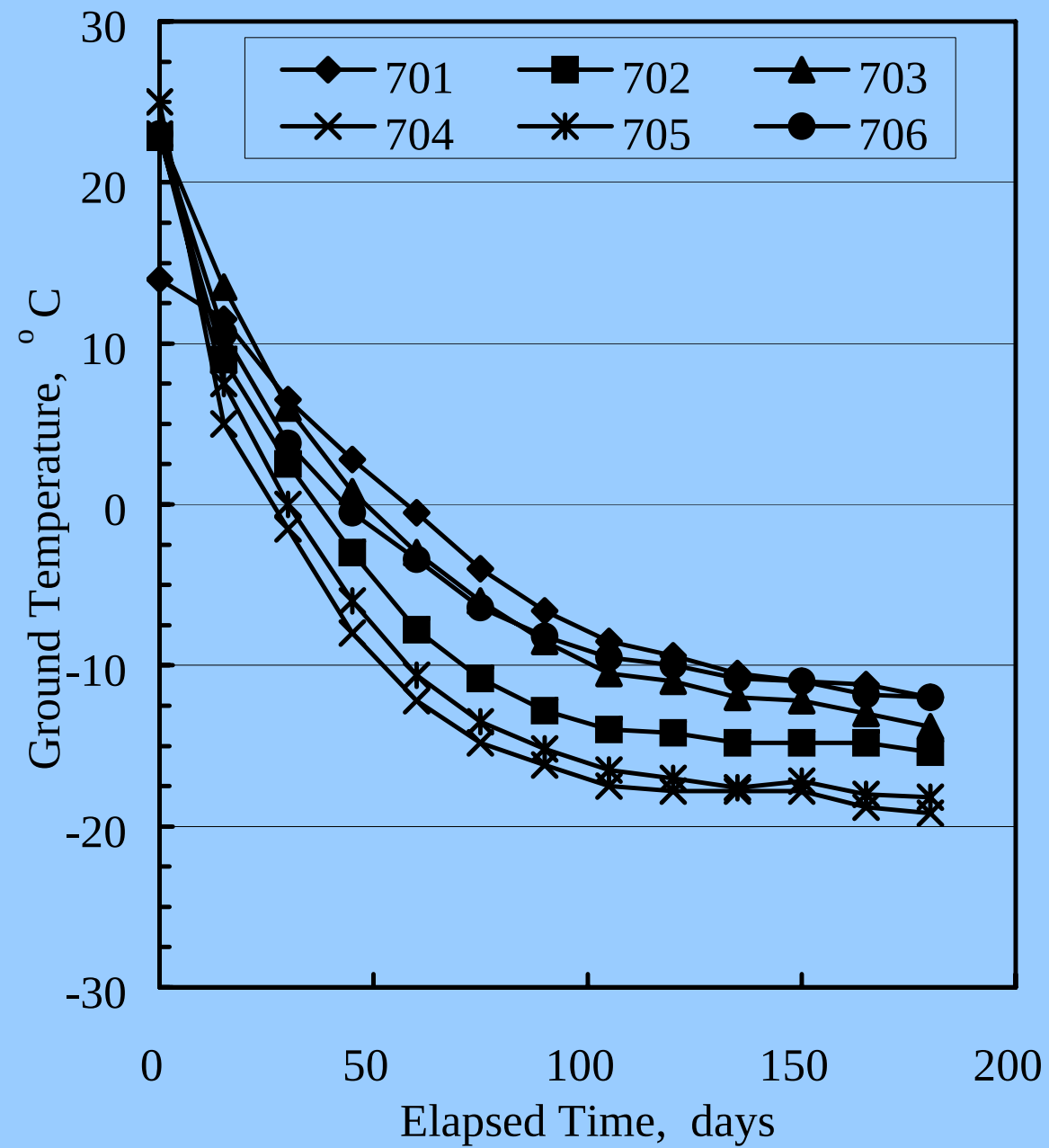
(c) Section B-B

















Ventilation Shaft

TYPE ($\odot$) Grouting 14.4 m

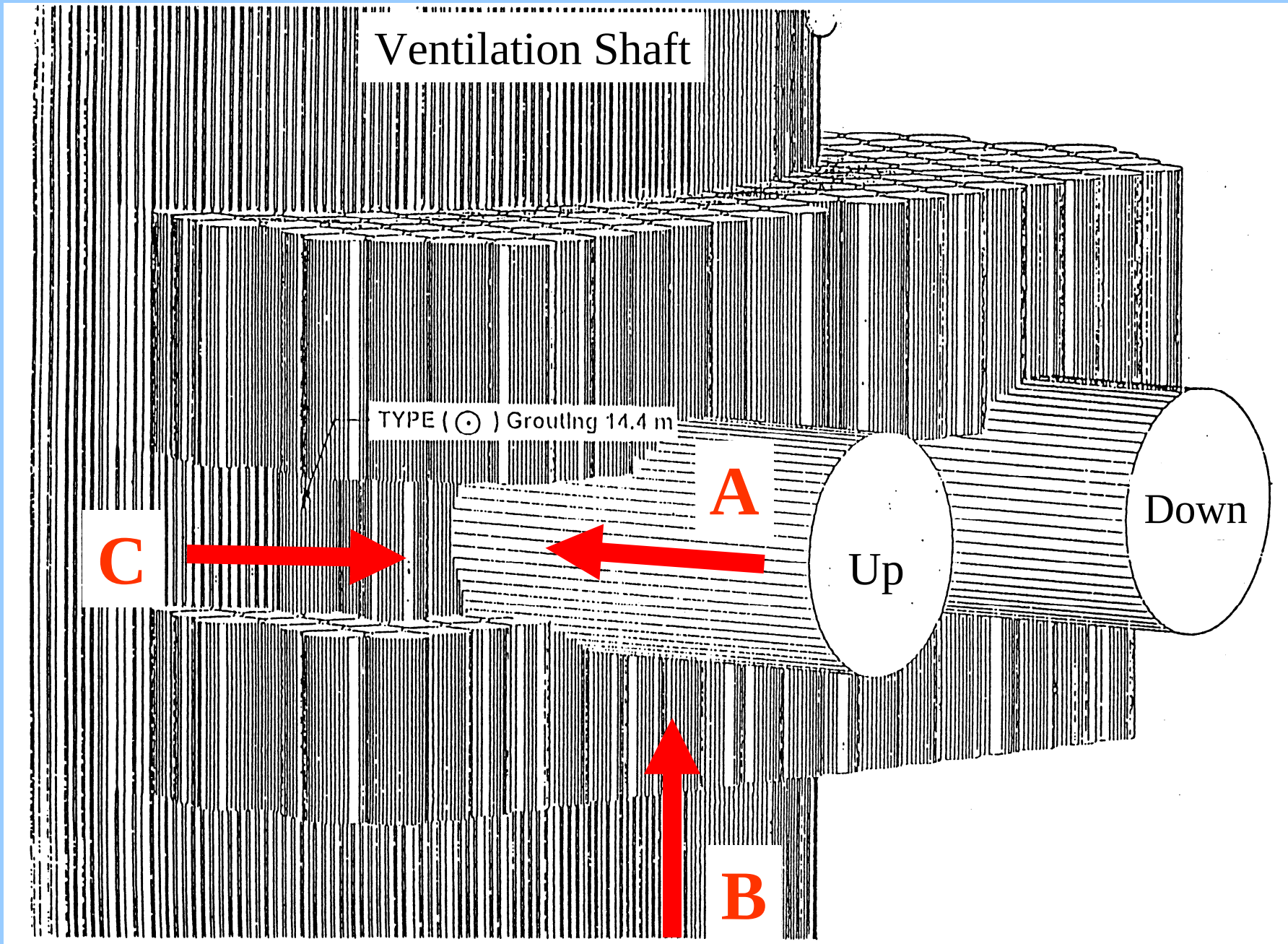
C

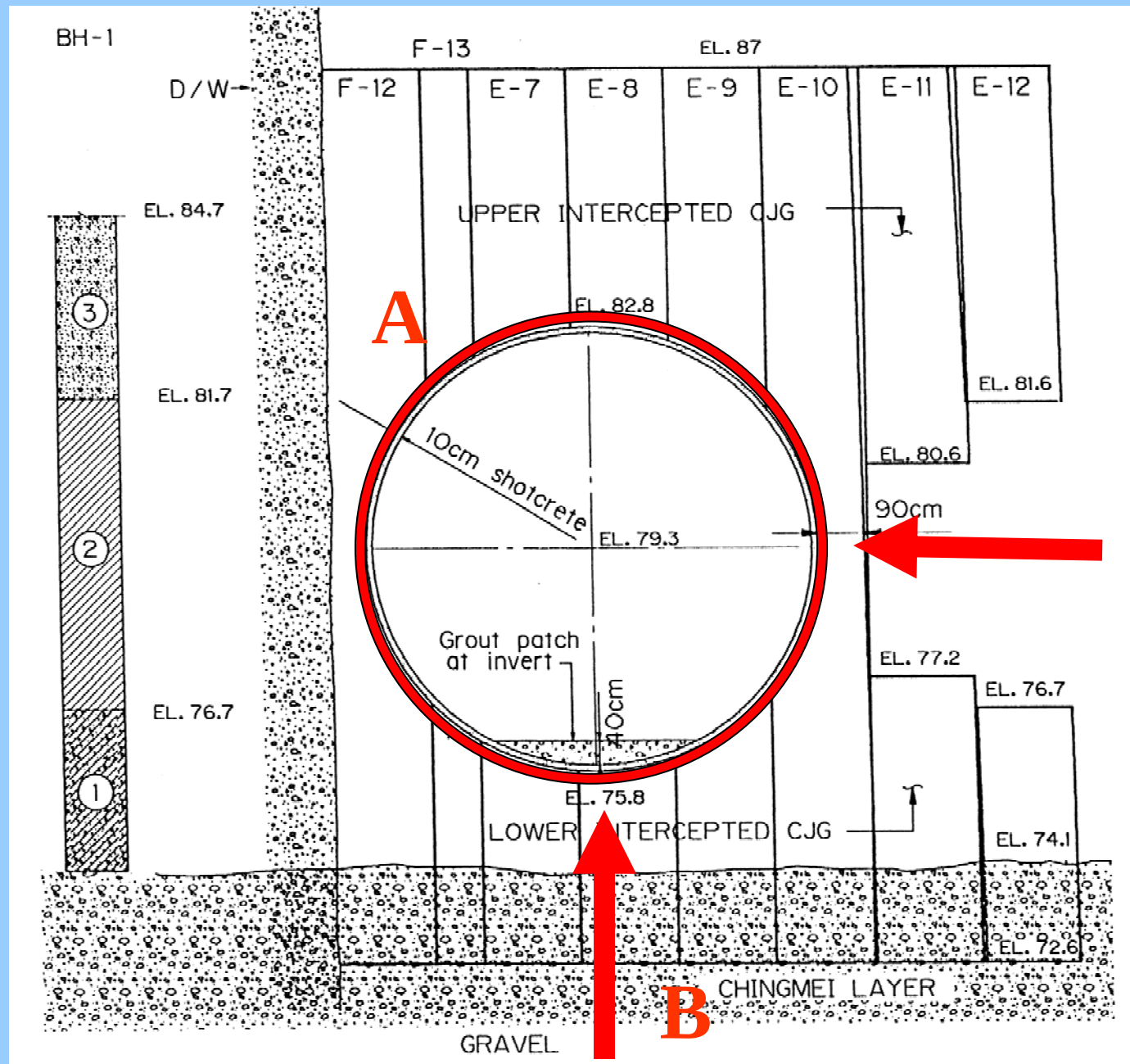
A

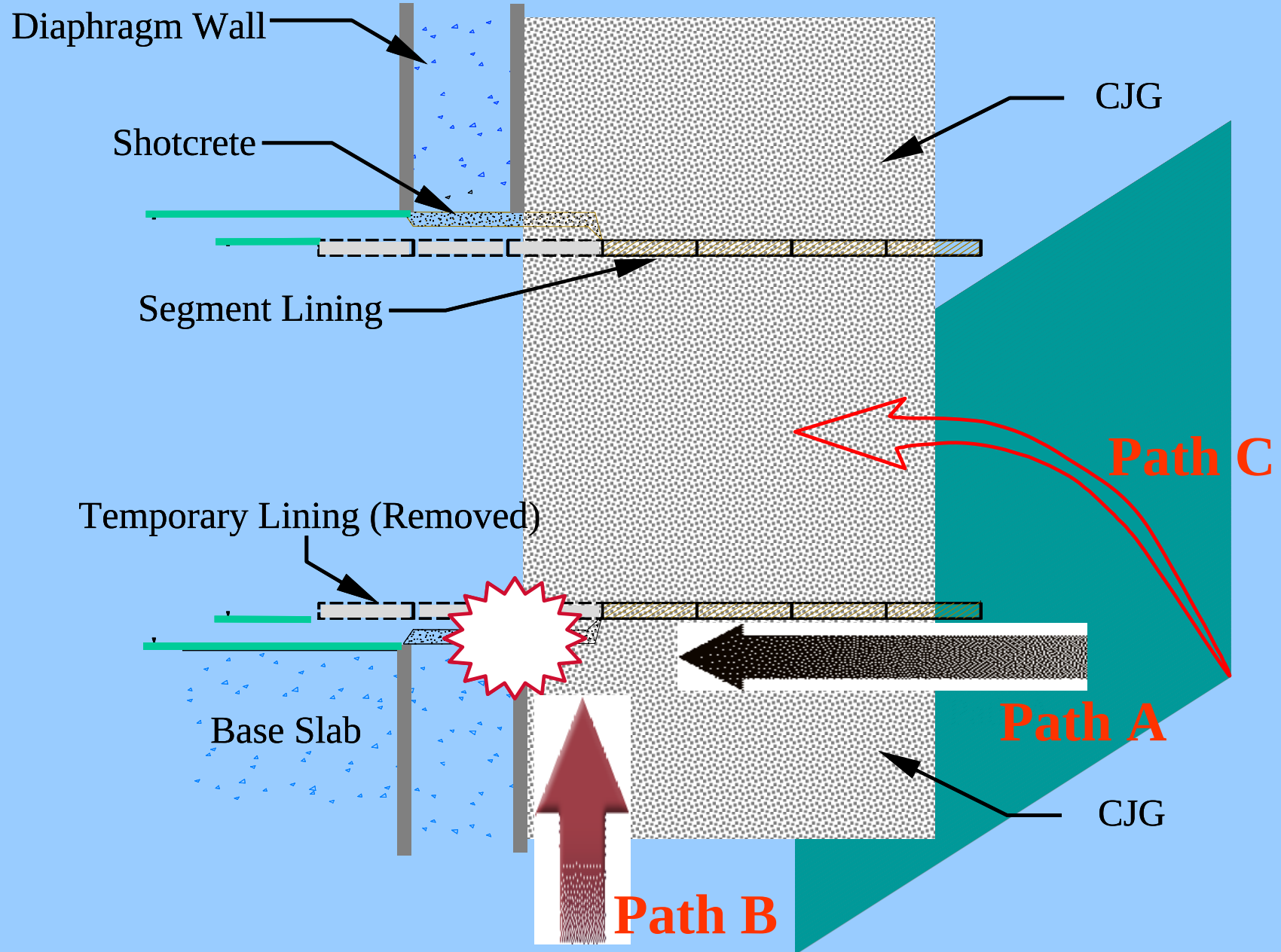
Up

Down

B







Opinions of Committee Members on Water Paths

	Member A	Member B	Member C	Member D	Member E
Path A	H	H	L	L	L
