CHAPTER 5
OUTLINE DESIGN (PHASE 2)

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The study of the Phase 2 Northern Route section between El Malek El Saleh and Ring Road Exit #18 via El Sawaha Square along Port Said Street was carried out at the level of an outline design. The train operating plan and required rolling stock number for the Phase 2 section was presented in Chapter 4, Section 4.2. Basic design concepts/criteria for Metro Line 4 Phase 2 are the same as for the Phase 1 section. These are presented in Chapter 4, Section 4.4.

5.1 Alignment Plan

According to the result of route selection, the JICA Study Team considers an alignment and station location for the northern route.

5.1.1 Design criteria

(1) Outline of Proposed Design Specifications

Table 5-1 Key Features for Alignment Planning (Phase 2)

	Items	Proposed Specification
1	Design speed	Tunnel section: 100 km/hr Viaduct and At-grade section: 120 km/hr
2	Minimum horizontal curve radius	Main line: 250 m Main line turnout curve: 160 m Workshop/Depot line: 160 m W/D line turnout curve: 120 m Platform section: 1000 m
3	Minimum vertical curve radius	Over 600 m horizontal radius 3,000 m Less than 600 m horizontal radius 4,000 m
4	Maximum gradient	Main line: 4% Platform section: 0.2% Stabling line: 0.2% Turnout section: 0%
5	Platform length	Total: 170 m

Source: JICA Study Team

All the design criteria are same as in Phase 1. The detail is shown in Chapter 4, Section 4.1.

5.1.2 Alignment Plan for Phase 2

(1) Alignment Planning Methodology

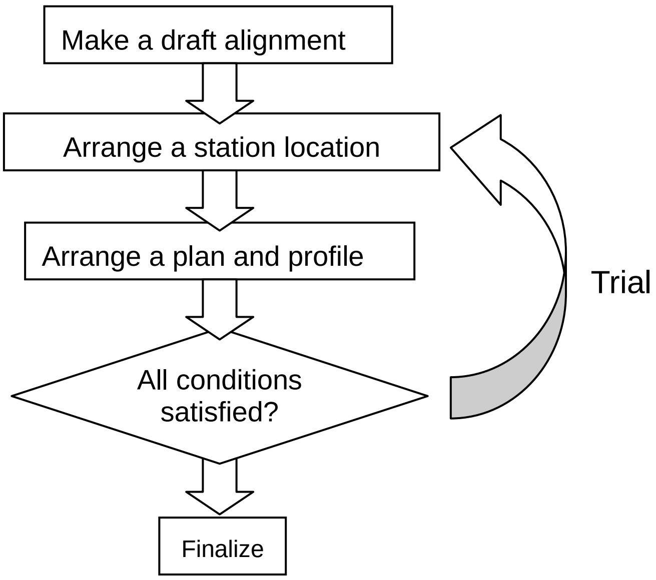
The alignment is planned on the basis of the selected route according to design criteria (refer to Section 5.1.1). Some control points are taken into consideration. The basic features of the selected route are tabulated in Table 5-2.

Table 5-2 Basic Features of Metro Line 4 (Phase 2)

Item	Basic Features
Outline of the Route	El Malek El Saleh – Children Cancer Centre - Sayida Zeinab Square - Bab El Shaaria Square – Ghamrah - El Sawaha Square - Ring Road Exit No.18
Route Length	17.6 km
Number of Station	16
Underground Section	12.6 km / 12 stations
Elevated Section	5.0 km / 4 stations
Workshop/Depot	On ground

Source: JICA Study Team

Planning methodology is as shown below:



Source: JICA Study Team

Figure 5-1 Planning Methodology

(2) Control Points and Basic Policy

The Phase 2 route will run along a world heritage area of Islamic Cairo. This area has a lot of mosques and archaeological buildings. Besides, there are some control points which restrict plan preparation and profile in addition to the station locations and types. There are many conditions to be considered. These conditions are related to existing structures, surface situation, road traffic impacts, geological condition, construction cost, construction method, social and environmental impacts, etc. Thus, it was necessary to conduct several trials to arrange the alignment to reflect alternative station locations and types related to these conditions.

In particular, it has to be decided how to deal with the control points for planning an alignment. The basic policies for alignment planning and station arrangement are as follows:

- How to avoid the archaeological things and existing structures
- How to minimize land acquisition and resettlement
- How to reduce the cost
- How to create the value for the city and/or citizens

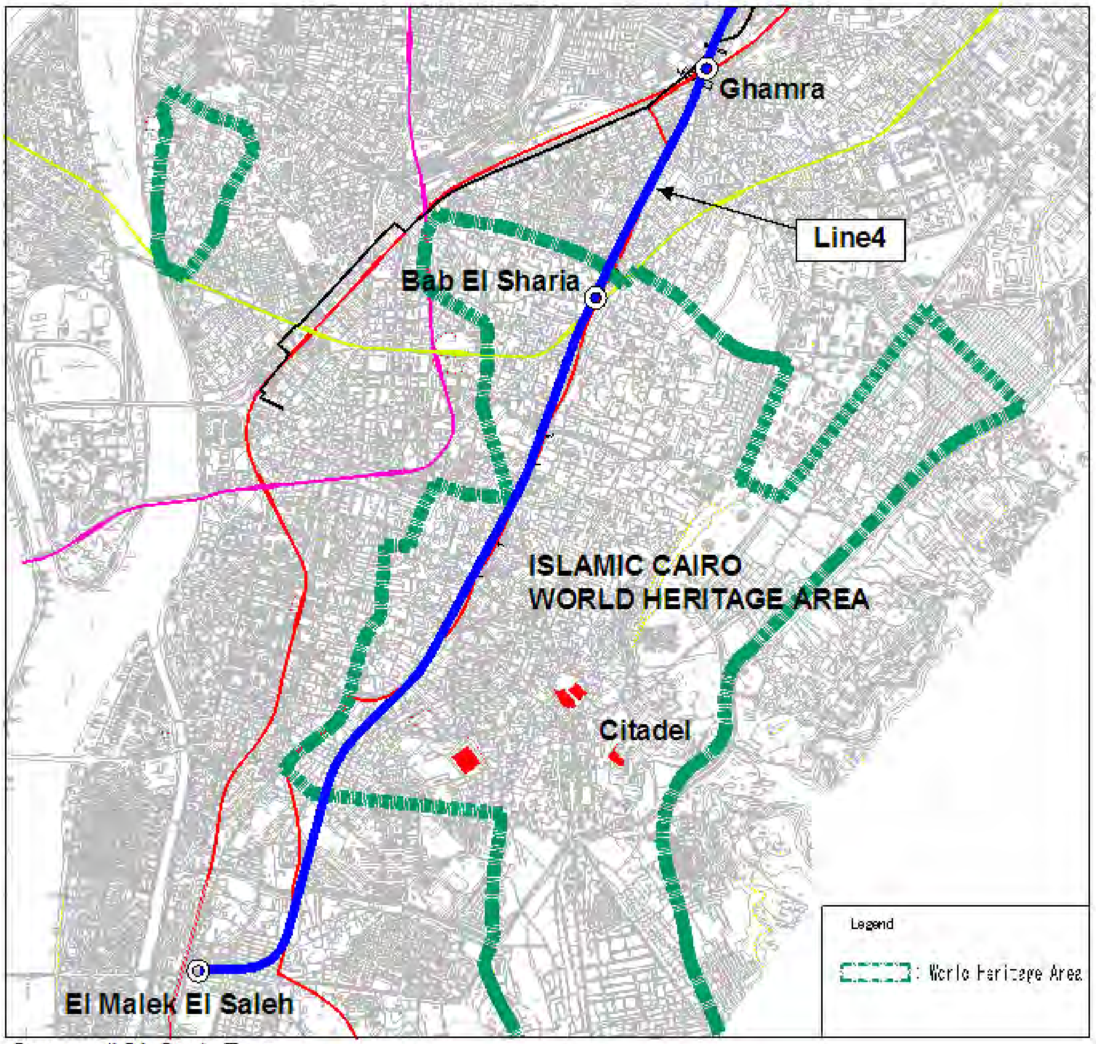
The priorities are given to the above policies, but it is also important to keep balances among these policies.

The top priority is to avoid the archaeological things and existing structures. Thus, some stations might be located deep beneath the road. On the other hand, the stations located in the shallow ground which enhance the convenience and access of the passengers and reduce the construction cost also have to be considered. Therefore, comprehensive planning regarding the alignment, track, structure, architecture, electro-mechanical and construction is required.

The policies to be applied for the determination of the alignment are as follows:

- Avoid passing through the archaeological area as much as possible;
- Avoid the foundation of existing structures as much as possible;
- Structures should be close to ground level as much as possible;
- Gentle curves and gentle gradients should be applied as much as possible;
- Minimize land acquisition and resettlement; and
- Locate stations within an interval of approximately 1 km from one another.

Alignment planning assumes the adoption of a single track double tunnel style as the shape of the tunnel similar to Phase 1.



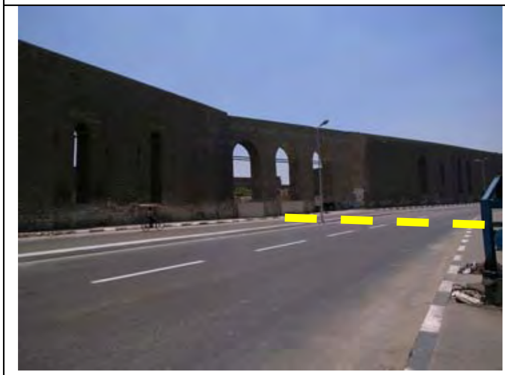
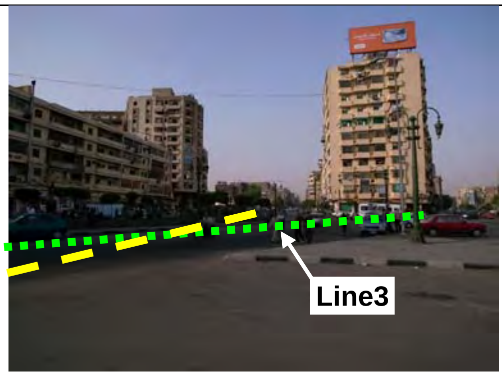
Source: JICA Study Team

Figure 5-2 The World Heritage of Islamic Cairo Area

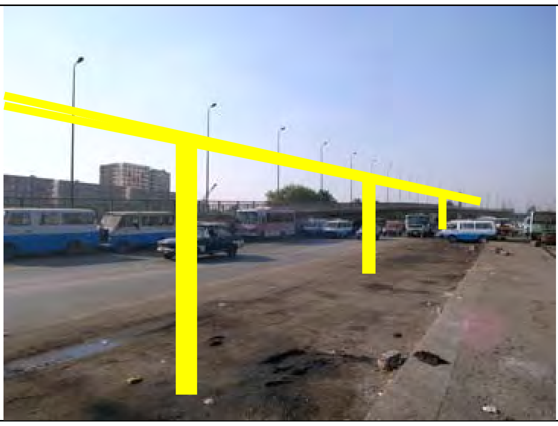
(3) Alignment Planning for Phase 2

Based on the abovementioned policies, the alignment and station location are decided taking into account the control points. The considerations and countermeasures of each control point to determine the alignment are tabulated in Table 5-3.

Table 5-3 Considerations for Possible Alignment for Phase 2

Control points	Considerations
Water Viaduct	To pass beneath the foundation of the water viaduct
	This is an ancient Roman water viaduct and is one of the cultural assets. Therefore, this structure should never be touched during construction.
Sewage Tunnel	To pass over or beneath the sewage tunnel on ground
Not available photo image	Metro Line 4 has to cross the sewage tunnel several times under Port Said Street.
Al Azhar Viaduct and Tunnel	To pass beneath the viaduct and tunnel
	There is a junction with Al Azhar Viaduct. This area is complicated because there are lots of foundations. In addition to this, Al Azhar tunnel runs underground beneath the road along Al Azhar Viaduct. Thus, it is important to avoid the foundations of the viaduct and tunnel.
Bab El Sharia Square	To pass beneath the Square
	Metro Line 3, which is under construction, will run a tunnel below this square along El Geish Street. Metro Line 4 has to cross the tunnel above or below avoiding some sewage pipes.

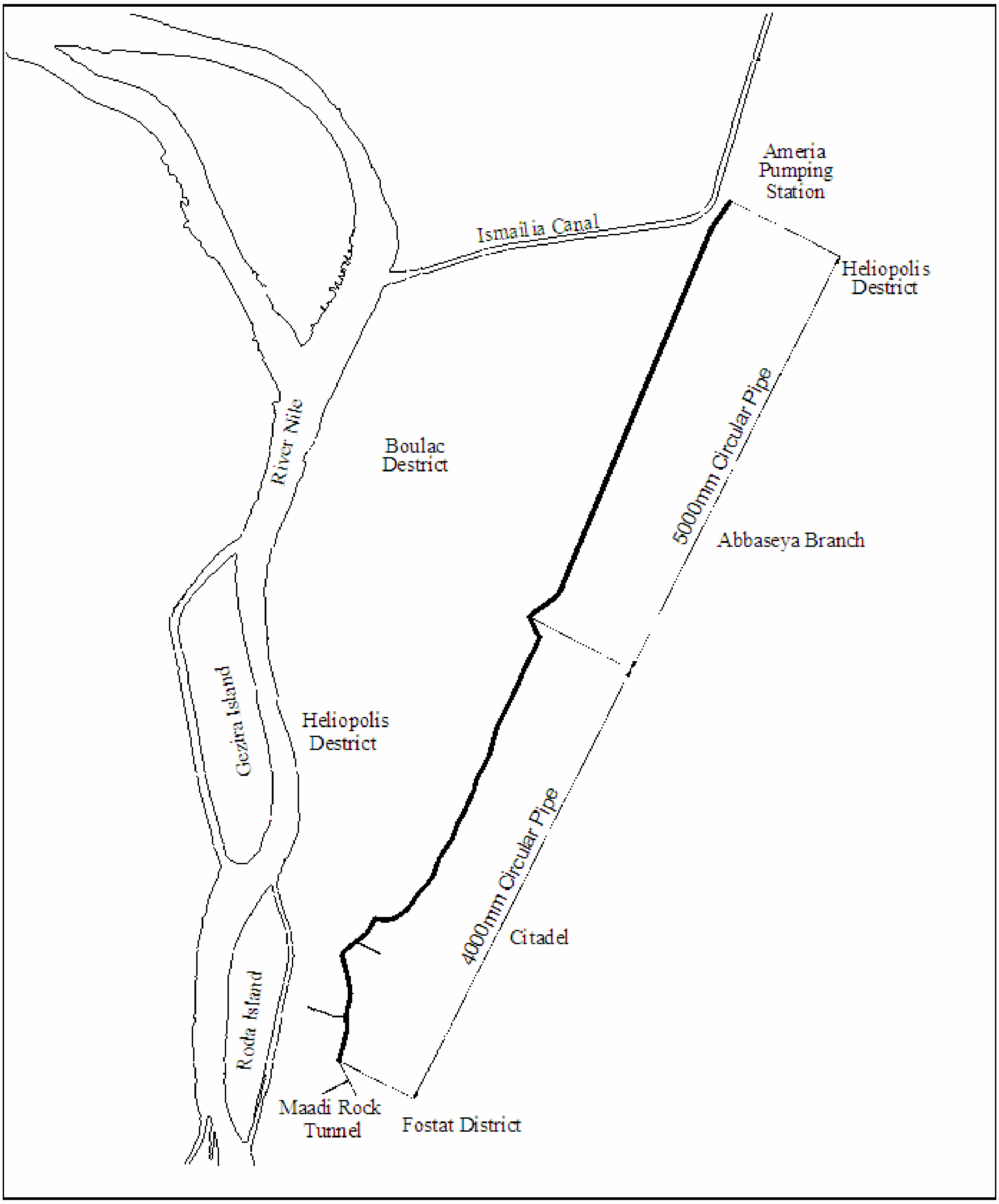
Control points	Considerations
An under-construction flyover	To avoid the foundations of the flyover as much as possible
	There are Port Said Flyover with ramp and the Ghamra Station Building, some footpaths and station facilities, etc.
Ghamrah Station in Metro Line1	To pass beneath the station and roads
	Metro Line 4 will run across under Ramsis St., Mahattat Sikkat El Hadid St., Heliopolis Tram line and Metro Line 1. Metro Line 4 should be connected with the existing Metro Line 1 station and Tram station. Thus, a station should be constructed in the vicinity of this area.
6th of October Bridge	To pass beneath the bridge
	The cable-stayed bridge has enough and wide span and the tunnels can pass between the piers (approximately 70 m).

Control points	Considerations
An under-construction viaduct	To consider the existence of the viaduct
	The viaduct will cross over Port Said Street through one span beam. Thus, Metro Line 4 can run under the viaduct.
El Amirya Bridge	To avoid the bridge
	The bridge crossing over the Ismailiyah Canal has a ramp starting from this square (El Sawaha Square). Metro Line 4 will have a station near here and run beside the bridge.
El Mostorod Bridge	To fly over the bridge
	Metro Line 4 will cross over the bridge via flyover structure, or pass under it.

Source: JICA Study Team

Almost all control points which should be cautiously considered are situated between El Sayeda Zeinab Square and Ghamra Station.

The most sensitive point is the main sewage tunnel, which is located approximately 15 m below Port Said Street. The inner diameter is approximately 4.0 m to 5.0 m. It was constructed in the 1990s. According to the operation organization, the tunnel has been damaged and deteriorated.



Source: JICA Study Team

Figure 5-3 Existing Spine Sewage Tunnels

(4) Outline of the Alignment for Phase 2

Phase 2 line starts from El Malek El Saleh Station connecting Phase 1 underground station. Starting from El Malek El Saleh Station, the line immediately turns to the north towards Sayeda Zeinab Square. On the way to Port Said Street, the line will run beneath the residential area, via in front of the Children Cancer Center. The first station in Phase 2 section is proposed at a garden in front of the hospital, the second one will be located in the Sayeda Zeinab Square.

After Sayeda Zeinab Square until Ghamra Station, it runs below Port Said Street in parallel with a sewage tunnel. Furthermore, it passes beneath the Al Ahzar Tunnel, avoiding the sewage tunnel at the crossing with the Al Azhar Street. Then, it crosses the Metro Line 3 tunnel at the Bab El Sharia Square. The station will be located in this square. Between Sayeda Zeinab Square and Ghamra Station, three other stations except the Bab El Sharia are planned. The alignment in this section should be decided taking into consideration the construction methodology regarding some obstacles.

After the intersection with the Metro Line 1 at the Ghamra Station, it will pass under Port Said Street until El Sawaha Square. Between Ghamra Station and El Sawaha Square, five stations will be located including the El Sawaha Square.

After the El Sawaha Square, Port Said Street runs parallel to Ismailia Canal. There is enough space for Metro Line 4 to emerge on the ground surface. From this point, the Metro Line 4 is planned as a viaduct structure located in the space between Port Said Street and Ismailia Canal. In this section, four elevated stations including final station are planned from El Sawaha Square until Ring Road Exit 18th.

