4.5 CONSTRUCTION PLANNING

In this section, the construction plan was studied for “Ben Thanh Central Station with Underground Shopping Mall (USM)” and “Line 1 tunnels with USM beneath Le Loi Street”.

The following issues were mainly studied:

1) Construction method and technical issues to be considered
   Construction methods including temporary works were studied, and the technical issues were listed with their countermeasures.
2) Countermeasures against traffic jam during construction
   Traffic management plan was studied as the countermeasure against traffic jam during construction.

4.5.1 Conditions for Study

The study was conducted based on the following conditions:

1) As shown in Figure 4.76, the construction plan was studied for two major areas, “Ben Thanh Central Station Area” and “Le Loi Street Area”.
2) For “Le Loi Street Area”, the construction plan was studied for the underground shopping mall together with the structures of Line 1 which also located beneath Le Loi Street.
3) For USM of Le Loi Street Area, Cut & Cover construction method was studied because of its shallow location for the connection with the commercial buildings along Le Loi Street and for the smooth access with the surface ground level.
4) For Ben Thanh Central Station Area, Cut & Cover construction method was planned. This is because of its complex structure formed by station structures for Line 1, Line 2, Line 3a (future extension of Line 1), Line 4 and USM.

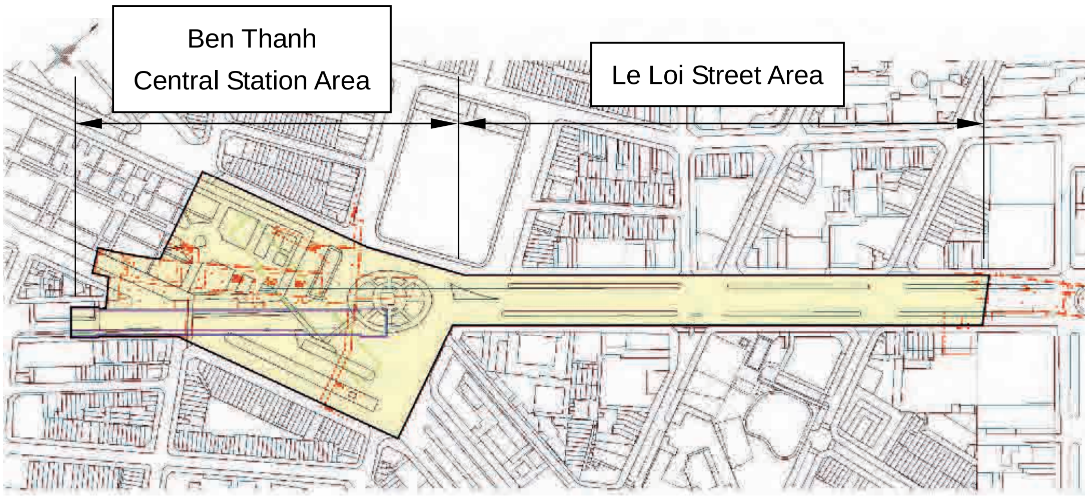


Figure 4.76 Demarcation of Construction Planning

5) Along the area for study, many neighbor buildings exist densely on the soft alluvial sandy layers, and the types of retaining walls and excavation methods were studied to prevent the settlement etc. of the neighbor buildings.
6) The alignment of Line 4 was planned to pass under Line 1 and go parallel with USM and Line 1 to Ben Thanh Station. The construction methods for "Crossing point of Line 1 and Line 4" and "Section where Line 4 and USM exist in parallel" were studied as the important points.
7) Many underground utilities were observed in the study area, and several utilities are impossible to be removed. The method to protect and maintain those utilities was studied.
8) Considering the heavy public traffic at the study area, the traffic management plans were studied for each step of construction plan.

4.5.2 Construction Planning for Le Loi Street Area

1) Objectives in Construction Planning

USM beneath Le Loi Street was planned above the underground structure of Line 1 with almost full width of Le Loi Street. After the commencement of commercial operation of USM, Line 4 tunnel structures are scheduled to be constructed by TBM under USM.

Furthermore, soft alluvium sandy layers exist thickly with high ground water level at the study area, with dense neighbor buildings, many underground utilities and heavy public traffic including pedestrians.

Considering the above conditions, the following objectives shall be studied:

(1) The effects to ongoing Line 1 Project shall be minimized.
(2) The plan, design and construction of Line 4 Project shall not be restricted.
(3) The effects to the neighbor buildings shall be minimized.
(4) The protection and maintain methods of underground utilities difficult to be removed shall be studied.
(5) The effects to public traffic shall be minimized.

2) Study on Construction Method of Line 1 Tunnel Structures related to USM Width

For the construction of USM beneath Le Loi Street by Cut & Cover Method, the coordination with the construction method of Line 1 tunnel (under preliminary design) is indispensable. The construction method of Line 1 tunnel was studied in this section, on the presumption that the USM is constructed by Cut & Cover Method.

In the Preliminary Design of Line 1 Project, about 310m of Line 1 tunnel at Opera House Station side is scheduled to be constructed by TBM, and the remaining part at Ben Thanh Station side is to be constructed by Cut & Cover Method. The typical cross section of Line 1 tunnels (about 310m section by TBM) with USM is shown in Figure 4.77.

As shown in the Figure, the structural distance between Line 1 tunnel and USM is not enough at Ben Thanh Station side. Furthermore, those structures are overlapped in the cross section at Opera House Station side.

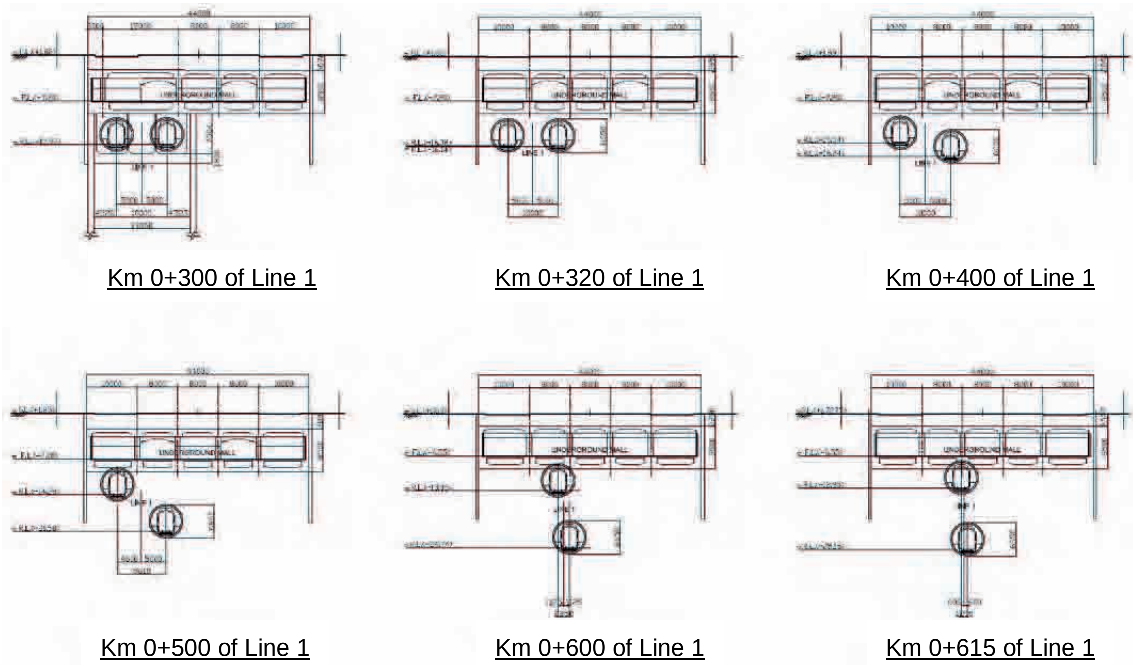


Figure 4.77 Locations of Line 1 Tunnels and USM

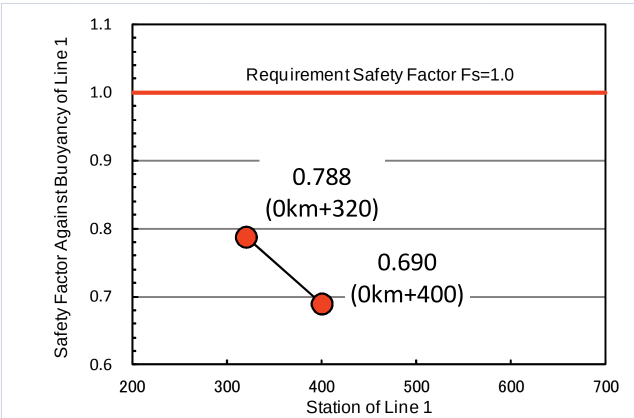


Figure 4.78 Safety Factors of Line 1 Tunnels against Buoyancy during Construction of USM by Cut & Cover Method

At the section (from km 0+320 to km 0+400 of Line 1) where the structural distance between Line 1 Tunnel and USM is impossible to be maintained, the problems like “floating of Line 1 tunnel structures” and/or “deformation of segment ring of Line 1 tunnel” will arise during the construction of USM. Besides, the USM structures are physically impossible to be constructed at the section (from km 0+500 to km 0+615 of Line 1) where Line 1 Tunnel structure and USM are overlapped.

Figure 4.78 indicates the stability of Line 1 Tunnel against buoyancy during the construction of USM by Cut & Cover Method. As shown in the figure, the safety factors against buoyancy fall below the prescribed safety value, 1.0 at the points of Line 1, km 0+320 and km 0+400. These results reveal the risk for the floating of Line 1 structure by the buoyancy during the construction of USM.

- The safety factors of Line 1 Tunnels against buoyancy were calculated based on page 45 to 45, "Design Standards for Railway Structures and Commentary (Shield Tunnel)" published by Railway Technical Research Institute of Japan.

Considering the above results, the construction of Line 1 Tunnel structures by TBM is impossible, and the Cut & Cover Method shall be adopted as the alternative.
The safety factors of Line 1 Tunnel against buoyancy are derived from the following formula:

$$Fs = \frac{2R_o\{\gamma'(H_w+R_o)+\gamma(H-H_w)\}-\pi R_o{}^2/2+2\pi R_o g+2R_o g+2R_o p_0+P_1}{\pi\gamma_w R_o{}^2} > 1.0$$

Where, F_s : Safety Factor (= Sum of "Loads & Resistances" divided by Buoyancy)
H : Depth of Earth Cover after Excavation (m)
H_w : Depth of Earth Cover above Ground Water Level (m)
g : Unit Weight of Segment Ring of Tunnel per m2 (kN/m2)
p_1 : Unit Load inside of Tunnels (kN/m)
p_0 : Unit Load on Ground (kN/m2)
γ : Unit Weight of Soil (kN/m3)
γ' : Unit Weight of Soil under Water Level (kN/m3)

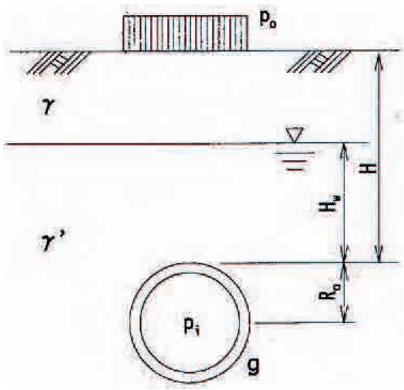


Figure: Cross Section for Analysis

The Unit Weight of Segment Ring of Tunnel is calculated by the following formula:

$$g = \frac{W}{\pi \cdot D_c \cdot b}\ (kN/m^2)$$

Where, g : Unit Weight of Segment Rings per m2 (kN/m2)
W : Total Weight of 1 Segment Ring (kN)
D_c : Diameter of Segment Ring at Centroid (m)
b : Width of Segment Ring (m)

Total Weight of 1 Segment Ring is calculated by the following formula:

$$W = \gamma_s \cdot \frac{\pi}{4}\left(D_o{}^2 - D_i{}^2\right) \cdot b\ (kN)$$

Where, W : Total Weight of 1 Segment Ring (kN)
γ_s : Unit Weight of Segment Ring (kN/m3)
D_o : Outer Diameter of Segment Ring (m)
D_i : Inner Diameter of Segment Ring (m)

Symbol	Unit	Description	Km 0+320	Km 0+400
H	m	Depth of Earth Cover after Excavation	0.654	0.114
H_w	m	Depth of Earth Cover above Ground Water Level	0.654	0.114
γ	kN/m^3	Unit Weight of Soil	19.5	19.5
γ'	kN/m^3	Unit Weight of Soil under Water Level	9.5	9.5
D_o	m	Outer Diameter of Segment Ring	6.650	6.650
D_i	m	Inner Diameter of Segment Ring	6.050	6.050
D_c	m	Diameter of Segment Ring at Centroid	6.350	6.350
γ_s	kN/m^3	Unit Weight of Segment Ring	26.0	26.0
g	kN/m^2	Unit Weight of Segment Rings per m2	7.80	7.80
P_i	kN/m^2	Unit Load inside of Tunnels	32.0	32.0
p_0	kN/m^2	Unit Load on Ground	0.0	0.0

3) Study of Retaining Walls

In Table 4.29, the results of alternative study are summarized for retaining walls necessary for Cut & Cover construction method.