Path B	M	M	H	L	L
Path C	L	L	M	H	H

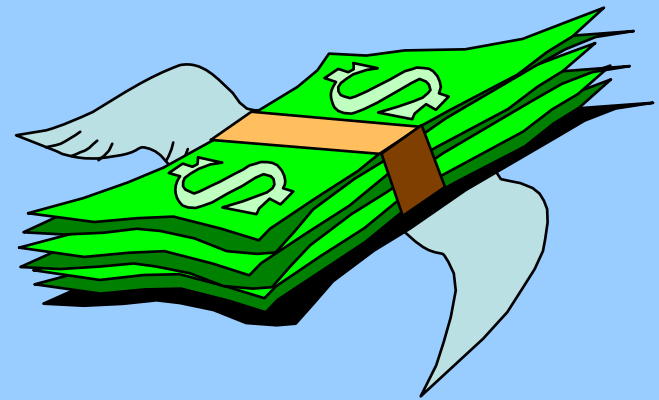
Notes: H – high possibility
M – medium possibility
L – low possibility

Opinions of Committee Members on Water Paths

	Member A	Member B	Member C	Member D	Member E	
Path A	3	3	1	1	1	9
Path B	2	2	3	1	1	9
Path C	1	1	2	3	3	10

Notes: 3 – high possibility
2 – medium possibility
1 – low possibility

A\$30,000,000?

