# DESIGN OF UNDERGROUND RAILWAY STRUCTURE IN THE AIRPORT RAIL LINK EXTENSION PROJECT

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## ABSTRACT

Underground Railway Structure in the Airport Rail Link Extension Project (ARLEX) is somewhat different from the existing MRTA Line using shield tunnel. In the ARLEX project, Cut and Cover Tunnel is selected and using top-down construction technique. Several site constraints such as available site space, traffic conditions, underground utilities and underground railway structure of RED Line make design of the structure more complicated and many precautions or warning system during construction are required. Soil structure interaction analysis and staged construction technique are major roles and be the Geotechnical challenge in this project.

## 1. INTRODUCTION

Policy to utilize Don Muang Airport sharing rapidly growing up work load of the Suvanabhumi Airport is a major cause driven development of the Airport Rail Link Extension Project. Main purposes of the project are therefore to connect the two airports and also grand station of State Railway of Thailand (SRT) at Bang Sue using express train mode. Local traveling of passengers along the route could be done by city-line mode (not the express). The project route is shown in the Figure 1. The project route is mostly in the existing right of way of SRT in order to minimize land acquisition problems.

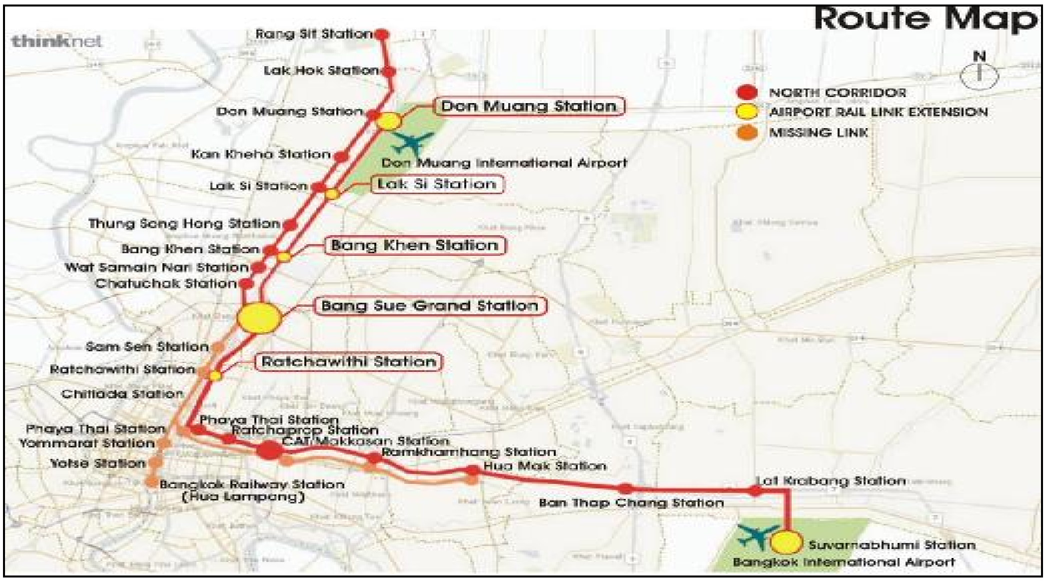



Figure 1: Route Map of Airport Rail Link Extension Project (ARLEX)

The project is an extension of the existing Airport Rail Link running from Phayathai Station to Suvanabhumi Airport. The extension starts from the Phayathai Station to the Don Muang Airport. Railway structure of the project could be divided into two sections such as underground and elevated section. The underground section required by Environmental regulation start from Rama VI Road intersection to Sam Sean Station near Pradiphat intersection as shown in Figure 2.

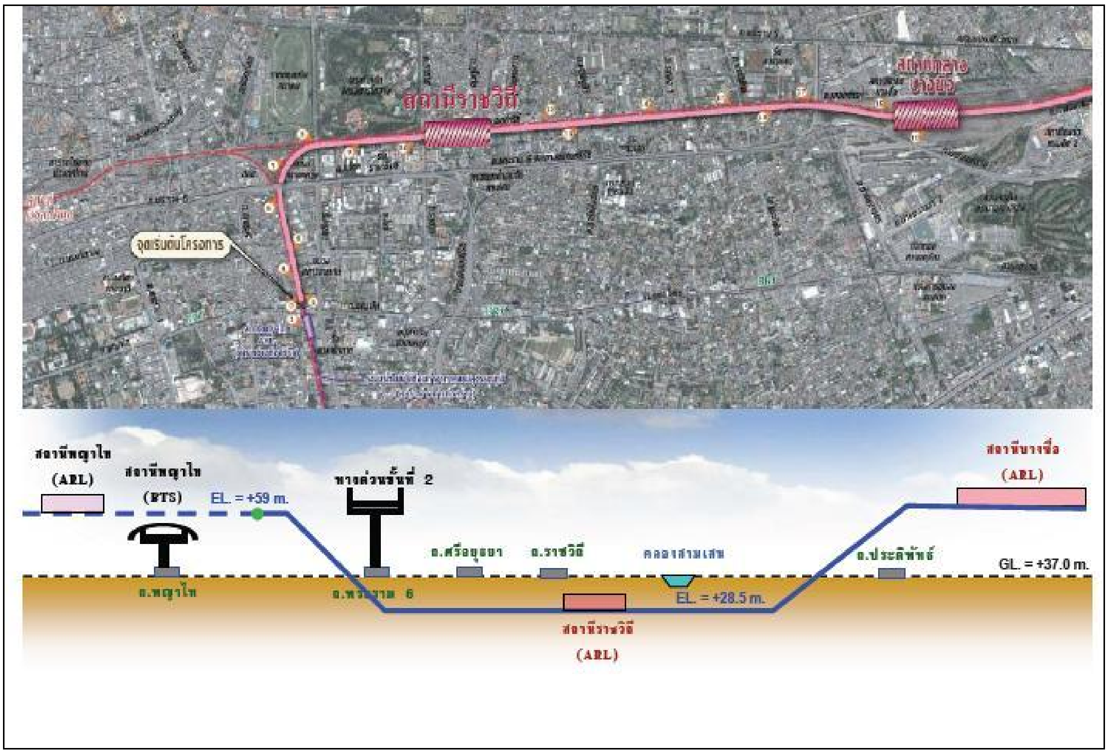



Figure 2  Plan and Profile of the Underground Section of The ARLEX

## 2. DESIGN CONSIDERATIONS

Considerations for design of underground railway structure should include the followings.

