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22 April 2010
**By Post and email**

**Attn : Dr. Glenn Frommer**

Dear Sir

**Express Rail Link**
**Consultancy Agreement No. C806**
**Independent Environmental Checker (IEC)**
**Environmental Permit No.: EP-349/2009**
**Hydrogeological Impact Assessment Report**

I refer to the Hydrogeological Impact Assessment Report received on 14 April 2010. Pursuant to the EP Condition 2.10, I hereby verify the Hydrogeological Impact Assessment Report.

Yours faithfully,
for MOTT MACDONALD HONG KONG LIMITED

Dr. Anne Kerr
Independent Environmental Checker (IEC)

MTR Corporation Limited

**Consultancy Agreement No. C803**
**Express Rail Link**
**Detailed Design for Tunnels & Associated Structures (North)**

# Deliverable No. 3.13A (BD Consultation) Hydrogeological Impact Assessment Report

January 2010

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**List of Abbreviations**

| | |
|---|---|
| ARUP | Ove Arup & Partners HK Ltd |
| BD | Buildings Department |
| CEDD | Civil Engineering and Development Department |
| CLP | China Light and Power |
| DSD | Drainage Services Department |
| NWDSM | MTRCL New Works Design Standards Manual |
| EAP | Emergency Access Point |
| EIA | Environmental Impact Assessment |
| ERS | Emergency Rescue Siding |
| EVA | Emergency Vehicular Access |
| GEO | Geotechnical Engineering Office |
| GIU | Geotechnical Information Unit |
| HGV | Huang Gang Park Ventilation Building (VB0) |
| HKSAR | Hong Kong Special Administrative Region |
| HyD | Highways Department |
| LKB | Lung Kwu Sheung Tan Barging Point |
| MD | Marine Department |
| MPV | Mai Po Ventilation Building (VB1) |
| MTRCL | MTR Corporation Limited |
| NTV | Ngau Tam Mei Ventilation Building (VB2) |
| PHV | Pat Heung Ventilation Building (VB4) |
| PLA | Peoples Liberation Army |
| RDO | Railway Development Office |
| SSS | Shek Kong Stabling Sidings |
| SLB | Siu Lam Barging Point |
| TKP | Tai Kong Po Plant Building |
| TLM | Tai Lam Magazine |
| VB | Ventilation Building |
| WSD | Water Supplies Department |
| XRL | Express Rail Link |

# Executive Summary

## General

The Guangzhou – Shenzhen - Hong Kong Express Rail Link is a committed cross boundary transport infrastructure project, which will provide high speed rail services between Hong Kong and Guangzhou, and a connection to the national high - speed passenger rail network serving major mainland cities outside of Guangdong province. The XRL, measuring about 26 km from West Kowloon to the boundary, will use a dedicated corridor to ensure that the required line capacity can be achieved and to ensure operational compatibility with the Mainland. The line will be within tunnels to be constructed by a combination of drill and blast, mined (bored) and cut and cover techniques.

The design and construction of the XRL project has been entrusted to MTRCL, who will be responsible for the design and construction of the works. The proposed tunnels for the XRL northern sections will be constructed by TBM, drill & blast and cut & cover methods.

This Hydrogeological Impact Assessment (HIA) Report studies the hydrogeological impact of the proposed tunnelling works from Huanggang to Tse Uk Tsuen on the potential receptors in the vicinity of the XRL tunnels under Works Contracts 823A, 823B, 824, 825 & 826. It includes the following:

- Interpretation on the existing geological and hydrogeological conditions;
- Assessment on the change of groundwater regime due to the XRL tunnel construction;
- Estimation on rates of groundwater inflow into the tunnels;
- Proposal for available mitigation options and the need for pre-excavation grouting;
- Specification, control and mitigation implementation procedures.

This HIA is considered as a general reference to demonstrate the proposed tunnelling and associated excavation works for the XRL Northern Hong Kong Section will not induce substantial impacts to the existing groundwater regime and thus the existing structures. For more information and impact caused by specific works, reference should be made to the relevant design report.

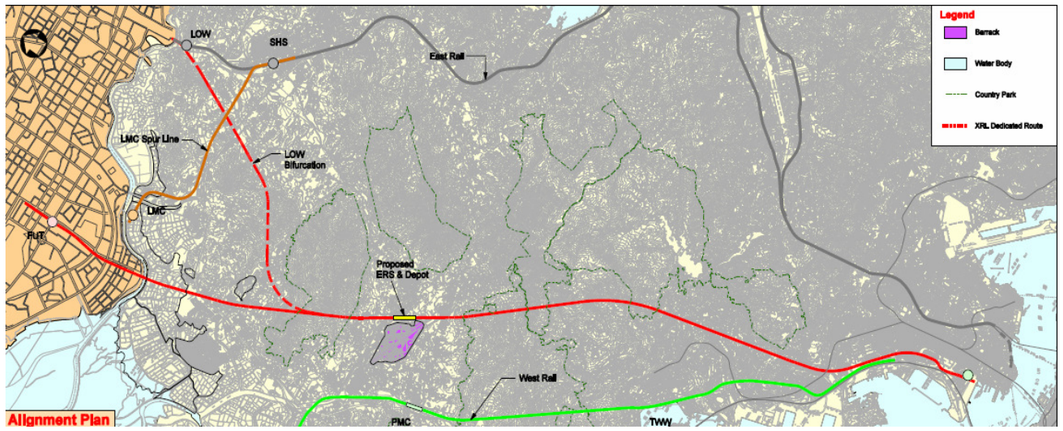
# 1 Introduction

## 1.1 Project Overview

The Express Rail Link Project is a committed cross boundary transport infrastructure project, which will provide high speed rail services between Hong Kong and Guangzhou, and a connection to the national high - speed passenger rail network serving major mainland cities outside of Guangdong province. This network, which will comprise some 12,000 km, is now under construction in the Mainland. It is understood that the section from Guangzhou to Shenzhen (Futian) will commence operation in 2010. The Hong Kong section of the Guangzhou - Shenzhen - Hong Kong Passenger Line is scheduled for urgent implementation following the announcement by the Chief Executive of the HKSAR in the 2007 - 08 Policy Address.

The XRL, measuring about 26 km from West Kowloon to the Boundary, will use a dedicated corridor to ensure that the required line capacity of 200kph can be achieved, operating at 20 trains per hour whilst ensuring operational compatibility with the Mainland. The line will be within tunnels to be constructed by a combination of drill and blast, mined, TBM and cut and cover techniques.

**Figure 1.1 Layout of XRL**




## 1.2 Project Objectives

Objectives of the XRL project are broadly described as follows:

- Provide a safe, reliable, convenient and comfortable high speed rail transport service for the public between Hong Kong and Mainland China.
- Be cost effective.
- Encourage alternative forms of transport to road based modes.
- Improve the urban environment by reducing road congestion and pollution.
- Encourage a comprehensive approach to urban planning and transport.
- Promote urban renewal in older districts.
- Improve the quality of life for Hong Kong residents.

## 1.3 Tunnels & Associated Works (North)

The Detailed Design of the XRL is split into three sections : Tunnels and Associated Works (North), Tunnels and Associated Works (South) and the WKT. Arup was appointed by the MTRCL as the Detailed Design Consultant on Consultancy Agreement No. C803 : Express Rail Link – Detailed Design for Tunnels and Associated Works (North) on 16 January 2009.

The Northern Section comprises running tunnels from the Shenzhen River to Tse Uk Tsuen, just north of Pat Heung Ventilation Building, the Stabling Sidings (SSS) and Emergency Rescue Station (ERS) at Shek Kong, the ventilation buildings at Mai Po and Ngau Tam Mei and an Emergency Access Point (EAP) at Tai Kong Po.

The layout of XRL Tunnels and Associated Works (North) is shown on Figure 1.2.

## 1.4 Scope and Purpose of This Report

The report reviews the hydrogeological setting, possible impacts of the proposed tunnel design concept in the vicinity of the XRL alignment (northern section) and outlines the proposed engineering mitigation measures that will be required.

This report describes the following:

- Interpretation on the existing geological and hydrogeological conditions;
- Assessment on the change of groundwater regime due to the XRL tunnel construction;
- Estimation on rates of groundwater inflow into the tunnels;
- Proposal for available mitigation options and the need for pre-excavation grouting;
- Specification, control and mitigation implementation procedures.

## 1.5 Previous Hydrogeological Studies

A Hydrogeological Impact Assessment (HIA) Report comprising one of the suite of Geotechnical Report submissions required under the scope of the consultancy agreement for the Express Rail Link — Preliminary Design Service of XRL Tunnels and Associated Structures (Consultancy Agreement NEX/2102) was submitted in December 2008.

The other reports within the suite are the Geotechnical Engineering Report (GER), Ground Movements Report (GMR), Geotechnical Instrumentation Report (GIR), Site Impact Assessment Report (SIAR), Natural Terrain Hazard Study Report (NTHSR), Structural Appraisal Report (SAR) and Blasting Assessment Report (BAR).

The main objective of the Preliminary Design HIA was to review the hydrogeological conditions along the entire alignment of the proposed XRL project, specifically the definition of the existing groundwater and hydrological systems and provide recommendations for further studies to be carried out following the completion of additional investigation and monitoring works.

## 1.6 Limitations

The information provided in this report is for the sole and specific use of MTRCL. Any other persons who use any information contained herein do so at their own risk.

Key limitations of this report relate to the availability and use of archival information reported by others, including the as-built information, the accuracy of which cannot be guaranteed. Other limitations relate primarily to the uncertainty with respect to the actual ground conditions (such as rockhead levels, profiles and geological structures), groundwater conditions, exact locations of underground utilities, and nature and location of underground obstructions.

Any persons who intend to use any information contained herein shall assess the applicability of the information and carry out their own interpretation.

# 2 Tunnel & Shaft Arrangement

## 2.1 General

The layout of the XRL (northern Hong Kong section) is shown on Figure 2.1. Types of tunnel to be constructed under individual works contract are summarized in Table 2.1.

**Figure 2.1 Layout of XRL (Northern Hong Kong Section)**

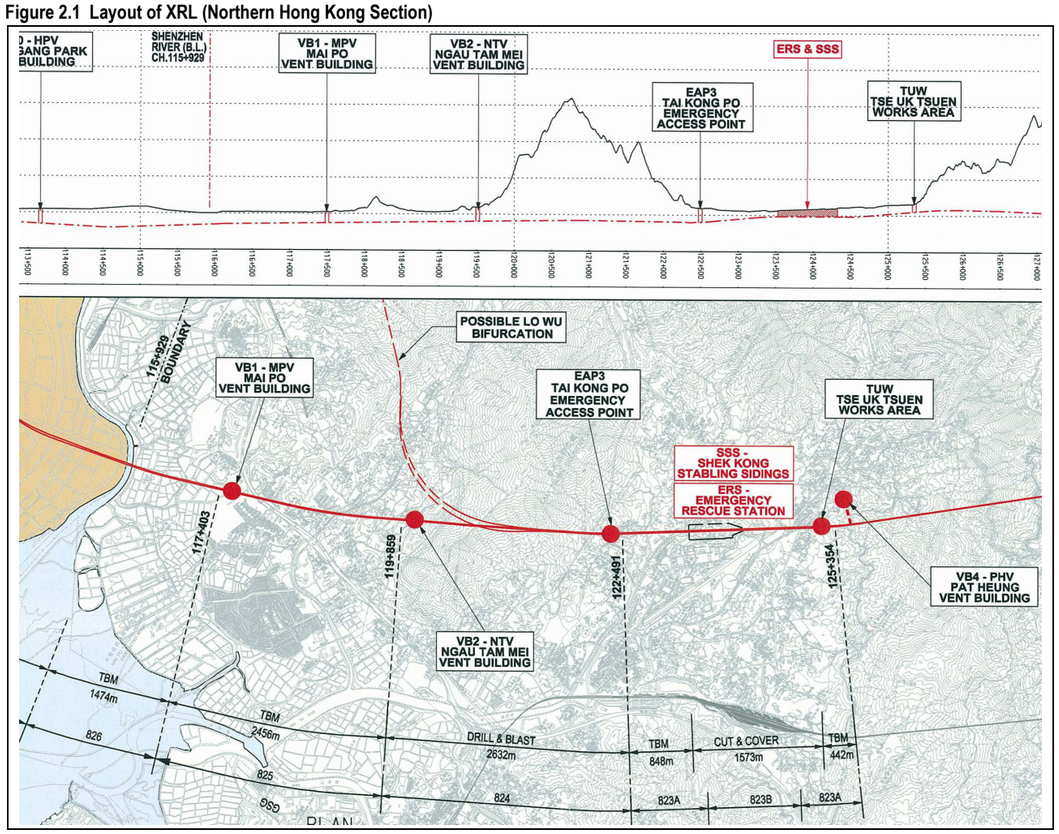



**Table 2.1 Tunnel Arrangement of XRL for the Northern Hong Kong Section**

| Contract No. | SB Chainage (from) | SB Chainage (to) | Length (m) | Construction Type of Tunnel / Shaft |
|---|---|---|---|---|
| 826 | 115+929 | 117+403 | 1474 | TBM bored tunnel |
| 825 | 117+403 | 117+511 | 108 | C&C ventilation shaft MPV |
| 825 | 117+511 | 119+865 | 2354 | TBM bored tunnel |
| 824 | 119+865 | 119+893 | 28 | C&C ventilation shaft NTV |
| 824 | 119+893 | 122+465 | 2572 | D&B tunnel |
| 824 | 122+465 | 122+491 | 26 | C&C Emergency Access Point TKP |
| 823A (north) | 122+491 | 123+339 | 848 | TBM bored tunnel |
| 823A (north) | 123+339 | 123+525 | 186 | C&C tunnel |
| 823B | 123+525 | 124+766 | 1241 | C&C tunnel |
| 823A (south) | 124+766 | 124+912 | 146 | C&C tunnel |
| 823A (south) | 124+912 | 125+336 | 424 | TBM bored tunnel |
| 823A (south) | 125+336 | 125+354 | 18 | C&C works shaft TUW |

*Notes : SB = Southbound; D&B = Drill & Blast ; C&C = Cut & Cover*

## 2.2 TBM Bored Tunnel Sections for 823A, 825 & 826

The tunnels will be designed as twin single bores with an internal diameter of 8.15m for Works Contract 823A and 825; and of 8.6m for Works Contract 826.

It is anticipated that a closed face TBM, either an Earth Pressure Balance Machine (EPBM) or a slurry machine, will be used for these soft ground and mixed ground drives. The permanent ground support will be in the form of an undrained precast reinforced concrete segmental lining. They will be installed at the tail skin of the TBM as it advances so as to provide immediate ground support. In order to further control ground settlement it is anticipated that the overcut annulus will be back-grouted as, or immediately after, the lining (ring) leaves the tail skin of the TBM.

At cross passage locations, ground treatment will be carried out prior to the excavation work. Temporary lining, in the form of shotcrete and steel lattice system, will be installed as excavation progresses. After the cross passage is fully excavated, a permanent cast-in-situ lining will be constructed.

## 2.3 Drill & Blast Tunnel Section for 824

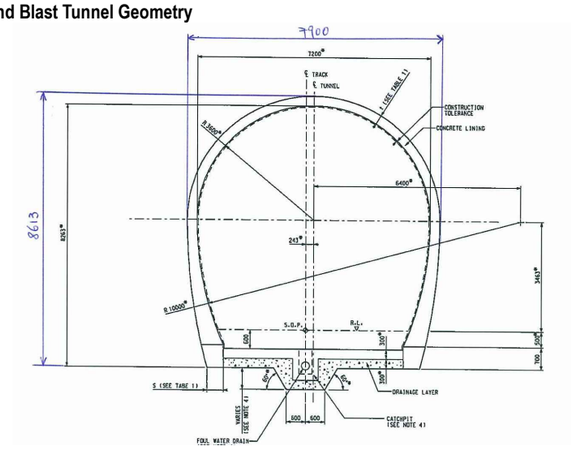
The Works Contract 824 section comprises 2.6km of twin single track tunnels excavated by drill and blast method. At either end of this length are the Ngau Tam Mei Ventilation Building (NTV) and the Emergency Access Point shaft at Tai Kong Po (TKP). Cross passages between the running tunnels are provided on average every 250m to satisfy life safety requirements. The various geometries of the drill & blast tunnel sections for Works Contract 824 are summarised in the table below (also see Appendix B for details):

**Table 2.2 Tunnel Geometry for Works Contract 824**

| Tunnel Type | Length (m) | % of the overall tunnel length for Works Contract 824 (%) | Tunnel Perimeter, excluded tunnel base (m) | Cross Sectional Area ($m^2$) |
|---|---|---|---|---|
| Single track tunnel | 1,730 x 2 | 68 | 21.7 | 60 |
| Single track tunnel with overhead ventilation duct | 350 x 2 | 14 | 30.5 | 105 |
| Enlarged single track tunnel for bifurcation | 420 x 2 | 16 | 21.7-35.9 | 60-200 |
| Twin track tunnel with overhead ventilation duct | 110 | 2 | 46.7-39.9 | 250-325 |

A typical cross section for the single track drill and blast running tunnels is given in Figure 2.2. For simplicity and inherent variability in inflow predictions, the size of the single track tunnel will be adopted for subsequent inflow analyses.

**Figure 2.2 Single Track Drill and Blast Tunnel Geometry**



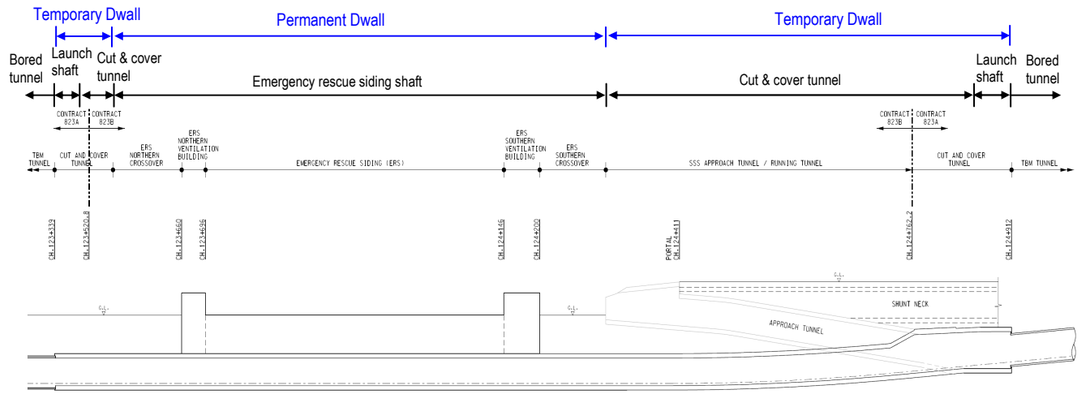
The tunnel permanent lining is designed as a drained lining, whereby groundwater pressure on the structure is relieved by allowing limited drainage to the tunnel invert, which is taken via the tunnel drainage system to a sump located at the low point of the vertical. From the sump point, water is collected and pumped to the surface.

An existing WSD aqueduct crosses the XRL alignment at approximate chainage Ch120+500. This aqueduct is 3.4m diameter with a clearance of approximately 22m between the aqueduct invert and the crown of the XRL tunnels.

## 2.4 Cut & Cover Tunnel Sections for 823A & 823B

The section of running tunnel between Tai Kong Po and Tse Uk Tsuen is a combination of twin single track bored tunnels, cut and cover tunnels and an access shaft. The tunnel will be constructed under two contracts namely 823A and 823B. Contract 823A includes two lengths of bored tunnels and two launching shafts. Contract 823B includes the construction of the Emergency Rescue Siding (ERS) shaft, two lengths of cut and cover tunnel and the at-grade Stabling Sidings in Shek Kong. The ERS includes ventilation structures at both ends, and bifurcated approach tunnels from the main line tunnels to at-grade Stabling Sidings. A schematic diagram illustrating the arrangement for the above is shown in Figure 2.3 and also enclosed in Appendix C.

**Figure 2.3 Schematic Section of the Tunnel Arrangement for 823A & 823B**




During construction the cut and cover tunnel sections require temporary dewatering, i.e. "***drained***". Any groundwater drawdown outside the site areas resulting from excavation works would typically be limited to 2m. In the long term they are designed to be "***undrained***" with a full hydrostatic head outside.

## 2.5 Shafts for 823A, 824 & 825

There are three permanent shafts and one temporary construction shaft distributed along the Hong Kong Northern Section of the XRL alignment as listed below:

Permanent Ventilation Shafts

- Works Contract 825 - Mai Po Ventilation Shaft (MPV or VB1)
- Works Contract 824 - Ngau Tam Mei Ventilation Shaft (NTV or VB2)

Permanent Emergency Access Point Shaft

- Works Contract 824 - Tai Kong Po Emergency Access Point (TKP or EAP3)

Temporary Construction Shaft

- Works Contract 823A - TBM Reception Shaft, Tse Uk Tsuen Works Area (TUW)

It is anticipated that MPV and TUW will be entirely in soft ground whereas NTV and TKP will be excavated through both soft ground and hard rock. A layout and sectional view of the shafts are shown on the geological long section as enclosed in Appendix B.

The shaft excavations will only require temporary dewatering during their construction, i.e. "***drained***" and any groundwater drawdown outside the site area resulting from such work would typically be limited to 2m within the site area in order to avoid adverse settlement impacts outside. In the long term they are designed to be "***undrained***" with a full hydrostatic head outside.

Where shaft excavation takes place through Grade III rock or better, temporary support shall be installed to stabilize the rock mass following each lift (blast). The permanent lining of the shaft shall consist of cast in place concrete backed by a waterproofing membrane and geotextile in order to relieve hydrostatic water pressures (***drained***). The exception to this is a short section of circular shaft at NTV which has been designed as undrained immediately below the rockhead in order to form a cut-off at the soil-rock interface and prevent excessive drawdown of water levels within the overlying unconsolidated materials.

## 2.6 Summary of Possible Groundwater Impacts

Groundwater impacts have been assessed for different types of tunnels and shafts under temporary and long term conditions as summarized in Table 2.3.

**Table 2.3 Summary of Possible Groundwater Impacts for Different Types of Tunnels & Shafts**

| Type of Tunnel / Shaft | Temporary Condition during Construction | Long Term Condition | Groundwater Impacts Need to be Assessed |
|---|---|---|---|
| TBM bored tunnel | Undrained | Undrained | • Nil |
| Drill & Blast tunnel | Drained | Drained | • Groundwater inflow estimate and control<br>• Effect to the existing WSD aqueduct |
| Cut & Cover tunnel | Drained | Undrained | • Temporary drawdown effect due to excavation<br>• Possible long term damming effect due to Dwall construction |
| Shafts (all in soft ground) | Drained | Undrained | • Temporary drawdown effect due to excavation |
| Shafts (partially soft ground ; partially in hard rock) | Drained | Undrained in upper soil portion; Drained in lower rock portion. | • Temporary drawdown effect due to excavation<br>• Long term groundwater inflow estimate and control for the lower rock portion |

# 3 Geological & Hydrogeological Setting

## 3.1 General

The interpretation of the site geology is based on the existing drillhole records and geological maps issued by the Geotechnical Engineering Office. A description of the topographical setting, general geology including solid geology, superficial geology, structural geology and hydrology is provided in the sub-sections below.

## 3.2 Topography

The topography along the northern section of the XRL alignment is characterised by rugged uplands and steep slopes with deeply dissected valleys; relatively wide, flat bottomed valleys where the natural drainage paths have been trained; and areas of flat, low lying flood plain. Table 3.1 below summarised the topography along the proposed XRL alignment.

**Table 3.1 Summary of Topography along the Proposed XRL Alignment**

| SB Chainage | | Location | Topography |
|---|---|---|---|
| From | To | | |
| 115+929 | 117+600 | Mai Po | • Working south from the Boundary crossing at Shenzhen River the ground level remains reasonably flat at about +4mPD as the tunnels pass beneath Mai Po wetlands, a wide and low lying flood plain to the south of Shenzhen River.<br>• Immediately to the south of the wetlands the alignment crosses San Tin Highway where the ground level rises to approximately +7mPD. |
| 117+600 | 119+900 | Ngau Tam Mei | • South of San Tin Highway, the topography rises to approx. +46mPD as the alignment passes beneath a ridge before descending to +5mPD as the alignment traverses the wide though of Tam Mei valley.<br>• To the south of Tam Mei valley, the alignment continues beneath Kai Kung Leng, a peak within the Lam Tsuen Country Park. |
| 119+900 | 122+300 | Kai Kung Leng | • The topography at Kai Kung Leng rises to a maximum of approximate +320mPD along the proposed tunnel alignment and then descends to +10mPD where the alignment enters the Kam Tin area near Pat Heung. |
| 122+300 | 125+354 | Shek Kong | • At Kam Tin, the alignment continues across the valley to the east of the Shek Kong airfield, where the Emergency Rescue Station (ERS) and the Shek Kong Stabling Sidings (SSS) are to be located, and beneath the Tse Uk Tsuen Village and to the northern slopes of Tai Mo Shan.<br>• The ground level in this area varies between +10mPD to the north of the airfield and +28mPD at the boundaries with Kai Kung Leng and Tai Mo Shan. |

## 3.3 Site Condition

Table 3.2 below summarised the site condition along the proposed XRL alignment. The aerial view of the site from the 2008 air photos is enclosed in Appendix A.

**Table 3.2 Summary of Site Condition along the Proposed XRL Alignment**

| SB Chainage | | Location | Topography |
|---|---|---|---|
| From | To | | |
| 115+929 | 117+600 | Mai Po | • The site commences from the border between China and Hong Kong beneath the Shenzhen River. The area consists of marshland and a number of fish ponds. The most important of which is the Mai Po Marshes, interspersed with areas of low density low rise residential and light industrial / commercial development. |
| 117+600 | 119+900 | Ngau Tam Mei | • The site area comprises low density low rise residential buildings such as Maple Gardens, Casa Paradizo, Yau Tam Mei Tsuen and Ngau Tam Mei. The population is low and traffic conditions within the site area relatively low. |
| 119+900 | 122+300 | Kai Kung Leng | • The site is at a hilly ground rises to a maximum elevation of +320mPD at the ridgeline of Kai Kung Leng with the Tai Kong Po shaft located at the foot of its southern facing slopes at an elevation of about +20mPD while the Ngau Tam Mei Ventilation Building (VB2) is situated part way up its northern foothills at an elevation of approximately +70mPD. The hillside is covered by sparse vegetation. Some low rise residential buildings and village houses are noted at the northern and southern foothill. |
| 122+300 | 125+354 | Shek Kong | • The site area comprises mainly agricultural lands interspersed with some low rise residential buildings, farm houses and open storage areas.<br>• The area is intersected by public roads and numerous open nullahs, generally flowing east to west, which drain the western slopes of Kai Kung Leng and the north-western slopes of Tai Mo Shan. Another prominent feature of the area is the Shek Kong airfield and barracks. |

## 3.4 Geological Setting

### 3.4.1 General

A geological key plan illustrating the regional geological along the XRL tunnel alignment is shown in Figure 3.1. The site geology has been determined from the available drillhole records and published geological maps. Detailed geological sections through the Southbound tunnel are enclosed in Appendix B.

**Table 3.3 Summary of Geological Setting along the Proposed XRL Alignment**

| SB Chainage | | Location | Geological Setting |
|---|---|---|---|
| From | To | | |
| 115+929 | 117+600 | Mai Po | • The Mai Po area is situated in a structurally complex Palaeozoic sedimentary basin surrounded by Mesozoic granitic and volcanic rocks. Carboniferous rocks predominate but are largely concealed by Quaternary superficial deposits.<br>• The geological structure of the district is dominated by north-east trending normal and reversed throws, termed the Tuen Mun – Lo Wu Fault Zone. The dominant fault direction trends north-eastwards, and these lines of weakness have been dislocated by later smaller movements at right-angles (Frost, 1992).<br>• Regional metamorphism was caused by the overthrusting of the Palaeozoic basement on to Mesozoic volcanics.<br>• The complex pattern of the solid geology in the district is buried to depths from 20m to 80m by superficial deposits.<br>• A regolith or zone of weathered rock occurs over most of the district. |
| 117+600 | 119+900 | Ngau Tam Mei | • The Tai Mo Shan Formation comprises mainly coarse ash to lapilli crystal tuff is widespread in the Ngau Tam Mei district.<br>• The proposed alignment intersects the San Tin Thrust Fault at around Chainage 117+600 where the Palaeozoic strata are thrust over from the NW, and overlie the volcanic rock of the Tai Mo Shan Formation. The location of MPV is thus underlain by Palaeozoic sedimentary rock.<br>• Regional metamorphism was caused by the overthrusting of the Palaeozoic basement on to |

| SB Chainage | | Location | Geological Setting |
|---|---|---|---|
| From | To | | |
| | | | Mesozoic volcanics.<br>• Superficial deposits around the Ngau Tam Mei area comprise a thin layer of Fill overlying 6m to 10m of Alluvium. The Alluvial deposits generally comprise silty Sand to gravelly Sand. A thin clay layer is present occasionally.<br>• Colluvium comprising unsorted gravelly, clayey Silt and Sand, with boulders and cobbles, can be found near the foothills.<br>• These superficial deposits are underlain by in-situ weathered strata of variable thickness. |
| 119+900 | 122+300 | Kai Kung Leng | • The solid geology of the district is dominated by Mesozoic volcanic rocks of Tai Mo Shan Formation. The Formation comprises mainly coarse ash to lapilli crystal tuff, which is widespread in the district.<br>• The tuffs in Kai Kung Leng are mostly affected by dynamic metamorphism, either in broad zones or narrow northeast-trending belts. The key engineering geological effect of regional metamorphism is the development of foliation.<br>• A regolith or zone of weathered rock occurs over the entire hillside area. Colluvium comprising unsorted gravelly, clayey Silt and Sand, with boulders and cobbles, can be found at valleys and near the foothills.<br>• The proposed tunnel alignment intersects an inferred fault identified from the published 1:20,000 geological map at around Ch122+160. A project specific inclined borehole No. 2108/XRL/A008 has been sunk at that location to verify the nature and extent of this fault. The geological condition around the fault is expected to include zones of deeper weathering and highly fractured rock.<br>• One photo-lineament close to the proposed XRL tunnel has been identified from the 1:20,000 geological map at around Ch121+520. A project specific inclined borehole No. 2108/XRL/A007 has been sunk at that location to verify the nature and extent of this fault and details are shown on the geological sections.<br>• A few unrecorded faults were also encountered in the project specific drillholes as shown on the geological sections. It is anticipated that some more unidentified faults will be encountered along the Contract 824 tunnel alignment during the tunnel construction.<br>• Some brecciated rocks were noted in the boreholes sunk in Kai Kung Leng. Presence of sub-horizontal quartz veins in various drillholes may imply vertical dilation associated with low angle shears.<br>• A feldsparphyric rhyolite dyke is noted from drillhole no. 2108/XRL/D438. Other unidentified dykes and mineral veins may have been intruded within the Tuff which are present close to or intersect the tunnel alignment. |
| 122+300 | 125+354 | Shek Kong | • The solid geology of the district is dominated by Mesozoic volcanic and intrusive igneous rocks. The Mesozoic volcanic rocks close to the proposed XRL alignment are Shing Mun Formation and Tai Mo Shan Formation.<br>• The volcanic rocks are intruded by Tai Po Granodiorite which is the oldest of the major intrusions and underlies large areas in the southern portion of the Kam Tin Plain.<br>• The alluvial plain lying between Kai Kung Leng and Tai Mo Shan is covered by a thin layer of Fill overlying Alluvium which is in turn underlain by a thick layer of debris flow deposits.<br>• The Alluvium generally comprises semi-sorted gravelly, sandy Clay / Silt and silty Sand. The debris flow deposit generally comprises unsorted gravelly, clayey Silt and Sand, with boulders and cobbles; thickness varying from a minimum of 2-3m to a maximum of 9-10m. These deposits are underlain by in-situ weathered strata of varying thickness.<br>• The proposed tunnel alignment intersects the regional Tai Lam Fault at the Kam Tin Plain. The XRL project specific vertical and inclined drillholes around Chainage Ch 123+750 have encountered this fault as a series of crushed zones which falls within the Contract 823B cutting across the proposed ERS. Width of the entire fault zone near the proposed ERS appeared to be around 80-100m. |

## 3.5 Hydrological Setting

### 3.5.1 Regional

Based on an assessment of the distribution of superficial deposits and a review of the locations of inferred spring lines it is apparent the groundwater is flowing from the higher elevation areas to the lower elevation areas and a spring line occurs within most valleys.

The hydrogeological concept for the region is that during the wet season groundwater recharge, from rainfall, to the superficial deposits and weathered rock occurs in areas of natural terrain. The bedrock beneath the weathered rock reduces in permeability with depth such that it can be assumed as no flow boundary.

Groundwater divides will be found along the principal ridge lines that form Kai Kung Leng and Tai Mo Shan. The groundwater divide acts as a no flow boundary to ground and surface water flow. The catchments along the Kai Kung Leng tunnel alignment comprise steep natural terrain slopes that flow to the north and south. The terrain is intersected by stream channels, a few of which have small base flows through the dry season. The streams gather the surface water run off during the rainfall events and flow downstream.

Flow “refraction” will take place with the large majority of flow occurring in the higher conductivity layers and with flow towards these conductive layers from the layers of lesser conductivity. This process includes flow from the rock mass to the upper more permeable zones in the lower areas of the catchment, but the quantities of flow are small. In general, flow takes place from the superficial layers, concentrated in the more conductive layers, towards the lower elevation areas to the stream channels, and associated valleys.

A similar system applies in the dry season; however, with negligible recharge reduced flows and a decline in the groundwater table are likely to occur. The position of groundwater divide can also vary slightly from the wet season to the dry season. However a water table will be maintained within the side slopes to the valleys throughout the year.

In general the magnitude of flow in the bedrock is limited when compared to the flow through the superficial materials due to the very large contrast in transmissivity. However, in the bedrock areas with major geological structures, such as faults, contacts and intrusions, the groundwater flows are also governed by these features.

In the low laying areas such as Mai Po the Marine Clay deposit is of low permeability and therefore inhibits discharge of the system. These deposits can sometimes act as a confining layer resulting in artesian groundwater pressures in the more permeable underlying strata.

### 3.5.2 Site Specific Groundwater Level

Groundwater levels have been determined from observations within the piezometers / standpipes installed in the project specific drillholes. The highest and lowest groundwater levels recorded from the project specific boreholes from September 2008 to July 2009 (covering one wet season and one dry season) are indicated on the geological long sections as enclosed in Appendix B. The monitoring works are being continued until the construction works commence. Groundwater monitoring points outside the excavation / tunnel alignment shall be handed over to the contractor for continuous monitoring during the construction period. Details of the instrumentation and monitoring plan are discussed in Section 10 of this report.

For some of the deep drillholes in Kai Kung Leng where no groundwater monitoring devices have been installed, the water levels at the beginning of the morning drilling shift was recorded and is also shown in geological long sections.

# 4 Regional Hydrological Data

## 4.1 General

Basic hydrological data along the alignment of the XRL has been obtained from the Geotechnical Engineering Office (GEO) and the Hong Kong Observatory (HKO). The data collected includes rainfall records and evaporation records, each of which is discussed in more detail in the following sections.

## 4.2 Rainfall Records

The relevant rainfall data collected includes readings taken at GEO Rain gauge Nos. N33 (Mai Po) and N36 (Shek Kong). A summary of the rain gauge locations and monthly monitoring results for the period 2003 to 2007 are provided in the tables below:

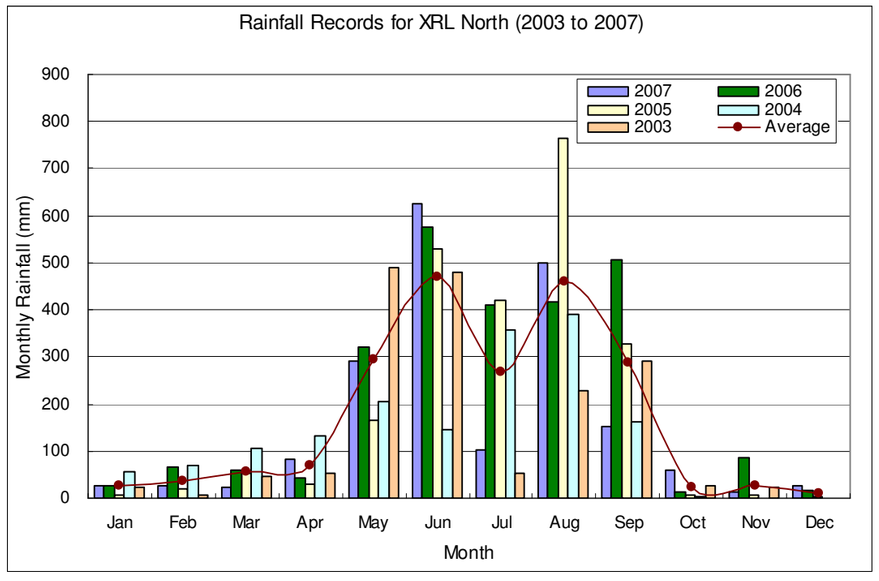
**Table 4.1 Rain Gauge Location**

| Rain Gauge Number | Rain Gauge Location |
|---|---|
| N33 | Bethel High School, 6 Golden Bamboo Road East, Fairview Park |
| N36 | Kadoorie Agricultural Research Centre, Lam Kam Road, Shek Kong |

**Table 4.2 Average Rainfall Reading**

| Year | Recorded Monthly Rainfall (mm) based on average reading from N33 & N36 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total Annual Rainfall |
| 2007 | 28 | 26 | 22 | 83 | 290 | 627 | 103 | 500 | 153 | 60 | 13 | 26 | 1930 |
| 2006 | 25 | 66 | 58 | 44 | 321 | 575 | 409 | 417 | 508 | 12 | 86 | 16 | 2536 |
| 2005 | 7 | 20 | 54 | 31 | 164 | 531 | 419 | 765 | 328 | 8 | 8 | 4 | 2338 |
| 2004 | 55 | 71 | 108 | 133 | 206 | 145 | 359 | 391 | 161 | 3 | 1 | 0 | 1632 |
| 2003 | 22 | 7 | 46 | 54 | 489 | 478 | 53 | 229 | 292 | 27 | 22 | 1 | 1717 |
| Average | 27 | 38 | 58 | 69 | 294 | 471 | 269 | 460 | 288 | 22 | 26 | 9 | 2031 |

**Figure 4.1 Monthly Rainfall Records for XRL North**




The above data indicates that the drainage catchments along the alignment of the XRL typically have a total input to the hydrological system between 1600 mm and 2600 mm per annum, with an average annual rainfall in the order of 2000 mm.

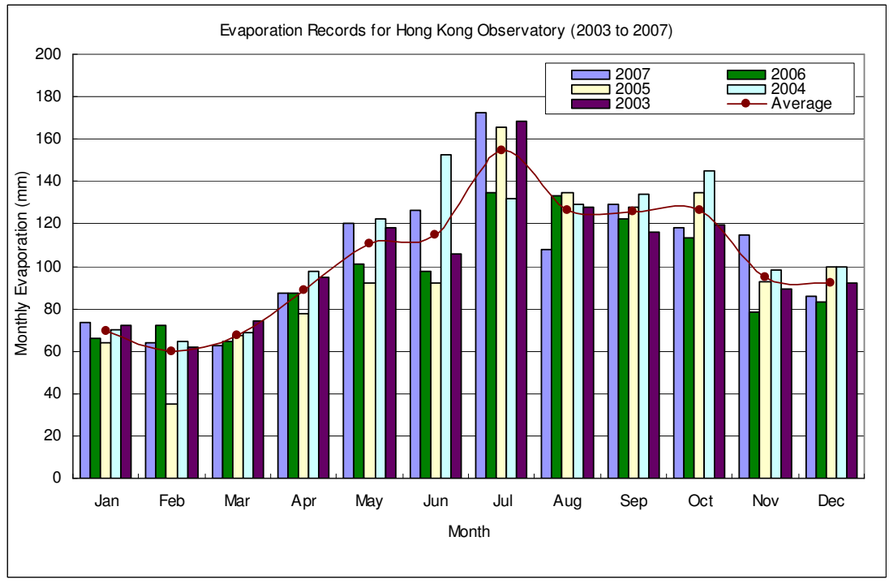
## 4.3 Evaporation

Whilst no direct monitoring of evaporation rates has been carried out in close proximity to the alignment, the records of monitoring at the Hong Kong Observatory record an average annual evaporation of about 1200mm. The relevant monitoring records used to determine this value are summarized in the following table:

**Table 4.3 Recorded Monthly Evaporation**

| Year | Recorded Monthly Evaporation (mm) based on reading from the HKO | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total Annual Rainfall |
| 2007 | 74 | 64 | 63 | 88 | 120 | 127 | 172 | 108 | 129 | 118 | 115 | 86 | 1264 |
| 2006 | 66 | 72 | 64 | 87 | 101 | 98 | 135 | 134 | 122 | 113 | 79 | 83 | 1154 |
| 2005 | 64 | 35 | 67 | 78 | 92 | 92 | 166 | 135 | 128 | 135 | 93 | 99 | 1184 |
| 2004 | 70 | 65 | 69 | 98 | 123 | 153 | 132 | 129 | 134 | 145 | 98 | 99 | 1315 |
| 2003 | 73 | 62 | 74 | 95 | 118 | 106 | 168 | 128 | 116 | 120 | 90 | 92 | 1242 |
| Average | 69 | 60 | 67 | 89 | 111 | 115 | 155 | 127 | 126 | 126 | 95 | 92 | 1232 |

**Figure 4.2 Monthly Evaporation Records from HKO**




This data indicates that the water balance for any standing water within catchments in the vicinity of the XRL is likely to be positive between May and September (precipitation exceeds evaporation) and negative between October and April (evaporation exceeds precipitation). This observation correlates reasonably well with the reductions in groundwater levels noted in many of the observation wells during the dry-season. However, it should be noted that much of the rainfall within the catchment areas would not provide a source for evaporation as it would be lost to the system either as direct surface run-off or through infiltration and recharge of the groundwater aquifers.

## 4.4 Surface Runoff

The amount of rain water infiltration is a function of the runoff coefficient. As recommended in the Geotechnical Manual of Slopes (Section 4.2.2), the run-off coefficient should be taken as 0.5 to 0.7.

The DSD's Stormwater Drainage Manual (2000) suggests a runoff coefficient between 0.25 to 0.35 for steep grassland (heavy soil) and between 0.4 and 0.9 for steep natural slopes or areas where a shallow soil surface is underlain by impervious rock. A run-off coefficient of 0.95 is also suggested for hard surfaced developed areas.

For the proposed ERS/SSS area in Shek Kong, the runoff coefficients shown on Table 4.4 have been used to estimate surface runoff flows from existing drainage catchments and the future SSS.

The SSS site area presently consists of village developments and natural areas. In the future, the SSS will comprise exposed ballasted tracks, the ERS, new buildings, access roads and landscape areas which will create additional surface runoff flows.

**Table 4.4 Runoff Coefficients Adopted for Storm Flow Estimations in the Drainage Impact Assessment**

| Area | Runoff Coefficient |
|---|---|
| Natural Areas | 0.50 (steep slopes) |
| Village Areas | 0.70 |
| Paved Areas | 0.95 |
| Exposed Ballasted Track | 0.70 |

# 5 Groundwater Impact for Undrained Bored Tunnel Sections (Works Contracts 823A, 825 & 826)

## 5.1 Envisaged Construction Works

It is anticipated that a closed face TBM, either an Earth Pressure Balance Machine (EPBM) or a slurry machine, will be used for these soft ground and mixed ground drives. The permanent ground support will be in the form of an undrained precast reinforced concrete segmental lining. They will be installed at the tail skin of the TBM as it advances so as to provide immediate ground support. In order to further control ground settlement it is anticipated that the overcut annulus will be back-grouted as, or immediately after, the lining (ring) leaves the tail skin of the TBM.

At cross passage locations, ground treatment will be carried out prior to the excavation work. Temporary lining, in the form of shotcrete and steel lattice system, will be installed as excavation progresses. After the cross passage is fully excavated, permanent cast-in-situ lining will be constructed.

## 5.2 Groundwater Drawdown for Bored Tunnels Constructed Using a TBM

Groundwater drawdown is effectively precluded in soft ground tunnelling through the use of closed face TBMs, either a slurry machine or an EPB machine. The hydrostatic head can be effectively supported by the pressure maintained in the front of TBM head which reduces groundwater losses at the TBM face. As a consequence groundwater drawdown due to TBM tunnel excavation is expected to be insignificant and ground settlement induced by the groundwater drawdown is considered to be negligible. As the TBM bored tunnel lining will be designed as undrained, groundwater drawdown after installation of permanent lining should not arise (any groundwater drawdown that did occur would indicate a fault with the lining).

In summary, groundwater drawdown is effectively precluded by the selection of an appropriate machine and a suitable lining.

## 5.3 Groundwater Drawdown for the Cross Passage Construction

Although water inflows can be reduced through ground treatment, it is likely that some local groundwater drawdown will occur in the cross passages during construction, either through the face of the cross passages or through the sprayed concrete lining prior to construction of the permanent, undrained, cast in-situ lining.

Groundwater drawdown can effectively be reduced through ground treatment in the form of grouted canopy tubes drilled out from the segments to form an umbrella around the future excavation. Following pre-excavation grouting, construction activity is not expected to affect the existing local groundwater regime by more than 1m. The permanent cast-in-situ lining would be designed and constructed as undrained, therefore long term groundwater drawdown is not anticipated.

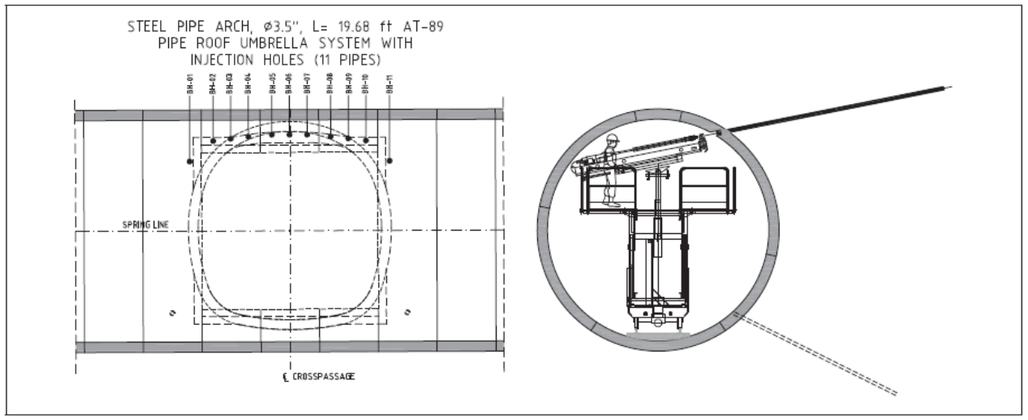



Figure 5.2 Example of Installed Pipe Umbrella Through Segments in Soft Ground TBM Tunnel (LA Metro Gold Line)

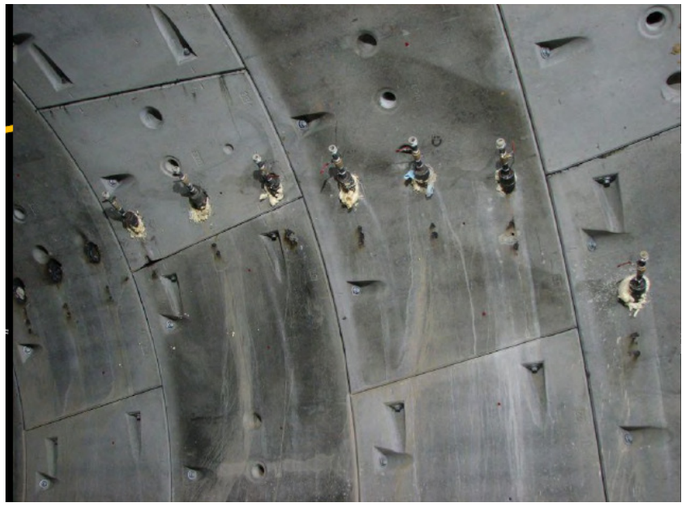


Figure 5.1 Grouted Pipe Umbrella Installed Through Segments Over Cross Passage Excavation

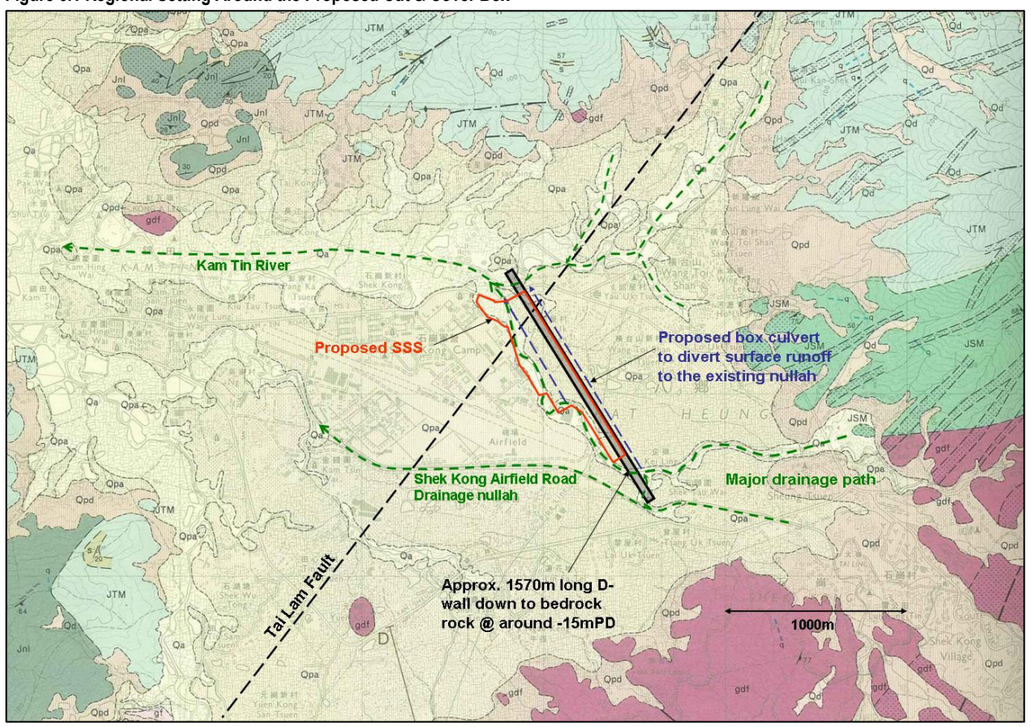
# 6 Groundwater Impact for Cut & Cover Tunnel Sections (Works Contracts 823A & 823B)

## 6.1 General

The sub-surface Emergency Rescue Station (ERS) and the at-grade Shek Kong Stabling Sidings (SSS) are situated within the floor of the valley which forms the Kam Tin sub-catchment adjacent to the Shek Kong Barracks. This sub-catchment is a large drainage basin to the northwest of Tai Mo Shan and comprises natural streams in its upper reaches which drain into the Kam Tin River in the lower reaches of the basin.

The construction of the ERS together with the associated approach tunnels and the TBM launching shafts are proposed to be constructed by cut & cover method requiring an excavation approximately 1570m long, 28m wide and 30m deep down to bedrock. The SSS is an at-grade facility comprising eight stabling tracks, four running maintenance tracks, six engineering tracks, a traction sub-station, a main building and numerous stores / workshop buildings. The sidings facility will be constructed on a flat platform, partly cut and partly fill, in an area of gently sloping ground.

**Figure 6.1 Regional Setting Around the Proposed Cut & Cover Box**




The alignment crosses a flat basin surrounded to the north, east and south by more elevated hilly areas. Surface water flows into the basin from all three sides before exiting to the west. The basin is about 2.5km wide, covered with relatively permeable superficial deposits (fill, alluvium and colluvium), has high (near surface) groundwater levels and is prone to flooding. The underlying bedrock is of much lower permeability.