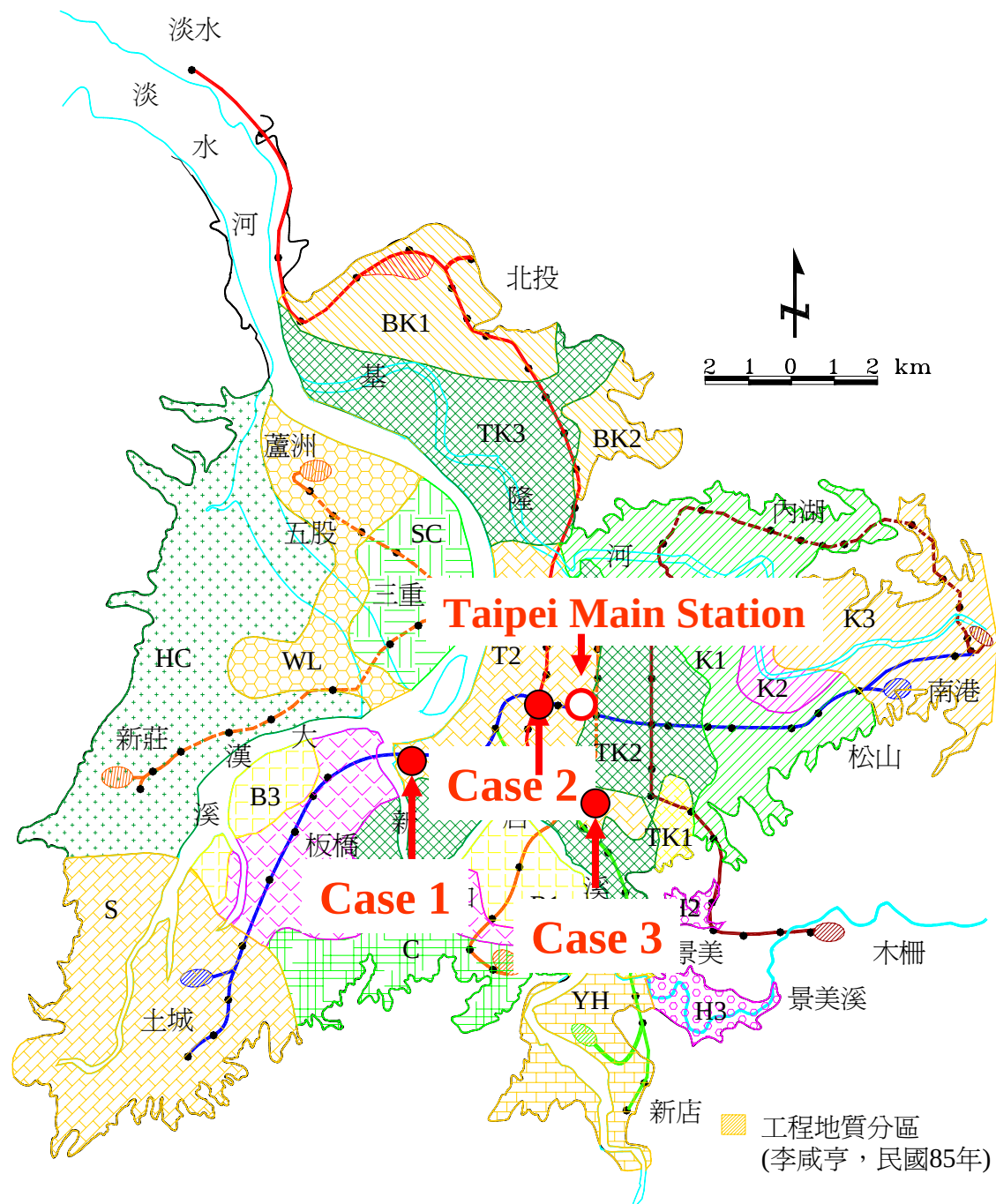


Lessons Learned

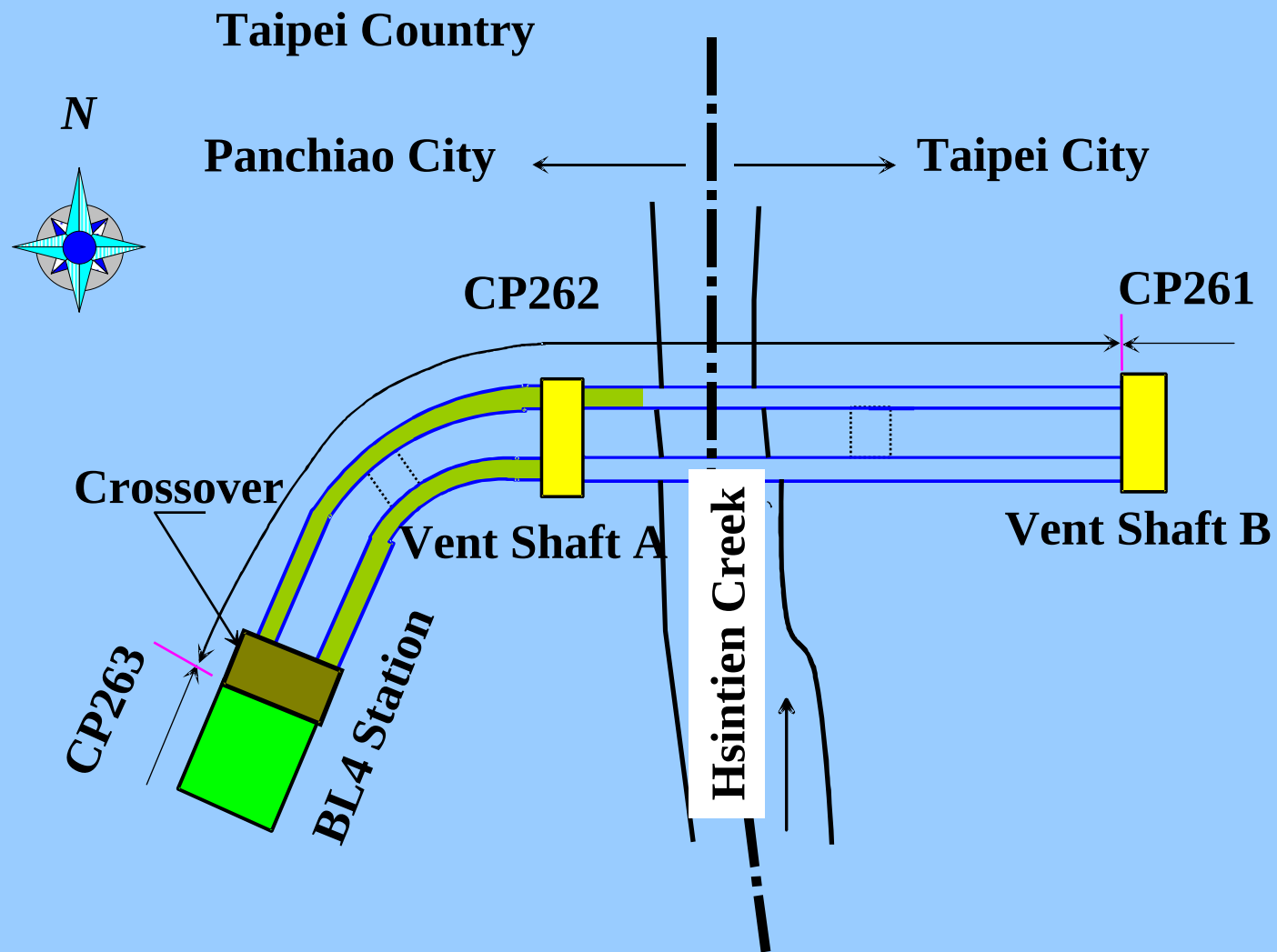
- Never under-estimate water problem
- Ground treatment can not be relied on
- Extra thickness is required when groundwater is a serious threat