- Train system and design requirements of railway structure as per major rules of State Railway of Thailand and relevant design codes such as AREMA.
- Topographic conditions and adjacent structures/buildings along project route
- Ground conditions along project route
- Area utilization before and after construction and accompanying development
- Current and available construction techniques, and past experiences of underground structure construction in Soft Bangkok Clay
- Construction cost  and construction period
- Current traffic conditions and possible traffic impact during constructions
- Construction impact on adjacent households and adjacent buildings
- Other site constraints such as underground utilities, land acquisition problems

In this project, underground railway structure starts from Sta. 0+700 to Sta. 4+250 to comply with environmental regulation required underground railway in vicinity of the Chitlada palace.  The underground structure in the project could be categorized as follows:

- Transition Structure for transitioning between tunnel and elevated structure

- Open trench structure for shallow underground railway
- Cut and Cover Tunnel to overcome urban constraints
- Cut and Cover Tunnel according to environmental regulations

The structure pattern for particular area has been designed to suit with changing of vertical alignment, impacts on adjacent structures including on and underground and subsurface conditions along the project route.

## 3. GROUND CONDITIONS

Ground conditions along the project route were investigated by performing soil borings and taking soil sample for laboratory tests. In addition, field vane shear tests were performed to obtain in-situ shear strength of soft clay. Ground conditions could be summarized as follows:

*Sandy or Clayey Soil Fill or Weathered Clay Crust Layer*:- thickness varies from 1.5 to 5.5 m, grayish brown to brown in color

*Very Soft to Soft Clay Layer*:- found under layer 1 with thickness varies from 5.5 to 10.5 m, dark gray to gray and greenish grey in color.

*Medium Clay Layer*:- encountered from 10-15 m depth

*First Stiff to Hard Clay Layer*:- encountered underneath medium clay layer, thickness varies from 9- 21 m

*First Sand Layer*: it is found underneath stiff to hard clay at 20.5 -34 m depth from ground surface.

*Alternating stiff to Hard Clay Layer and Sand Layers*- found under the first sand layer

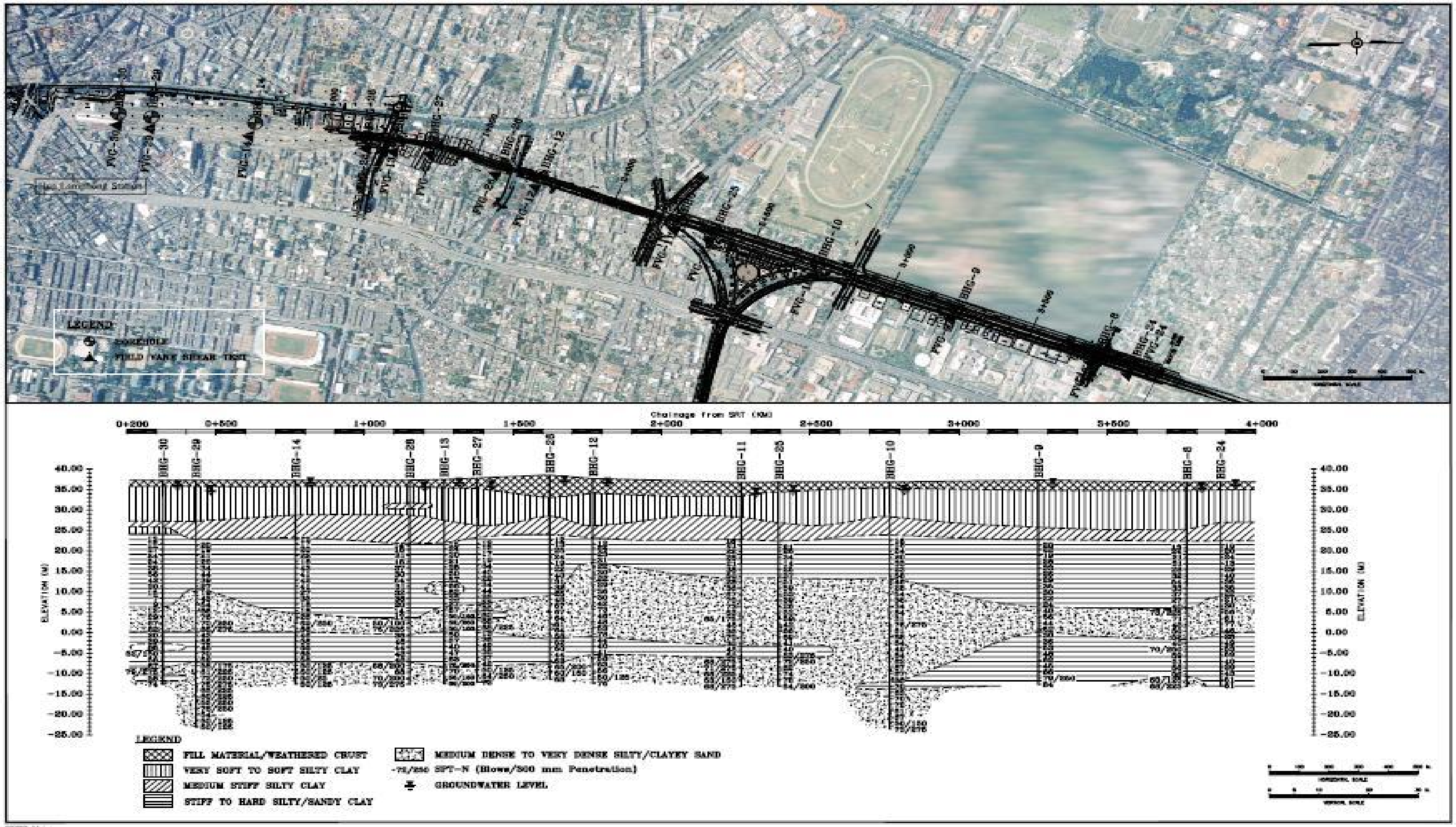



Figure 3:  Soil profile

## 4. TRANSITION STRUCTURE

Transition between elevated railway structure and tunnel in vicinity of Phayathai and Samsean Station has been designed by using bearing slab on bored piles. Flood is one of serious issues for the underground structure, it is therefore protected by providing flood protection wall up to +38.0 m (SRT datum) level or about 3 m MSL, as shown in Figure 4