The requirements for the retaining walls at the study area are as follows:

- High impermeability to prevent the fall down of underground water level
- High rigidity to prevent the settlement of surrounding grounds and neighbor buildings
- Low vibration and noise during construction

"Diaphragm wall" and "Soil-cement diaphragm wall" satisfy the above requirements. Diaphragm wall is constructed by excavation of the ground with stabilization by bentonite slurry or polymer slurry, installation of steel members or rebar cages and casting of concrete. The structures of diaphragm wall can be used as the part of the permanent structure.

Soil-cement diaphragm wall is one type of column type diaphragm wall. Soil-cement is used for the wall structure instead of cement mortar for other column type diaphragm wall. The soil-cement wall is constructed by continuous sliding of trench cutter with ejecting of the hardening agent slurry.

For "Le Loi Street Area", "Diaphragm wall" was applied for most part of the retaining walls of USM and Line 1 tunnel to utilize them as the permanent structure, and "Soil-cement diaphragm wall" was applied for important points, namely the "Section where Line 4 and USM exit in parallel." The details were described in the following section 5).

Figure 4.79 indicates the cross section of USM, Line 1 & Line 4 tunnels with soil boring log. The excavation depth of USM is 12m approximately, and the embedment length of retaining walls was assumed as the same length, 12m.

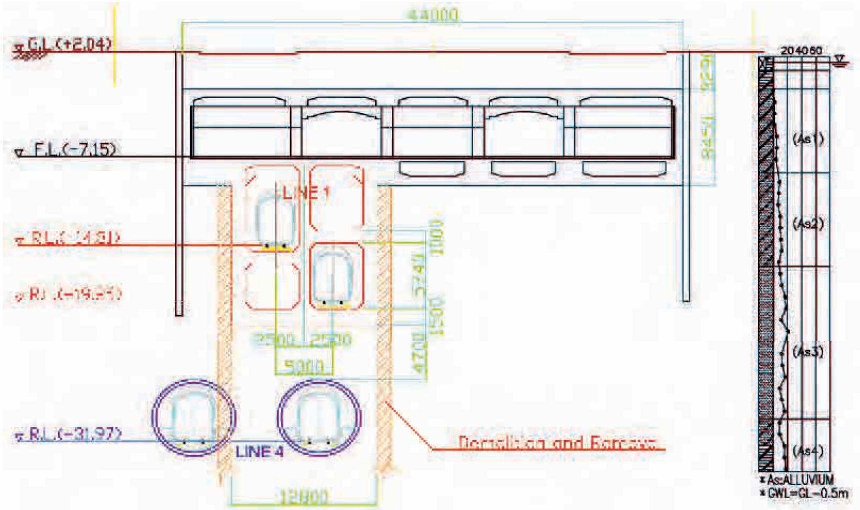


Figure 4.79 Cross Section of USM with Soil Boring Log

4) Study of Excavation Method

Two excavation methods, "Bottom up" and "Top down" are applicable for the Cut & Cover Construction of USM. "Bottom up" method is generally applied in the past, and recently, "Top down" method is often applied for the cases that the allowable displacement of retaining wall is limited because of the existence of the important structures in neighborhood.

Figure 4.80 indicates the construction sequence of "Bottom up" and Figure 4.81 indicates that of "Top down", respectively. By "Bottom up" method, the excavation is completed to the bottom and subsequently the construction of the tunnel structure is commenced from the bottom slabs to top slabs. By "Top down" method, excavation and construction of tunnel structure is conducted alternately from the ground surface level to the bottom.

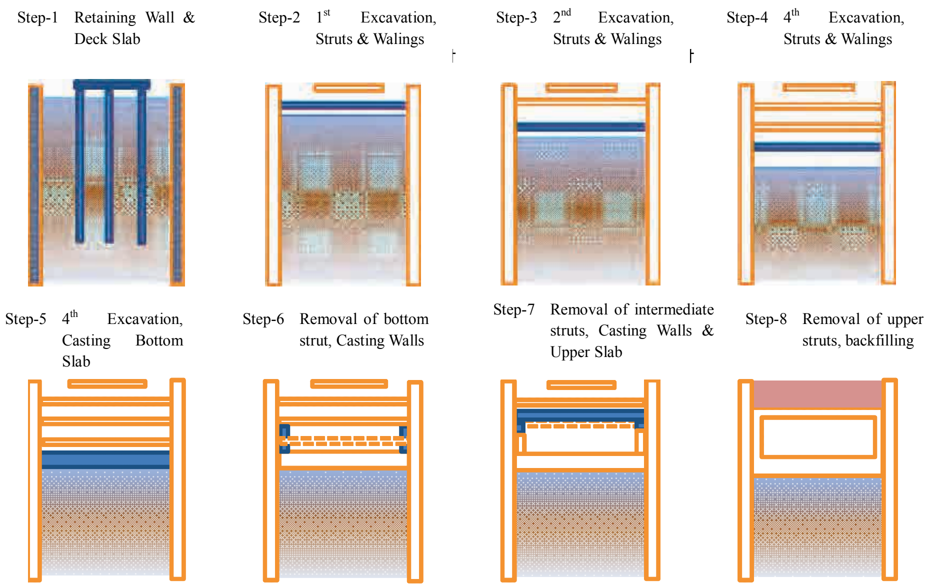


Figure 4.80 Construction Sequence of "Bottom up" Method

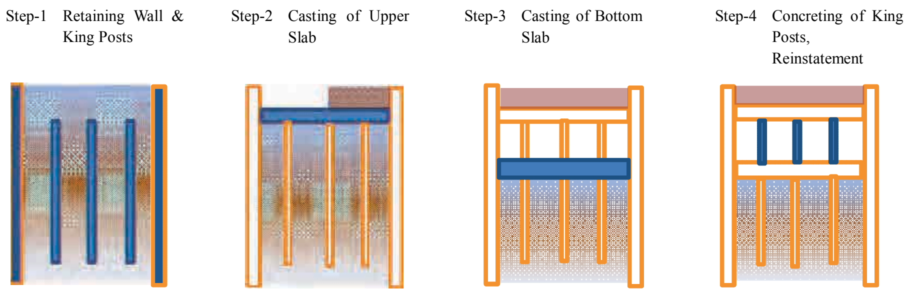


Figure 4.81 Construction Sequence of “Top down” Method

Dr. Eiri studied “Top down” method applied for the construction of Akiharaba station of Tukuba Express, and compared with “Bottom up” method in the aspects of the construction cost and duration. According to that study, the advantages of “Top down” method over “Top down” method are as follows:

- Struts of temporary support for retaining walls can be reduced, because the casted concrete slabs prior to the excavation can behave as the struts.
- Duration for installation of struts can be shorter, and struts can be reused smoothly from upper part to lower part, because the struts are able to be released after the upper slabs are constructed.
- Deformation of retaining walls is reduced because the rigidity of the concrete slabs supporting the retaining wall is higher than that of struts.
- The space on the constructed concrete slabs can be utilized for the construction yards.
- The construction works beneath the constructed concrete slabs is not affected by the weathers.
- The construction duration is reduced because of the deduction of the rows of struts, no necessity of temporary replacement of struts, simultaneous construction works at upper and lower sides, deduction of quantities of supports & formworks for concrete structures.

Besides, the following issues are mentioned as disadvantages of “Top down” method:

- Increase of quantities of king posts to support the dead load of concrete slabs and live loads for construction works
- Additional construction cost for non-shrinkage mortar for connection of side walls & columns with upper slabs, disposal of debris of lean concrete after casting of slabs.

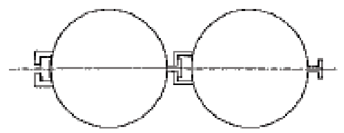
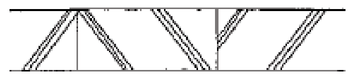
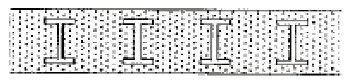
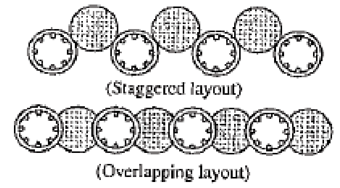
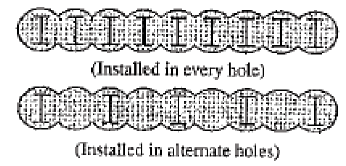
Generally, “Top down” method causes more thickness of permanent structures including concrete slabs and retaining walls (diaphragm wall to be used as permanent structures), and contributes to reduce the quantities for temporary works including steel deck slabs and temporary supports (steel beams and columns etc.) for retaining walls.

Generally in the developing countries like Vietnam, the labor costs and material costs for concrete etc. are comparatively lower than those of Japan, and the procurement costs for steel materials including deck slabs, beams and columns are not so cheap.

Because of its contribution to reduce the quantities for temporary works including steel materials, “Top down” method is frequently adopted in those countries.

It is recommended that the excavation method shall be finally defined based on the further study and design results of USM in the next stage, with considering the advantages and disadvantages of “Bottom up” and “Top down” methods.

Table 4.29 Alternative Study of Retaining Walls

		Sheet pile soil retaining wall	Steel pipe sheeting soil retaining wall	Diaphragm wall	Slurry solidified diaphragm wall	Column type diaphragm wall	Soil-cement diaphragm wall
Structure		 Soil retaining wall formed by continuously placing sheet piles with U-shaped, Z-shaped, straight, H-shaped sections underground, and engaging their joints.	 Soil retaining wall made by continually placing steel pipe piles with shape steel, pipes, or other joints attached underground, by engaging their joints.	 Method of constructing a continuous soil retaining wall underground by using the ground stabilization action of bentonite slurry or polymer slurry to cut the ground and inserting steel material or rebar columns, then filling them with concrete.	 A type of diaphragm wall, it is a soil retaining wall made by inserting H-shaped steel, sheet piles, or precast panels into a trench that was cut using a stabilizing fluid such as bentonite slurry, then mixing a hardener with the stabilizing fluid to solidify the stabilizing fluid.	 A soil retaining wall that is continuously constructed by inserting re-bar columns or shaped steel into cast-in-place concrete piles. Existing piles are also inserted in place of the rebar columns or shaped steel.	 One type of column diaphragm wall, it is a soil cement in place of mortar. Recently, it has been used as a method of constructing a soil cement wall by sliding a trench cutter continuously while ejecting a hardening agent slurry.
Characteristics	Merits	Its water cutoff property is good and the embedded part under the bottom surface of the cut maintains continuity, so it is a generally used in ground where the groundwater level is high or in soft ground.	Its water cutoff property is good, the embedded part under the bottom surface of the cut maintains continuity, and its section performance is large, so it is used for large-scale cutting work in ground with groundwater or in soft ground.	Its water cutoff property is good, the embedded part under the bottom surface of the cut maintains continuity, and its section performance is large, so it is used for large-scale cutting work, work near important structures, and for work is soft ground. Its characteristics are that it can be used as part of the main structure and the work produces little vibration and noise.	With the diaphragm method, disposing of unnecessary stabilizing fluid is a problem, but this is a method that solidifies the stabilizing fluid to use it as part of the soil retaining wall.	Cast-in-place piles provide substantial section performance and the work produces little noise and vibration, so this method is often used in place of sheet pile soil retaining wall in urban districts.	Its section performance is not quite as good as that of the column type diaphragm wall, but its water cutoff property is good. In the case of the TRD method, ground materials above and below are mixed by agitation, so relatively uniform section performance is obtained in the depth direction.
	Demerits	If the noise and vibration produced by the placing will cause problems, it is necessary to take care to adopt a low noise and low vibration execution method. Generally there are many cases where U-steel or plates are used, but their stiffness may be inadequate for large-scale cutting.	When noise or vibration will cause problems, it is necessary to considering adopting a low noise, low vibration method. Generally, it cannot be removed, so in many cases it is left in the ground.	To adopt this method, the work cost and work period must be studied, because it is time-consuming work, many obstructions are moved, and it is necessary to extend continuous working hours.	Because execution conditions have a big impact on work costs, its adoption must be studied.	In many cases, its water cutoff performance is poor, its work cost high, and its work period is long.	Soil cement, but according to the ground is used as material for use as material for soil cement, so the method is used carefully. And according to the layer, large variations in the section performance may appear in the depth direction.
Adaptability of the site	Applicable length of soil retaining wall	about until 25m	about until 50m	about until 100m	about until 50m	about until 25m (It is possible until 50m by all casing boring machine.)	about until 40m (It is impossible until 50m under soil condition.)
	Water cutoff property	good	good	good	slightly less	no good	good
	Use of soil retaining wall as the main structure	impossible	impossible	possible	possible	impossible	impossible
	Bending rigidity	medium	high	high	medium	medium	slightly high
	Impact of cut and cover excavation to adjacent buildings	slightly less	good	good	slightly less	slightly less	slightly less
	Temporary diversion and/or protection of existing underground utility facilities	It is desirable temporary diversion. If temporary diversion of existing underground utility facility is impossible, It is necessary soil improvement for covering loss of retaining wall.	It is desirable temporary diversion. If temporary diversion of existing underground utility facility is impossible, It is necessary soil improvement for covering loss of retaining wall.	It is desirable temporary diversion. If temporary diversion of existing underground utility facility is impossible, It is necessary soil improvement for covering loss of retaining wall.	It is desirable temporary diversion. If temporary diversion of existing underground utility facility is impossible, It is necessary soil improvement for covering loss of retaining wall.	It is desirable temporary diversion. If temporary diversion of existing underground utility facility is impossible, It is necessary soil improvement for covering loss of retaining wall.	It is desirable temporary diversion. If temporary diversion of existing underground utility facility is impossible, It is necessary soil improvement for covering loss of retaining wall.
	Noise during construction	It should be adopt jacking-up method.	It should be adopt jacking-up method.	little noise	little noise	little noise	little noise
	Vibration during construction	It should be adopt jacking-up method.	It should be adopt jacking-up method.	little vibration	little vibration	little vibration	little vibration
	Cost of construction	relatively reasonable	relatively unreasonable	unreasonable	unreasonable	relatively unreasonable	relatively reasonable
	Period of construction	relatively quick	relatively slow	slow	relatively slow	relatively slow	relatively slow
Comprehensive evaluation		Not Recommended	Not Recommended	Recommendation	Not Recommended	Not Recommended	Recommendation

5) Study of Construction Method for Important Points

(1) Crossing point of Line 1 and Line 4

The construction method for crossing point of Line 1 and Line 4 was studied in this section. (The final decision on construction method and further study is recommended to be conducted in Line 1 Project.)