Case 3 - Unforeseen Condition

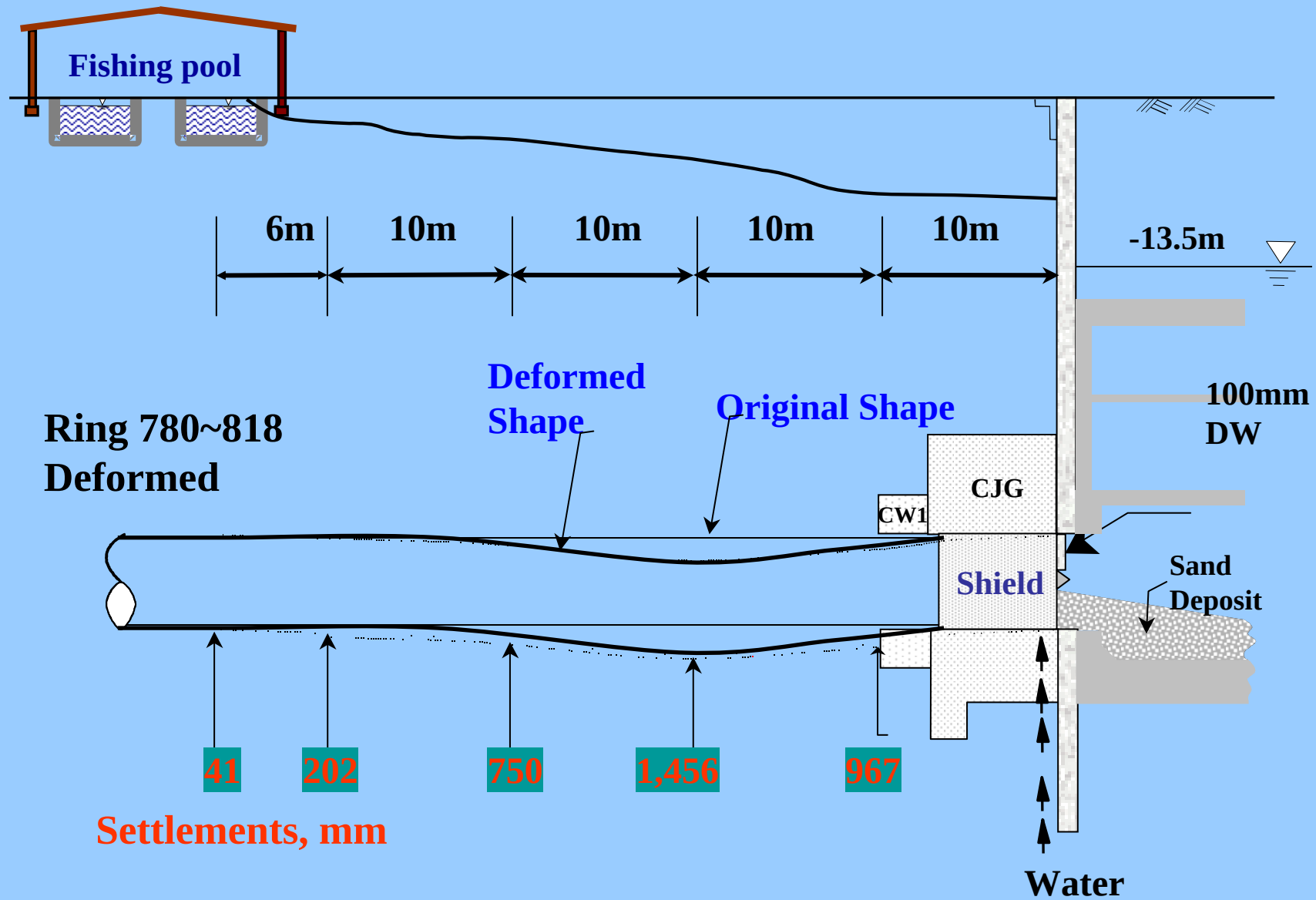
- Panchiao Line
- Opening of A Tunnel Eye at Ventilation Shaft A