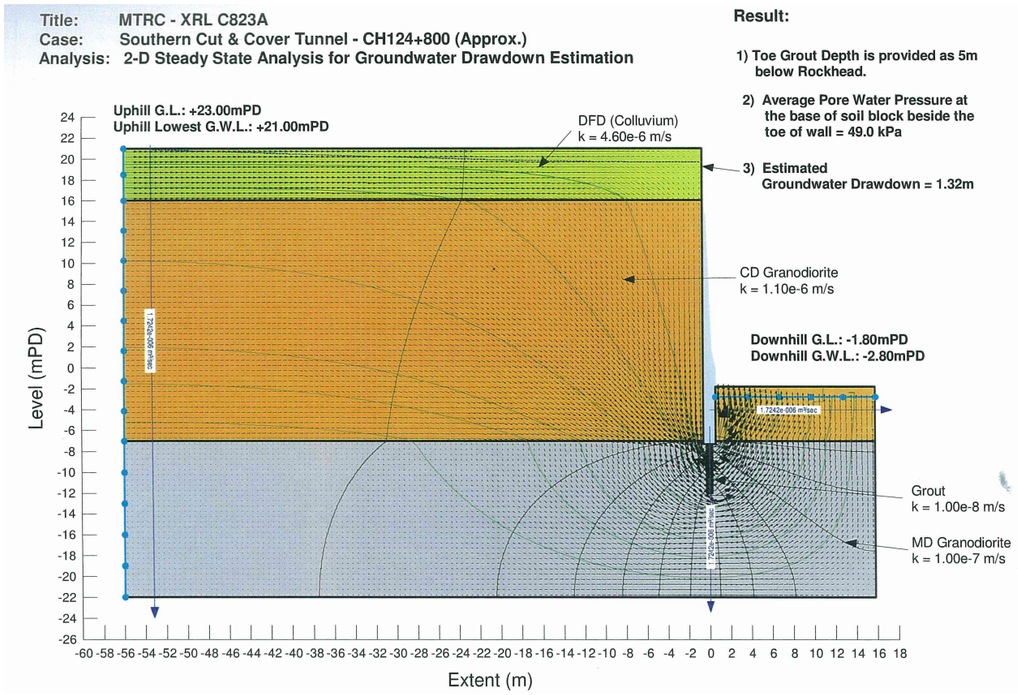
The cut and cover tunnel sections require temporary dewatering during the construction stage; but for long term they are designed to be undrained with a full hydrostatic head outside. The temporary dewatering during construction may lead to settlement in the vicinity whereas construction of some 1500m long Dwall down to bedrock may have a damming effect leading to possible flooding and impacting on groundwater dependent ecosystems. These issues are to be assessed in the following sections.

## 6.2 Temporary Drawdown Effect due to Excavation

### 6.2.1 Seepage Analysis

A seepage analysis was done base on a permeability of $1.0x10^{-7}$ m/s for rock mass. The bottom level of the toe grout is adjusted in the analysis to control the water drawdown immediately besides the retaining wall to within 2m. A typical result of SEEP/W analyses is shown in Figure 6.2. However, due to limited ground investigation data, the design permeability of rock mass need to be further assessed during the construction stage and the length of toe grout verified.

**Figure 6.2 Typical SEEP/W Analysis for 823A & 823B Cut & Cover Excavation**




It is envisaged that the control of groundwater drawdown outside the cofferdam due to dewatering shall be achieved by a combination of toe grouting and provision of recharging well. The required depth of toe grouting shall be reviewed and verified by further ground investigation during construction stage. To ensure the temporary works design is consistent with the water drawdown assumptions adopted in the settlement analysis, the performance criteria for toe grouting and settlement limit arising from dewatering have been specified in the drawings.

### 6.2.2 Pumping Test

Subsequent to the completion of diaphragm wall construction and toe grouting and prior to the commencement of excavation work, a full scale pumping test shall be undertaken for the following purposes:

(i) to verify the water cut-off effectiveness;

(ii) to verify the effectiveness of sand drains; and

(iii) to assess the effects of dewatering on adjacent structures.

The test is proposed to lower the existing groundwater table within the excavation to 1000mm below the proposed final excavation levels and to undertake monitoring to demonstrate the acceptance criteria is strictly fulfilled.

Details of the temporary drawdown analyses and preventive measures shall refer to the following reports:

- Deliverable No. 3.13A (BD Consultation) Design Calculations for Excavation and Lateral Support Works of Emergency Rescue Siding Part 1 - Contract 823B : Shek Kong Stabling Sidings and ERS.
- Deliverable No. 3.13A (BD Consultation) Design Calculations for Excavation and Lateral Support Works of Cut & Cover Tunnel / Launching Shafts Part 1 - Contract 823A : Tai Kong Po to Tse Uk Tsuen.

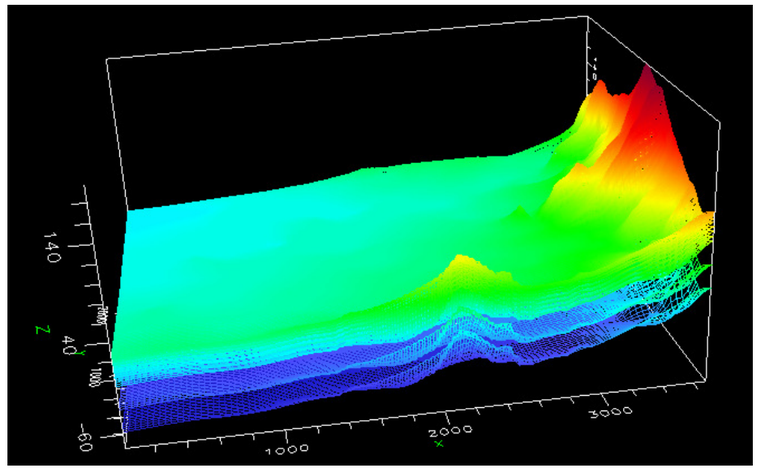
## 6.3 Potential for Long Term Damming Effect

### 6.3.1 Existing Hydrogeological Regime Around the ERS / SSS Area

#### 6.3.1.1 Topography

The topography of the study area is dominated by a relatively wide, flat bottomed valley. The basin is surrounded on three sides by rugged uplands and steep slopes with deeply dissected valleys. The ground level in this area varies between +10mPD near the centre of the flood plain and +20mPD to +30mPD at the boundaries with Kai Kung Leng and Tai Mo Shan respectively. An illustration of the topography of the model area is given in Figure 6.3. The site area comprises mainly agricultural land interspersed with some low rise residential buildings, farm houses and open storage areas.

**Figure 6.3 Surface Elevation Across Model Domain**




#### 6.3.1.2 Geology

- The underlying volcanic and intrusive igneous bedrock is considered to be of uniformly low permeability.
- The alluvial plain lying between Kai Kung Leng and Tai Mo Shan is covered by a thin layer of Fill overlying Alluvium which is in turn underlain by a thick layer of debris flow deposits (colluvium).
- The Alluvium generally comprises semi-sorted gravelly, sandy Clay / Silt and silty Sand. The debris flow deposit generally comprises unsorted gravelly, clayey Silt and Sand, with boulders and cobbles; thickness varying from a minimum of 2-3m to a maximum of 9-10m. These deposits are underlain by in-situ weathered strata of varying thickness.
- The regional NE trending Tai Lam fault consists of an 80-100m wide high-permeability zone crosses the cut & cover box almost perpendicularly. This may act as a drain under the cut & cover box and lessen the impact of the structure on groundwater flow.

#### 6.3.1.3 Aquifer Properties

- The Fill, Alluvium, Colluvium and weathered Granodiorite are considered to make a single linked unconfined aquifer of varying hydraulic conductivity.

#### 6.3.1.4 Groundwater Levels

- Recorded levels indicate that the water table (or potentiometric surface) is a subdued reflection of topography, with groundwater flow from areas of higher elevation towards streams and drainage channel discharge zones.
- A total of 11 observation wells are used for calibration of the groundwater levels in the model, all of which are located along the alignment. They vary in type (standpipes / piezometers) and in depth of installation.
- Generally only six to nine months data is available at most monitoring points, so it is not possible to estimate the full annual variation in groundwater levels.
- Average difference between minimum and maximum observed groundwater levels is approximately 1.5m.

Groundwater contour plots with the location of the existing groundwater monitoring points showing the highest and lowest groundwater level recorded during October 2008 to July 2009 are enclosed in Appendix C.

#### 6.3.1.5 Existing Wells / Groundwater Abstraction

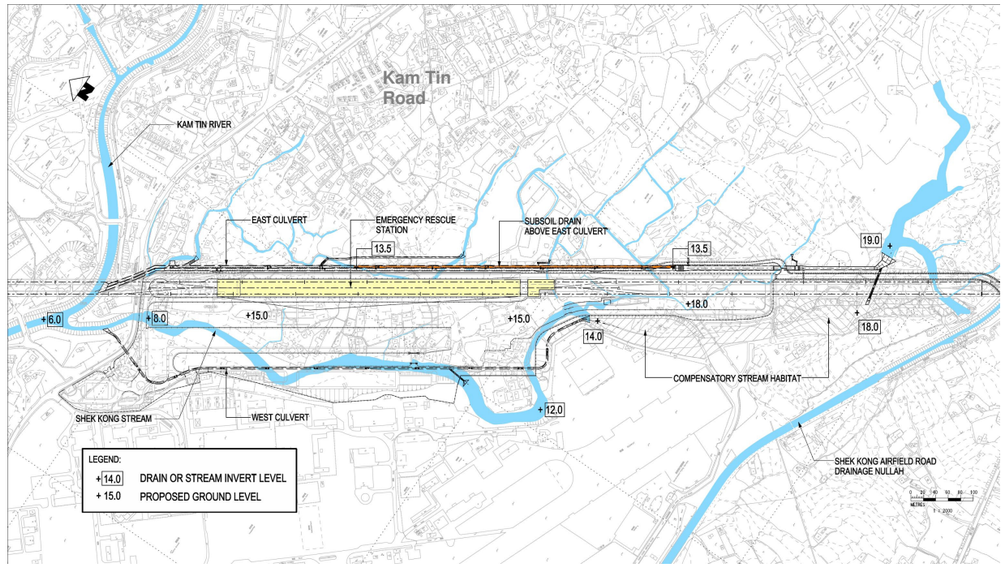
There are some existing wells within the model area but most of them are not actively used. Those within the ERS/SSS area will be demolished during the construction works. No significant groundwater abstraction activities were identified within the model area.

#### 6.3.1.6 Surface Drainage System Around the ERS / SSS Area

Storm flows to and around the ERS / SSS are from catchments that comprise steeply sloping hills in the upstream areas of the catchment near Lam Kam Road and from natural terrain, agricultural land, open storage areas and villages in the downstream catchment areas surrounding the ERS / SSS. The catchment topography generally falls to the northwest from an elevation of around +500mPD to +13mPD at Kam Tin Road, which is aligned along the valley floor. The site of the ERS / SSS is situated within a relatively flat area that is drained and intersected by several natural streams.

Flood alleviation projects have been implemented in the Kam Tin and Shek Kong area over the last ten years. These projects included the upgrading of the Kam Tin River to the north of the ERS / SSS. This nullah conveys storm flows from the east of the Kam Tin sub-catchment and intercepts flows from the nullah which runs along the Shek Kong Airfield Road to the south of the ERS / SSS which collects storm flows from the south region of the Kam Tin sub-catchment (Figure 6.4).

**Figure 6.4 Existing and Proposed Drainage System Around the ERS / SSS Area**



The local natural Shek Kong Stream crosses above the cut and cover ERS / SSS approach tunnels and then runs, in a northerly direction, along the western side of the ERS / SSS site. Along the western side of the ERS / SSS the stream meanders cutting the proposed site boundary at numerous points; the stream bed itself comprises stones and boulders and falls at varying gradients from +19.7mPD near the south-eastern end of the Cut & Cover box to +8.2mPD where crossing under Kam Tin Road. The elevations of the streams around the Cut & Cover box were set to actual survey elevations in the model.

Further details of the existing and proposed drainage systems of the area shall refer to the "Deliverable D2.4P - Drainage Impact Assessment Report". Drawings relate to the surface drainage system around the ERS / SSS and extent of the catchments are extracted and enclosed in Appendix C.

### 6.3.2 Groundwater Impact Assessment

#### 6.3.2.1 Method of Assessment

The purpose of developing a numerical groundwater model is to provide insight by simulating the groundwater flow and estimating the change in the area of influence upon existing levels. The results of the modelling can be used to assess potential flooding problem, environmental impacts and to estimate likely settlement associated with drawdown of groundwater levels.

Model simulations were undertaken using the MODFLOW system as developed by the United States Geological Survey (USGS). MODFLOW is a modular three dimensional finite difference groundwater modelling system that can be used for the description and prediction of the behaviour of groundwater systems. A finite difference approach is adopted whereby a set of partial differential equations for groundwater movement is used to solve the groundwater flow equations.

MODFLOW is now considered to be the worldwide de-facto standard code for aquifer simulation. The model was developed using the commercial pre-processor (or graphical interface program) Visual MODFLOW, produced by Schlumberger Water Services.

The objective of numerical modelling is to simulate the impact of the ERS subsurface box structure on the existing groundwater regime, specifically to assess the extent and amount of draw-down or draw-up in groundwater levels around the ERS/SSS area. This modelling looked at steady state conditions to obtain a comparison with observed groundwater levels along the alignment. A prediction was then made for the impact of the ERS/SSS structures.

#### 6.3.2.2 Model Design and Geometry

The area modelled is a rectangle measuring 3.7 km x 2.8 km. The model grid is offset from principal grid north by about 20° to align the model grid rows approximately parallel with existing groundwater flow direction (i.e.SE to NW).

Two scenarios are modelled:

- 1st Model - the base model which is designed to represent the average current groundwater regime;
- 2nd Model - the predicted groundwater regime following construction of the cut & cover box, groundwater control drains and site formation works for the SSS.

The model grid comprises 30m x 40m squares across most of the area. These have been refined within the vicinity of the tunnel and the ERS box into row and column widths/lengths of 15m x 20m to allow more detailed modelling of the geology in this area (Figure 6.5).

**Figure 6.5 Groundwater Model Grid Set Up & Boundaries**



The model represents elevations between +200mPD to -75mPD and is subdivided into six lithological units, comprising 11 layers of varying elevations and thickness, with Layer 1 at the top, and Layer 11 at the bottom, as outlined in Table 6.1 below.

**Table 6.1 Summary of Hydraulic Conductivity**

| Layer Number | Thickness (m) | Lithological Description | Assigned Hydraulic Conductivity, kx, ky, kz (m/s) |
|---|---|---|---|
| 1 | 1.5 | Fill | 5E-6, 5E-6, 5E-7 |
| 2 | 2.5 | Alluvium | 5E7, 5E-7, 5E-8 |
| 3 | | | |
| 4 | 6.0 | Colluvium | 5E-6, 5E-6, 5E-6 |
| 5 | | | |
| 6 | 20.0 | Completely Decomposed Granodiorite (CDGd) | 1E-6, 1E-6, 1E-6 (uniform $k_{xyz}$ ) |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | 50.0 | Bedrock (Grade II/III) | 1E-8, 1E-8, 1E-8 (uniform $k_{xyz}$ ) |
| 11 | - | Tai Lam Fault | 1E-5, 1E-5, 1E-5 (uniform $k_{xyz}$ ) |

All the available ground investigation information is located close to the proposed alignment and there is a lack of geological information across the remainder of the model domain. The geological strata are of fairly uniform thickness in the vicinity of the cut & cover box and in the absence of any other data, it was decided to model each of the principal layers at a uniform thickness across the full model domain. As most groundwater flow occurs in the near surface layers, such a simplification is permissible in a preliminary simulation.

The surface elevations were imported from a GIS digital terrain model and subsequent layers defined at a specified offset (depth) below this surface elevation to create a series of parallel layers (Figure 6.3).

#### 6.3.2.3 Hydrogeological Zones

The model is constructed with 6 different lithological / hydrogeological zones that are divided into 11 layers in order to provide sufficient detail to distinguish the units of interest (see Table 6.1). The bedrock is assumed to be impermeable at a depth of 50m below rockhead, which has therefore been set as the base of the model.

The Tai Lam fault, which is a regional NE trending structure, consists of an approximate 80m wide high-permeability zone that crosses the cut and cover box almost perpendicularly. It may act as a drain under the cut & cover box and lessen the impact of the structure on groundwater flow which crosses the northern end of the box. It has been modelled as a separate high conductivity feature embedded within layers 6 to 11.

Examples of the distribution of these hydrogeological zones are shown for selected layers (Figure 6.6), row sections (Figure 6.7) and column sections (Figure 6.8).

**Figure 6.6 Example of Model Setup – Plan View of Layer 6**

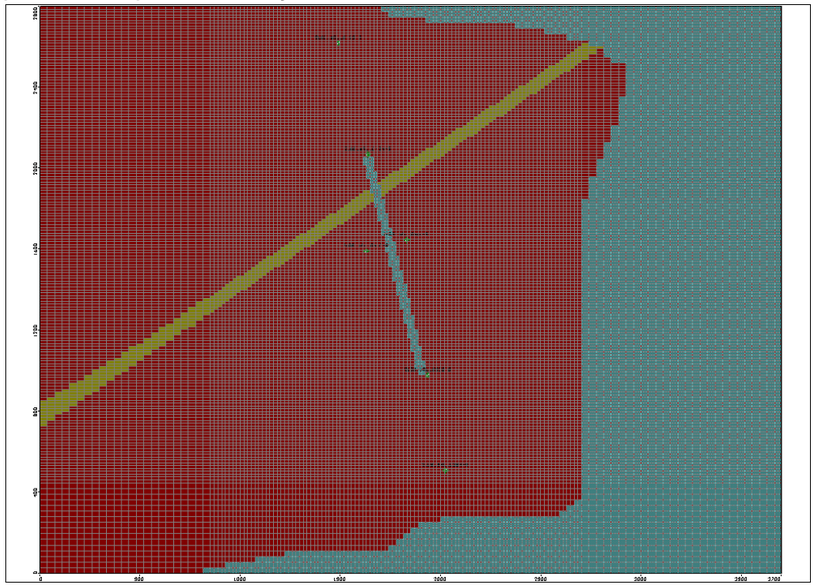


**Figure 6.7 Example of Model setup – Cross Section Along Row 99 (3x Vertical exaggeration)**

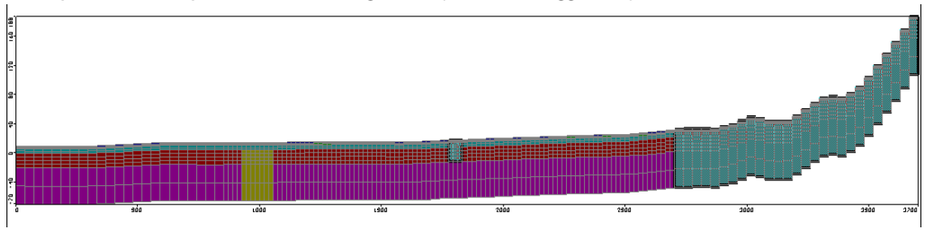
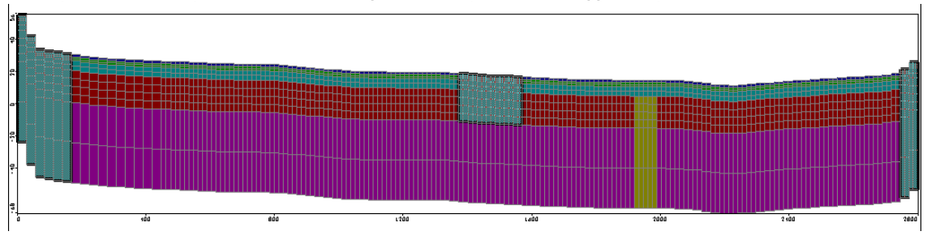


**Figure 6.8 Example of Model Setup – Cross Section Along Column 74 (5x Vertical exaggeration)**



### 6.3.2.4 Adopted Material Properties

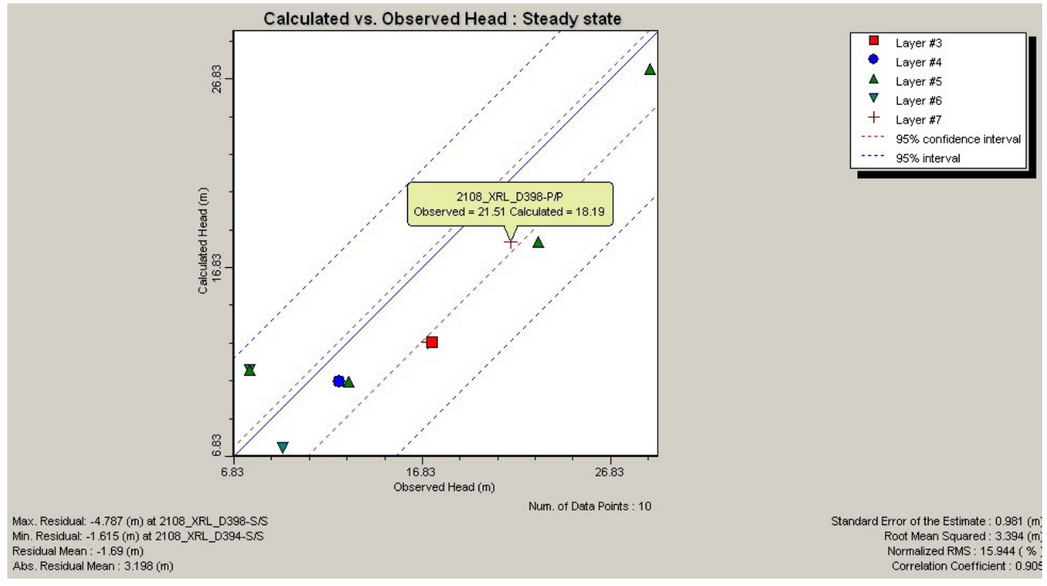
The hydraulic conductivities used in the model are given in Table 6.1. The values are based on the insitu permeability test results with reference to the material properties described in the borehole logs.

The sources above were used to obtain median values of hydraulic conductivity for each of the hydrogeological zones. For modelling purposes it was assumed that these values represent the bulk hydraulic conductivity for each of the hydrogeological zones.

No information is available on the relative vertical and horizontal conductivity or possible anisotropy. The vertical hydraulic conductivity values for most of the upper units are likely to be less, as a result of clay layers and possibly presence of layering structures, and are assumed to be approximately one tenth of horizontal values. In the CDG and bedrock layers it is assumed that there is no difference between vertical and horizontal conductivity.

The model is designed to represent steady-state conditions. Due to limited amount of observation data (generally less than 12 months level data is available), the maximum groundwater level data measured regardless of the length of the monitoring period has been used to calibrate the base model (Figure 6.9).

**Figure 6.9 Calibration Targets**




Observed heads at all observation wells have been compared (calibrated) against calculated head as illustrated in the graph in Figure 6.9. The graph shows that all observation points plot within the 95th percentile confidence limit with a residual mean of 3.2m. The fit between observed and calculated data is considered reasonably good, given the numerous simplifying assumptions that have been used in the model. However it should be noted that the observation wells are all located along the tunnel route which is aligned more or less parallel to the direction of groundwater flow. Because the observation wells are essentially located along a single groundwater flowpath they are therefore not well placed to monitor levels across the whole model domain.

### 6.3.2.5 Boundary Conditions

1st Model - Base Model

A constant head boundary has been set up along the eastern edge of the model domain. The head is calculated as being 1.0m below ground surface, so the elevation actually varies between +17mPD and +39mPD at points along the boundary. The edge of the model approximately coincides with the edge of the basin.

A number of streams and rivers, including the Kan Tin River and their associated alluvium deposits drain the basin to the east. The surface watercourses are believed to be in hydraulic continuity with the underlying aquifer and they have been modelled as a series of drain cells. The elevation of the cells along the Shek

Kong Stream and the subsoil drains along the proposed East Culvert surrounding the ERS / SSS have been modelled to their actual invert level whereas the remaining natural drainage lines in the vicinity of the site were assumed to be a uniform depth of at 0.5m below the ground surface.

The drain cells for the natural streams have been assigned a conductance factor of 50 m³/day/metre whereas the cells for the proposed artificial subsoil drains have been assumed to have a higher conductance factor of 100 m³/day/metre in order to remove any excess water from the cell.

No flow boundaries have been set up along the northern and southern edges of the model where the edge of the basin is located and is therefore assumed to be essentially impermeable.

2nd Model - Predicted groundwater regime following construction of the cut & cover box, east culvert and site formation works for the SSS

In the second model, a series of inactive cells have been inserted to simulate the ERS cut & cover box. These inactive cells extend down to bedrock level (about 30m) and either fully extend to the surface to form a complete barrier to flow (permanent Dwall section), or are cut-off at 2m below the ground surface which would allow some groundwater flow across the top of the box (temporary Dwall section), see Figure 2.3.

Moreover, the land surface was cut down to comply with proposed final site formation levels within the SSS site boundary, mostly to +15.0mPD but some areas to south were set at +18.0mPD.

A drain of conductance 100m$^3$/m/day was inserted adjacent to the eastern side of the box at the base of the cutting to model for the proposed subsoil drain at level +13.5mPD above the East Culvert.

An assessment was made of the impact of the TBM bored tunnel on either side of the cut & cover box. However, close review of the geological sections show that the bored tunnel is mainly excavated in completely decomposed material close to rockhead and is therefore unlikely to have much of an impact on groundwater flow in the upper levels.

#### 6.3.2.6 Recharge and Abstraction Assumptions

There is insufficient monitoring, hydrological and hydrogeological data to create a transient (i.e. time variable) model. It is possible to ignore recharge as a factor in a steady state model and replace the source of water it with a simple constant head. Although this approach is simplistic, it is considered appropriate, given the limited information that is available.

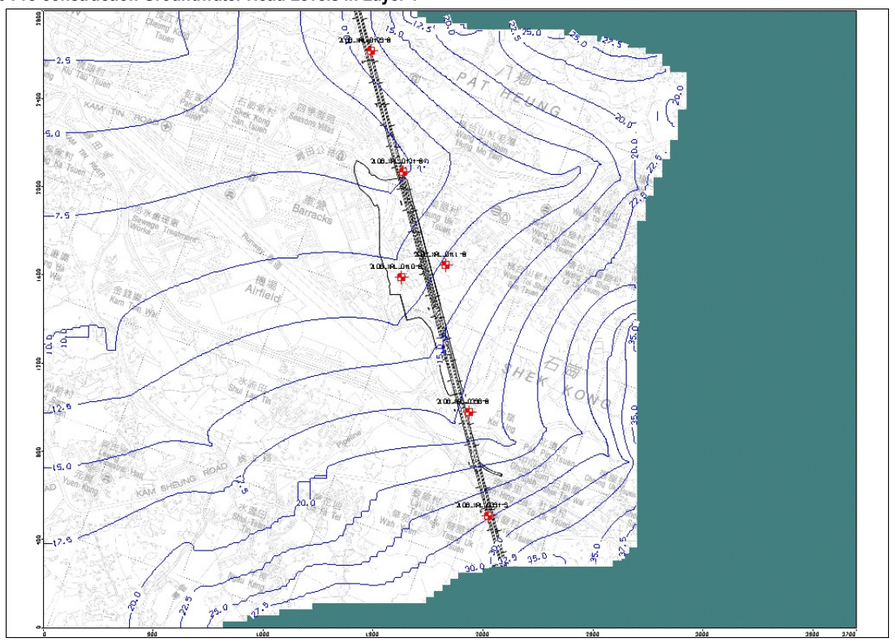
There is no evidence with regard to current groundwater abstractions within the vicinity of the site and so no abstractions have been modelled.

#### 6.3.2.7 Modelling of Current Groundwater Level

Modelling of steady-state conditions (1825 days or 5 years run time), thought to be representative of current conditions has been undertaken for the base model using the input parameters described above.

The model has produced values of head and water table elevation for each cell, which have analysed by means of a groundwater contour plot (Figure 6.10). This map shows that there is generally a low and uniform hydraulic gradient present across the Shek Kong area with groundwater flowing in a north-westerly direction towards the Kam Tin River. Groundwater levels are generally very high across the whole model domain; usually within five meters of ground level.

**Figure 6.10 Pre-construction Groundwater Head Levels in Layer 1**




A reasonable mass balance has been achieved in the analysis and a credible representation of the current groundwater regime, prior to the construction of the underground structures, has also been achieved i.e. the base model can be considered to be calibrated.

A reasonable mass-balance was achieved with inputs from the constant head closely matching outputs from the drain cells. Recharge and storage factors are not required for a steady state simulation.

#### 6.3.2.8 Effect of the ERS Boxes on Groundwater Flow

The predicted groundwater regime following construction of the cut & cover box has been modelled using the same input parameters as the base model. The cut & cover box has been modelled as a series of inactive cells (i.e. no flow boundaries). The flow direction predicted by the model is orientated in a more north south direction than that previously estimated (i.e. more or less parallel to the tunnel alignment) and therefore the damming effects are not significant.

The model has produced values of head for each cell of the aquifer, which has been analysed by means of a groundwater contour plot (Figure 6.11). The hydraulic gradient downstream from the cut & cover box is low (0.01- 0.005 as would be expected in permeable materials. The heads around the cut & cover box are highest on the eastern side and lowest on the western side as might be expected if groundwater flow is damming behind the impermeable Dwall structure.

**Figure 6.11 Post-construction Groundwater Head Levels in Layer 1**

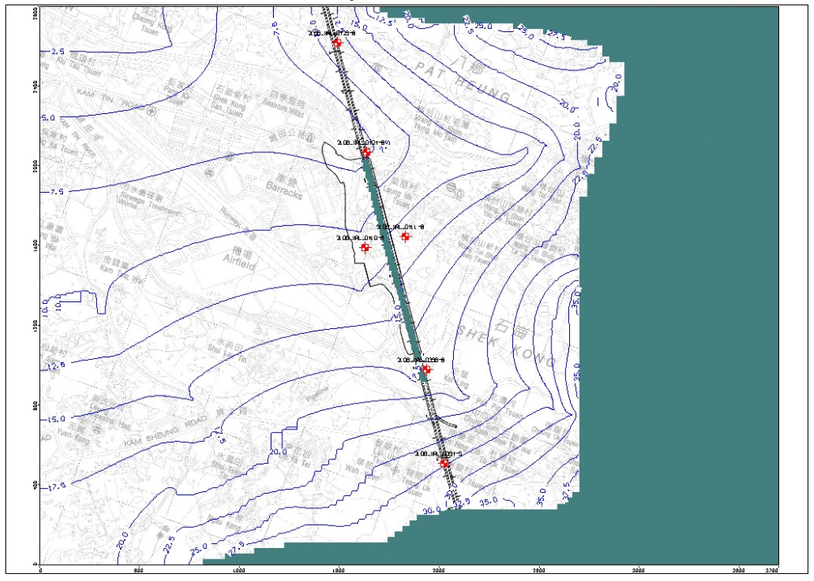
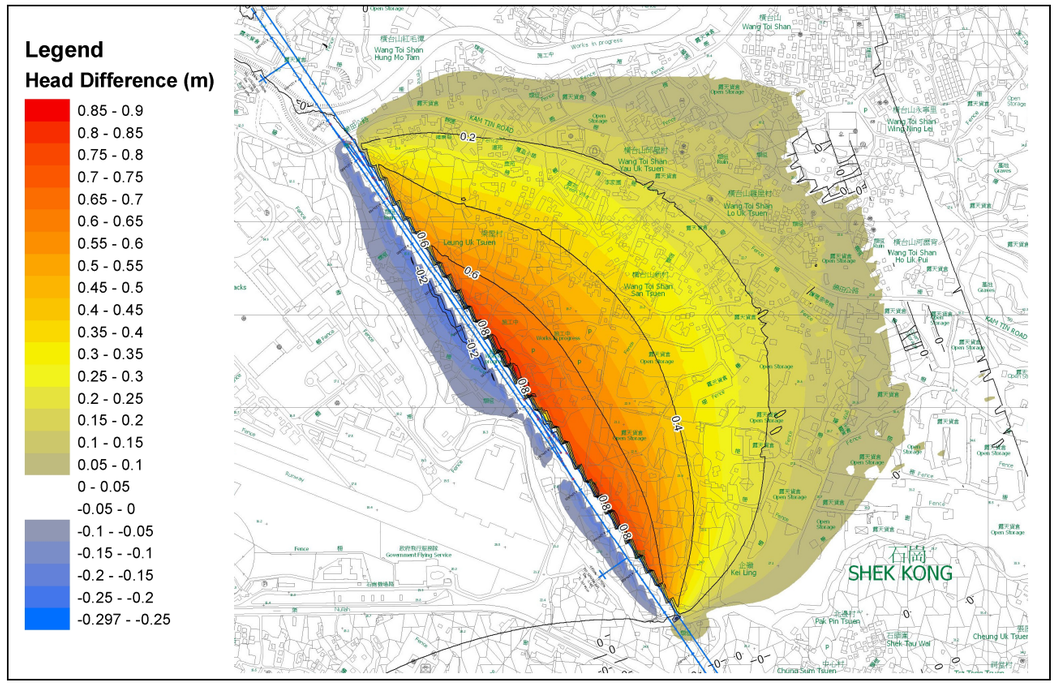


Figure 6.12 illustrates the change in groundwater levels between the base model case and predicted groundwater regime following construction of the cut & cover box, installation of the groundwater control drains and site formation works for the SSS.

**Figure 6.12 Impact of the Cut & Cover Box – Comparison of Pre and Post Construction Water Table Levels (difference in metres) [refer to Appendix C for a more detailed figure]**




The head difference across the ERS box is negligible at the southern and northern ends of the box, but increases to a maximum of about 1.5 m (variation of water level either side of the box in the order of -0.3m and +1.0m) at the centre of the box. This variation is equivalent to the average seasonal range of groundwater level of about 1.5m, as measured in local observation wells. The results can provide the design basis for settlement calculations. The zone of draw-up (rise in levels) is likely to extend about 500m to the east side of the ERS box, but will not extend beyond the ends of the box in a north-south direction. The modelled falls in levels on the western side of the box is narrow, extending no more than 200m from the wall.

In normal circumstances, the small changes in groundwater level across the box that are predicted by the groundwater model would not be of concern. The small water pressure imbalance (up to 1.5 m head) across the box is a second order effect, and would simply be included as a load in the structural design of the wall.

#### 6.3.2.9 Sensitivity Analysis

It is generally considered good practice to undertake sensitivity analyses on each parameter such as aquifer properties and recharge. However as a result of the lack of background data and wide range of uncertainties it was felt that it would not be useful to undertake a systematic series of sensitivity analyses. However properties for some critical layers including the fill, and CDG were varied, both up and down, by one order of magnitude, to understand the possible impact on groundwater levels and calibration. The variation in results obtained from the sensitivity analysis were not considered significant, possibly as a consequence of the location and alignment of the monitoring wells, as discussed in Section 6.3.2.4 above.

#### 6.3.2.10 Settlement Due to Groundwater Drawdown

From the MODFLOW analysis, it can be seen that the presence of the proposed ERS structure will induce a maximum drawdown of groundwater table of not more than 0.5m within the SSS area. Outside the site boundary, a maximum of 0.2m drawdown has been predicted. In the design and impact assessment for the ERS and approach tunnel excavation, a 2.0m groundwater drawdown has been assumed in the settlement prediction calculation. The induced settlement was found to be within the tolerance of all adjacent existing structures. The modelling indicates that the possible water drawdown is likely to be less than 2.0m, and it is therefore concluded that no adverse impact will be made to any adjacent existing structures. For the detail of the damage assessment, reference shall be made to the ERS excavation and approach tunnel excavation design report and the Existing Building Impact Assessment Report.

### 6.3.3 Conclusion of the Analyses

Regarding temporary groundwater drawdown effect due to excavation, the drawdown immediately besides the diaphragm wall during construction is limited to within 2m below ground level, achieved by a combination of toe grouting and provision of recharging well. The required depth of toe grouting shall be verified by further ground investigation during construction stage. To ensure the temporary works design is consistent with the water drawdown assumption as adopted in the settlement analysis, the performance criteria for toe grouting and settlement limit arising from dewatering have been specified in the drawing.

Regarding the possible long term damming effect due to the construction of the impermeable cut & cover box, a 3D MODFLOW groundwater model has been developed to assess the impact of groundwater regime in the Shek Kong area. A steady state model was successfully run, a reasonable mass balance was obtained and a credible representation of the current groundwater regime, prior to the construction of the underground structures, has been achieved i.e. the base model has been calibrated.

The direction of groundwater flow predicted by the model is orientated in a more N-S direction than that previously estimated and therefore the damming effects are less significant than originally thought. With the D-Wall in place and ground level of the SSS adjusted to it's final formation level, groundwater levels are found to be not significantly impacted on the downstream side. The subsoil drains along the proposed East Culvert is acting as the single most important control and prevents any increase in levels or damming on the up-gradient side of the cut & cover box. Also, the model shows that there will be minimal impact on stream flows.

The changes to the surface drainage characteristics, potential drainage impacts which might arise from the construction works and the proposed drainage impact mitigation works are detailed in the Deliverable No. 2.4P - Drainage Impact Assessment Report.

# 7 Groundwater Impact for Shafts Excavation (Works Contracts 823A, 824 & 825)

## 7.1 General

As stated in Section 2.5, there are three permanent shafts and one temporary construction shaft distributed along the Hong Kong Northern Section of the XRL alignment as listed below:

- Works Contract 825 - Mai Po Ventilation Shaft (MPV or VB1)
- Works Contract 824 - Ngau Tam Mei Ventilation Shaft (NTV or VB2)
- Works Contract 824 - Tai Kong Po Emergency Access Point (TKP or EAP3)
- Works Contract 823A - TBM Reception Shaft, Tse Uk Tsuen Works Area (TUW)

In these areas, the excavations for the permanent shafts and temporary construction shaft will only require temporary dewatering during their construction and any groundwater drawdown outside the site area resulting from such work would typically be limited to 2m within the site area in order to avoid adverse settlement impacts outside. In the long term they are designed to be "undrained" with a full hydrostatic head outside.

Where shaft excavation takes place through Grade III rock or better, temporary support shall be installed to stabilize the rock mass following each lift. The permanent lining of the shaft shall consist of cast in place concrete backed by a waterproofing membrane and geotextile in order to relieve hydrostatic water pressures (drained). The exception to this is a short section of circular shaft at VB2 which has been designed as undrained immediately below the rockhead in order to form a cut-off at the soil-rock interface and prevent excessive drawdown of water levels within the overlying unconsolidated materials.

It is anticipated that MPV and TUW will be entirely / mostly in soft ground whereas NTV and TKP will be excavated through both soft ground and hard rock.

## 7.2 Groundwater Drawdown Assessment Method

The groundwater drawdown due to dewatering has been estimated by using the computer program PLAXIS Version 18.2. PLAXIS is a finite element program to obtain a solution of plane groundwater flow. The ground profile is divided into layers of soil clusters with different permeabilities.

A simulation model is developed to estimate the maximum groundwater drawdown outside the excavation by assuming that the source of water locates beyond the radius of influence of dewatering activities inside the excavation area. The radius of influence is calculated by an empirical equation that recommended in CIRIA Report No 113. The pore water pressure from the PLAXIS analyses is used for the estimation of settlement due to the groundwater drawdown.

## 7.3 Works Contract 825 – Mai Po Ventilation Shaft (MPV)

### 7.3.1 Proposed Works

Within Works Contract 825, a single 200m long cofferdam excavation will be formed from ground level to launch the TBM machine for Works Contract 825 and either receive or launch the TBM from Works Contract 826. In the final condition a permanent 40m long ventilation shaft will be constructed at the southern end. A buried cut and cover tunnel incorporating a scissor cross over will be constructed along the remaining length.

The MPV is approximately 200m long by 33m wide by 35m depth which will be formed using temporary diaphragm walls supported by multi-level temporary strutting. Excavation will be undertaken from existing ground level which varies between approximately of +3mPD and +5mPD to a level of between -28mPD and -29mPD. The site is located in a rural area with few sensitive receivers. The excavation is expected to be undertaken using mechanical means. The permanent cut & cover tunnels and the ventilation building structure will be constructed from the bottom up within the construction shaft.

### 7.3.2 Design Groundwater Level

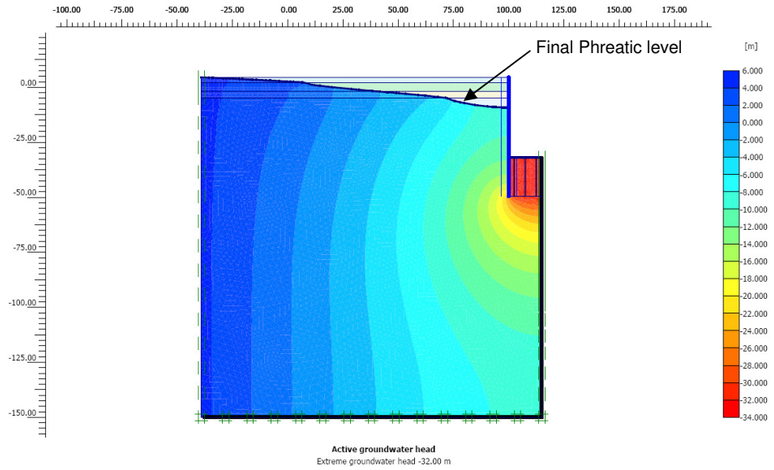
The existing ground level at the site is around +4.3mPD. A total of 4 standpipe / piezometers have been installed around the MPV area. The groundwater monitoring records indicate that the groundwater level ranges from +2.2mPD to +3.6mPD.

The Drainage Impact Assessment (DIA) report determined that the 1 in 200 year design flood level in this area is +4.5mPD. The highest design groundwater level is taken as +4.5mPD. Based on the available groundwater monitoring data, the lowest design groundwater is assumed to be +2.2mPD.

### 7.3.3 Temporary Groundwater Drawdown due to Excavation

The result of groundwater drawdown from the PLAXIS analyse is shown in Figure 7.1. The maximum groundwater drawdown is estimated to be 11.32m immediately behind the Dwall. The drawdown is only temporary as in long term the box is sealed and groundwater level will recover with full hydrostatic head outside.

**Figure 7.1 Seepage Analysis for MPV**




The estimated ground settlement due to the groundwater drawdown and the associated site impact shall refer to the "Deliverable No. 3.13A (BD Consultation) Design Calculations for Excavation and Lateral Support Works of Mai Po Shaft Part 1".

### 7.3.4 Possible Damming Effect

As shown in the air photos enclosed in Appendix A, the proposed shaft is located at a low lying flat ground surrounded to the east and south by more elevated hilly terrains. The direction of groundwater flow is oriented in a south-east direction almost parallel to the long section of the proposed shaft. Therefore the damming effect is considered to be negligible in view of the extent and the orientation of the proposed box structure.

## 7.4 Works Contract 824 – Ngau Tam Mei Ventilation Shaft (NTV )

### 7.4.1 Proposed Works

The proposed Ngau Tam Mei Ventilation Shaft is a circular shaft with internal diameter of 17m. It connects to the proposed basement structure and forms part of the ventilation structure. The size of the cofferdam for basement excavation is approximately 25m x 37m.

The Ngau Tam Mei Shaft will be excavated to a depth of about 85m from the existing ground down to the tunnel level, it includes approximately 40m in soft ground and 45m through competent rock. The shaft itself will be used for an access shaft for recovery of the tunnel boring machine (TBM) drives southwards from Mai Po and the construction of the drill and blast tunnels towards Tai Kong Po. Subsequently the shaft will be used as part of the permanent ventilation structure.

The shaft is proposed to be formed by using secant bored pile wall, supported by multi-level reinforced concrete ring beams. Permanent structure will be constructed from the bottom up within the shaft.

The dimension of the cofferdam is approximately 25m x 37m on plan. It will be excavated to a depth of about 10m in soft ground from +63.5mPD to +53.8mPD. It is proposed to be formed by using sheet pile walls and supported by two layers of temporary steel struts.

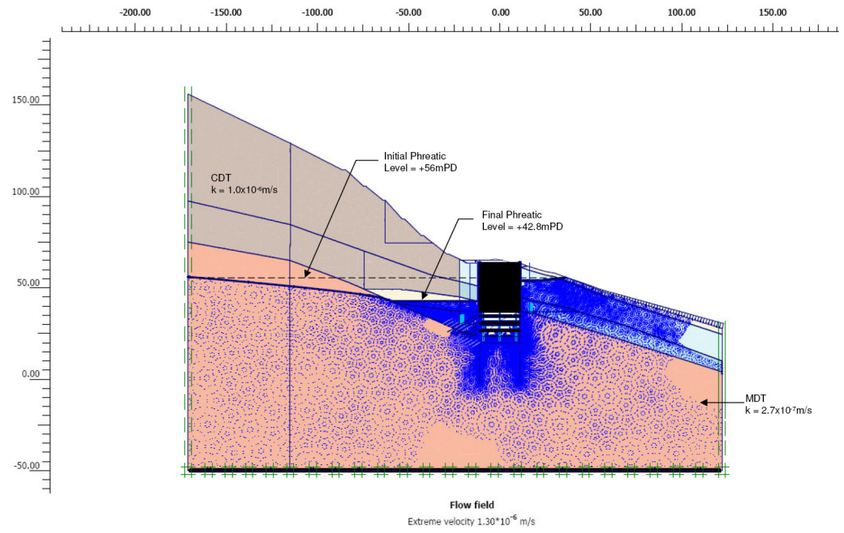
### 7.4.2 Design Groundwater Level

A total of 5 standpipe / piezometers have been installed inside borehole nos. 2108/XRL/A005a, A005d, A006a, and D444. An automatic data acquisition system has been installed at borehole no. 2108/XRL/D444 where groundwater data are measured at 30minutes time lapse. The groundwater monitoring records measured between April and August 2009 indicate that the groundwater level ranges from +42.37mPD to +53.66mPD. To allow for possible groundwater increase, the highest design groundwater level is conservatively taken as +56.0mPD. Based on the available groundwater monitoring data, the lowest design groundwater level is assumed to be +42.4mPD.

### 7.4.3 Temporary Groundwater Drawdown due to Excavation

The result of groundwater drawdown from the PLAXIS analyse is shown in Figure 7.2. The maximum groundwater drawdown is estimated to be 13.2m immediately behind the secant bored pile wall. The drawdown is only temporary as in long term the box is sealed and groundwater level will recover with full hydrostatic head outside.

**Figure 7.2 Seepage Analysis for NTV**




The estimated ground settlement due to the groundwater drawdown and the associated site impact shall refer to the “Deliverable No. 3.13A (BD Consultation) Design Calculations for Excavation and Lateral Support Works of Ngau Tam Mei Shaft and Cofferdam Part 1”.

### 7.4.4 Long Term Groundwater Inflow in the Lower Rock Portion

Similar to NTV, in the long term, the upper portion of the shaft situated in decomposed tuff has been designed as “undrained”. This effectively forms a cut-off at the soil-rock interface and prevents excessive drawdown of water levels within the overlying unconsolidated materials. Only the lower portion of the shaft founded in sound rock shall be “drained”, with permeability controlled by the interconnectivity and aperture of rock joints. The Contractor will be required to control the groundwater inflow to an average of less than 0.3 l/min/m of the shaft prior to casting of the permanent lining, so it is not expected that fracture flow through the grouted rock mass will cause drawdown in the overlying sediments even if the grout breaks down over time.

## 7.5 Works Contract 824 – Tai Kong Po Emergency Access Point (TKP)

### 7.5.1 Proposed Works

The Tai Kong Po Shaft is to be constructed under Works Contract package 824. The shaft provides the transition between the drill and blast tunnels of Contract 824 to the north and the TBM driven tunnels excavated from the south under Contract 823A. The 18m wide by 33m long shaft will be constructed, partly in soft ground and partly in competent rock, to a depth around 40m below ground level.

The shaft itself will be used for the recovery of the Contract 823A TBMs excavating the twin bored tunnel drives northward, the construction of the twin drill and blast tunnels towards Ngau Tam Mei as part of this contract, providing space for the plant and equipment associated with the Emergency Access Point above and the running tunnels, and providing emergency and maintenance access in the event of an incident or maintenance if is required during the operational phase.

The upper portion of this shaft, extending from +15.5mPD to -4mPD will be constructed within a temporary diaphragm wall cofferdam with temporary props and wailings. Within the rock, below -4mPD, the shaft will be excavated using the drill and blast method through the Tuff with the shaft supported by a temporary lining. The shaft will terminate at -22.70 mPD.

Subsequent to the completion of the tunnel excavation works, the shaft will be permanently lined with reinforced concrete using the bottom up approach.

### 7.5.2 Design Groundwater Level

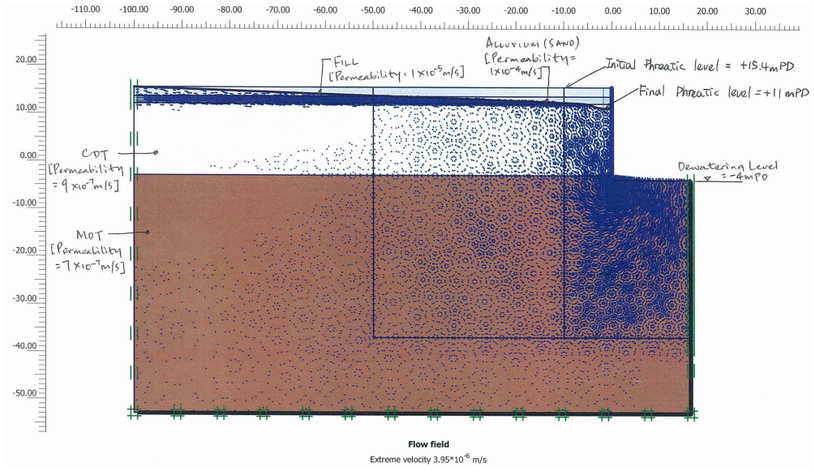
A total of 7 standpipes / piezometers have been installed inside borehole nos. 2108/XRL/D433, D434, D435 and A008b. The groundwater monitoring records indicate that the groundwater level ranges from +11.77mPD to +18.05mPD.

The existing ground level at the site varies from +15.3mPD to +19.2mPD. A temporary platform at a level of +15.5mPD will be formed prior to the construction of diaphragm wall and shaft excavation. The highest design groundwater level is assumed to be near to the ground level (i.e. +15.4mPD). Based on the available groundwater monitoring data, the lowest design ground water table is taken as +11.80 mPD.

### 7.5.3 Temporary Groundwater Drawdown due to Excavation

The result of groundwater drawdown from the PLAXIS analyse is shown in Figure 7.3. The maximum groundwater drawdown is estimated to be 4.4m immediately behind the Dwall. The drawdown is only temporary as in long term the box is sealed and groundwater level will recover with full hydrostatic head outside.

**Figure 7.3 Seepage Analysis for TKP**



The estimated ground settlement due to the groundwater drawdown and the associated site impact shall refer to the "Deliverable No. 3.13A (BD Consultation) Design Calculations for Excavation and Lateral Support Works of Tai Kong Po Shaft Part 1".

### 7.5.4 Long Term Groundwater Inflow in the Lower Rock Portion

In the long term, the upper portion of the shaft situated in decomposed tuff has been designed as "undrained". This effectively forms a cut-off at the soil-rock interface and prevents excessive drawdown of water levels within the overlying unconsolidated materials. Only the lower portion of the shaft founded in sound rock shall be "drained", with permeability controlled by the interconnectivity and aperture of rock joints. The Contractor will be required to control the groundwater inflow to an average of less than 0.3 l/min/m of the shaft prior to casting of the permanent lining, so it is not expected that fracture flow through the grouted rock mass will cause drawdown in the overlying sediments even if the grout breaks down over time.

## 7.6 Works Contract 823A – Tse Uk Tsuen Works Shaft (TUW)

### 7.6.1 Proposed Works

The TUW shaft is a construction shaft under Works Contract 823A. The outside of the south-eastern wall serves as the demarcation between Works Contract 822 and Works Contract 823A to the northwest. The TUW shaft is a 16m long by 32m wide temporary shaft and to be used for the reception of the tunnel boring machines for Works Contract 823A from the north and the mined tunnel cut through at 822/823A interface from the south. The cut and cover tunnel structure will be constructed thereafter connecting the TBM tunnel section and the mined tunnel section at both ends.

The TUW shaft is proposed to be formed by using temporary diaphragm walls and supported by multi-level temporary steel struts. The reference design of the excavation and lateral support system has been carried out under the Detailed Design Consultancy Agreement No. C803. The excavation is approximately 22m deep in soft ground and 5m in hard rock. It will be undertaken from existing ground level of approximately +31.5mPD to final formation at +7.0mPD and locally at +5.9mPD at proposed sump pit. The site is located in a rural area. Excavation is expected to be undertaken using mechanical means. Permanent cut & cover tunnels structure and sump pit will be constructed from the bottom up within the construction shaft.