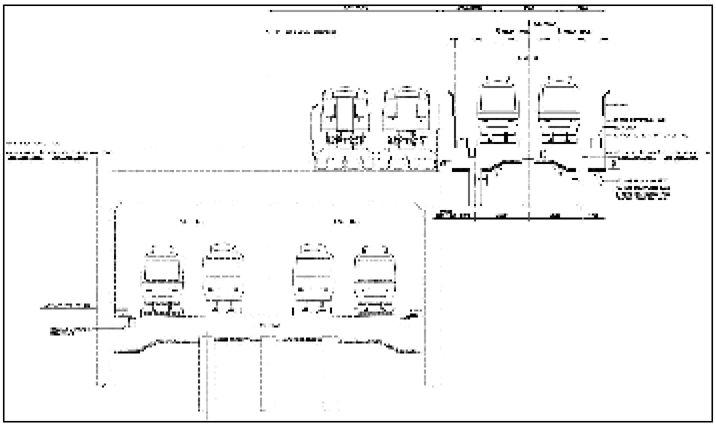


Figure 4 Typical Transition Structure in the ARLEX Project

## 5. OPEN TRENCH STRUCTURE AT SHALLOW DEPTH

When the underground rail level is deeper but less than 3 meter, the structure has been changed to Open Trench by using Conventional Retaining Wall System that excavate for constructing wall as shown in Figure 5. Temporary earth retaining system such as sheetpile wall and bracing system is required to protect the soil during excavation for bottom up construction technique. This technique is selected because less construction cost but its application is not suitable when the excavation depth is greater to minimize ground movement and its impacts to adjacent buildings or Red line underground railway.

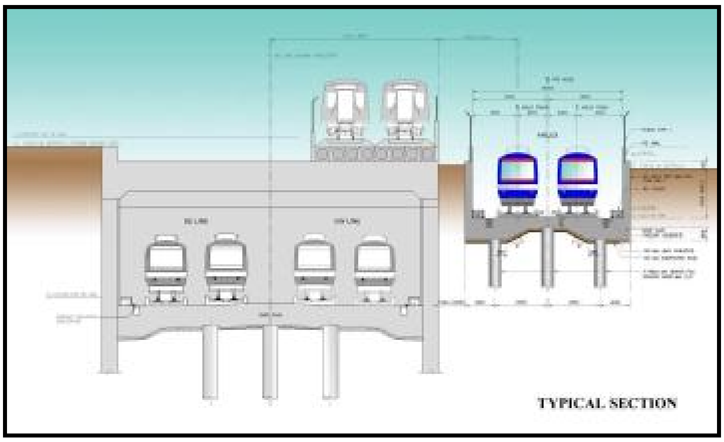



Figure 5 Typical Underground Structure Type at Shallow depth

When the rail level is deeper than 3 meters, the earth retaining system has been changed to be Diaphragm Wall and using Top Down construction technique. Diaphragm wall is utilized for temporary wall during excavation and permanent retaining wall of Open Trench structure to minimize ground movement during construction. Typical railway structure is shown in Figure 6.

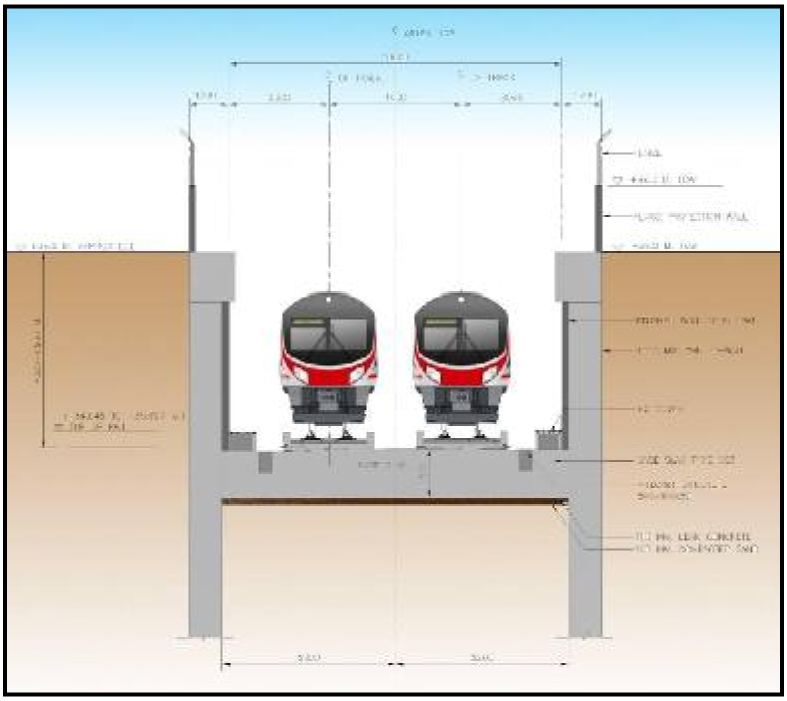


Figure 6 Typical Deep Open Trench Structure

## 6. CUT AND COVER TUNNEL TO OVERCOME URBAN CONSTRAINTS

Where the project route intersect with urban roads such as Rama VI road, Sri Ayutthaya road, Rajavithi road and Nakornchaisri road, cut and cover tunnel is adopted to allow for utilization of space above tunnel for other works such as local road for serving station and other underground utilities, as shown in Figures 7 & 8.

Furthermore, the special short Diaphragm wall is used to provide the space underneath the railway tunnel for allowing other future underground utilities possible to pass through the railway route, as shown in Figure 9. In addition**,** avoiding impacts on foundation of the second express way, it was decided to change the route passing through the highway department's area as shown in Figure 9. In this particular area, cut and cover tunnel is adopted, as shown in Figure 10, so that highway department can use top area of tunnel.