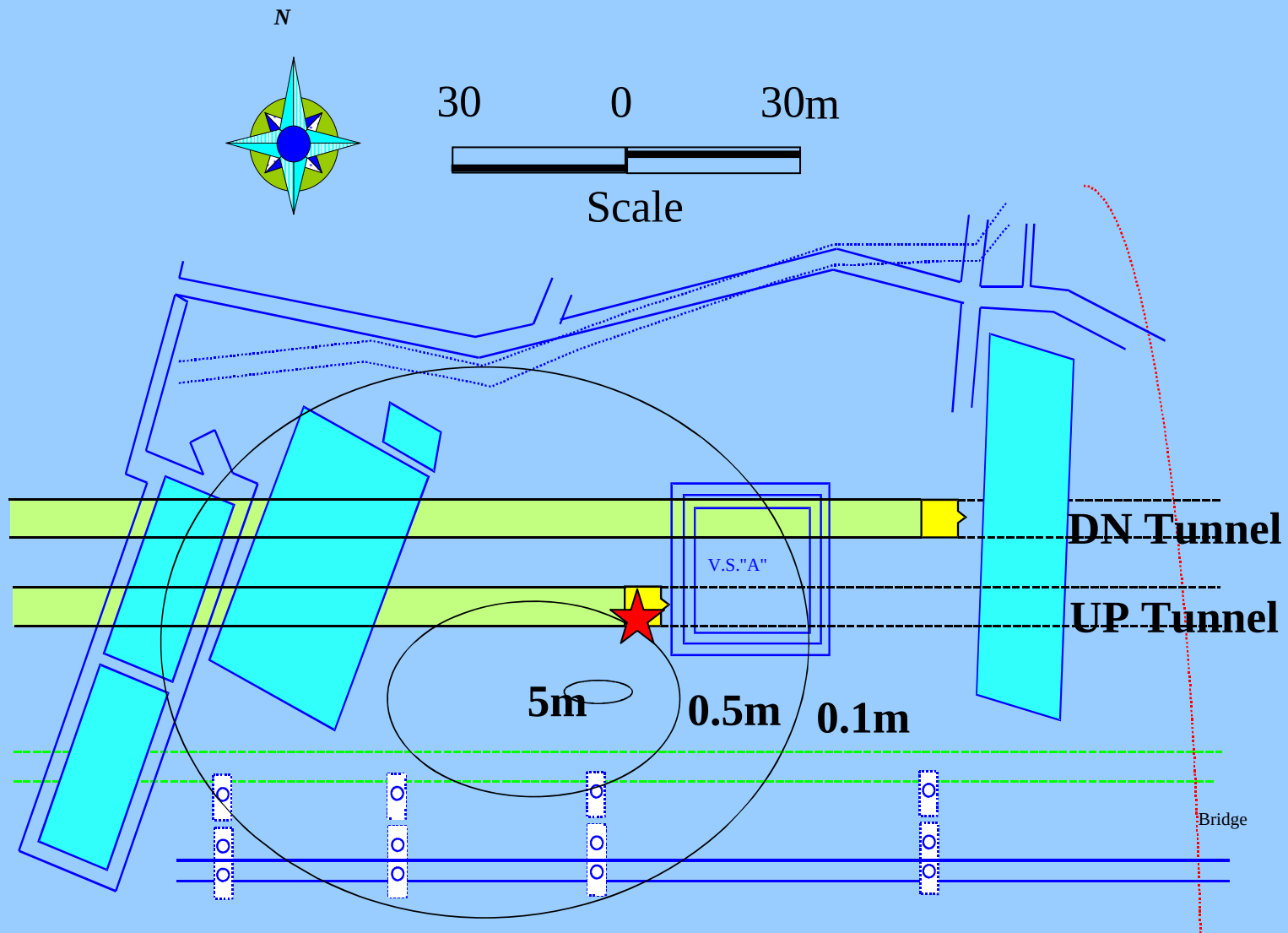
Geological Zoning of the Taipei Basin



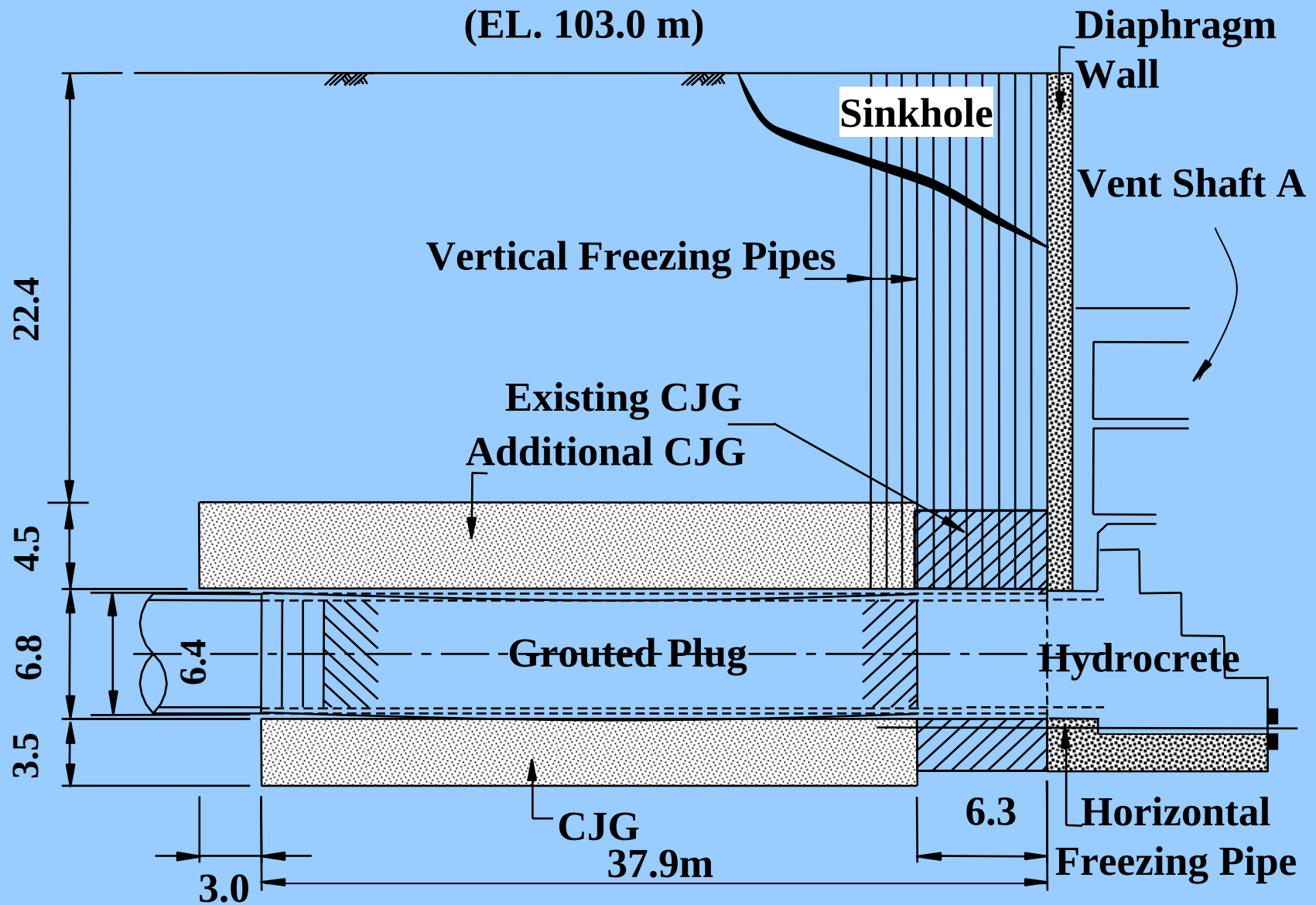
Plan of Panchiao Line Contract CP262



Settlement Profile