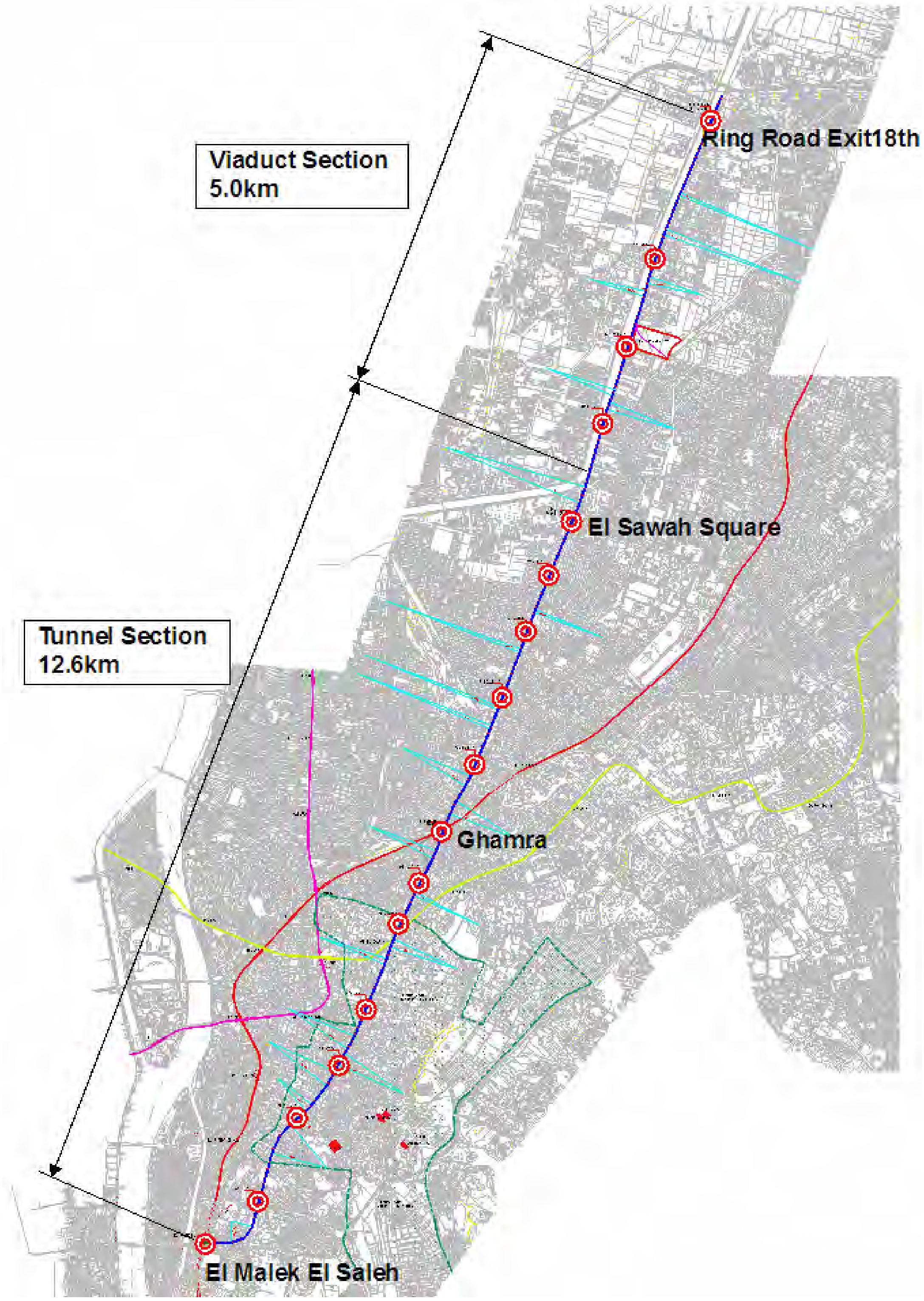
A depot is planned in the Phase 2 section. It is recommended to locate it in the agriculture area near Station No. 15. The leading line to the depot needs a slope which becomes 350 m or longer, because the main line will be a viaduct in this section and the depot will be on the surface. Thus, the leading line branches from Station No. 16.

- ☞ The proposed alignment plan is shown in Figure 5-4.
- ☞ The proposed alignment sketch is shown in Figure 5-5.
- ☞ The proposed station arrangement is shown in Table 5-4.
- ☞ The proposed track layout plan is shown in Figure 5-6.

Table 5-4 Proposed Station Arrangement for Phase 2

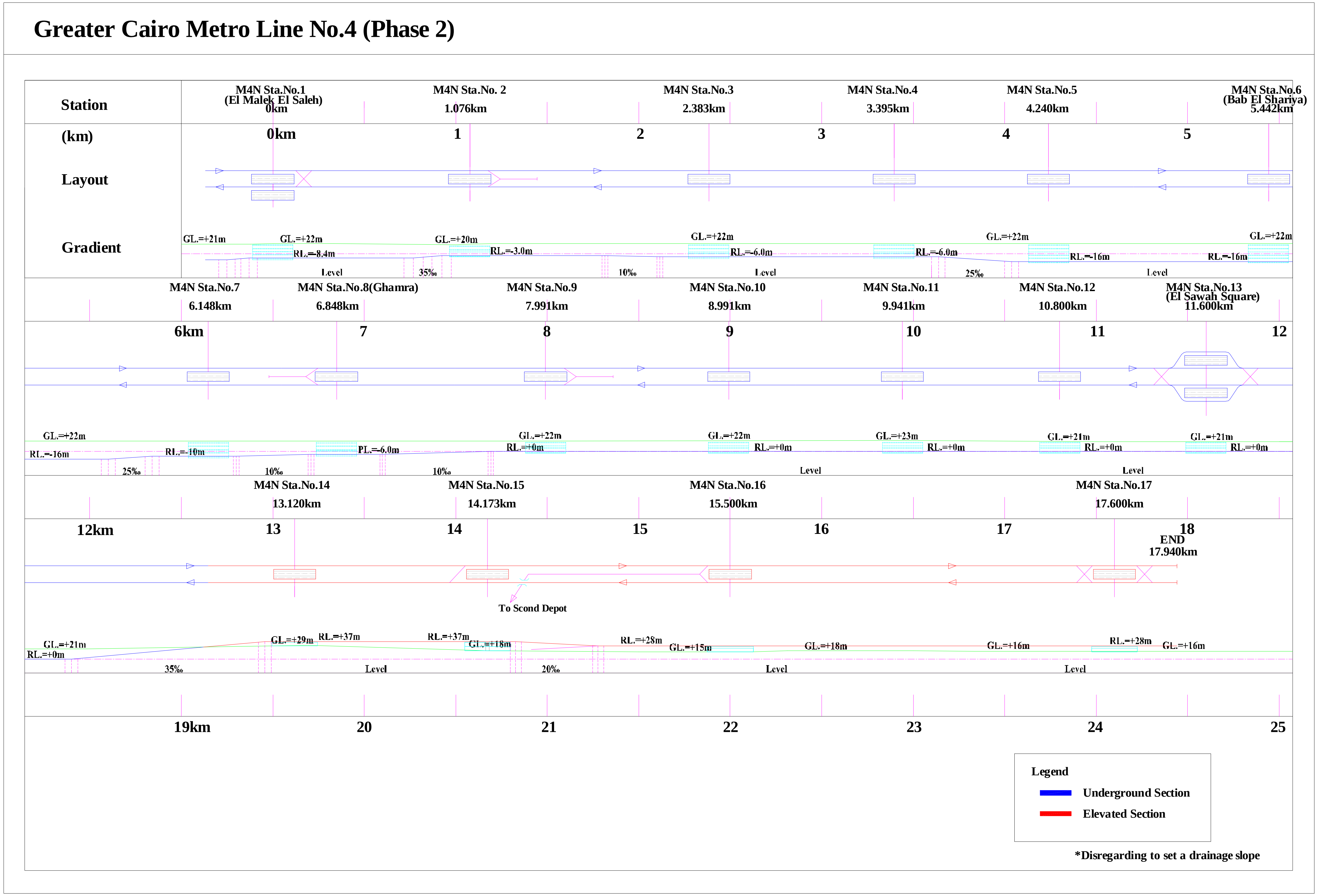
Phase2					
No.	Station	kilometerage		Platform Type	Article
		km	km		
1	M4N-Station No.1				
	(El Malek El Saleh)	0.00		Island + Separate	Scissor crossing for shuttling
2	M4N-Station No.2		1.08		
	(Children Cancer Center)	1.08		Island	Head shunting line
3	M4N-Station No.3		1.30		
	(Sayeda Zeunab Square)	2.38		Island	
4	M4N-Station No.4		1.02		
		3.40		Island	
5	M4N-Station No.5		0.84		
		4.24		Island	
6	M4N-Station No.6		1.20		
	(Bab El Sharia)	5.44		Island	
7	M4N-Station No.7		0.71		
		6.15		Island	
8	M4N-Station No.8		0.70		
	(Ghamra)	6.85		Island	Head shunting line
9	M4N-Station No.9		1.14		
		7.99		Island	Head shunting line
10	M4N-Station No.10		1.00		
		8.99		Island	
11	M4N-Station No.11		0.95		
		9.94		Island	
12	M4N-Station No.12		0.86		
		10.80		Island	
13	M4N-Station No.13		0.80		Scissor crossing for shuttling
	(El Sawah Square)	11.60		2 Islands	2 subtracks
14	M4N-Station No.14		1.52		
		13.12		Island	
15	M4N-Station No.15		1.05		
		14.17		Island	
16	M4N-Station No.16		1.33		
		15.50		Island	Depot leading line
17	M4N-Station No.17		2.10		Scissor crossing for shuttling
		17.60		Island	2 stabling lines
		Total	17.60		

Source: JICA Study Team



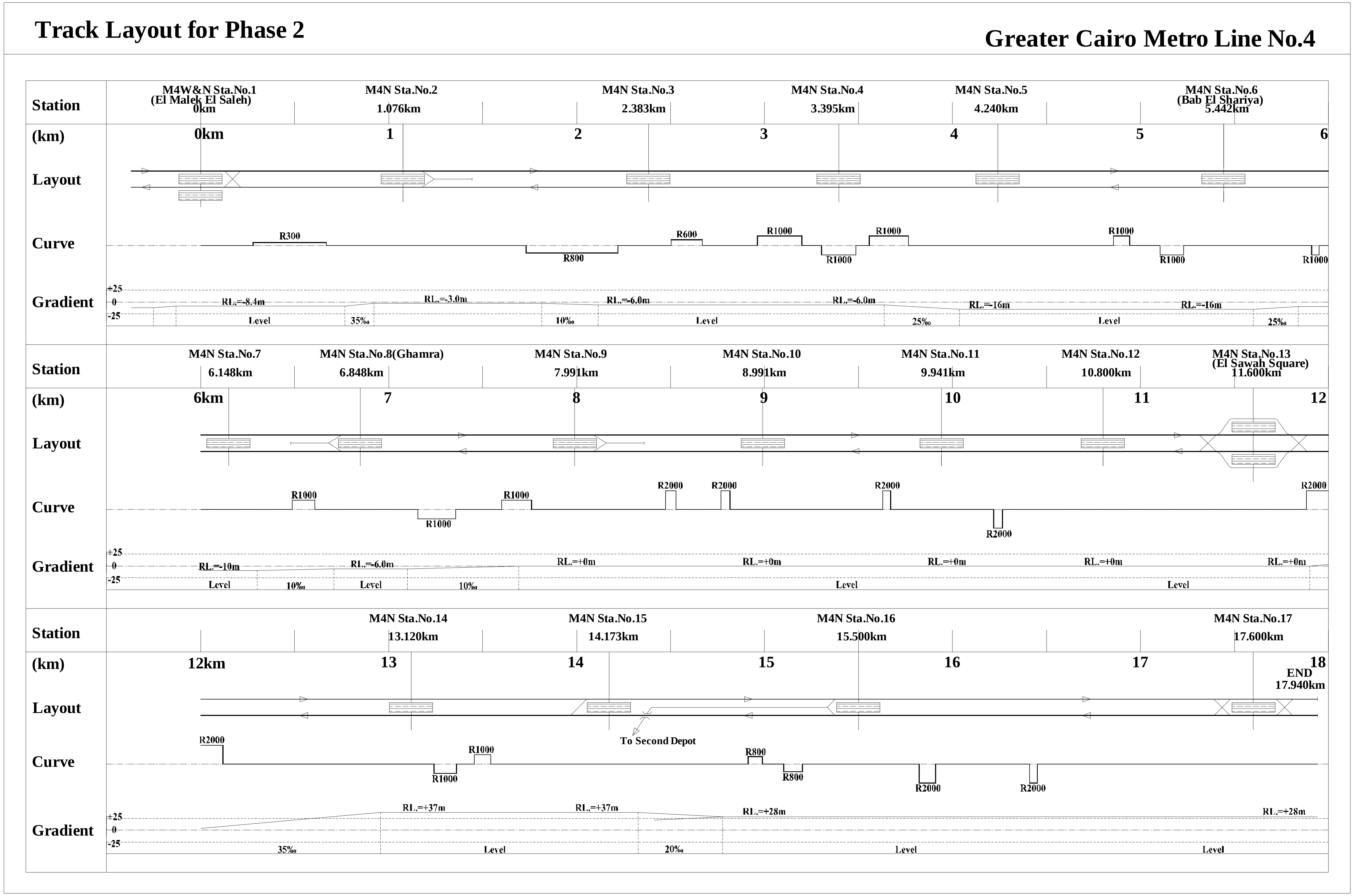
Source: JICA Study Team

Figure 5-4 Proposed Alignment Plan View for Phase 2



Source: JICA Study Team

Figure 5-5 Sketch of Proposed Alignment for Phase 2



Source: JICA Study Team

Figure 5-6 Proposed Track Layout Plan for Phase 2

5.2 Civil Works (Underground Section)

5.2.1 Basic Condition

(1) Geological Condition

According to the geological survey of Phase 1 and regarding collected data, the considerations in design and construction of this civil work are as follows:

- The ground water level is 2.5 m deep from the ground level.
- The main stratum where the shield TBM is expected to pass is sand stratum. The sand stratum is dense to very dense but it is collapsed ground of low uniform coefficient and low content of fine material.
- The corrosion ingredient such as the sulphuric-acid may be contained in the ground.

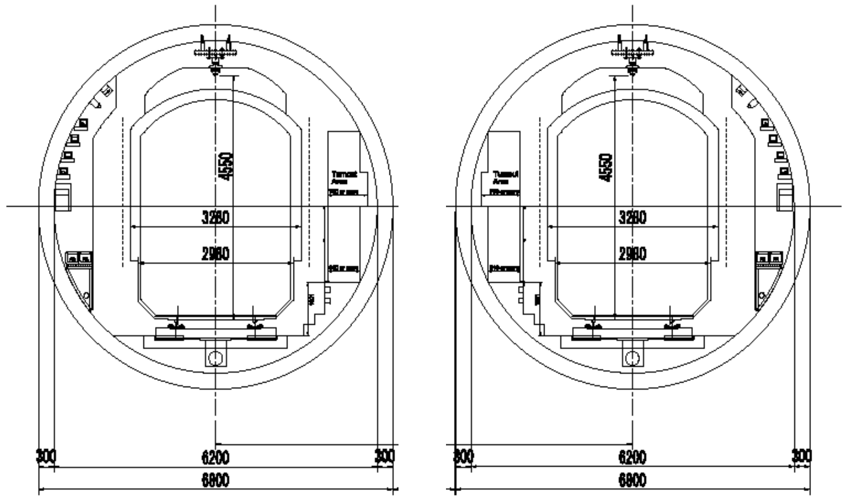
Table 5-5 Geotechnical Soil Parameters

	SPT-N	γ	φ	C	Eo	ν
	-	tf/m3 (10kN/m3)	°	kgf/cm2 (100kN/m2)	kgf/cm2 (100kN/m2)	-
FILL	8	1.7	32	0.0	170	0.35
CLAY(1)	14	1.7	0	0.9	290	0.40
SAND(1)	16	1.8	33	0.0	340	0.35
SAND(2)	51	1.9	38	0.0	710	0.30
SAND(3)	100	2.0	40	0.0	980	0.30

Source: JICA Study Team

(2) Clearance of Tunnel (Construction Gauge)

Considering the connection to Phase 1 and possibility of diversion of shield TBM, the clearance of tunnel is the same as in Phase 1. The clearance of tunnel is shown in Figure 5-7.



Source: JICA Study Team

Figure 5-7 Clearance of Tunnel

(3) Basic Requirements of Underground Stations

The basic requirements in the planning of the underground station of Metro Line 4 Phase 2 are summarized in Table 5-6.

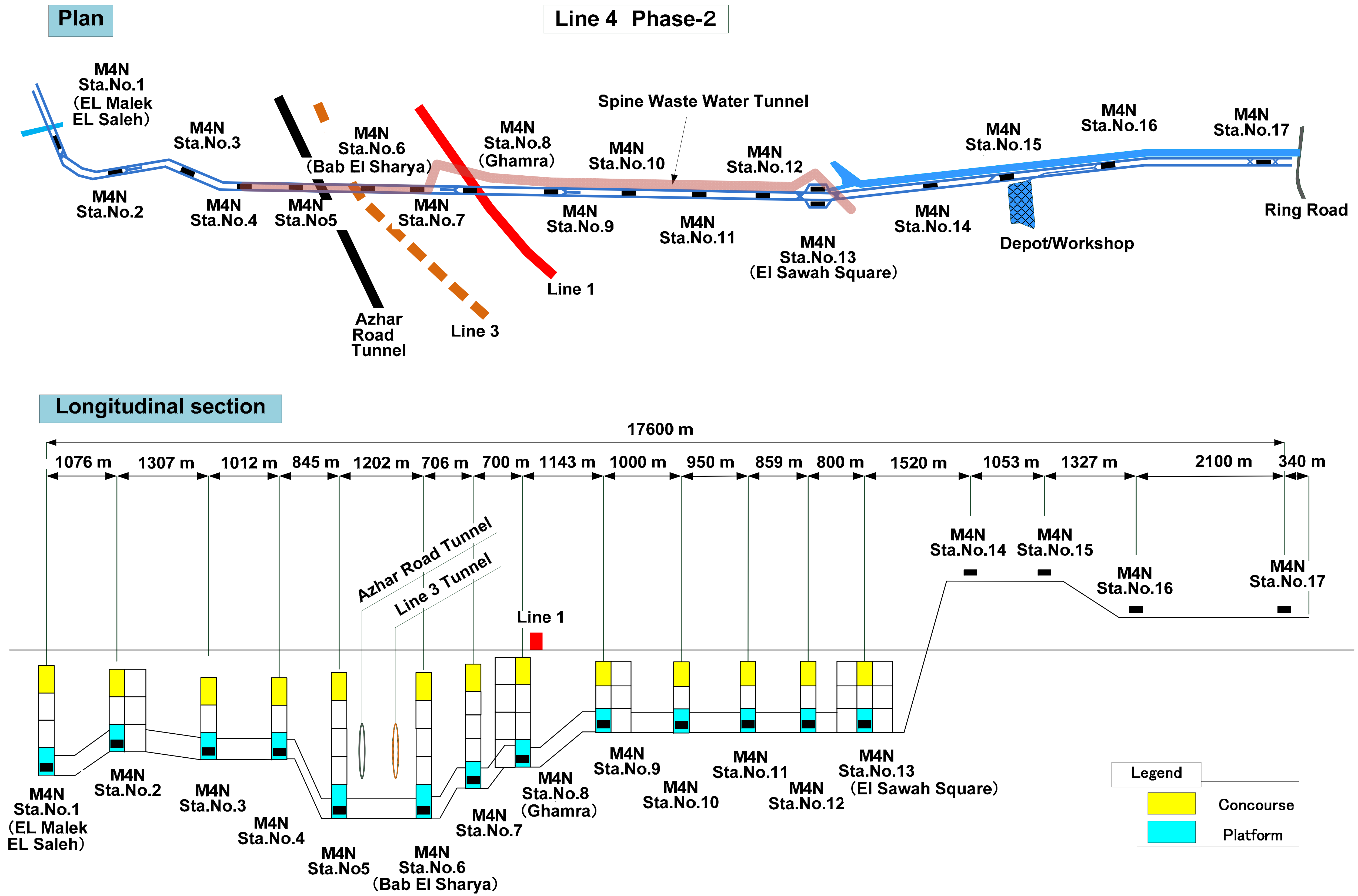
Table 5-6 Basic Requirements for Structural Planning

Items	Specifications
Platform type	Island type
Platform width	12.0 m
Platform length	170.0 m
Minimum passenger corridor width between PSD and stair and escalator	2.5 m
Station length (3~5 stories)	190.0 m
Minimum height of platform story	5.0 m (including duct space)
Minimum height of concourse story	5.0 m (including duct space)
Tunnel type between stations	single track double tube

PSD: platform screen door
Source: JICA Study Team

(4) Outline of Metro Line 4 (Phase 2)

The outline of station location and station types are shown in Figure 5-8 and the characteristics of each station are summarized in the next page.