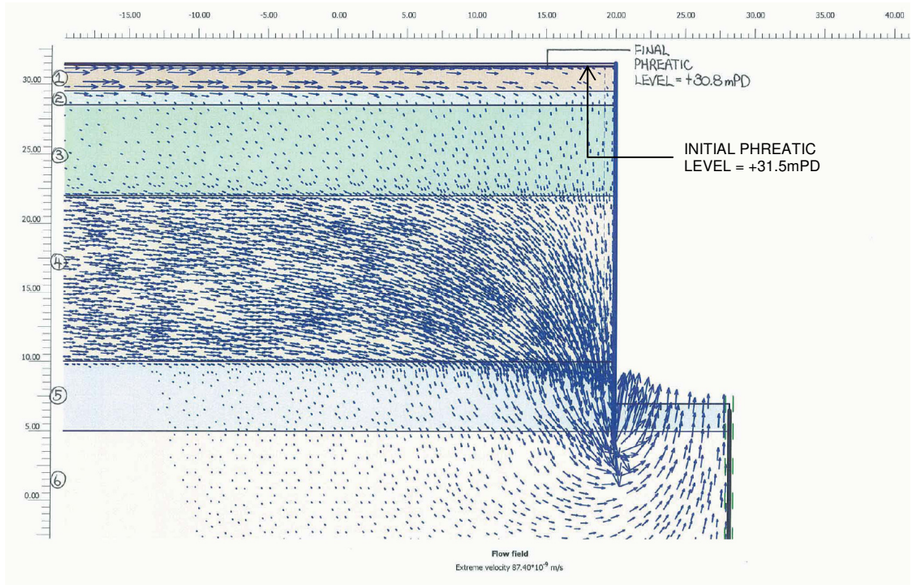
### 7.6.2 Design Groundwater Level

There is no available groundwater monitoring data in vicinity of the shaft for groundwater level interpretation. The design groundwater level is hence based on existing available data including the measured groundwater level from borehole drilling process and the initial groundwater level measured from in-situ peameability test. These measurements indicate that the groundwater level ranges from +29.29mPD to +30.93mPD conducted in dry season between September and October 2008. To allow for possible groundwater increase during wet season, the design groundwater level is conservatively taken as +31.5mPD, which is at the existing ground level.

### 7.6.3 Temporary Groundwater Drawdown due to Excavation

The result of groundwater drawdown from the PLAXIS analyse is shown in Figure 7.4. The maximum groundwater drawdown is estimated to be 0.7m immediately behind the Dwall. The drawdown is only temporary as in long term the box is sealed and groundwater level will recover with full hydrostatic head outside.

**Figure 7.4 Seepage Analysis for TUW**




The estimated ground settlement due to the groundwater drawdown and the associated site impact shall refer to the "Deliverable No. 3.13A (BD Consultation) Design Calculations for Excavation and Lateral Support Works of Tse Uk Tsuen Shaft Part 1".

## 7.7 Groundwater Control Strategy

In order to mitigate any drawdown effects to the groundwater table outside of the site boundary during the operation of the temporary dewatering works the following measures will be put in place at each location:

- Toe grouting shall be applied beneath the toe level of the temporary / permanent cofferdam walls as necessary to lengthen the effective flow path of groundwater from outside and thus control the amount of water inflow to the excavation.
- Recharge wells shall be installed as necessary outside the excavation to pump water obtained from the excavation back into the ground.
- Subsequent to the completion of diaphragm wall construction and toe grouting and prior to the commencement of excavation work, a full scale pumping test will be undertaken to verify the water cut-off effectiveness and the effects of dewatering on adjacent structures. The test is proposed to lower the existing groundwater table within the excavation to 500mm below the proposed final excavation levels and to undertake monitoring to demonstrate the acceptance criteria is strictly fulfilled.

# 8 Groundwater Impact for Drained Tunnel Sections (Works Contract 824)

## 8.1 Tunnel Inflow Precedent in Hong Kong

### 8.1.1 Inflow to Tunnel Excavations in Rock

Several tunnel excavations have recently been completed in Hong Kong where water inflow measurements were observed, both pre- and post grouting.

The majority of rock tunnels in Hong Kong have experienced only minor inflows over their lengths due to the generally low hydraulic conductivity of the rock mass. This low conductivity can be attributed to a poorly connected joint network (low persistence) and tight aperture. Data available from five recently completed MTRC tunnels illustrates the typical variation of conditions encountered. These are summarized in the table below:

**Table 8.1 Summary of Recorded Inflows into Recent MTRC Tunnels**

| Tunnel Project | Length of Drained Tunnel (m) | Rock Type | Final Groundwater Inflows | | |
|---|---|---|---|---|---|
| | | | m3/day | l/min/m | l/min/m$^2$ |
| West Rail Tai Lam Tunnels | 5140 | Volcanic & Granitic | 2960.6 | 0.4 | 0.017 |
| Pak Shing Kok Tunnels | 1178 | Volcanic | 298.5 | 0.2 | 0.015 |
| Tai Yam Teng Tunnel | 716 | Volcanic & Rhyolitic Dyke | 105.2 | 0.1 | - |
| Black Hill Tunnels | 1650 | Granitic | 68 | 0.03 | 0.002 |
| Quarry Bay Congestion Relief Works | 1800 | Granitic | 6.2 | 0.002 | - |

Both Pak Shing Kok and Black Hills Tunnels were constructed by drill and blast as part of the Tseung Kwan O Extension through fractured granite and volcanic tuff, respectively. The tunnel size was roughly 35m$^2$.

Pak Shing Kok Tunnels encountered high inflows in a series of adjacent bifurcation cavern located with shallow cover and beneath a river with high base flow that historically was maintained throughout the year. No grouting was carried out during excavation of the tunnels, although grouting was undertaken after completion of the final lining in order to lower inflows into the drainage system. Throughout the rest of the tunnel only localized minor inflows and seepages were observed, but again no systematic forward probing or grouting was undertaken during construction. Despite this, the total final inflows are relatively small, equating to 0.2 l/min/m. For tunnels that have not encountered high localized inflows, such as those within the granitic rock mass encountered at Quarry Bay Extension, the final inflows were very low.

The Tai Lam Tunnel was also constructed by drill and blast methods with a cross sectional area of 110m$^2$. This tunnel is the closest to the XRL alignment. A probehole flow criterion of 20 l/min was initially set for 50mm diameter hole. This was subsequently relaxed during construction to 50 l/min. In response to this change, pre-excavation grouting was undertaken at only 9 locations to treat 11 discrete structural features associated with high inflows. These numbers should be kept in mind during XRL excavation and may serve as a means of “calibrating” the expected tunnel inflow against the numbers provided here. Details of the recorded tunnel inflows and location of the grouted zones for the Tai Lam Tunnel are summarised in two figures enclosed in Appendix D.

Analysis of the available records indicates that this was inadequate to control the final inflows to the required 0.55 l/min/m, and extensive post excavation grouting was required to reduce inflows. The final inflows recorded in the sumps following completion of the post excavation grouting program equate to approximately 0.4 l/min/m, or 0.017 l/min/m$^2$ of tunnel.

The Tai Lam Tunnel passes close (24m) beneath WSD Water Tunnel No. 3. The specification imposed the following constraints at 60m either side (measured horizontally) of WSD water tunnels as WSD Drainage Mitigation Zones:

- If water inflows greater than 20 l/min were encountered in a probe hole, grouting ahead of the tunnel excavation face (pre-excavation grouting) was to be undertaken.
- Elsewhere the final inflows had to comply with a final tunnel inflow of less than 0.55 l/min/m.

The most notable case for high inflow occurred on SSDS Contracts 13 and 14 where three of five subsea tunnels experienced inflows of 17-25 l/s which could not be adequately controlled by available equipment. Extensive post grouting was required to meet the specified inflow criterion.

Photos showing the amount of groundwater inflow during different tunnel excavation together with the rock cores retrieved from ground investigation for the four recently completed MTR tunnels are presented in Appendix D. Typical rock cores retrieved from the Kai Kung Leng along the proposed XRL alignment are also presented for comparison.

### 8.1.2 General Implications of Past Precedent for the Proposed XRL Drained Tunnel

Based upon the extensive amount of tunnelling experience in volcanic and granitic rock in Hong Kong (more than 100 km excavated) it is clear that site specific details are very influential on the hydrogeological response of the rock mass to tunnel excavation. This suggests the following:

- Inflows vary according to rock mass conditions including lithology, cover (insitu stress and water head), weathering state, and proximity to recharge sources.
- Higher, potentially problematical inflows are typically associated with discrete transmissive structural features including dykes, faults, shear zones, geological contacts and intersections of persistent vertical/sub vertical joints.
- When these conditions are located in proximity to a recharge source, the inflows tend to be sustained. In the absence of a nearby recharge source, groundwater drawdown may occur if inflows are not controlled by grouting.
- Pre-excavation grouting in not typically required for long lengths of tunnel excavation, except in very sensitive urban settings where stringent inflow criteria may apply.
- Post excavation grouting tends to be difficult to control and implement, and also time consuming.
- Hong Kong precedent suggests inflows to hard rock tunnels are controllable by pre-excavation grouting methods when adequately designed and implemented with appropriate equipment from the advancing face. However, there are a number of HK examples where pre-excavation grouting was not adequately specified or implemented, leading to high final inflows with the need for post excavation grouting.

## 8.2 Proposed Construction Concept for 824 Single Track Tunnels and Crossover

The selected permanent structural lining design concept for the single track drill and blast running tunnels and associated caverns is a pressure relieved drained lining, whereby the groundwater is directed through a drainage fleece backed by PVC waterproofing membrane to the tunnel invert, which is taken via the tunnel drainage system to a sump situated at a low point, from where it is discharged. This concept is appropriate where it is not structurally or economically feasible to design against the full static groundwater head, and where limited groundwater drawdown is acceptable. Drained linings are also suitable for rock tunnels where mass permeability is relatively low (compared to sandy soils for example) and impact on the surrounding water table in minimal. The drained tunnel concept has recently been adopted on West Rail Tai Lam Tunnel and Eagles Nest Highway Tunnel.

The design is therefore a balance between minimizing the permanent lining thickness through pressure relief while limiting inflow to the drainage system to volumes easily handled by the tunnel sumps.

WSD has raised concern that drainage inflows might be sufficiently large to cause water pressure fluctuations around their 3.4m diameter aqueduct, beneath which the XRL alignment passes. The impact of the tunnels on the aqueduct has been assessed by numerical modelling, as discussed in Section 8.3.4.

## 8.3 Inflow Estimate

### 8.3.1 Rock Mass Permeability

Packer tests were carried out in numerous project specific boreholes as part of the preliminary and detailed design. Reference should be made to the 'Geotechnical Engineering Report' produced by Arup or the Final Ground Investigation Fieldwork Report prepared by GCE for details. A summary of the data is given in the figures below. The data has been split into two groups; one to reflect the background, or typical values expected to be encountered at depth in competent rock, and another to reflect the more permeable features and fracture zones characteristic of the rock mass conditions under the slope flanks. It should be noted that higher flow zones could be encountered at depth, associated with discrete structural features.

Figures 8.1 and 8.2 show the typical strong Tuff at Kai Kung Leng and the localised highly fractured shear zones. Figures 8.3 and 8.5 show the location and depth of lugeon tests considered in the analysis.

**Figure 8.1 Typical Strong Intact Grade II or better Tuff with Widely Spaced Joints Found in the Project Specific Boreholes in Kai Kung Leng**

**Figure 8.2 Localised Shear Zones (typically one to few metres wide) Associated with Crushed Rock, Low Angle Quartz Veins and Cataclasitic Texture**




**Figure 8.3 Geological Section of 824 Alignment Ch119+879 to Ch120+200**

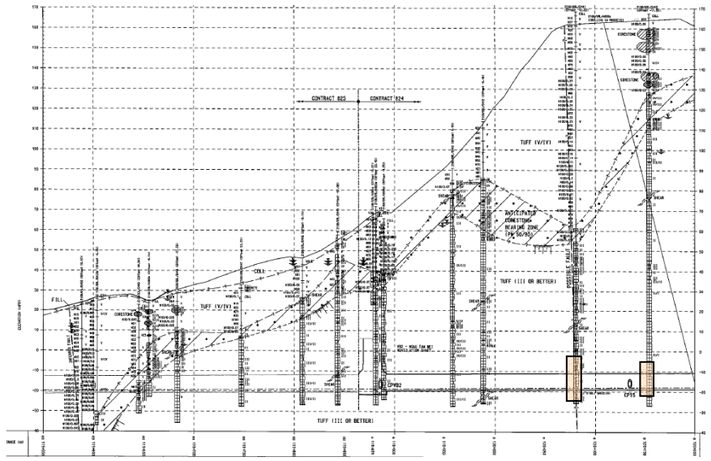


**Figure 8.4 Geological Section of 824 Alignment Ch120+200 to Ch120+850**

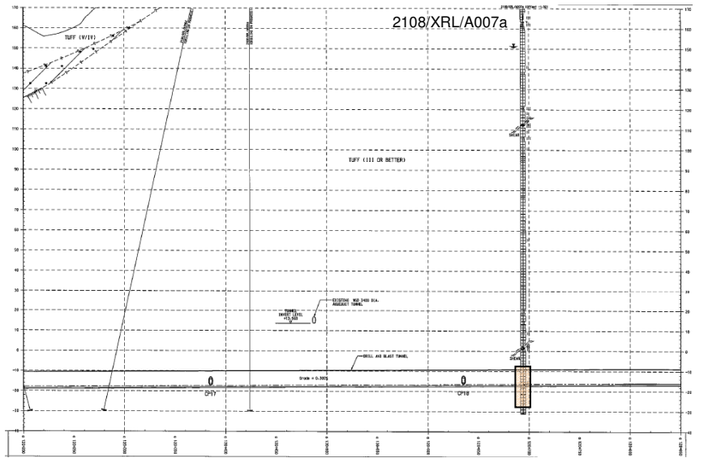



**Figure 8.5 Geological Section of 824 Alignment Ch121+500 to Ch122+150**

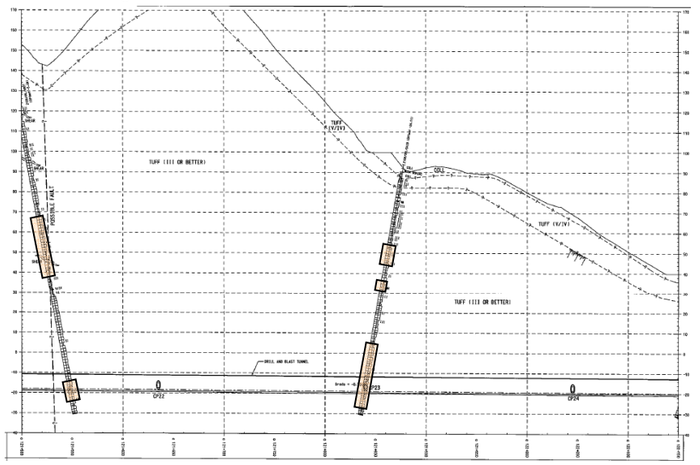


**Figure 8.6 Typical Background Permeability Under Kai Kung Leng (from Borehole 2108/XRL/A007a)**

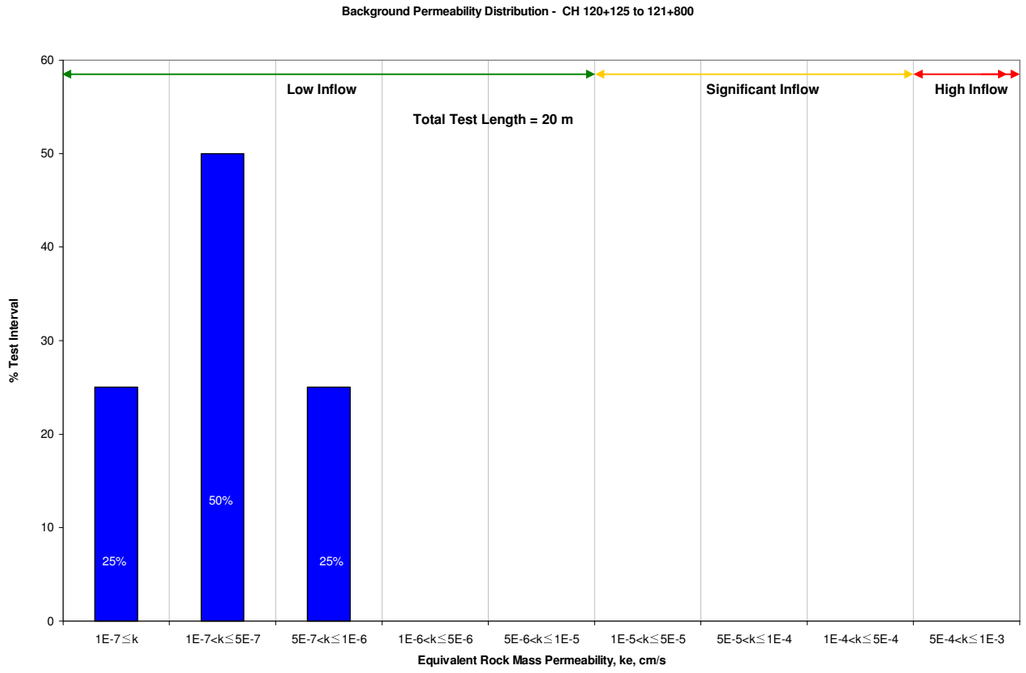
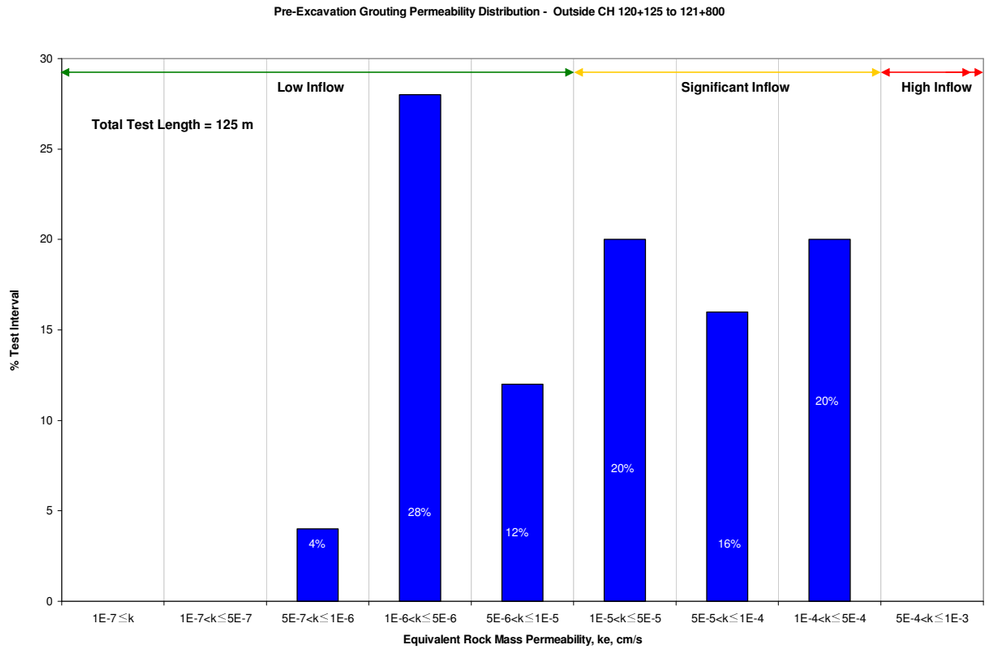



**Figure 8.7 Typical Permeability Under Kai Kung Leng Slope Flanks**




The packer test data from Contract 824 was broadly separated into two categories: the background, or typical equivalent rock mass permeability associated with fair to good rock and tight aperture fractures characteristic of rock at depth under Kai Kung Leng, and the poor to very poor heavily fractured, open rock mass characteristic of the rock found under the slope flanks on either end of the Contract. The histograms for each of the zones are given in Figures 8.6 and 8.7. Based on the distribution of the limited test data shown in the figures, a design permeability was selected for each of the ground types.

**Table 8.2 Summary of Design Equivalent Permeability for Contract 824**

| Type | Design Equivalent Permeability (m/s) |
|---|---|
| Transmissive features (i.e.heavily jointed, open rock) | $5 \times 10^{-7}$ |
| Typical (background) | $5 \times 10^{-9}$ |

These design values form the basis for the numerical modelling discussed in Section 8.3.2.4.

While a broad indication of the variation in permeability with depth is presented, any specific trends are likely to be obscured by the following:

- Data from test lengths of typical rock mass conditions is less than data from more highly fractured zones;
- Testing is generally targeted at more permeable zones.

### 8.3.2 Inflow Calculation Methods

#### 8.3.2.1 General

Two methods have been used to calculate the expected inflows into the tunnels during construction. The results obtained from these analyses will then be used to determine an appropriate limiting final inflow rate which shall be used to size the tunnel sump and drainage system. This final inflow figure will be a compromise between minimizing the required ground treatment (grouting) while limiting drainage to keep pumping and storage costs economically feasible and not impact serviceability requirements of the tunnel structure itself.

1. Semi-Empirical – This approach is based on correlating packer test data and rock mass characteristics to tunnel inflows observed in various geological and hydrogeological conditions through basic groundwater flow equations. Two semi-empirical approaches have been considered, that of Heuer (1995,2005) and the IMS system which was developed specifically from Hong Kong case studies.
2. Numerical – The second approach uses the SAFE computer program to assess the groundwater flows. SAFE is a finite element software product for analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock. The program allows analyses ranging from simple, saturated steady-state problems to more sophisticated, saturated-unsaturated time-dependent problems.

The most important input parameter for both of these methods is the equivalent permeability of the rock mass, as determined through borehole packer tests.

#### 8.3.2.2 Heuer Semi-Empirical Method

Analytical methods relating to the estimation of inflow (Heuer 1995, 2005) rely on a number of simplifying assumptions, the most pertinent which are summarized below:

- Rock mass is homogenous and has isotropic permeability;
- Steady state flow conditions are in effect;
- Tunnel boundary is modelled as a free flow boundary;
- Based on recorded case histories of tunnels up to 10m span.

Due to these assumptions, it must be noted that the predicted inflow quantities will be an approximation at best, and will be underestimated for higher flow zones associated with shears and faults. Estimating inflow from singular, rarely occurring features (i.e. faults) is generally not amendable to calculation. These features are often not detected by exploratory borings and will only be encountered through probe hole drilling ahead

of the face. The best estimates of inflow from singular features should be made based on local experience in similar geological conditions.

For the Heuer analysis, the tunnel alignment was divided up into six different zones based on available packer test data and rock mass characteristics. The tests carried out within each zone where tabulated into various permeability ranges to give a detailed distribution of the values. An example is shown in Figure 8.8 below.

**Figure 8.8 Distribution of Permeability for Zone 2 (comprising of packer test data from boreholes A007a and D440).**

| Zone 2 | Lugeon | k [cm/s] | Length [m] | For Plot | | |
|---|---|---|---|---|---|---|
| | 0.04 | 5.20E-07 | 5 | Bin | | |
| A007a | 0.005 | 6.50E-08 | 5 | 1E-7≤k | 2 | 20 |
| | 0.01 | 1.30E-07 | 5 | 1E-7<k≤5E-7 | 3 | 30 |
| | 0.03 | 3.90E-07 | 5 | 5E-7<k≤1E-6 | 0 | 0 |
| | 0.01 | 1.30E-07 | 5 | 1E-6<k≤5E-6 | 5 | 50 |
| | 0.15 | 1.95E-06 | 5 | 5E-6<k≤1E-5 | 0 | 0 |
| D440 | 0.1 | 1.30E-06 | 5 | 1E-5<k≤5E-5 | 0 | 0 |
| | 0.09 | 1.17E-06 | 5 | 5E-5<k≤1E-4 | 0 | 0 |
| | 0.16 | 2.08E-06 | 5 | 1E-4<k≤5E-4 | 0 | 0 |
| | 0.14 | 1.82E-06 | 5 | 5E-4<k≤1E-3 | 0 | 0 |
| | | | | | 10 | 100 |

The percentages for each range of permeability (shown in the far right column of Figure 8.8) are then input into the Heuer spreadsheet along with the length of the zone. The zone length is used analagous to the distribution of permeabilities. For example, if the zone length is 100 meters long, from Figure 8.8 the length of tunnel in the lowest permeability range (1x10$^{-7}$ cm/s) would be assumed to be 20m. This logic is then used to compute the inflow for each range, which is then summed up to give a total expected inflow for the overall zone length. An example of the Heuer spreadsheet is given in Figure 8.9.

**Figure 8.9 Steady State Inflow Calculation Based on Heuer Method**

A. Steady State Inflow - 1995 Method

Zone 1 — 745 ft

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. | $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | |
| b. | $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| c. | Percent in interval | 0.0% | 0.0% | 9.0% | 0.0% | 31.0% | 41.0% | 0.0% | 19.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| d. | Tunnel Length, m | 0.0 | 0.0 | 20.4 | 0.0 | 70.4 | 93.1 | 0.0 | 43.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| e. | $q_s/H$, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 |
| f. | $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 2.4 | 7.6 | 24.4 | 76.2 | 243.8 | 762.0 |
| g. | $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.2 | 0.0 | 5.4 | 22.7 | 0.0 | 105.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| h. | $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 10 | 20 | 0 | 110 | 0 | 0 | 0 | 0 | 0 |
| | $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 5.3 | 0.0 | 29.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

100.0%
745.0
133
Total Qs = 140 L/min
= 37 gpm

Assumptions:
* Groundwater Elevation at +220m and average cavern invert at -21m.
Head (ft): 100

The accuracy of the Heuer Method is based on how well the packer tests statistically represent the equivalent permeability of the rock mass. Therefore, with more tests that are carried out, a higher degree of confidence will be obtained in the results.

The results of the assessment are summarized in Table 8.3. Details of the calculations are enclosed in Appendix E. Note that the approach does not consider the effects of two tunnels adjacent to each other.

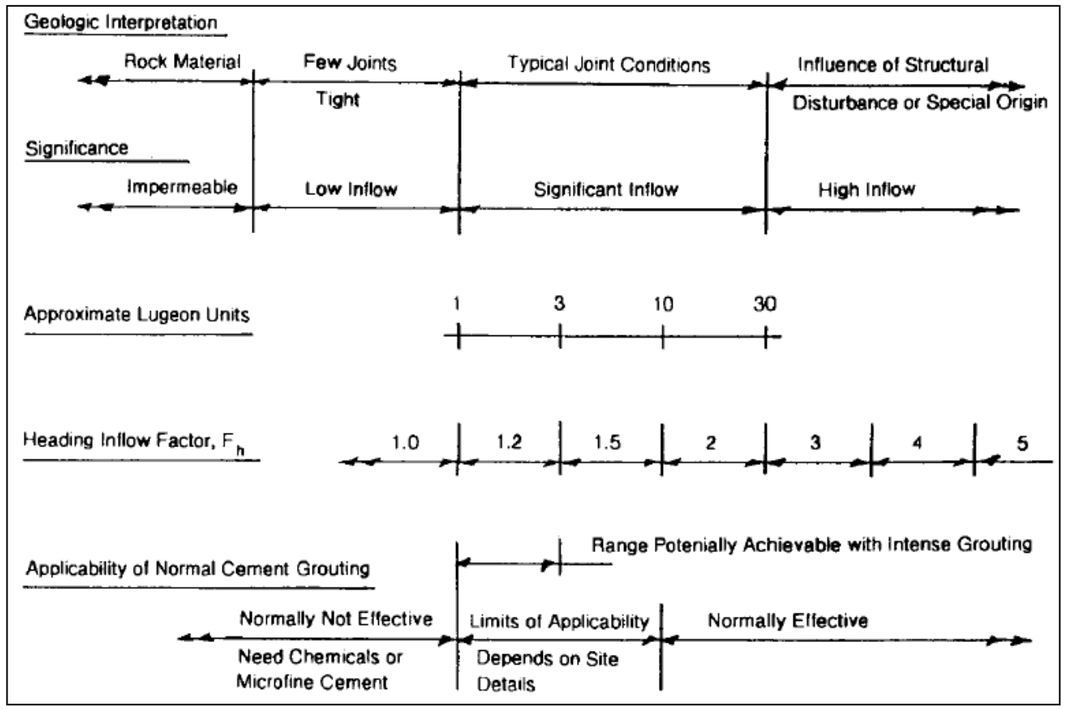
**Table 8.3 Summary of Semi-Empirical Inflow Analyses (After Heuer 1995,2005)**

| Geologic Zones (Identified by Chainage) | Linear Meter of Tunnel | Average Tunnel Steady State Inflow (L/min/m) |
|---|---|---|
| 1.SB CH 119+890(±) to SB CH 120+140(±) | 250 | 6.0 |
| 2.SB CH 120+140(±) to SB CH 121+450(±) | 1310 | 0.1 |
| 3.SB CH 121+450(±) to SB CH 121+550(±) | 100 | 6.0 |
| 4.SB CH 121+550(±) to SB CH 121+800(±) | 250 | 1.0 |
| 5.SB CH 121+800(±) to SB CH 122+260(±) | 460 | 5.0 |
| 6.SB CH 122+260(±) to SB CH 122+475(±) | 227 | 1.0 |

Based on the project specific borehole data and the *average* inflow calculated along each zone, approximately half of the rock mass along the Works Contract 824 alignment is estimated to have a tunnel inflow rate of 0.1 l/min/m based on the Heuer analysis.

Heuer also ties together expected inflow magnitudes with rock mass characteristics and grouting potential through the following figure:

**Figure 8.10 Characterization of Rock Mass Permeability (After Heuer, 1995)**




It can be seen from Figure 8.10 that for lugeon values less than approximately 1.0 (1.3x10$^{-7}$ m/s), inflow will be negligible and ground treatment not required. From Figure 8.7, roughly half of the targeted transmissive features in the poor ground type associated with the slope flanks were less permeable than this value and would not require treatment. This conclusion, along with the results given in Table 8.3, suggest that between 25-50% of the tunnel length may require grouting (as an initial estimate). This range will be further refined through subsequent analyses.

#### 8.3.2.3 IMS Semi-Empirical Method

The IMS Method for tunnel inflow prediction is based off of Hong Kong tunnelling experience in granitic rocks close to water sources. Therefore, allowance is made for the location of the tunnels to large bodies of water such as reservoirs or the sea. The method also defines IMS rock mass classes (based on joint spacing and weathering condition) which have been loosely correlated to Barton's Q system as follows:

**Table 8.4 Correlation of IMS Rock Classes to Barton's Q System**

| IMS Class | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| *Q*-value | ≥ 50 | ≈ 10 | ≈ 1 | ≈ 0.1 | ≤ 0.01 |

The basis behind the inflow calculation is the Darcy equation, which is subsequently factored to account for nearby water sources, static water head, and rock mass class. As shown in Table 8.3, the same six geological zones where used in the IMS analysis for comparison against the Heuer Method. The results are presented in Table 8.5. Full details of the analysis can be found in McFeat-Smith et al., 1998.

**Table 8.5 Summary of Semi-Empirical Inflow Analyses (After McFeat-Smith et al 1985)**

| Geologic Zones (Identified by Chainage) | IMS Class | Average Tunnel Steady State Inflow (L/min/m) |
|---|---|---|
| 1.SB CH 119+890(±) to SB CH 120+140(±) | 3 | 3 |
| 2.SB CH 120+140(±) to SB CH 121+450(±) | 2 | 0.1 |
| 3.SB CH 121+450(±) to SB CH 121+550(±) | 4 | 3 |
| 4.SB CH 121+550(±) to SB CH 121+800(±) | 2 | 0.2 |
| 5.SB CH 121+800(±) to SB CH 122+260(±) | 3 | 2.5 |
| 6.SB CH 122+260(±) to SB CH 122+475(±) | 4 | 2.5 |

The results tend to show less inflow (roughly 50%) compared against the Heuer Method, likely indicating greater dependence on empirical data rather than correlating actual packer test data. As noted in Section 8.3.2.1, several simplifying assumptions are made in the Heuer calculation which generally lead to overestimation of inflow. Therefore for a conservative estimate, greater dependence shall be placed on the Heuer values going forward.

#### 8.3.2.4 Numerical Modelling

A numerical inflow simulation was carried out for the typical tunnel section characteristic of the fair to good rock mass conditions encountered under Kai Keung Leng (Zone 2) using the SAFE software package. In this case, a simple steady-state model was constructed as groundwater flows into the excavation will have stabilized following construction activities.

The model accounts for the presence of both running tunnels as well as an initial static water head of 22 bar at tunnel level. An equivalent design rock mass permeability of 5 x $10^{-9}$ m/s (typical background permeability as shown on Table 8.2) has been assumed. The rock level is taken at the top of the model. Model assumptions include:

- No grouting around the running tunnels;
- Rock mass properties (permeability) is homogeneous and isotropic;
- Permeability of the drainage layer is ignored;
- Recharge from infiltration is ignored;
- No pressure at tunnel slab level resulting in higher inflow;
- The pressure head around the tunnel boundaries has been set to atmospheric pressure in order to simulate fully drained conditions.

A difficulty with developing a functional model with this particular geometry is the rugged topography which influences the groundwater levels and recharge. Recharge is less certain and can be influenced by the steepness of the terrain and three dimensional effects of water being lost to other catchments. Also, the physical reality of fracture fluid flow is dependent on the interconnectivity of the joint system as well as the aperture and nature of infilling, if any. All these factors are lumped into the equivalent permeability factor derived from the packer test data which is applied for the entire model. Therefore, the program is not modelling the physical mechanism of inflow, but aims to model an average equivalent flow condition which will yield an inflow value representative of the actual condition. The results of the numerical analysis are given in Table 8.6.

**Table 8.6 Summary of Numerical Inflow Analyses (Using SAFE)**

| Type | Average Tunnel Steady State Inflow (L/min/m) |
|---|---|
| Typical (background) | 0.13 |

The resulting inflow into the tunnels is calculated as 0.13 l/min/m of tunnel by assuming a typical background permeability for the overall rock mass. The value is similar compared with the semi-empirical Heuer and IMS methods. Slightly higher inflow would be expected as the SAFE program accounts for both tunnels.

### 8.3.3 Summary of Inflow Estimate

Different analysis methods have been considered for the determination of steady state inflow into the XRL running tunnels. If a typical running tunnel perimeter of 20m is considered, the values quoted in Tables 8.3, 8.5 and 8.6 can be converted to l/min/$m^2$. A comparison of the expected background inflow value between the three methods is made in the following table:

**Table 8.7 Comparison of Steady State Inflow Values Per Unit Area of Tunnel**

| Analysis Type | Grouting Condition | Average Tunnel Steady State Inflow (L/min/$m^2$) |
|---|---|---|
| Past Precedent (Tai Lam Tunnel) | Post-grouted | 0.017 |
| Semi-Empirical Methods | Pre-grouted; assuming permeability based on packer test and Q value | 0.1 l/min/m ÷ 20m (approx.) = 0.005 |
| SAFE Numerical Method | Pre-grouted; assuming typical background permeability of 5 x $10^{-9}$ m/s | 0.13 l/min/m ÷ 20m (approx.) = 0.007 |

The average tunnel inflow from the SAFE modelling is similar to that obtained from the semi-empirical methods. The observed inflow rate of the Tai Lam Tunnel, which is situated close to and in a similar geological environment as the XRL tunnels, is 2 to 3 times greater than the calculated values. This is not surprising given the variability in prediction methods and reliance on simplifying assumptions. It is not unusual for prediction methods to be an order of magnitude off of the observed inflow rates.

### 8.3.4 Design Inflow for Tunnel Sumps

Based on the above discussion, a value of 0.015 L/min/$m^2$ is selected as the design inflow rate to be accommodated by the tunnel drainage and sump system. This value is considered to be safely conservative with respect to the variability of prediction methods. Also, estimation of the inflow rate based on past precedent is deemed reasonable as it can account for all the intrinsic factors that govern joint water flow as mentioned in Section 8.3.2.3.

If a typical running tunnel perimeter of 20m is considered, the inflow rate per meter of tunnel is calculated to be:

$$0.015 \text{ L/min/m}^2 \times 20\text{m} = 0.3 \text{ L/min/m}$$

Due to uncertainty associated with inflow calculations, a factor of safety equal to 2 is adopted for the design of the sump pit size. The design inflow to the sumps is therefore:

Design Inflow = 0.3 l/min/m x FOS = 2 = 0.6 l/min/m

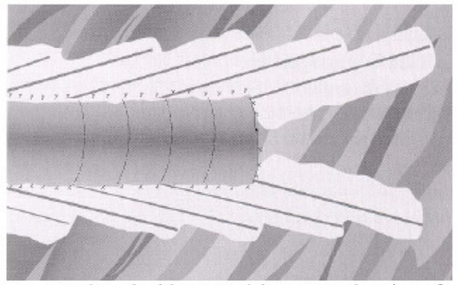
For comparison, a typical post grouted inflow criterion for subsea road tunnels in Norway (with infinite water recharge) is 30 l/min/100m of tunnel (Grov, 2002) consistent with what has been adopted above. Therefore, inflow rates which exceed this design value will need to be controlled through pre-excavation grouting ahead of the tunnel face. Where additional cutoff measures are required behind the active face (from grout washout or shrinkage cracking of pre-excavation grout) post-excavation grouting will be carried out until the design inflow criterion is met.

## 8.4 Inflow Control Methodology

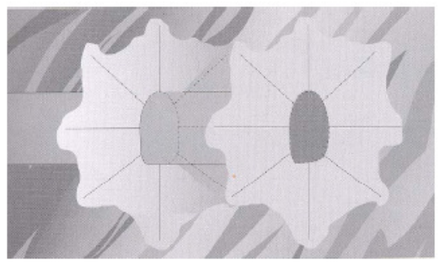
### 8.4.1 Pre-Excavation Grouting

The advantages of successful pre-grouting works are well demonstrated by the extensive experience of drill and blast tunnelling in Hong Kong, and on MTR projects in particular. Several recent cases where high post excavation inflows have been encountered have proven extremely difficult to resolve via post excavation grouting, and solutions become even more complex once the final lining has been installed. Pre-excavation grouting is generally preferred to post-excavation grouting as it can be carried out ahead of the face in a truncated cone shape, enabling an umbrella to be formed above the tunnel. In post-excavation grouting, a radial fan pattern is drilled perpendicular to the tunnel profile which makes crossing water bearing features more difficult.

**Figure 8.11 Schematic of Pre-Excavation and Post-Excavation Grouting Methods**



Pre-grouting, double cover (always overlapping of 1-1.5 * blasting round)



Post grouting, curtain grouting at the dripping places.

Specification of a relatively tight criterion in terms of inflow from probe holes is therefore beneficial to ensure the inflow criterion for the final excavated tunnel is achieved.

The general approach will be as follows:

- Investigation – probing;
- Treatment of transmissive flowing features identified by probing observations;
- Systematic grouting in areas of enhanced permeability (expected fault zones and near foothills).

Heuer (1995) states that theory and experience suggest the tunnel will commonly encounter in the range of 2 to 5 times the flow from a probe hole, owing to the increase of surface area compared to that of the probe. For purposes of this evaluation, a typical value of 3 has been adopted. However, it should be noted that if multiple probe holes are drilled in the face, the correlation will be reduced to 1-2 on average.

If the groundwater inflow into the tunnel must be limited to 0.3 l/min/m, the theoretical limit on inflow into a probe hole is 0.3 l/min/m / 3 = 0.1. For a 20m long probe hole, this equates to 0.1 l/min/m x 20m = 2 l/min.

The number of probe holes will vary according to the particular risks associated with an alignment interval, but will comprise a minimum of a single probe hole with minimum 5m overlap. If the inflow criterion from the probehole(s) is exceeded, the probehole(s) will be pressure grouted according to the specification. A minimum array of primary grout holes will be drilled around the circumference of the tunnel and grouted to the contractor's proposed methods and in accordance with the specification. An array of primary check holes will be subsequently drilled and water outflows checked against the probe hole criterion. If any of the check hole flows exceed the criterion, a secondary array of grout holes would be drilled and the procedure repeated.

Details of the grouting sequence and design will vary according to the ground conditions encountered. A number of designs shall be developed by the Contractor with a fully prepared methodology for each including specification of the following:

- Inclination and length of the grout holes from the tunnel axis
- Number and layout of grout holes
- Grout mix design including specification of additives and setting times
- Grout Pressures
- 'Stop Grout' Criteria (typically to refusal at certain pressure, held for several minutes)

Based on this assessment, the following three probe hole inflow categories have been defined for purposes of estimating the percentage of tunnel length that will require pre-excavation grouting.

- Probehole flow Type A: $Q_p \leq 2$ l/min (no grouting required)
- Probehole flow Type B: 2 l/min < $Q_p \leq 30$ l/min (moderate fracture grouting)
- Probehole flow Type C: $Q_p > 30$ l/min (significant grouting required)

Table 8.3 is reproduced below with the anticipated percentage of probe hole inflow types for each of the geological regions.

**Table 8.8 Estimates of Groundwater Inflow Rates from Probe Hole Inflows**

| Geological Zones (Identified by SB Chainage) | Linear Meter of Tunnel | Expected Maximum Sustained Inflow [l/min/m] | Expected Probehole Inflow Type [%] |
|---|---|---|---|
| CH 119+900(±) to CH 120+140(±) | 240 | 6 | Type A: 30% |
| | | | Type B: 25% |
| | | | Type C: 45% |
| CH 120+140(±) to CH 121+450(±) | 1310 | 0.1 | Type A: 90% |
| | | | Type B: 5% |
| | | | Type C: 5% |
| CH 121+450(±) to CH 121+550(±) | 100 | 6 | Type A: 30% |
| | | | Type B: 40% |
| | | | Type C: 30% |
| CH 121+550(±) to CH 121+800(±) | 250 | 1 | Type A: 75% |
| | | | Type B: 20% |
| | | | Type C: 5% |
| CH 121+800(±) to CH 122+260(±) | 460 | 5 | Type A: 50% |
| | | | Type B: 40% |
| | | | Type C: 10% |
| CH 122+260(±) to CH 122+487(±) | 227 | 1 | Type A: 60% |
| | | | Type B: 15% |
| | | | Type C: 25% |

The type of probe hole flow within each zone can be assessed by returning to the Heuer Method and considering the distribution of permeability (see Row C in Figure 8.9). Used in conjunction with Figure 8.10, relative percentages of each type of probe hole flow can be estimated for purposes of cost estimation and the Geotechnical Baseline Report.

### 8.4.2 Summary of Inflow Control Criteria

The following criteria are proposed for the full length of the Works Contract 824 drill and blast tunnels:

- Pre-excavation grouting shall be carried out ahead of the excavation according to the following criteria :

  *Water flowing from a 20m long probe hole drilled ahead of the face exceeds 5 l/min (for a single probe hole) or a total of 10 l/min (for more than one probe hole), measured a minimum of 1 hour after termination of drilling.*

- After excavation and prior to construction of the final lining the following criteria shall apply :

  *Cumulative water inflows averaging 0.015 l/min/m$^2$ over any 25m length of tunnel as measured by weir device. Post excavation grouting will be carried out and the final lining not constructed until the criterion has been met.*

## 8.5 Groundwater Drawdown Estimate at Tai Kong Po Shaft

The rock cover above the tunnels at the southern end of the alignment near the Tai Kong Po shaft is expected to be only 8-10m. In light of the shallow rock cover, a seepage model was carried out in SAFE to assess the potential drawdown impact on the water table due to the tunnelling works.

Figure 8.12 shows the setup and inputs for the seepage model. The model was considered to be on the conservative side as natural recharge was assumed to be available only at the two sides (east-west direction) of the tunnels. In reality, natural recharge would also be available from the uphill side. The actual drawdown of groundwater and reduction of pore water pressure in soil would be less than those estimated in the SAFE model.

Figures 8.13 and 8.14 show the results of the SAFE analysis. It can be seen that as Grade III/IV Tuff (M/HDT) is slightly more permeability to the completely decomposed Tuff (CDT) that lies above, most of the groundwater flow comes from the M/HDT layer. The water table is slightly drawn down with a maximum magnitude of 2.4m. The groundwater pressure is reduced by not more than 25 kPa within the CDT layer (Figure 8.14). Further details of the analysis can be found in Appendix E.

The predicted ground settlement due to groundwater drawdown is expected to be a maximum of 4mm (refer to Appendix E for the settlement prediction calculation). Given the conservatism built in the calculation, it can be concluded that the settlement due to groundwater drawdown is negligible. In addition, the existing structures nearby the site are mainly pig sty and small village houses. The anticipated small ground movement will not cause any adverse impacts to these structures.

**Figure 8.12 Seepage Model for 824 Rock Tunnel near Tai Kong Po Shaft**

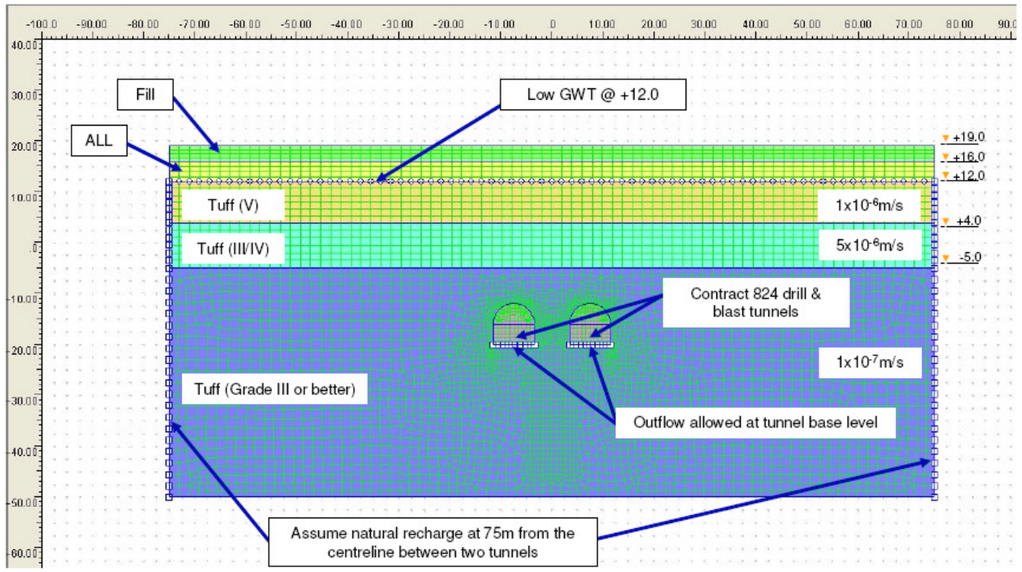



**Figure 8.13 Calculated Pore Water Pressure Due to the Presence of 824 Rock Tunnels Near Tai Kong Po Shaft**

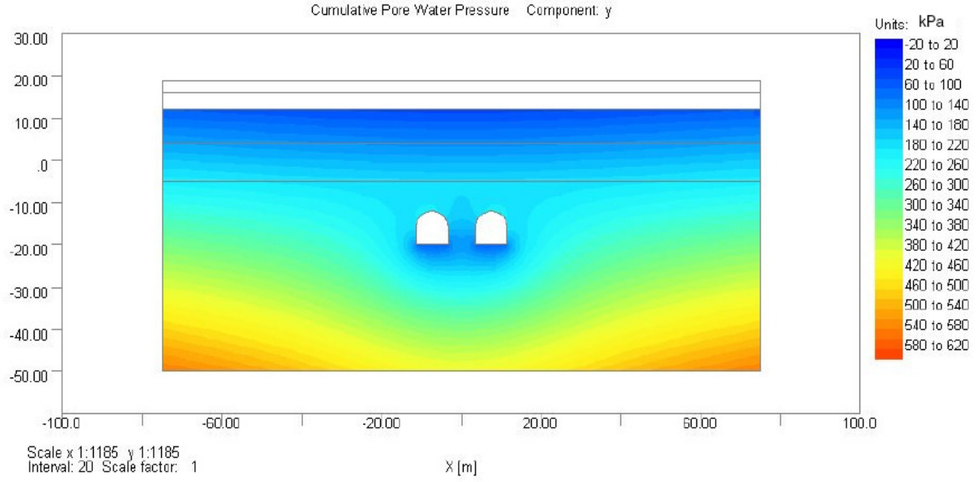
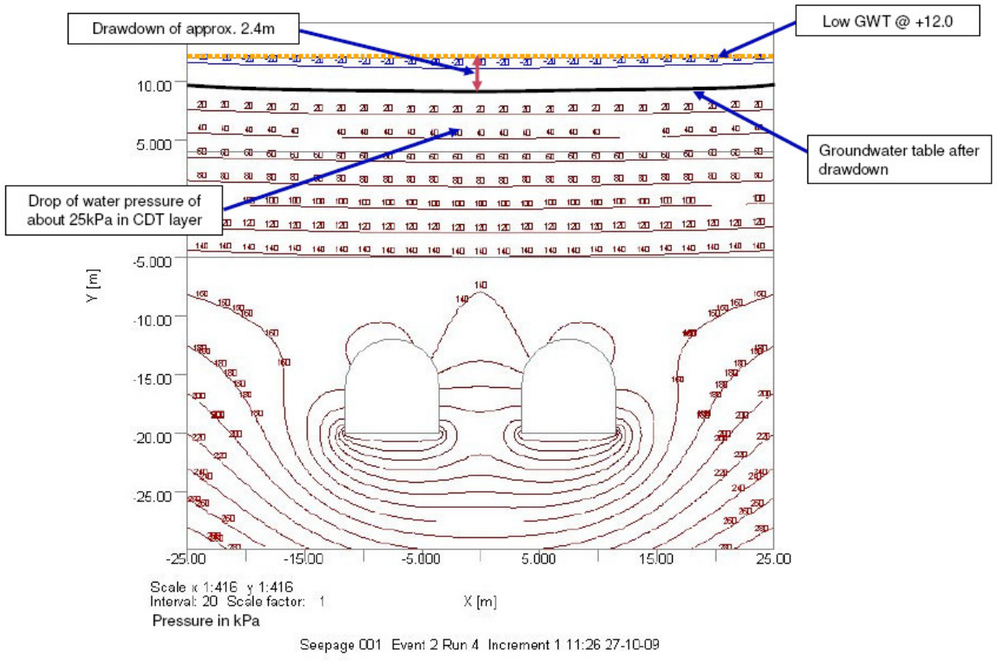


**Figure 8.14 Water Pressure Contours for 824 Rock Tunnels Near Tai Kong Po Shaft**




## 8.6 Long Term Inflow Monitoring & Contingency Proposal

Based on the design inflow rate of 0.6 l/min/m of tunnel (with FOS=2), two sump pits have been sized with volumes equal to 309$m^3$ and 427$m^3$ located at the NTV shaft and Tai Kong Po shaft, respectively.

Locations of the sump pits are shown on the schematic tunnel drainage drawing in Appendix E.

In each sump pit, three sump pumps (two on duty and one standby) are provided to discharge the groundwater to the public storm water system in the nearby ventilation building / plant building. Moreover, an overflow pipe will be provided to connect each sump pit to the nearby tunnel foul water system or building waste water system such that in the event of failure of more than one sump pump, the excess groundwater will be discharged to the foul sewerage system. In case of malfunctioning of the whole pumping system, the volume of the two sump pits was designed to be capable of holding the groundwater inflow for at least 4 hours.

Long term monitoring comprising regular measurement of inflow to all sump pits will be undertaken by MTR. The total volume of inflow can be estimated by multiplying the flow rate of the pumps and the total running time of all the pumps. The average inflow rate can be estimated by dividing the total volume of groundwater discharged to the time elapsed and comparing it to the design inflow number.

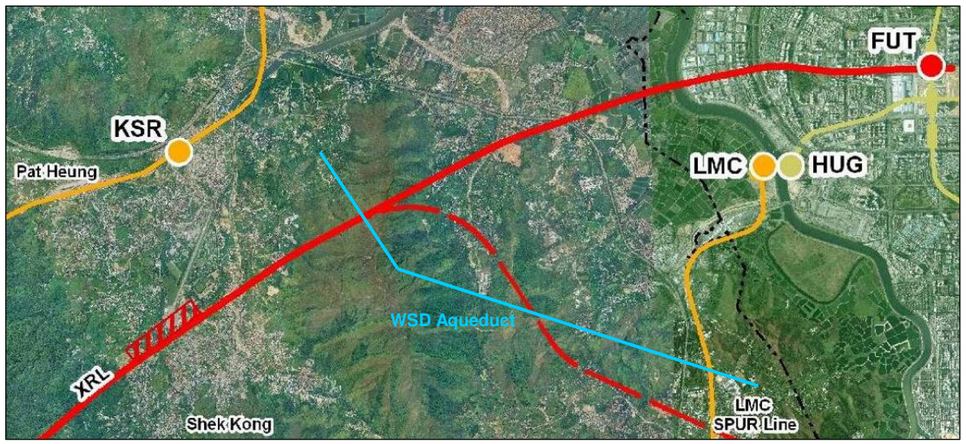
# 9 Evaluation of Impact on WSD Aqueduct (Works Contract 824)

## 9.1 Details of the WSD Aqueduct

### 9.1.1 General

The Western Aqueduct crosses the XRL alignment roughly perpendicular at approximate CH 120+500. This tunnel is 3.4m in diameter with a curved horseshoe shape formed using the drill and blast excavation technique. It was constructed in 1981 to supply water from Dong Jiang to both Au Tau water treatment works and the Tai Lam Chung Reservoir. It is a critical facility for which disruption of the flow of water through this tunnel is unacceptable. It is understood that if this tunnel were damaged during construction of the XRL tunnels, raw water stored in Tai Lam Chung Reservoir will only be able to provide a reserve supply for up to 25 days. This will have a severe impact on the raw water supply to the water treatment plant and have serious implications to keeping up with fresh water demand to Tuen Mun, Yuen Long, Tsuen Wan, Kwai Chung, and Lantau. The approximate location of this aqueduct in relation to the XRL alignment is shown on the figure below and more detail in the drawings enclosed in Appendix F.