Settlement Contours



Remedial Measures

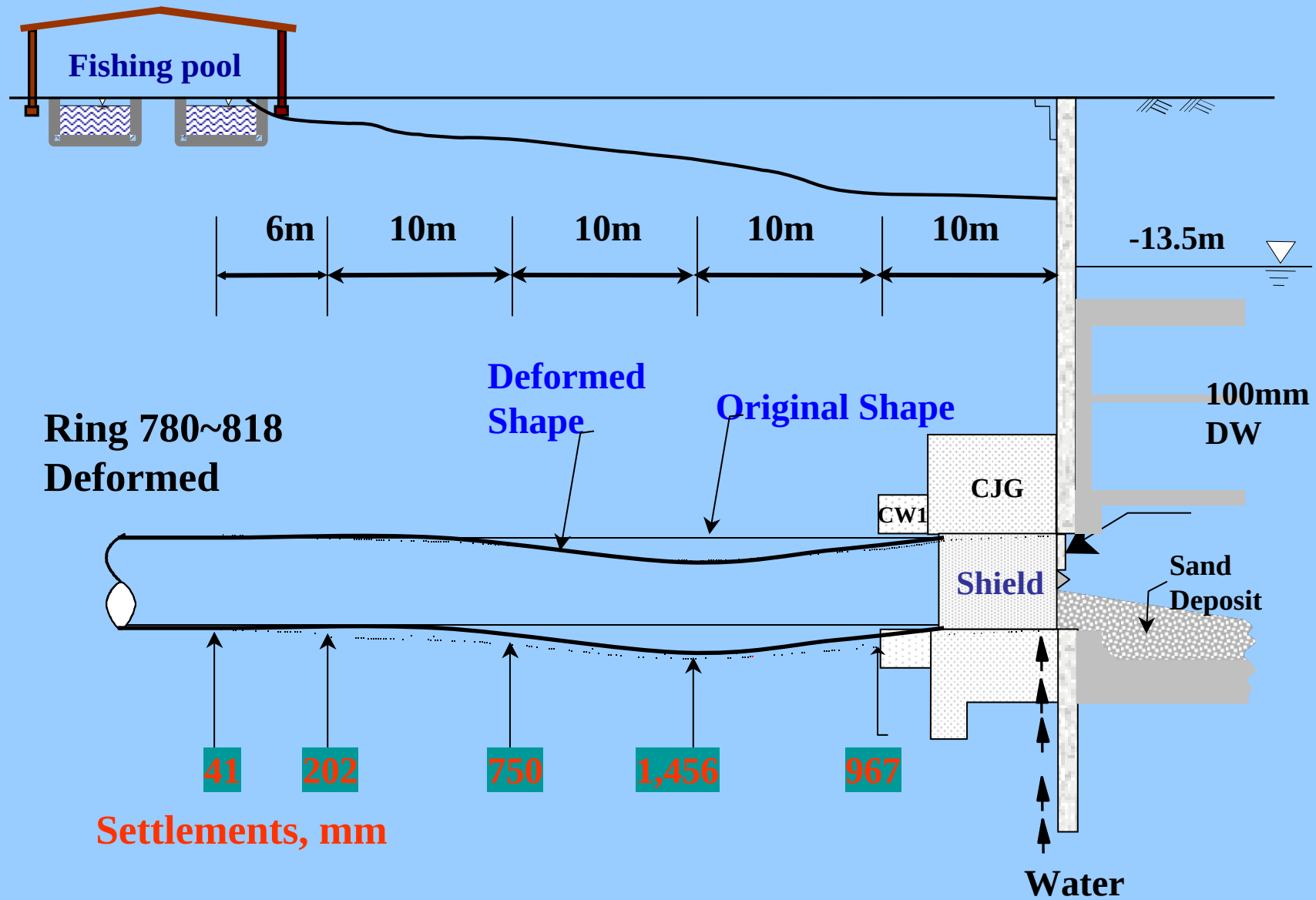




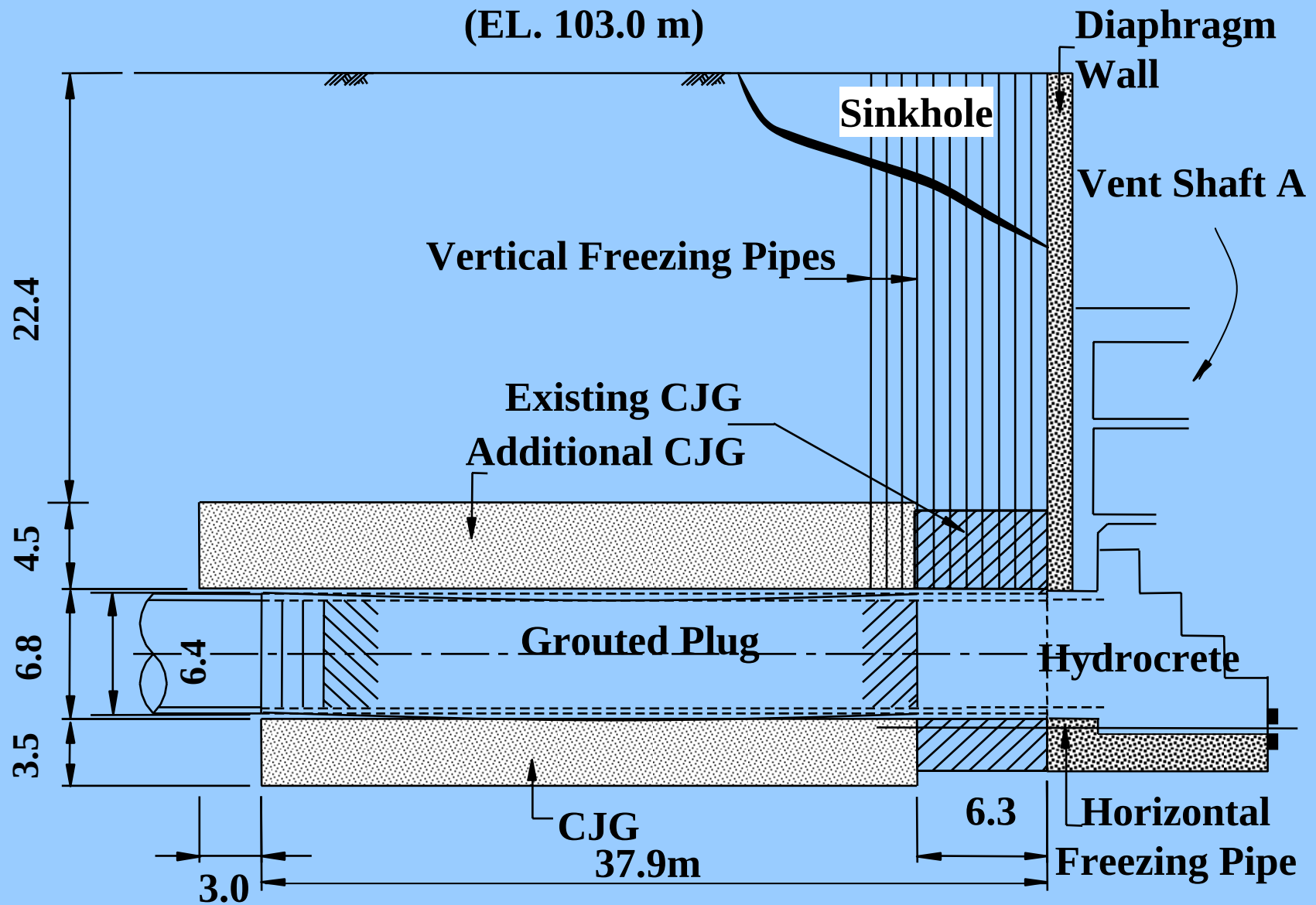




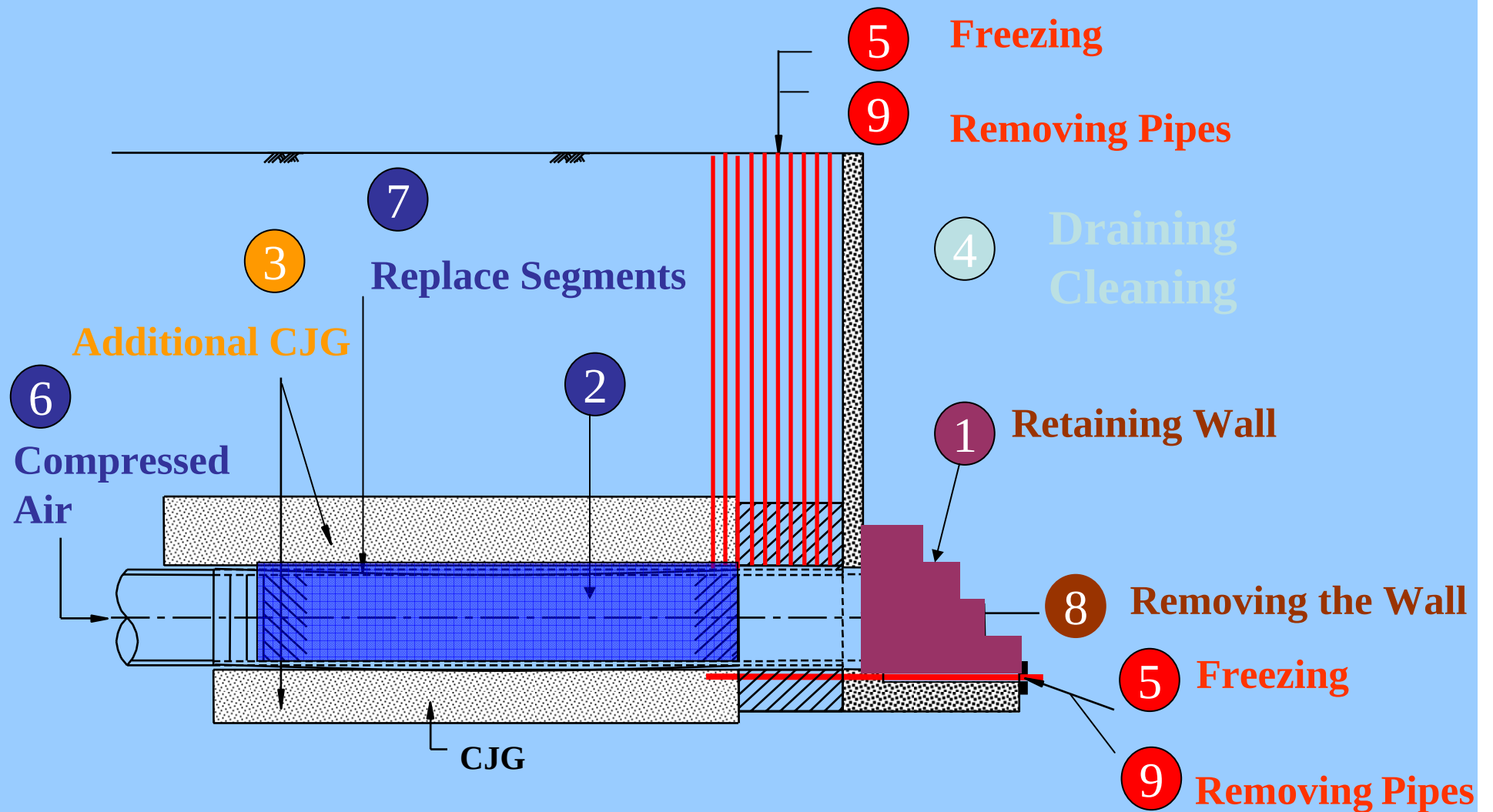