Source: JICA Study Team

Figure 5-8 Outline of Station Location and Station Type

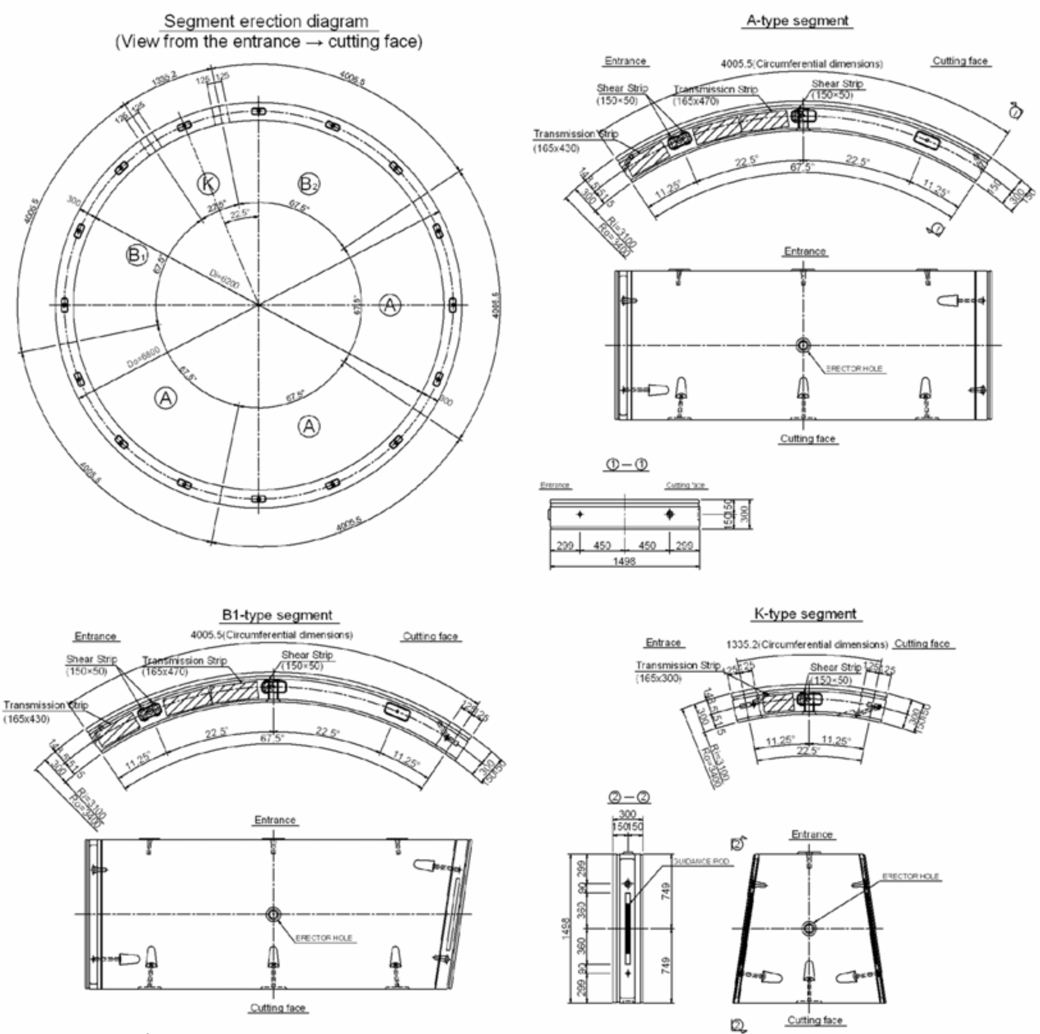
5.2.2 Tunnel Section

(1) Tunnel Structures

According to the previous basic condition, the tunnel structure is essentially the same as the one in Phase 1. The recommendation of segmental lining is shown in Table 5-7.

Table 5-7 Material and Structure of the Segmental Lining

Item		Recommendation
Main body	Material	Reinforced Concrete type
	Thickness	300mm
	Longitudinal length	1500mm
Wooterproof		Gasket type



Source: JICA Study Team

Figure 5-9 Structure of Segmental Lining

(2) Tunnel Construction Method

a) Risks and Considerations

The risks and considerations for the tunnel construction are as follows:

- Many buildings and structures are densely concentrated along the alignment of Metro Line 4. Therefore, it is required to control and minimize the ground deformation and ground surface settlement caused by the metro construction.
- Especially, it should be necessary to consider the Spine Waste Water Tunnel (SWWT) because the shield TBMs have to be driven under SWWT through approximately 4 km.
- The shield TBMs have to be launched from the launch shaft, drive and arrive to the arrival shaft in the sand stratum of small uniformity coefficient under high water pressure.
- It is necessary to control excavation and advance to prevent the deterioration of the segmental lining which would cause water leakage.

b) Countermeasures for Tunnel Construction

The solutions and countermeasures for the risks and consideration of tunnel construction are studied as follows:

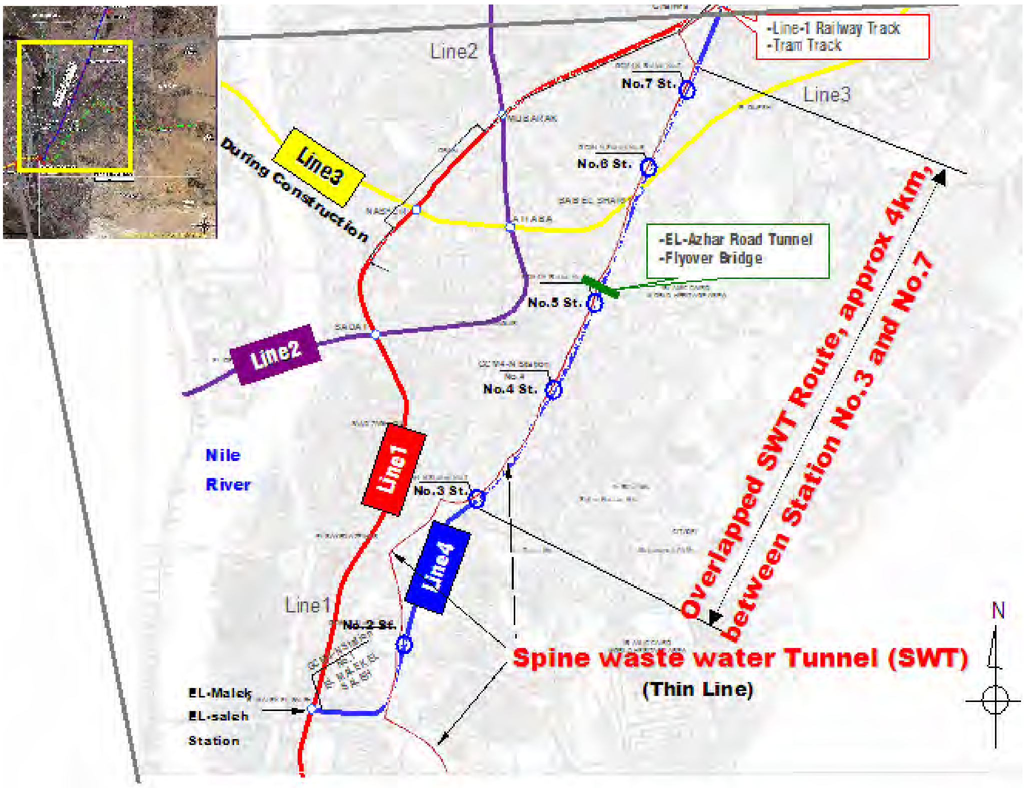
- Application of the Earth Pressure Balanced Shield (EPBS) TBM
- Minimization of the tail void
- Application of two component type backfill material
- Trial construction and measurement in similar conditions
- Post injection through the grout hole of the segmental lining
- Use of the shield TBM with soil improvement equipment at cutting face
- Use of the visualization equipment in the excavation chamber
- Installation of the radar detector on the cutter head
- Installation of the man lock in the shield TBM
- Use of the Control System of the Hydraulic Push Jacks
- Use of Fibre-reinforced Foamed Urethane (FFU) for Launch and Arrival Shaft

The details of the above solutions and countermeasures are shown in the previous Section 4.6.

(3) Countermeasures for Tunnel Construction at SWWT

The section of the route which runs parallel to the SWWT is approximately 4 km as shown in Figure 5-10. The countermeasures for SWWT which needs thorough consideration are studied as follows:

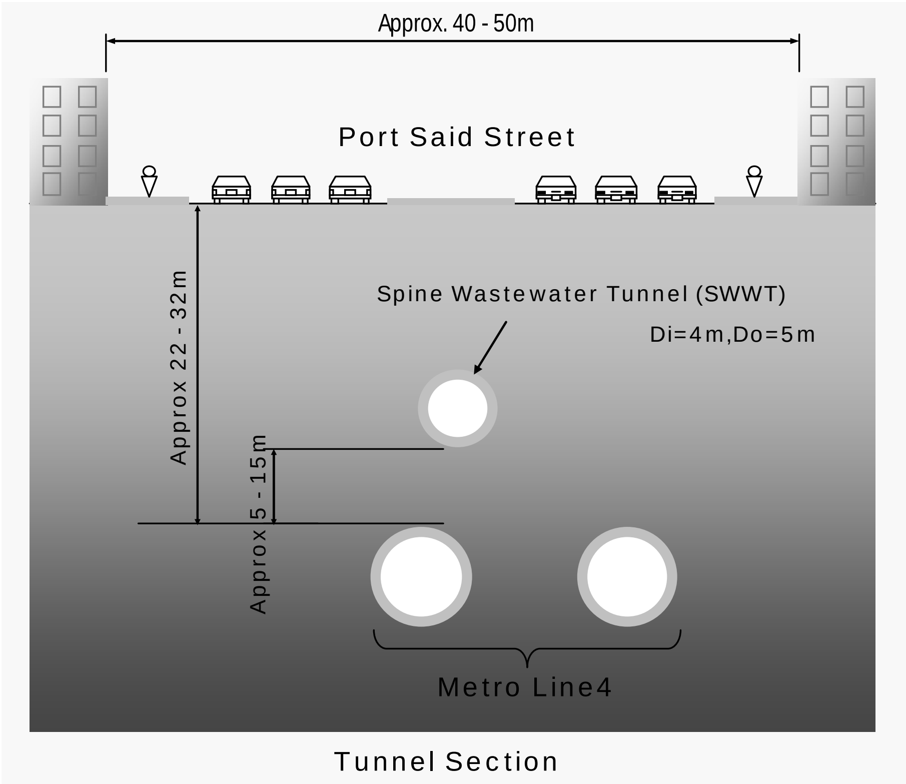
- The procedure of observation method for tunnel construction
- The survey method for large scale waste water tunnel such as SWWT



Source: JICA Study Team

Figure 5-10 Route Overlapped with SWWT

The outline of the cross section of Metro Line 4 and SWWT is shown in Figure 5-11.



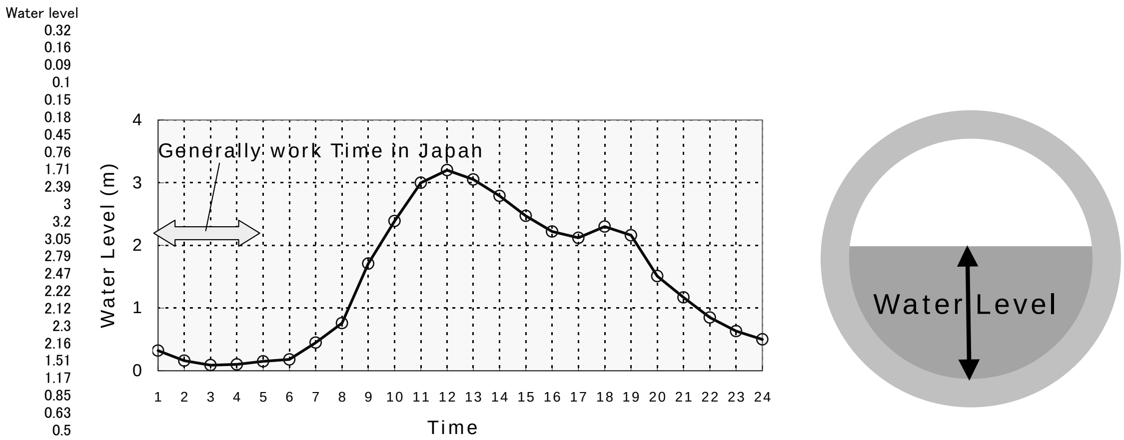
Source: JICA Study Team

Figure 5-11   Outline of Cross Section of Metro Line 4 and SWWT

a) Procedure of Observation Method for Tunnel Construction

For the construction of the tunnel under SWWT, it is necessary to know the existing condition and carry out the monitoring of the SWWT during the construction of Metro Line 4 tunnel.

In this study, actual waste water level of SWWT has not been confirmed yet. Therefore, the following two cases of the waste water level are assumed and considered. One is based on the Japanese practice that the water level usually fluctuates according to time of the day. The other is unofficial information from the sewage operation organization (HCWW), i.e., full water level throughout the day. Figure 5-12 shows the assumed waste water level based on Japanese practices.



Source: JICA Study Team

Figure 5-12 Daily Waste Water Level Image of SWWT

Therefore, the procedure of observation method of SWWT is studied based on the following 2 cases:

Case 1: Water level in SWWT is based on the Japanese practices. (The work in SWWT is possible during midnight, for approximately 4 hours.)

Case 2: Water level in SWWT is fully filled throughout the day. (The work in SWWT is impossible.)

i) Procedure for Case1

The procedure for Case1 of observation method for SWWT is as follows:

STEP 1

- Pre-checking condition of SWWT and installation of the sensor on SWWT.
- Installation of the movement sensor on ground.

STEP 2

- Setting pressure at bulk head, driving speed, backfill grouting pressure, backfill grouting volume, etc are adjusted to the most suitable condition by Trial Monitoring Method.

STEP 3

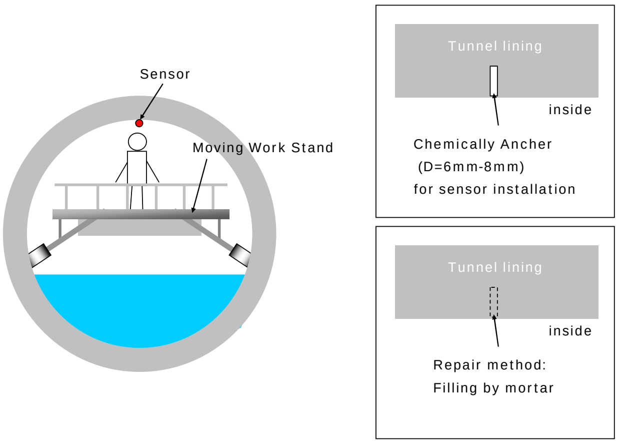
- Excavation under SWWT while keeping stability through the observation method, which is monitoring movement of SWT and control of shield TBM driving.
- Remove ground movement sensor after one month from passing tail of shield TBM.

STEP 4

- Remove SWWT movement sensor after the stability of SWWT has been confirmed.
- Final Checking Condition of SWWT.
- Completion of the neighbouring construction.

Installation of the Sensor

As a reference, how to install the sensor in SWWT is shown in Figure 5-13. This is the practice in Tokyo. In this case, the inner diameter of the waste water tunnel is 6 m larger than the SWWT.



Source: JICA Study Team

Figure 5-13 Installation of the Sensor in the Waste Water Tunnel

Movement Sensor

One of the suitable sensors is shown in Figure 5-14. This is the optical fibre sensor. The principal characteristics of this sensor are as follows:

Distributed and long range (approximately10 km) measurement can be carried out.

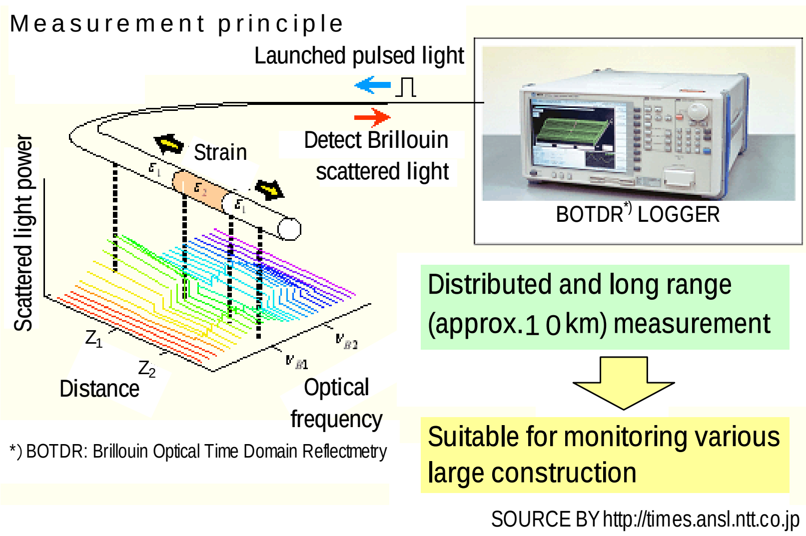
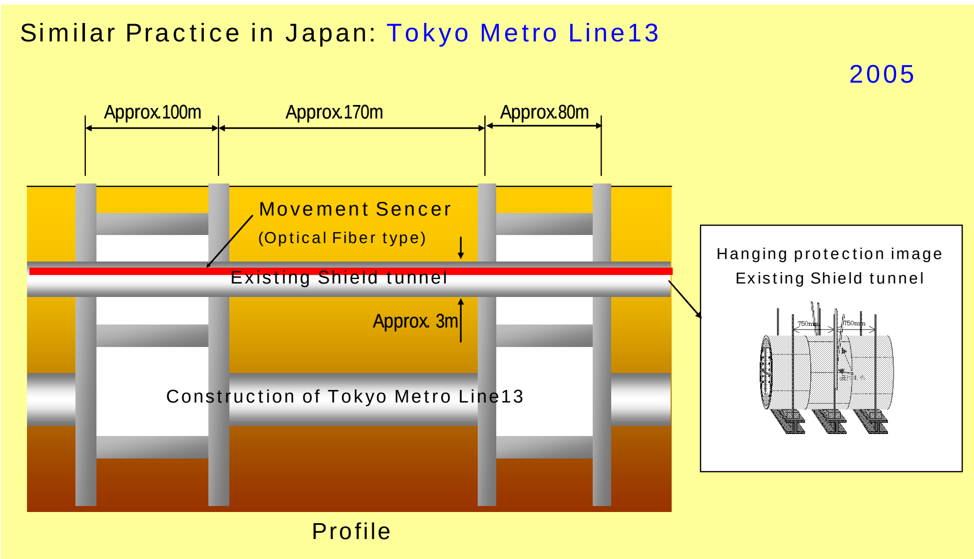


Figure 5-14 Optical Fibre Sensor

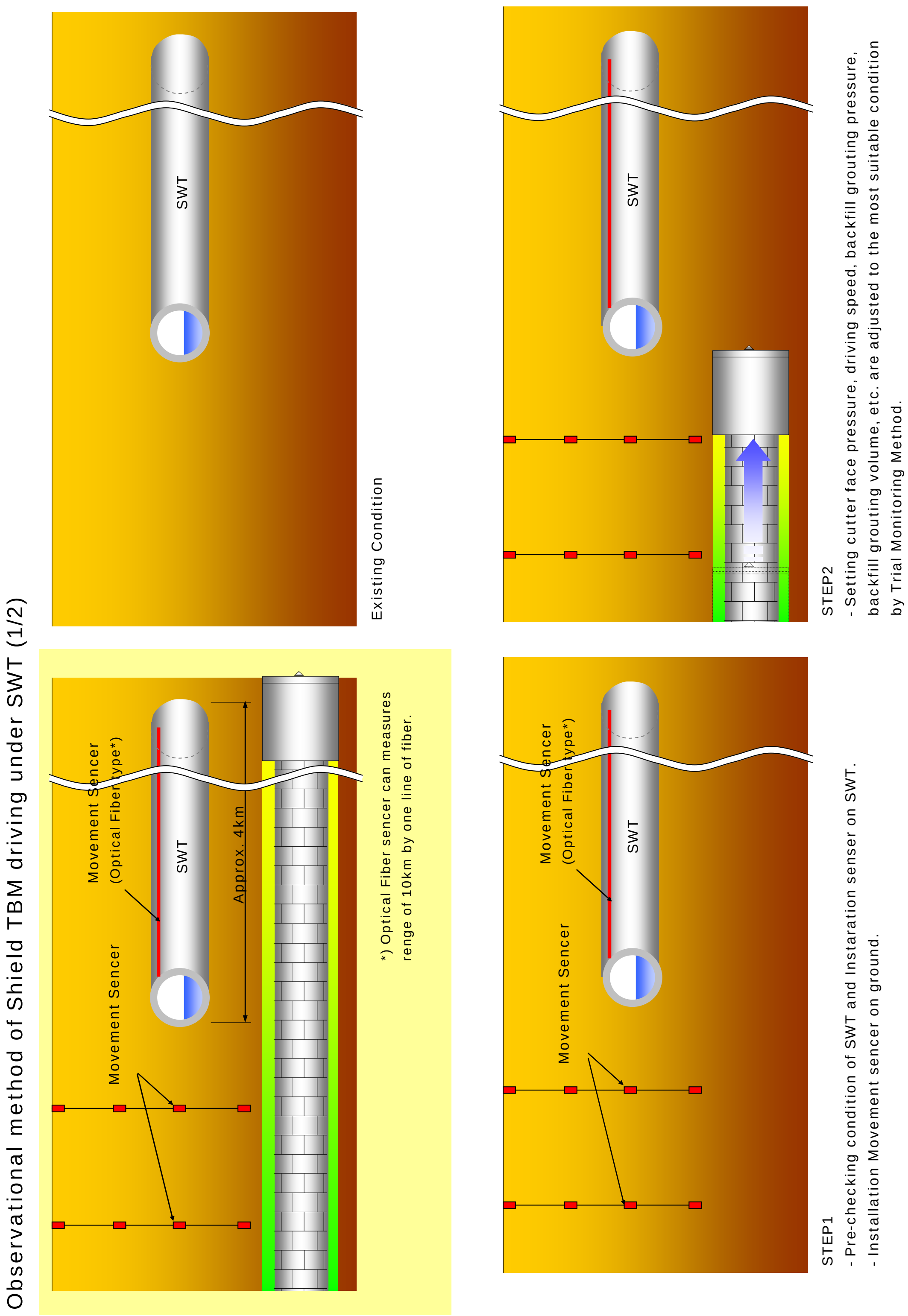
The similar practice in Japan is shown in Figure 5-15.