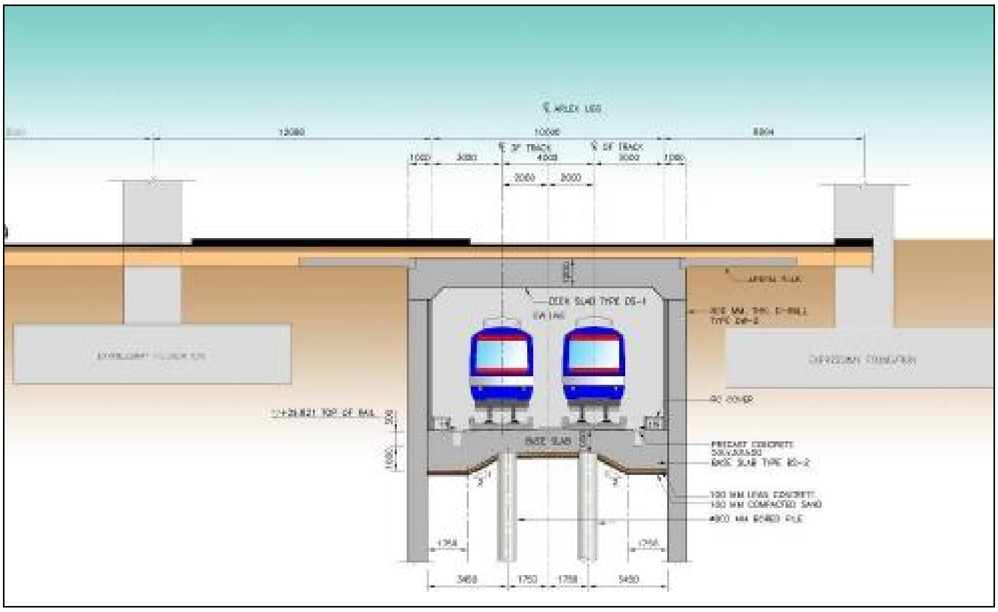


Figure 7 Underground Railway Structure at Rama VI Intersection

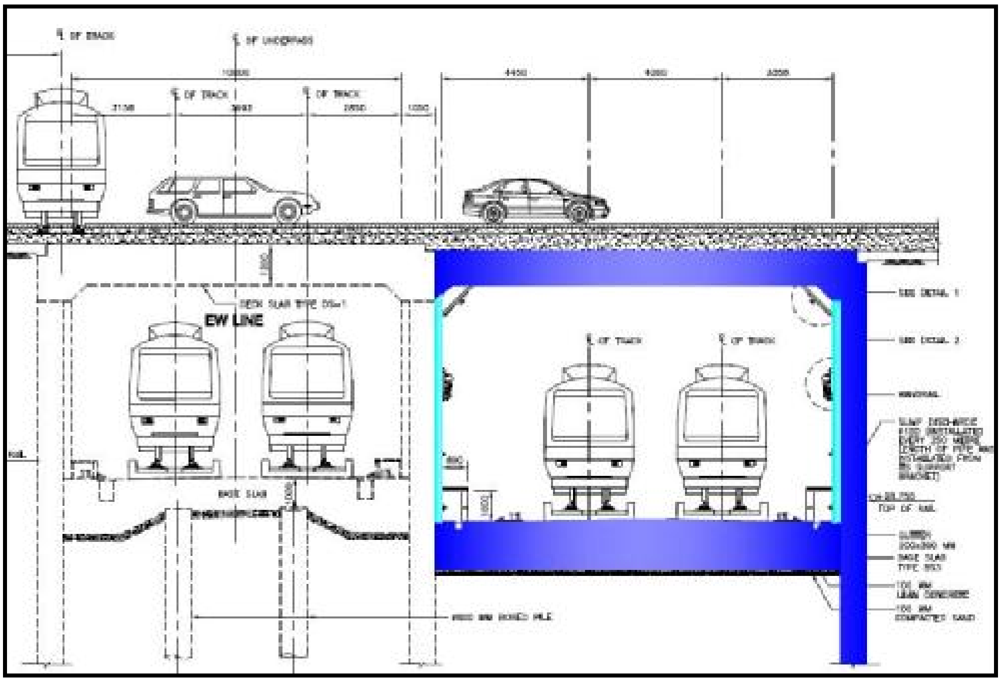



Figure 8 Underground Railway Structure at Nakhonchaisri Intersection

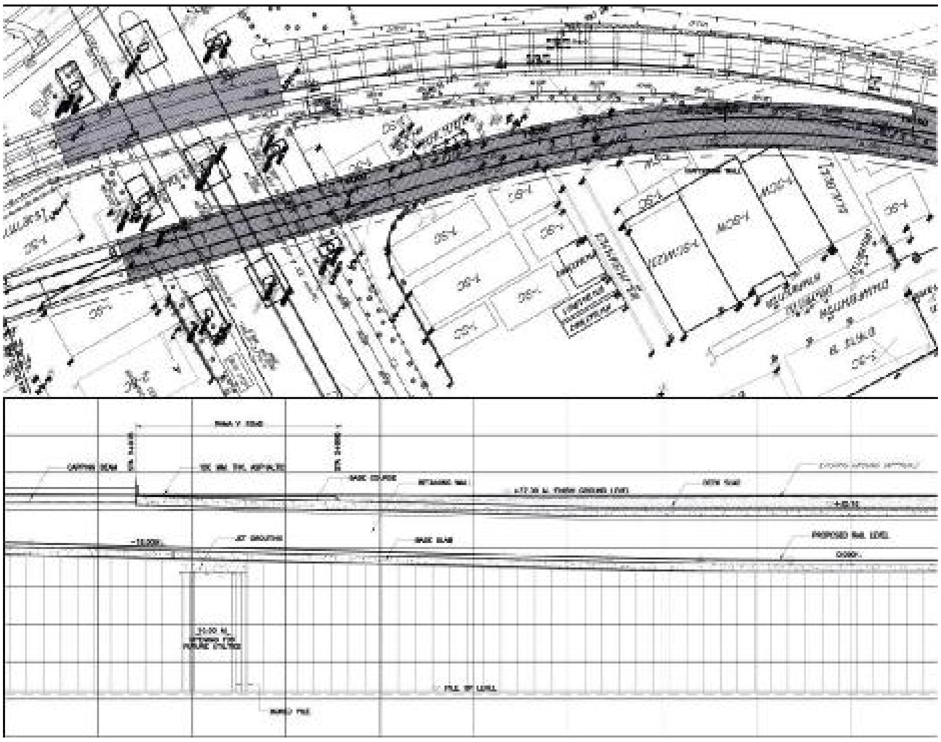


Figure 9 Plan and Profile of the Railway in vicinity of Rama VI road and Department of Highway