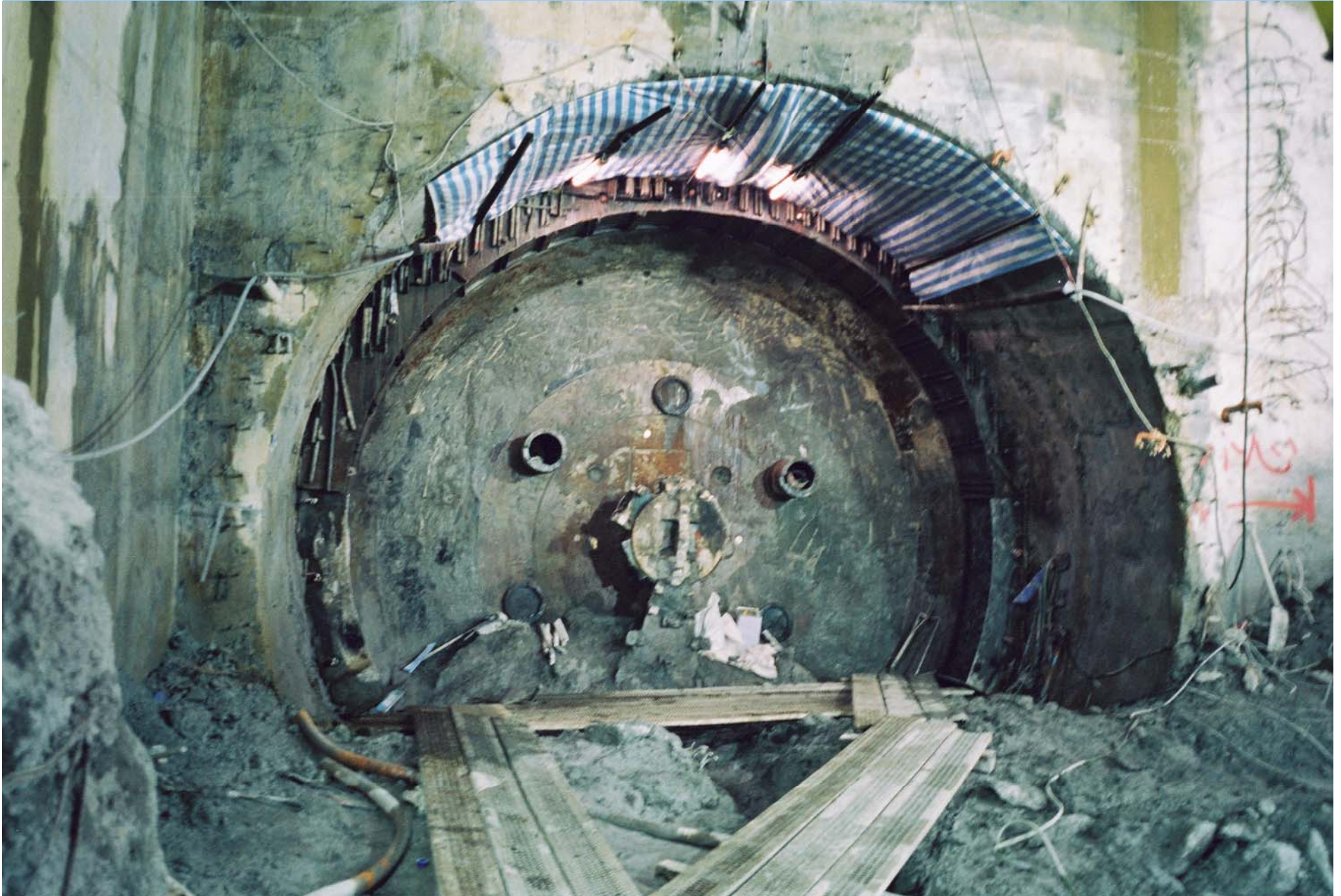
Settlement Profile



Remedial Measures



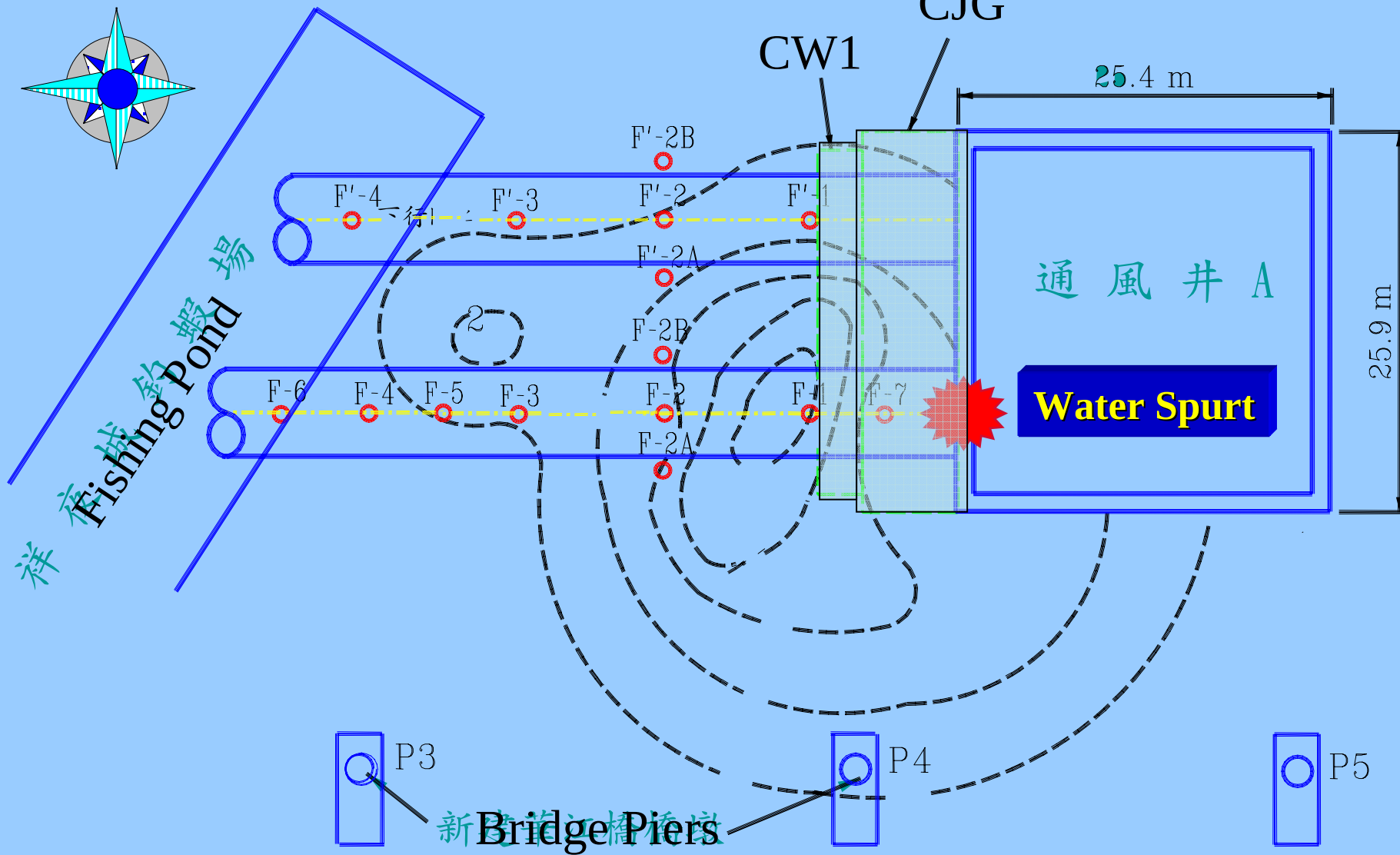
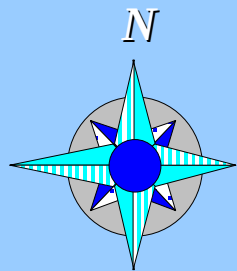
Remedial measures