Source: JICA Study Team

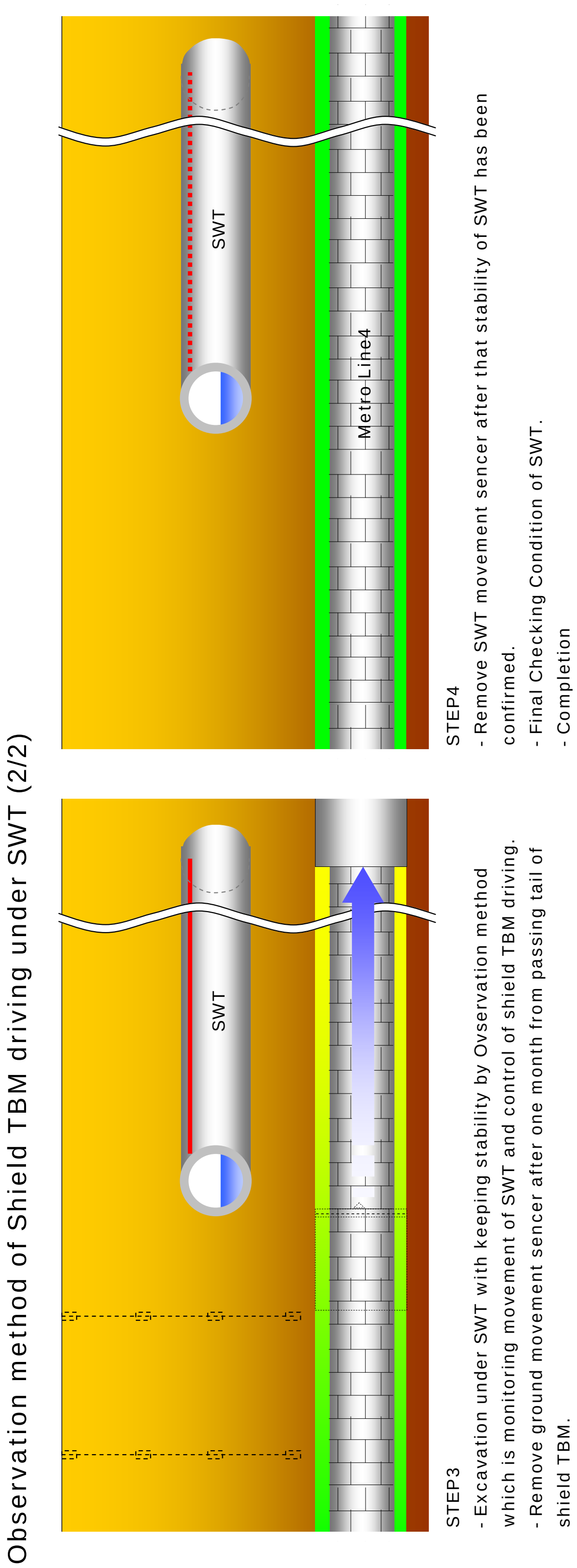
Figure 5-15 Practice of Using Optical Fibre Sensor in Tunnel

The procedure for Case 1 of observation method for SWWT is shown in Figure 5-16.



Source: JICA Study Team

Figure 5-16 Procedure (1) for Case 1 of Observation Method for SWWT



Source: JICA Study Team

Figure 5-17 Procedure (2) for Case 1 of Observation Method for SWWT

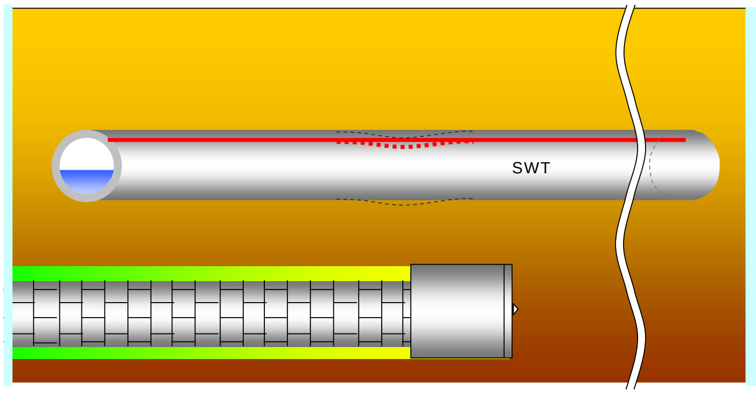
In order to secure the condition of SWWT, the particular steps during construction are taken as follows:

Particular STEP 1:

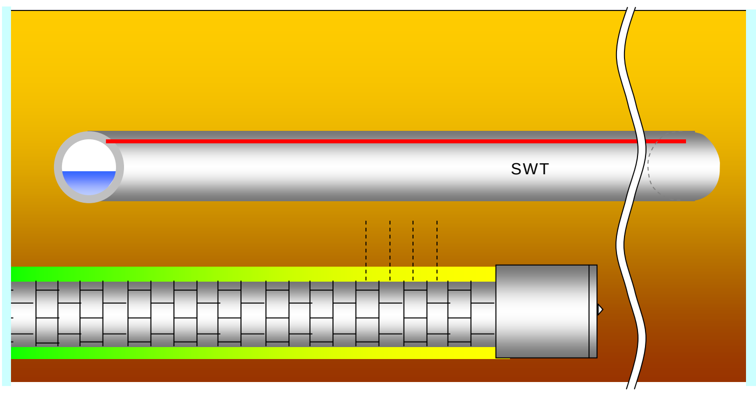
- In case that the measured strain on SWWT exceeds the control value, the frequency of monitoring will be increased and shield TBM driving will be done more carefully.

Particular STEP 2:

- Post injection from grout hole of segment will be executed for stability of the SWWT.



Particular STEP1:
- In case that the measured strain on SWT exceeds control value, the frequency of monitoring will be increased and Shield TBM driving will be driven more carefully.



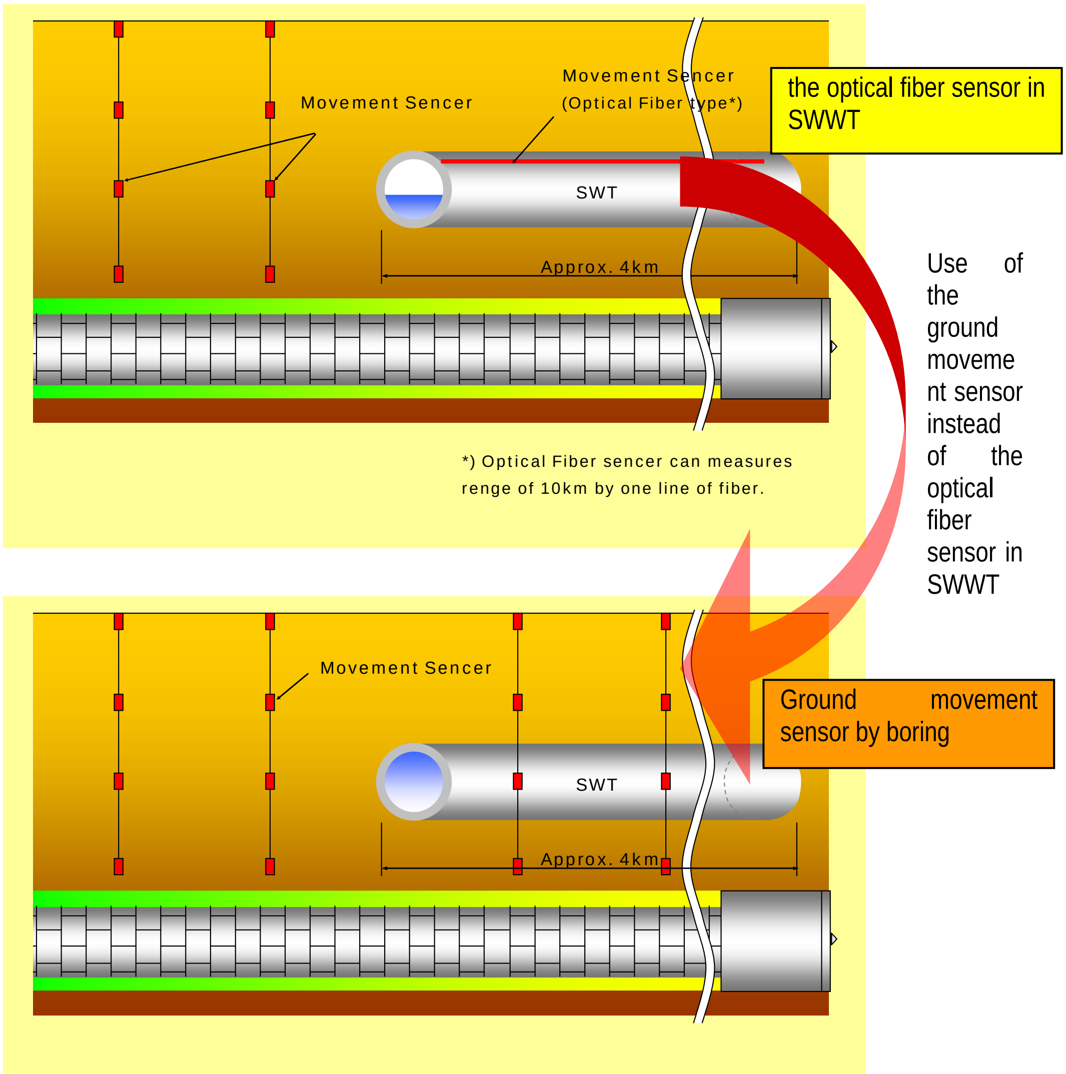
Particular STEP2:
- Post injection from grout hole of segment will be excuted for stability of SWT.

Source: JICA Study Team

Figure 5-18 Procedure for Case 1 of Observation Method for SWWT (3)

ii) Procedure for Case 2

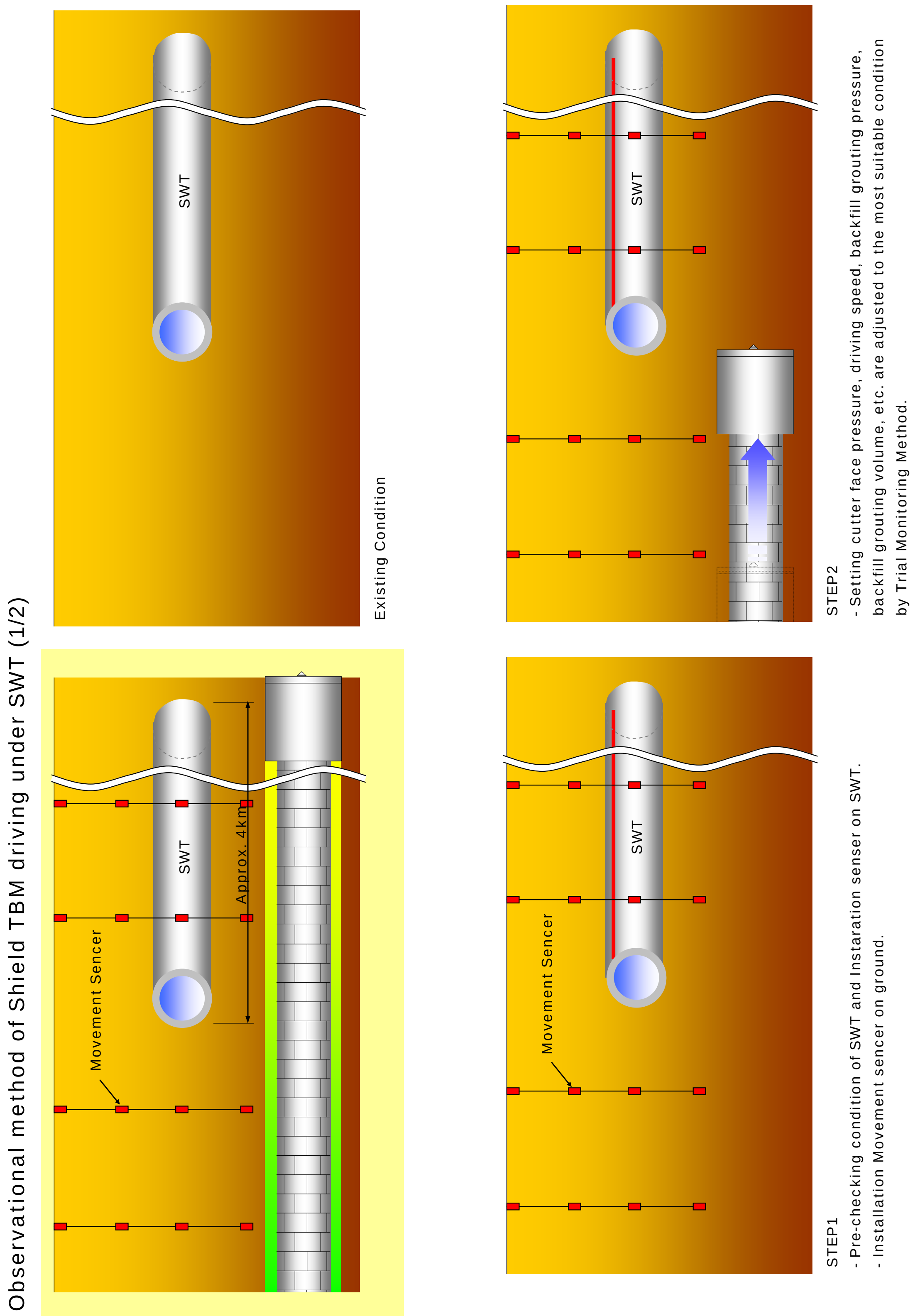
In Case 2, the water level in SWWT is fully filled all throughout the day. Thus, installation of the sensor in SWWT is impossible. Therefore, the ground movement sensor instead of the optical fibre sensor in SWWT will be used as in the following Figure 5-19.



Source: JICA Study Team

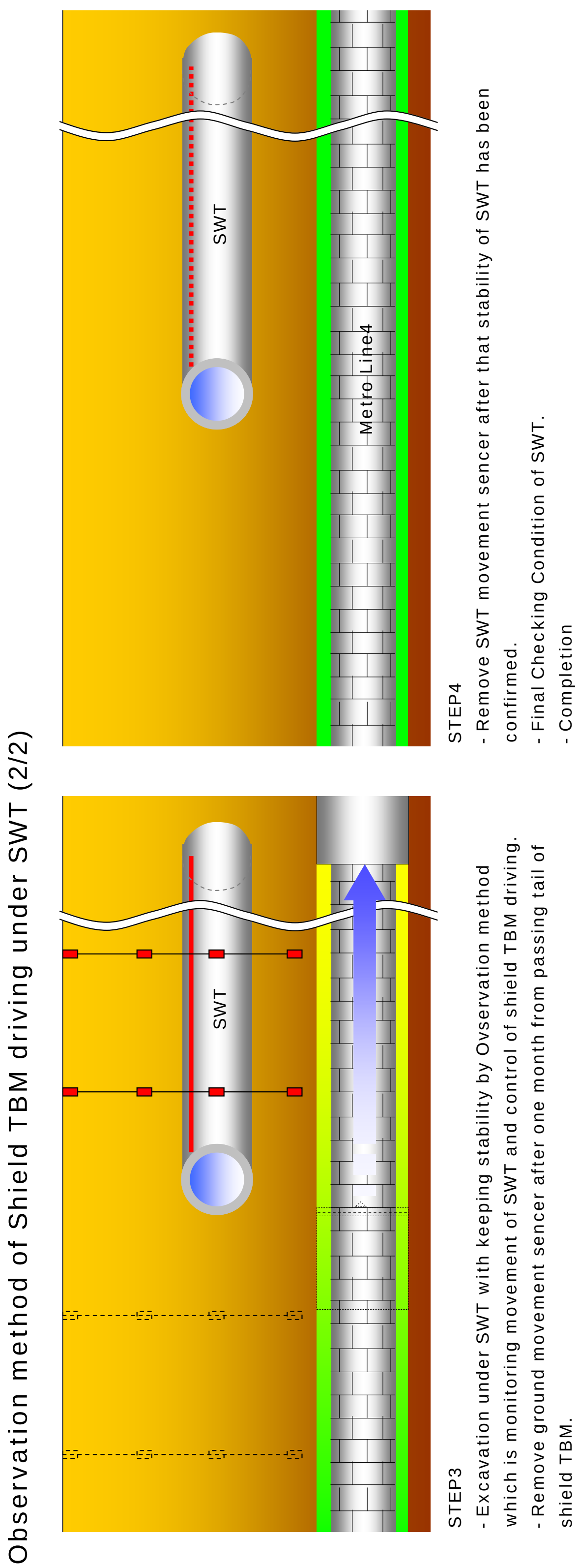
Figure 5-19 Movement Sensor in Case 2

The procedure for Case 2 of the observation method for SWWT is as follows:



Source: JICA Study Team

Figure 5-20 Procedure (1) for Case 2 of Observation Method for SWWT



Source: JICA Study Team

Figure 5-21 Procedure (2) for Case2 of Observation Method for SWWT

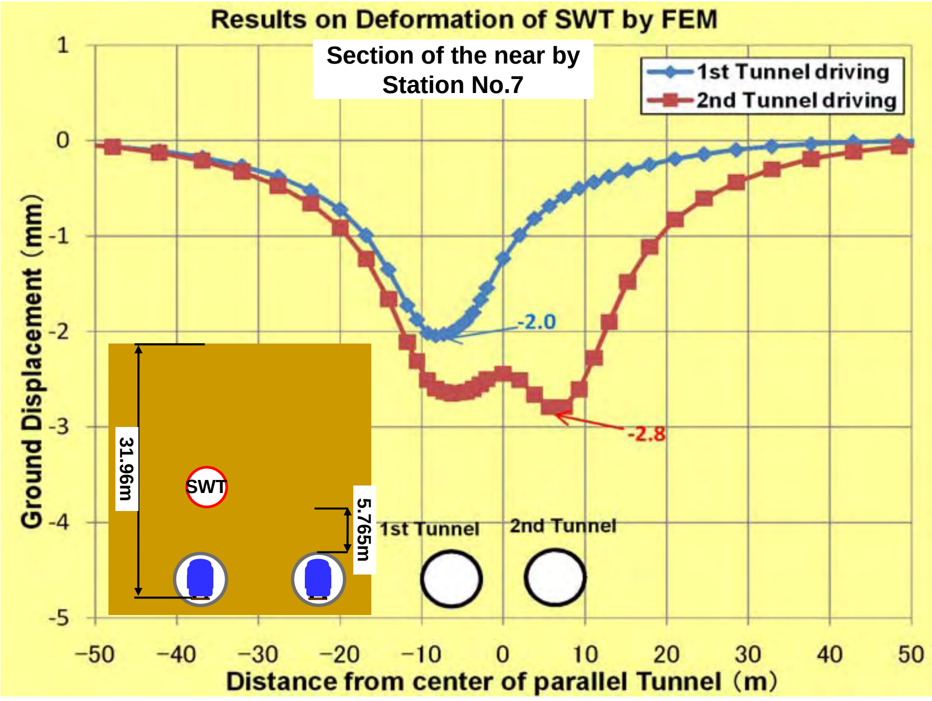
b) Estimation of Deformation of SWWT

To estimate the impact to SWWT by the tunnel construction, simulation analysis of the finite element method (FEM) is conducted. The estimated result for the deformation of the SWWT is shown in Figure 5-22.