**Figure 9.1 Location of the WSD Aqueduct**




### 9.1.2 As-Built Drawings

The as-built construction drawings of the aqueduct also give a clue as to the rock mass quality depending on what lining types were installed at the intersection location. Generally, unlined or light support (thin shotcrete 50-75mm) is indicated at the XRL intersection chainage, verifying the assumption of a good quality rockmass with minimal jointing.

The clearance between the crown level of the XRL tunnels and the invert of the existing aqueduct is approximately 22m. It should be noted that the existing ground cover above the aqueduct is approximately 230m. As-built construction drawings have been provided by WSD which show the installed tunnel support along the alignment as well as typical cross sections. The cross sections and installed support details for 100m either side of the XRL tunnels are given in Appendix F. In general, three support types have been used within the zone of influence of the XRL tunnels:

- Unlined, with occasional spot or pattern bolting;
- Pattern bolts with 50mm of mesh reinforced shotcrete;
- Pattern bolts with 75mm of mesh reinforced shotcrete.

## 9.2 Hydrogeological Assessment

### 9.2.1 General

A hydrogeological assessment has been carried out to evaluate the impact of the XRL running tunnel construction on the WSD aqueduct. It is understood that the aqueduct currently conveys water at an internal pressure of 4.5 bar. Measurements of water levels in boreholes have been used to determine that the current external hydrostatic water pressure around the aqueduct is 20-22 bar, depending on seasonal fluctuations. Therefore, a net external water pressure of 17.5-15.5 bar currently acts on the aqueduct. It is required to demonstrate that construction of the drained running tunnels will not reduce this external net pressure to a value where seepage out of the aqueduct could occur through existing fractures. Two methods have been used to assess the degree of drawdown caused by the XRL drained tunnels; namely a semi-empirical method, which is then verified through numerical modelling.

### 9.2.2 Semi-Empirical Inflow Calculation

As discussed in Section 8, the Heuer Method was used to predict tunnel inflow in the vicinity of the WSD aqueduct. The aqueduct falls within Geological Zone 2 where the expected inflow is only 0.1 l/min/m of tunnel. A quick literature search on allowable inflow rates for tunnels in urban areas where settlement due to groundwater drawdown was forbidden revealed a range of values between 0.02-0.1 l/min/m (Grov, Heuer). Therefore, pre-excavation inflow values within the influence zone of the aqueduct should be low enough so as to not adversely impact the water table. However, as this is at the upper limit of past precedence, it will be required of the Contractor to limit inflow to 0.07 l/min/m (probe hole flow of 0.5 l/min) within 60m either side of the point of intersection.

### 9.2.3 Numerical Modelling

In order to find the decrease in head at the aqueduct level, a finite element model has been created using the program Oasys SAFE. The model accounts for the presence of both running tunnels as well as an initial static water head of 20 bar at the level of the aqueduct. An equivalent rock mass permeability of 5 x $10^{-7}$ m/s has been assumed based on Table 8.2. This permeability is consistent with that which would be obtained through grouting, if necessary. The rock level is taken at the top of the model.

Figure 9.2 shows the pre-construction water pressure distribution that currently exists around the aqueduct. The external head is considerably higher than the maximum internal pressure, so it would be expected that no leakage is taking place out of the aqueduct. The purpose of this model is to confirm that the same condition exists following construction of the XRL tunnels.

The post-construction water pressure distribution is shown in Figure 9.3. As expected, a decrease in pressure head occurs as a result of the tunnel excavation. The steady state pressure head at aqueduct level is approximately 11 bar following excavation of the XRL tunnels. This value is compared to the internal water pressure of 4.5 bar which results in a net external water pressure of 6.5 bar around the aqueduct tunnel. Therefore, it can be concluded that no outward seepage of water will occur in the post-construction water pressure state.

**Figure 9.2 Finite Element Model of Pre-Construction Pressure Head at Western Aqueduct [in bar]**

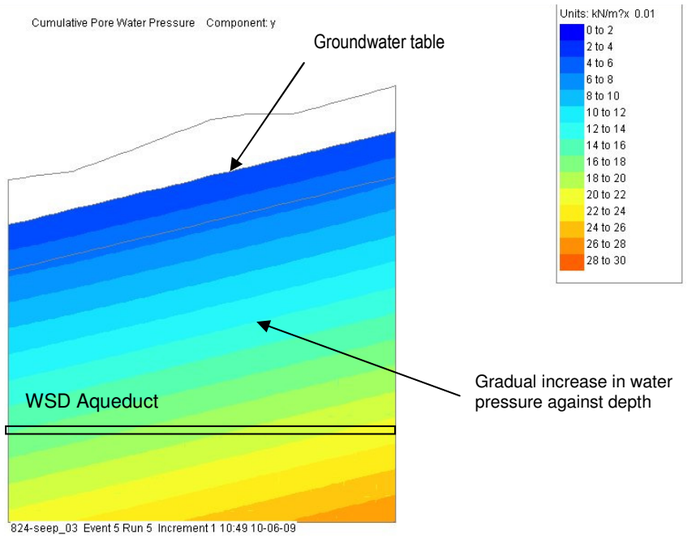
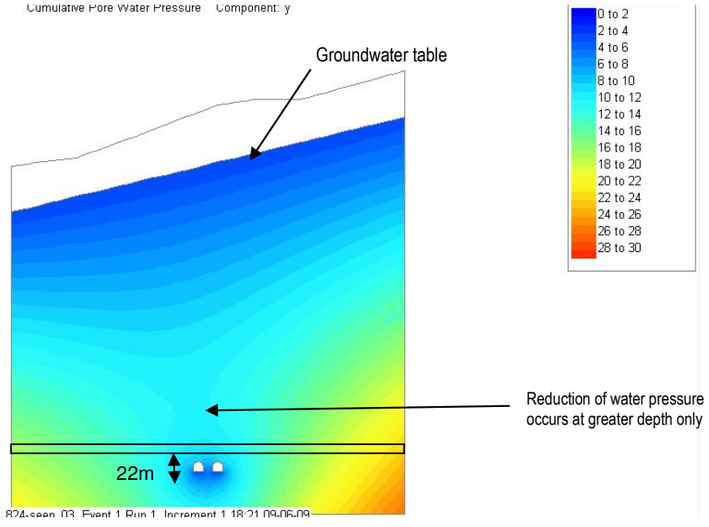



**Figure 9.3: Finite Element Model of Post-Construction Pressure Head at Western Aqueduct [in bar]**



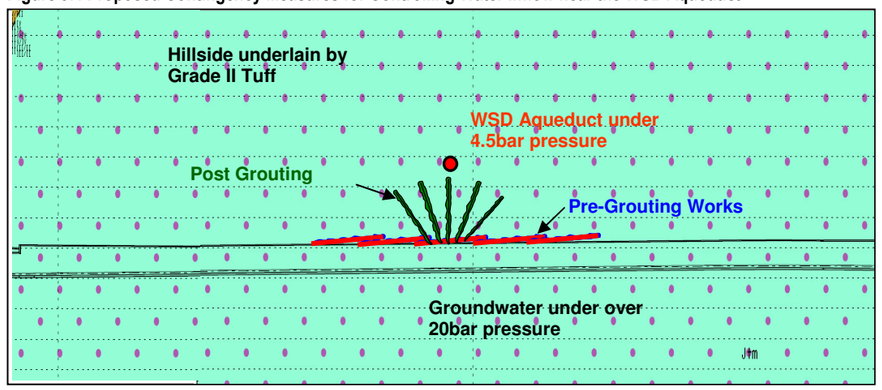

Several sensitivity runs were conducted using higher permeability, up to $1x10^{-3}$ m/s in the extreme case. It was found that the water pressure around the aqueduct will only decrease to a certain value, thereafter remaining unchanged with further increase in permeability. This demonstrates that the cone of depression widens outward with increasing permeability, rather than further reducing the head directly above the tunnels. Further reductions in permeability would result in the tunnels being inundated with water and are not realistic since grouting of transmissive features would be triggered before this point.

### 9.2.4 Summary of the Results

In conclusion, the models show that tunnel excavation will have an effect on the water pressure around the aqueduct, but the overall net pressure will remain externally positive, thereby preventing any loss of water from within the aqueduct. Higher inflows do not produce a further decrease in head around the aqueduct, but rather widen the cone of depression around the sink (XRL tunnels).

The inflow criterion of the XRL tunnels within 60m of the WSD aqueduct will tightened to 0.07 l/min/m in order to account for any unknowns and increase the degree of safety around this critical water delivery structure. Figure 9.4 illustrates a possible arrangement for grouting from the XRL tunnel near the WSD aqueduct if pre-excavation grouting is found to be insufficient in controlling water inflow.

**Figure 9.4 Proposed Contingency Measures for Controlling Water Inflow near the WSD Aqueduct**




For full details on the effect of the WSD aqueduct due to the XRL tunnel construction, reference can be made to Deliverable No. “D2.10G - WSD Impact Assessment Supplementary Report”.

# 10 Proposed Instrumentation and Monitoring for Groundwater

## 10.1 Proposed Instrumentation

Groundwater monitoring instrumentation will basically include:

(i) Groundwater monitoring equipped with piezometers and standpipes in the XRL project specific drillholes shall be continued – to provide continuous groundwater level information in the coming wet and dry seasons around the excavation.

(ii) Groundwater monitoring point including proposed piezometers and standpipes – to monitoring the groundwater level and piezometric head for sensitive area where groundwater monitoring device has not yet been provided in the site investigation stage.

(iii) Inflow monitoring pits (sump pits) for drained tunnel.

The recommended monitoring and instrumentation plans outside the excavation are presented in the drawings enclosed in Appendix G.

## 10.2 Baseline Instrumentation

The following baseline instrumentation and monitoring is recommended:

(i) Installation of the proposed piezometer / standpipes prior to commencement of works at a monthly basis to ascertain the groundwater regime assumptions adopted in the design.

(ii) All the recommended instruments are to be installed at least one month prior to the commencement of construction works, and monitored at weekly intervals to establish a set of baseline readings.

## 10.3 AAA Response Values

According to the MTRCL Design Standard Manual (Section 4: Civil engineering, 4.04 General Design Criteria, Clause 4.2.6), the movement control levels for monitored elements shall be defined in accordance with the following criteria:

| | |
|---|---|
| Alert Value | Remedial measures agreed, set at 0.5 times of serviceability limit |
| Action Value | Remedial measures instituted and revised Alert and Action levels set, set at 0.8 times of serviceability limit |
| Alarm Value | Serviceability limit, stop work, set at the serviceability limit. |

The general requirements for instrumentation works are specified on the drawings. AAA response values for the groundwater level and piezometric head shall be adopted to ensure the variation of the groundwater levels are within the acceptable limits and thus the adjacent structures would not subject to any adverse impact.

It is envisaged that the Contractor shall implement the following in the event of excessive groundwater drawdown:

(i) Pre-installed recharge wells should be activated immediately in order to resume all the groundwater table to it's initial condition.

(ii) A critical review on the cause of excessive drawdown should be carried out and necessary mitigation works (e.g. grouting, modification of construction sequence and methods, etc.) be proposed to the Engineer for approval within two days of the event.

(iii) Mitigation measures, once approved, should be implemented immediately.

(iv) The Contractor should not proceed with the works further unless they are able to demonstrate to the satisfaction of the Engineer that it is safe to do so.

(v) Monitoring frequency should be increased to the satisfaction of the Engineer.

# 11 Conclusion & Recommendations

A hydrogeological impact assessment due to the tunnel construction works for the XRL northern Hong Kong Section has been carried out. The conclusions and recommendations are given as follows:

TBM Bored Tunnel (Undrained)

- Groundwater drawdown is effectively precluded through the use of closed face TBM machine. The hydrostatic head can be effectively supported by the pressure maintained in the front of TBM head which reduces groundwater losses at the TBM face.
- As the TBM bored tunnel lining will be designed as undrained, groundwater drawdown after installation of permanent lining should not arise.

Soft Ground Mined Tunnel for Cross Passages (Undrained)

- Water inflow could be effectively reduced through ground treatment prior to the excavation. The permanent cast-in-situ lining would be designed and constructed as undrained, therefore long term groundwater drawdown is not anticipated.

Cut & Cover Tunnel in Shek Kong (Temporary Drained, Permanent Undrained)

- Regarding temporary groundwater drawdown effect due to excavation, the drawdown immediately besides the Dwall during construction is limited to within 2m below ground level, achieved by a combination of toe grouting and provision of recharging well.
- Regarding the possible long term damming effect due to the construction of the impermeable cut & cover box, a 3D MODFLOW groundwater model has been developed to assess the impact of groundwater regime in the Shek Kong area.
- With the Dwall in placed and ground level of the SSS adjusted to it's final formation level, groundwater levels are found to be not significantly impacted on the downstream side (groundwater drawdown <0.5m).
- The suspected damming effects on the up-gradient side of the cut & cover box was found to be successfully controlled by the subsoil drains along the proposed East Culvert.
- Also, the model shows that there will be minimal impact on stream flows.

Shafts (Temporary Drained, Permanent Undrained for Soil Portion & Drained for Rock Portion)

- During Excavation, temporary groundwater drawdown outside the site area would typically be limited to 2m in order to avoid adverse settlement impacts. Toe grouting will be applied beneath the toe level of the cofferdam walls as necessary to lengthen the effective flow path of groundwater.
- In the long term, the upper portion of the shaft situated in soil has been designed as "undrained". This effectively forms a cut-off at the soil-rock interface and prevents excessive drawdown of water levels within the overlying unconsolidated materials.
- Only the lower portion of the shaft founded in sound rock shall be "drained", with permeability controlled by the interconnectivity and aperture of rock joints. The Contractor will be required to control the groundwater inflow to an average of less than 0.3 l/min/m of the shaft prior to casting of the permanent lining, so it is not expected that fracture flow through the grouted rock mass will cause drawdown in the overlying sediments.

Drill &Blast Rock Tunnel in Kai Kung Leng (Drained)

- Inflow rate will be controlled to be within 0.3 l/min/m by grouting which was confirmed to be feasible by the precedent of tunnelling works in Hong Kong and the site specific groundwater inflow analyses. Specification of a relatively tight criterion in terms of inflow from probe holes is therefore beneficial to ensure inflow criteria for the final excavated tunnel are achieved and to avoid post-excavation grouting as much as possible.
- The number of probe holes will vary according to the particular risks associated with an alignment interval, but will comprise a minimum of a single probe hole drilled a minimum of 20m ahead of the face at any one time.
- Groundwater drawdown is found to be negligible with respect to settlement. Moreover, effect to the existing WSD aqueduct has been assessed and found to be acceptable.
- In the long term, groundwater inflows will be conveyed to groundwater line sumps for onward conveyance, via pressurised mains through the ventilation shafts to NTV and TKP for discharge into the surface water drainage system.
- In case of malfunctioning of the whole pumping system, the volume of the two sump pits was designed to be capable of holding the groundwater inflow for at least 4 hours.
- Long term monitoring comprising regular measurement of inflow to all sump pits will be undertaken by MTR. When excess groundwater inflow was recorded, post grouting will be undertaken at the location(s) where the inflow rate exceeds the criteria.

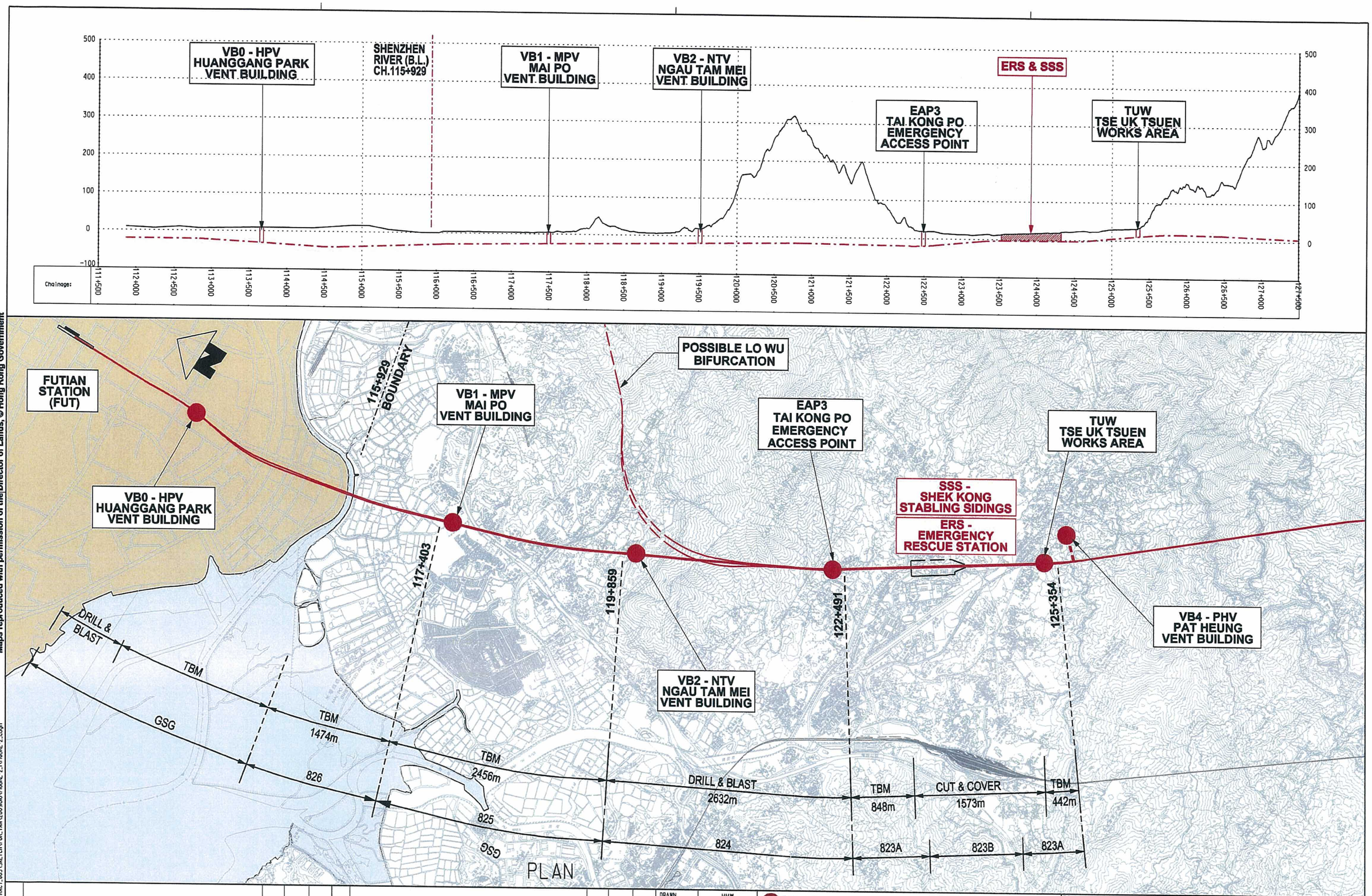
Comprehensive Monitoring Programme

- It is recommended that a comprehensive instrumentation and monitoring system be implemented to monitor the groundwater levels in the vicinity of the proposed XRL alignment during the course of the construction works.
- Groundwater monitoring instrumentation will basically include:
  - Groundwater monitoring equipped with piezometers and standpipes in the XRL project specific drillholes shall be continued – to provide continuous groundwater level information in the coming wet and dry seasons around the excavation.
  - Groundwater monitoring point including proposed piezometers and standpipes – to monitoring the groundwater level and piezometric head for sensitive area where groundwater monitoring device has not yet been provided in the site investigation stage.
  - Inflow monitoring pits (sump pits) for drained tunnel.
- An Alert-Action-Alarm monitoring system based on different levels of the site impact will be adopted.

# 12 References


- Burland,J.B., Standing,J.R., Jardine,F.M., editor (2001). Building response to tunnelling: case studies from the Jubilee Line Extension, London: volume 1: projects and methods, London, CIRIA and Thomas Telford.
- GEO (1992). GEOGUIDE 4 – Guide to Cavern Engineering, Civil Engineering Department, Hong Kong.
- GEO (2008). Catalogue of Hong Kong Tunnels.
- Goodman et al (1965). Groundwater Inflows during Tunnel Driving. Bulletin of Engineering Geology.
- Grov, E (2002). Water Control in Norwegian Tunnelling.
- Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G. (2000). MODFLOW-2000, the U.S. Geological Survey modular ground-water model - User guide to modularization concepts and the Ground-Water Flow Process. USGS Open-File Report 00-92.
- Heuer, R.E. (1995). Estimating Rock Tunnel Water Inflow. Proc. of 1995 Conference on Rock Excavation and Tunnelling (RETC).
- Heuer, R.E. (2005). Estimating Rock Tunnel Water Inflow – Part II. Proc. of 2005 Conference on Rock Excavation and Tunnelling (RETC).
- Hoek, E and Brown, E. (1980). Underground Excavations in Rock. Institute of Mining and Metallurgy.
- Lui J. Y. H. & Yau P. K. F. (1996) “The Performance of the Deep Basement for Dragon Centre” Proceeding of the Seminar on Instrumentation in Geotechnical Engineering.
- McDonald M.G. & Harbaugh A.W.(1988), MODFLOW, A modular three dimensional finite difference groundwater flow model: USGS Techniques of water resources investigations, Book 6, Chapter A1, 586pp.
- McDonald & Harbaugh A.W. (1996) Users Documentation MODFLOW-96, An update to the USGS modular three dimensional finite difference groundwater flow model, USGS Open-File Report 96-485.
- McFeat-Smith et al (1998). Water Inflows in Bored Tunnel Driven in Hong Kong: Prediction, Construction Issues and Control Measures. Proc. of Conference on Urban Ground Engineering, Hong Kong. Thomas Telford.
- McLearle, D., Foreman, W., Hansmire, W., Tong, E. (2001). Hong Kong Strategic Sewage Disposal Scheme Stage I Deep Tunnels, 2001 Proc. of 2001 Conference on Rock Excavation and Tunnelling (RETC).
- Morton K, Cater RW and Linney L (1980) “Observed Settlements of Buildings adjacent to Stations Constructed for Modified Initial System of the Mass Transit Railway, Hong Kong”. Proceedings of the 6th South East Asian Conference on Soil Engineering, Taipei.
- MTR Corporation (2008). Design Standards Manual Section 4 – Civil Engineering (Rev. A2)
- MTR Coporation (2009). Drainage Impact Assessment Report. XRL Consultancy Agreement No. C803.
- MTR Corporation (2009). Geotechnical Engineering Reports. XRL Consultancy Agreement No. C803.
- MTR Coporation (2009). Existing Building Impact Assessment Report. XRL Consultancy Agreement No. C803.
- MTR Coporation (2009). WSD Impact Assessment Supplementary Report – Assessment of Construction Impacts to Western Aqueduct and Associated Water Utilities. Contract 824: Ngau Tam Mei to Tai Kong Po. XRL Consultancy Agreement No. C803.
- Preene et al (2000). CIRIA Report C515 - Groundwater control – design and practice.
- Rankin, W.J. (1988). Ground movements resulting from urban tunnelling; predictions and effects. Engineering Geology Special Publication No. 5, pp79-92.
- Raymer, J.H. (2001). Predicting Groundwater Inflows into Hard Rock Tunnels: Estimating the High End of the Permeability Distribution. Proc. of 2001 Conference on Rock Excavation and Tunnelling (RETC).
- Raymer, J.H. (2005). Groundwater Inflow into Hard Rock Tunnels: A New Look at Inflow Equations. Proc. of 2005 Conference on Rock Excavation and Tunnelling (RETC).
- Sewell, R.J., Campbell, S.D.G., Fletcher, C.J.N, Lai, K.W. & Kirk, P.A. (2000). The Pre-Quaternary Geology of Hong Kong. Hong Kong Geological Survey, Geotechnical Engineering Office, Hong Kong.
- S. H. Someville, CIRIA Report 113: Control of Groundwater for Temporary Works.
- USACOE Tunnels and Shafts in Rock. (1997) EM 1110-2-2901.

# Figures




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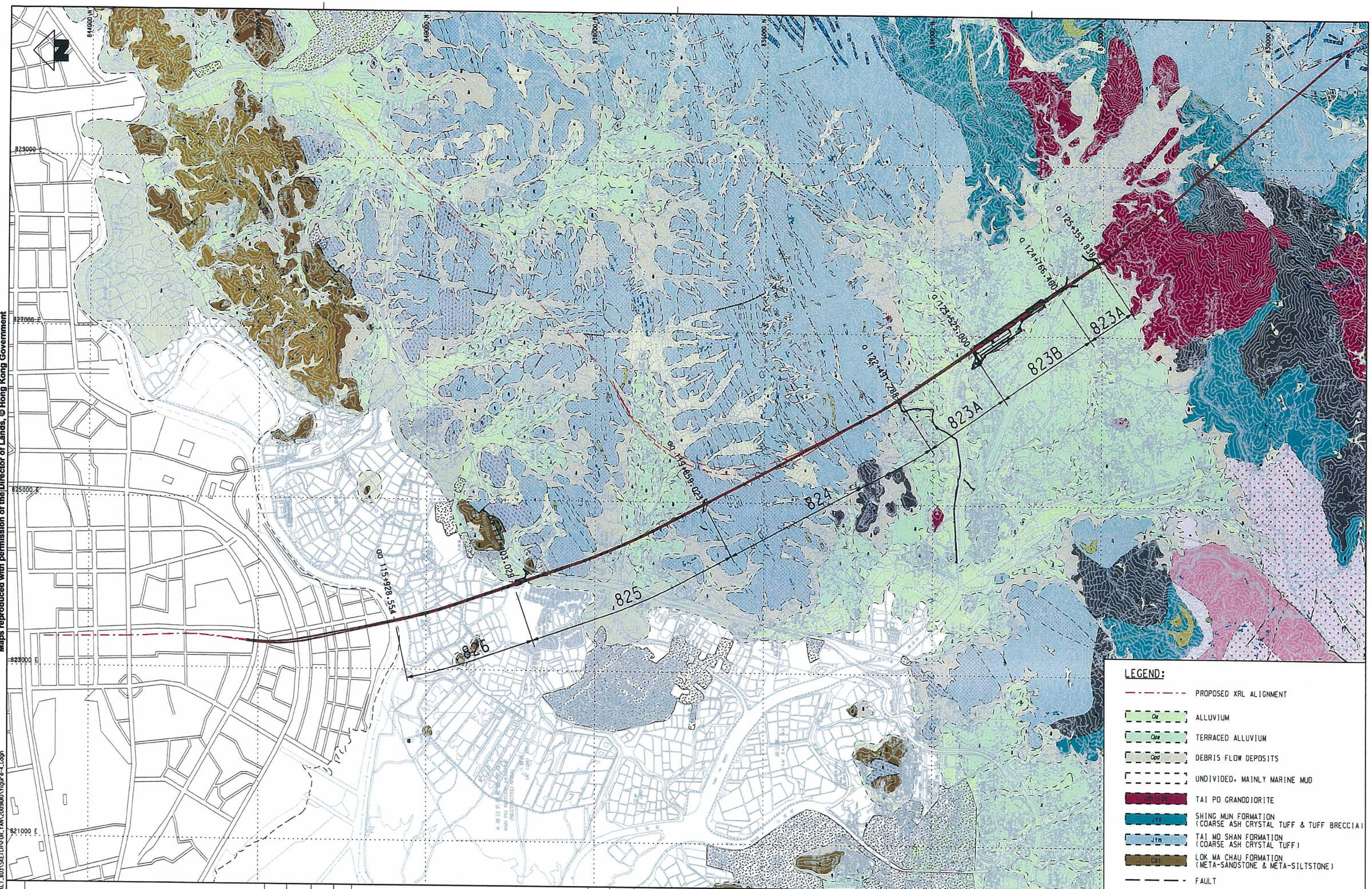
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Supported by :
Atkins, TFP Farrells, DLS,
Knight Frank, SIYUAN,
Urbis, BMT Asia

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TITLE
C803
TUNNELS & ASSOCIATED STRUCTURES (NORTH)
SITE LOCATION
(PLAN & PROFILE)

SCALE N.T.S.
DRAWING NO. FIGURE 2.1
REV. A

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TITLE

C803

TUNNELS & ASSOCIATED STRUCTURES (NORTH)

GEOLOGICAL KEY PLAN

SCALE 1 : 20000 (A1)

DRAWING NO. FIGURE 4.1

REV. –

# Appendix A

## Year 2008 Air Photo along the Proposed XRL Alignment




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CADD REF.

TITLE
YEAR 2008 AIR PHOTO

SCALE 1:5000

DRAWING NO. Works Contract 826

REV.




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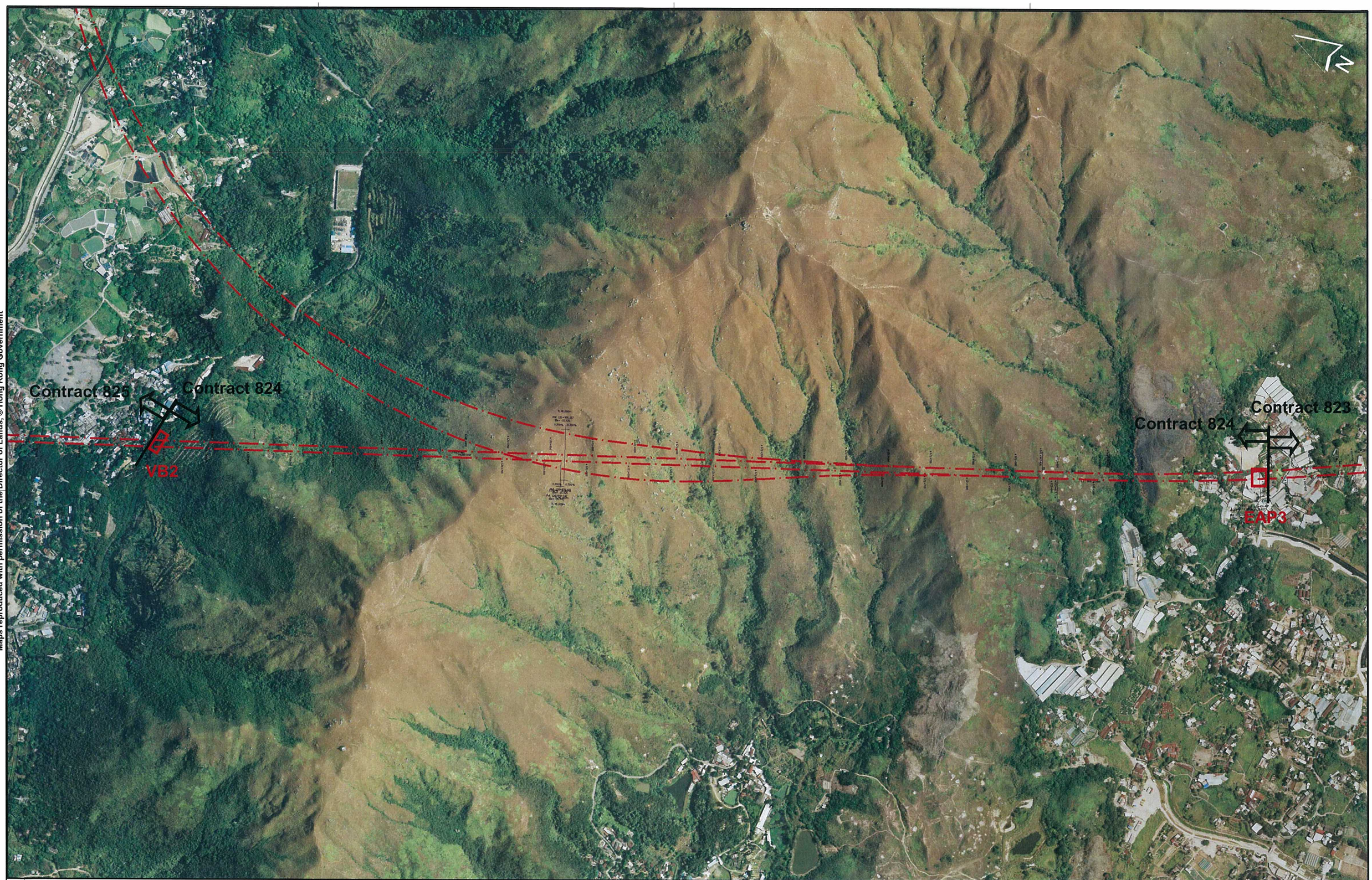
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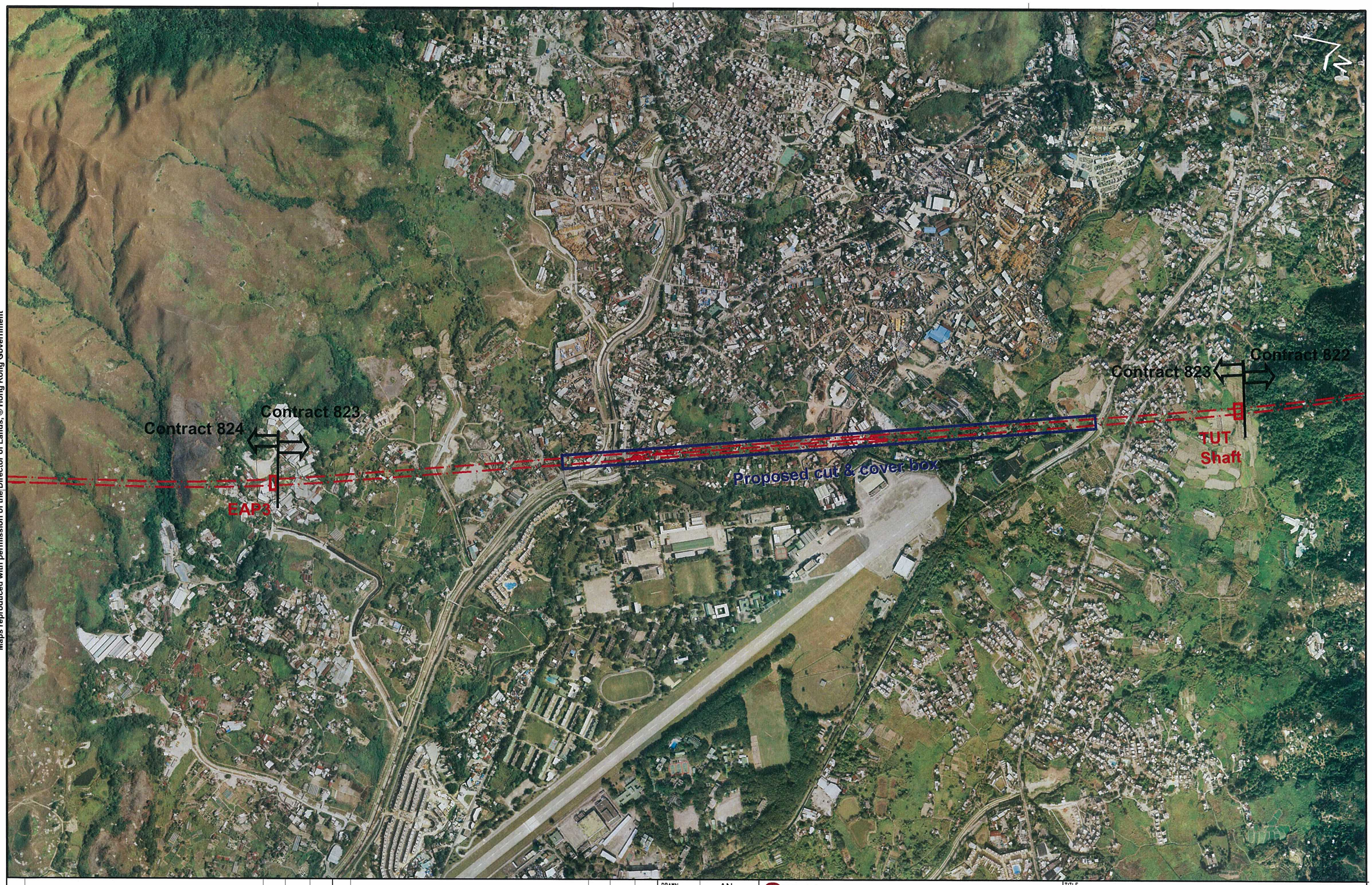
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TITLE

# YEAR 2008 AIR PHOTO

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# YEAR 2008 AIR PHOTO

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# Appendix B

## Geological Plans & Sections

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GSG CONTRACT

CONTRACT 826

SHENZHEN RIVER

SOUTHBOUND

NORTHBOUND

CP1

CP2

1:5,000

MATCH LINE
FOR CONTINUATION
SEE FIGURE 826/B/310/OAP/C05/102

FOR REFERENCE ONLY

0 10 20 30 40 50
METRES
1:1000

## LEGEND:

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

GEOLOGICAL STRUCTURE :-

- 1:100,000 — FAULT FROM 1:100,000 GEOLOGY MAP
- 1:20,000 — FAULT FROM 1:20,000 GEOLOGY MAP
- 1:20,000 — PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP
- 1:5,000 — FAULT FROM 1:5,000 GEOLOGY MAP
- GASP — FAULT FROM GASP REPORT
- GASP — PHOTOLINEAMENT FROM GASP REPORT
- ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT
- DENOTE THRUST FAULT

TENDER

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| APPROVED | JM |
| DATE | 27/MAR/2009 |

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TITLE

CONTRACT 826
HUANGGANG TO MAI PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 1

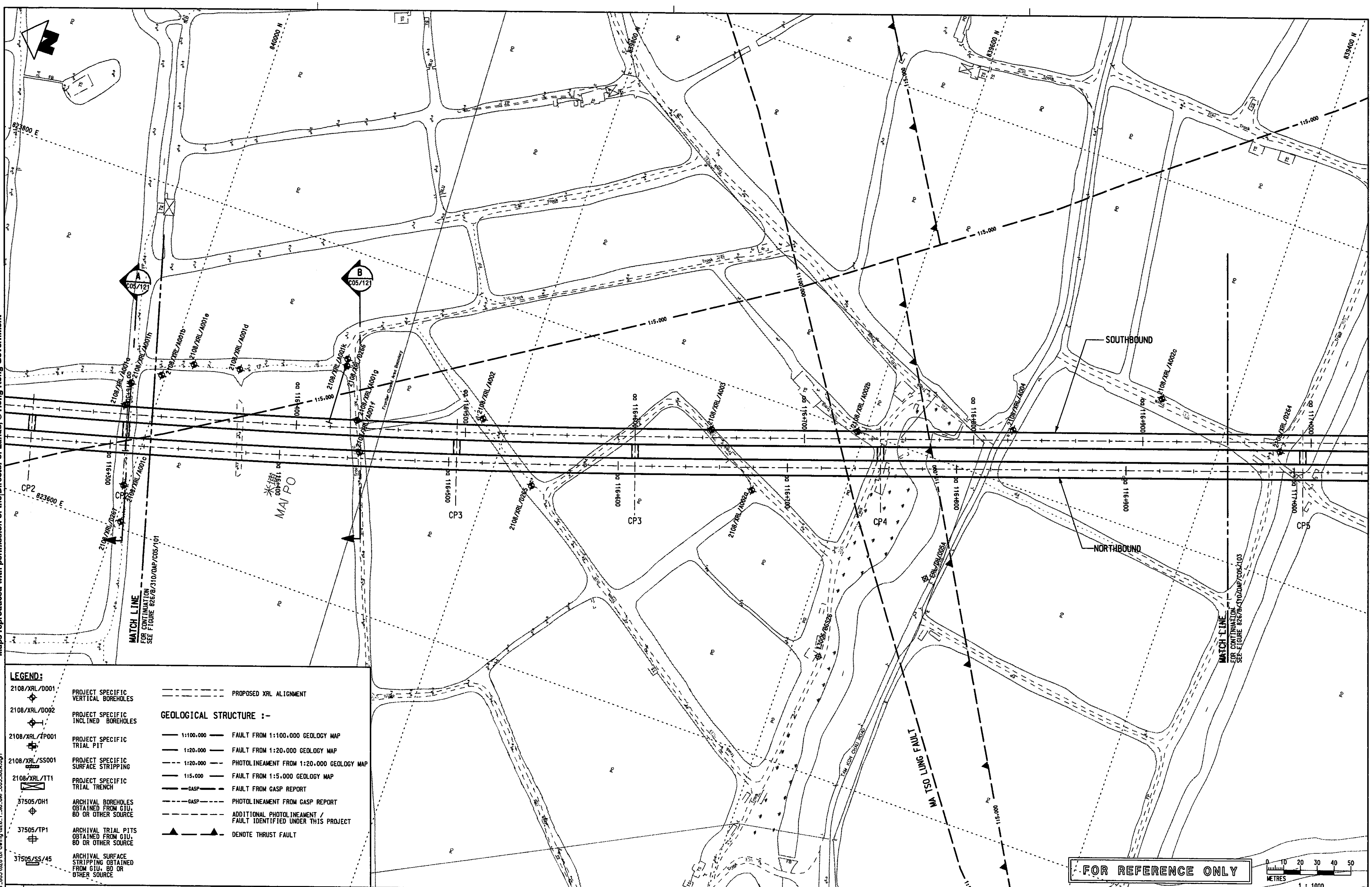
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| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES | GEOLOGICAL STRUCTURE :- | |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT | 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| | | 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING | 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH | 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| | | GASP | FAULT FROM GASP REPORT |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE | GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | | | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE | | DENOTE THRUST FAULT |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE | | |

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TITLE
# CONTRACT 826
## HUANGGANG TO MAI PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 2

SCALE 1: 1000 (A1)

DRAWING NO. 826/T/310/OAP/C05/102

REV. A

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CONTRACT 826 | CONTRACT 825

SOUTHBOUND

NORTHBOUND

CP5

CP6

CPVBT

MATCH LINE FOR CONTINUATION SEE FIGURE 826/R/310/OAP/C05/102

1:5,000

SAN TIN FAULT

FOR REFERENCE ONLY

0 10 20 30 40 50 METRES 1 : 1000

**LEGEND:**

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| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

GEOLOGICAL STRUCTURE :-

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| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

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TITLE

# CONTRACT 826
## HUANGGANG TO MAI PO
### GROUND INVESTIGATION
### STATIONS AND GEOLOGICAL FEATURE PLAN
### SHEET 3

SCALE 1: 1000 (A1)

DRAWING NO. 826/T/310/OAP/C05/103

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WORKS CONTRACT 826 | WORKS CONTRACT 825

SOUTHBOUND

NORTHBOUND

CP5

CP6

CPVB1-A

CPVB1-B

MATCH LINE
FOR CONTINUATION
SEE DWG 825/T/320/OAP/C05/102

SAN TIN FAULT

FOR REFERENCE ONLY

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1:1000

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| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

GEOLOGICAL STRUCTURE :-

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| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
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TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 1

SCALE 1: 1000 (A1)

DRAWING NO. 825/T/320/OAP/C05/101

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| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU. BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU. BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU. BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

**GEOLOGICAL STRUCTURE :-**

| | |
|---|---|
| 1:100.000 | FAULT FROM 1:100.000 GEOLOGY MAP |
| 1:20.000 | FAULT FROM 1:20.000 GEOLOGY MAP |
| 1:20.000 | PHOTOLINEAMENT FROM 1:20.000 GEOLOGY MAP |
| 1:5.000 | FAULT FROM 1:5.000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

SOUTHBOUND

NORTHBOUND

MATCH LINE
FOR CONTINUATION
SEE DWG 825/T/320/OAP/C05/103

MATCH LINE
FOR CONTINUATION
SEE DWG 825/T/320/OAP/C05/101

FOR REFERENCE ONLY

0 10 20 30 40 50
METRES
1:1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR
ARUP

Supported by :
Atkins, TFP Farrells, DLS,
Knight Frank, SIYUAN,
Urbis, BMT Asia

CADD REF. 825_T_320_OAP_C05_102B.dgn

TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 2

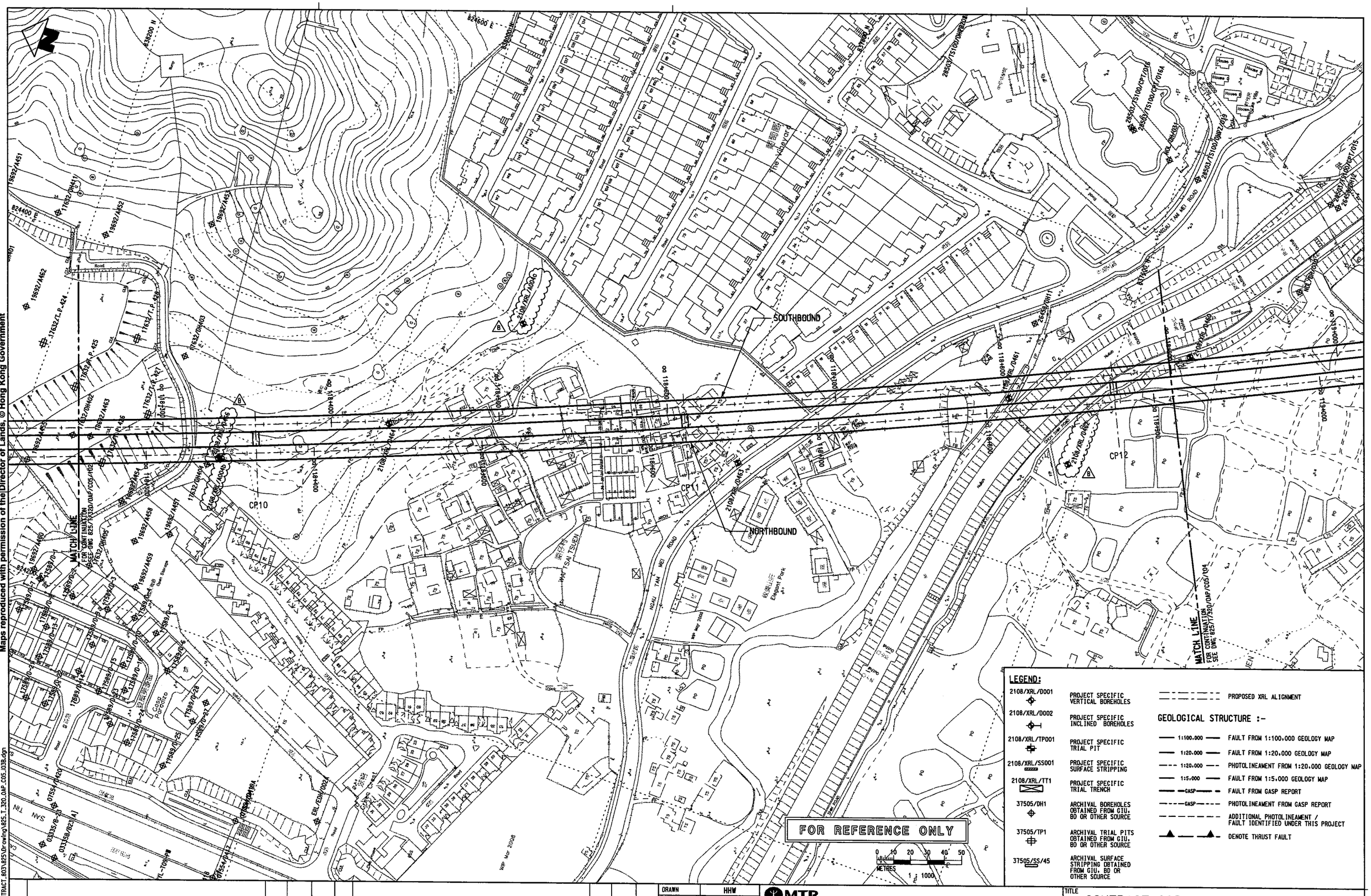
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DRAWING NO. 825/T/320/OAP/C05/102

REV. B

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**LEGEND:**

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100.000 | FAULT FROM 1:100.000 GEOLOGY MAP |
| 1:20.000 | FAULT FROM 1:20.000 GEOLOGY MAP |
| 1:20.000 | PHOTOLINEAMENT FROM 1:20.000 GEOLOGY MAP |
| 1:5.000 | FAULT FROM 1:5.000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR

ARUP

Supported by :
Atkins, TFP Farrells, DLS,
Knight Frank, SIYUAN,
Urbis, BMT Asia

CADD REF. 825_T_320_OAP_C05_103B.dgn

TITLE

CONTRACT 825
MAI PO TO NGAU TAM MEI
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 3

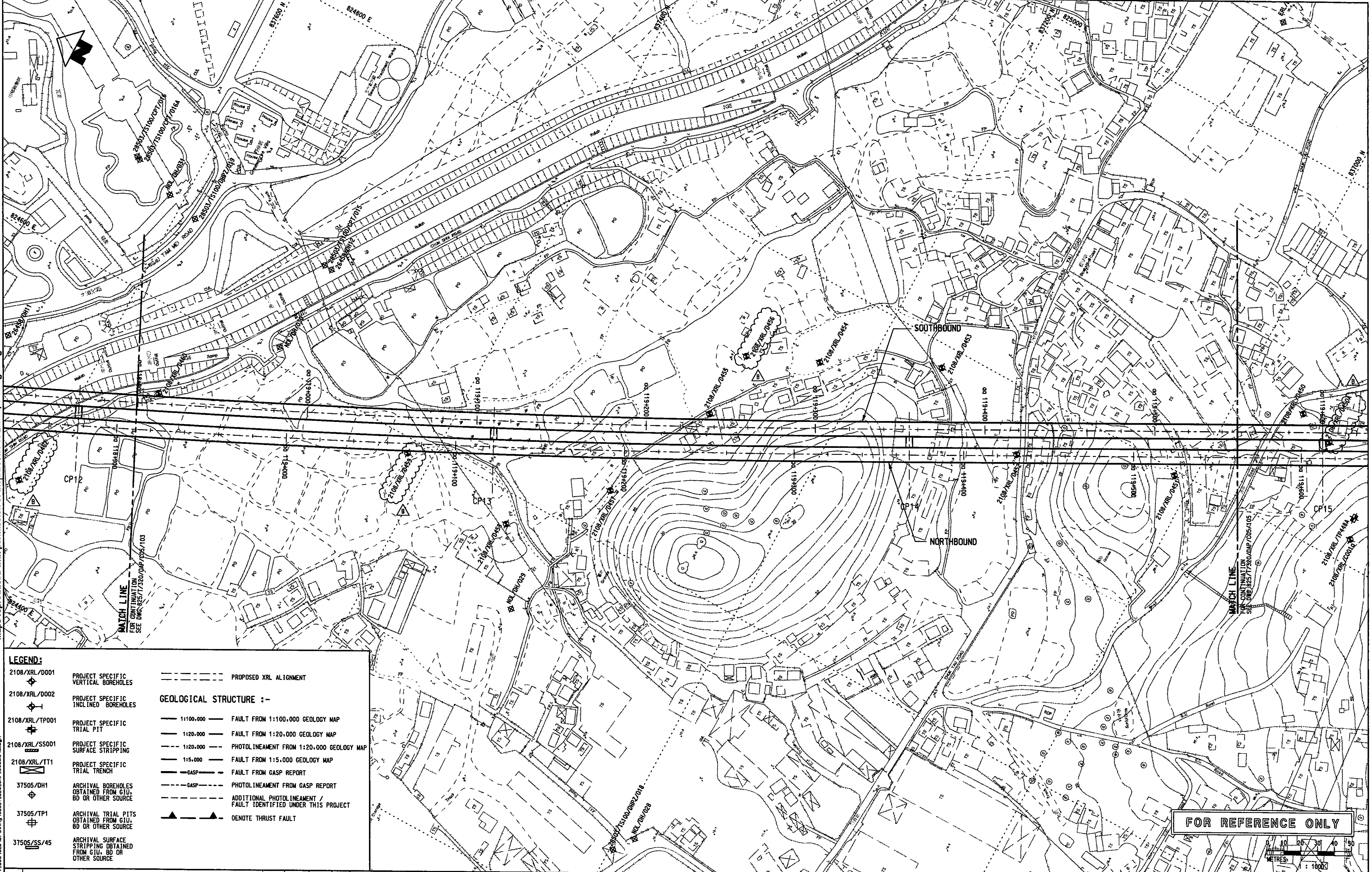
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DRAWING NO. 825/T/320/OAP/C05/103

REV. B

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MODIFIED BY: cshcm
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## LEGEND:

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

### GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

FOR REFERENCE ONLY

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR
ARUP

Supported by :
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CADD REF. 825_T_320_OAP_C05_104B.dgn

TITLE
# CONTRACT 825
## MAI PO TO NGAU TAM MEI
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 4

SCALE 1: 1000 (A1)
DRAWING NO. 825/T/320/OAP/C05/104
REV. B

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FILENAME: M:\C803\CONTRACT_803\825\Drawing\825_T_320_OAP_C05_104B.dgn

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WORKS CONTRACT 825 | WORKS CONTRACT 824