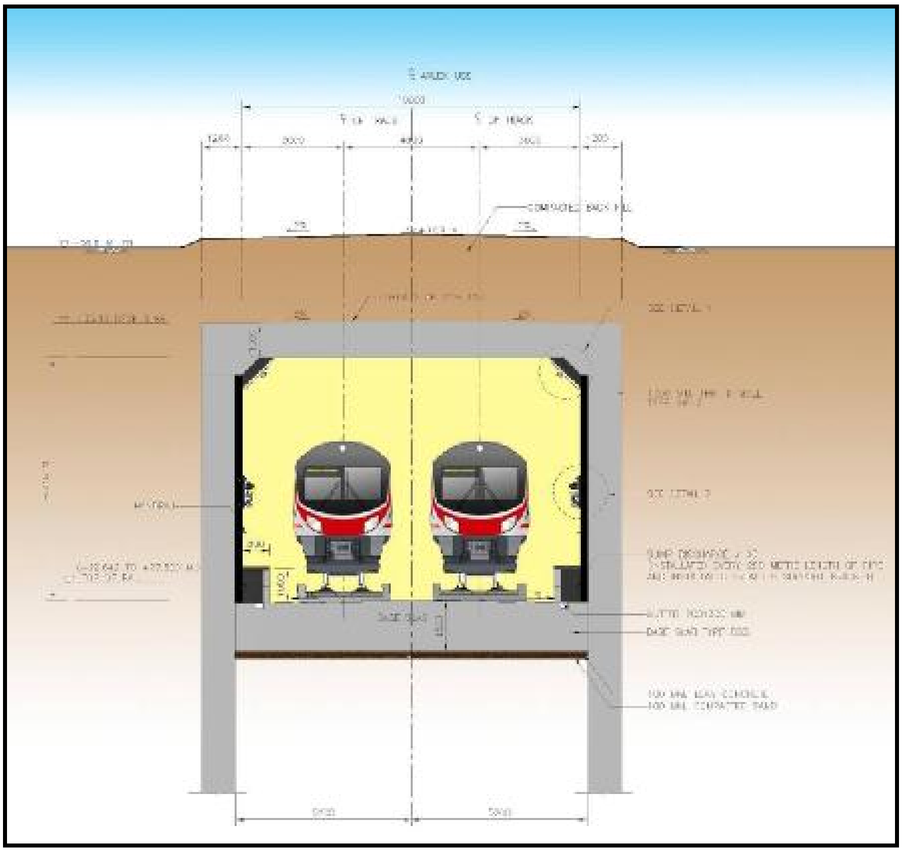


Figure 10 Typical Section of Underground Structure underneath the Area of Department of Highway

## 7. Underground Railway Structure according to Environmental Regulations

Development of the project passing Chitlada station has been controlled by three aspects, first is environmental regulation specified for underground structure and second is existing red line project that already design as two level underground railway structure, and the last one is limitation of the right of way. Therefore, development of ARLEX structure has to be complied with the above restrictions. It is decided to use cut and cover tunnel the same as railway structure of the red line project. Common diaphragm wall is adopted due to limitation of right of way. The other side of tunnel wall is therefore necessary to be deep to avoid differential settlement of the two projects. Typical section of the ARLEX structure in this area is shown in Figure 11.