According to the result, the deformation of SWWT due to the tunnel construction is estimated to be approximately 3 mm.

Generally, the allowable deformation of the shield tunnel such as SWWT is approximately 10 mm. Therefore, the harmful influence on SWWT will not occur.

In general, however, the actual displacement will be different from the result of simulation because the simulation is conducted using limited data such as geological boring survey data. Therefore, the observation method should be conducted during the actual construction.



Source: JICA Study Team

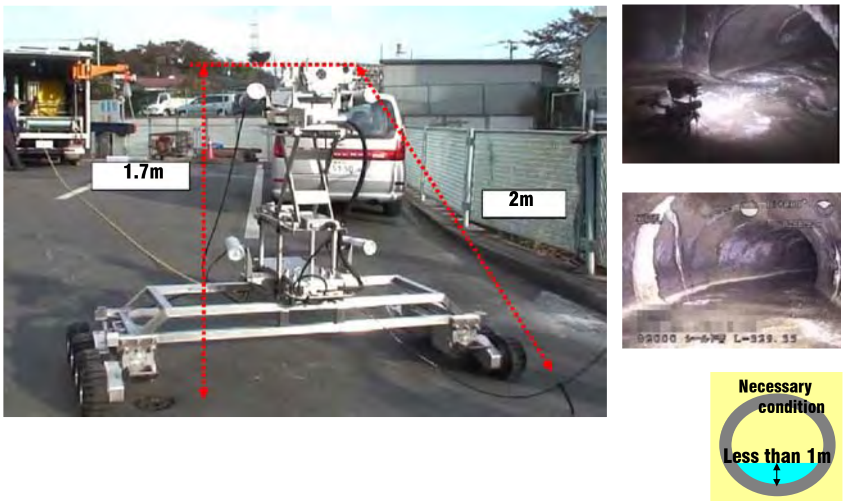
Figure 5-22 Estimated Result on Deformation of SWWT

c) Survey Method for Large-Scale Waste Water Tunnel such as SWWT

In order to secure the condition of the SWWT, it is important to confirm its current condition for determining its allowable deformation and to design the tunnel taking all the information into account.

There are survey practices for large waste water tunnels in Japan. In this section, Japanese advance technology for the survey is introduced as shown in Figure 5-23.

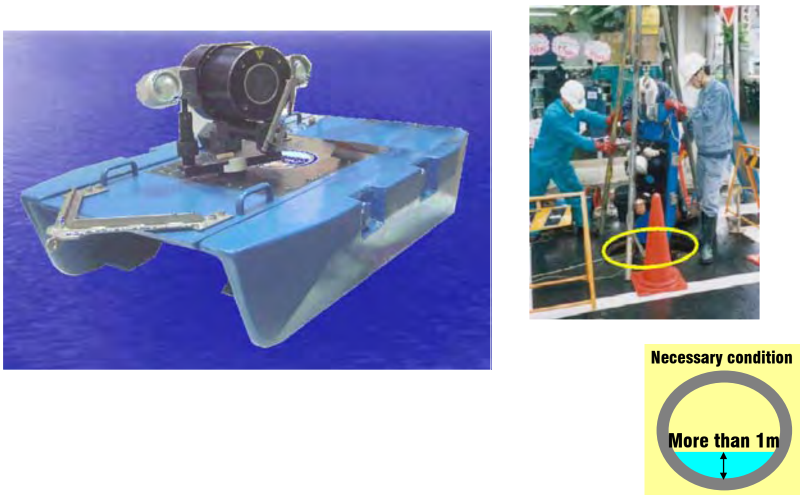
i) In case the water level is less than 1 m in a tunnel



Source: JICA Study Team

Figure 5-23 Moving Car Type Survey Equipment

ii) In case the water level is more than 1 m in a tunnel



Source: JICA Study Team

Figure 5-24 Boat Type Survey Equipment

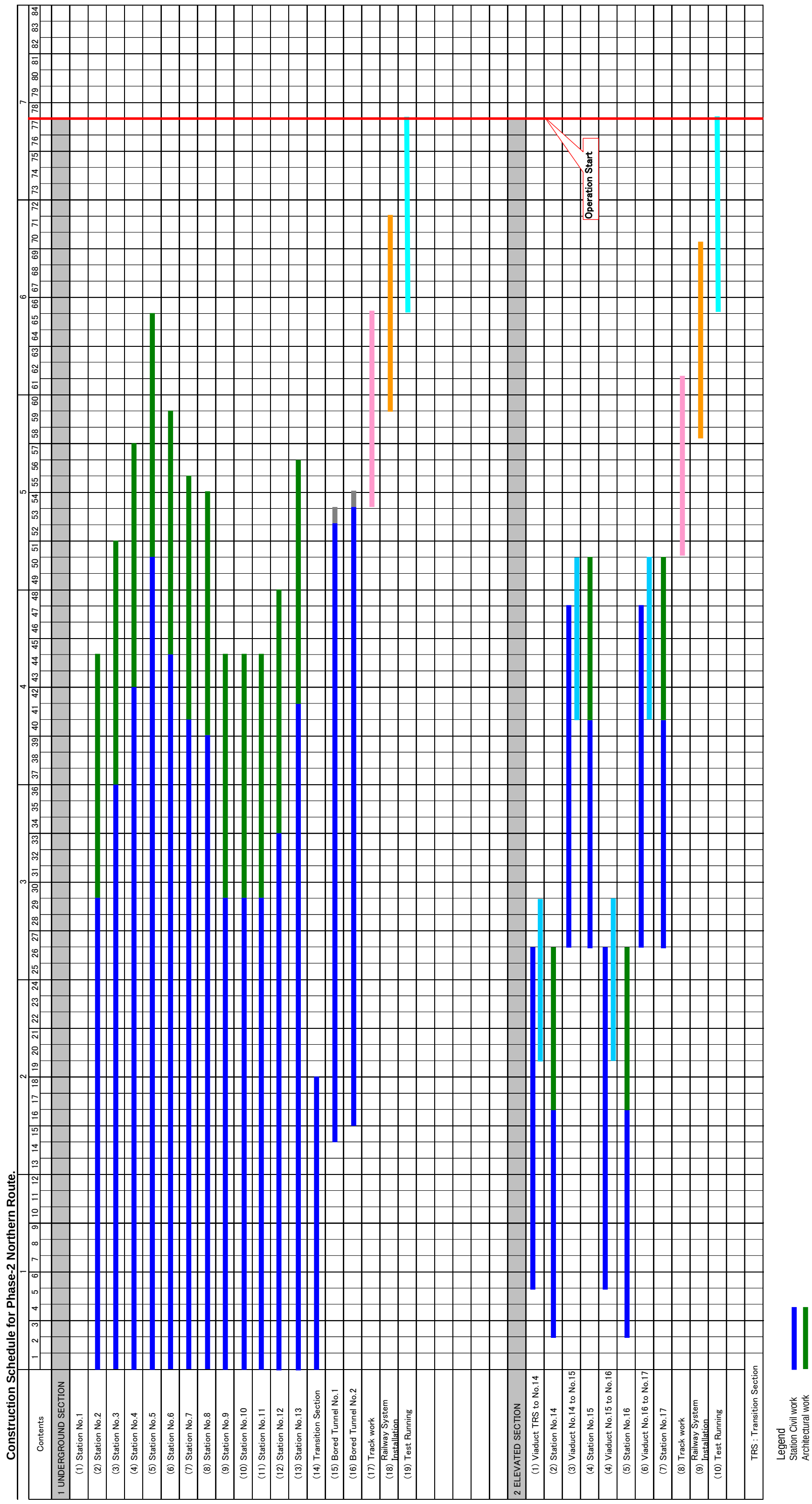
(4) Construction Schedule

The schedule of the tunnel construction is studied. It is found from the geological survey that a risky geological stratum exists in the project area. Therefore, the construction plan is carried out taking safe construction into consideration.

The driving speed of shield TBM is considered to be approximately 300 m/month according to the Phase 1 study.

The proposed number of shield TBM for Phase 2 section is two sets, which is similar to the result shown in Report No. 2. Regarding the construction period, the period of shield tunnelling work is extended from 33 to 38 months. However, the whole construction period is not affected and extended because the period of shield tunnelling work was not on critical path. Therefore, the construction period for Phase 2 is approximately 6.5 years.

The construction schedule for Phase 2 is shown in the next page.



Source: JICA Study Team

Figure 5-25 Construction Schedule for Phase 2

5.2.3 Underground Stations

Table 5-8 Outline of Metro Line 4 Underground Stations (Phase 2)

	M4N Station No. 1	M4N Station No. 2	M4N Station No. 3
Tentative name	EL Malek EL Saleh	—	—
Platform type	island side	island	Island
Length of station	190 m	190 m	190 m
Inner width of station	26.0 m	21.0 m	21.0 m
Number of storey	4	3	3
Depth of station	32.0 m	25.6 m	30.6 m
Remarks	Phase 1 turn-back Transfer to Metro Line 1 station plaza	turn-back	

	M4N Station No. 4	M4N Station No. 5	M4N Station No. 6
Tentative name	—	—	Bab EL Shaaria
Platform type	island	island	island
Length of station	190 m	190 m	190 m
Inner width of station	21.0 m	21.0 m	21.0 m
Number of storey	3	5	5
Depth of station	30.6 m	41.6 m	41.6 m
Remarks			

	M4N Station No. 7	M4N Station No. 8	M4N Station No. 9
Tentative name	—	Ghamrah	—
Platform type	island	island	island
Length of station	190 m	190 m	190 m
Inner width of station	21.0 m	21.0 m	21.0 m
Number of Story	4	4	3
Depth of station	35.6 m	31.6 m	24.6 m
Remarks		turn-back	turn-back

	M4N Station No. 10	M4N Station No. 11	M4N Station No. 12	M4N Station No. 13
Tentative name	—	—	—	—
Platform type	island	island	Island	islands
Length of station	190 m	190 m	190 m	190 m
Inner width of station	21.0 m	21.0 m	21.0 m	21.0 m
Number of storey	3	3	3	3
Depth of station	25.6 m	25.6 m	24.6 m	24.6 m
Remarks				turn-back

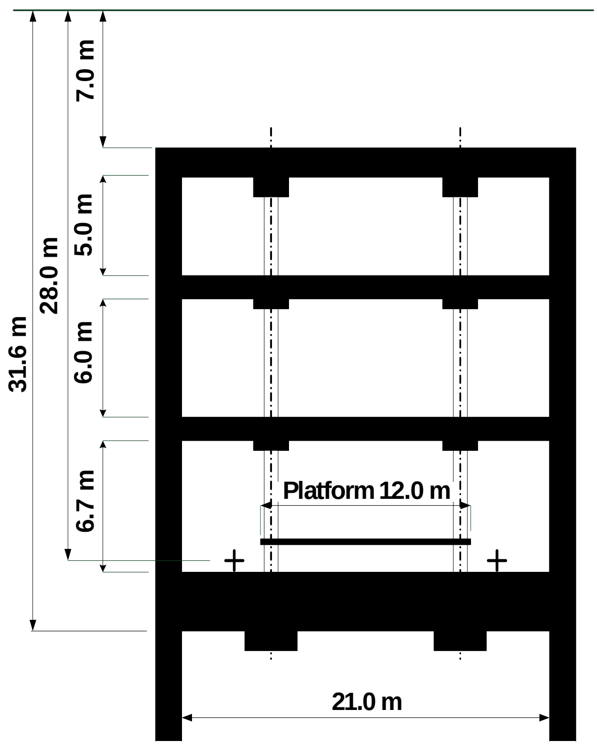
Note: M4N means Metro - Line 4 - North
Source: JICA Study Team

(1) Typical Underground Station (Standard Station)

Section of standard platform structure is shown in Figure 5-25.

Characteristics of the structure are as follows:

- Standard type is proposed as three storeys and a three-span rigid-frame in order to reduce the construction cost.
- Structural columns of the station shall be combined with the columns of the PSD to ensure adequate space.



Source: JICA Study Team

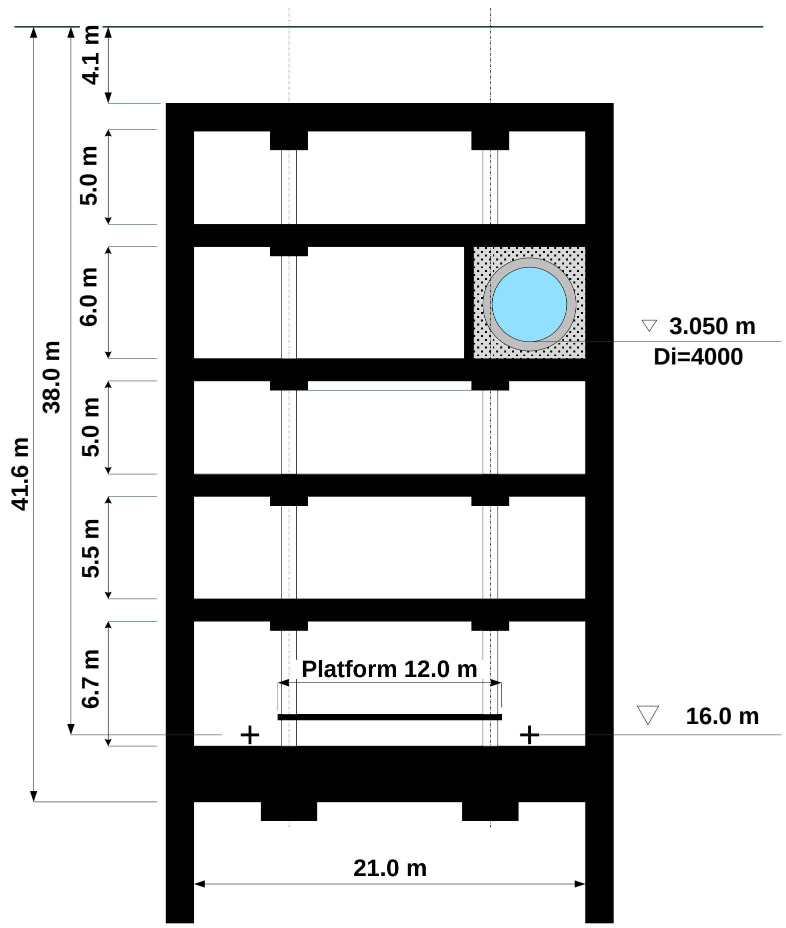
Figure 5-25 Cross Section of Typical Station (3 storeys)

(2) Station for Special Requirements (Including Existing SWWT)

One of the stations which require special and technical consideration is shown in Figure 5-27.

The characteristic of such structure is as follows:

- Station structure is proposed as five storeys and three-span rigid-frame.
- Structural columns of station shall be combined with columns of the PSD to ensure adequate space.
- Station structure contains the existing SWWT.

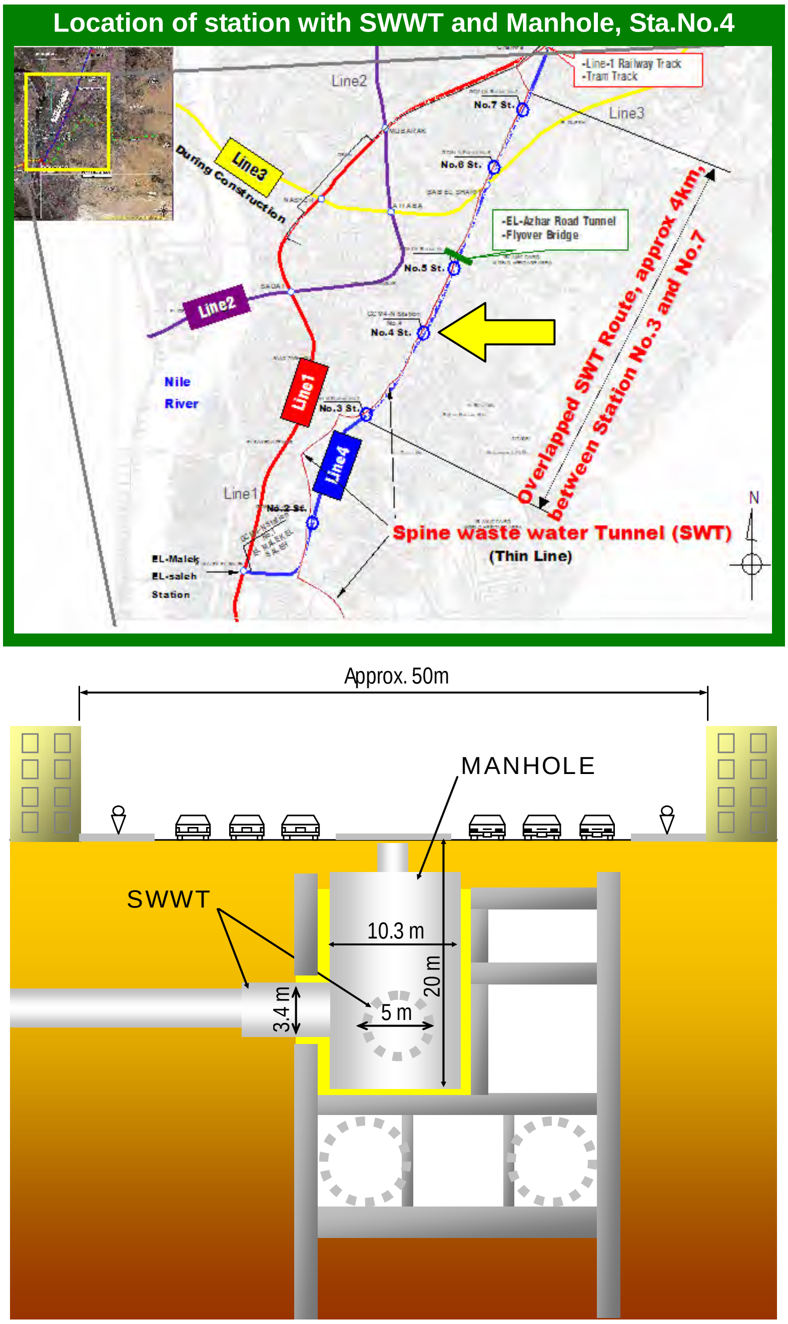


Source: JICA Study Team

Figure 5-27 Station for Special Requirements

(3) Further Study on the Construction Method for SWWT

Station No. 4, where the SWWT and its manhole are located, is shown in Figure 5-26. The construction of this station will be most difficult due to the existence of the manhole. Compared with the construction of Sta. No.4, the construction of other stations would be easier. The construction method for Sta. No. 4 is explained as below:



Note: This figure is modified to simplify the explanation of the construction method.