Because Line 1 tunnel is planned to be constructed by Cut & Cover method, TBMs for Line 4 tunnel will encounter the diaphragm walls of Line 1 tunnel with sharp angles, in the future.

a) Soil Improvement for Facilitation of TBM (Line 4) boring through of Diaphragm Walls of Line 1 Tunnels

The soil improvement around the diaphragm walls of Line 1 tunnels can be an alternative to facilitate TBM for Line 4 boring through of diaphragm walls of Line 1 tunnels. (Refer to Figure 4.82)

i) Purpose and Area of Soil Improvement

The purpose and area of soil improvement are as follows:

* <u>Facilitation of Boring through of Diaphragm Walls of Line 1 Tunnels by TBM:</u>

As shown in Figure 4.82, TBMs for Line 4 tunnels will bore through the parts of diaphragm walls of Line 1 tunnel with sharp angles. Because of the different hardness of diaphragm walls and surrounding soils, it will be difficult to control the TBMs in the right positions during the boring through of diaphragm walls.

The careful operation of TBMs will be required and the driving speed of TBMs will be reduced. Consequently, the exceeding excavated soils might be taken inside of TBMs, and it will induce the risk of ground subsidence at neighbor areas.

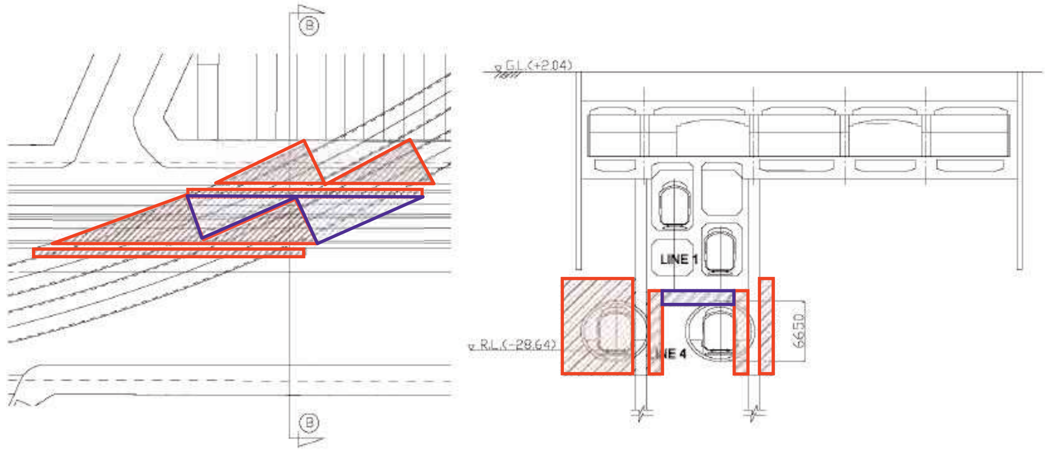
To avoid the above mentioned difficulties, the soil improvement around diaphragm walls is proposed by the creation of high strengthened soils at the red-colored areas in Figure 4.82. This soil improvement will reduce the different hardness of soils and diaphragm walls and also relieve the sharp angles for boring by TBMs.

* <u>Facilitation of TBMs Driving under Line 1 Tunnels and Prevention of Risks for Stability of Line 1 Tunnels:</u>

The soft sand layers existing under Line 1 tunnels will be plasticized when Line 1 tunnels are constructed by Cut & Cover method, and the further plasticization might occur when TBMs for Line 4 tunnels will bore through them.

This plasticization will induce the possibilities of tunnel face collapse (by abnormal disposal of excavated soils) or difficulty of the control of TBMs in the right positions, and it will cause unfavorable effects for the stability of Line 1 tunnels.

To avoid the above risks, soil improvement under Line 1 Tunnels (blue-colored areas in Figure 4.82) by the creation of high strengthened soils is proposed.



: (1) Facilitation of Boring through of Diaphragm Walls of Line 1 Tunnels by TBM

: (2) Facilitation of TBMs Driving under Line 1 Tunnels and Prevention of Risks for Stability of Line 1 Tunnels

Figure 4.82 Area for Soil Improvement

ii) Features of Construction Method (CJG Method) for Soil Improvement

CJG Method (Column Jet Grouting Method) will be recommended for soil improvement. The soils at site are cut by the high pressure water jet and slimes will be exhausted to the construction base levels. Simultaneously the hardening agents are injected to replace the cut slime and to create a cylindrical stabilized and strengthened soil columns. (Refer to Figure 4.83)

The work procedure is indicated in Figure4.83. Because the stabilized and strengthened soil columns are created at the same time with disposal of slimes, the ground water shall not be pressured at the construction base level. Accordingly, the construction base level for this method is the ground surface level in the most of the cases.

iii) Construction Method for Point

The described soil improvement is necessary for the construction of Line 4 tunnels by TBM method, and preferable to be conducted in the scope of Line 4 project.

Besides, the areas for soil improvement locate below both of USM and Line 1 tunnels. Furthermore, the construction of Line 4 (driving of TBMs) will be commenced when the Line 1 and USM will be under commercial operations.

Based on the above conditions, it is recommended that the soil improvement is conducted simultaneously with the construction of Line 1 tunnels by Cut & Cover method, because of the following reasons:

* After Line 1 tunnels and USM will be constructed, it is relatively difficult to conduct the soil improvement from the ground surface level. The tunnel structures of Line 1 and USM will be obstacles to install the casing pipes etc. for soil improvement. The drilling into tunnel structures will be required, and it will induce the risks to cut of reinforcement steels in tunnel structures. Furthermore,

the soil improvement can not be conducted during the business hours of Line 1 and USM.

* Soil Improvement from within TBM for Line 4 tunnel is studied, and it is concluded that the chemical grouting method from within TBM is not suitable for the point.

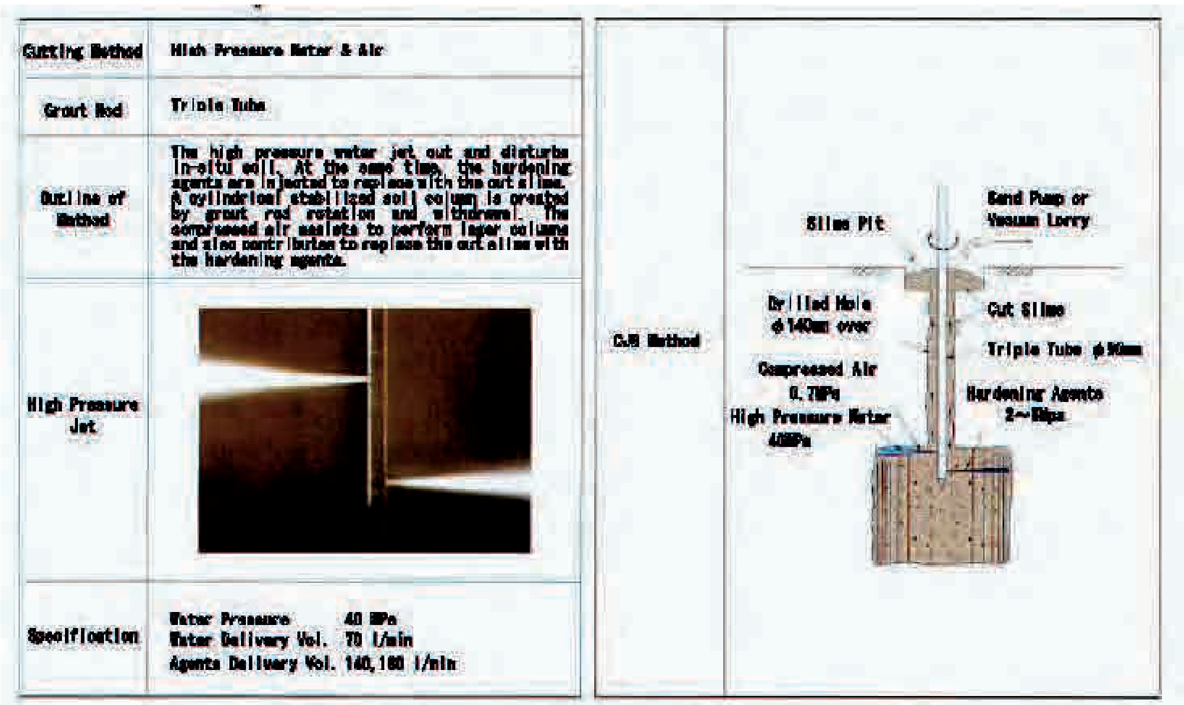


Figure 4.83 Specifications of CJG Method

iv) Issue to be considered for "Soil Improvement at Crossing Point of Line 1 and Line 4 at Le Loi Street"

The soil improvement creates the high strengthened soils around diaphragm walls, reduces the different hardness of soils and diaphragm walls, and relieves the sharp angles for boring by TBMs.

This soil improvement shall be conducted by the Contractor of Line 1 tunnel prior to the construction of Line 4 tunnel, because it is impossible to be conducted simultaneously with the construction of Line 4 tunnel, or after the construction of USM above Line 1 Tunnel.

In case TBM for Line 4 cannot bore through the improved soils & the diaphragm walls of Line 1, or in case the ground subsidence at neighbor areas is caused by tunnel face collapse of Line 4 during the operation of TBM, the Contractor of Line 4 tunnel claims to the Employer that those problems are caused by the insufficient quality of soil improvements conducted by the Contractor of Line 1 tunnel.

The quality of soil improvement by the Contractor of Line 1 tunnel shall meet the Employer's Requirements in the Contract, and the Contractor of Line 1 tunnel has the responsibility for the quality to the Employer. Subsequently, the Employer provides the improved soils with diaphragm walls of Line 1 tunnel to the Contractor of Line 4 tunnel as the site conditions for the construction, and the Employer has the responsibility for the quality to the Contractor of Line 4 tunnel.

In case the Contractor of Line 4 tunnel submits the claim, the complicated arguments about the responsibility of the quality of soil improvement are unavoidable.

b) Demolition and Removal of Diaphragm Walls of Line 1 Tunnel

The removal of the diaphragm walls of Line 1 tunnel is studied.

The photographs and figures of "Demolition and Removal of Diaphragm Walls" are shown in Figure 4.84, and Figure 4.85 indicates the construction sequence.

Application of Hydraulic crush machine with casing (inner excavation method) contributes the removal of the underground RC structures etc. with low vibration and less noises.

The advantages of this method are as follows:

(1) Underground structures are demolished in the casing, and accordingly, debris does not scatter widely.
(2) Structures are broken by hydraulic arm with cutting edges (open & close type), and no vibration occurs.
(3) Hydro Grab enables the taking out of crushed concrete debris and re-bars simultaneously.
(4) Easy separation of concrete debris and re-bars contribute the smooth disposal and also recycle.
(5) Low vibration and less noises of the machine enable the night time works.

source：http://www.yokoyamakiso.co.jp/industrial/acr/index.html

c) Cost Comparisons of Construction Methods

The construction costs of two construction methods, "Soil Improvement" and "Demolition & Removal of Diaphragm Walls" are summarized in Table 4.30.