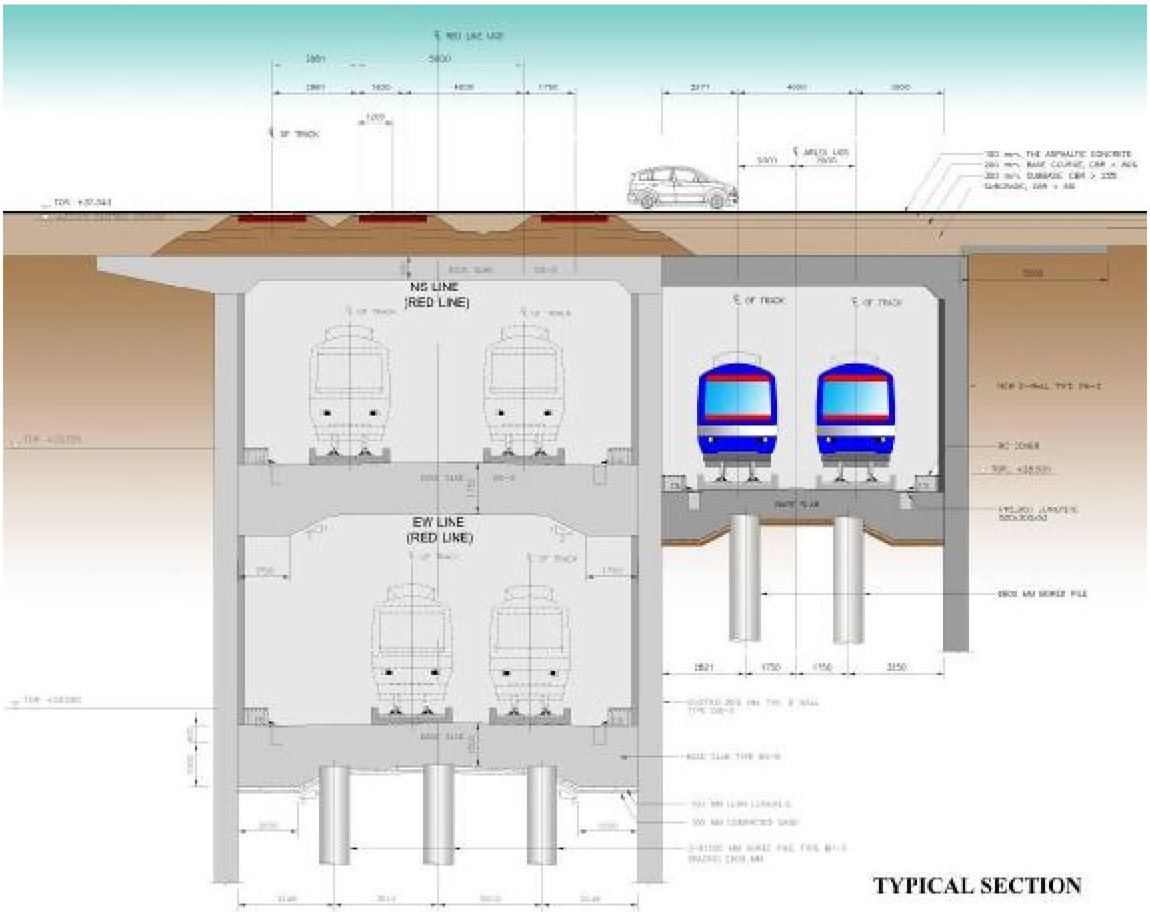



Figure 11 Typical Section of Underground Structure in front of Chitlada Palace

In addition, space above tunnel is provided for other infrastructures construction of the bridge on top for service road at Rajavithi Station as shown in Figure 12 and Figure 13. The bridge was designed and divided to 3 parts which the last part will use for underground infrastructure through east and west such as big water pipe and gas pipe for Chitlada Station.