SOUTHBOUND

NORTHBOUND

MATCH LINE
FOR CONTINUATION
SEE DWG 2108/XRL/T320/OAP/C05/104

CP15

CP16

## LEGEND:

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |
| | PROPOSED XRL ALIGNMENT |

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

FOR REFERENCE ONLY

0 10 20 30 40 50
METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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ORIGINATOR
ARUP
Supported by :
Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_OAP_C05_105B.dgn

TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 5

SCALE 1: 1000 (A1)
DRAWING NO. 825/T/320/OAP/C05/105
REV. B

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FILENAME: M:\C803\CONTRACT_803\825\Drawing\825_T_320_OAP_C05_105B.dgn

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CONTRACT 825

CONTRACT 824

SOUTHBOUND

NORTHBOUND

CP15

CP16

MATCH LINE FOR CONTINUATION SEE DWG 824/T/330/OAP/C05/102

## LEGEND:

- 2108/XRL/D001 — PROJECT SPECIFIC VERTICAL BOREHOLES
- 2108/XRL/D002 — PROJECT SPECIFIC INCLINED BOREHOLES
- 2108/XRL/TP001 — PROJECT SPECIFIC TRIAL PIT
- 2108/XRL/SS001 — PROJECT SPECIFIC SURFACE STRIPPING
- 2108/XRL/TT1 — PROJECT SPECIFIC TRIAL TRENCH
- 37505/DH1 — ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE
- 37505/TP1 — ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE
- 37505/SS/45 — ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE
- PROPOSED XRL ALIGNMENT

### GEOLOGICAL STRUCTURE :-

- 1:100,000 — FAULT FROM 1:100,000 GEOLOGY MAP
- 1:20,000 — FAULT FROM 1:20,000 GEOLOGY MAP
- 1:20,000 — PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP
- 1:5,000 — FAULT FROM 1:5,000 GEOLOGY MAP
- GASP — FAULT FROM GASP REPORT
- GASP — PHOTOLINEAMENT FROM GASP REPORT
- ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT
- DENOTE THRUST FAULT

0 10 20 30 40 50 METRES 1 : 1000

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

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|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 824_T_330_OAP_C05_101A1.dgn

TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 1

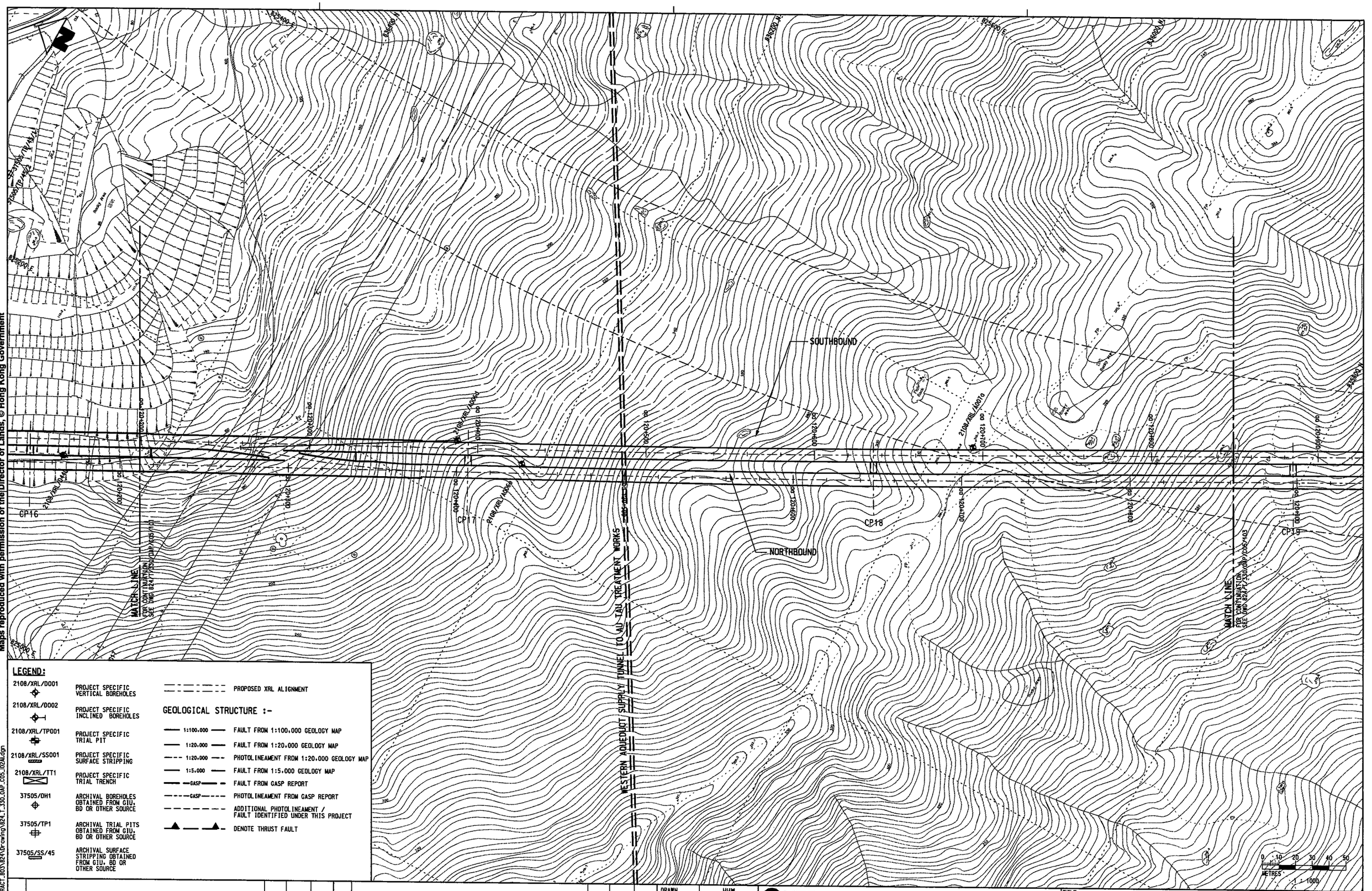
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DRAWING NO. 824/T/330/OAP/C05/101

REV. A1

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FILENAME: M:\C803\CONTRACT_803\824\Drawing\824_T_330_OAP_C05_001A1.dgn

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## LEGEND:

- 2108/XRL/D001 — PROJECT SPECIFIC VERTICAL BOREHOLES
- 2108/XRL/D002 — PROJECT SPECIFIC INCLINED BOREHOLES
- 2108/XRL/TP001 — PROJECT SPECIFIC TRIAL PIT
- 2108/XRL/SS001 — PROJECT SPECIFIC SURFACE STRIPPING
- 2108/XRL/TT1 — PROJECT SPECIFIC TRIAL TRENCH
- 37505/DH1 — ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE
- 37505/TP1 — ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE
- 37505/SS/45 — ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE

PROPOSED XRL ALIGNMENT

GEOLOGICAL STRUCTURE :-

- 1:100,000 — FAULT FROM 1:100,000 GEOLOGY MAP
- 1:20,000 — FAULT FROM 1:20,000 GEOLOGY MAP
- 1:20,000 — PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP
- 1:5,000 — FAULT FROM 1:5,000 GEOLOGY MAP
- GASP — FAULT FROM GASP REPORT
- GASP — PHOTOLINEAMENT FROM GASP REPORT
- ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT
- DENOTE THRUST FAULT

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

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|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 824_T_330_OAP_C05_102A1.dgn

TITLE
# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 2

SCALE 1: 1000 (A1)

DRAWING NO. 824/T/330/OAP/C05/102

REV. A1

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FILENAME: M:\C803\CONTRACT_803\824\Drawing\824_T_330_OAP_C05_102A1.dgn

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SOUTHBOUND

NORTHBOUND

CP19

CP20

CP21

MATCH LINE
FOR CONTINUATION
SEE DWG 824/T/330/OAP/C05/102

MATCH LINE
FOR CONTINUATION
SEE DWG 824/T/330/OAP/C05/104

## LEGEND:

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |
| | PROPOSED XRL ALIGNMENT |

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

0 10 20 30 40 50
METRES
1 : 1000

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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EXPRESS RAIL LINK

ORIGINATOR
ARUP
Supported by :
Atkins, TFP Farrells, DLS,
Knight Frank, SIYUAN,
Urbis, BMT Asia

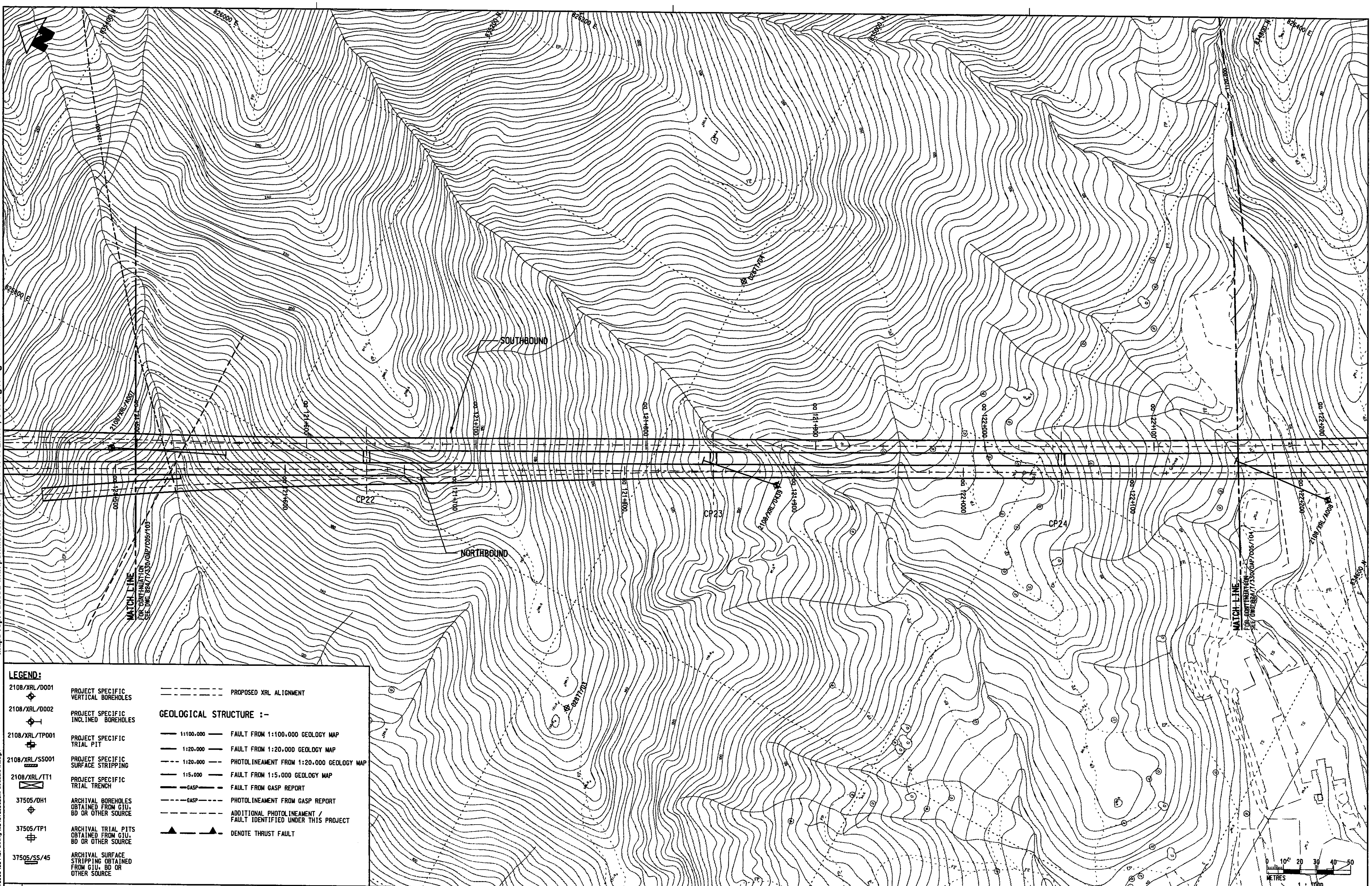
CADD REF. 824_T_330_OAP_C05_103A1.dgn

TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 3

SCALE 1: 1000 (A1)
DRAWING NO. 824/T/330/OAP/C05/103
REV. A1

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## LEGEND:

| | | | |
|---|---|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES | | PROPOSED XRL ALIGNMENT |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES | GEOLOGICAL STRUCTURE :- | |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT | 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING | 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH | 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE | 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE | GASP | FAULT FROM GASP REPORT |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE | GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | | | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | | | DENOTE THRUST FAULT |

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

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|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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MTR

EXPRESS RAIL LINK

ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 824_T_330_OAP_C05_104A1.dgn

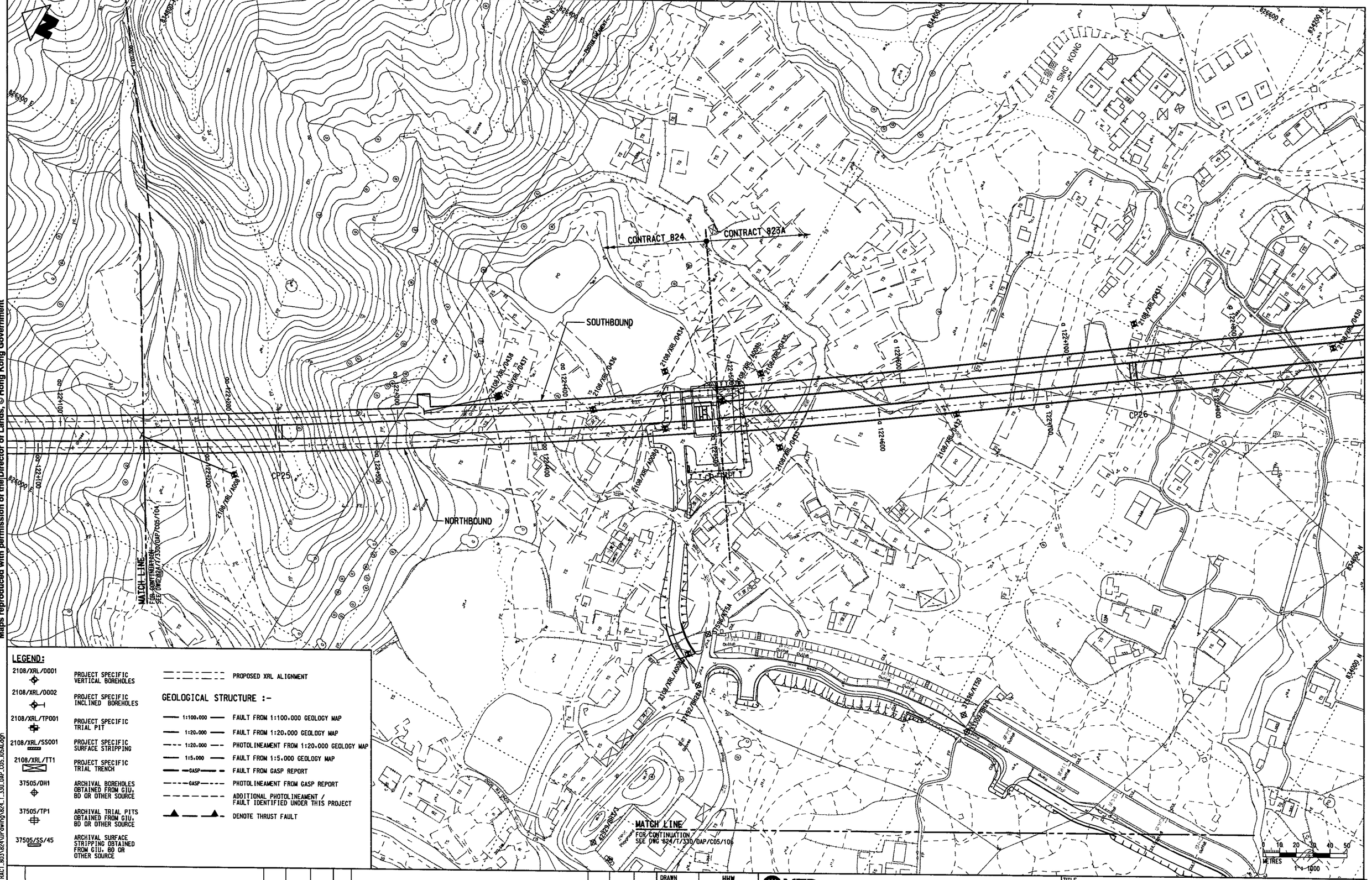
TITLE

# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 4

SCALE 1: 1000 (A1)
DRAWING NO. 824/T/330/OAP/C05/104
REV. A1

PLOT DRV: M:\C803\CONTRACT_803\CAD_ADMIN\PLOTDRIVER\LHP_2086B3-A3.PLT
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FILENAME: M:\C803\CONTRACT_803\824\Drawing\824_T_330_OAP_C05_104A1.dgn

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**LEGEND:**

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |
| | PROPOSED XRL ALIGNMENT |

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

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ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 16SEP09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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Supported by :
Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 824_T_330_OAP_C05_105A1.dgn

TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 5

SCALE 1: 1000 (A1)
DRAWING NO. 824/T/330/OAP/C05/105
REV. A1

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CONTRACT 824

CONTRACT 823A

SOUTHBOUND

NORTHBOUND

CP25

CP26

MATCH LINE
FOR CONTINUATION
SEE DWG 823A/T/340/DAP/C05/102

## LEGEND:

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |
| | PROPOSED XRL ALIGNMENT |

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

0 10 20 30 40 50
METRES
1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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CADD REF. 823A_T_340_OAP_C05_101A1.dgn

TITLE
CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 1

SCALE 1: 1000 (A1)
DRAWING NO. 823A/T/340/OAP/C05/101
REV. A1

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PRINTED BY: 28/07/2009 5:06:50 PM
cskwan

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## LEGEND:

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |

PROPOSED XRL ALIGNMENT

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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ARUP
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CADD REF. 823A_T_340_OAP_C05_102A1.dgn

TITLE
CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 2

SCALE 1: 1000 (A1)
DRAWING NO. 823A/T/340/OAP/C05/102
REV. A1

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CONTRACT 823A

CONTRAGT 823B

SOUTHBOUND

NORTHBOUND

CP29

CPER(S/N)

ERS(S)

MATCH LINE
FOR CONTINUATION
SEE DRAWING 823B/T/350/OAP/C05/102

INFERRED TAI LAM FAULT ZONE BASED ON PROJECT SPECIFIC BOREHOLES

1:100,000

0 10 20 30 40 50
METRES
1 : 1000

**LEGEND:**

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU. BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU. BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU. BD OR OTHER SOURCE |
| | PROPOSED XRL ALIGNMENT |

GEOLOGICAL STRUCTURE :-

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 30OCT09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 30/OCT/2009 |

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CADD REF. 823B_T_350_OAP_C05_101A1.dgn

TITLE

CONTRACT 823B
SHEK KONG STABLING SIDINGS AND ERS
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 1

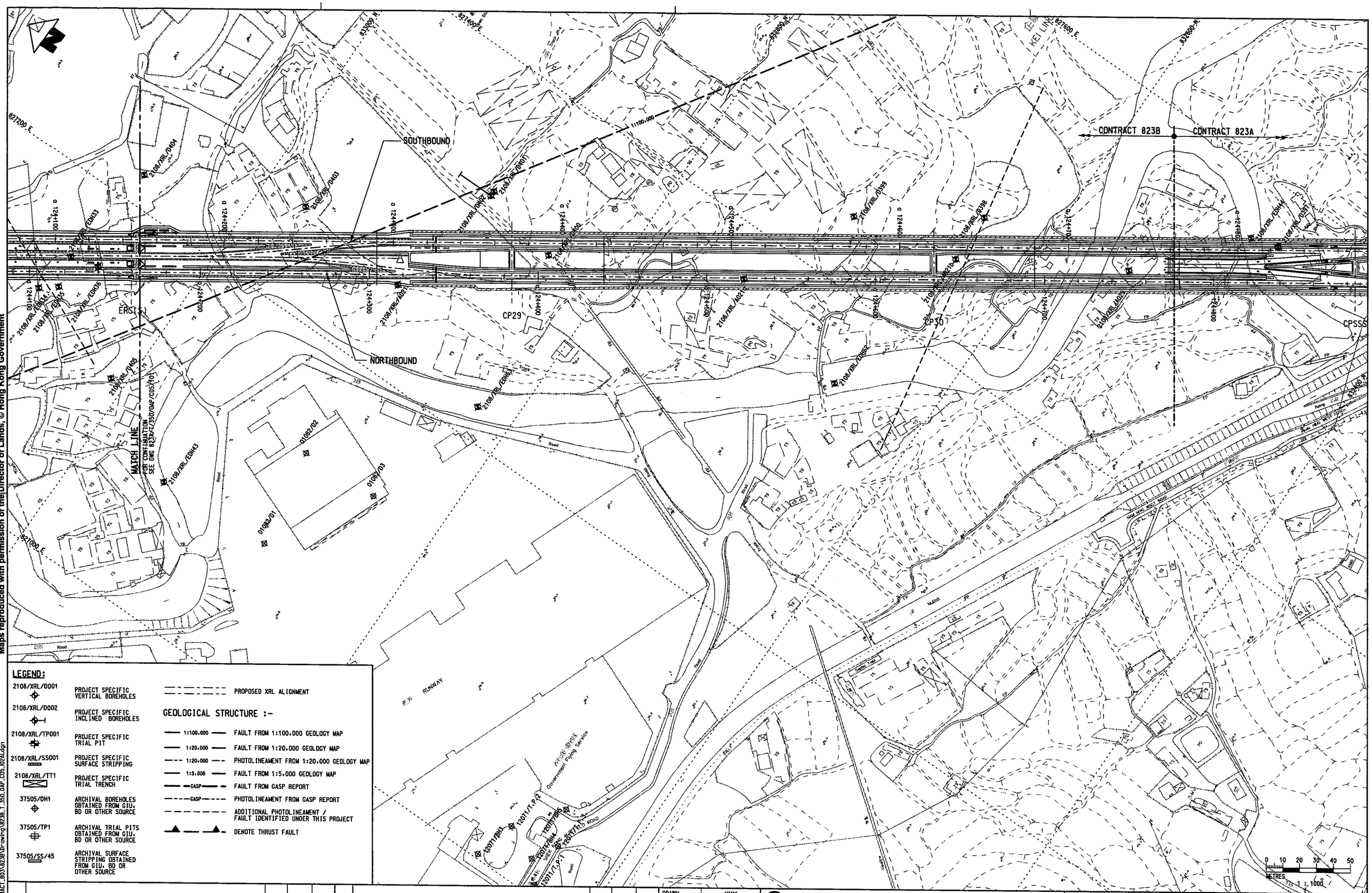
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DRAWING NO. 823B/T/350/OAP/C05/101

REV. A1

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FILENAME: M:\C803\CONTRACT_803\823B\Drawing\823B_T_350_OAP_C05_101A1.dgn

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**LEGEND:**

| | |
|---|---|
| 2108/XRL/D001 | PROJECT SPECIFIC VERTICAL BOREHOLES |
| 2108/XRL/D002 | PROJECT SPECIFIC INCLINED BOREHOLES |
| 2108/XRL/TP001 | PROJECT SPECIFIC TRIAL PIT |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE |
| | PROPOSED XRL ALIGNMENT |

**GEOLOGICAL STRUCTURE :-**

| | |
|---|---|
| 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| GASP | FAULT FROM GASP REPORT |
| GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | DENOTE THRUST FAULT |

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Default PRINTED BY: cskcn 27/10/2009 9:45:23 AM

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 30OCT09 | JM |

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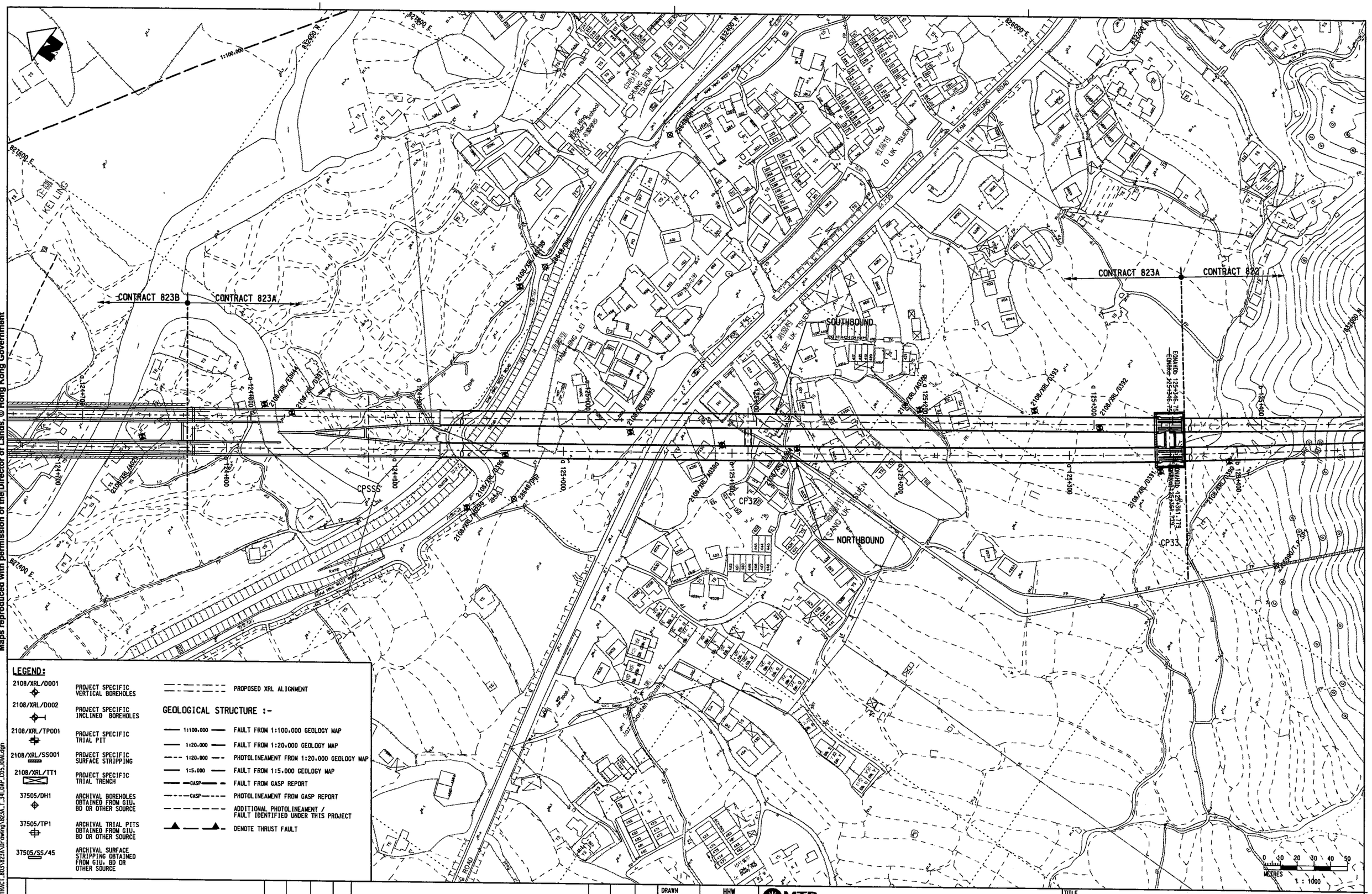
| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 30/OCT/2009 |

MTR
EXPRESS RAIL LINK
ORIGINATOR
ARUP
Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia
CADD REF. 823B_T_350_OAP_C05_102A1.dgn

TITLE
CONTRACT 823B
SHEK KONG STABLING SIDINGS AND ERS
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 2

SCALE 1: 1000 (A1)
DRAWING NO. 823B/T/350/OAP/C05/102
REV. A1

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**LEGEND:**

| | | | |
|---|---|---|---|
| 2108/XRL/DD01 | PROJECT SPECIFIC VERTICAL BOREHOLES | | PROPOSED XRL ALIGNMENT |
| 2108/XRL/DD02 | PROJECT SPECIFIC INCLINED BOREHOLES | GEOLOGICAL STRUCTURE :- | |
| 2108/XRL/TPD01 | PROJECT SPECIFIC TRIAL PIT | 1:100,000 | FAULT FROM 1:100,000 GEOLOGY MAP |
| 2108/XRL/SS001 | PROJECT SPECIFIC SURFACE STRIPPING | 1:20,000 | FAULT FROM 1:20,000 GEOLOGY MAP |
| 2108/XRL/TT1 | PROJECT SPECIFIC TRIAL TRENCH | 1:20,000 | PHOTOLINEAMENT FROM 1:20,000 GEOLOGY MAP |
| 37505/DH1 | ARCHIVAL BOREHOLES OBTAINED FROM GIU, BD OR OTHER SOURCE | 1:5,000 | FAULT FROM 1:5,000 GEOLOGY MAP |
| 37505/TP1 | ARCHIVAL TRIAL PITS OBTAINED FROM GIU, BD OR OTHER SOURCE | GASP | FAULT FROM GASP REPORT |
| 37505/SS/45 | ARCHIVAL SURFACE STRIPPING OBTAINED FROM GIU, BD OR OTHER SOURCE | GASP | PHOTOLINEAMENT FROM GASP REPORT |
| | | | ADDITIONAL PHOTOLINEAMENT / FAULT IDENTIFIED UNDER THIS PROJECT |
| | | | DENOTE THRUST FAULT |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | HHW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 823A_T_341_OAP_C05_101A1.dgn

TITLE
# CONTRACT 823A
## TAI KONG PO TO TSE UK TSUEN
GROUND INVESTIGATION
STATIONS AND GEOLOGICAL FEATURE PLAN
SHEET 3

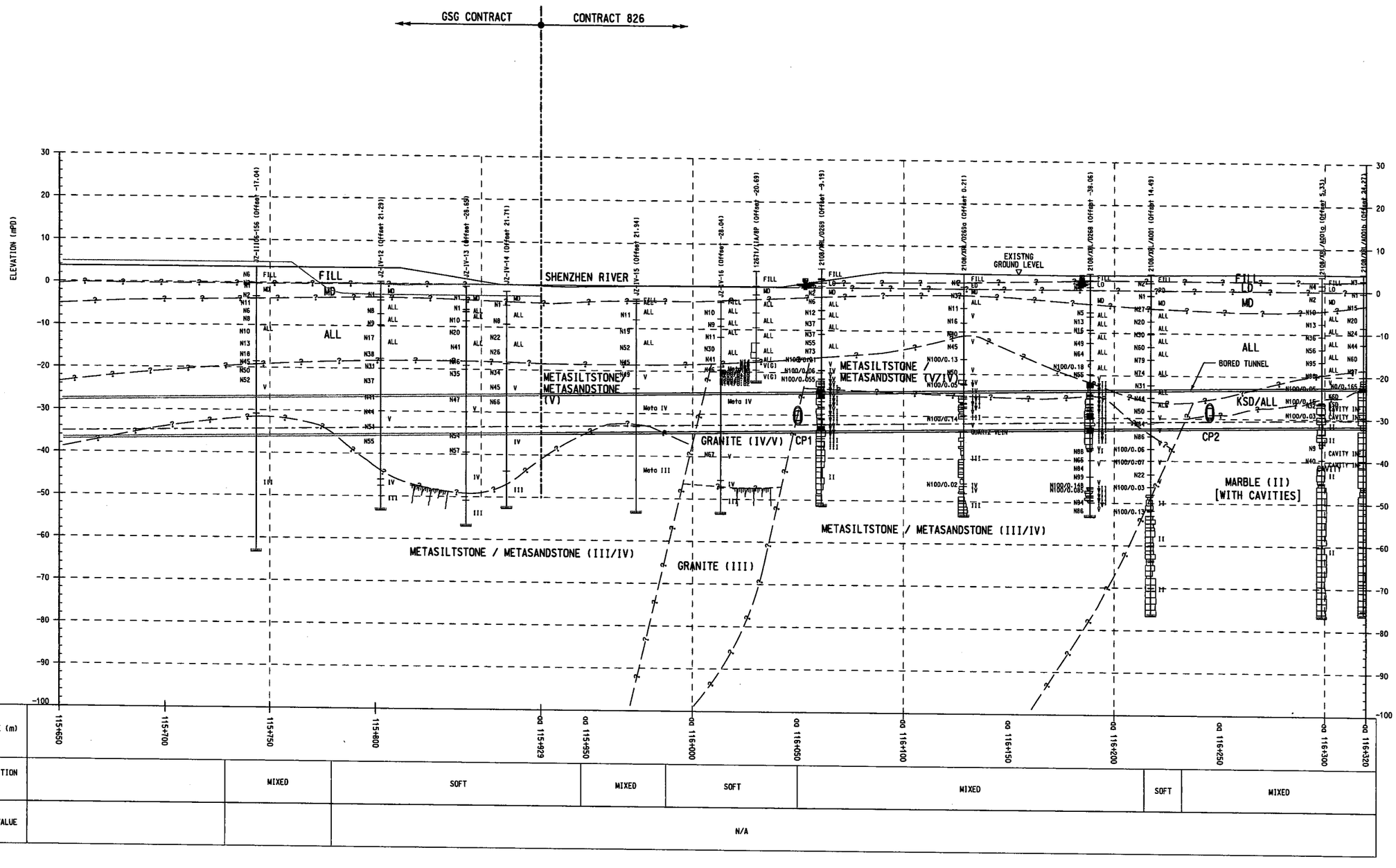
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DRAWING NO. 823A/T/341/OAP/C05/101

REV. A1

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## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

METRES 1 : 500 — METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 826_T_310_OAP_C05_111A.dgn

TITLE
CONTRACT 826
HUANGGANG TO MAI PO
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 1

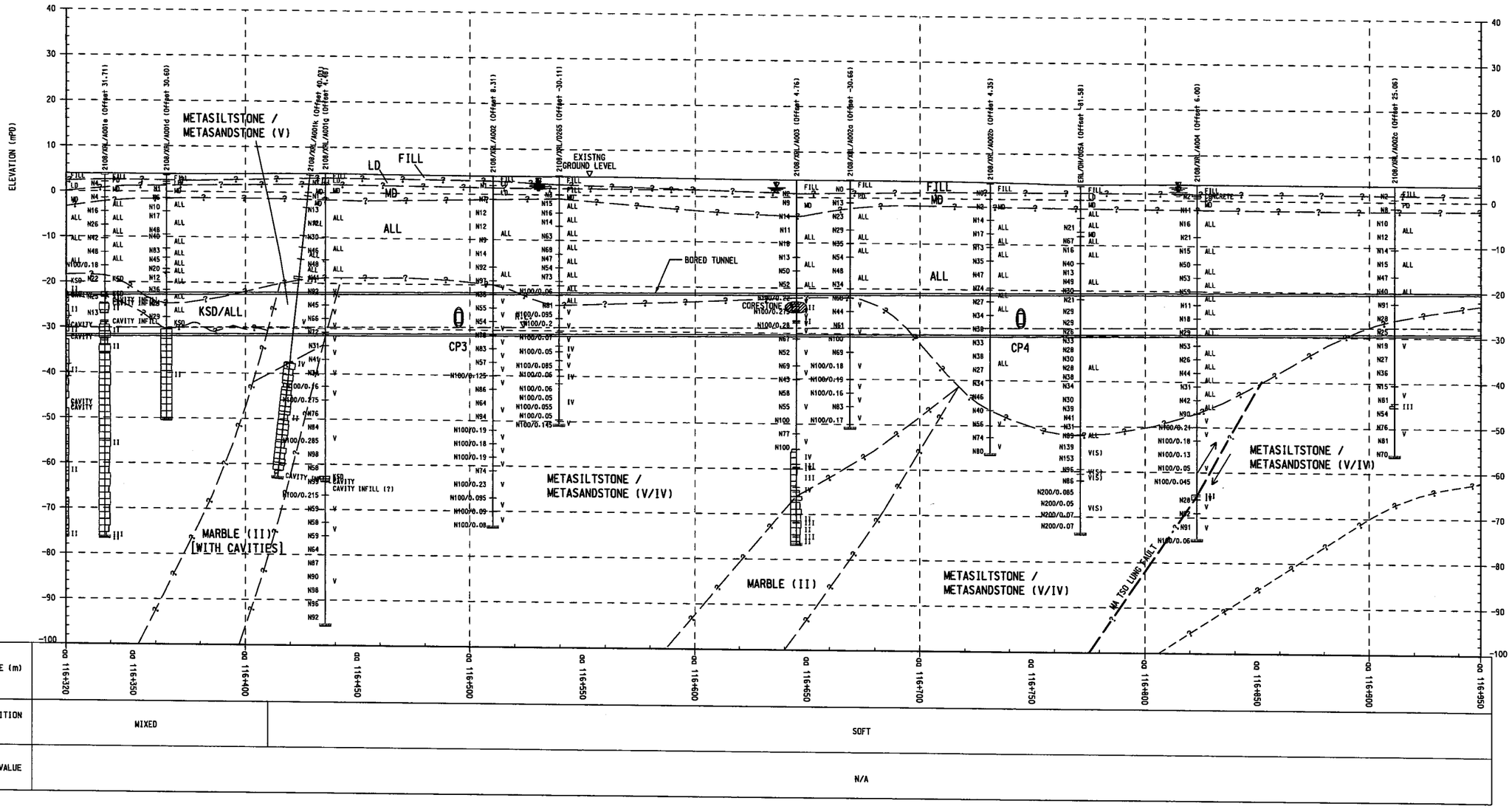
SCALE AS SHOWN (A1)

DRAWING NO. 826/T/310/OAP/C05/111

REV. A

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FILENAME: M:\C803\CONTRACT_803\826\Drawing\826_T_310_OAP_C05_111A.dgn

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| CHAINAGE (m) | 00 116+320 | 00 116+350 | 00 116+400 | 00 116+450 | 00 116+500 | 00 116+550 | 00 116+600 | 00 116+650 | 00 116+700 | 00 116+750 | 00 116+800 | 00 116+850 | 00 116+900 | 00 116+950 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | MIXED | | | | | SOFT | | | | | | | | |
| INTERPRETED Q VALUE | N/A | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

METRES 1 : 500 — METRES 1 : 1000

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TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | TW | 14AUG09 | JM |

| DRAWN | CSK |
|---|---|
| DESIGNED | HHY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

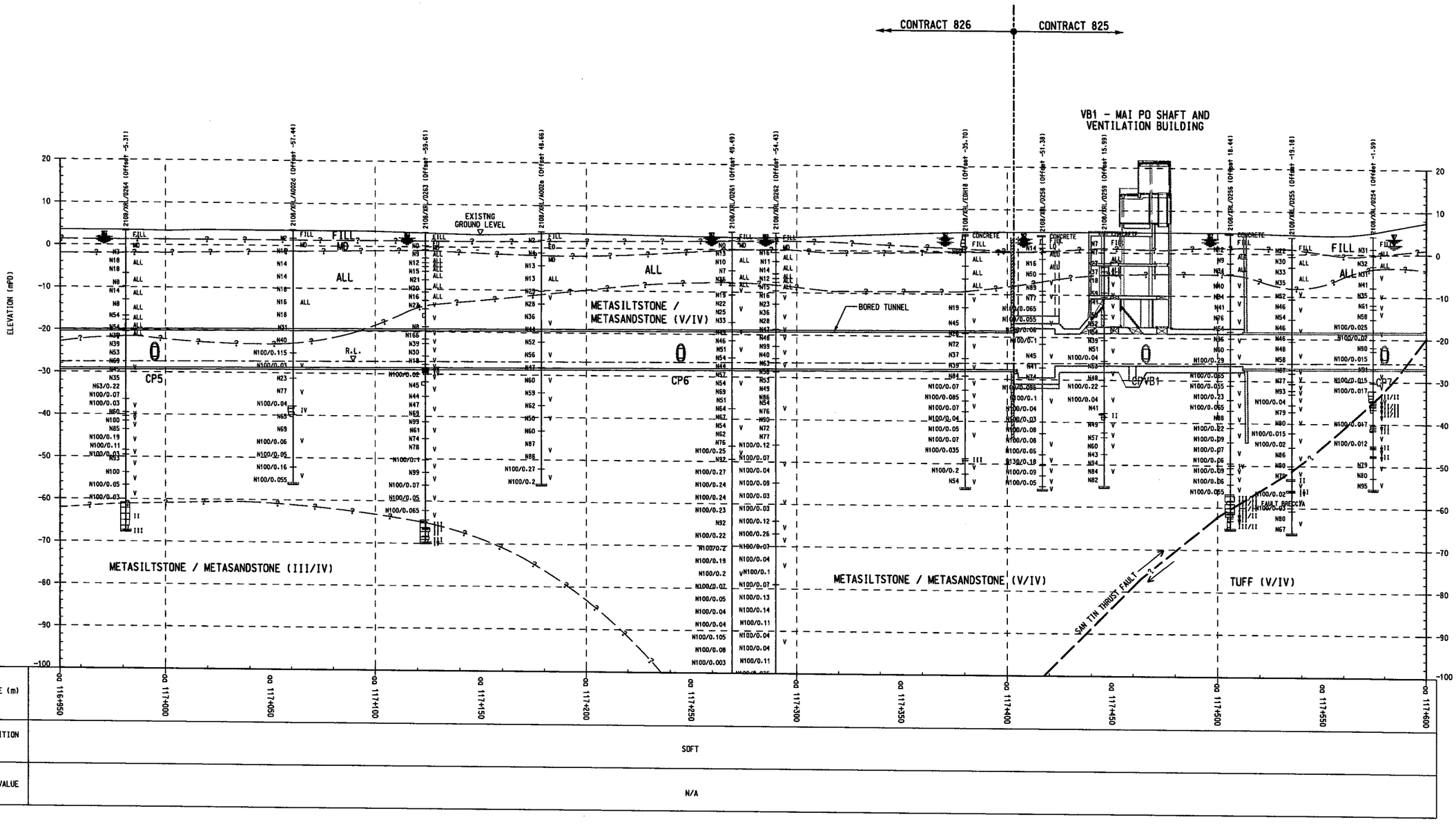
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CADD REF. 826_T_310_OAP_C05_112A.dgn

TITLE
CONTRACT 826
HUANGGANG TO MAI PO
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 2

SCALE AS SHOWN (A1) | DRAWING NO. 826/T/310/OAP/C05/112 | REV. A

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## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

METRES 1 : 500 — METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 826_T_310_OAP_C05_113A.dgn

TITLE
CONTRACT 826
HUANGGANG TO MAI PO
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 3

SCALE AS SHOWN (A1)

DRAWING NO. 826/T/310/OAP/C05/113

REV. A

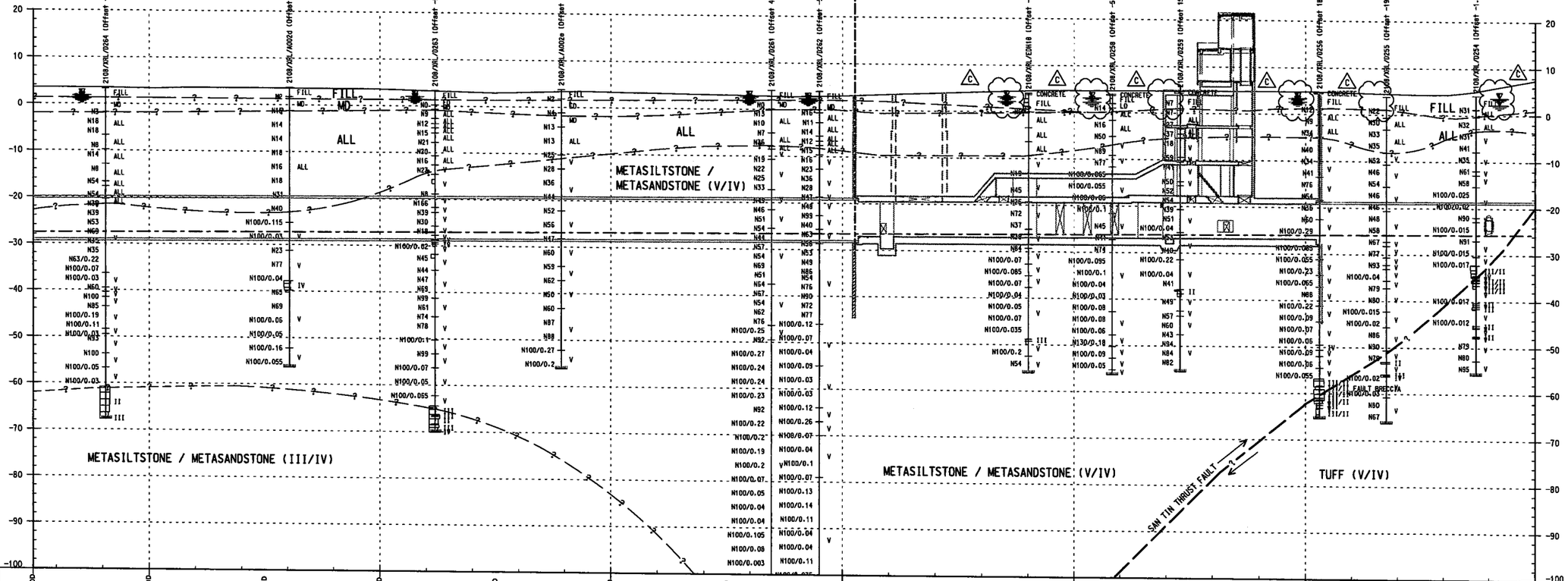
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MODELNAME: Default PRINTED BY: csksn 28/10/2009 5:53:26 PM
FILENAME: M:\C803\CONTRACT_803\825\Drawing\825_T_320_OAP_C05_111C.dgn

CONTRACT 826 | CONTRACT 825

VB1 - MAI PO VENTILATION SHAFT (MPV)




| CHAINAGE (m) | 116+950 | 117+000 | 117+050 | 117+100 | 117+150 | 117+200 | 117+250 | 117+300 | 117+350 | 117+400 | 117+450 | 117+500 | 117+550 | 117+600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | SOFT | | | | | | | | | | | | MIXED | |
| ANTICIPATED Q VALUE (TUNNEL LEVEL) MIN. - MAX. | N/A | | | | | | | | | | | | | |
| ANTICIPATED Q VALUE (TUNNEL LEVEL) TYPICAL VALUE | N/A | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| C | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_OAP_C05_111C.dgn

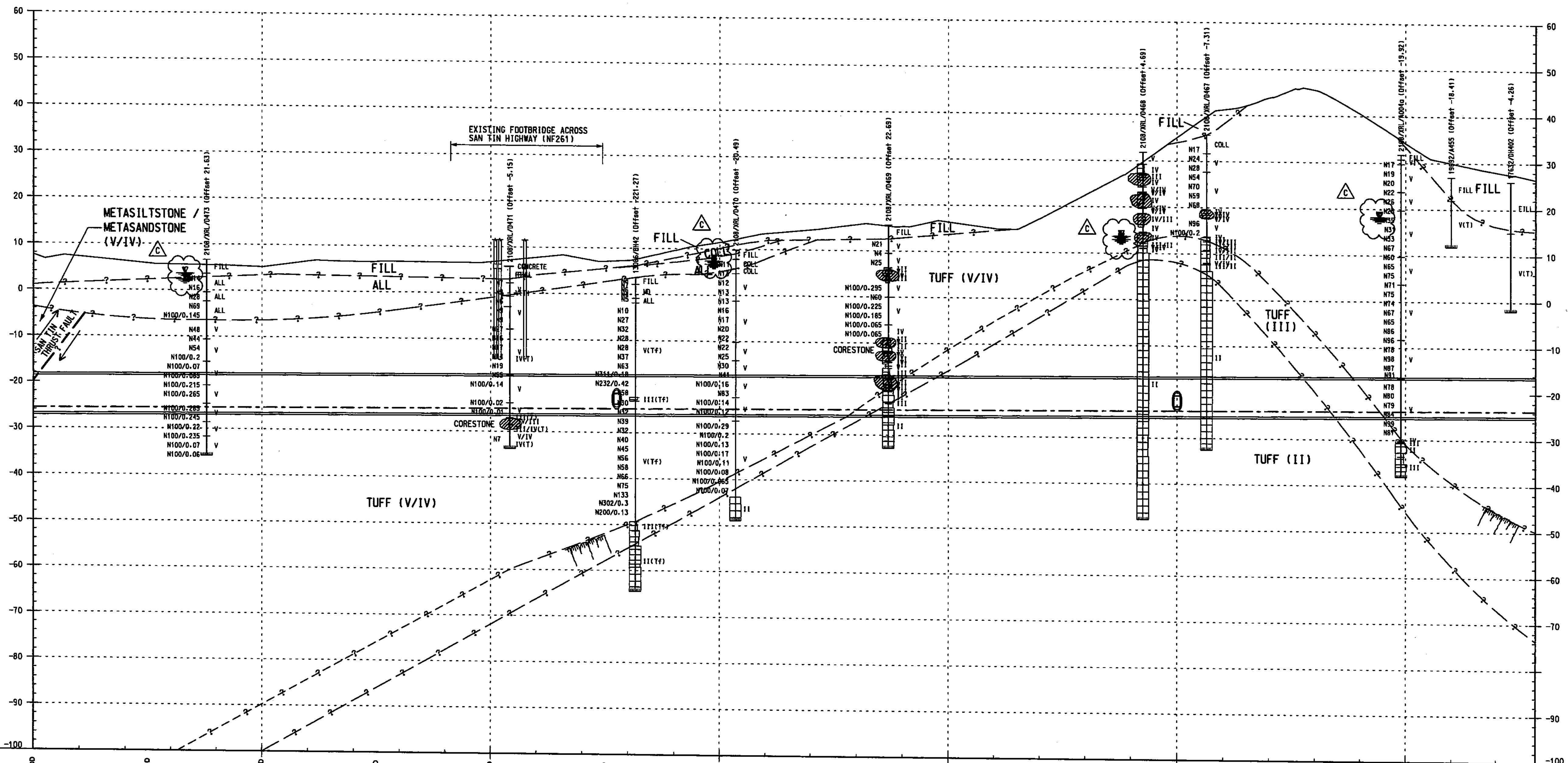
TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 1

SCALE AS SHOWN

DRAWING NO. 825/T/320/OAP/C05/111

REV. C

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| CHAINAGE (m) | | DD 117+600 | DD 117+650 | DD 117+700 | DD 117+750 | DD 117+800 | DD 117+850 | DD 117+900 | DD 117+950 | DD 118+000 | DD 118+050 | DD 118+100 | DD 118+150 | DD 118+200 | DD 118+250 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | MIXED | SOFT | | | | | | MIXED | BEDROCK | | | | MIXED | SOFT |
| ANTICIPATED Q VALUE (TUNNEL LEVEL) | MIN. - MAX. | N/A | | | | | | | | 1.1 - 6.7 | | | | N/A | |
| | TYPICAL VALUE | | | | | | | | | 3.6 | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| C | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR ARUP

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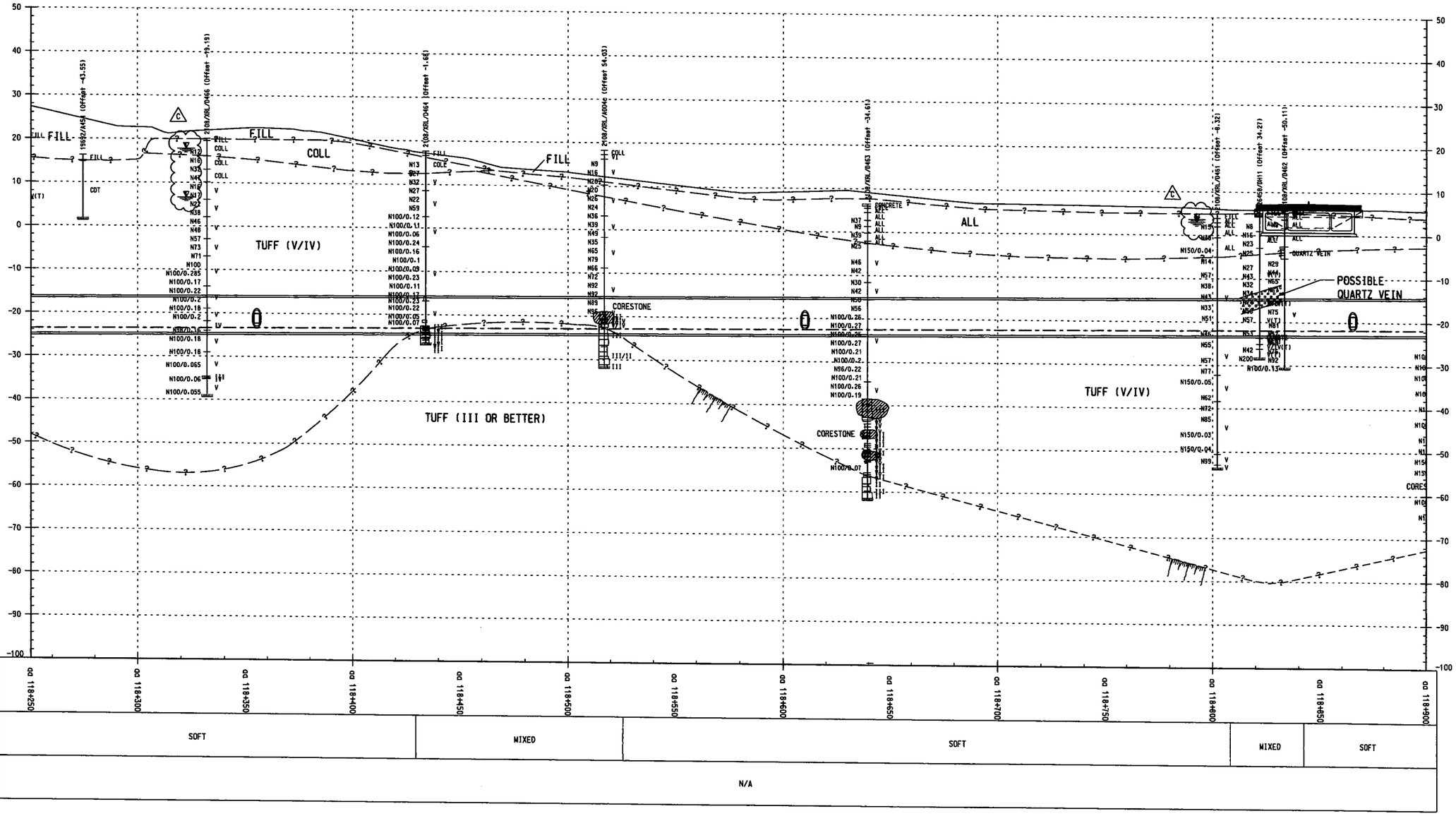
CADD REF. 825_T_320_OAP_C05_112C.dgn