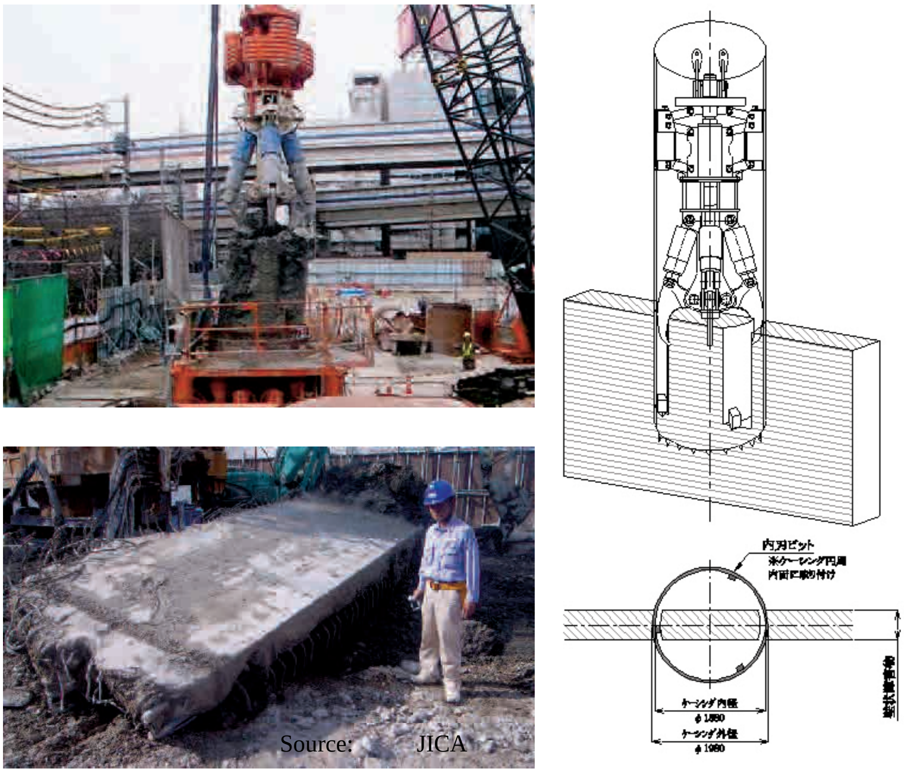
Table 4.30 Comparison of Construction Costs for Countermeasures

Items	Unit	Quantity	Unit Price (Combined in JPY)	Amount (Combined in JPY)
Soil Improvement under Diaphragm Wall of Line 1	m^3	7,500	99,000	742,500,000
Removal & Demolition of Diaphragm Wall of Line 1	m^2	5,600	178,000	996,800,000

The construction cost for "Soil Improvement" is about 25% lower than that of "Demolition & Removal of Diaphragm Walls". However, if "Soil Improvement" will be adopted, the potential risk of the claim by the Contractor of Line 4 tunnel about the quality of Soil "Improvement" will arise. Consequently, the total construction cost including both of Line 1 and Line 4 might increase more than the originally estimated cost.

d) Conclusion and Recommendation

To avoid the potential risk of the claim by the Contractor of Line 4 tunnel about the quality of "Soil Improvement" by the Contractor of Line 1 tunnel, the adoption of "Demolition & Removal of Diaphragm Walls" is strongly recommended.



source：http://www.yokoyamakiso.co.jp/industrial/acr/index.html

Figure 4.84 Removal & Demolition of Diaphragm Wall

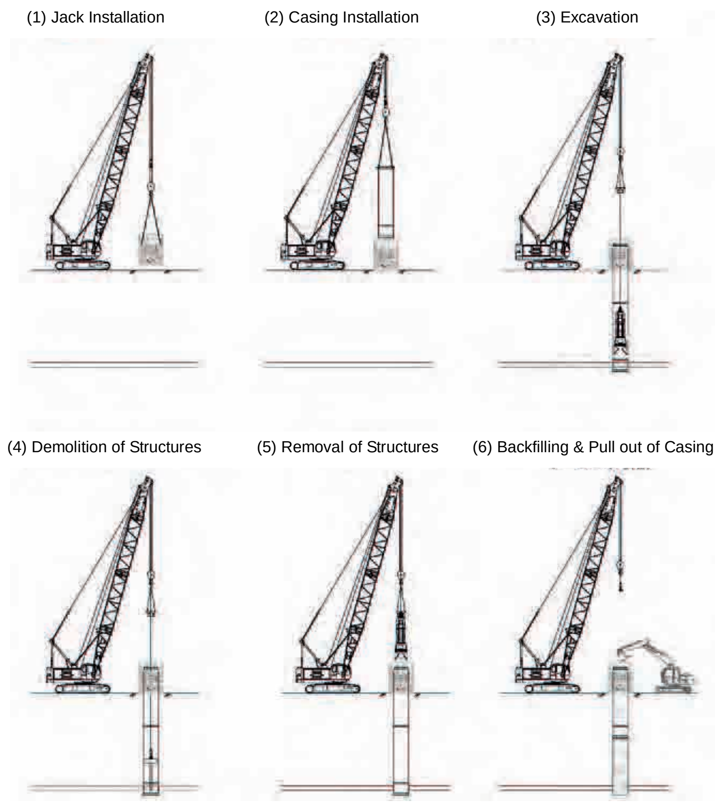


Figure 4.85 Work Procedure of Removal & Demolition of Diaphragm Wall

(2) Section where Line 4 and USM exist in parallel

As shown in Figure 4.86, the horizontal alignment of Line 4 comes from north east, and go to Ben Thanh Station along Le Loi Street. In this section, about 150m of the retaining walls of USM will be the obstacles for TBM driving for Line 4 tunnels, as shown in Figure 4.87.

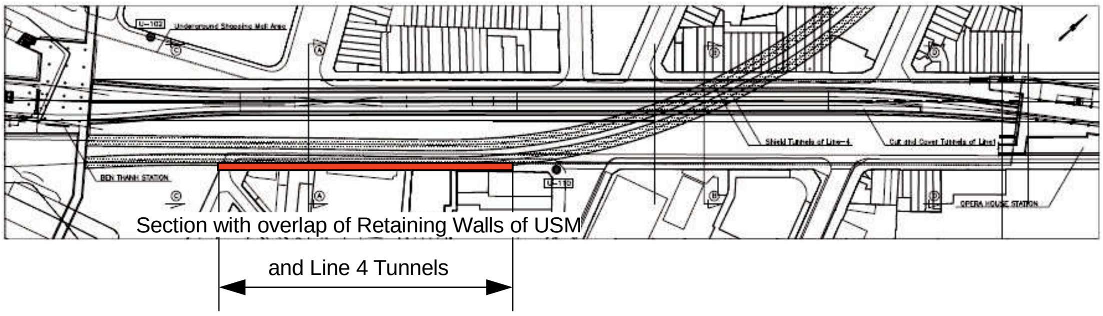


Figure 4.86 Section with Overlap of Retaining Walls of USM and Line 4 Tunnels

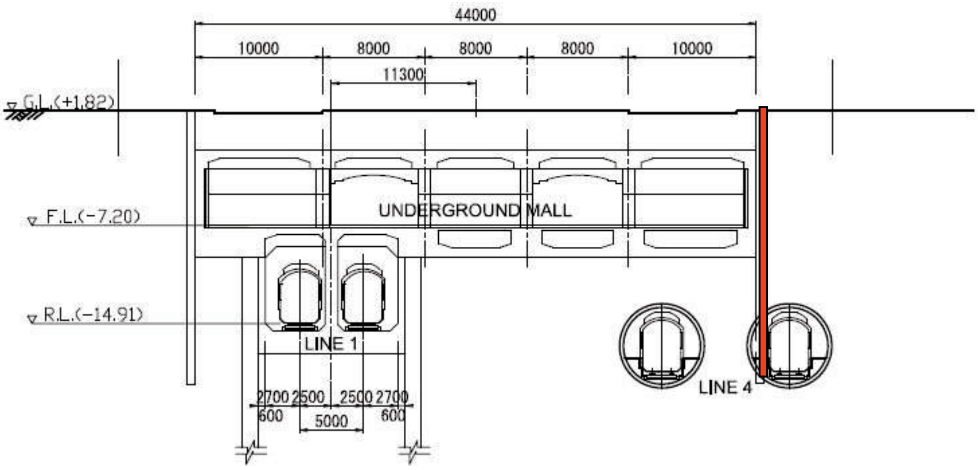


Figure 4.87 Cross Section with Retaining Walls of USM and Line 4 Tunnels

The type of retaining walls of USM was studied as follows:

i) Soil-cement diaphragm wall is adopted to be bored by TBM for Line 4.

ii) Commonly, H Steel beams are applied for the core piles. For the core piles in Soil-cement diaphragm wall, the material, FFU (Fiber Reinforced Foamed Urethane, etc.) which can be bored by TBM is applied for the necessary portions of walls. (Refer to Figure 4.88 and Figure 4.89)

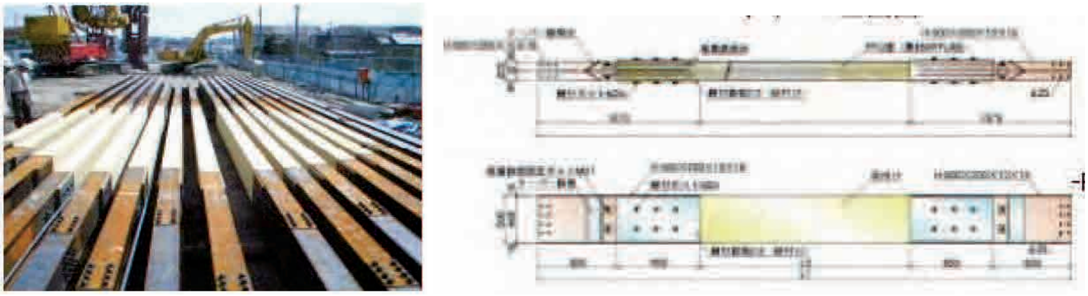


Figure 4.88 Connection of FFU and H Steel Beam (Core pile for Soil-cement D-Wall)

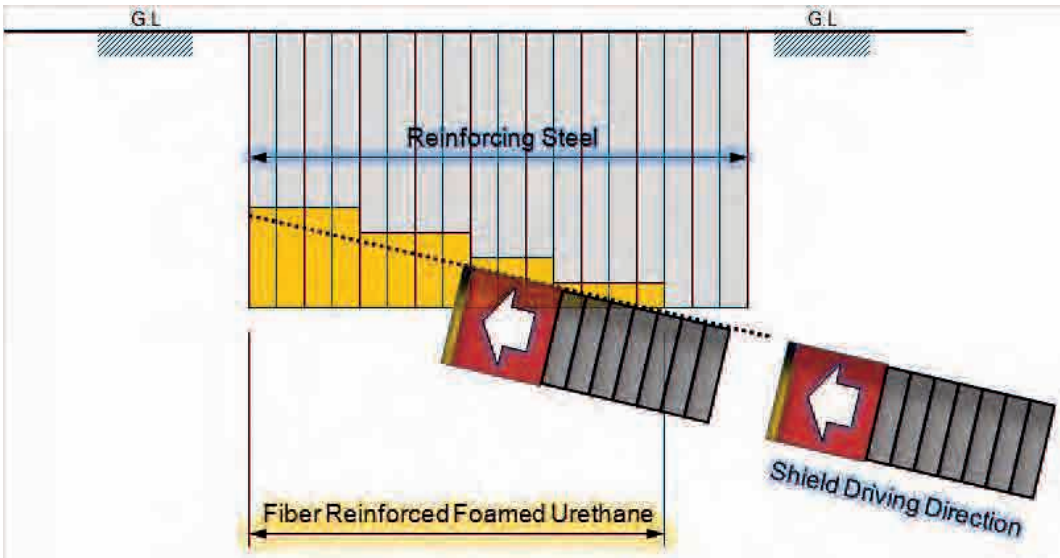


Figure 4.89 Boring of Soil-Cement Diaphragm Wall by TBM

(6) Protection and Maintenance of Underground Utilities during Construction

Underground utilities will be the obstacles for the construction of USM, if they will not be removed. In principle, it is recommended that the underground utilities at study area shall be removed by HPC prior to the commencement of the construction of USM.

For several underground utilities which are difficult to be removed (drainage etc.), temporary diversions and/or temporary protections are required. For those protection and maintenance works, the Contractor of USM shall check the type, earth covering, form, strengths of the utilities at site or available data, and the location of the utilities at site shall be indicated by plates or tapes etc. with the presence of the staff of the responsible organization. The details of the protection and maintenance methods shall be approved by the responsible organization, prior to the actual works. The procedure of diversion of utilities is shown in Figure 4.90.

The major drainage pipes are difficult to be diverted and temporary protection by hanging method shall be applied. At the locations of hanged drainage pipes, the retaining walls of USM are impossible to be constructed and soil improvement by jet grouting method is required. The work procedure is summarized in Figure 4.91. The photograph of temporary hanging method is shown in Figure 4.92.