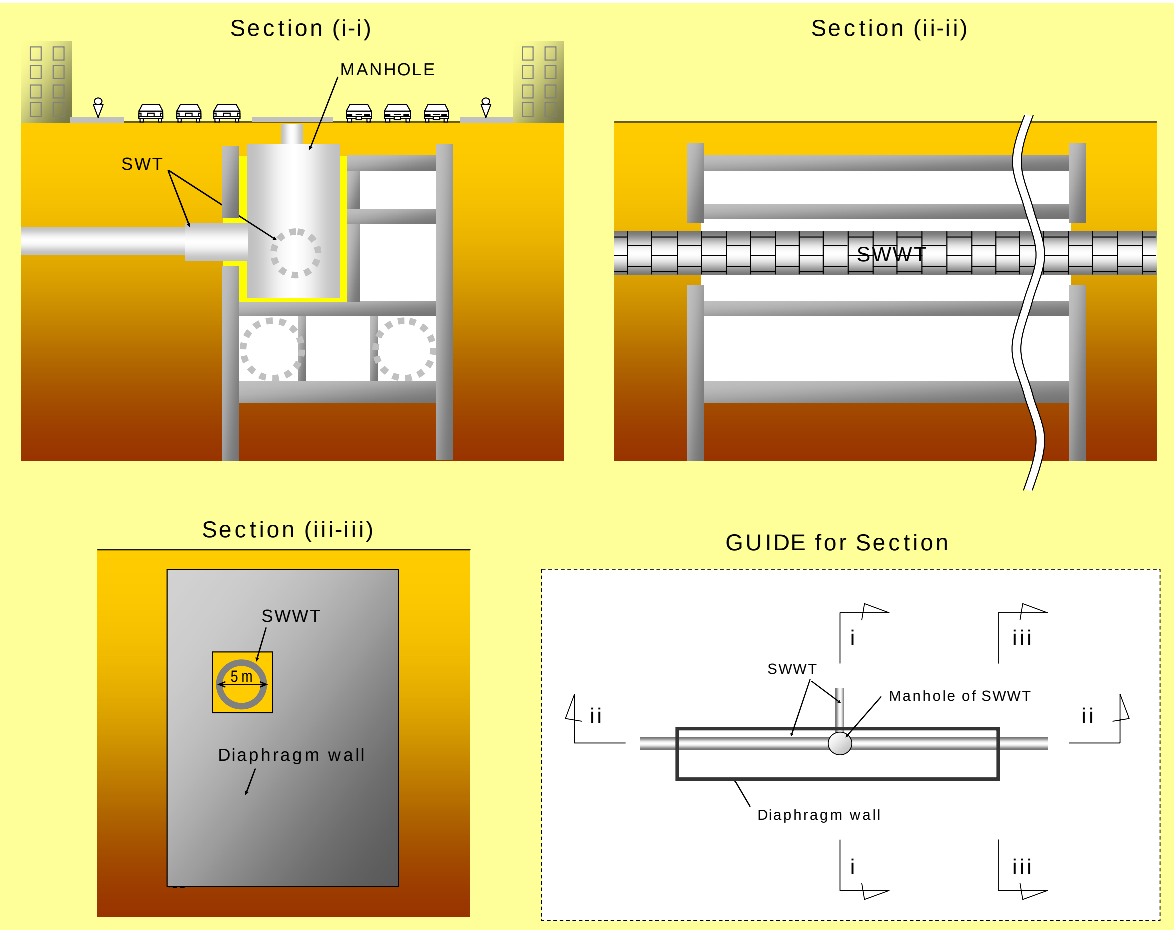
Source: JICA Study Team

Figure 5-26 Cross Section of Station with SWWT and its Manhole

Regarding the construction of the station with SWWT and its manhole, the principal technical issues are as follows:

- How to construct the underpinning for the large manhole
- How to construct the underpinning for SWWT of large tunnel
- How to construct the installation of the diaphragm wall at the obstacle tunnel

Figure 5-27 shows the section related to the above three issues.



Source: JICA Study Team

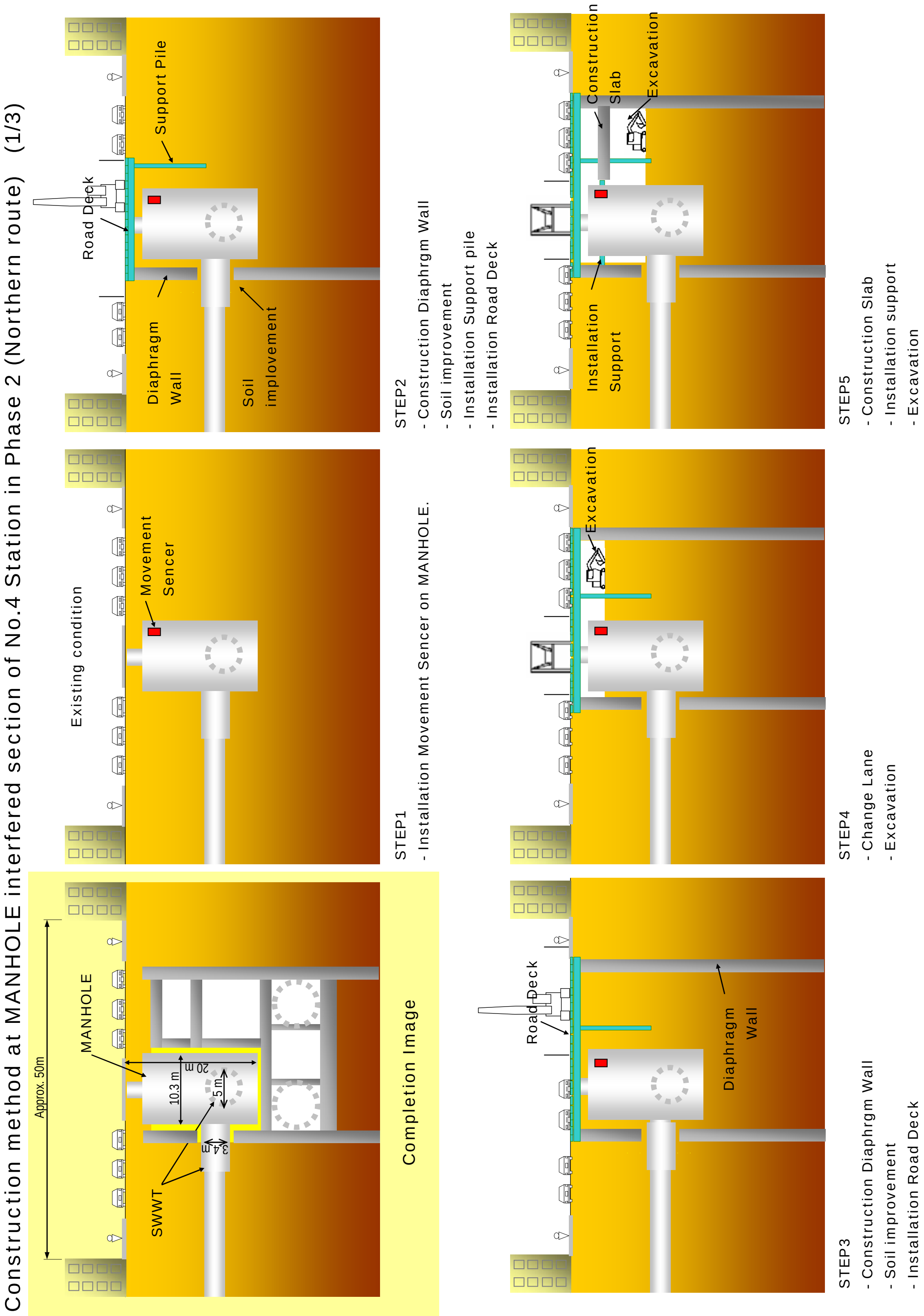
Figure 5-27 Sections Based on Technical Study

a) Construction Method at the Manhole-affected Section of Station

In this study, the principal considerations are as follows:

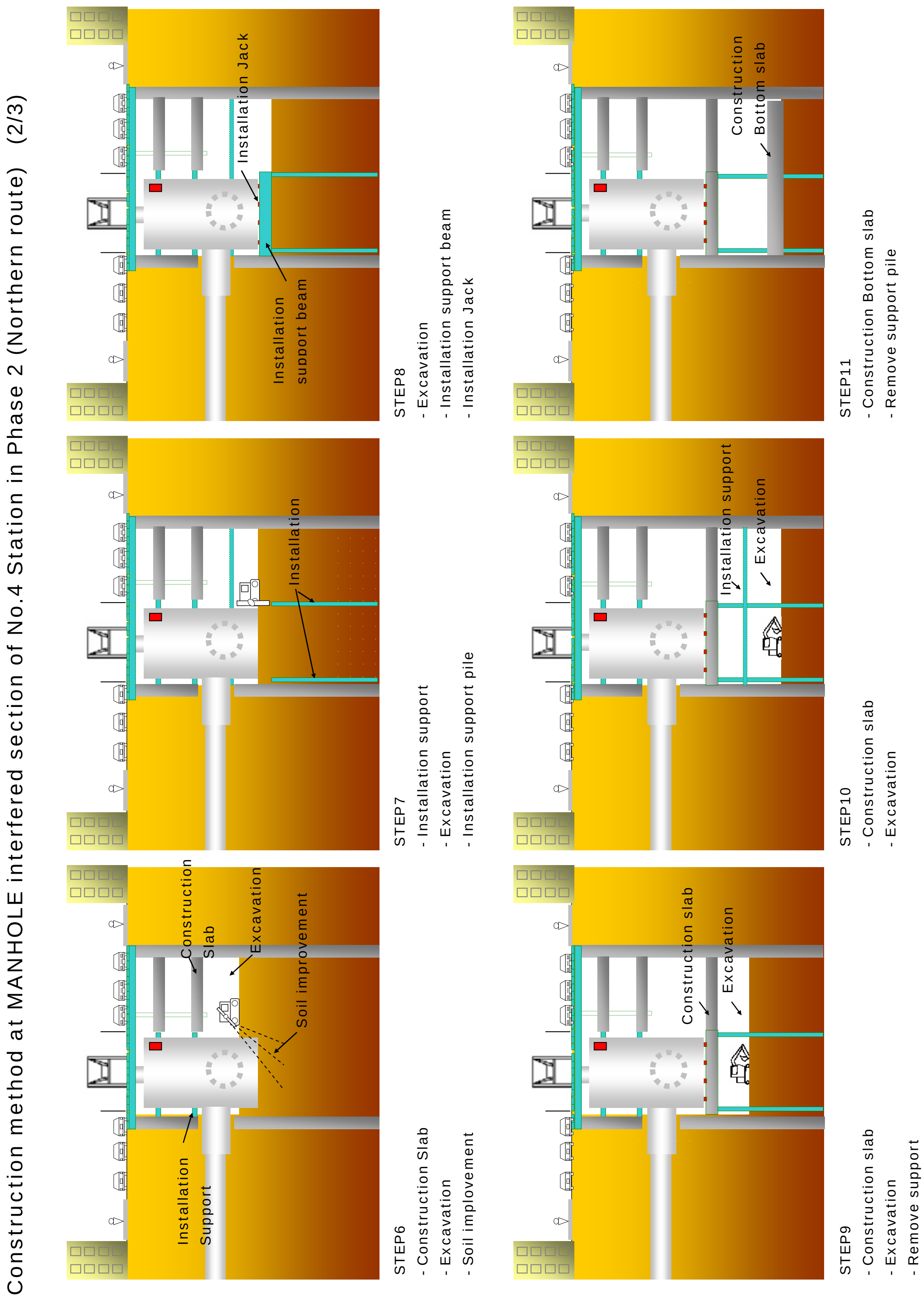
- Keeping the safety of the manhole of SWWT
- Waterproof of ground water
- Mitigation of impact to the existing traffic

Considering above, the procedure for construction using 17 steps is shown in Figure 5-28 to Figure 5-30.



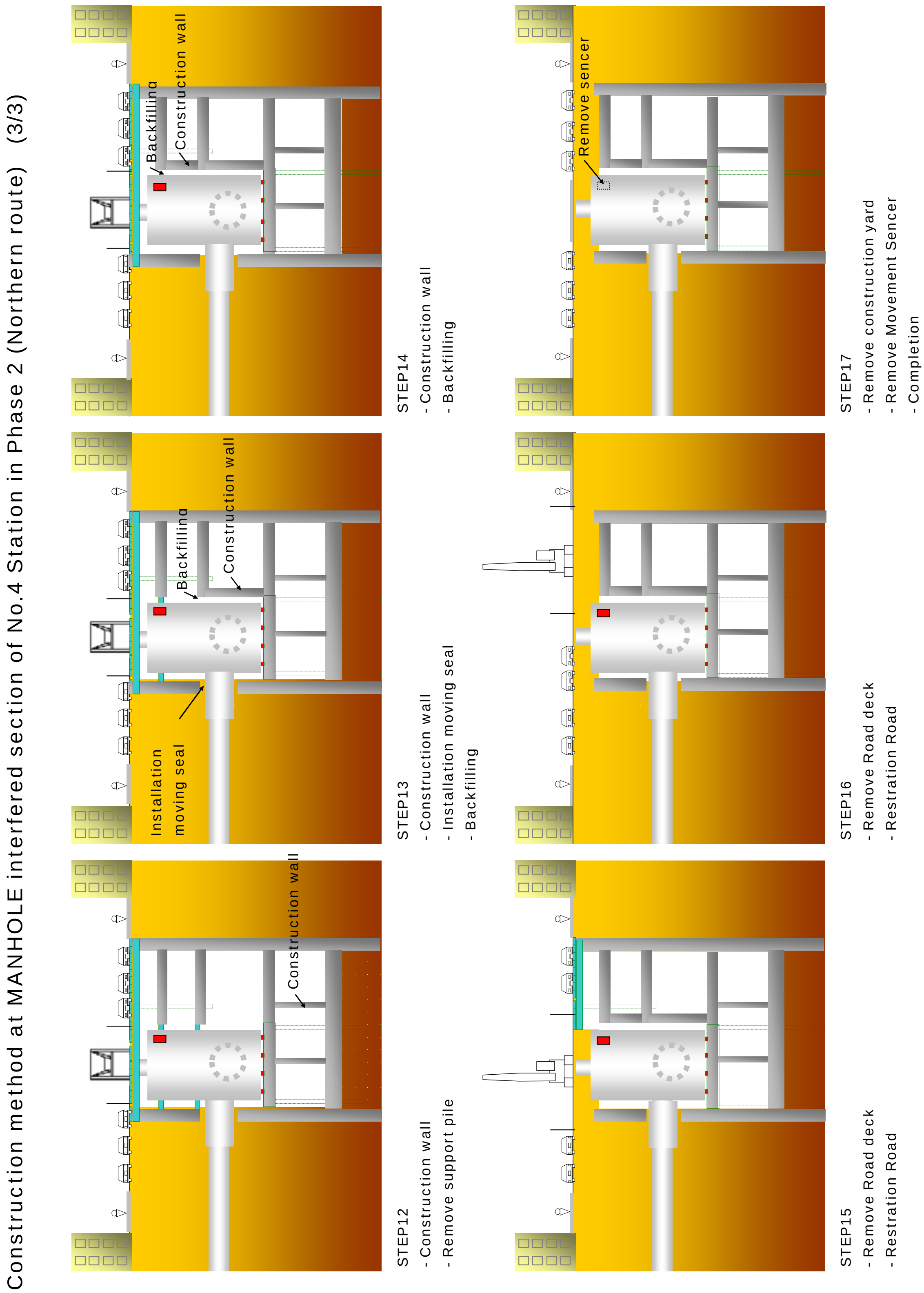
Source: JICA Study Team

Figure 5-28 Construction Method (1) for the Manhole-affected Section of Station



Source: JICA Study Team

Figure 5-29 Construction Method (2) for the Manhole-affected Section of Station



Source: JICA Study Team

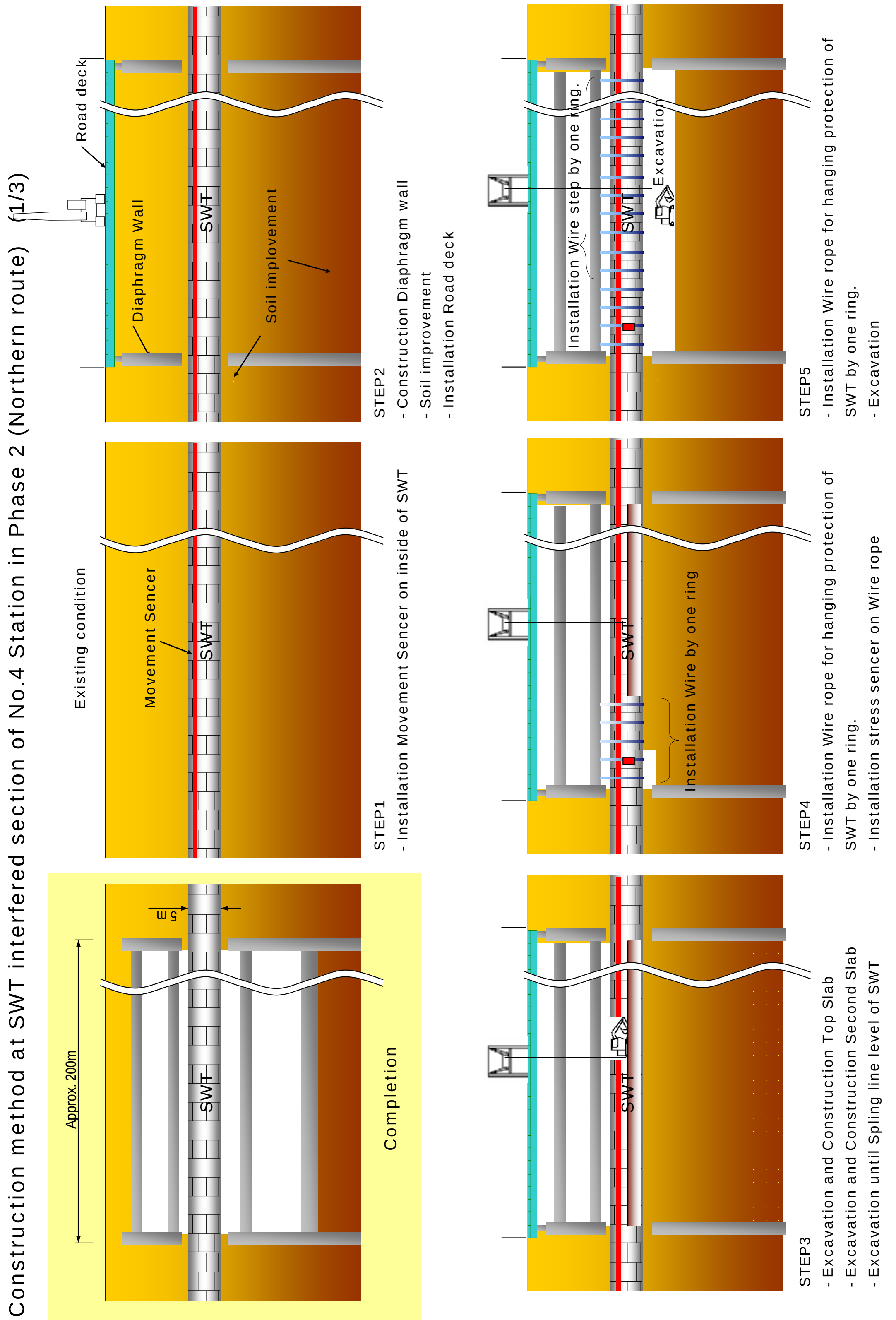
Figure 5-30　Construction Method (3) for the Manhole-affected Section of Station

b) Construction Method for the SWWT-affected Section of the Station

In this study, the principal considerations are as follows:

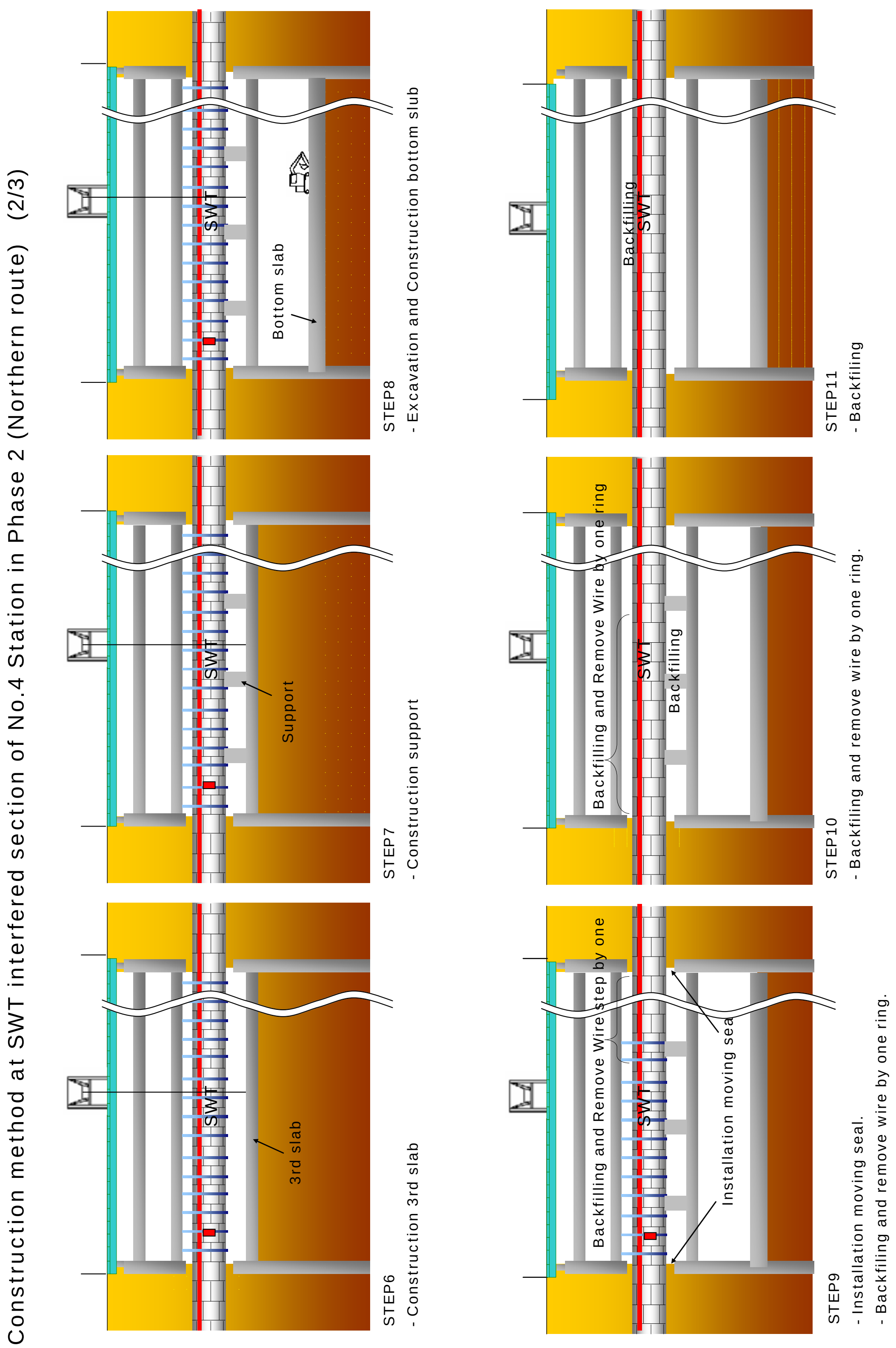
- Keeping SWWT safe
- Waterproofing of ground water
- Countermeasure against different movements of SWWT and Station

Considering the above, the procedure for construction using 13 steps is shown in Figure 5-31 to Figure 5-33.



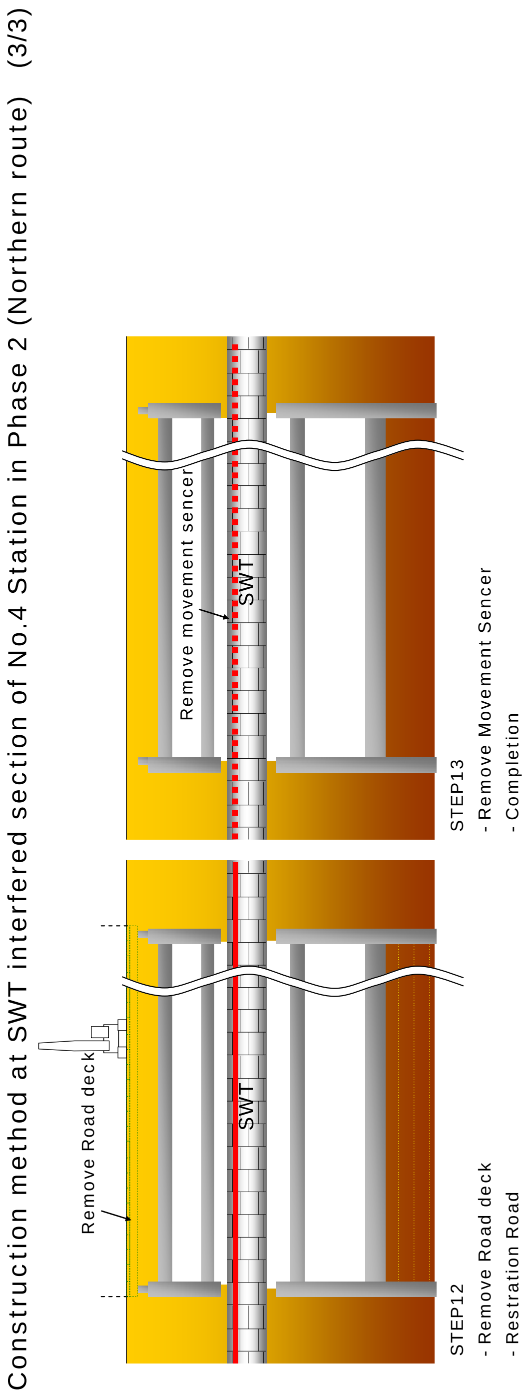
Source: JICA Study Team

Figure 5-31　Construction Method (1) for the SWWT-affected Section of the Station



Source: JICA Study Team

Figure 5-32 Construction Method (2) for the SWWT-affected Section of the Station



Source: JICA Study Team

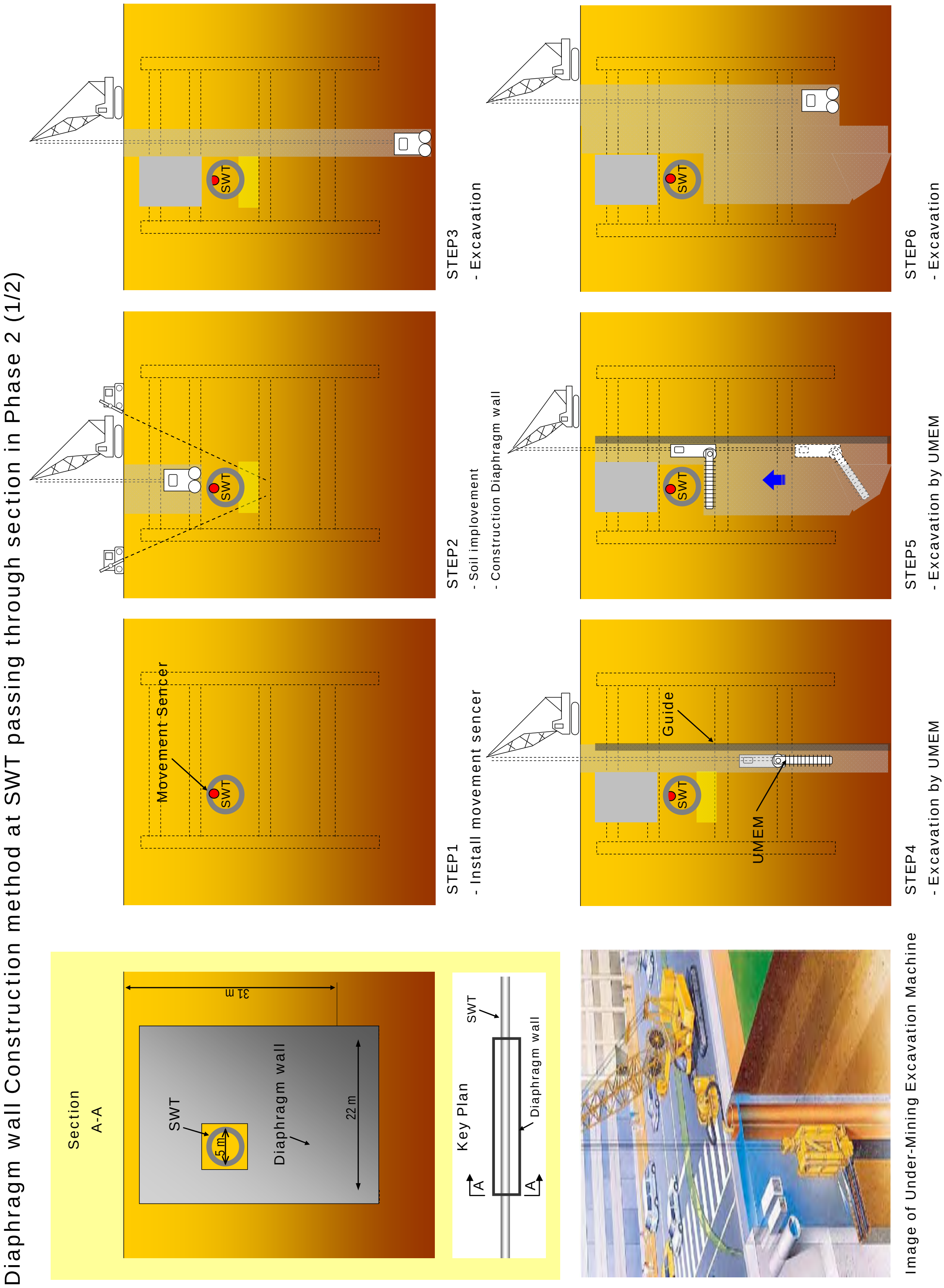
Figure 5-33 Construction Method (3) for the SWWT-affected Section of the Station

c) Diaphragm Wall Construction Method at SWWT Passing Through Section

In this study, the principal considerations are as follows:

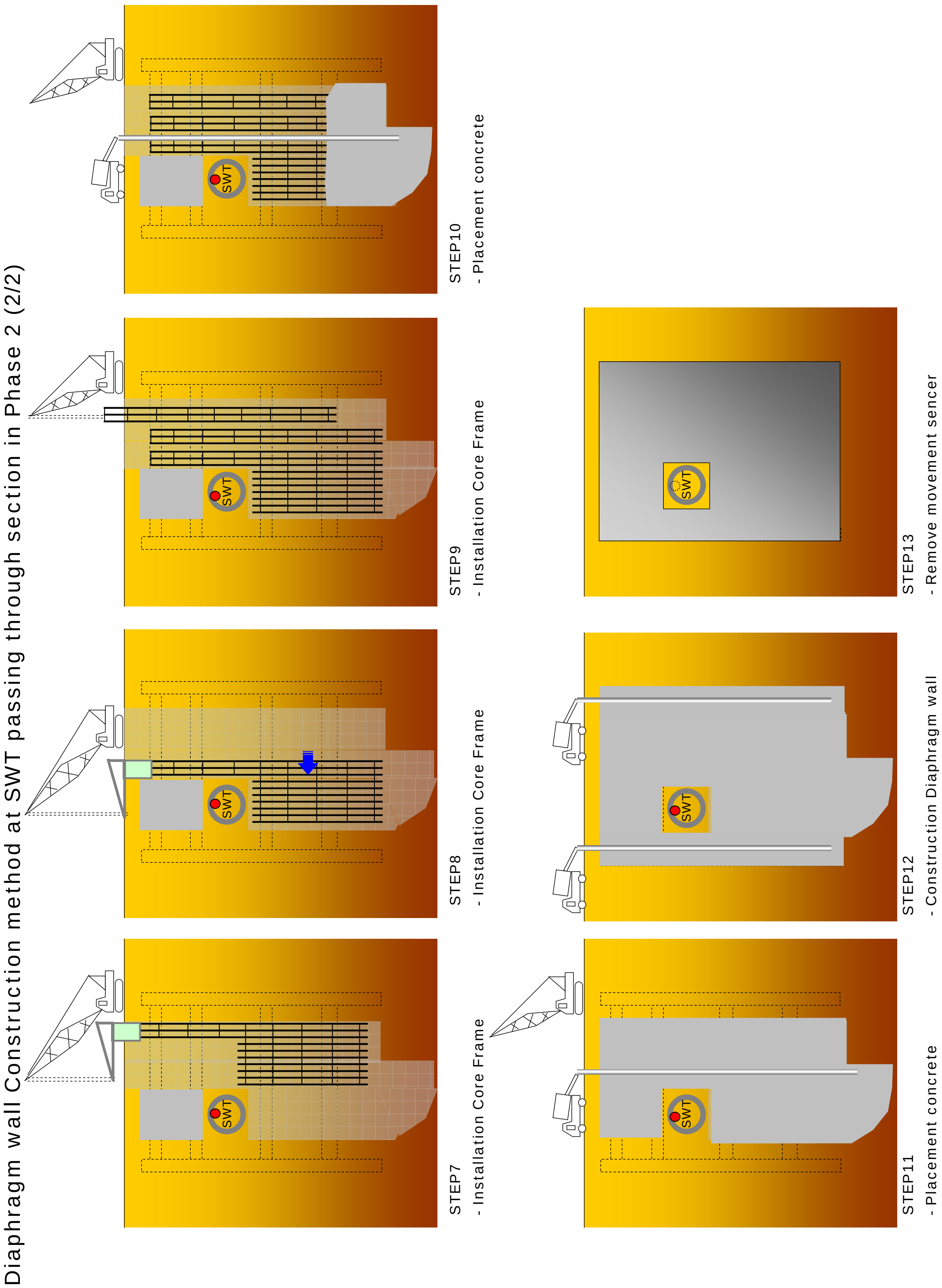
- Keeping SWWT safe
- Waterproof of ground water
- Countermeasure against the different movements of SWWT and Station

Considering the above, the procedures of construction using 13 steps are shown in Figure 5-34 and Figure 5-35.



Source: JICA Study Team

Figure 5-34 Construction Method (1) for Underpinning of Large Manhole

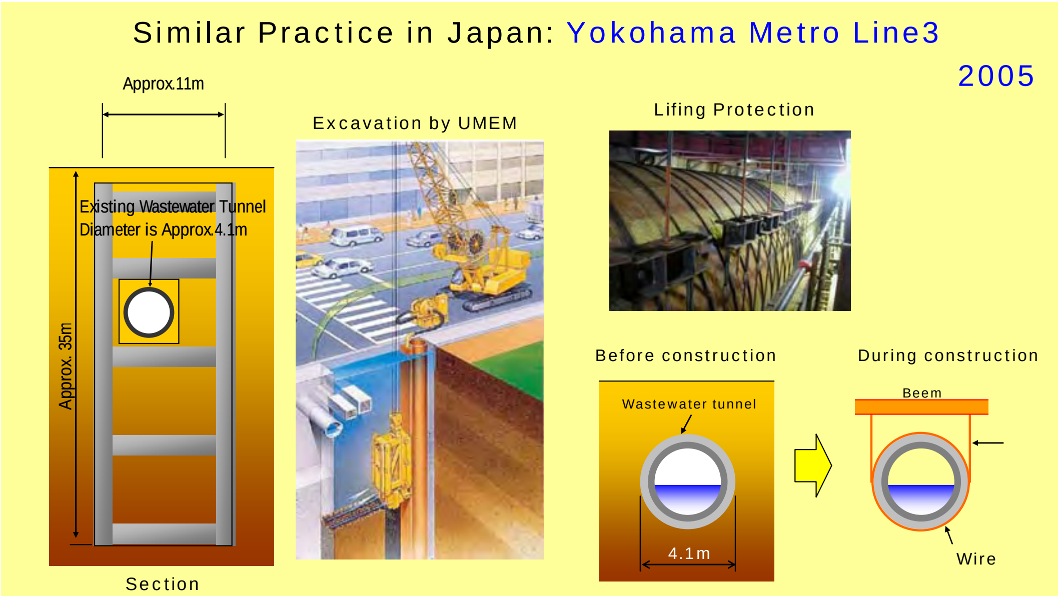


Source: JICA Study Team

Figure 5-35 Construction Method (2) for Underpinning of Large Manhole

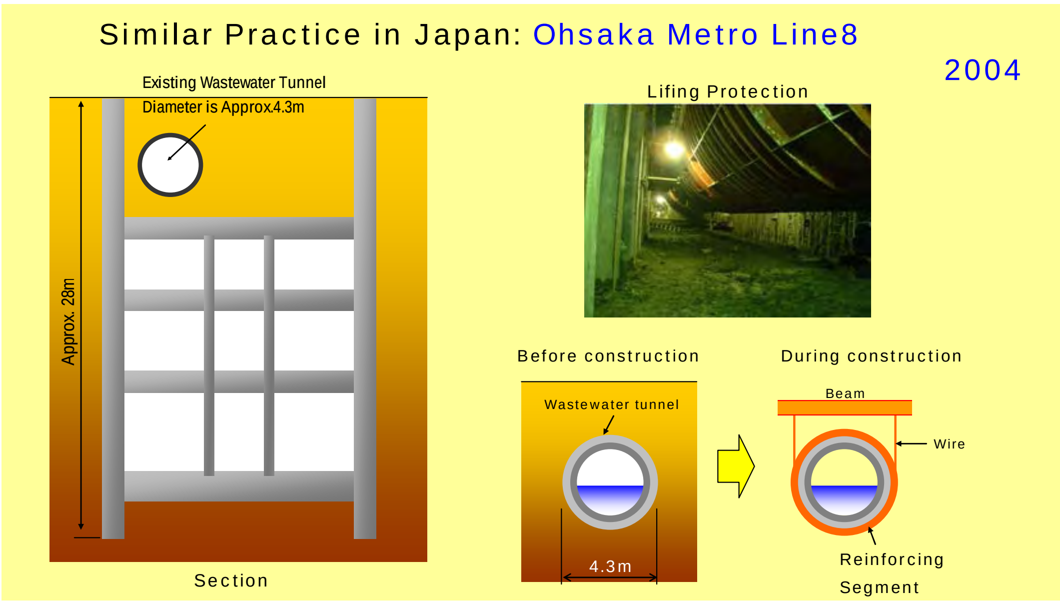
d) Similar Construction Practice with Existing Wastewater Tunnel

There are similar construction practices implemented in Japan where existing large wastewater tunnels need to be avoided. The outline of such similar practices is shown in Figure 5-36 and Figure 5-37. These were safely completed without any damage and deterioration caused to the existing large waste water tunnel.