TITLE
# CONTRACT 825
## MAI PO TO NGAU TAM MEI
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 2

SCALE AS SHOWN | DRAWING NO. 825/T/320/OAP/C05/112 | REV. C

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FILENAME: M:\C803\CONTRACT_803\825\Drawing\825_T_320_OAP_C05_112C.dgn

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| CHAINAGE (m) | @ 118+250 | @ 118+300 | @ 118+350 | @ 118+400 | @ 118+450 | @ 118+500 | @ 118+550 | @ 118+600 | @ 118+650 | @ 118+700 | @ 118+750 | @ 118+800 | @ 118+850 | @ 118+900 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | SOFT | | | | MIXED | | SOFT | | | | | | WIXED | SOFT |
| ANTICIPATED Q VALUE (TUNNEL LEVEL) MIN. - MAX. | N/A | | | | | | | | | | | | | |
| ANTICIPATED Q VALUE (TUNNEL LEVEL) TYPICAL VALUE | | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| C | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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CADD REF. 825_T_320_OAP_C05_113C.dgn

TITLE

CONTRACT 825

MAI PO TO NGAU TAM MEI

INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND) SHEET 3

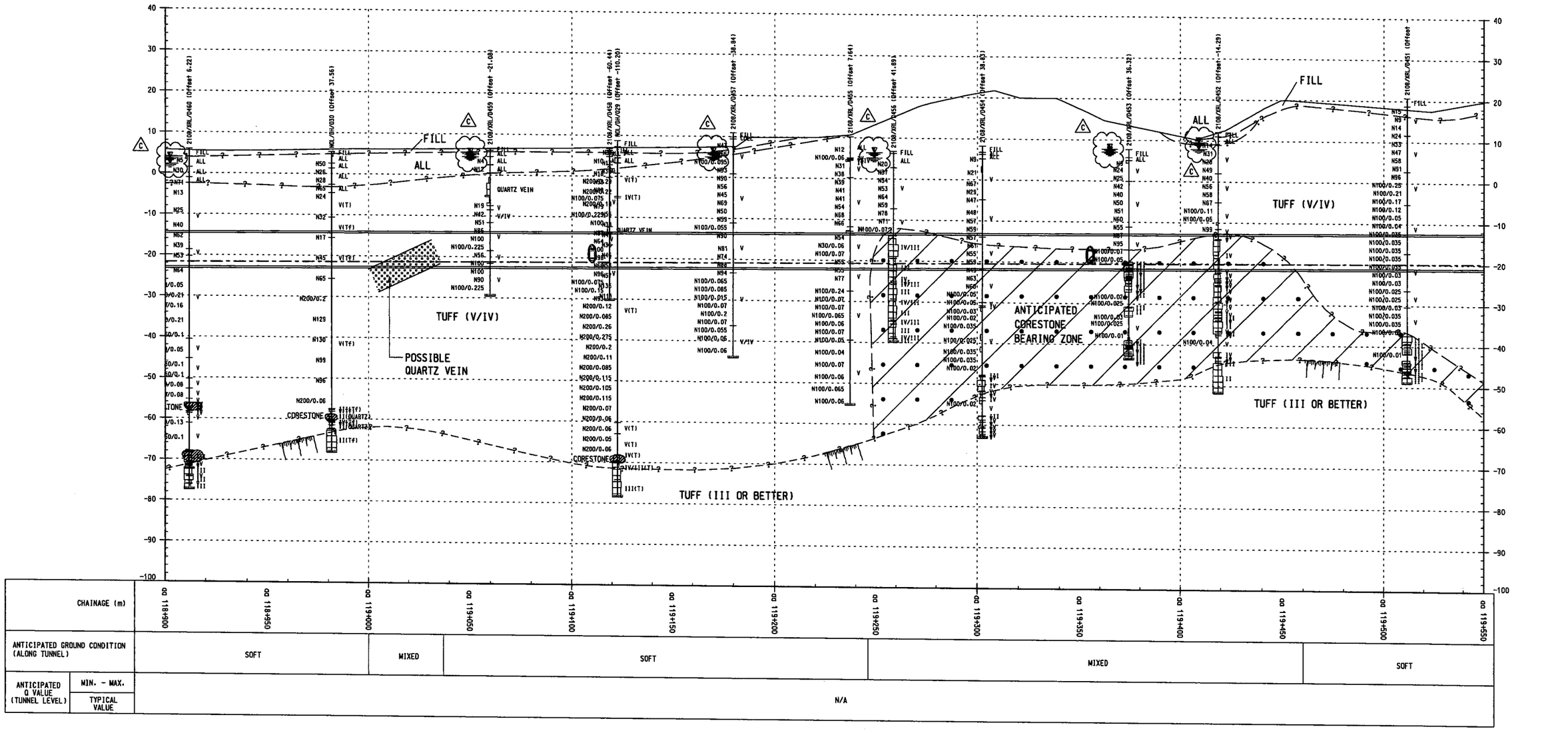
SCALE AS SHOWN (A1)

DRAWING NO. 825/T/320/OAP/C05/113

REV. C

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| CHAINAGE (m) | | @ 118+900 | @ 118+950 | @ 119+000 | @ 119+050 | @ 119+100 | @ 119+150 | @ 119+200 | @ 119+250 | @ 119+300 | @ 119+350 | @ 119+400 | @ 119+450 | @ 119+500 | @ 119+550 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | SOFT | | MIXED | | SOFT | | | | MIXED | | | | SOFT | |
| ANTICIPATED Q VALUE (TUNNEL LEVEL) | MIN. - MAX. | N/A | | | | | | | | | | | | | |
| | TYPICAL VALUE | | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

FOR REFERENCE ONLY

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| C | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_OAP_C05_114C.dgn

TITLE

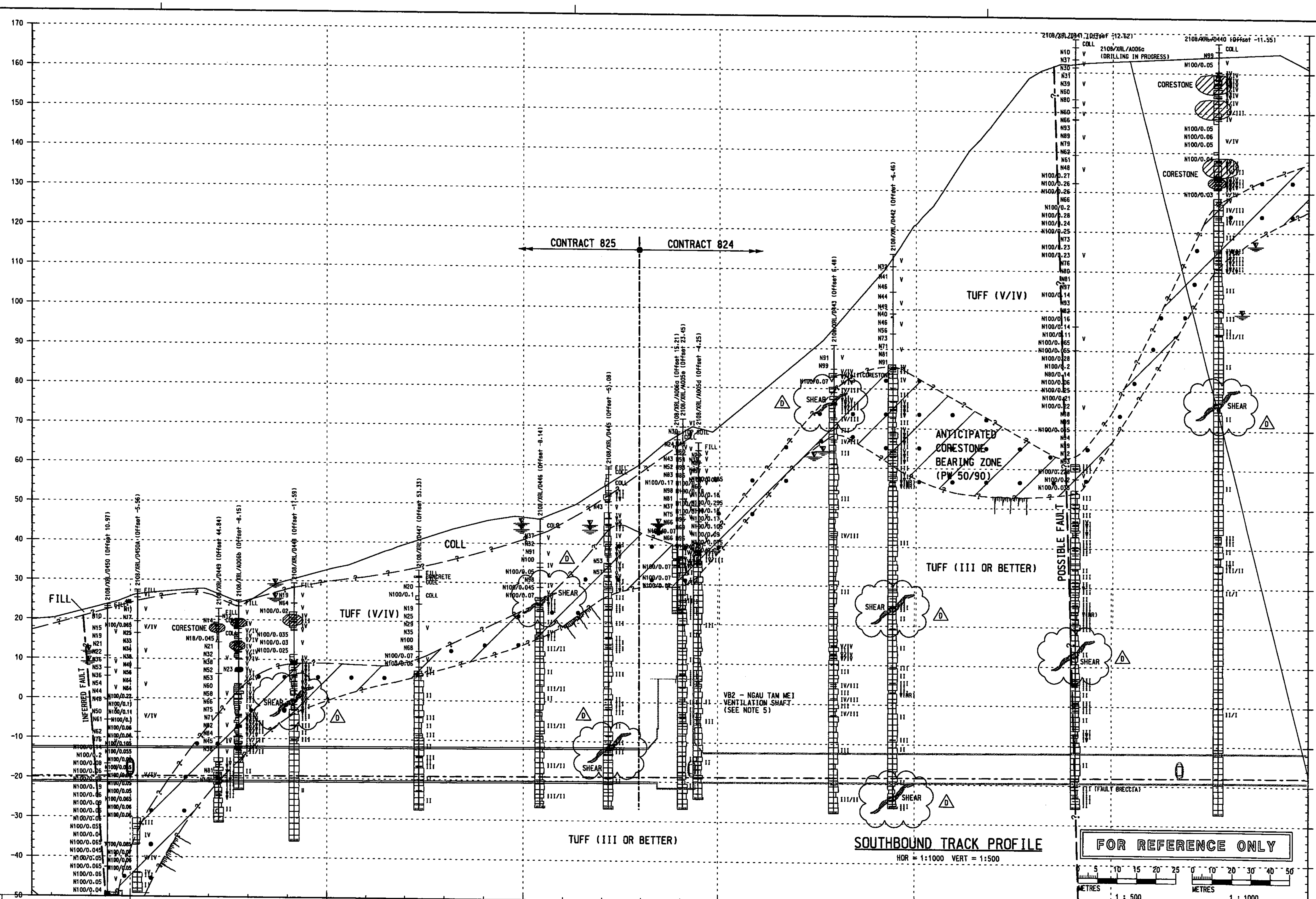
CONTRACT 825
MAI PO TO NGAU TAM MEI
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 4

SCALE: AS SHOWN

DRAWING NO.: 825/T/320/OAP/C05/114

REV.: C

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FILENAME: M:\C803\CONTRACT_803\825\Drawing\825_T_320_OAP_C05_114C.dgn




| CHAINAGE (m) | DD 119+550 | DD 119+600 | DD 119+650 | DD 119+700 | DD 119+750 | DD 119+800 | DD 119+850 | D 119+900 | D 119+950 | D 120+000 | D 120+050 | D 120+100 | D 120+150 | D 120+200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | SOFT | MIXED | BEDROCK | | | | | |
|---|---|---|---|---|---|---|---|---|
| ANTICIPATED Q VALUE (TUNNEL VALUE) — MIN. - MAX. | N/A | | 2.2 - 6.6 | 0.5 - 12 | 0.1 - 1.6 | 0.3 - 2.6 | 0.5 - 3.0 | 2.2 - 6.6 | 5.6 - 8.3 |
| ANTICIPATED Q VALUE (TUNNEL VALUE) — TYPICAL VALUE | N/A | | 3.6 | 2 | 0.9 | 2 | 1 | 3 | 7 |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| D | POST TENDER ISSUE | TW | 21OCT09 | JM |
| C | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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EXPRESS RAIL LINK

ORIGINATOR ARUP

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CADD REF. 825_T_320_OAP_C05_115D.dgn

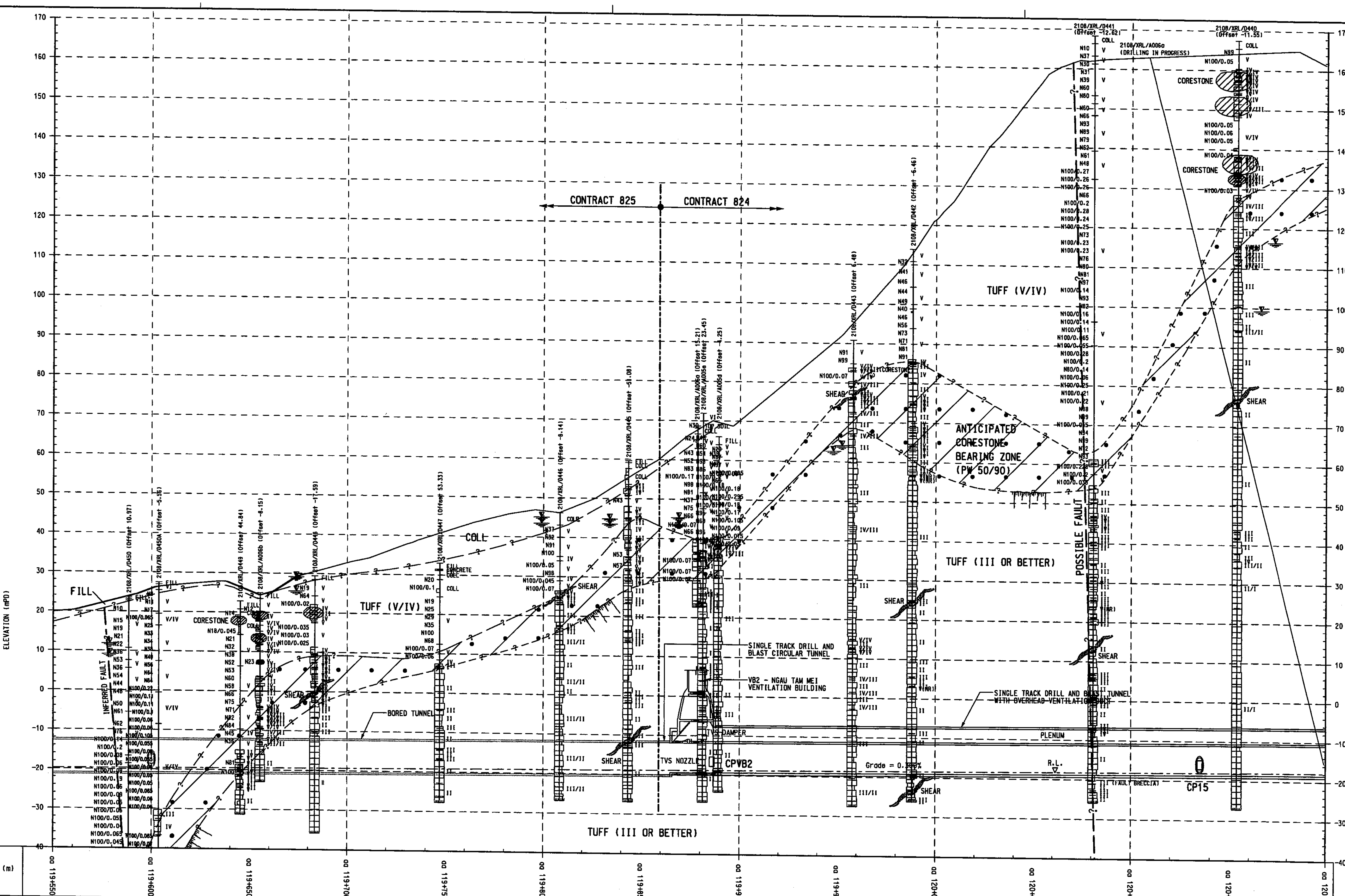
TITLE
# CONTRACT 825
## MAI PO TO NGAU TAM MEI
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 5

SCALE: AS SHOWN
DRAWING NO. 825/T/320/OAP/C05/115
REV. D

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MODELNAME: Default PRINTED BY: cskan 28/10/2009 6:00:48 PM
FILENAME: M:\C803\CONTRACT_803\825\Drawing\825_T_320_OAP_C05_115D.dgn

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | SOFT | MIXED | BEDROCK | | | | | | |
| INTERPRETED Q VALUE | MIN. - MAX. | N/A | | 2.2 - 6.6 | 0.5 - 12 | 0.1 - 1.6 | 0.3 - 2.6 | 0.1 - 2.2 | 0.5 - 3.0 | 2.2 - 6.6 | 5.6 - 8.3 |
| | WEIGHTED MEAN | | | 3.6 | 2.0 | 0.9 | 2.0 | 0.5 | 1.0 | 3.0 | 7.0 |
| CONSTRUCTION TYPE | | CONTRACT 825 TBM TUNNEL | | | | | | D & B SHAFT (824/T/331/OAP/T04/641) | SINGLE TRACK D & B TUNNEL WITH OVERHEAD VENT DUCT (824/T/330/OAP/T04/121) | | |
| TEMPORARY SUPPORT TYPE | | N/A | | | | | | VB2 SHAFT | TYPE IIP | TYPE IP | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

Scale bars: 0 5 10 15 20 25 METRES 1 : 500; 0 10 20 30 40 50 METRES 1 : 1000

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

ACP

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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EXPRESS RAIL LINK

ORIGINATOR ARUP

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CADD REF. 824_T_330_OAP_C05_111A1.dgn

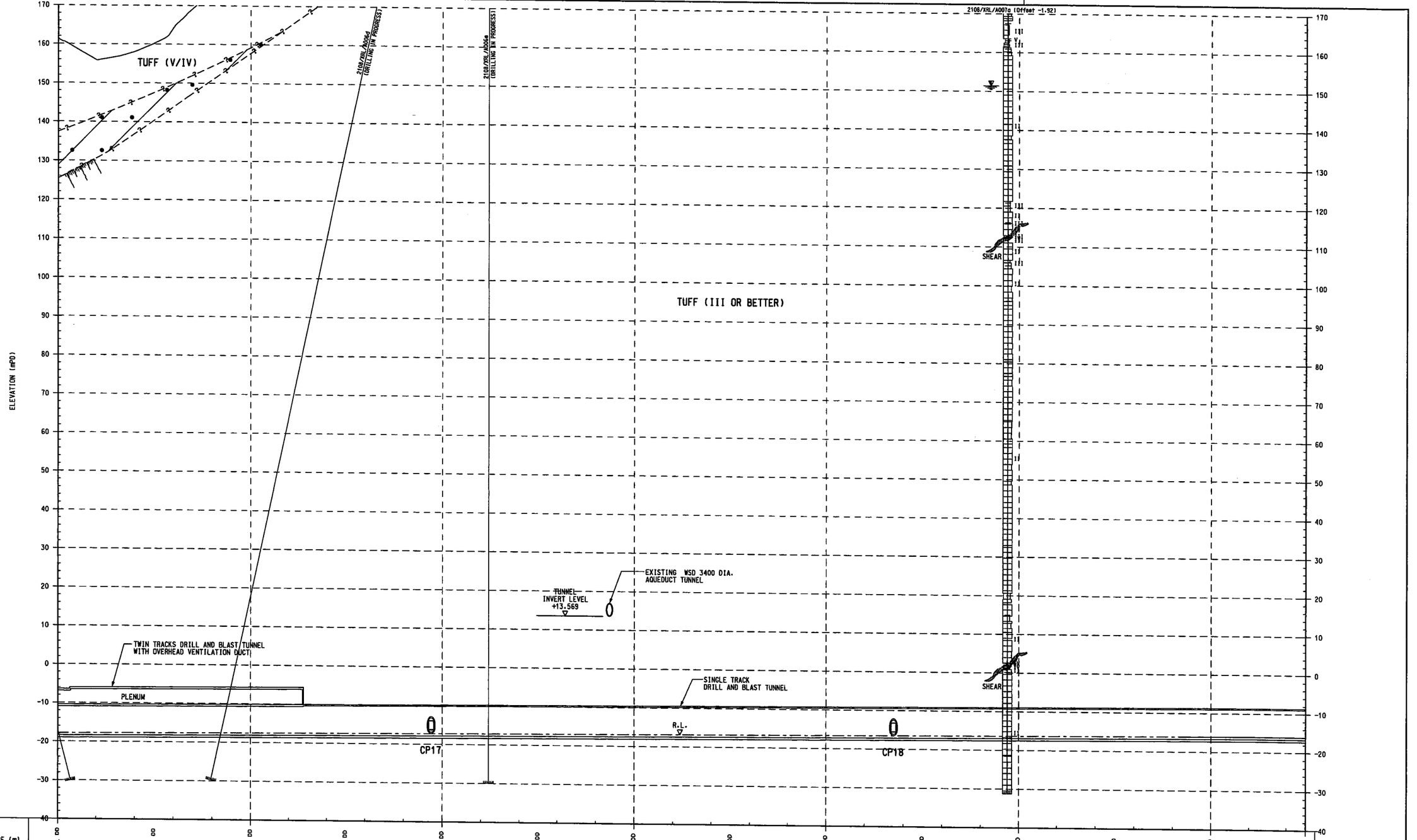
TITLE

# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
### INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND) SHEET 1

SCALE: AS SHOWN | DRAWING NO. 824/T/330/OAP/C05/111 | REV. A1

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FILENAME: M:\C803\CONTRACT_803\824\Drawing\824_T_330_OAP_C05_111A1.dgn

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| CHAINAGE (m) | | | | |
|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | BEDROCK | | |
| INTERPRETED Q VALUE | MIN. - MAX. | 5.6 - 8.3 | 5 - 20 (LOCALLY COULD BE AS LOW AS<0.1 WHEN STRUCTURAL FEATURE IS ENCOUNTERED) | |
| | WEIGHTED MEAN | | 7.0 | |
| CONSTRUCTION TYPE | | TWIN TRACK D & B TUNNEL WITH OVERHEAD VENT DUCT (824/T/330/DAP/T04/171) | | SINGLE TRACK D & B TUNNEL (824/T/330/DAP/T04/111) |
| TEMPORARY SUPPORT TYPE | | TYPE IXC | | TYPE II |

0 5 10 15 20 25 METRES
1 : 500

0 10 20 30 40 50 METRES
1 : 1000

## SOUTHBOUND TRACK PROFILE HOR = 1:1000 VERT = 1:500

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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ORIGINATOR: ARUP
Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

EXPRESS RAIL LINK

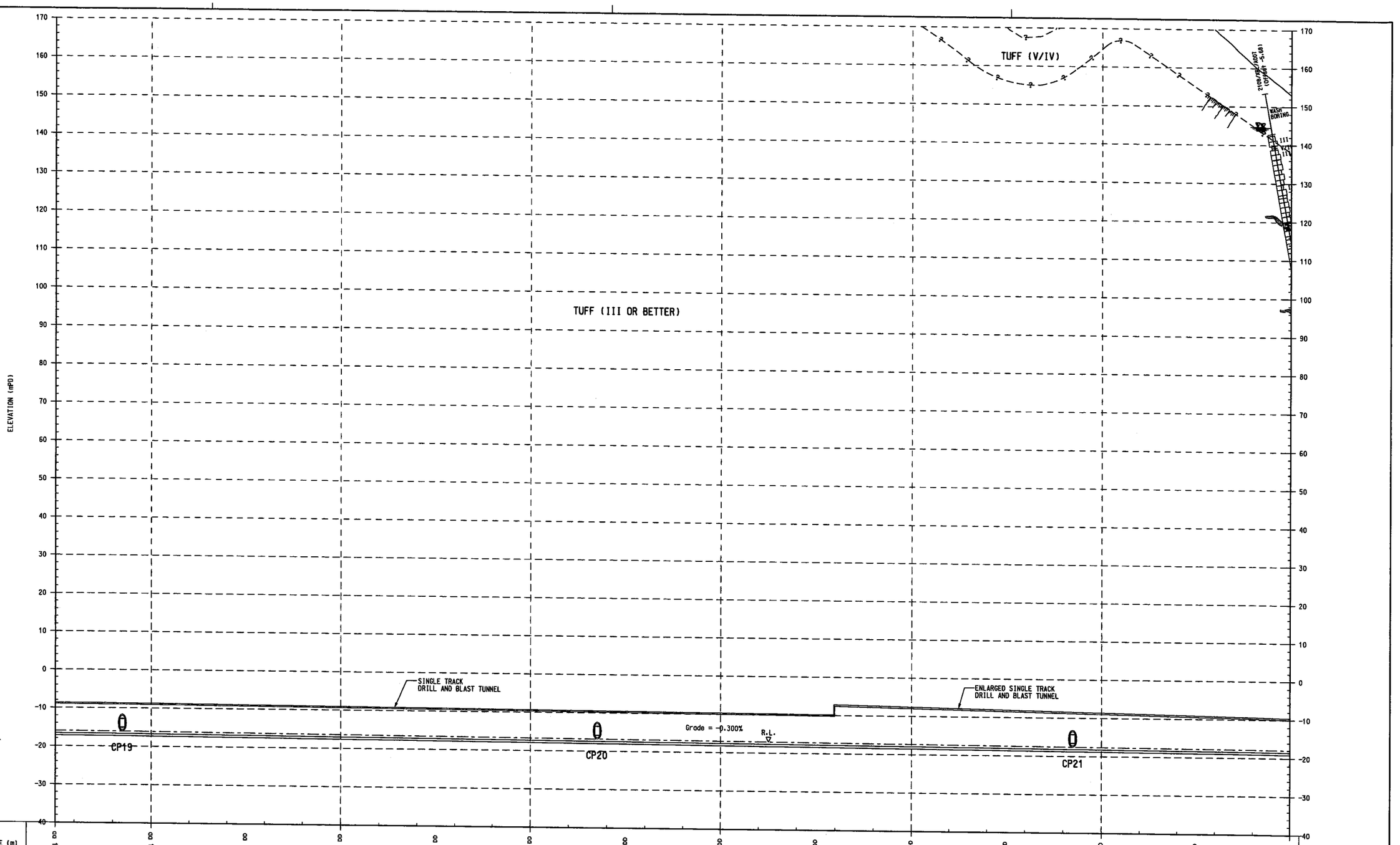
CADD REF. 824_T_330_OAP_C05_112A1.dgn

TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 2

SCALE 1: 1000 (A1)
DRAWING NO. 824/T/330/OAP/C05/112
REV. A1

PLOT DRV: M:\CB03\CONTRACT_803\CAD_ADMIN\PLOTDRIVER\LHP_208683-A3.PLT
MODELNAME: Default PRINTED BY: cskcn 29/10/2009 lh0653 AM
FILENAME: M:\CB03\CONTRACT_803\824\Drawing\824_T_330_OAP_C05_112A1.dgn

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| CHAINAGE (m) | | 120+650 | 120+900 | 120+950 | 121+000 | 121+050 | 121+100 | 121+150 | 121+200 | 121+250 | 121+300 | 121+350 | 121+400 | 121+450 | 121+500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | BEDROCK | | | | | | | | | | | | | |
| INTERPRETED Q VALUE | MIN. - MAX. | 5 - 20 (LOCALLY COULD BE AS LOW AS=<0.1 WHEN STRUCTURAL FEATURE IS ENCOUNTERED) | | | | | | | | | | | | 1.1 - 3.3 | |
| | WEIGHTED MEAN | 7.0 | | | | | | | | | | | | 3 | |
| CONSTRUCTION TYPE | | SINGLE TRACK D & B TUNNEL (824/T/330/DAP/T04/111) | | | | | | | ENLARGED D & B TUNNEL FOR BIFURCATION (824/T/330/DAP/T04/151) | | | | | | |
| TEMPORARY SUPPORT TYPE | | TYPE II | | | | | | | TYPE IC | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

PLOT DRV: M:\C803\CONTRACT_803\CAD_ADMIN\PLOTDRIVER\LHP_206683-A3.PLT
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FILENAME: M:\C803\CONTRACT_803\824\Drawing\824_T_330_OAP_C05_113A1.dgn

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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ORIGINATOR ARUP

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CADD REF. 824_T_330_OAP_C05_113A1.dgn

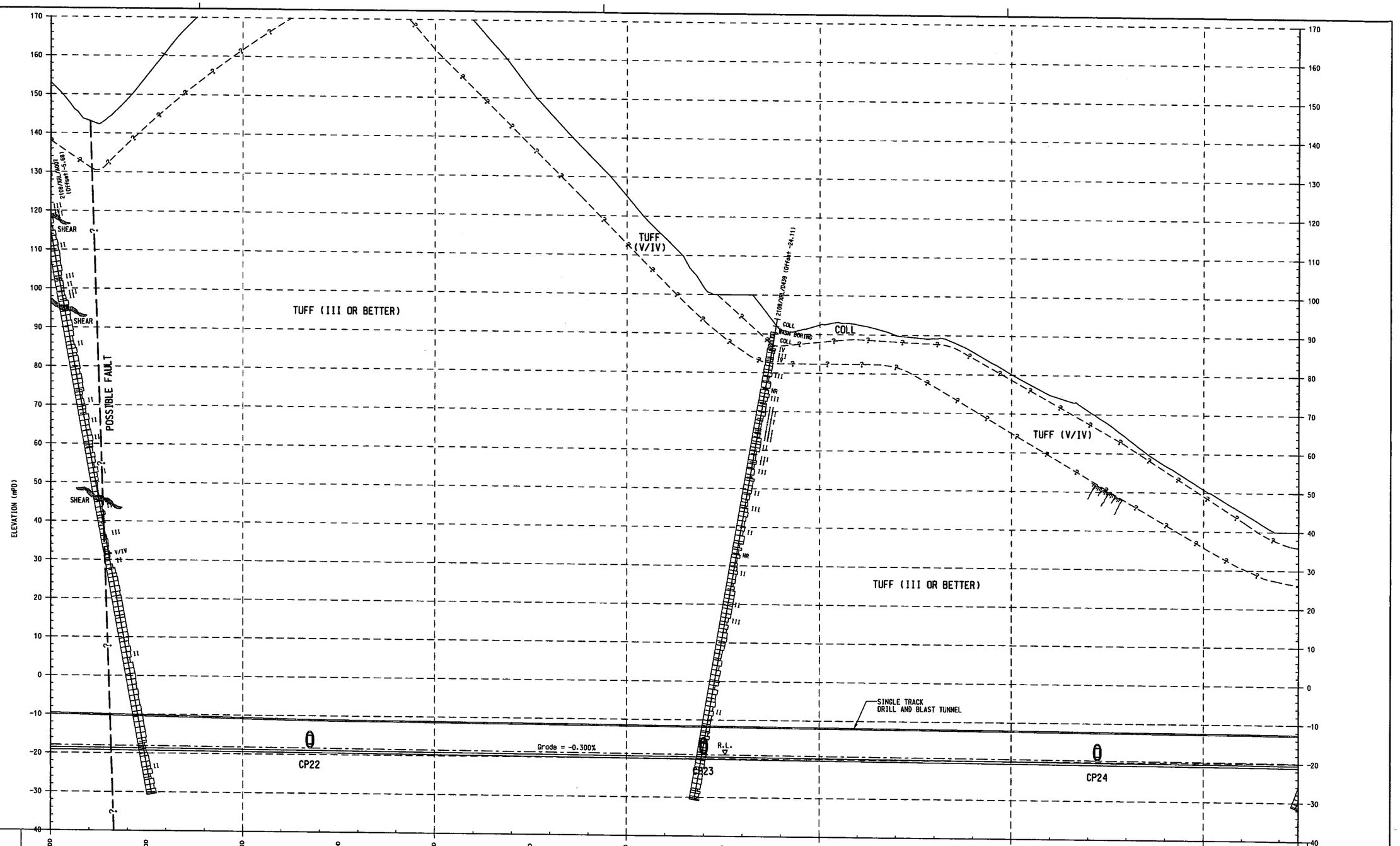
TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION
(SOUTHBOUND)
SHEET 3

SCALE AS SHOWN (A1)

DRAWING NO. 824/T/330/OAP/C05/113

REV. A1

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| | | | | | | |
|---|---|---|---|---|---|---|
| CHAINAGE (m) | | | | | | |
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | BEDROCK | | | | |
| INTERPRETED Q VALUE | MIN. - MAX. | 1.1 - 3.3 | 0.1-0.5 | 1.1-3.3 | 5.0 - 20 (LOCALLY COULD BE AS LOW AS<=0.1 WHEN STRUCTURAL FEATURE IS ENCOUNTERED) | 0.7 - 4.1 |
| | WEIGHTED MEAN | 3 | 0.2 | 3 | 7.0 | 3.0 |
| CONSTRUCTION TYPE | | ENLARGED D & B TUNNEL FOR BIFURCATION (824/T/330/OAP/T04/111 - 151) | | | SINGLE TRACK D & B TUNNEL (824/T/330/OAP/T04/111) | |
| TEMPORARY SUPPORT TYPE | | TYPE IC | TYPE IIC /TYPE IIP | | TYPE IP | TYPE II |

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

## SOUTHBOUND TRACK PROFILE HOR = 1:1000 VERT = 1:500

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 824_T_330_OAP_C05_114A1.dgn

TITLE

# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
### INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND) SHEET 4

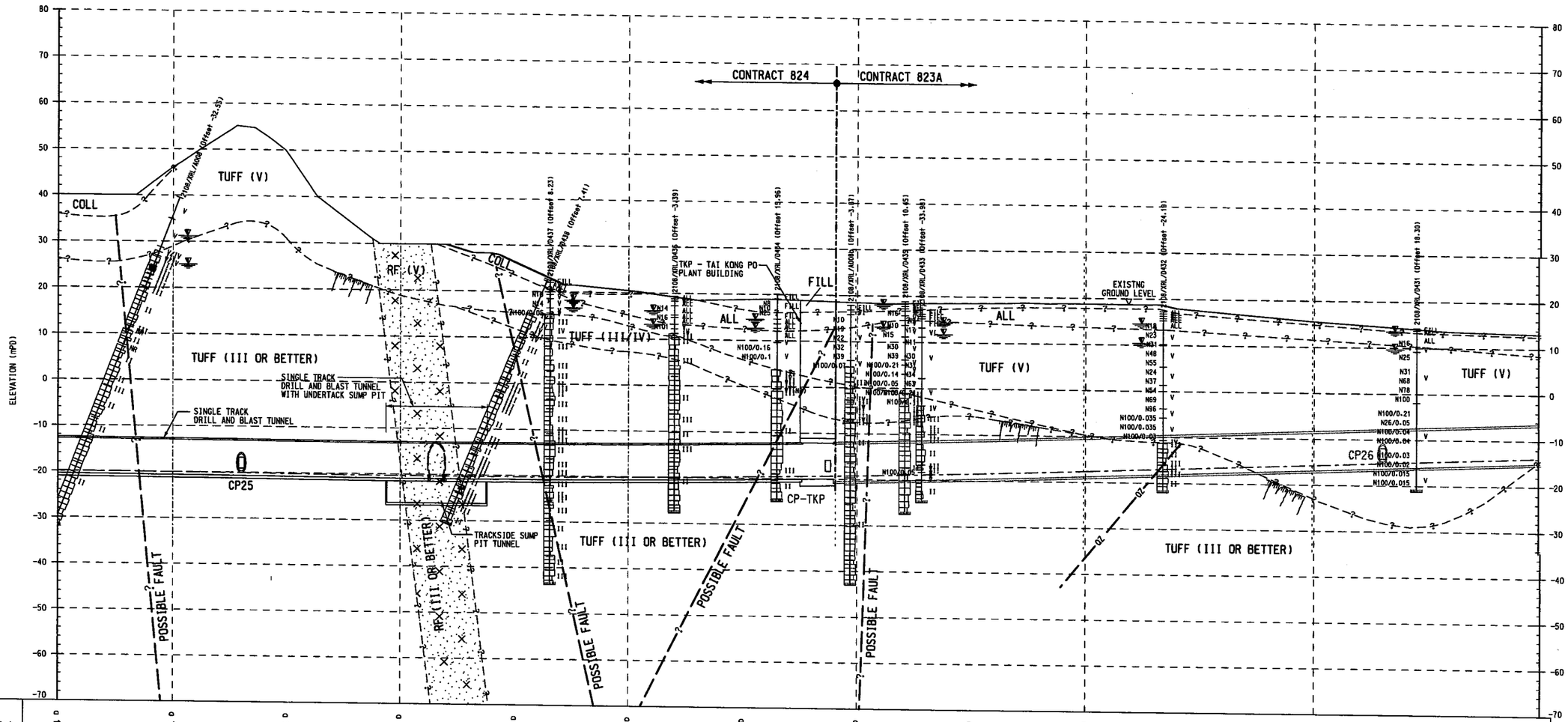
SCALE AS SHOWN (A1)

DRAWING NO. 824/T/330/OAP/C05/114

REV. A1

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| CHAINAGE (m) | @ 122+150 | @ 122+200 | @ 122+250 | @ 122+300 | @ 122+350 | @ 122+400 | @ 122+450 | @ 122+500 | @ 122+550 | @ 122+600 | @ 122+650 | @ 122+700 | @ 122+750 | @ 122+800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | BEDROCK | | | | | | | | | MIXED | SOFT | | | |
| INTERPRETED Q VALUE MIN. – MAX. | 0.7 – 4.1 | 0.1 – 0.7 | 0.7 – 4.1 | 0.1 – 6.3 | 0.03 – 0.4 | 0.6 – 1.6 | 0.04 – 0.4 | 0.3 – 2.0 | 0.1 – 1 | 0.2 – 2.1 | | | | |
| INTERPRETED Q VALUE WEIGHTED MEAN | 3.0 | 0.3 | 3.0 | 1 | 0.09 | 1.0 | 0.3 | 1.5 | 0.5 | 1.0 | N/A | | | |
| CONSTRUCTION TYPE | SINGLE TRACK D & B TUNNEL (824/T/330/OAP/T04/111) | | | SINGLE TRACK D & B TUNNEL WITH SUMP PIT (824/T/330/OAP/T04/431) | SINGLE TRACK D & B TUNNEL (824/T/330/OAP/T04/111) | | | SINGLE TRACK D & B TUNNEL (824/T/330/OAP/T04/471) | D & B SHAFT (824/T/330/OAP/T04/541) | | | | | |
| TEMPORARY SUPPORT TYPE | TYPE II | TYPE IV | TYPE II | TYPE III | TYPE V | TYPE III | | TYPE VI | EAP3 | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

1 : 500 METRES (0 5 10 15 20 25)

1 : 1000 METRES (0 10 20 30 40 50)

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 18SEP09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 18/SEP/2009 |

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CADD REF. 824_T_330_OAP_C05_115A1.dgn

TITLE

CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 5

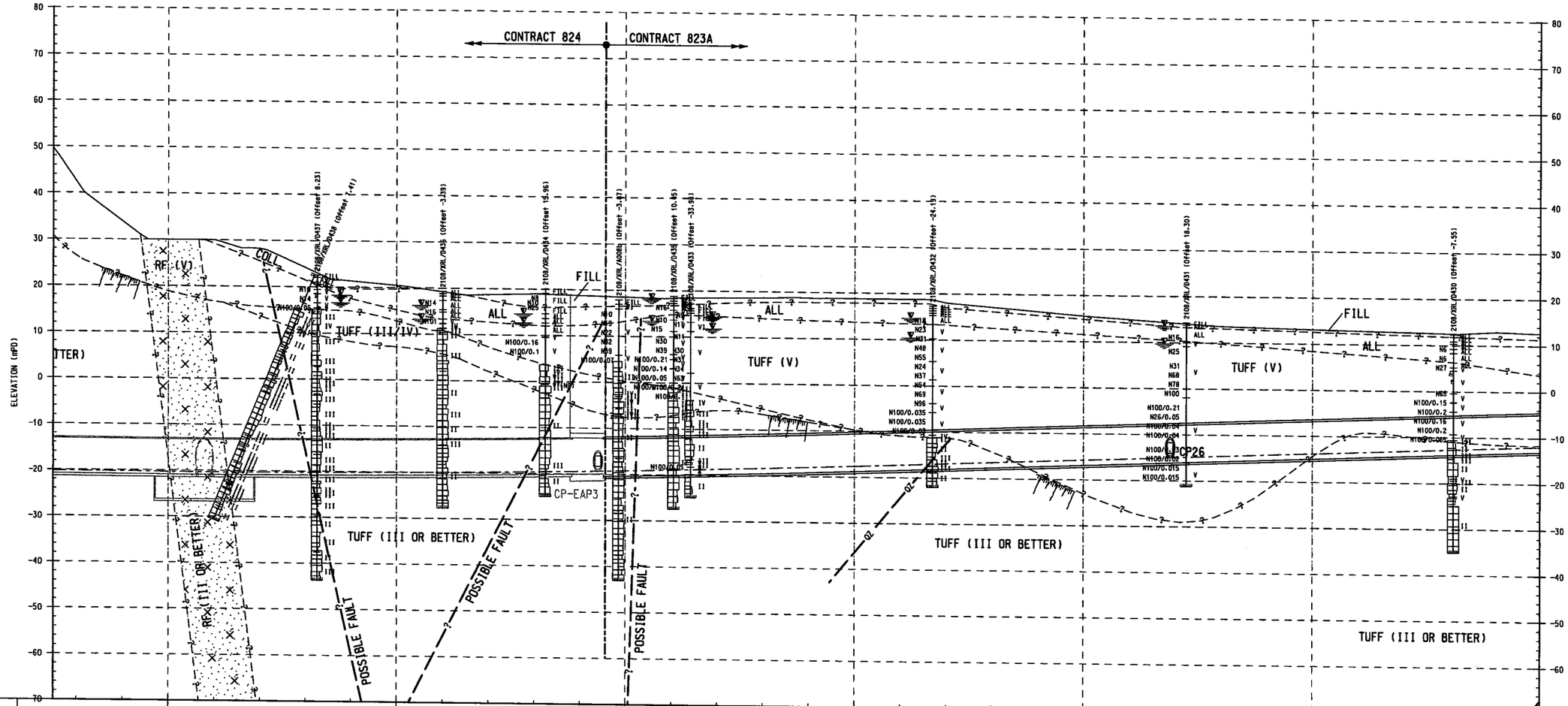
SCALE AS SHOWN (A1)

DRAWING NO. 824/T/330/OAP/C05/115

REV. A1

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| CHAINAGE (m) | @ 122+250 | @ 122+300 | @ 122+350 | @ 122+400 | @ 122+450 | @ 122+500 | @ 122+550 | @ 122+600 | @ 122+650 | @ 122+700 | @ 122+750 | @ 122+800 | @ 122+850 | @ 122+900 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | BEDROCK | | | | | | | | MIXED | SOFT | | MIXED | | |
| INTERPRETED Q VALUE MIN. - MAX. | 0.7 - 4.1 | 0.1 - 6.3 | | 0.03 - 0.4 | 0.6 - 1.6 | 0.04 - 0.4 | 0.3 - 2.0 | 0.1 - 1 | 0.2 - 2.1 | | | | | |
| INTERPRETED Q VALUE WEIGHTED MEAN | 3 | 1 | | 0.09 | 1.0 | 0.3 | 1.5 | 0.5 | 1.0 | N/A | | | | |
| CONSTRUCTION TYPE | SINGLE TRACK D & B TUNNEL (824/T/330/OAP/T04/111) | SINGLE TRACK D & B TUNNEL WITH SUMP PIT 824/T/330/OAP/T04/431 | SINGLE TRACK D & B TUNNEL (824/T/330/OAP/T04/111) | | | SINGLE TRACK D & B TUNNEL (824/T/330/ OAP/T04/471) | D & B SHAFT (824/T/ 330/OAP/ T04/541) | | | | | | | |
| TEMPORARY SUPPORT TYPE | TYPE II | TYPE III | | TYPE V | TYPE III | TYPE VI | EAP3 | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 29/MAY/2009 |

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ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 823A_T_340_OAP_C05_111A1.dgn

TITLE
CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 1

SCALE AS SHOWN (A1)

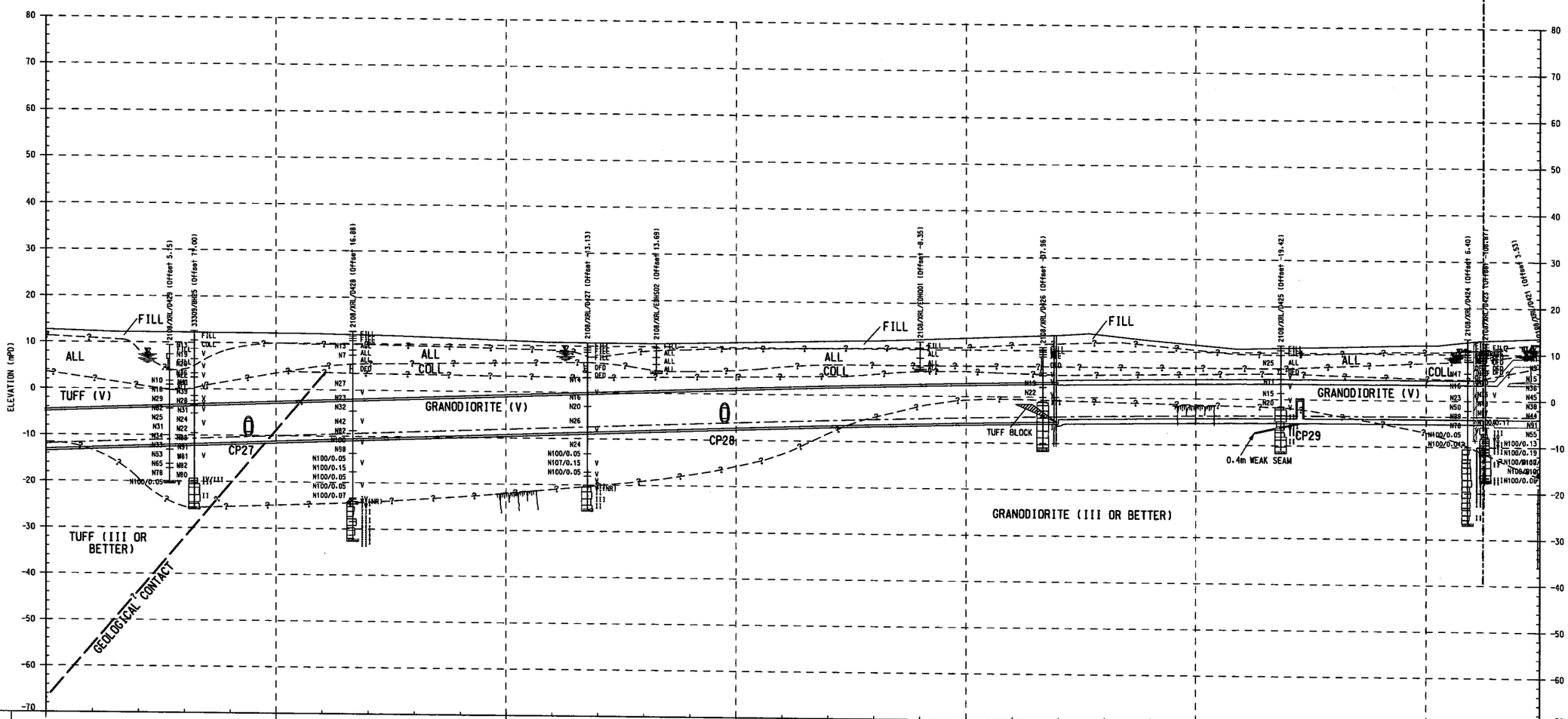
DRAWING NO. 823A/T/340/OAP/C05/111

REV. A1

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FILENAME:

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CONTRACT 823A | CONTRACT 823B




| CHAINAGE (m) | | 0 122+900 | 0 122+950 | 0 123+000 | 0 123+050 | 0 123+100 | 0 123+150 | 0 123+200 | 0 123+250 | 0 123+300 | 0 123+350 | 0 123+400 | 0 123+450 | 0 123+500 | 0 123+550 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | MIXED | SOFT | | | | | | MIXED | | | | | SOFT | |
| INTERPRETED Q VALUE | MIN. - MAX. | N/A | | | | | | | | | | | | | |
| | WEIGHTED MEAN | | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 14AUG09 | JM |

| DRAWN | CSK |
|---|---|
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 29/MAY/2009 |

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ORIGINATOR ARUP

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CADD REF. 823A_T_340_OAP_C05_112A1.dgn

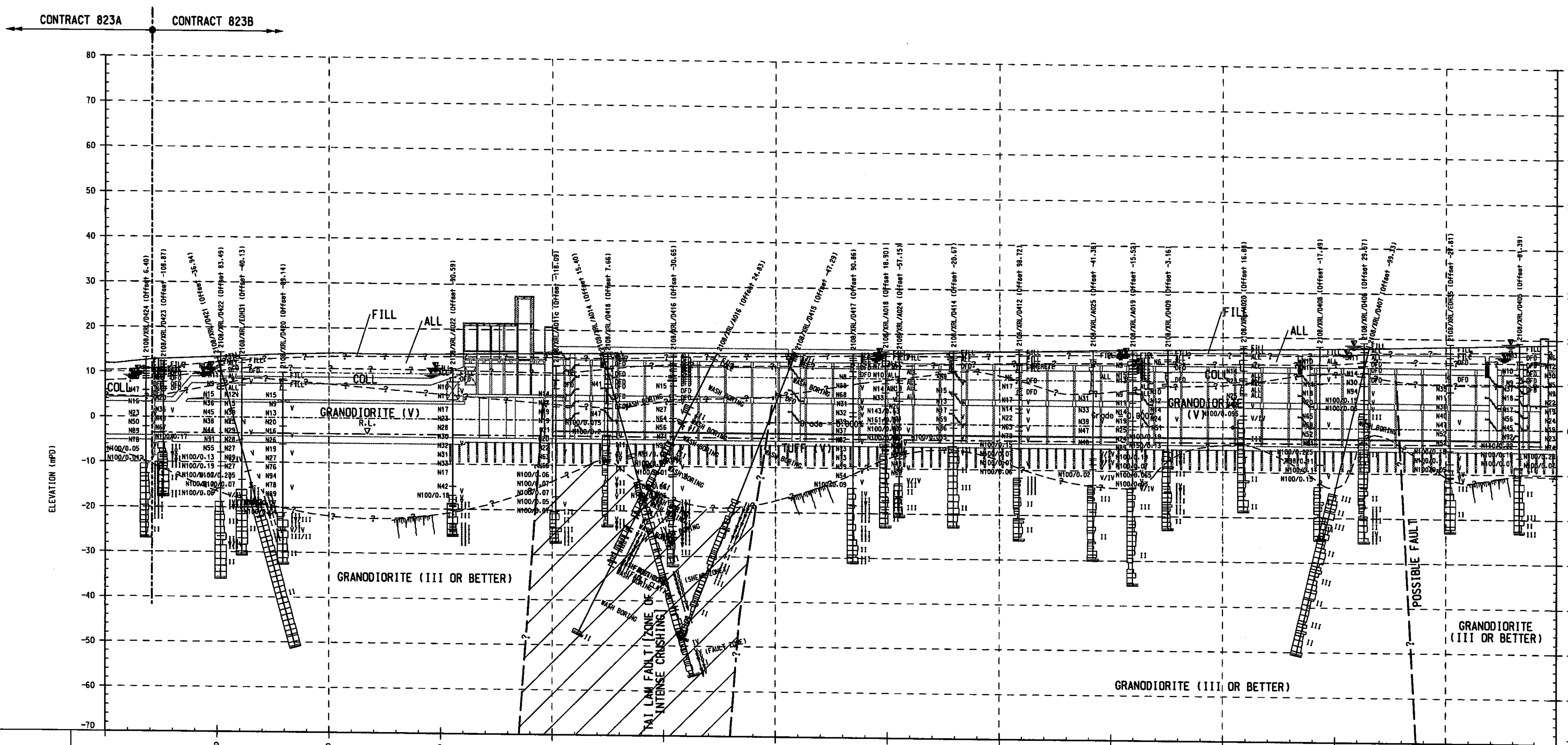
TITLE
CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 2

SCALE AS SHOWN (A1)

DRAWING NO. 823A/T/340/OAP/C05/112

REV. A1

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| CHAINAGE (m) | | 123+550 | 123+600 | 123+650 | 123+700 | 123+750 | 123+800 | 123+850 | 123+900 | 123+950 | 124+000 | 124+050 | 124+100 | 124+150 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | SOFT | | | | | | | | | | MIXED | SOFT | |
| INTERPRETED Q VALUE | MIN. - MAX. | N/A | | | | | | | | | | | | |
| | WEIGHTED MEAN | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