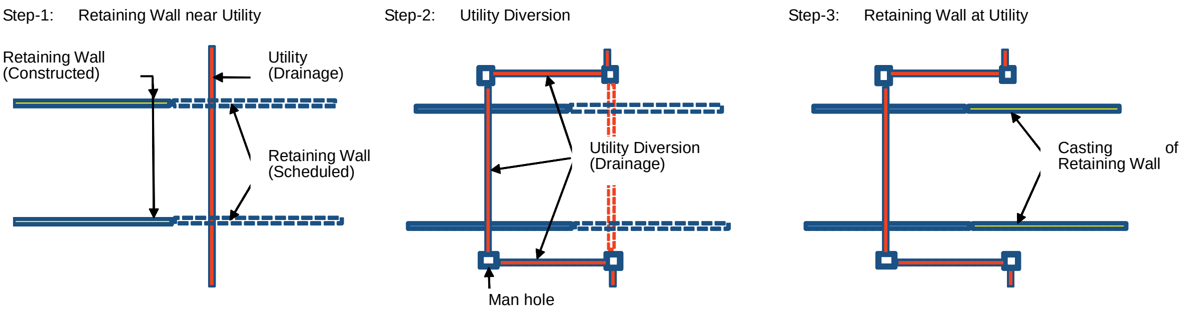


Figure 4.90 Diversion Procedure of Utility crossing Le Loi Street

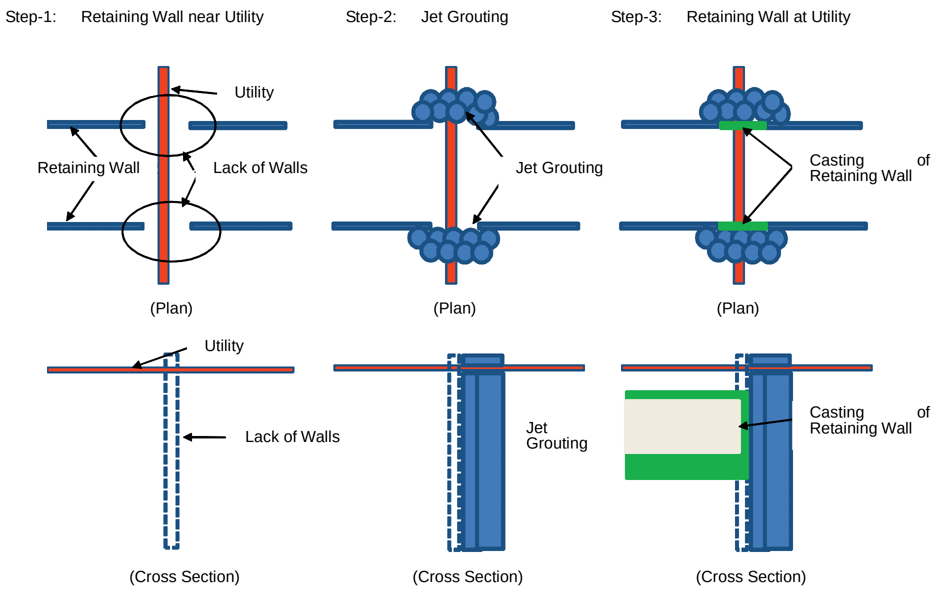


Figure 4.91 Temporary Hanging Method with Jet Grouting Reinforcement


Figure 4.92 Temporary Hanging Method (Example)

7) Traffic Management and Construction Sequences

The Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street is indicated in Figure 4.93 – Figure4.106. The construction of Line 1 Tunnel is scheduled in the 1st stage, and subsequently, the construction of USM will follow. The traffic management plans are also studied considering the following issues, and indicated in the figure.

1) Principally, the current traffic on Le Loi Street shall not be blocked.
2) The duration of the traffic restrictions shall be minimized for the roads crossing Le Loi Street.

8) Preliminary Construction Schedule

The preliminary construction schedule of "Phased Construction (1st Phase: Line 1 Tunnel, 2nd Phase: USM)" of Line 1 Tunnel and USM beneath Le Loi Street is shown in Table 4.31.

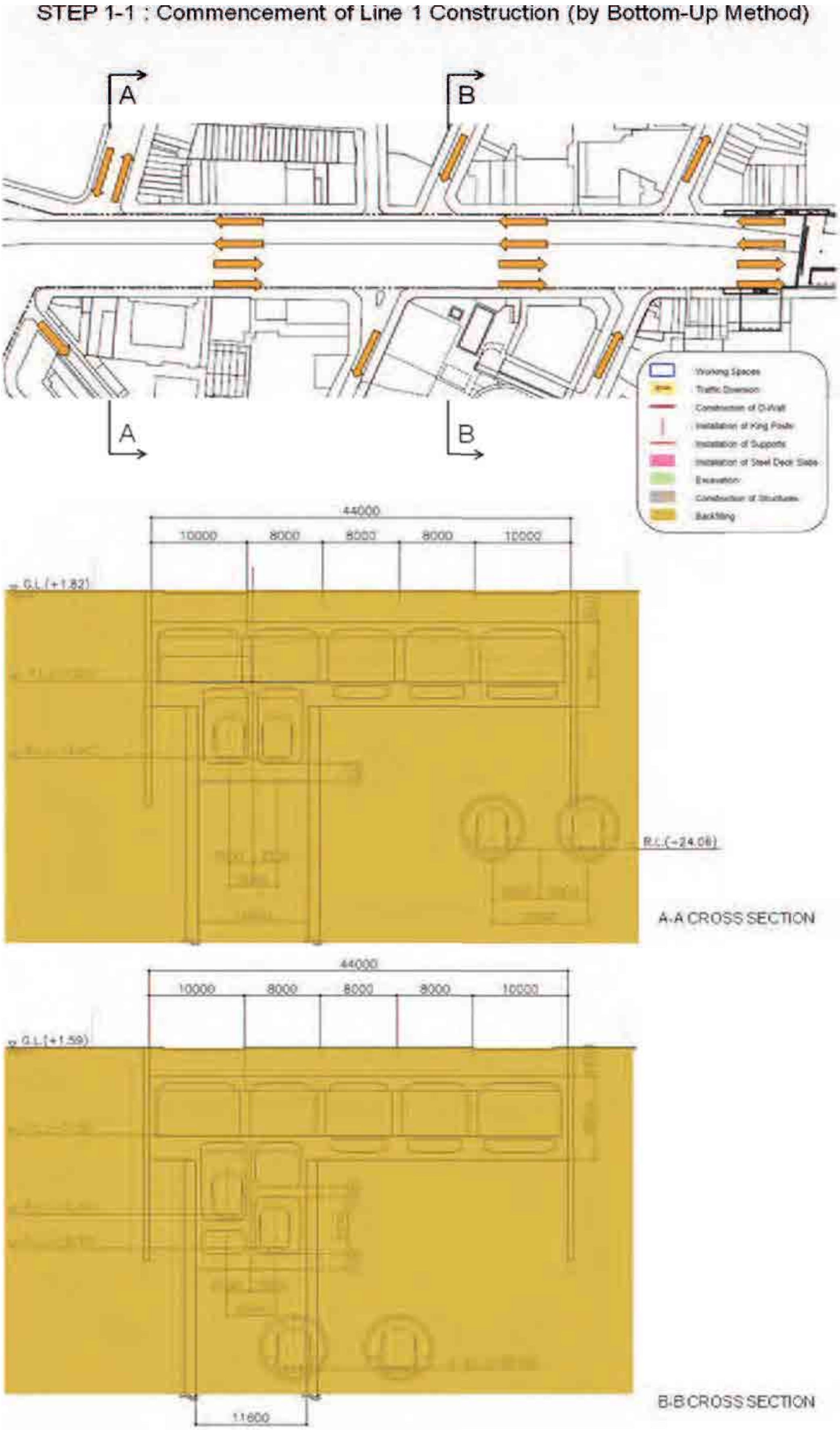


Figure 4.93 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (1/14)

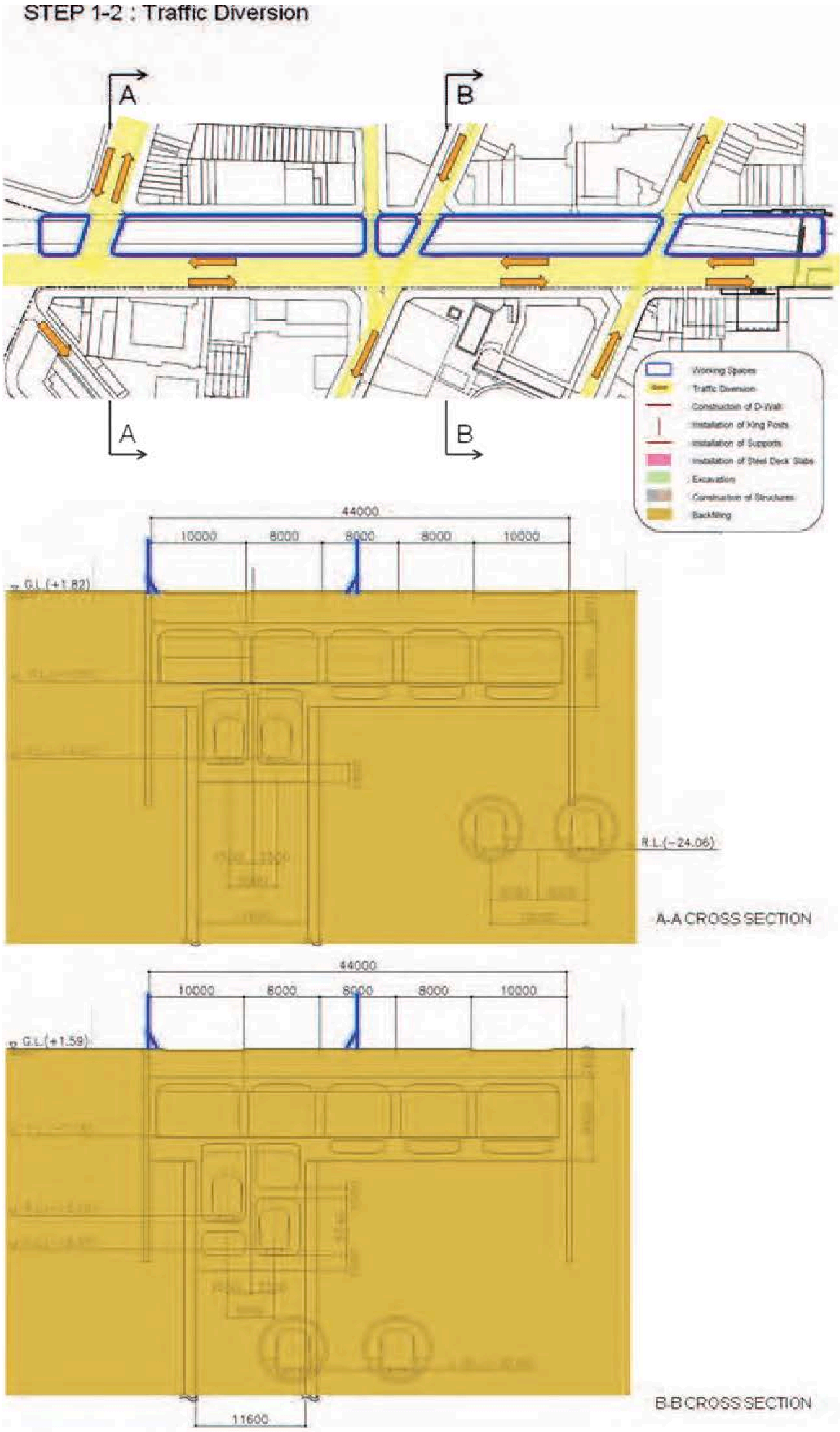


Figure 4.94 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (2/14)

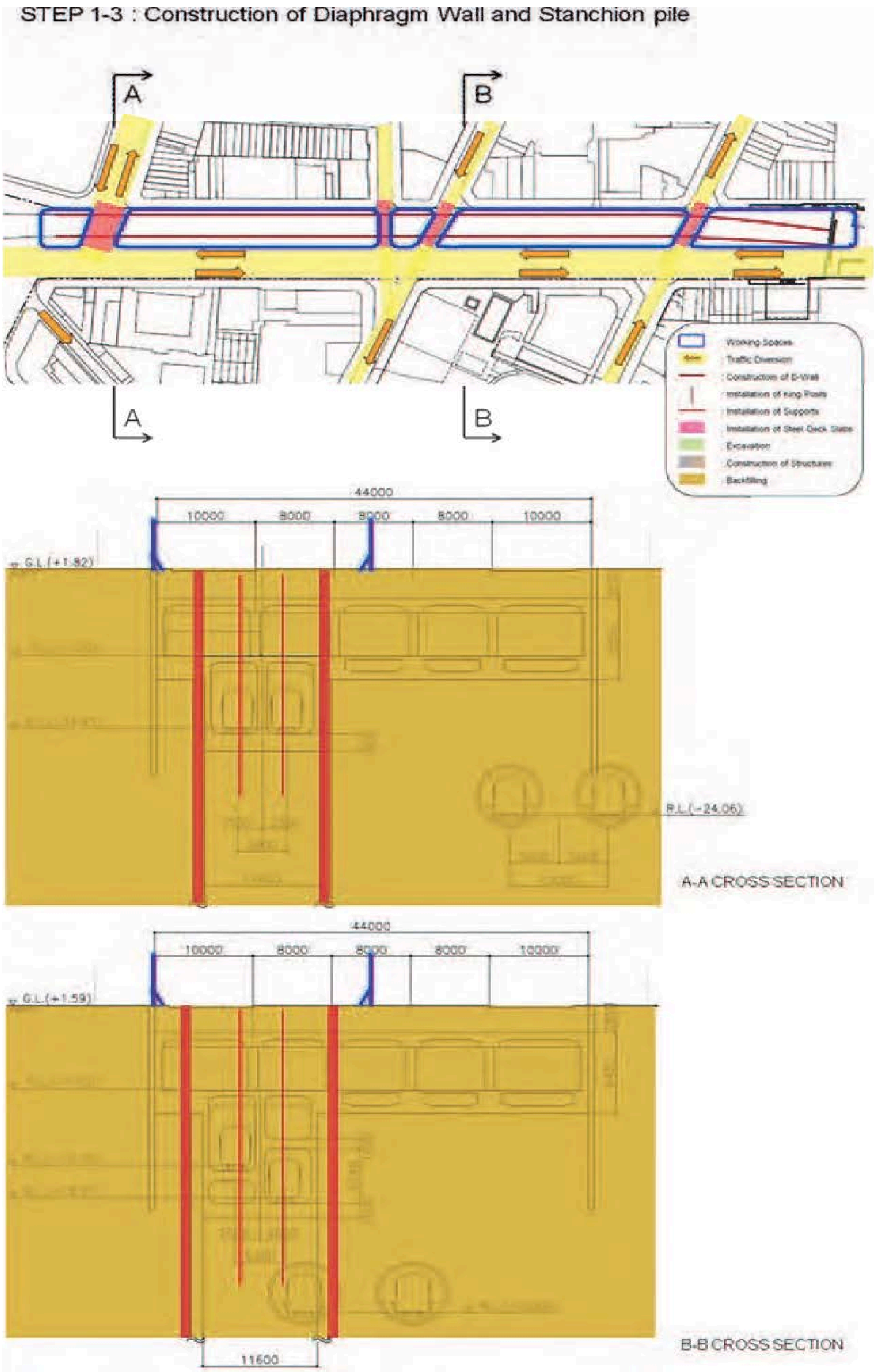


Figure 4.95 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (3/14)