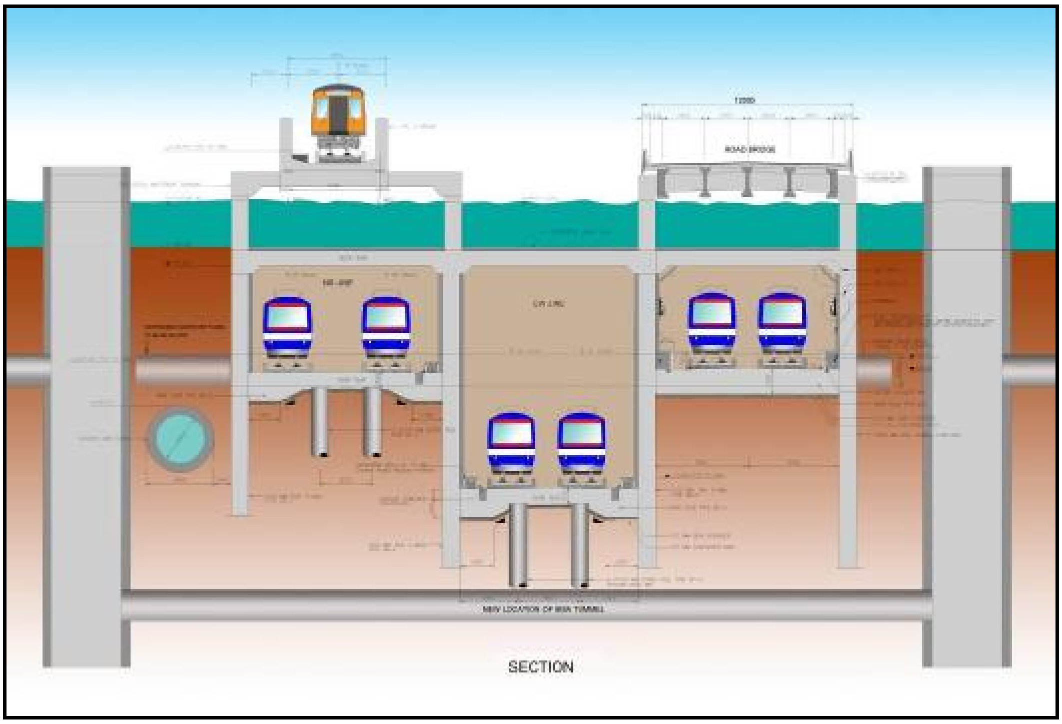



Figure 12 Underground Railway in Area of Khlong Samsean

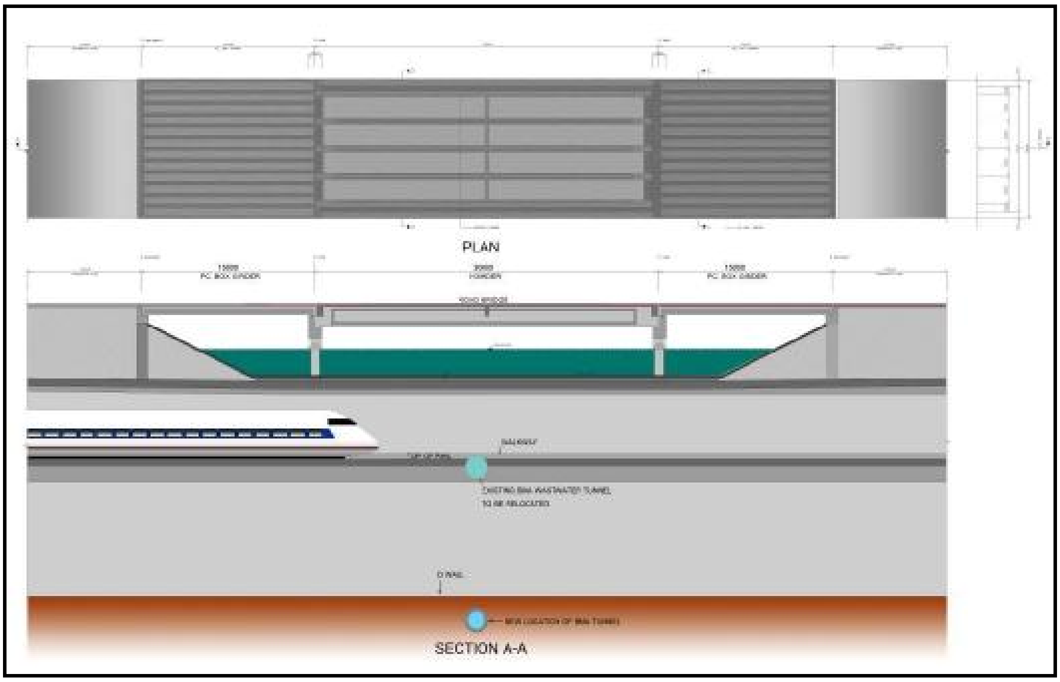



Figure 13 Proposed Bridge over Khlong Samsean

## 8. Underground Railway in Area of Satsanguan Vittaya School

Due to the limit of underground infrastructure including big size tunnel of the Metropolitan Waterworks Authority which is located in the west of this project around Sam Sen canal and red line tunnel that avoid water tunnel to the east. The area of train department has limited and not enough to support tunnel structure of Airport Link Extension. Thus, the land expropriations around Sam Sen canal to Sam Sen Train station are needed. The structure was therefore designed together with red line project as shown in Figures 14 &15.

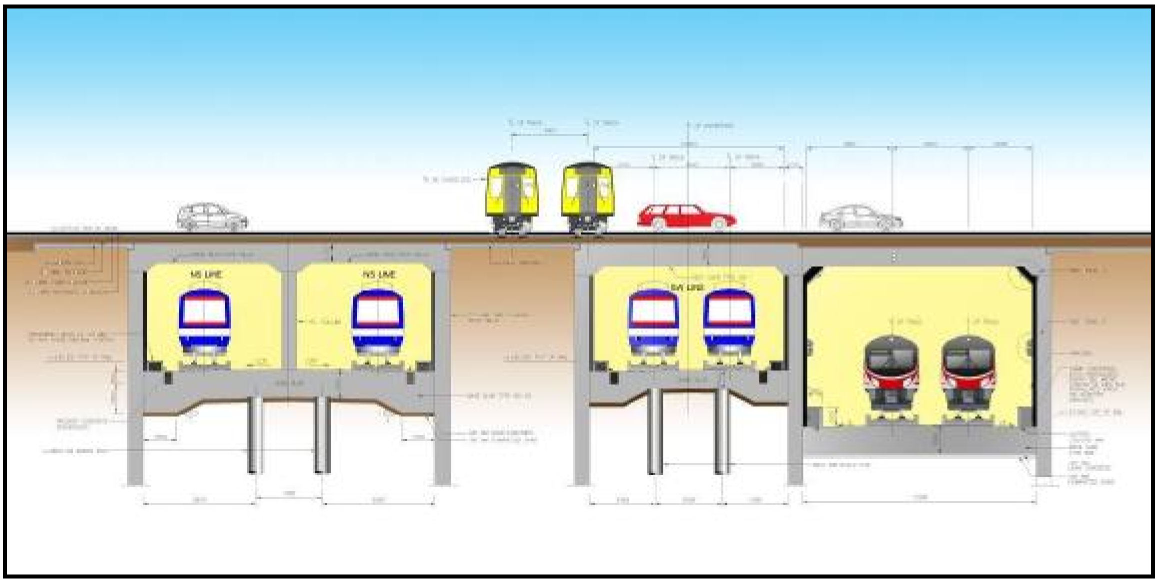
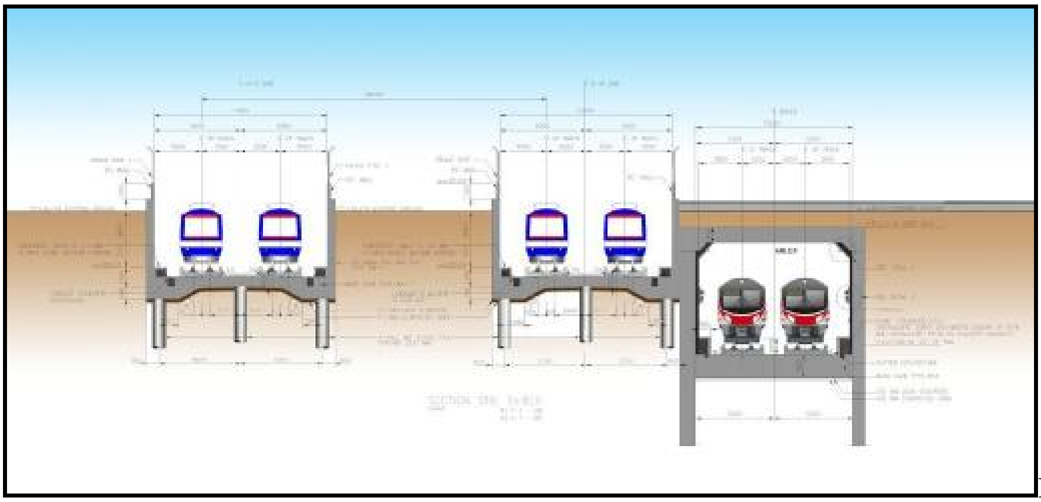


Figure 14 Railway Structure at Nakhonchaisri Intersection



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igure 15 Underground Railway in Area of Sam Sean Station

Moreover, alternative design considered as Optional Design were carried out using Shield Tunnel instead of Cut and Cover. However, in this case Rajavithi Station is omitted as shown in Figures 16.