Source: JICA Study Team

Figure 5-36 Similar Construction Practice (1) with Existing Wastewater Tunnel



Source: JICA Study Team

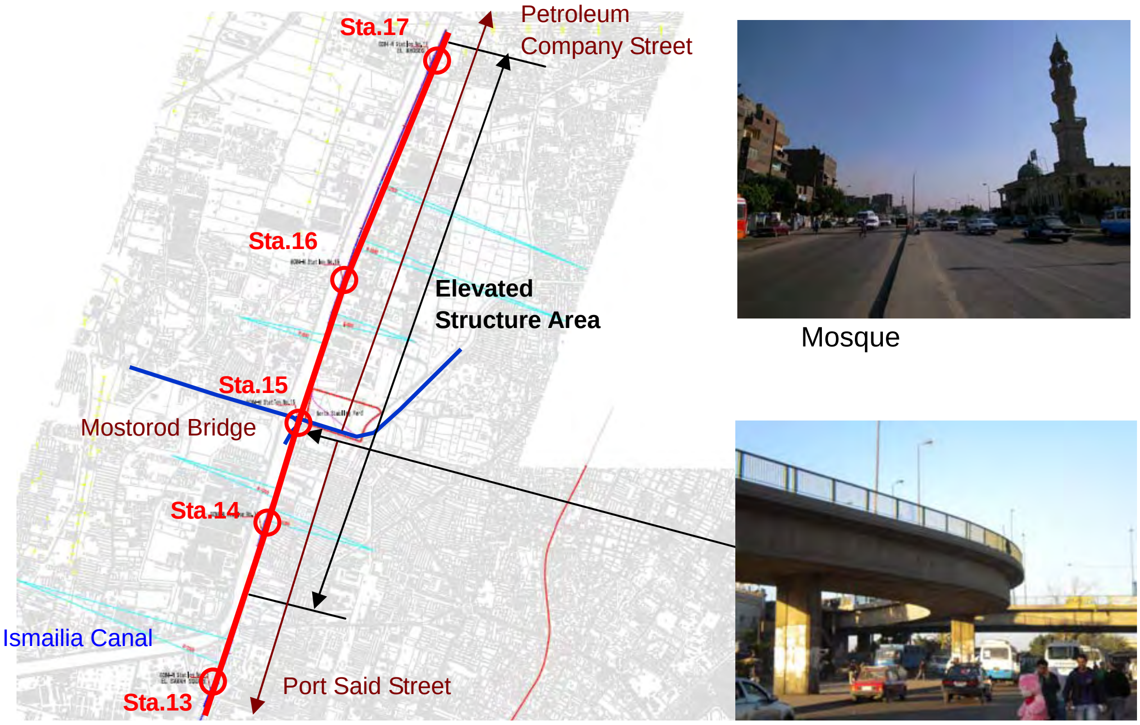
Figure 5-37 Similar Construction Practice (2) with Existing Waste Water Tunnel

5.3 Civil Works (Elevated Section)

5.3.1 Elevated Structures

(1) Overview of Elevated Section

The elevated section starts from the halfway point between Sta.13 and Sta.14, and reaches Sta.17 (final station) as shown in Figure 5-38. The alignment runs to the north along Port Said Street and Petroleum Company Street up to the Ring Road Exit #18, beside the Ismailia Canal. There are few obstructing structures in this section. It is only necessary to avoid a mosque beside the canal and to pass above the Mostorod Bridge of El Horreya Street near Station No. 15.



Mostorod Bridge

Source: JICA Study Team

Figure 5-38 Key Map

(2) Existing Condition Along the Metro Line 4 Route

The width of Port Said Street is sufficient for the construction of elevated structures. However, the sewage tunnel (dimension of 3,000 × 4,000 mm situated in a depth of approximately 5 m) runs under the street. Petroleum Company Street which starts from Mostorod Bridge toward the north has not enough width for the construction. There are some residential and commercial buildings on the east side of Port Said Street and Petroleum Company Street. However, the west side of both streets have some open spaces between the street and the canal.

Considering the above condition, elevated structures should be constructed using the open spaces as much as possible to minimize the road traffic impacts and effects to some utilities and buildings during and after the construction.

The outline of conditions in both streets is shown in Table 5-9.

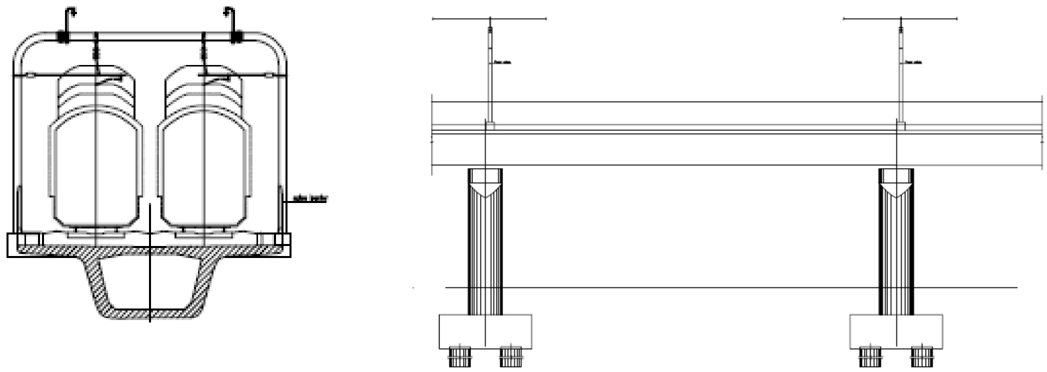
Table 5-9 Outline of Each Street

	Port Said Street	**Petroleum Company Street**
Location	Southern area from Mostorod Bridge	Northern area from Mostorod Bridge
Road width	20-25 m 	15 m 
Roadside space	5-10 m	20-30 m
Main land use at western side of road (between street and canal)	Sidewalk, Planting zone, Few buildings 	Open space (Official use) 
Main land use at eastern side of road	Residential building 	Petroleum company 
Traffic condition	Traffic volume is comparatively large, with a high ratio of large sized cars. Plenty of unused cars and parked cars exist on the street.	Traffic volume is comparatively small, also with a high ratio of large sized cars.
Others	There is a sewage tunnel (3,000 × 4,000 mm, depth: approximately 5 m) connecting from the southern area and running under Port Said Street.	It is assumed that several pipes are passing under the street from the Petroleum companies to the Islmailia Canal.

Source: JICA Study Team

(3) Superstructure

In this study, the PC Box Girder is proposed as superstructure because some section needs to pass above existing structures, requiring 30 m spans or longer. The typical section of the PC Box Girder is shown in Figure 5-39.



Source: JICA Study Team

Figure 5-39 Example of PC Box Girder Superstructure

(4) Substructure

The types of foundation and pier should be decided from the results of a geological survey. Generally, the shallow stratum of Cairo consists of silty fine sands. These silty sands, which are saturated, could possibly be subject to liquefaction in case of an earthquake.

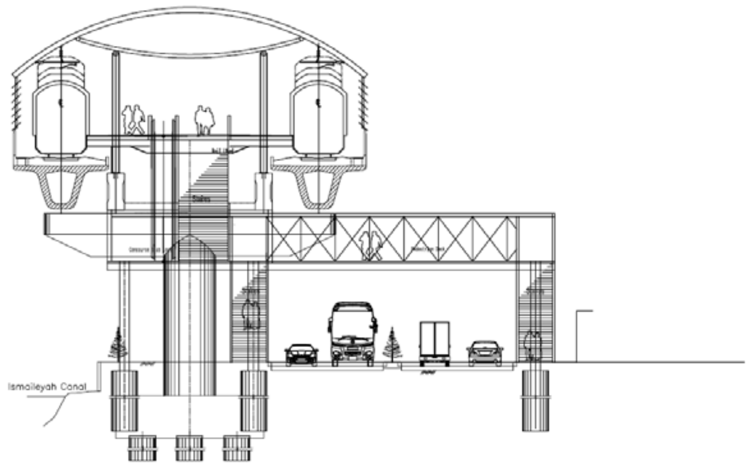
It should be noted that several earthquakes have occurred before in Egypt. In particular, the Dahshour Earthquake (12th October 1992) caused impressive amount of damages. A moderate earthquake of magnitude 5.9 struck the area of Dahshour of Cairo, resulting in 561 deaths and a significant damage to thousands of old buildings and many monuments in the governorates of Cairo, Giza and Fayoum. Therefore, some consideration of countermeasures against earthquakes should be required at the basic design stage.

In order to decide the arrangement of piers, a survey of public utilities should also be conducted.

5.3.2 Elevated Stations

One of the examples of a typical elevated station is shown in Figure 5-40.

This station structure has an island platform with a girder settled between both of the track on the pre-stressed concrete girder. Ticket gate, station office and some related facilities will be installed on the concourse floor under the platform. The concourse floor will be connecting both sides of the road by pedestrian path. Heavy facilities such as electrical room and/or mechanical room might be arranged in a vacant area on the ground.



Source: JICA Study Team

Figure 5-40 Description of Elevated Station

The outline of elevated stations is shown in Table 5-10.

Table 5-10 Outline of Elevated Stations (Phase 2)

	M4N Station No. 14	M4N Station No. 15	M4N Station No. 16	M4N Station No. 17
Platform type	island	Island	island	island
Length of station	170 m	170 m	170 m	170 m

Note: M4N means Metro - Line 4 - North
Source: JICA Study Team

5.4 Architectural Work

Station facilities arrangement is almost the same as in the Phase 1 section. The types of station are specified in Table 5-11 below:

Table 5-11 Typical Types of Station

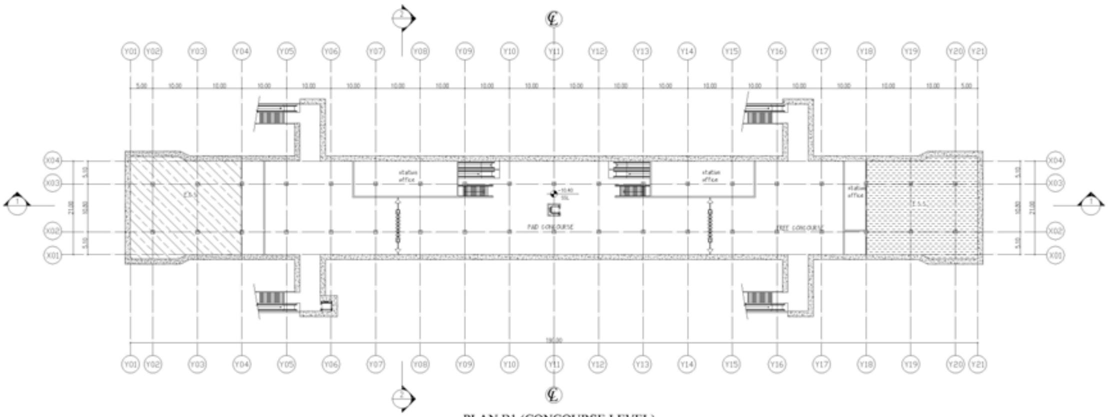
	Type 1	Type 2	Type 3	Type 4
Station type	underground	underground	underground	elevated
Platform length	170 m	170 m	170 m	170 m
Station length	190 m	220 m	280 m	180 m
Station width	21 m	21 m	21 m	21 m
Number of storeys	3 storeys	3 storeys	2 storeys	2 storeys
Substation	-	installed	-	-

Source: JICA Study Team

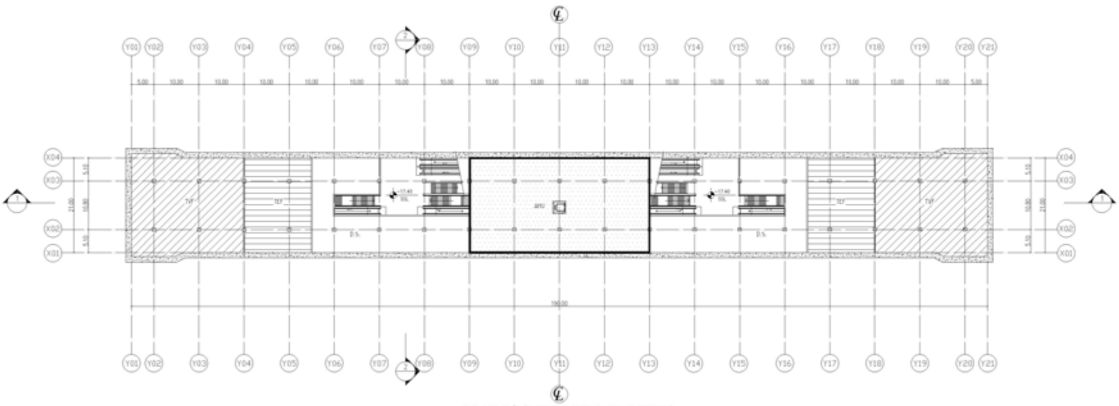
Station facilities will be installed similar to those in Phase 1 stations. Main facilities are as follows:

- Station office (Supervisor's office, Ticket sales room, etc.)
- Ticket Vending Machine (Automatic Fair Collector or AFC)
- Ticket Gates
- Restroom
- Escalator and Elevator

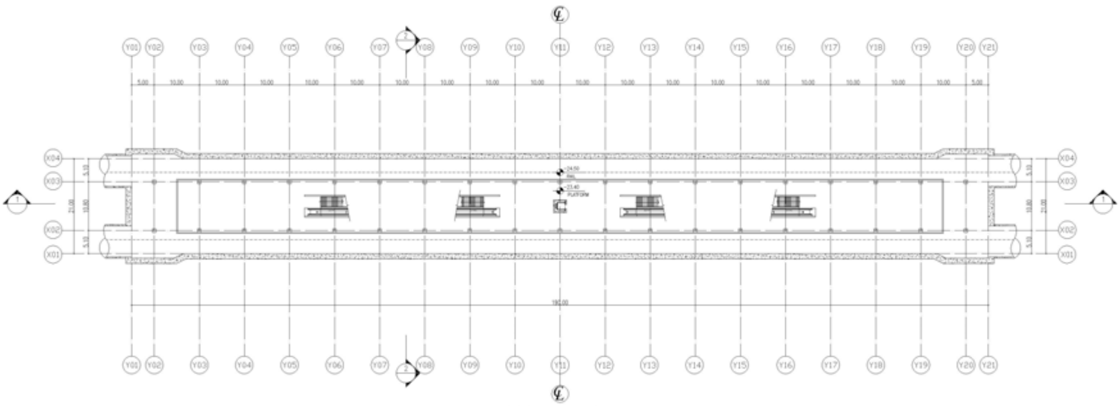
Typical types of facility arrangement are shown in Figure 5-41.



PLAN B1 (CONCOURSE LEVEL)



PLAN B2 (INTERMEDIATE LEVEL)



PLAN B3 (PLATFORM LEVEL)

Source: JICA Study Team

Figure 5-41 Typical Types of Station Arrangement

5.5 System, Facilities and Equipment Plan

The basic requirement and specification for each system, facilities and equipment are described in Chapter 4, Section 4.10. The outline design of items is consistent with the Phase 1 design.

The detailed layout plan and required capacity for individual facilities and equipment will be developed in the basic design stage, once the Phase 2 route alignment and station locations have been finalized.

5.6 Depot and Workshop Plan

5.6.1 General

Heavy maintenance, repair and overhaul for the Phase 2 rolling stock will be undertaken at the Phase 1 depot. However, this facility cannot accommodate the stabling or light maintenance of the Phase 2 fleet and therefore, as part of the Phase 2 facilities, a light maintenance and stabling depot will be required.

5.6.2 Depot location

For the northern alignment going to Ring Road Exit #18 via El Sawaha Square, there are no free and clear lands upon which to construct such a facility due to the already high density of buildings along the whole length of the route. There are very few potential sites along this route, namely:

- One potential site which would involve sharing with the existing Egyptian National Railway (ENR) depot and yards adjacent to M4N Station No. 10;
- A second potential site involving the conversion of the existing tram depot close to M4N Station No.12; and
- A third possible site involving the conversion of some agricultural lands just to the north of M4N Station No. 15.

The yard facilities needed for Phase 2 are the following: an administration and stores building, a light maintenance/repair facility, covered stabling for 20 x 8 car trains, a bi-directional automatic train wash, a facility for the stabling of a diesel shunting locomotive, and a fuel storage.

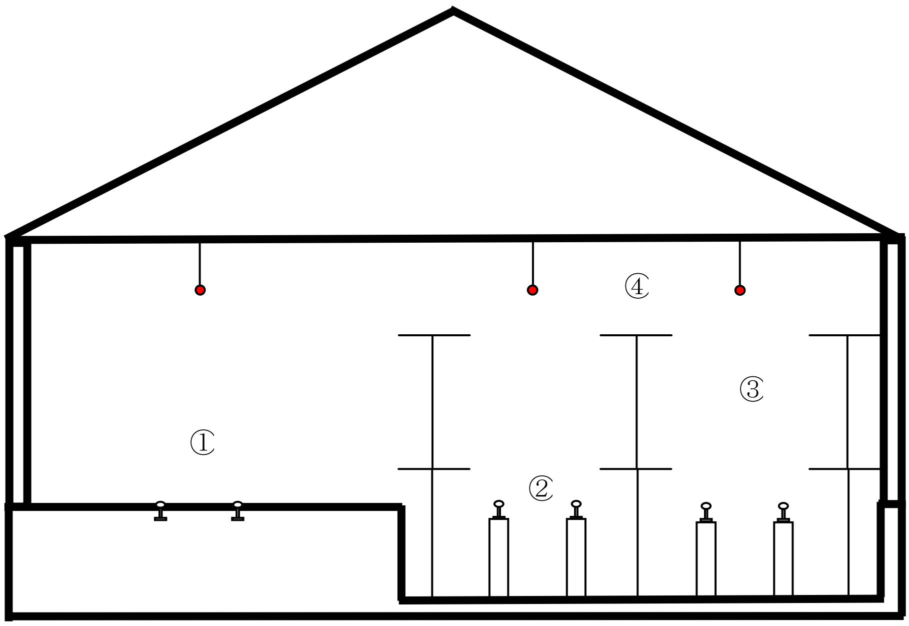
Depending upon the shape of the available site for the location of the Phase 2 depot, two types of development may be envisaged. The first is concentrated in width, having all facilities in a single complex. The second minimises the width of the depot and splits the stabling into two separate sections. The alternative of a single, long, covered stabling, housing one train behind another and two or more trains to each track should be avoided due to operational constraints.

In case of sharing with the ENR yard facilities close to M4N Station No. 10, it is extremely difficult to find adequate available space, even to create the stabling only with no light maintenance facility at all. This would not only imply that the Phase 1 depot light maintenance facilities would need to be expanded to accommodate the requirements of the Phase 2 fleet; but also that all trains requiring maintenance would have to be sent to the Phase 1 depot at the remote end of the line for such work to be undertaken. It is considered that this location presents significant difficulties at a practical level and embodies significant inconveniences and therefore should be disregarded.

In case of the conversion of the existing tram depot close to Station No. 12, it is possible to accommodate the facilities mentioned above within this site. This location, however, requires the use of a very tight curve (~80 m) at the approach to the facility and, moreover, it is not known whether it will be possible, at all, to acquire this facility for use by Metro Line 4.

In the case involving the conversion of agricultural lands, just to the north of M4N Station No. 15, it is also possible to find a way to accommodate the appropriate facilities for the Phase 2 depot. Compared with the other two possible sites, this will be the most preferable area for the depot of the Phase 2 section.

The detailed layout of the servicing depot and its equipment and facilities will be developed in the basic design stage. The following sketch shows a typical cross section of the servicing depot tracks:



① Servicing and test track with mobile access platforms, interlocked with catenary supply
② Light maintenance tracks with depressed floor for ease of access
③ Body level access platforms along full length of train

④ Roof level access platforms, interlocked with catenary supply

A possible location and layout for the depot is shown in Figure 5-42.

Source: JICA Study Team

Figure 5-42 Possible Location and Layout of the Depot