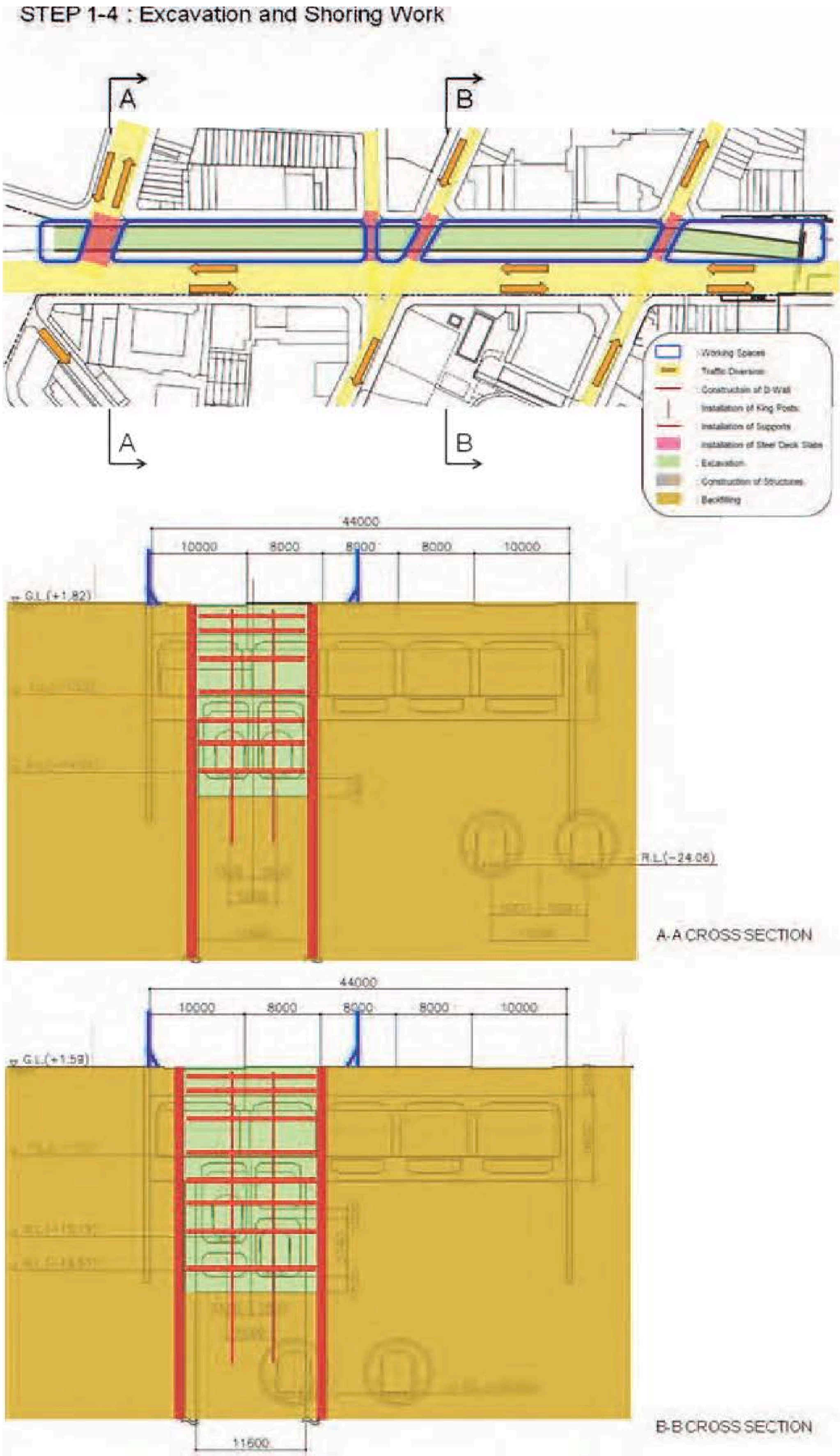


Figure 4.96 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (4/14)

Figure 4.97 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (5/14)

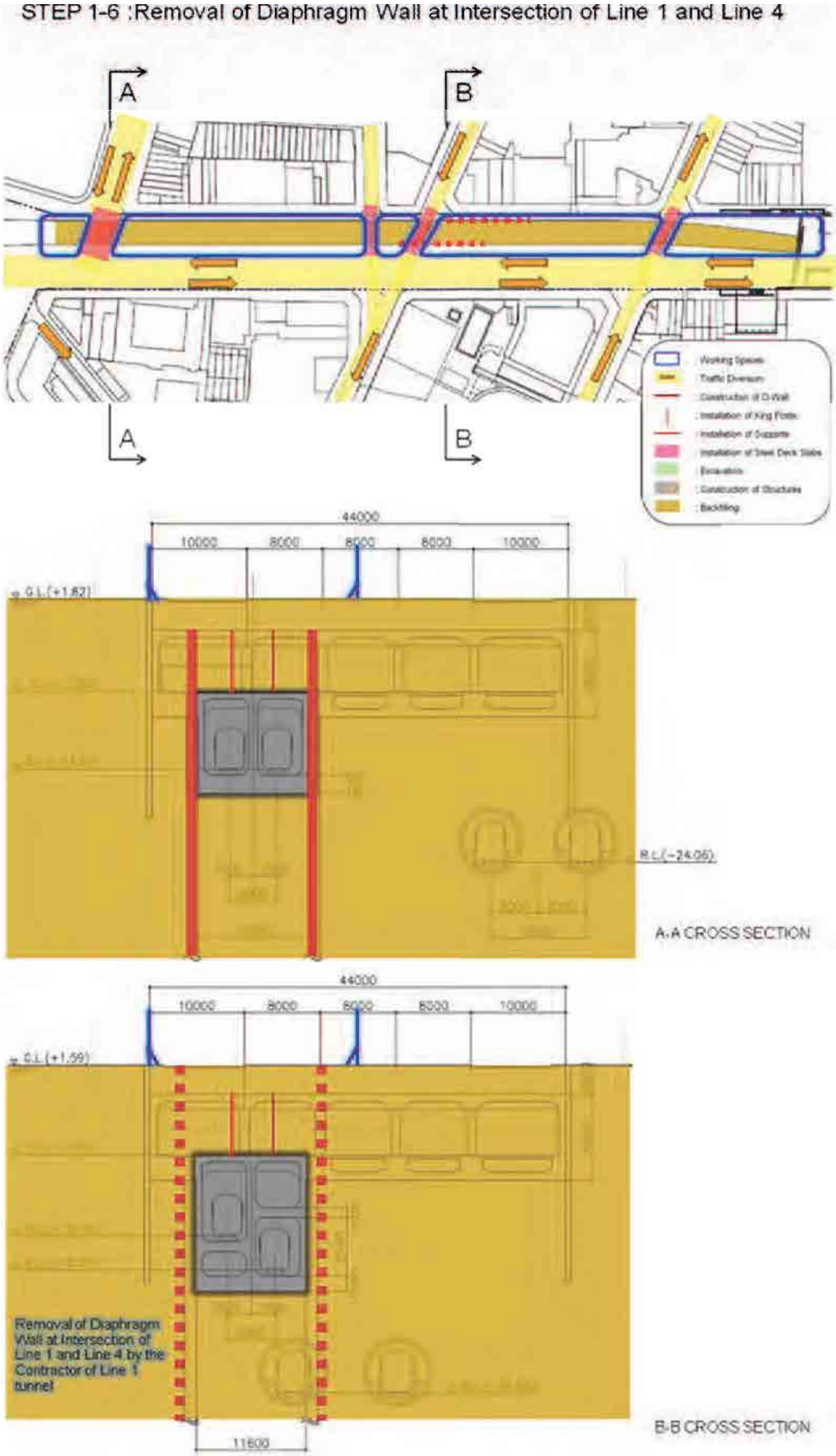


Figure 4.98 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (6/14)

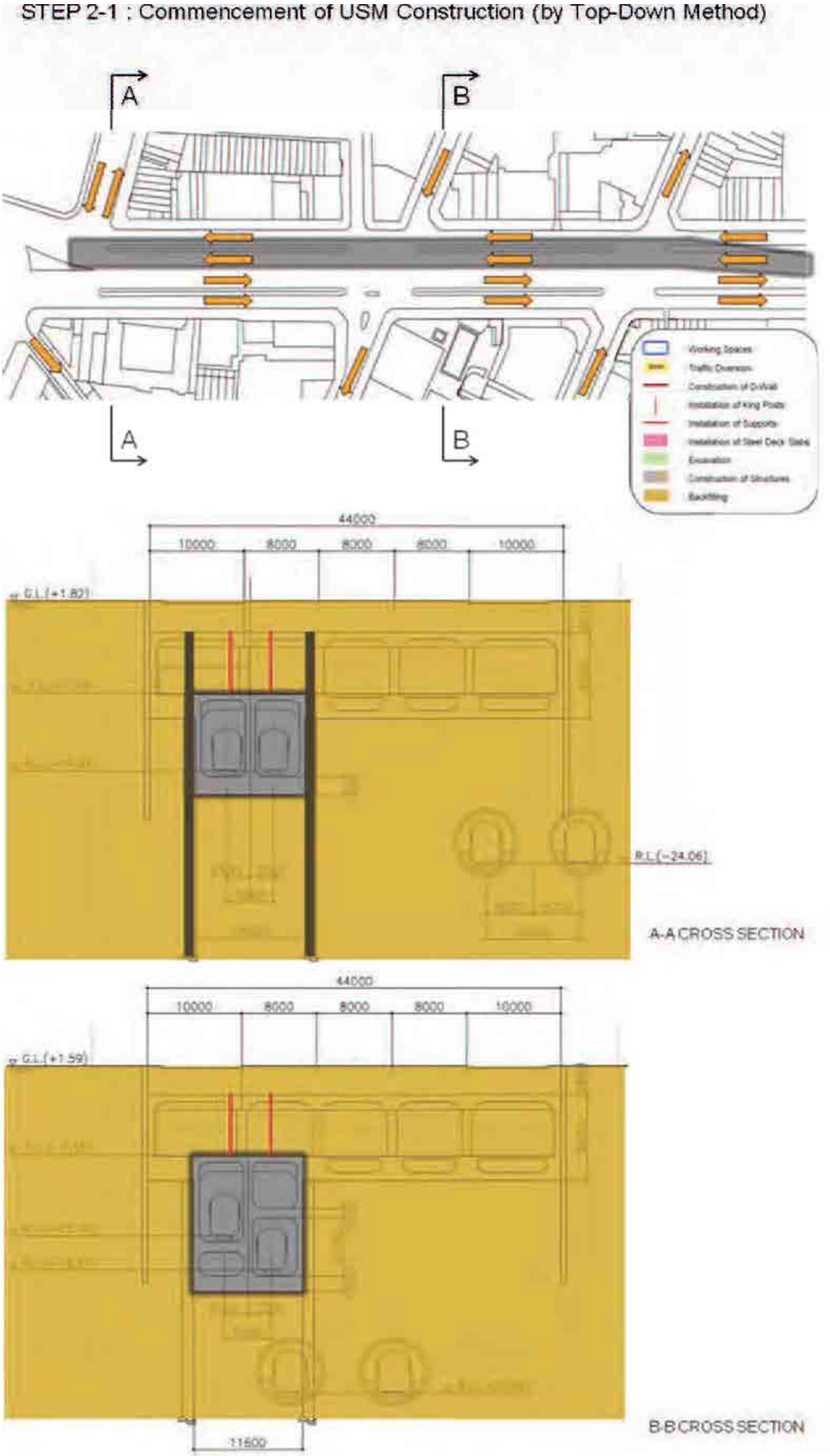


Figure 4.99 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (7/14)