0 5 10 15 20 25 METRES 1 : 500

0 10 20 30 40 50 METRES 1 : 1000

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ACP

| REV | DESCRIPTION | BY | DATE | APPROVED | REV | DESCRIPTION | BY | DATE | APPROVED |
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| | | | | | A1 | TENDER DRAWINGS ACPS ISSUE | TW | 30OCT09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 30/OCT/2009 |

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EXPRESS RAIL LINK

ORIGINATOR

ARUP

Supported by :
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Knight Frank, SIYUAN,
Urbis, BMT Asia

CADD REF. 823B_T_350_OAP_C05_111A1.dgn

TITLE

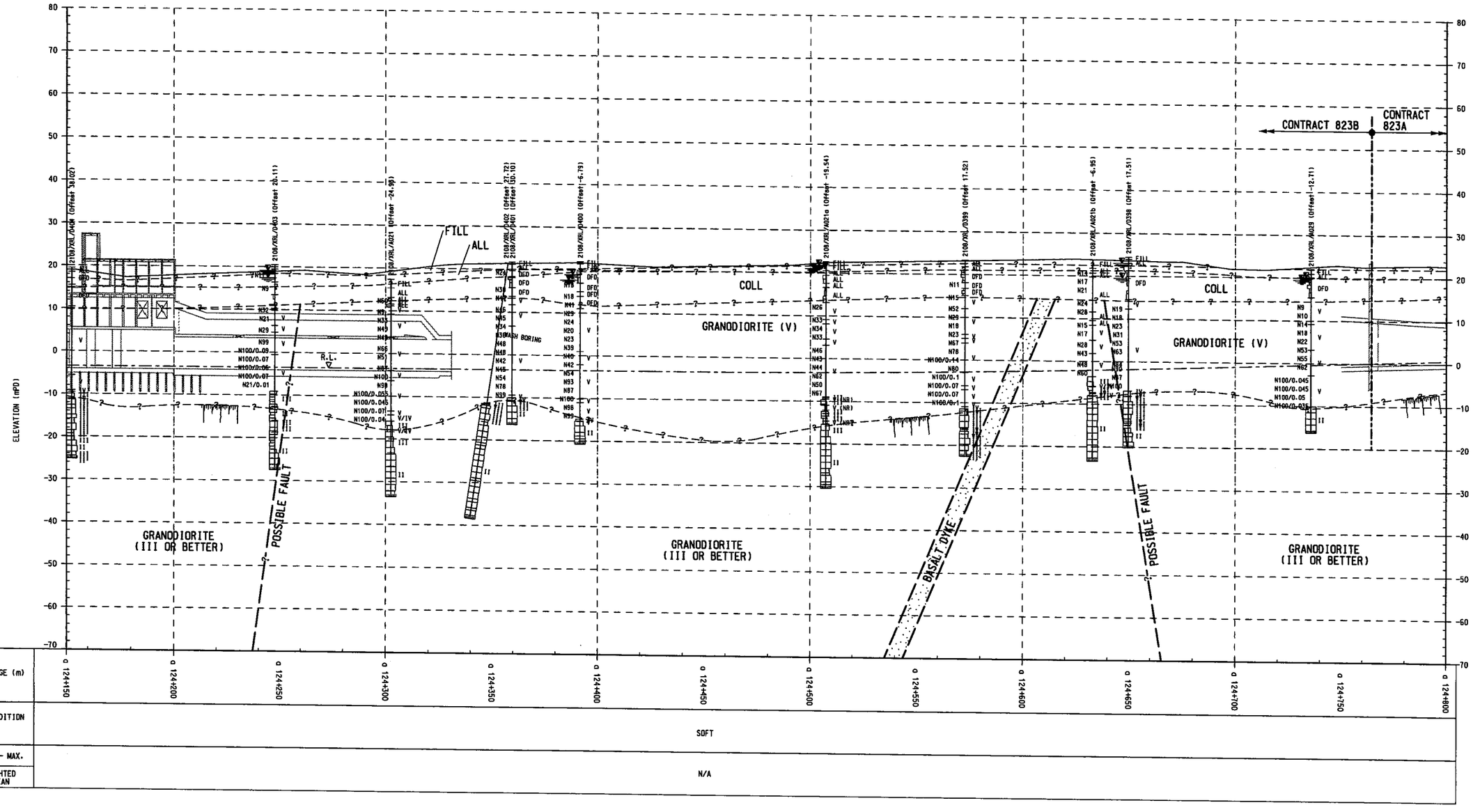
# CONTRACT 823B

## SHEK KONG STABLING SIDINGS AND ERS

INTERPRETED GEOLOGICAL LONGITUDINAL SECTION
(SOUTHBOUND)
SHEET 1

SCALE AS SHOWN (A1) | DRAWING NO. 823B/T/350/OAP/C05/111 | REV. A1

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| CHAINAGE (m) | | @ 124+150 | @ 124+200 | @ 124+250 | @ 124+300 | @ 124+350 | @ 124+400 | @ 124+450 | @ 124+500 | @ 124+550 | @ 124+600 | @ 124+650 | @ 124+700 | @ 124+750 | @ 124+800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | | SOFT | | | | | | | | | | | | | |
| INTERPRETED Q VALUE | MIN. – MAX. | N/A | | | | | | | | | | | | | |
| | WEIGHTED MEAN | | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

METRES 0 5 10 15 20 25 — 1 : 500

METRES 0 10 20 30 40 50 — 1 : 1000

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 30OCT09 | JM |

ACP

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 30/OCT/2009 |

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ORIGINATOR ARUP

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CADD REF. 823B_T_350_OAP_C05_112A1.dgn

TITLE
CONTRACT 823B
SHEK KONG STABLING SIDINGS AND ERS
INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
SHEET 2

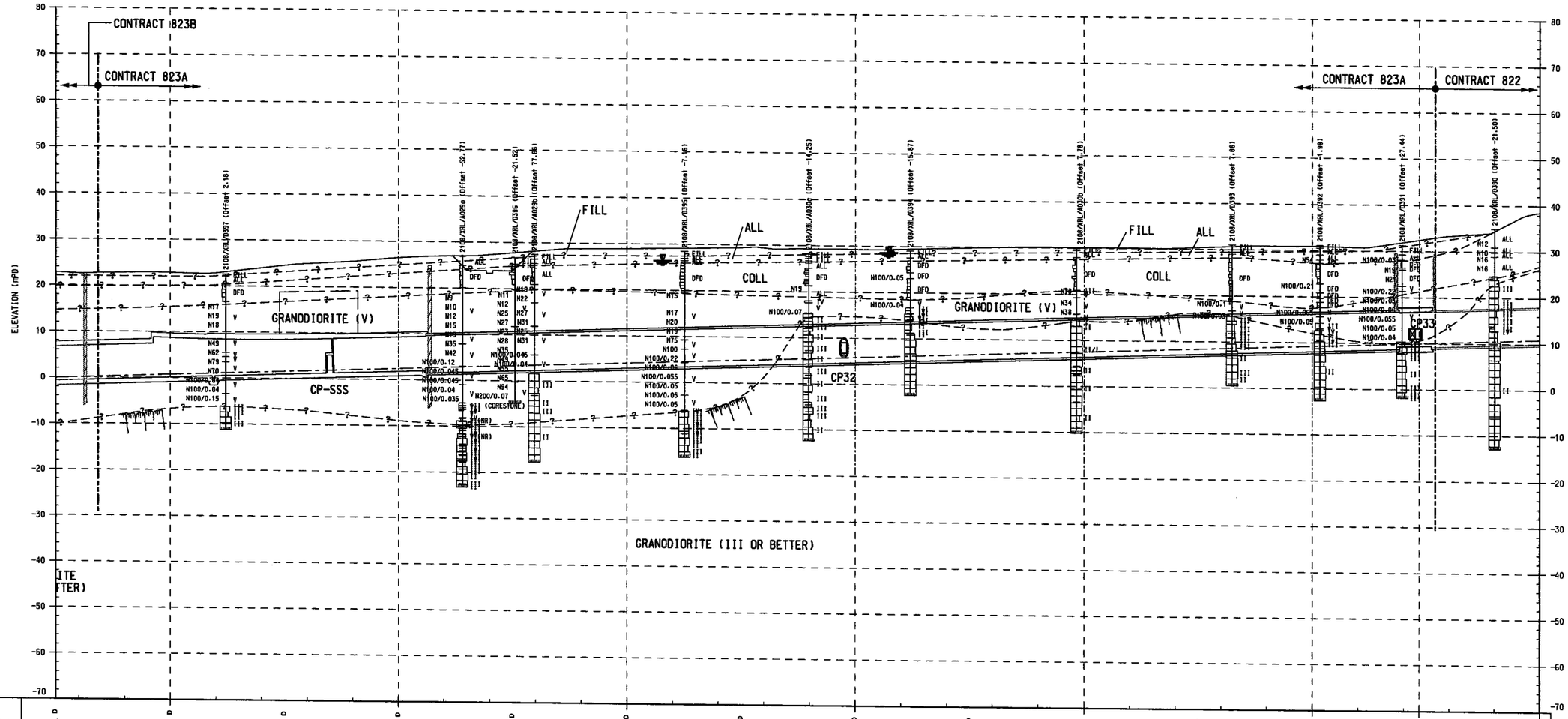
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DRAWING NO. 823B/T/350/OAP/C05/112

REV. A1

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| CHAINAGE (m) | a 124+750 | a 124+800 | a 124+850 | a 124+900 | a 124+950 | a 125+000 | a 125+050 | a 125+100 | a 125+150 | a 125+200 | a 125+250 | a 125+300 | b 125+350 b 125+341 | b 125+400 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTICIPATED GROUND CONDITION (ALONG TUNNEL) | SOFT | | | | | | | MIXED | ROCK / MIXED | | | MIXED | | |
| INTERPRETED Q VALUE — MIN. - MAX. | N/A | | | | | | | | | | | | | |
| INTERPRETED Q VALUE — WEIGHTED MEAN | | | | | | | | | | | | | | |

## SOUTHBOUND TRACK PROFILE

HOR = 1:1000 VERT = 1:500

METRES 0 5 10 15 20 25 — 1 : 500

METRES 0 10 20 30 40 50 — 1 : 1000

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | CSK |
| DESIGNED | HHY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 29/MAY/2009 |

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ORIGINATOR ARUP

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CADD REF. 823A_T_341_OAP_C05_111A1.dgn

TITLE

# CONTRACT 823A
## TAI KONG PO TO TSE UK TSUEN
### INTERPRETED GEOLOGICAL LONGITUDINAL SECTION (SOUTHBOUND)
### SHEET 1

SCALE 1: 1000 (A1)

DRAWING NO. 823A/T/341/OAP/C05/111

REV. A1

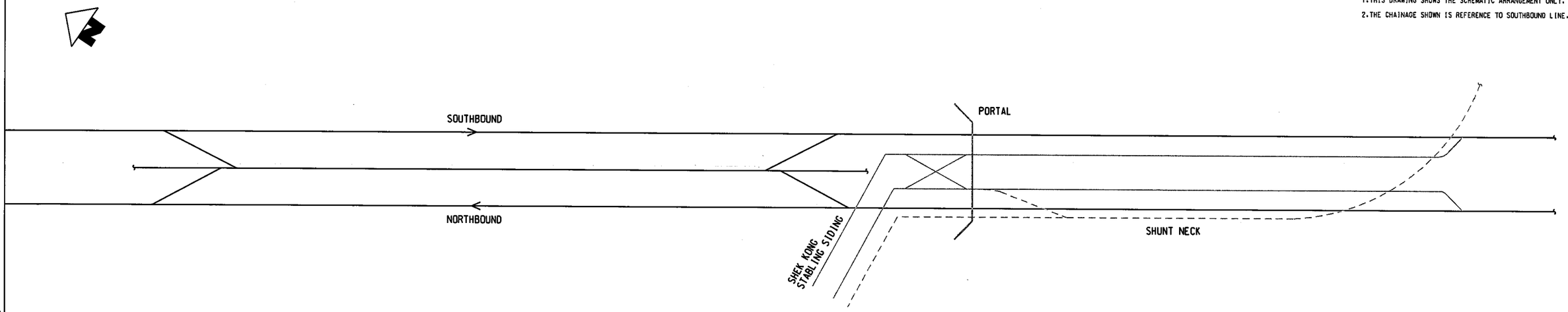
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# Appendix C

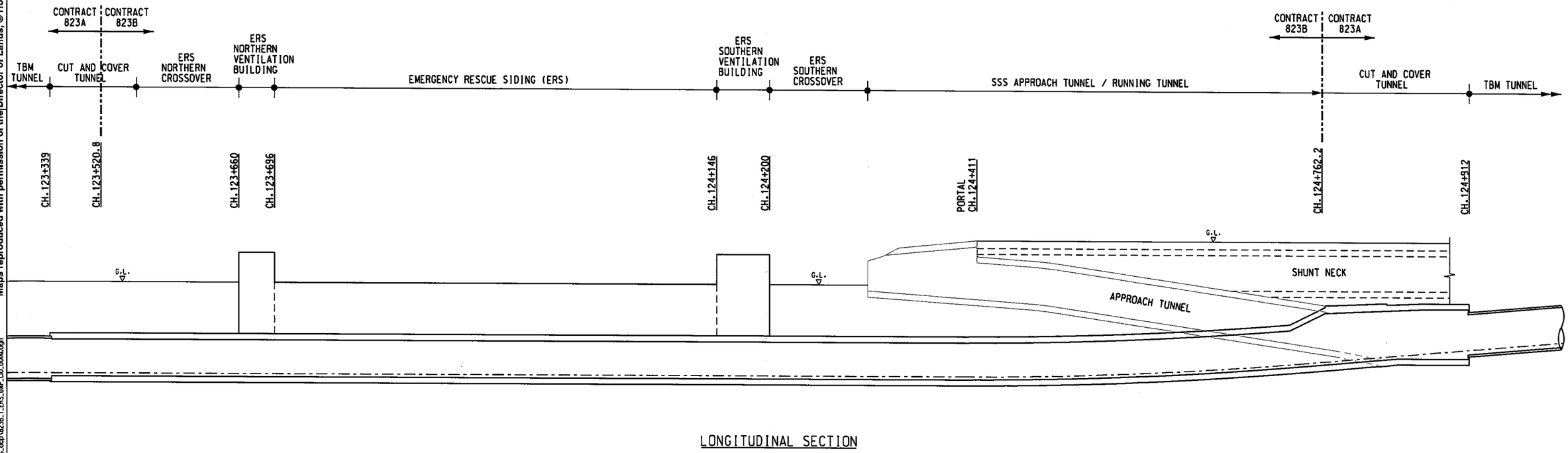
## Works Contract 823A & 823B – ERS / SSS Drawings

NOTES:

1. THIS DRAWING SHOWS THE SCHEMATIC ARRANGEMENT ONLY.
2. THE CHAINAGE SHOWN IS REFERENCE TO SOUTHBOUND LINE.




PLAN




LONGITUDINAL SECTION

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ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | WC | 10NOV09 | JM |

| | |
|---|---|
| DRAWN | ST |
| DESIGNED | AH |
| CHECKED | MT |
| APPROVED | JM |
| DATE | 31/MAR/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 823B_T_ERS_OAP_C10_001A1.dgn

TITLE

# CONTRACT 823B
## SHEK KONG STABLING SIDINGS AND ERS
### EMERGENCY RESCUE SIDING AND CUT AND COVER TUNNEL - SCHEMATIC DIAGRAM

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| N.T.S. (A1) | 823B/T/ERS/OAP/C10/001 | A1 |

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Default
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PRINTED BY: mtlcmw
27/10/2009 12:03:48 PM

CONTRACT 824

CONTRACT 823A

SOUTHBOUND

NORTHBOUND

CP25

CP26

TSAT SING KONG

MATCH LINE
FOR CONTINUATION
SEE FIGURE 9

FOR REFERENCE ONLY

NOTE:

GROUNDWATER PROFILES

1. GROUNDWATER PROFILES SHOWN HAVE BEEN REFERENCED TO THE GROUNDWATER LEVEL CONTOURS IN THE GEOTECHNICAL ENGINEERING REPORT.

2. GROUNDWATER LEVELS SHOWN HAVE BEEN DETERMINED FROM GROUNDWATER MONITORING READINGS TAKEN FOR THE XRL. THE GROUNDWATER LEVELS ARE BASED ON MONTHLY READINGS TAKEN FROM OCT 2008 TO JUL 2009.

LEGEND:

21607/2050 — ARCHIEVE DRILLHOLE

2108/XRL/EDH18 — PROJECT SPECIFIED DRILLHOLE

2 — INFERRED GROUNDWATER CONTOUR (IN mPD)

Groundwater monitoring points (with highest and lowest groundwater level recorded)

(reference to highest groundwater level recorded)

METRES 0 10 20 30 40 50

1 : 1000

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|

| | |
|---|---|
| DRAWN | AL |
| DESIGNED | FS |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 05/JUN/2009 |

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CADD REF. FIGURE J06.dgn

TITLE

CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
INFERRED GROUNDWATER CONTOUR PLAN

SHEET 1

SCALE 1 : 1000 (A1)

DRAWING NO. FIGURE J6

REV. –

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SOUTHBOUND

NORTHBOUND

CONTRACT 823A

CONTRACT 823B

CP27

CP28

CP29

MATCH LINE - FOR CONTINUATION SEE DWG. J6

KAM TAI ROAD

KAM TIN RIVER

FOR REFERENCE ONLY

NOTE:

1. FOR NOTES ON GROUNDWATER PROFILE, REFER TO DRAWING NO. 823A/T/340/DAP/C05/201.

LEGEND:

21607/205D — ARCHIEVE DRILLHOLE

2108/XRL/EDH18 — PROJECT SPECIFIED DRILLHOLE

—2— INFERRED GROUNDWATER CONTOUR (IN mPD)

METRES 0 10 20 30 40 50 1 : 1000

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| REV | DESCRIPTION | BY | DATE | APPROVED |

| | |
|---|---|
| DRAWN | AL |
| DESIGNED | FS |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 05/JUN/2009 |

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CADD REF. FIGURE J07.dgn

TITLE

# CONTRACT 823A
## TAI KONG PO TO TSE UK TSUEN
### INFERRED GROUNDWATER CONTOUR PLAN

SHEET 2

SCALE 1 : 1000 (A1)

DRAWING NO. FIGURE J7

REV. –

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CONTRACT 823A

CONTRACT 823B

SOUTHBOUND

NORTHBOUND

CPERS(N)

ERS(S)

MATCH LINE
FOR CONTINUATION
SEE FIGURE J09

FOR INFORMATION ONLY

NOTE:

GROUNDWATER PROFILES

1. GROUNDWATER PROFILES SHOWN HAVE BEEN REFERENCED TO THE GROUNDWATER LEVEL CONTOURS IN THE GEOTECHNICAL ENGINEERING REPORT.

2. GROUNDWATER LEVELS SHOWN HAVE BEEN DETERMINED FROM GROUNDWATER MONITORING READINGS TAKEN FOR THE XRL. THE GROUNDWATER LEVELS ARE BASED ON MONTHLY READINGS TAKEN FROM OCT 2008 TO MAR 2009.

LEGEND:

- 21607/205D — ARCHIEVE DRILLHOLE
- 2108/XRL/EDH18 — PROJECT SPECIFIED DRILLHOLE
- 2 — INFERRED GROUNDWATER CONTOUR (IN mPD)

METRES 0 10 20 30 40 50

1 : 1000

| REV | DESCRIPTION | BY | DATE | APPROVED | REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| DRAWN | AL |
| DESIGNED | FS |
| CHECKED | DL |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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CADD REF. FIGURE J08.dgn

TITLE

CONTRACT 823B

SHEK KONG STABLING SIDINGS AND ERS

INFERRED GROUNDWATER CONTOUR PLAN

SHEET 1

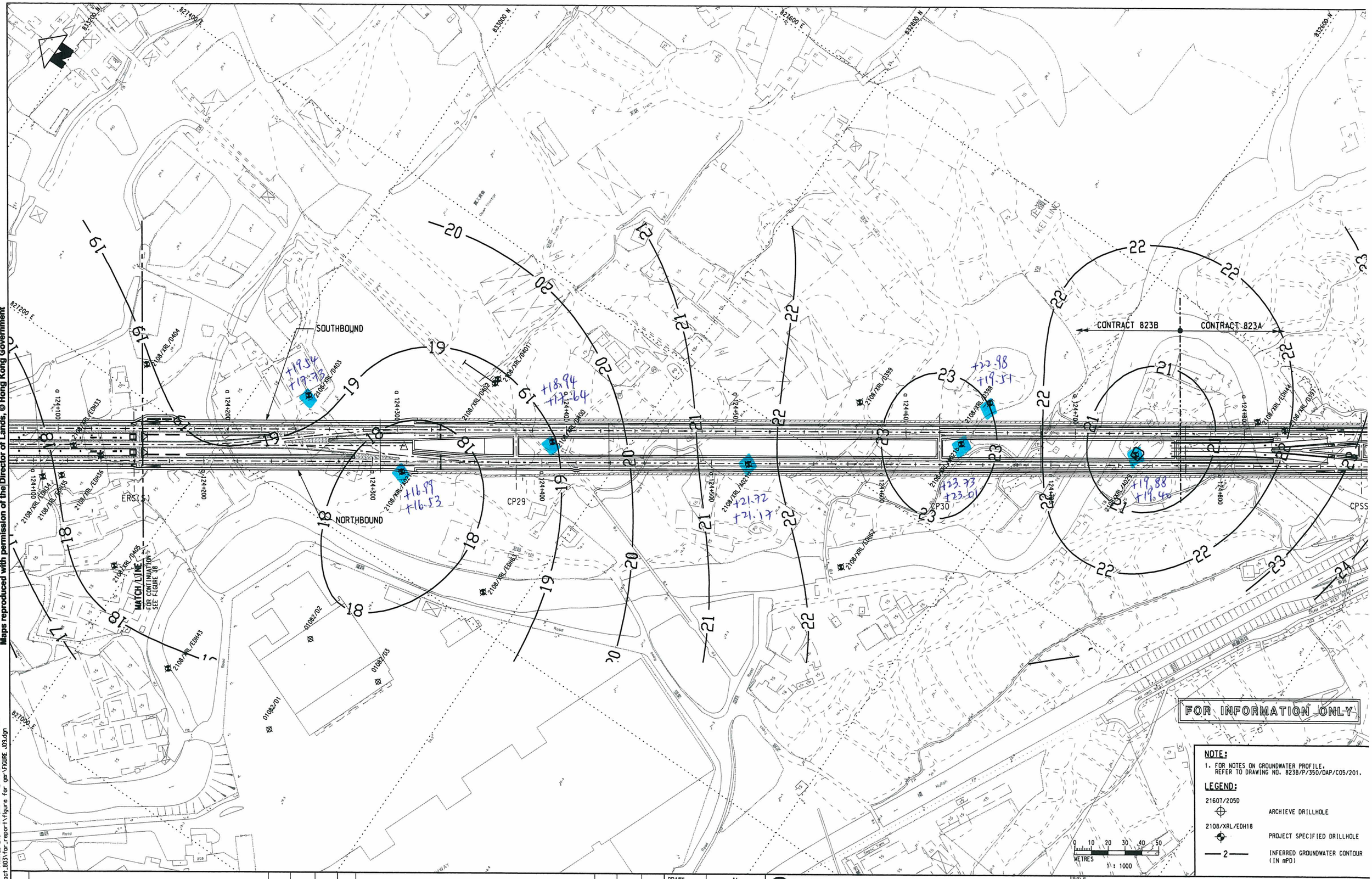
SCALE 1 : 1000 (A1)

DRAWING NO. FIGURE J8

REV. –

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NOTE:

1. FOR NOTES ON GROUNDWATER PROFILE, REFER TO DRAWING NO. 823B/P/350/DAP/C05/201.

LEGEND:

- 21607/205D — ARCHIEVE DRILLHOLE
- 2108/XRL/EDH18 — PROJECT SPECIFIED DRILLHOLE
- 2 — INFERRED GROUNDWATER CONTOUR (IN mPD)

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|

| | |
|---|---|
| DRAWN | AL |
| DESIGNED | FS |
| CHECKED | DL |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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CADD REF. FIGURE J09.dgn

TITLE

# CONTRACT 823B

## SHEK KONG STABLING SIDINGS AND ERS

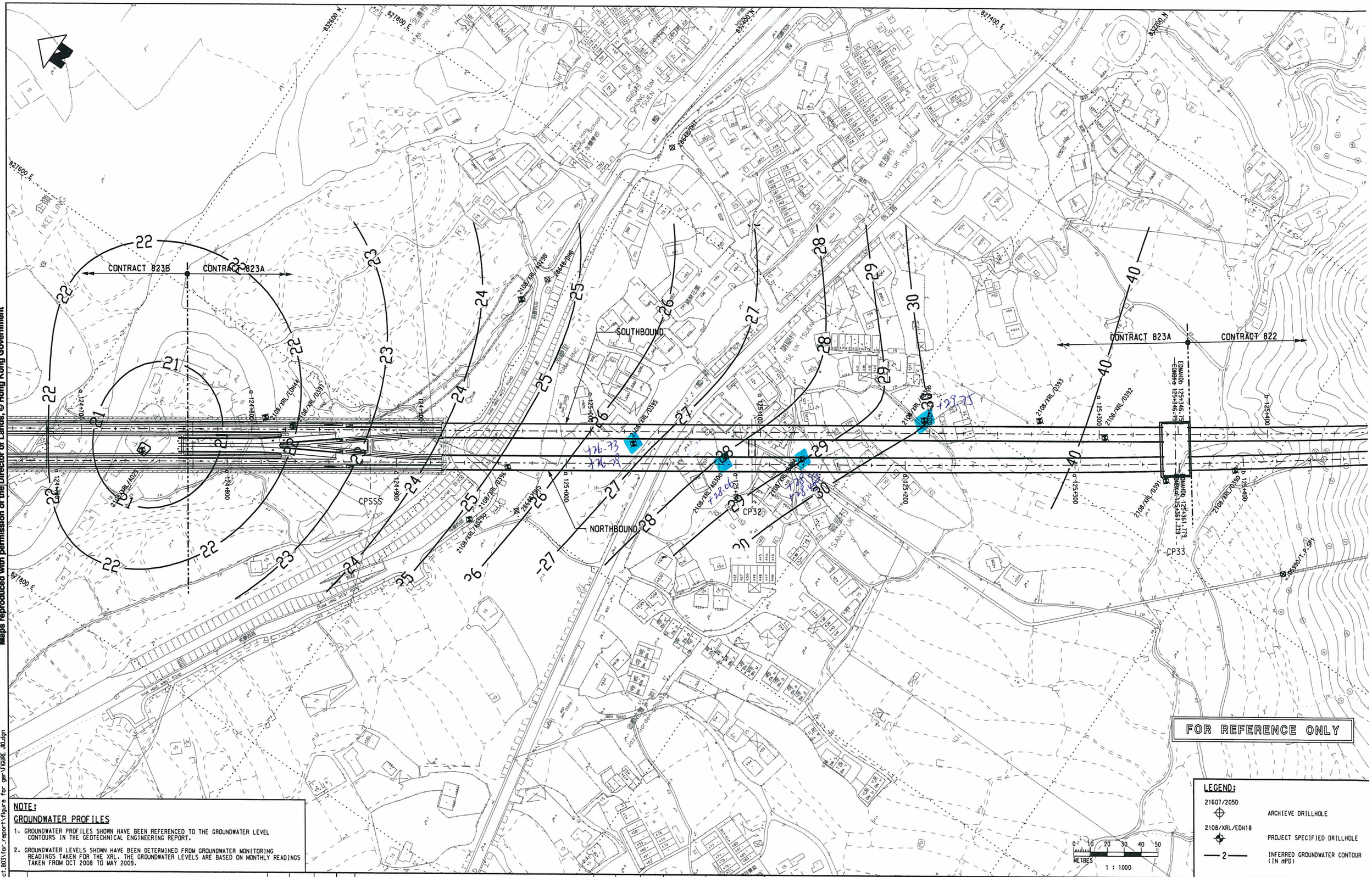
INFERRED GROUNDWATER CONTOUR PLAN

SHEET 2

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1 : 1000 (A1) | FIGURE J9 | - |

PLOT DRV: M:\C803\CONTRACT_803\CAD_ADMIN\plotdrv\DR_20863LPH_A3.pltPRINTED BY: williamw 27/07/2009 12:04:25 PM
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NOTE:

GROUNDWATER PROFILES

1. GROUNDWATER PROFILES SHOWN HAVE BEEN REFERENCED TO THE GROUNDWATER LEVEL CONTOURS IN THE GEOTECHNICAL ENGINEERING REPORT.
2. GROUNDWATER LEVELS SHOWN HAVE BEEN DETERMINED FROM GROUNDWATER MONITORING READINGS TAKEN FOR THE XRL. THE GROUNDWATER LEVELS ARE BASED ON MONTHLY READINGS TAKEN FROM OCT 2008 TO MAY 2009.

LEGEND:

21607/205D — ARCHIEVE DRILLHOLE

2108/XRL/EDH18 — PROJECT SPECIFIED DRILLHOLE

—2— INFERRED GROUNDWATER CONTOUR (IN mPD)

| REV | DESCRIPTION | BY | DATE | APPROVED |
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| DRAWN | AL |
| DESIGNED | KH |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 05/JUN/2009 |

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CADD REF. FIGURE J10.dgn

TITLE

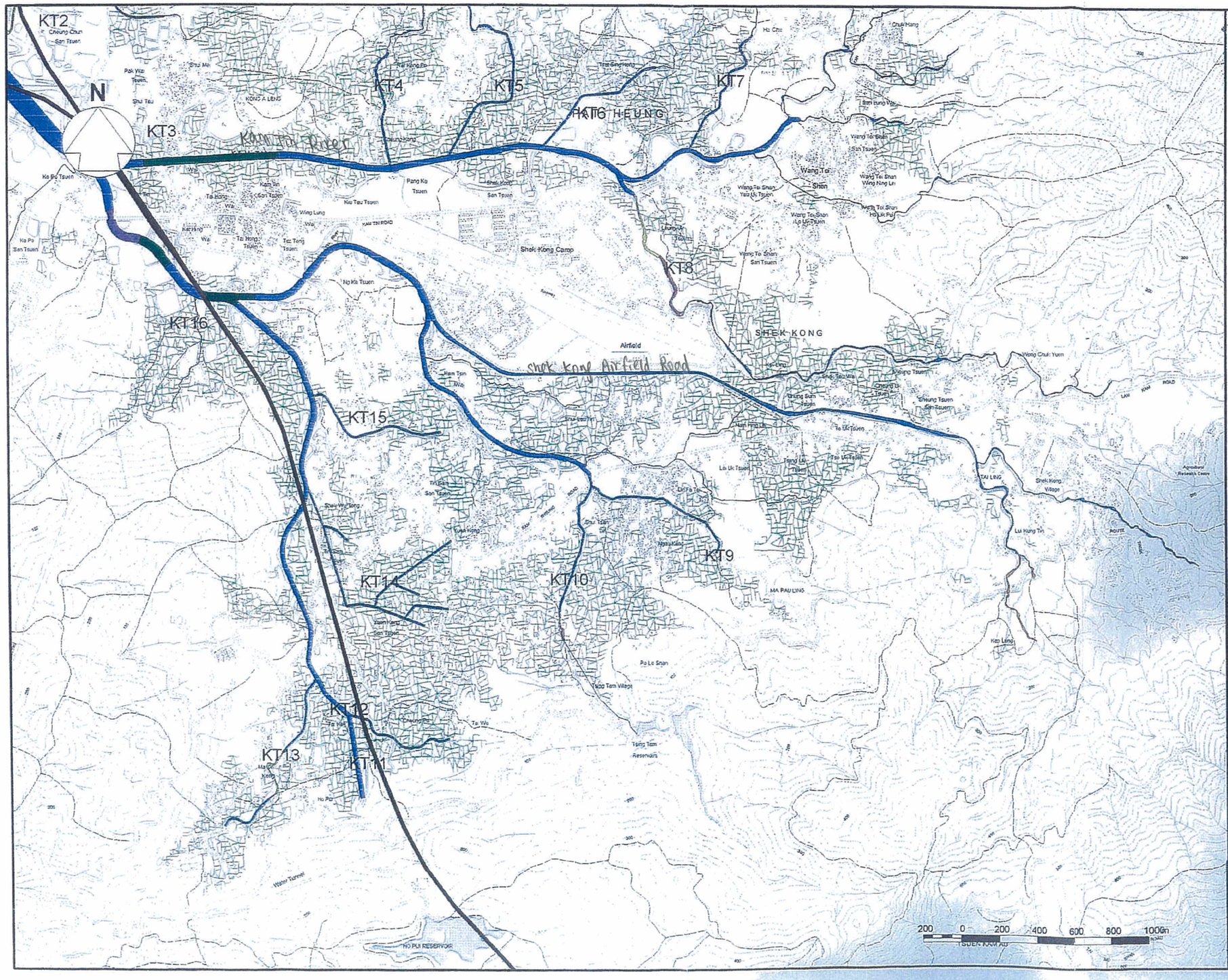
# CONTRACT 823A
## TAI KONG PO TO TSE UK TSUEN
### INFERRED GROUNDWATER CONTOUR PLAN

SCALE 1 : 1000 (A1)

DRAWING NO. FIGURE J10

REV. –

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## LEGEND

West Rail

Manholes

- 95 Flooding volume 95 cu.m in 50 year event
- Flooding less than 50 cu.m
- No Flooding
- f Pipe surcharged by flow in 50 year event
- * Manhole cover level <4mPD

Pipes

- 200 yr event capacity
- 100 yr
- 50 yr
- 20 yr
- 10 yr
- 5 yr
- 2 yr
- Less than 2 yr

Dia. is shown for all pipes in mm




| Revision | Date | Description | | Initial |
|---|---|---|---|---|
| | Designed | Checked | Drawn | Checked |
| Initial | CSL | ECO | LC | ECO |
| Date | 10/98 | 10/98 | 10/98 | 10/98 |

Approved

**AGREEMENT No. CE 57/95**

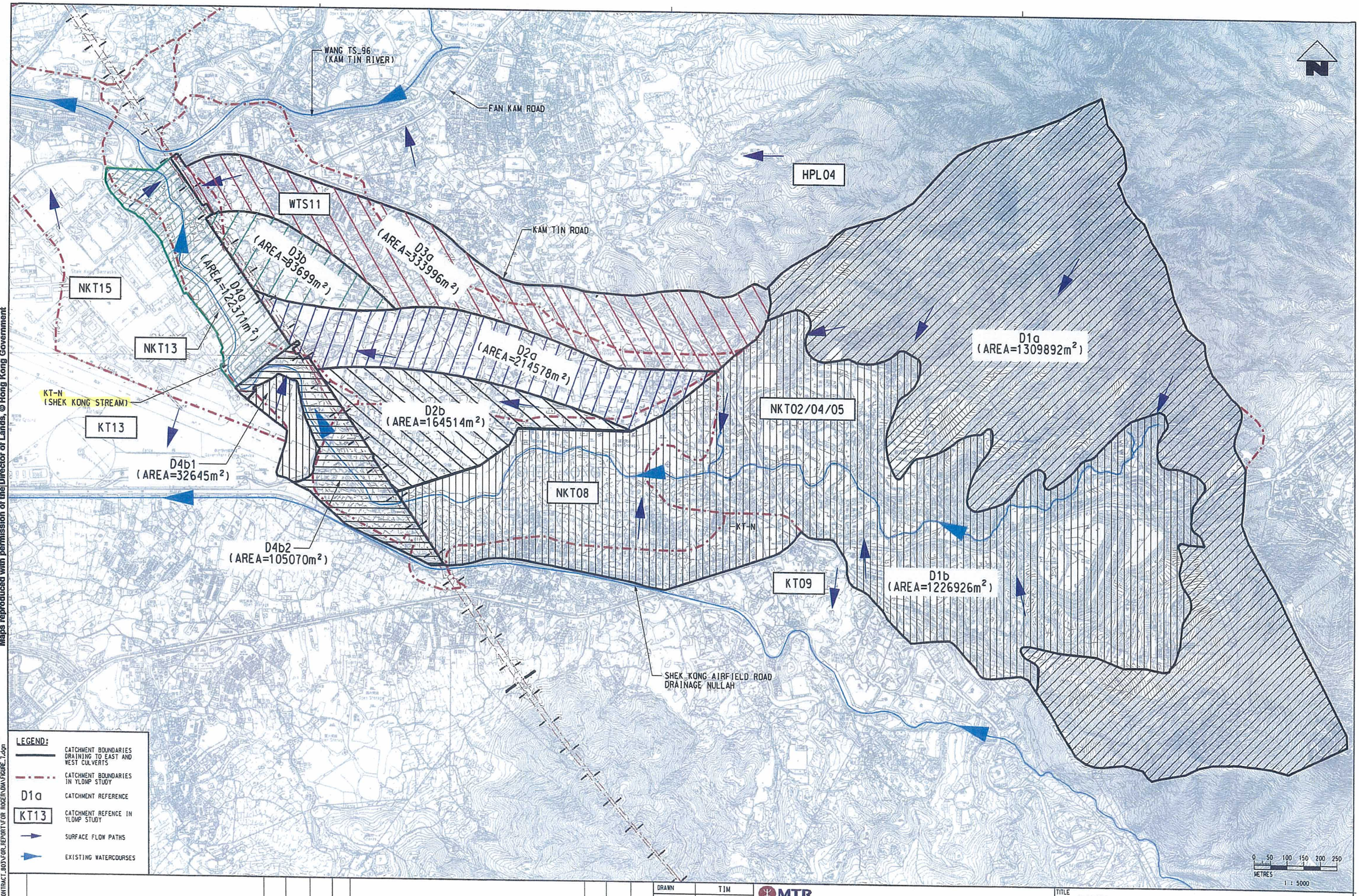
Contract title
**YUEN LONG, KAM TIN, NGAU TAM MEI & TIN SHUI WAI DMP STUDY**

Figure title
PERFORMANCE DRAWING
Basin 9
ULTIMATE DEVELOPMENT - MIKE11
Sheet 4 of 4

Drawing no. 0023/PD9/160 A
Scale 1 : 20000

Client
DRAINAGE SERVICES DEPARTMENT 渠務署 HONG KONG 香港

Consultant
BINNIE CONSULTANTS LIMITED 賓尼工程顧問有限公司
ENGINEERS AND SCIENTISTS




LEGEND:

- CATCHMENT BOUNDARIES DRAINING TO EAST AND WEST CULVERTS
- CATCHMENT BOUNDARIES IN YLOMP STUDY
- D1a — CATCHMENT REFERENCE
- KT13 — CATCHMENT REFENCE IN YLOMP STUDY
- SURFACE FLOW PATHS
- EXISTING WATERCOURSES

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PLOT DRN: M:\C803\CONTRACT_803\CAD_ADMIN\plotdrv\DR_2006&3P-A3C.plt
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| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | D1A REPORT ISSUE 2 | TW | 15MAY09 | JM |

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| DRAWN | TIM |
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| CHECKED | MT |
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Urbis, BMT Asia

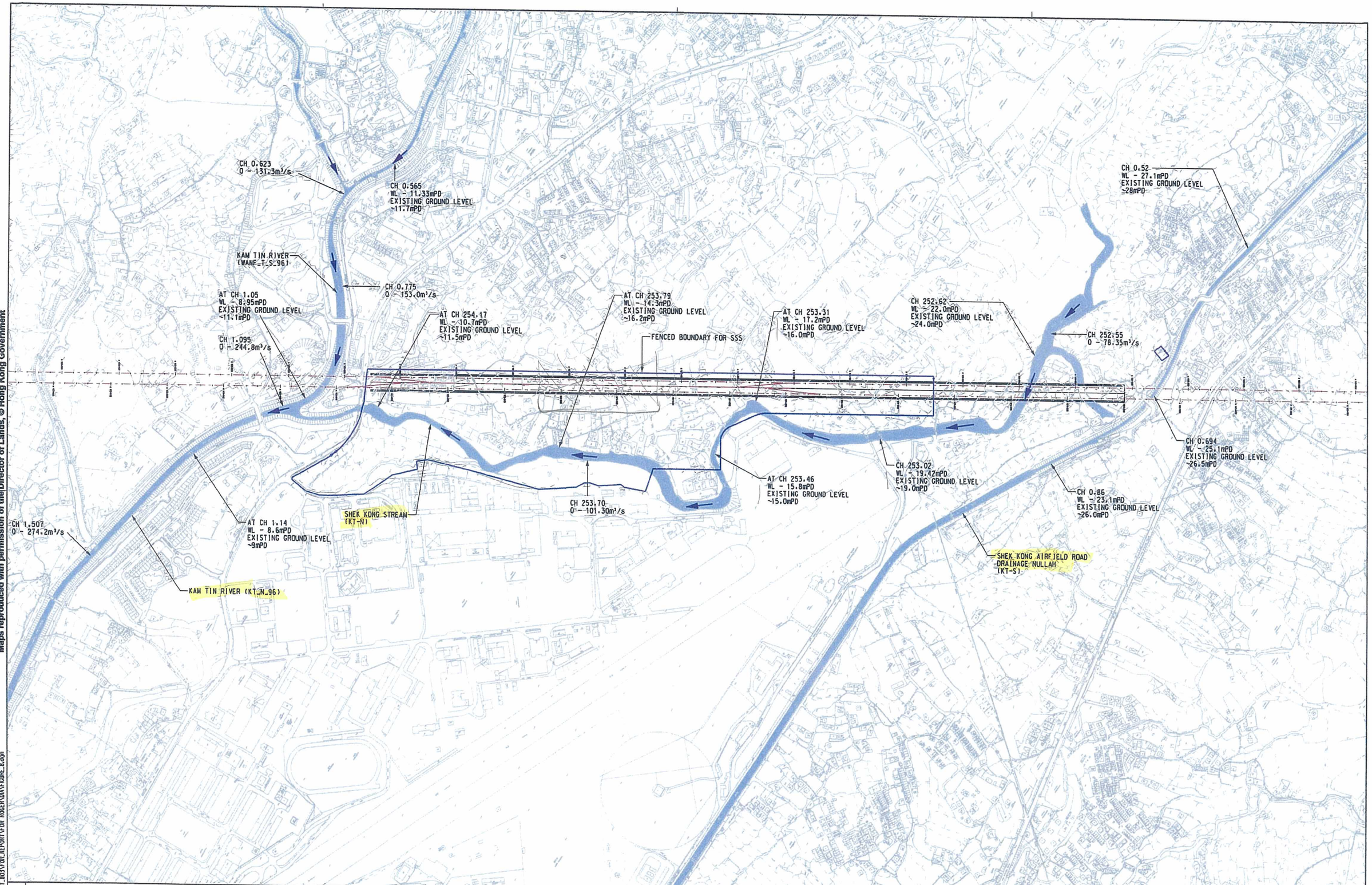
CADD REF.
FIGURE_7.dgn

TITLE
C803
TUNNELS & ASSOCIATED STRUCTURES (NORTH)
CATCHMENT AREAS RELEANT TO SHEK KONG SIDINGS (SSS)

SCALE
1 : 5000 (A1)

DRAWING NO.
FIGURE 7

REV.
A




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| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | DIA STUDY REPORT | TW | 28APR09 | JM |

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|---|---|
| DRAWN | WMC |
| DESIGNED | RA |
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| APPROVED | JM |
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CADD REF. FIGURE_8.dgn

TITLE
C803
TUNNELS & ASSOCIATED STRUCTURES (NORTH)
ESTIMATED 200 YEAR
STORM EVENT WATER LEVEL AND FLOW AT THE SSS FROM
YL DMP STUDY

SCALE 1 : 3000 (A1) | DRAWING NO. FIGURE 8 | REV. A

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D 3a

D 3b

D 2a

D 2b

D 2b

D 2b

EAST CULVERT

STREAM DIVERSION CHANNEL

1a + 1b

D4b(1)

SSS FENCE LINE

PROJECT BOUNDARY

SHEK KONG STREAM (KT-N)

WEST CULVERT

CH 1,507
Q = 274.2m³/s

KAM TIN RIVER (KT_N_96)

LEGEND

2a, 2b — EXISTING STREAMS TO BE MAINTAINED UNTIL EAST CONVERT OUTFALL COMPLETE

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| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | DIA REPORT ISSUE 2 | TW | 28APR09 | JM |

| | |
|---|---|
| DRAWN | WMC |
| DESIGNED | RA |
| CHECKED | MT |
| APPROVED | JM |
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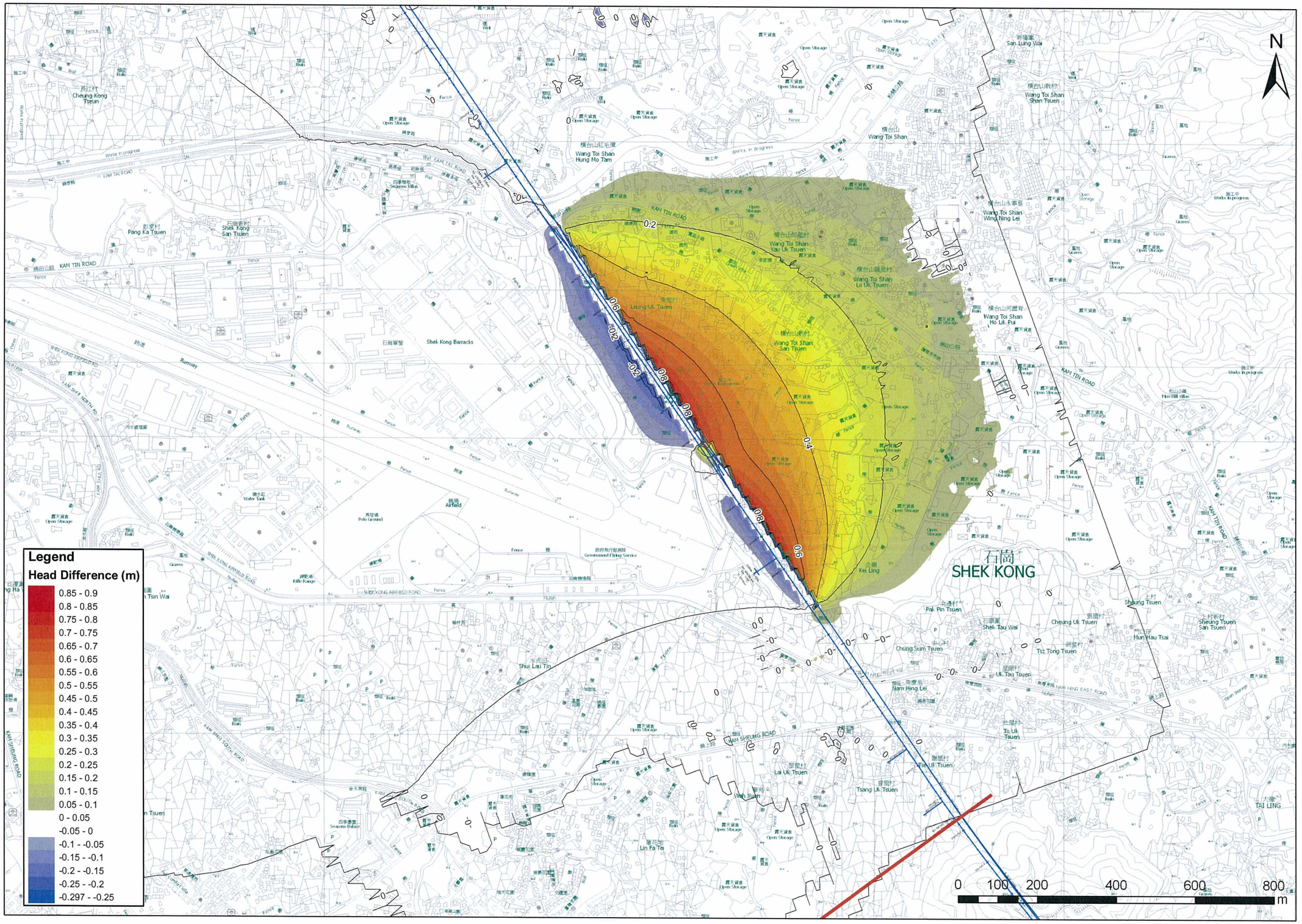
CADD REF. FIGURE_10.dgn

TITLE
C803
TUNNELS & ASSOCIATED STRUCTURES (NORTH)
TEMPORARY DRAINAGE ARRANGEMENTS AT SSS

SCALE 1 : 3000 (A1)

DRAWING NO. FIGURE 10

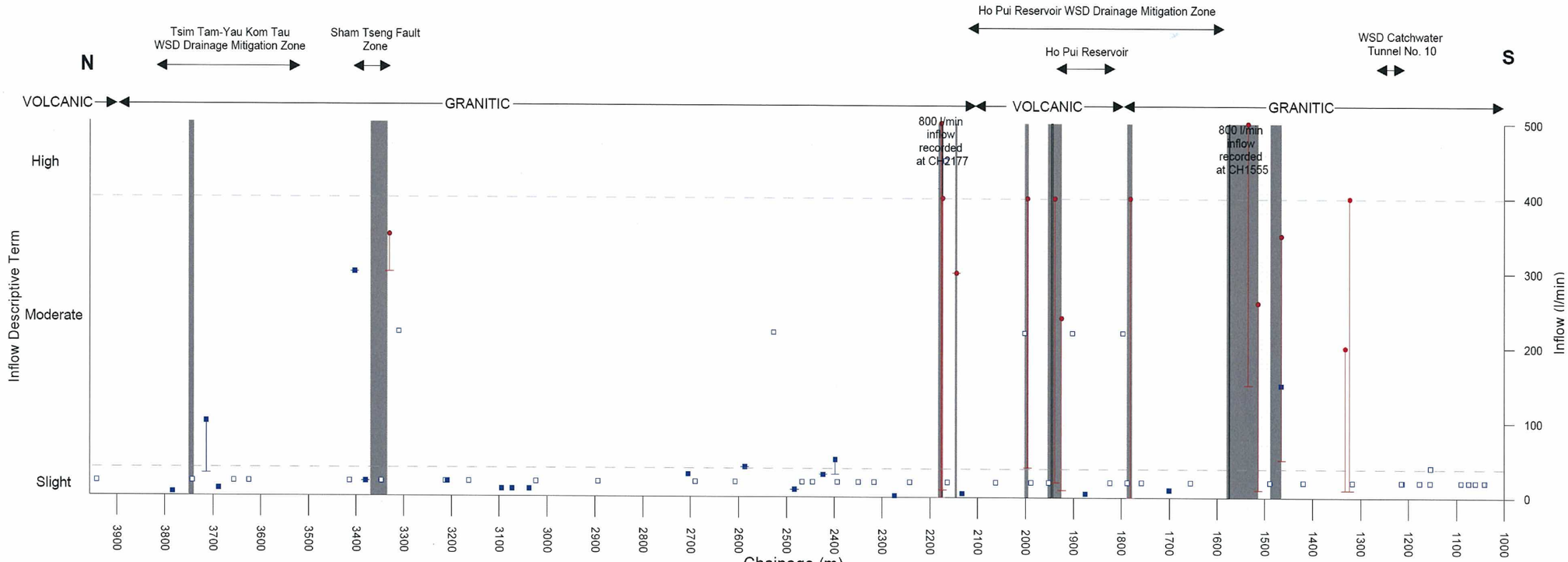
REV. A




**Impact of the Cut & Cover Box – Comparison of Pre and Post Construction Water Table Levels (difference in metres)**

# Appendix D

# Inflow and Geology of Some Recently Completed MTR Tunnels




**Notes**

1. Data extracted from As-Built Geological Records (Nishimatsu and Maunsell Consultants Asia Ltd)
2. Inflows are those recorded from probeholes and excavation logging