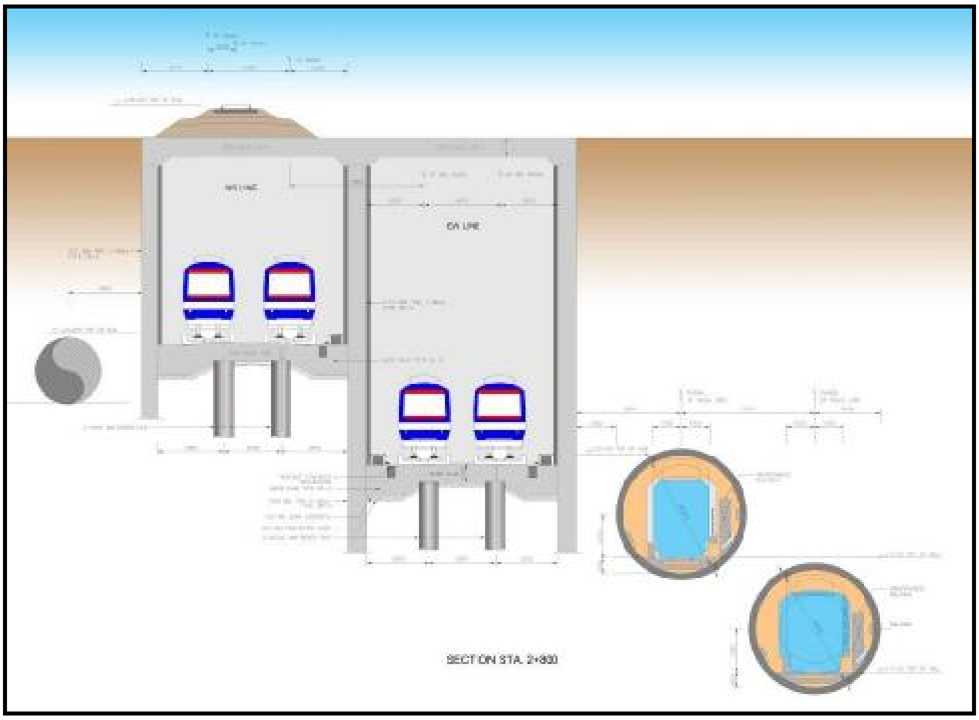


Figure 16  Optional Shield Tunnel Arrangement

## 9. GEOTECHNICAL RISKS

As can bee seen from the above mentioned, underground structure in the project concerns understanding soil/structure interaction behaviors, variation of subsurface conditions, impact of ground movement on adjacent structures and buildings as well as existing underground utilities such as old reinforced concrete water tunnel, .etc. Therefore, construction of the project requires proper risk management resulting from the geotechnical aspects. Observation method using geotechnical instrumentation to monitor responses or behaviors of the underground structure during construction would be one of possible technique that could minimize the risks. Example of the instrument layout is shown in Figure 17.

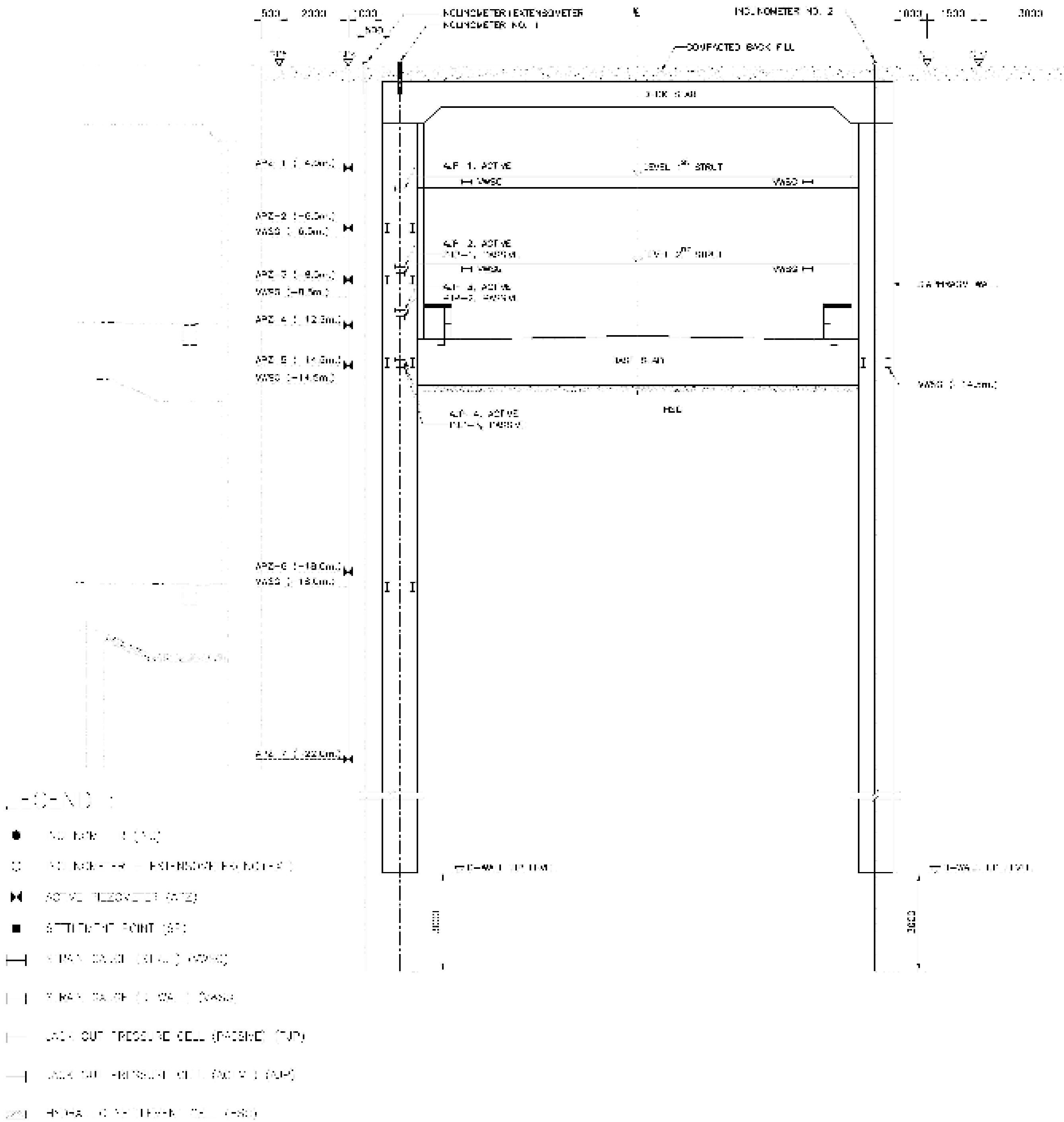

Figure 17 Typical Instrumentation Layout for Construction of Cut and Cover Tunnel