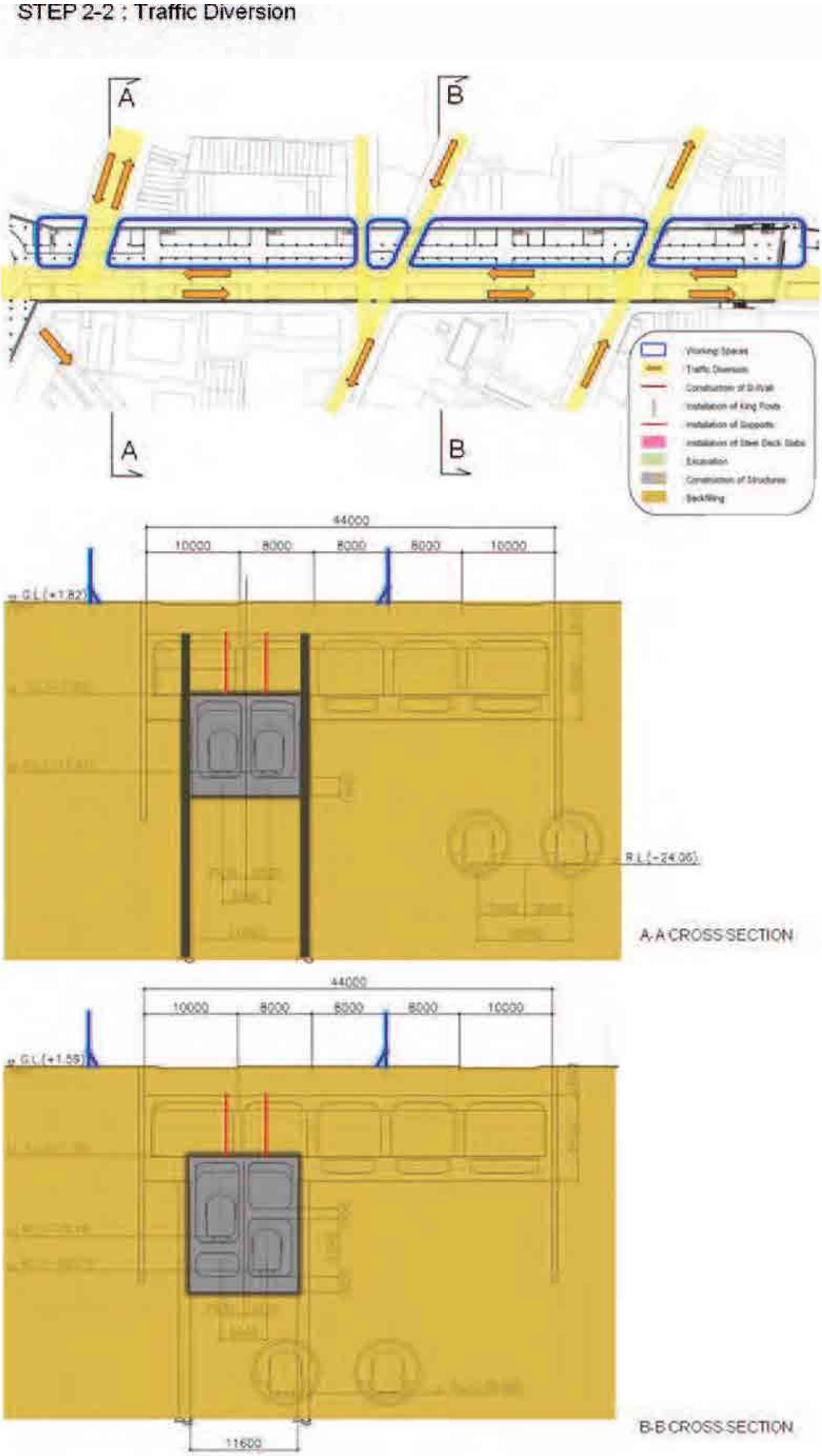


Figure 4.100 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (8/14)

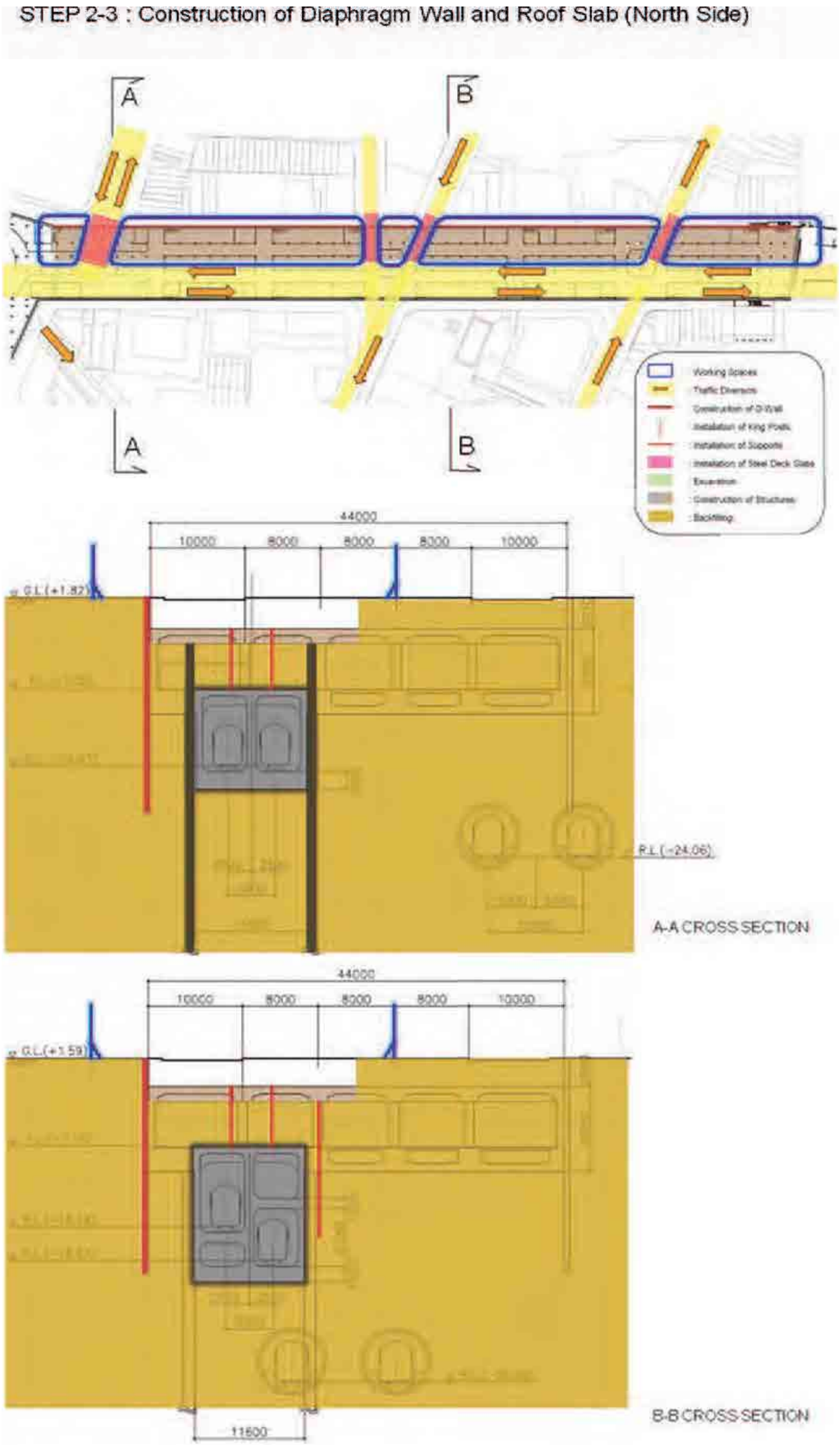


Figure 4.101 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (9/14)

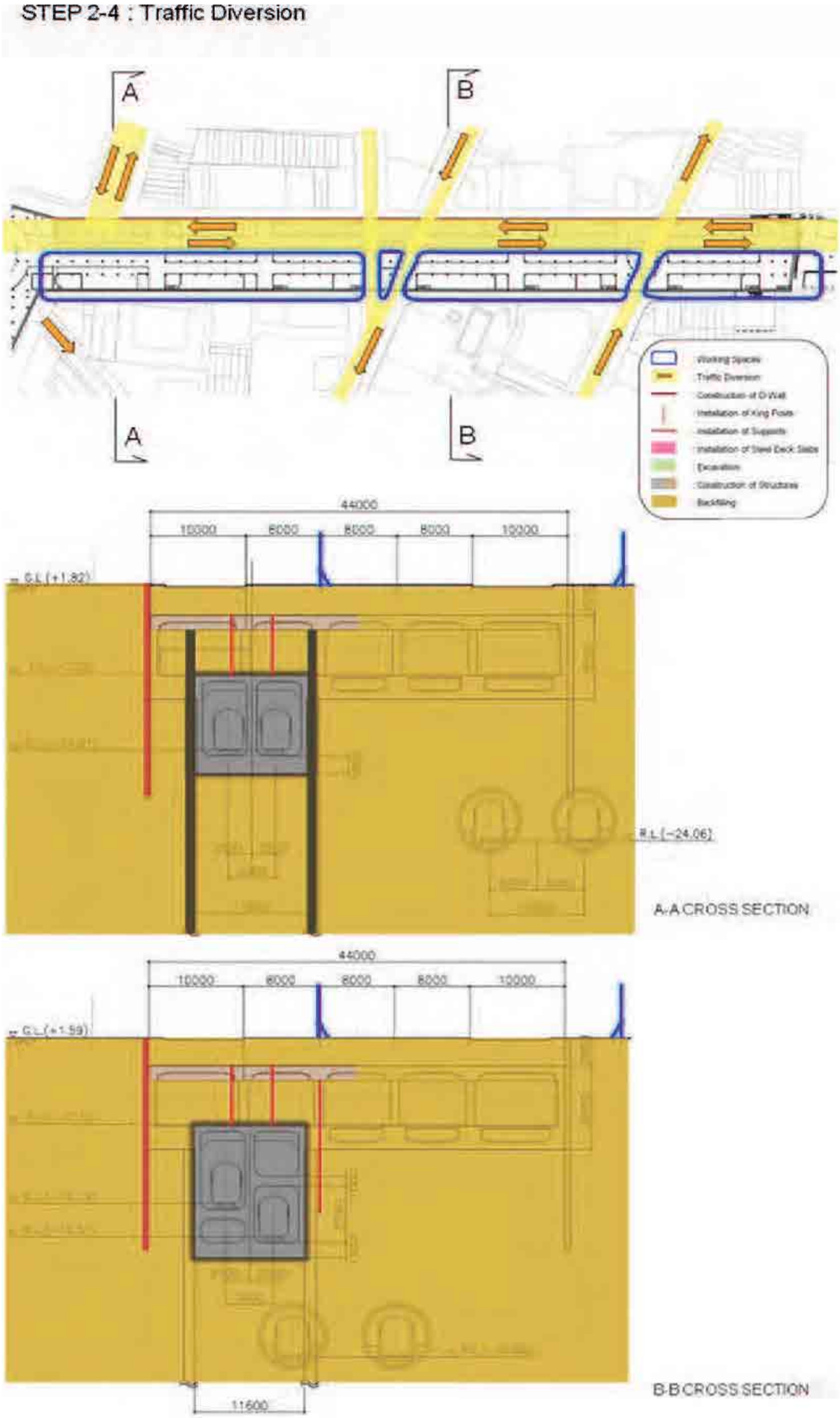


Figure 4.102 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (10/14)

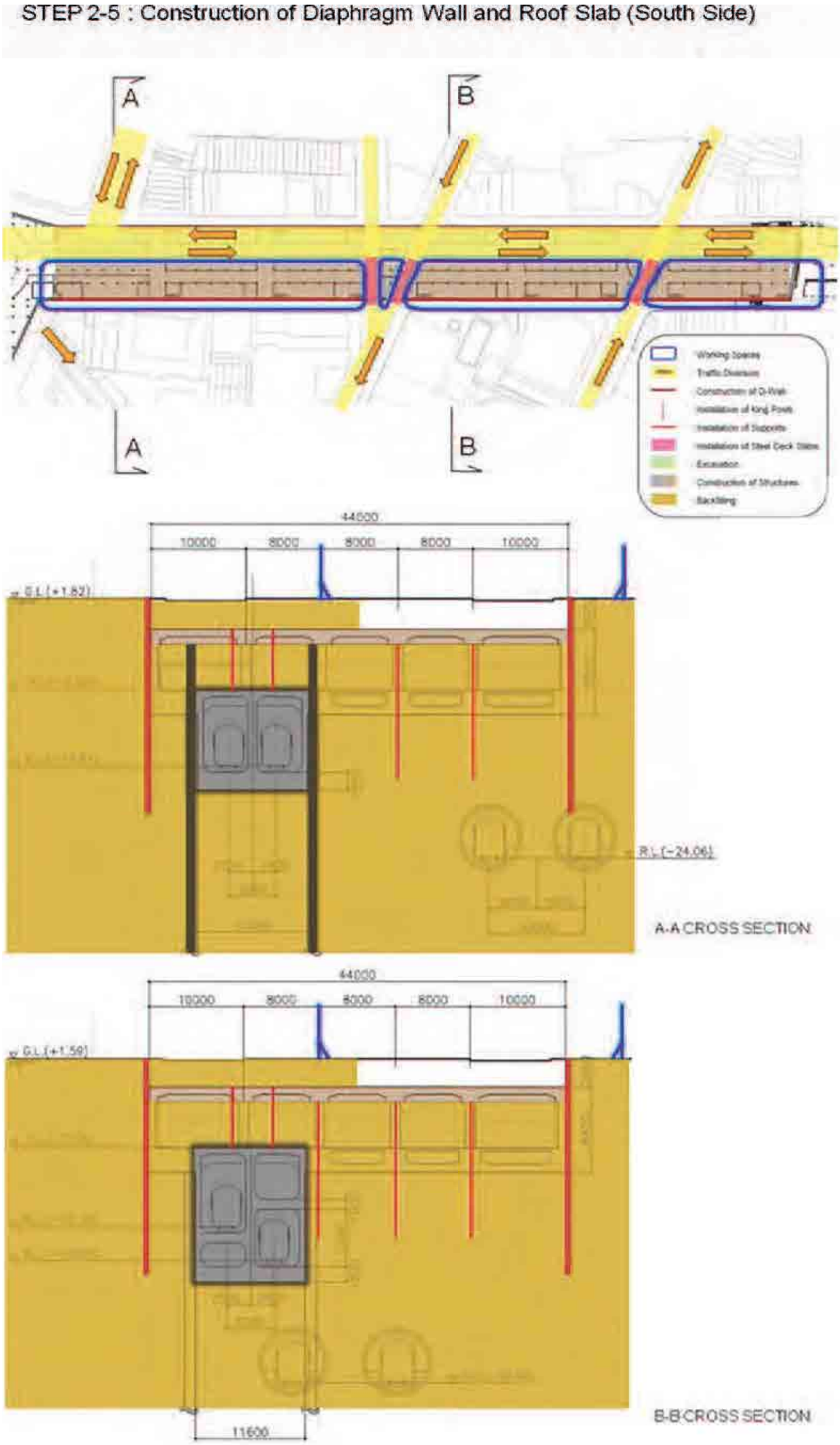


Figure 4.103 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (11/14)