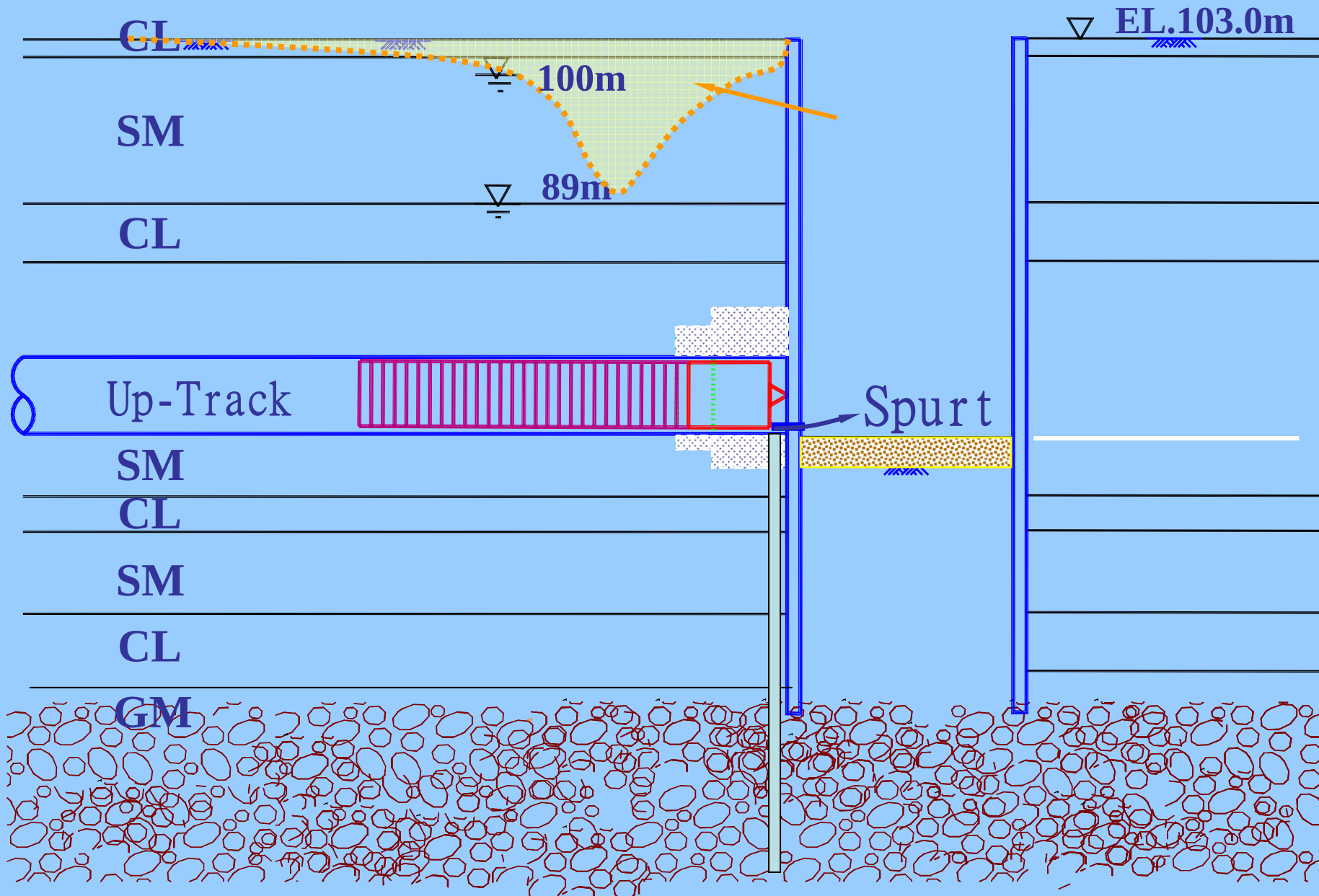


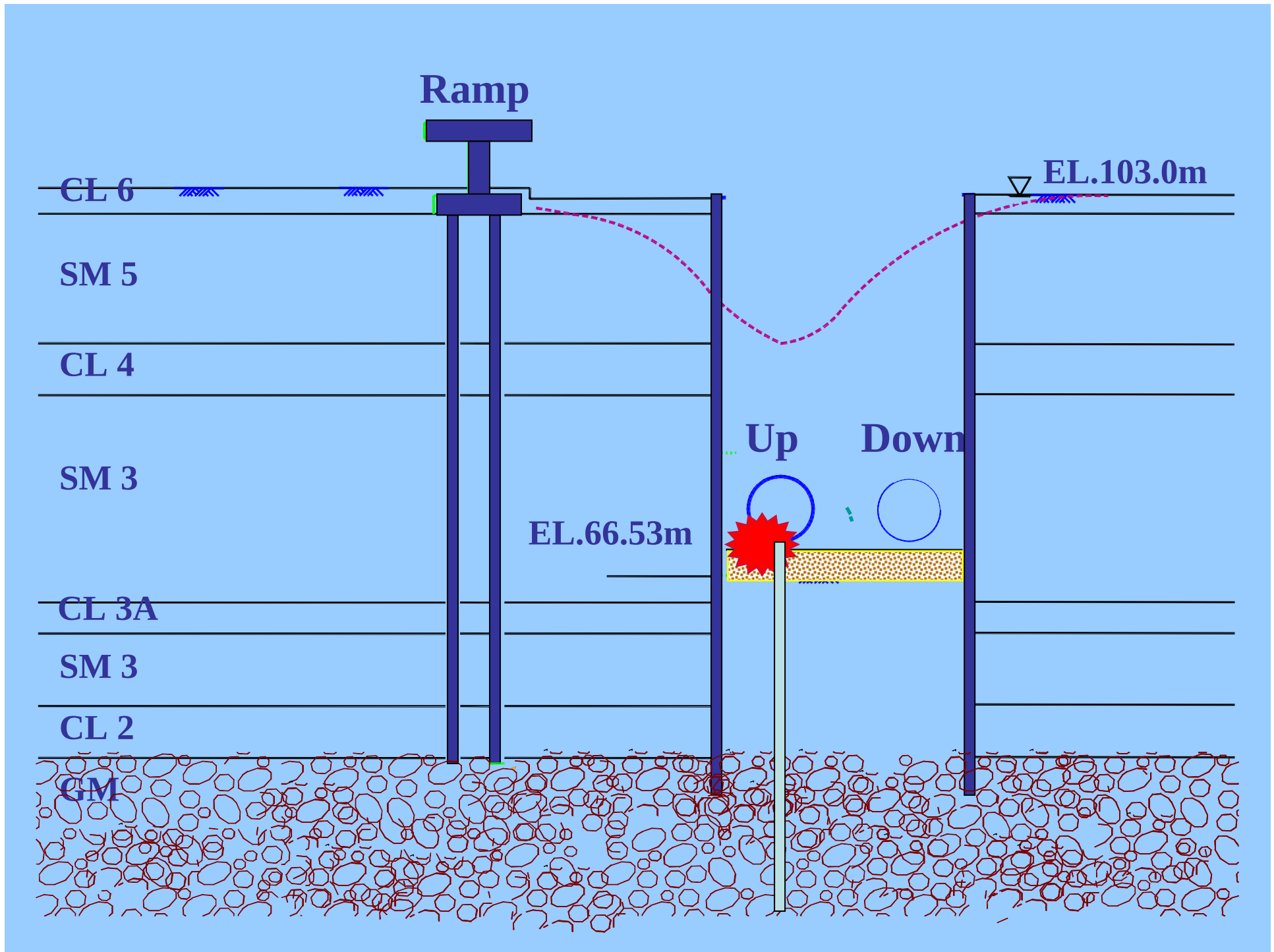






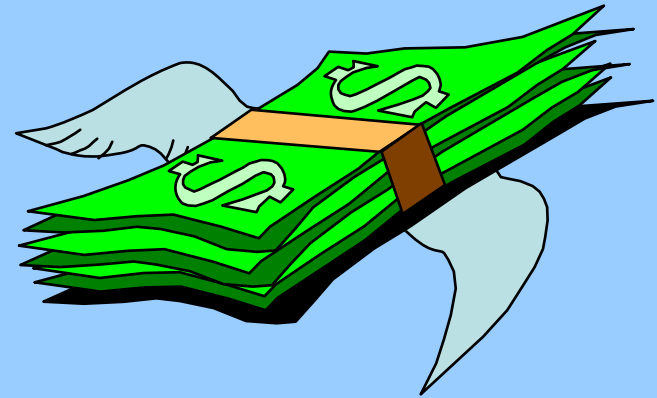
Vent Shaft A

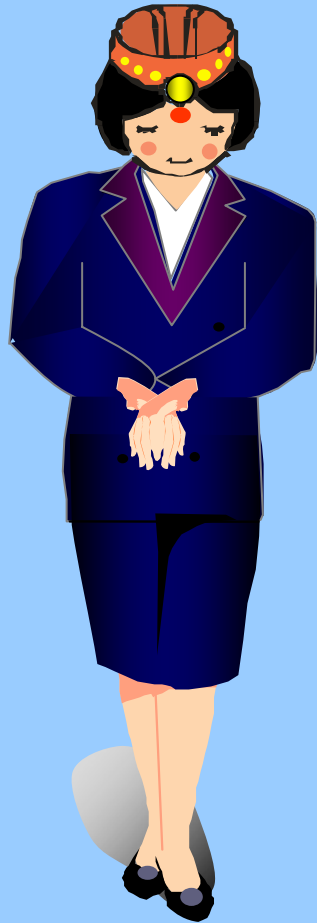




- Purchasing one new shield machine
- Overhauling one shield machine
- Replacing

A\$60,000,000





Thank You