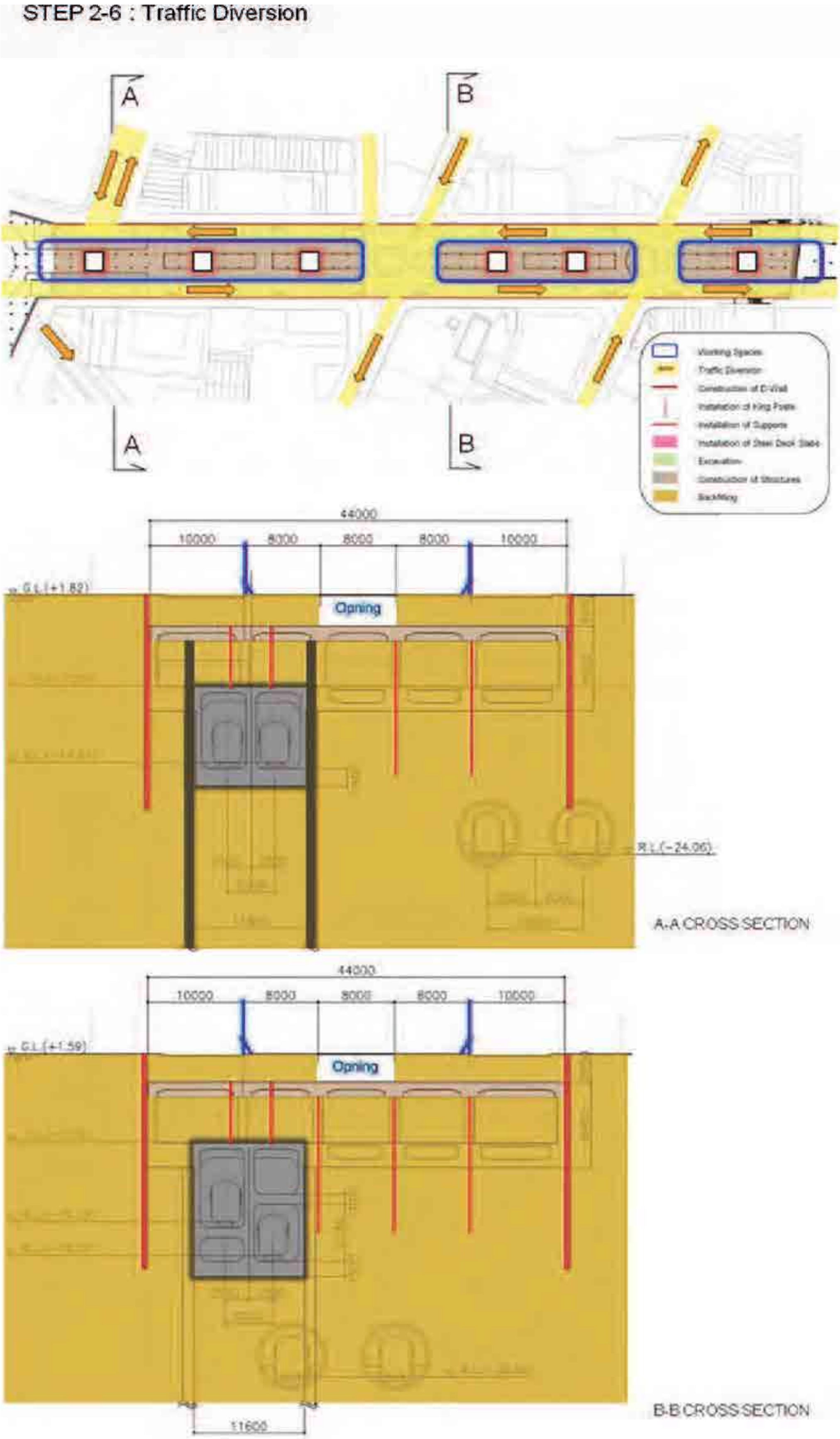


Figure 4.104 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (12/14)

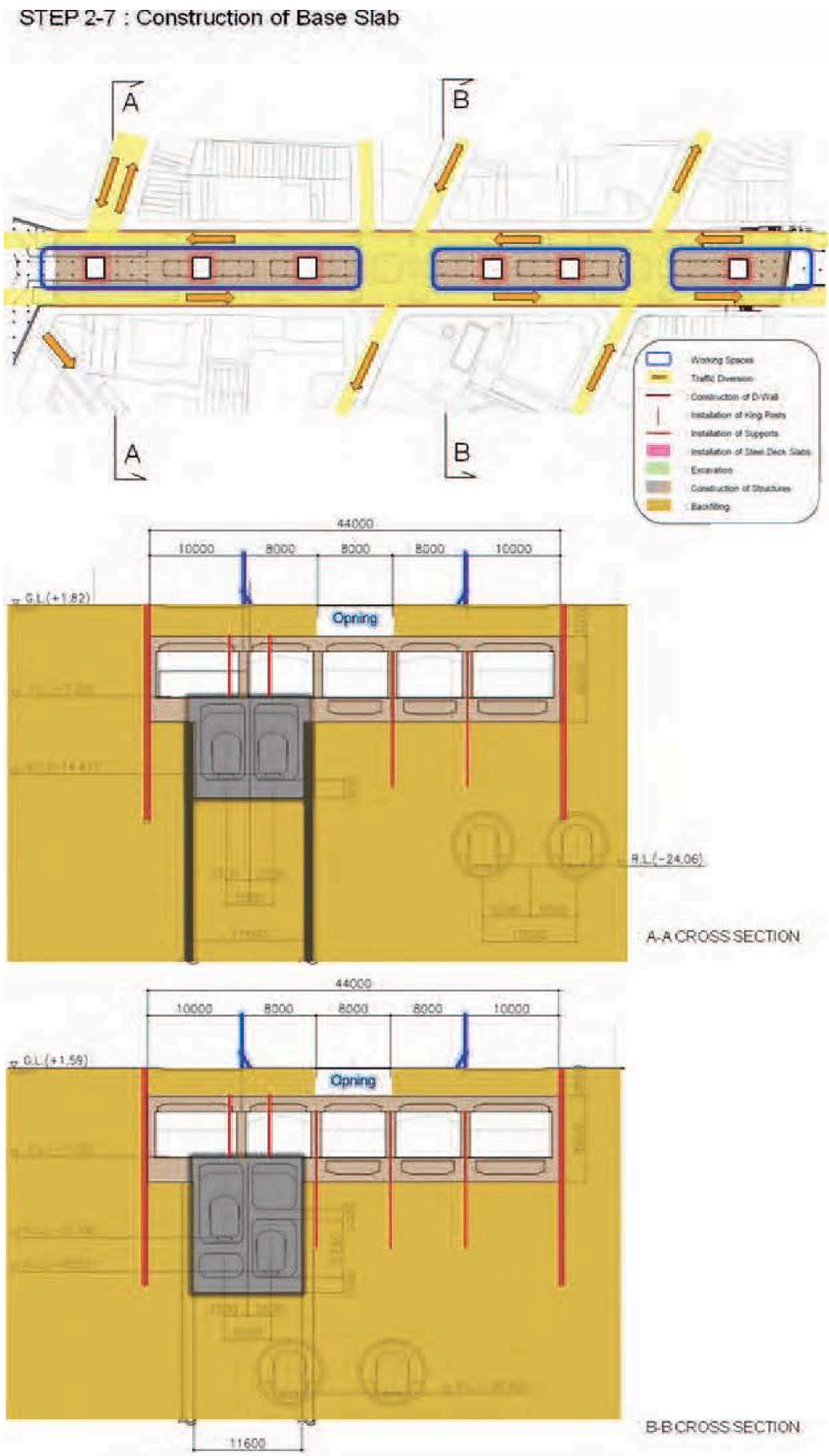


Figure 4.105 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (13/14)

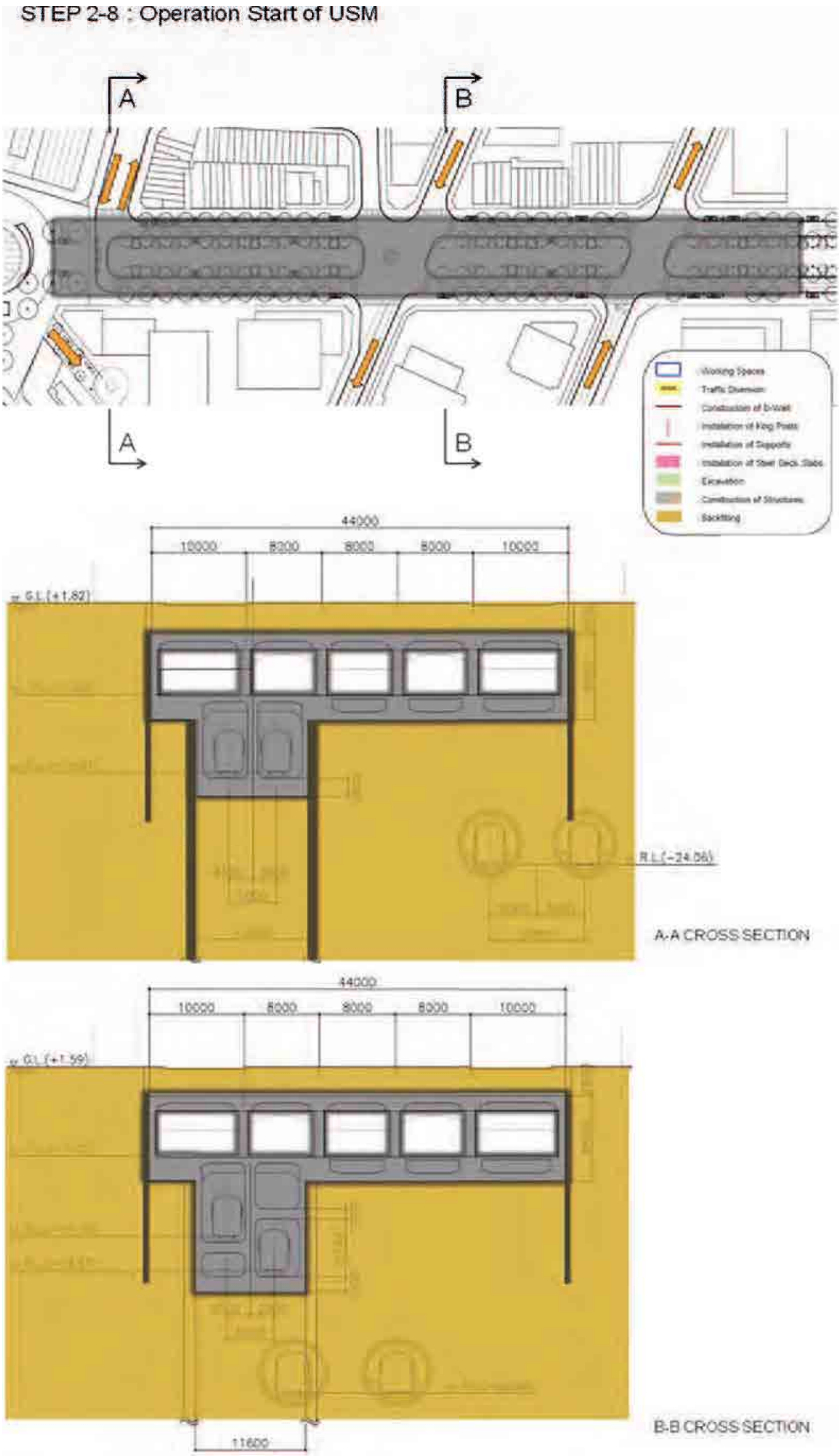


Figure 4.106 Construction Sequences of Line 1 Tunnel and USM beneath Le Loi Street (14/14)

Table 4.31 Preliminary Construction Schedule of Line 1 Tunnels and USM beneath Le Loi Street (Phased Construction)