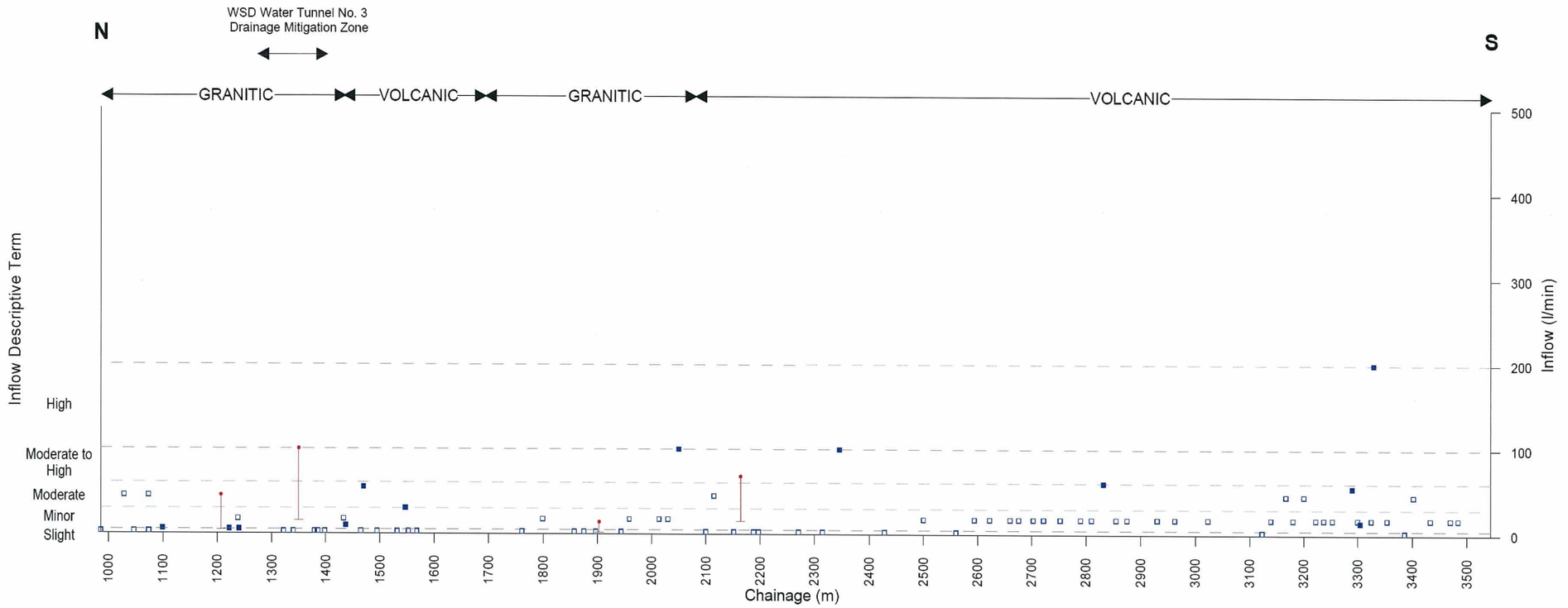
**Inflow Ranges**

| | Range | Mid-Point |
|---|---|---|
| Slight | 0 - 40 | 20 |
| Moderate | 40 - 400 | 220 |
| High | >400 | 450 |

**LEGEND:**

- Measured tunnel inflow from probehole showing reduction over time
- Measured tunnel inflow from probehole showing reduction after grouting (reduction in flow logged post excavation)
- Measured tunnel inflow from excavation logging
- Measured tunnel inflow from excavation logging showing reduction over time
- Descriptive Tunnel Inflow (Flow Range Mid-Point Used for Plot)
- Grouted Zone
- Geological feature encountered within grouted zone

# Tai Lam Tunnel - Recorded Tunnel Inflows – Northern Section




**Notes**

1. Data extracted from As-Built Geological Records (Dragages and Maunsell Consultants Asia Ltd)

2. Inflows are those recorded from probeholes and excavation logging

**Inflow Ranges**

| | Range | Mid-Point |
|---|---|---|
| Slight | 0 - 5 | 2.5 |
| Minor | 5 - 30 | 17.5 |
| Moderate | 30 - 60 | 45 |
| Moderate to High | 60 - 100 | 80 |
| High | 100 - 200 | 150 |

**LEGEND:**

- Measured tunnel inflow from probehole showing reduction over time
- Measured tunnel inflow from probehole showing reduction after grouting (reduction in flow logged post excavation)
- Measured tunnel inflow from excavation logging
- Measured tunnel inflow from excavation logging showing reduction over time
- Descriptive Tunnel Inflow (Flow Range Mid-Point Used for Plot)
- Grouted Zone
- Geological feature encountered within grouted zone

# Tai Lam Tunnel - Recorded Tunnel Inflows – Southern Section

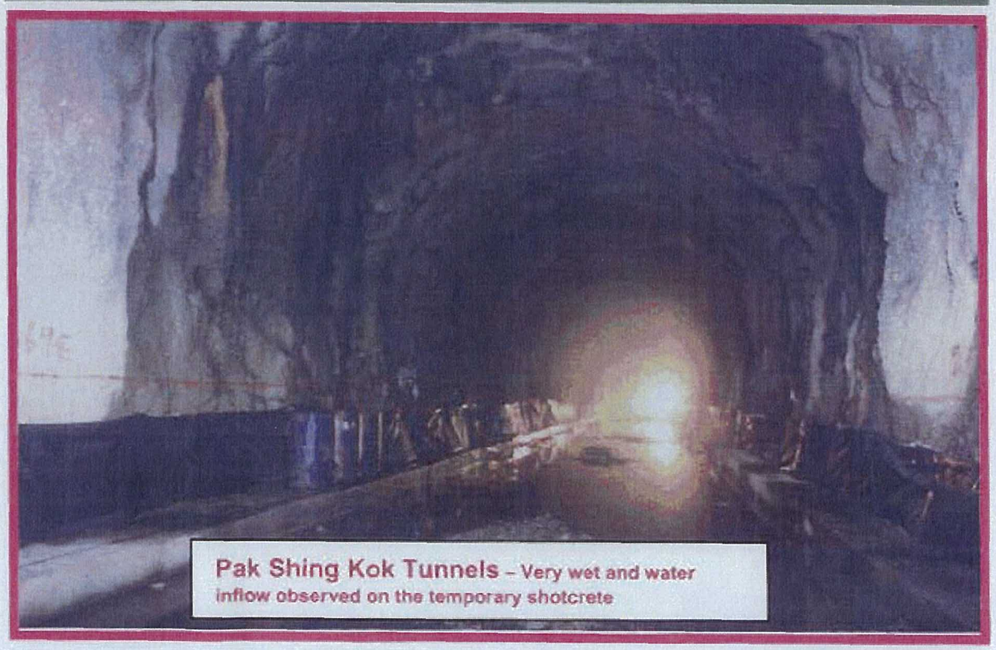
# Photos showing the amount of ground water inflow during the excavation



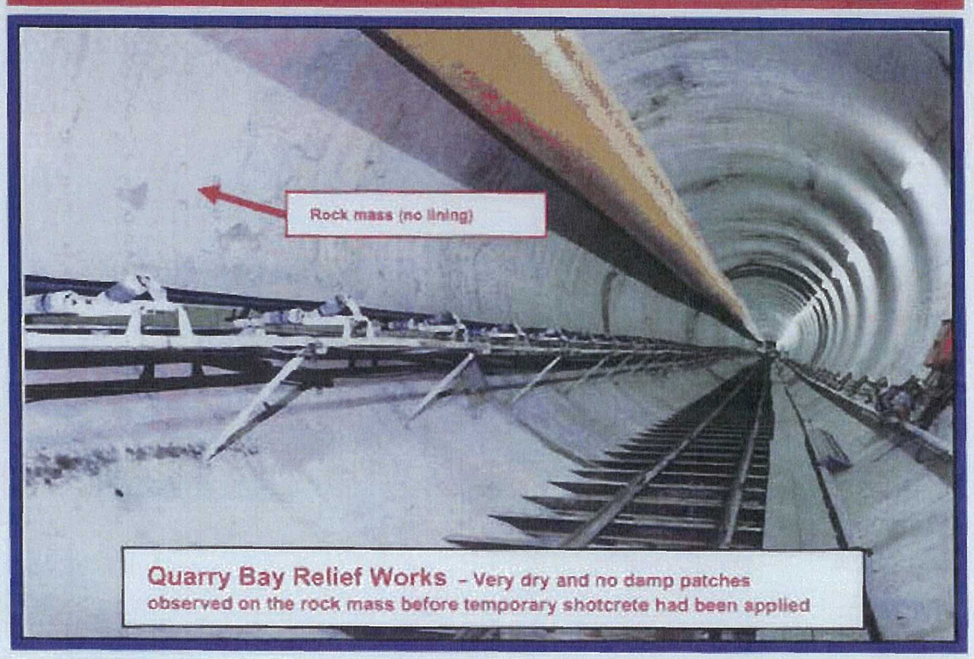
**Tai Lam Teng Tunnel** – Damp patches observed on the temporary shotcrete



**Black Hill Tunnels** – Very dry and only small damp patches observed on the rock mass before temporary shotcrete had been applied



**Pak Shing Kok Tunnels** – Very wet and water inflow observed on the temporary shotcrete




**Quarry Bay Relief Works** – Very dry and no damp patches observed on the rock mass before temporary shotcrete had been applied

# Sample of Core Photos

## Black Hill Tunnels




## Pak Shing Kok Tunnels



# Sample of Core Photos

## Tai Yam Teng Tunnels




## Quarry Bay Relief Works



# Sample Core Photos of Kai Kung Leng

(from Drillhole No. 2108/XRL/A007a)

Typical Strong Intact Grade II Tuff with Widely Spaced Joints Found below Rockhead










Localised Shear Zones - Typically Few Metres Wide Associated with Crushed Rock (locations of the shears shall refer to the geological long sections)

# Appendix E

## Works Contract 824 - Inflow Analysis (Heuer Method & SAFE) & Schematic Tunnel Drainage Drawings

Heuer Method

**A. Steady State Inflow - 1995 Method**

Zone 1 : CH 119+900(±) to CH 120+140(±)

787 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 5.0% | 14.0% | 14.0% | 23.0% | 2.0% | 42.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 12.0 | 33.6 | 33.6 | 55.2 | 4.8 | 100.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 239.9 m | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.9 | 2.7 | 8.5 | 26.7 | 85.3 | 266.7 | 853.4 | 2667.0 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.3 | 2.9 | 9.0 | 47.1 | 12.8 | 859.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 932 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 10 | 50 | 10 | 860 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 930 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 13.2 | 2.6 | 227.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 246 gpm |

Assumptions:

*

Head (ft): 350

**A. Steady State Inflow - 2005 Method**

Zone 1

787 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 5.0% | 14.0% | 14.0% | 23.0% | 2.0% | 42.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 12.0 | 33.6 | 33.6 | 55.2 | 4.8 | 100.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 239.9 m | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 1.3 | 4.3 | 12.8 | 42.7 | 128.0 | 426.7 | 1280.2 | 4267.2 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.5 | 4.3 | 14.3 | 70.6 | 20.5 | 1289.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 1400 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 10 | 70 | 20 | 1290 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 1390 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 18.5 | 5.3 | 340.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 367 gpm |

Assumptions:

*

Head (ft): 350

**A. Steady State Inflow - 1995 Method**

Zone 2: CH 120+140(±) to CH 121+450(±)

4297 ft

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | | |
| c. Percent in interval | 20.0% | 30.0% | 0.0% | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | | |
| d. Tunnel Length, m | 261.9 | 392.9 | 0.0 | 654.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1310 m | | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 1.3 | 4.0 | 12.8 | 40.0 | 128.0 | 400.1 | 1280.2 | 4000.5 | | | |
| g. $\Delta Q_s$, L/min | 1.0 | 5.0 | 0.0 | 83.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 90 | |
| h. $\Delta Q_s$, rounded, L/min | 0 | 10 | 0 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 90 L/min | |
| $\Delta Q_s$, rounded, gpm | 0.0 | 2.6 | 0.0 | 21.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 24 gpm | |

Assumptions:

*

Head (ft): 525

< 1 diameter rock cover.

**A. Steady State Inflow - 2005 Method**

Zone 2

4297 ft

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | | |
| c. Percent in interval | 20.0% | 30.0% | 0.0% | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | | |
| d. Tunnel Length, m | 261.9 | 392.9 | 0.0 | 654.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1310 m | | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.1 | 0.2 | 0.6 | 1.9 | 6.4 | 19.2 | 64.0 | 192.0 | 640.1 | 1920.2 | 6400.8 | | | |
| g. $\Delta Q_s$, L/min | 1.7 | 7.5 | 0.0 | 125.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 135 | |
| h. $\Delta Q_s$, rounded, L/min | 0 | 10 | 0 | 130 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 140 L/min | |
| $\Delta Q_s$, rounded, gpm | 0.0 | 2.6 | 0.0 | 34.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 37 gpm | |

Assumptions:

*

Head (ft): 525

* < 1 diameter rock cover.

**A. Steady State Inflow - 1995 Method**

Zone 3: CH 121+450(±) to CH 121+550(±)

15 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 2.4 | 7.6 | 24.4 | 76.2 | 243.8 | 762.0 | 2438.4 | 7620.0 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 348.4 | 0.0 | 0.0 | 0.0 | 0.0 | | 348 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 350 | 0 | 0 | 0 | 0 | Total Qs = | 350 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 92.5 | 0.0 | 0.0 | 0.0 | 0.0 | = | 92 gpm |

Assumptions:

* Analysis targeted on a narrow fault zone. Expected maximum sustained inflow was further estimated from past precedent and IMS analysis.

Head (ft): 1000

*

**A. Steady State Inflow - 2005 Method**

Zone3

15 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.1 | 0.4 | 1.2 | 3.7 | 12.2 | 36.6 | 121.9 | 365.8 | 1219.2 | 3657.6 | 12192.0 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 557.4 | 0.0 | 0.0 | 0.0 | 0.0 | | 557 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 560 | 0 | 0 | 0 | 0 | Total Qs = | 560 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 147.9 | 0.0 | 0.0 | 0.0 | 0.0 | = | 148 gpm |

Assumptions:

*

Head (ft): 1000

*

**A. Steady State Inflow - 1995 Method**

Zone 4: CH 121+550(±) to CH 121+800(±)

820 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 30.0% | 20.0% | 20.0% | 30.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 75.0 | 50.0 | 50.0 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 249.9 | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 | 1.5 | 4.7 | 15.2 | 47.5 | 151.9 | 474.7 | 1519.1 | 4747.3 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 3.6 | 7.6 | 23.7 | 113.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 149 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 10 | 20 | 110 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 140 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 2.6 | 5.3 | 29.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 37 gpm |

Assumptions:
*

Head (ft): 623

**A. Steady State Inflow - 2005 Method**

Zone 4

820 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 30.0% | 20.0% | 20.0% | 30.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 75.0 | 50.0 | 50.0 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 249.9 | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 2.3 | 7.6 | 22.8 | 76.0 | 227.9 | 759.6 | 2278.7 | 7595.6 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 5.7 | 11.4 | 38.0 | 170.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 226 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 10 | 10 | 40 | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 230 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 2.6 | 2.6 | 10.6 | 44.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 61 gpm |

Assumptions:
*

Head (ft): 623

**A. Steady State Inflow - 1995 Method**

Zone 5: CH 121+800(±) to CH 122+260(±)

1509 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 9.0% | 17.0% | 13.0% | 13.0% | 39.0% | 0.0% | 4.0% | 0.0% | 4.0% | 0.0% | 0.0% | 0.0% | 99.0% | |
| d. Tunnel Length, m | 0.0 | 41.4 | 78.2 | 59.8 | 59.8 | 179.4 | 0.0 | 18.4 | 0.0 | 18.4 | 0.0 | 0.0 | 0.0 | 455.3 m | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.6 | 1.9 | 6.1 | 19.1 | 61.0 | 190.5 | 609.6 | 1905.0 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.3 | 1.5 | 3.6 | 11.4 | 109.3 | 0.0 | 112.2 | 0.0 | 1121.5 | 0.0 | 0.0 | 0.0 | | 1360 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 10 | 110 | 0 | 110 | 0 | 1100 | 0 | 0 | 0 | Total Qs = | 1330 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 29.1 | 0.0 | 29.1 | 0.0 | 290.6 | 0.0 | 0.0 | 0.0 | = | 351 gpm |

Assumptions:

*

Head (ft): 250

**A. Steady State Inflow - 2005 Method**

Zone 5

1509 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 9.0% | 17.0% | 13.0% | 13.0% | 39.0% | 0.0% | 4.0% | 0.0% | 4.0% | 0.0% | 0.0% | 0.0% | 99.0% | |
| d. Tunnel Length, m | 0.0 | 41.4 | 78.2 | 59.8 | 59.8 | 179.4 | 0.0 | 18.4 | 0.0 | 18.4 | 0.0 | 0.0 | 0.0 | 455.3 m | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.9 | 3.0 | 9.1 | 30.5 | 91.4 | 304.8 | 914.4 | 3048.0 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.4 | 2.4 | 5.5 | 18.2 | 164.0 | 0.0 | 168.2 | 0.0 | 1682.3 | 0.0 | 0.0 | 0.0 | | 2041 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 10 | 20 | 160 | 0 | 170 | 0 | 1700 | 0 | 0 | 0 | Total Qs = | 2060 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 2.6 | 5.3 | 42.3 | 0.0 | 44.9 | 0.0 | 449.1 | 0.0 | 0.0 | 0.0 | = | 544 gpm |

Assumptions:

*

Head (ft): 250

**A. Steady State Inflow - 1995 Method**

Zone 6: CH 122+260(±) to CH 122+487(±)

745 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 9.0% | 0.0% | 31.0% | 41.0% | 0.0% | 19.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 20.4 | 0.0 | 70.4 | 93.1 | 0.0 | 43.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 227.1 m | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 2.4 | 7.6 | 24.4 | 76.2 | 243.8 | 762.0 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.2 | 0.0 | 5.4 | 22.7 | 0.0 | 105.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 133 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 10 | 20 | 0 | 110 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 140 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 5.3 | 0.0 | 29.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 37 gpm |

Assumptions:

*

Head (ft): 100

**A. Steady State Inflow - 2005 Method**

Zone 6

745 ft

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_e$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | |
| c. Percent in interval | 0.0% | 0.0% | 9.0% | 0.0% | 31.0% | 41.0% | 0.0% | 19.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | |
| d. Tunnel Length, m | 0.0 | 0.0 | 20.4 | 0.0 | 70.4 | 93.1 | 0.0 | 43.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 227.1 m | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 1.2 | 3.7 | 12.2 | 36.6 | 121.9 | 365.8 | 1219.2 | | |
| g. $\Delta Q_s$, L/min | 0.0 | 0.0 | 0.2 | 0.0 | 8.6 | 34.1 | 0.0 | 157.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 201 |
| h. $\Delta Q_s$, rounded, L/min | 0 | 0 | 0 | 0 | 10 | 30 | 0 | 160 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 200 L/min |
| $\Delta Q_s$, rounded, gpm | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 7.9 | 0.0 | 42.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 53 gpm |

Assumptions:

*

Head (ft): 100

*

Groundwater Drawdown Estimate

SAFE Analysis

# Seepage model input

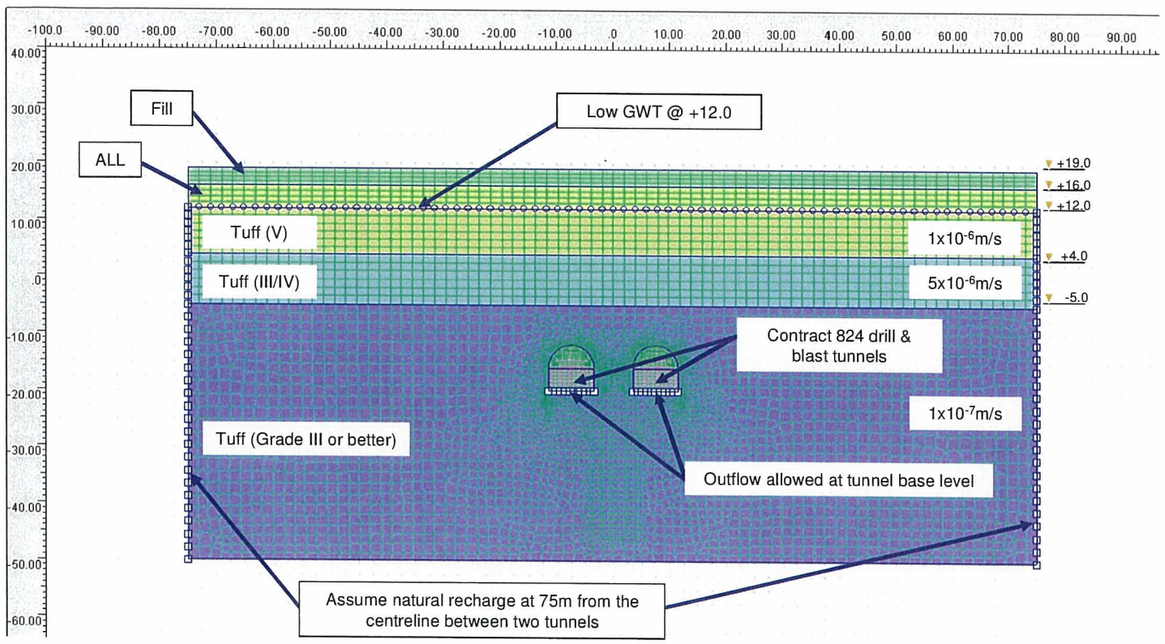



**Figure 1**

**Material Permeability**

| Material | Drainage condition | Unit wt of pore fluid | Bulk Modulus | Permeabilities | | Inclination | Y0 | Gradient of K | Desens factor | Min. pwp | Perm'y factor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | k | k1 | k2 | | | | | | |
| | | kN/m$^3$ | kN/m$^2$ | m/s | | deg | | | | kN/m$^2$ | |
| Fill | No water | 0 | 2.20E+06 | 0.00E+00 | 0.00E+00 | 0 | 0 | 0 | 1 | -100 | 1.00E-06 |
| ALL | No water | 10 | 2.20E+06 | 0.00E+00 | 0.00E+00 | 0 | 0 | 0 | 1 | -100 | 1.00E-06 |
| TUFF (V) | Consolidating | 10 | 2.20E+06 | 1.00E-06 | 1.00E-06 | 0 | 0 | 0 | 1 | -100 | 1.00E-06 |
| TUFF (III/IV) | Consolidating | 10 | 2.20E+06 | 5.00E-06 | 5.00E-06 | 0 | 0 | 0 | 1 | -100 | 1.00E-06 |
| TUFF (III or better) | Consolidating | 10 | 2.20E+06 | 1.00E-07 | 1.00E-07 | 0 | 0 | 0 | 1 | -100 | 1.00E-06 |
| VOID | No water | 0 | 2.20E+06 | 0 | 0 | 0 | 0 | 0 | 1 | -100 | 1.00E-06 |

ARUP

**Seepage Restraints**

| Node no. | Restraint type | Piezometric level | Outflow |
|---|---|---|---|
| | | m | $m^3/s$ |
| 12284 | Fixed head | 12 | |
| 12290 | Phreatic | | |
| 12296 | Phreatic | | |
| 12325 | Phreatic | | |
| 12384 | Phreatic | | |
| 12411 | Phreatic | | |
| 12458 | Phreatic | | |
| 12524 | Phreatic | | |
| 12588 | Phreatic | | |
| 12647 | Phreatic | | |
| 12736 | Phreatic | | |
| 12772 | Phreatic | | |
| 12818 | Phreatic | | |
| 12907 | Phreatic | | |
| 12994 | Phreatic | | |
| 13111 | Phreatic | | |
| 13199 | Phreatic | | |
| 13267 | Phreatic | | |
| 13325 | Phreatic | | |
| 13397 | Phreatic | | |
| 13460 | Phreatic | | |
| 13487 | Phreatic | | |
| 13538 | Phreatic | | |
| 13568 | Phreatic | | |
| 13631 | Phreatic | | |
| 13665 | Phreatic | | |
| 13689 | Phreatic | | |
| 13721 | Phreatic | | |
| 13742 | Phreatic | | |
| 13773 | Phreatic | | |
| 13803 | Phreatic | | |
| 13818 | Phreatic | | |
| 13837 | Phreatic | | |
| 13856 | Phreatic | | |
| 13877 | Phreatic | | |
| 13885 | Phreatic | | |
| 13900 | Phreatic | | |
| 13908 | Phreatic | | |
| 13930 | Phreatic | | |
| 13938 | Phreatic | | |
| 13948 | Phreatic | | |

**Seepage Restraints**

| Node no. | Restraint type | Piezometric level | Outflow |
|---|---|---|---|
| | | m | $m^3/s$ |
| 13960 | Phreatic | | |
| 13965 | Phreatic | | |
| 13972 | Phreatic | | |
| 13979 | Phreatic | | |
| 13985 | Phreatic | | |
| 13993 | Phreatic | | |
| 13998 | Phreatic | | |
| 14008 | Phreatic | | |
| 14013 | Phreatic | | |
| 14017 | Phreatic | | |
| 14023 | Phreatic | | |
| 14031 | Phreatic | | |
| 14036 | Phreatic | | |
| 14040 | Phreatic | | |
| 14048 | Phreatic | | |
| 14055 | Phreatic | | |
| 14062 | Phreatic | | |
| 14071 | Phreatic | | |
| 14076 | Phreatic | | |
| 14083 | Phreatic | | |
| 14090 | Phreatic | | |
| 14096 | Phreatic | | |
| 14106 | Phreatic | | |
| 14111 | Phreatic | | |
| 14114 | Phreatic | | |
| 14121 | Phreatic | | |
| 14130 | Phreatic | | |
| 14135 | Phreatic | | |
| 14144 | Phreatic | | |
| 14155 | Phreatic | | |
| 14162 | Phreatic | | |
| 14171 | Phreatic | | |
| 14180 | Phreatic | | |
| 14189 | Phreatic | | |
| 14199 | Phreatic | | |
| 14203 | Fixed head | 12 | |
| 3032 | Fixed head | 12 | |
| 3084 | Fixed head | 12 | |
| 3207 | Fixed head | 12 | |
| 3360 | Fixed head | 12 | |
| 3583 | Fixed head | 12 | |

**Seepage Restraints**

| Node no. | Restraint type | Piezometric level | Outflow |
|---|---|---|---|
| | | m | $m^3/s$ |
| 3815 | Fixed head | 12 | |
| 4144 | Fixed head | 12 | |
| 4456 | Fixed head | 12 | |
| 4846 | Fixed head | 12 | |
| 5182 | Fixed head | 12 | |
| 5563 | Fixed head | 12 | |
| 5906 | Fixed head | 12 | |
| 6246 | Fixed head | 12 | |
| 6587 | Fixed head | 12 | |
| 6908 | Fixed head | 12 | |
| 7291 | Fixed head | 12 | |
| 7703 | Fixed head | 12 | |
| 8178 | Fixed head | 12 | |
| 8678 | Fixed head | 12 | |
| 9205 | Fixed head | 12 | |
| 9647 | Fixed head | 12 | |
| 10127 | Fixed head | 12 | |
| 10480 | Fixed head | 12 | |
| 10847 | Fixed head | 12 | |
| 11076 | Fixed head | 12 | |
| 11292 | Fixed head | 12 | |
| 11460 | Fixed head | 12 | |
| 11625 | Fixed head | 12 | |
| 11776 | Fixed head | 12 | |
| 11910 | Fixed head | 12 | |
| 12028 | Fixed head | 12 | |
| 12158 | Fixed head | 12 | |
| 4479 | Fixed head | 12 | |
| 4547 | Fixed head | 12 | |
| 4657 | Fixed head | 12 | |
| 4820 | Fixed head | 12 | |
| 5014 | Fixed head | 12 | |
| 5233 | Fixed head | 12 | |
| 5462 | Fixed head | 12 | |
| 5679 | Fixed head | 12 | |
| 5890 | Fixed head | 12 | |
| 6134 | Fixed head | 12 | |
| 6370 | Fixed head | 12 | |
| 6597 | Fixed head | 12 | |
| 6865 | Fixed head | 12 | |
| 7201 | Fixed head | 12 | |

**Seepage Restraints**

| Node no. | Restraint type | Piezometric level | Outflow |
|---|---|---|---|
| | | m | $m^3/s$ |
| 7569 | Fixed head | 12 | |
| 7977 | Fixed head | 12 | |
| 8424 | Fixed head | 12 | |
| 8932 | Fixed head | 12 | |
| 9409 | Fixed head | 12 | |
| 9902 | Fixed head | 12 | |
| 10361 | Fixed head | 12 | |
| 10795 | Fixed head | 12 | |
| 11143 | Fixed head | 12 | |
| 11468 | Fixed head | 12 | |
| 11764 | Fixed head | 12 | |
| 12084 | Fixed head | 12 | |
| 12380 | Fixed head | 12 | |
| 12722 | Fixed head | 12 | |
| 13056 | Fixed head | 12 | |
| 13386 | Fixed head | 12 | |
| 13673 | Fixed head | 12 | |
| 13954 | Fixed head | 12 | |
| 4858 | Fixed head | -20 | |
| 4869 | Fixed head | -20 | |
| 4873 | Fixed head | -20 | |
| 4879 | Fixed head | -20 | |
| 4888 | Fixed head | -20 | |
| 5076 | Fixed head | -20 | |
| 5164 | Fixed head | -20 | |
| 5179 | Fixed head | -20 | |
| 5494 | Fixed head | -20 | |
| 5543 | Fixed head | -20 | |
| 5567 | Fixed head | -20 | |
| 4957 | Fixed head | -20 | |
| 4999 | Fixed head | -20 | |
| 5005 | Fixed head | -20 | |
| 5013 | Fixed head | -20 | |
| 5032 | Fixed head | -20 | |
| 5238 | Fixed head | -20 | |
| 5315 | Fixed head | -20 | |
| 5324 | Fixed head | -20 | |
| 5617 | Fixed head | -20 | |
| 5646 | Fixed head | -20 | |
| 5797 | Fixed head | -20 | |

Outputs

# Pore water pressure

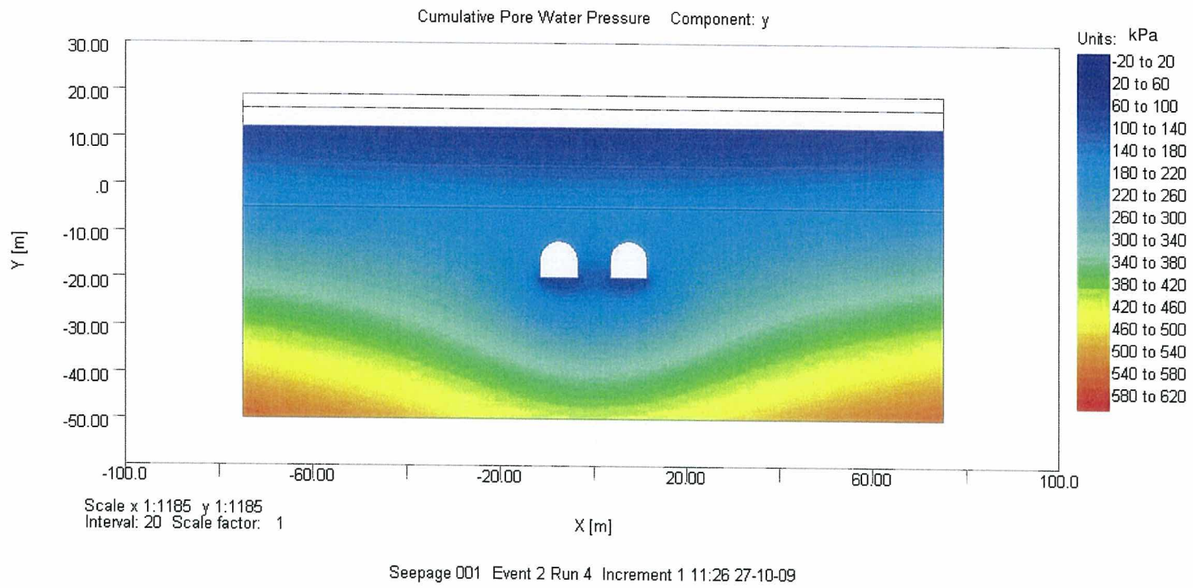



**Figure 2**

ARUP

# Pore water pressure (close-up)

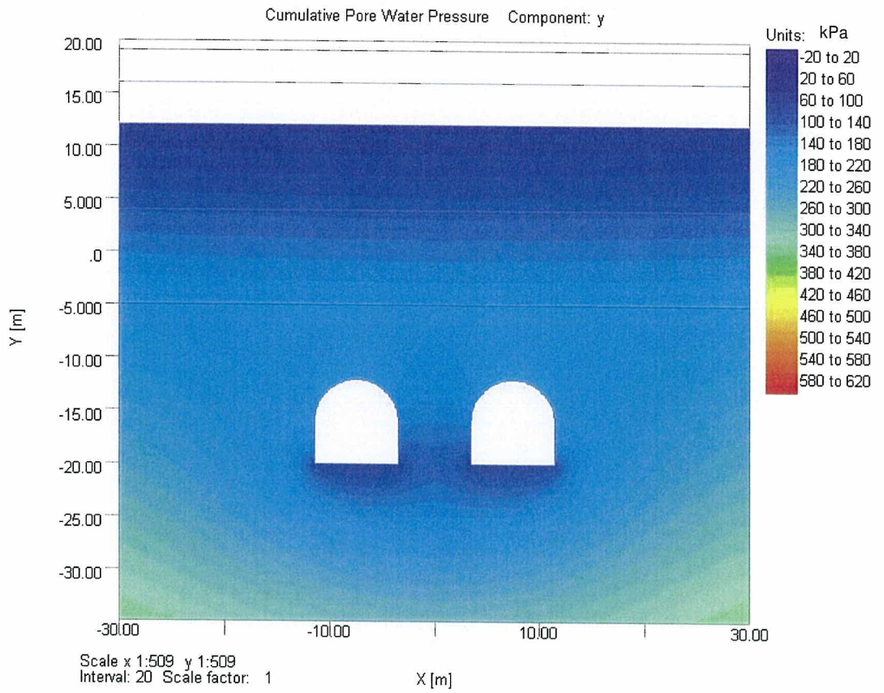



**Figure 3**

ARUP

# Pore water pressure contours

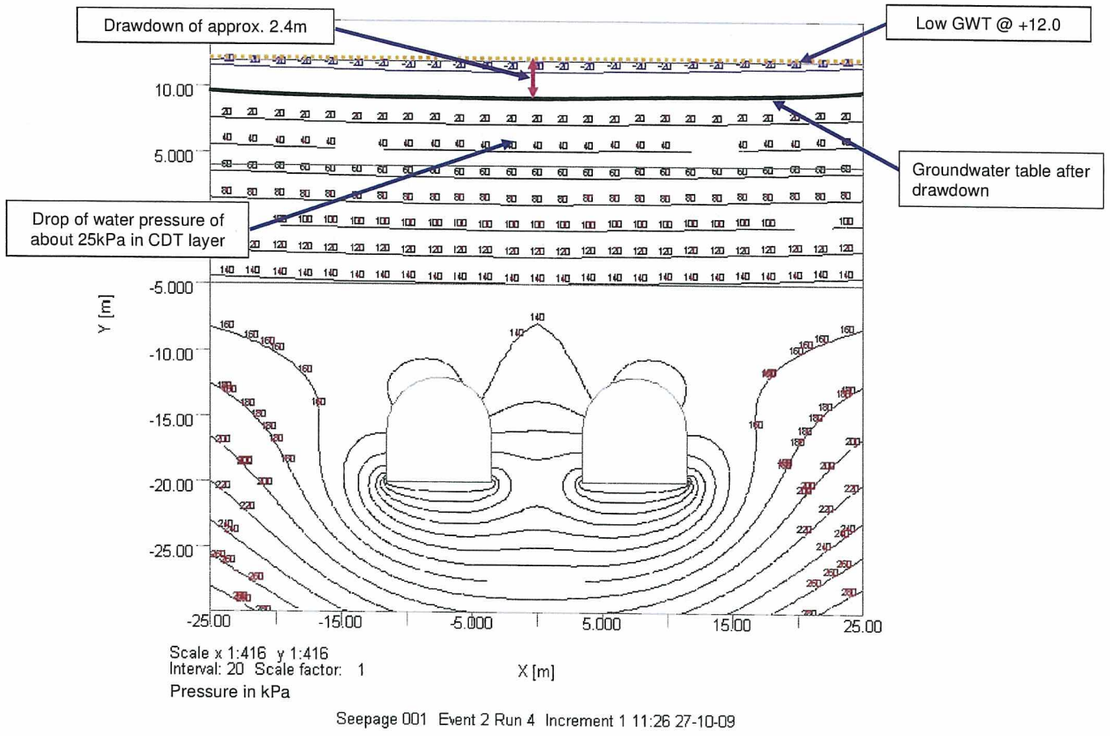



**Figure 4**

ARUP

# Flow velocity vector

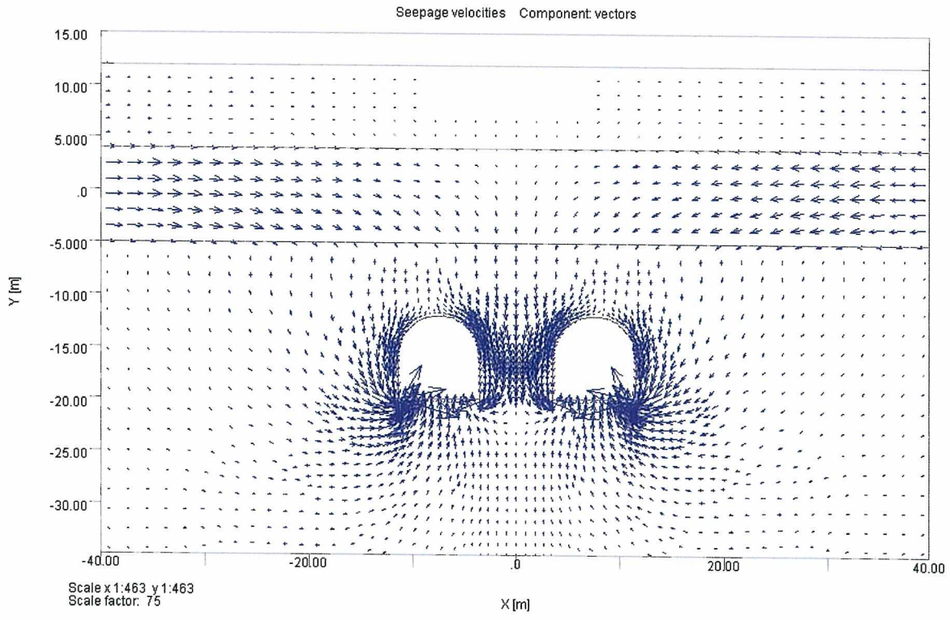



**Figure 5**

ARUP

# Flow velocity vector (close-up)

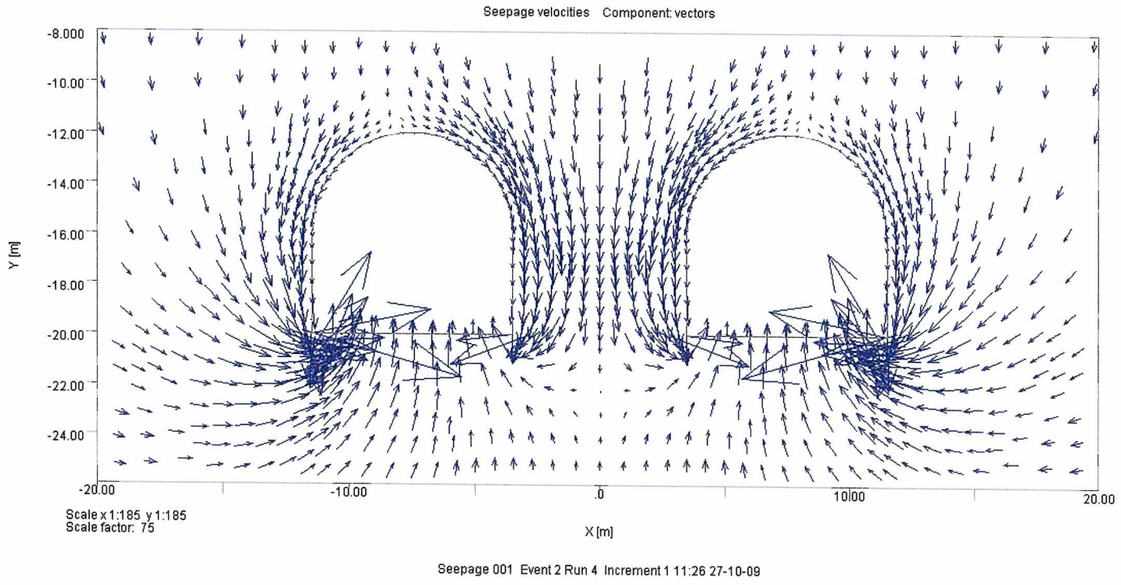



**Figure 6**

ARUP

# Geological section adopted

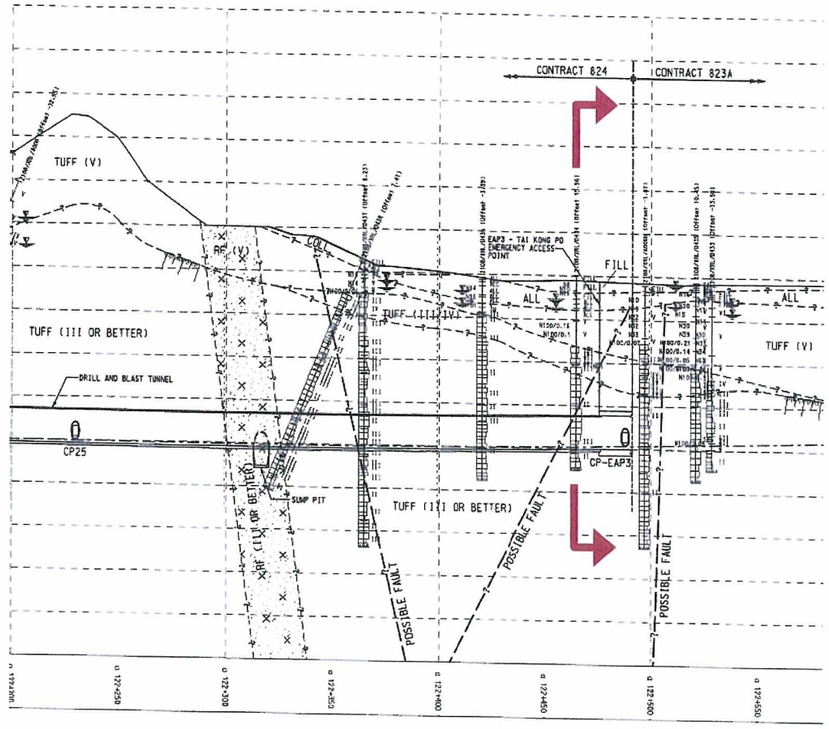



**Figure 7**

ARUP

# Settlement Prediction

OAP 20

ARUP Ove Arup & Partners Hong Kong Ltd
Calculation Sheet

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 208683 | 1 | |

Member / Location

Job Title: Express Rail Link.
Hydrogeology Impact Assessment

Drg. Ref.

Made by: JY Date: 29/10/2008 Chd.

Settlement prediction (Due to groundwater drawdown from SEK drill & blast tunnels near Tai King Po)

1. From the seepage analysis result, the drawdown of groundwater table is about 2.4m. The drop in pore water pressure in CDT layer is approx. 25 kPa.

2. Since the lowest measured groundwater table (GWT) is below Fill and alluvium layer, settlement due to water drawdown only occurs in CDT layer. Given the drained nature of CDT, only immediate settlement is considered.

3. It is assumed that HDT and MDT layer will have negligible settlement because of their high stiffness.

4. From the nearest borehole 2108/XRL/10434, SPT N-value in CDT layer is well over 100. Assume N=50 in the calculations for conservative estimate.

For $N = 50$, Take $E = 1N$ MPa

$E = 50$ MPa

Settlement $\delta$

$= \frac{\Delta\sigma \cdot H}{E}$ where H is the thickness of CDT layer

$= \frac{25\,kPa \cdot 8\,m}{50\,MPa}$

$= 4$ mm

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FILENAME:

803 | 802

GCG | 826 | 825 | 824 | 823A | 823B | 823A | 822

HUANGGANG PARK VENT BUILDING
MAI PO VENT BUILDING
NGAU TAM MEI VENT BUILDING
TAI KONG PO EAP 3 BUILDING
EMERGENCY RESCUE STATION
TSE UK TSUEN SHAFT
PAT HEUNG VENT BUILDING

BORE TUNNEL | BORE TUNNEL | DRAINED TUNNEL | BORE TUNNEL | CUT & COVER TUNNEL | BORE TUNNEL | DRAINED TUNNEL

Level (mPD)

SLP -0.10% | SLP -1.20% | SLP -1.20% | SLP 0.81% | SLP 0.40% | SLP 0.30% | SLP 0.30% | SLP -0.30% | SLP 1.90% | SLP 0.00% | SLP 1.70% | SLP 1.70% | SLP -0.30%

PVI o 112+000.000 ELEV -21.179
PVI o 113+000.000 ELEV -37.619
LO o 114+493.248 ELEV -44.770
PVI o 114+500.000 ELEV -44.891
PVI o 116+306.541 ELEV -30.668
PVI o 117+002.448 ELEV -27.417
OUTLET
IN BASEMENT OF VENT BUILDING
HI o 120+833.811 ELEV -16.015
PVI o 120+833.811 ELEV -15.925
SUMP AT TUNNEL LOW POINT AND DISCHARGED VIA RISING MAIN TO EAP3
LO o 122+316.581 ELEV -20.305
OUTLET
PVI o 122+435.570 ELEV -20.431
SHEK KONG STABLING
SUMP AT PORTAL ENTRANCE
PORTAL
OUTLET
OUTLET
OUTLET
OUTLET TO SSS DRAINAGE SYSTEM
PVI o 123+393.554 ELEV -3.300
IN NORTHERN VENT BUILDING
PVI o 124+002.191 ELEV 12.267
IN SOUTHERN VENT BUILDING
SHUNT NECK
APPROACH TUNNEL
IN CROSS PASSAGE AT WORKS SHAFT (TUT)
PVI b 125+231.402 ELEV 16.347
PVI b 126+316.152 ELEV 16.350

CHAINAGE

111+760 | 112+000 | 113+000 | 114+000 | 115+000 | 115+488 | 115+600 | 116+136 | 117+000 | 117+312 | 118+000 | 119+000 | 119+859 | 120+000 | 121+000 | 122+000 | 122+317 | 122+491 | 123+000 | 123+521 | 123+680 | 124+000 | 124+160 | 124+485 | 124+655 | 124+750 | 124+850 | 125+000 | 125+354 | 125+819 | 126+000

GWLS1 | GWLS2 | GWLS3

## GROUND AND SURFACE WATER DRAINAGE SYSTEM

**NOTES:**

1. ALL CHAINAGES SHALL REFER TO SOUTHBOUND TRACK ALIGNMENT

**LEGEND:**

GROUND WATER SUMP

SURFACE WATER SUMP

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS 1SSUE | AL | 18SEP09 | JM |

| | |
|---|---|
| DRAWN | AL |
| DESIGNED | NN |
| CHECKED | YKL |
| APPROVED | JM |
| DATE | 22/MAR/2009 |

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CADD REF. 824_T_330_OAP_D04_001A1.dgn

TITLE

CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
TUNNEL DRAINAGE SCHEMATIC
GROUND AND SURFACE WATER

SCALE N/A

DRAWING NO. 824/T/330/OAP/D04/001

REV. A1

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803

GCG | 826 | 825 | 824 | 823A | 823B | 823A | 822

HUANGGANG PARK VENT BUILDING
MAI PO VENT BUILDING
NGAU TAM MEI VENT BUILDING
TAI KONG PO EAP 3 BUILDING
EMERGENCY RESCUE STATION
TSE UK TSUEN SHAFT
PAT HEUNG VENT BUILDING

BORE TUNNEL | BORE TUNNEL | DRAINED TUNNEL | BORE TUNNEL | CUT & COVER TUNNEL | BORE TUNNEL | DRAINED TUNNEL

Level (mPD)

SHUNT NECK
APPROACH TUNNEL
SHEK KONG STABLING

SLP -0.10%
SLP -1.20%
SLP -1.20%
SLP 0.81%
SLP 0.40%
SLP 0.30%
SLP 0.30%
SLP -0.30%
SLP 1.90%
SLP 0.00%
SLP 1.70%
SLP 1.70%
SLP -0.30%

OUTLET
OUTLET
OUTLET
OUTLET

PVI a 112+000.000 ELEV -21.119
PVI a 113+500.000 ELEV -37.619
LO a 113+469.248 ELEV -44.710
PVI a 114+406.800 ELEV -44.710
SUMP AT TUNNEL LOW POINT AND DISCHARGED VIA RISING MAIN TO MAIN DRAINAGE SYSTEM
PVI a 116+306.547 ELEV -31.280
PVI a 117+002.446 ELEV -21.417
IN BASEMENT OF VENT BUILDING
HI a 120+433.311 ELEV -16.075
PVI a 120+433.311 ELEV -16.075
SUMP AT TUNNEL LOW POINT AND DISCHARGED VIA RISING MAIN TO EAP3
LO a 122+396.581 ELEV -20.305
PVI a 122+436.570 ELEV -20.731
PVI a 123+545.554 ELEV -3.560
IN NORTHERN VENT BUILDING
PVI a 124+552.161 ELEV -3.560
IN SOUTHERN VENT BUILDING
FOUL WATER TO ERS FOUL WATER SUMP
PVI b 125+331.402 ELEV 14.553
PVI b 126+136.152 ELEV 14.553
HI b 125+836.365 ELEV 15.153

CHAINAGE: 111+700 | 112+000 | 113+000 | 114+000 | 115+000 | aa 115+828 | aa 116+000 | aa 116+136 | aa 117+000 | aa 117+312 | aa 118+000 | aa 119+000 | aa 119+459 | a 120+000 | a 121+000 | a 122+000 | a 122+317 | a 122+491 | a 123+000 | a 123+521 | a 123+680 | a 124+000 | a 124+160 | a 124+485 | a 124+655 | a 124+762 | a 124+826 | a 125+000 | b 125+354 | b 125+819 | b 126+000

FWLS1 | FWLS4 | FWLS2 | FWLS3

NOTES:
1. ALL CHAINAGES SHALL REFER TO SOUTHBOUND TRACK ALIGNMENT

LEGEND:
FOUL WATER SUMP

## FOUL WATER DRAINAGE SYSTEM

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | AL | 18SEP09 | JM |

ACP

| | |
|---|---|
| DRAWN | AL |
| DESIGNED | NN |
| CHECKED | YKL |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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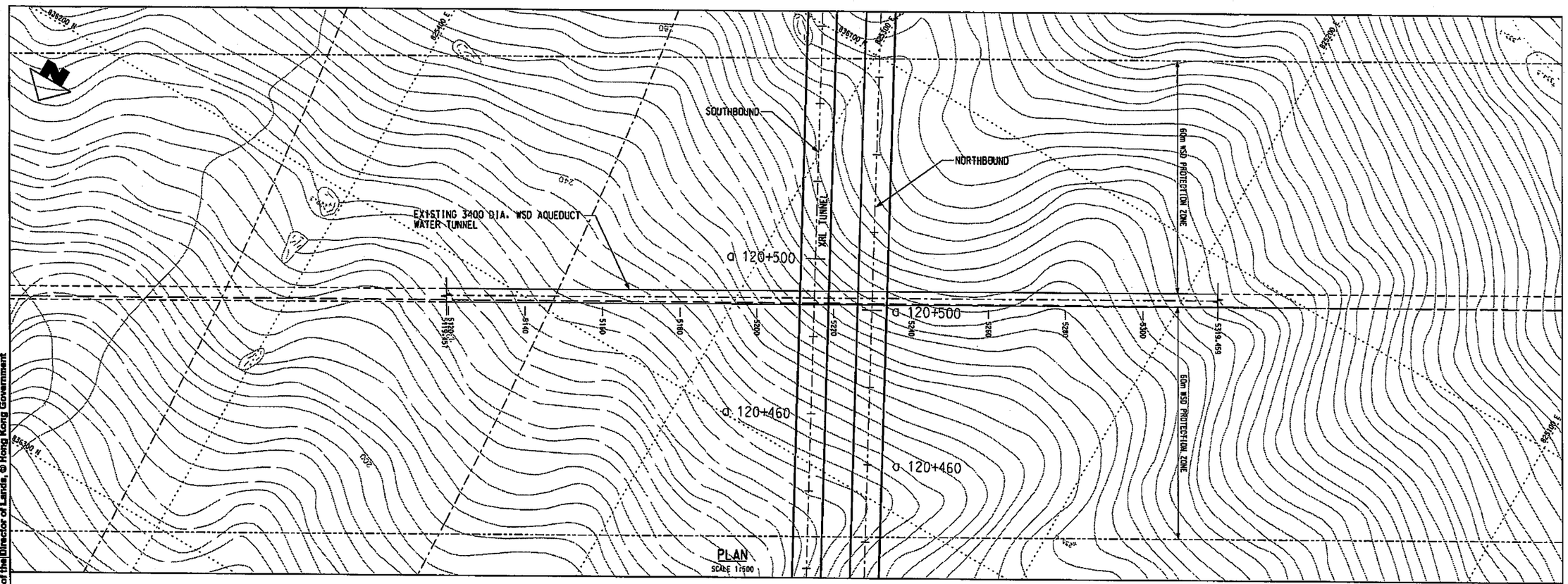
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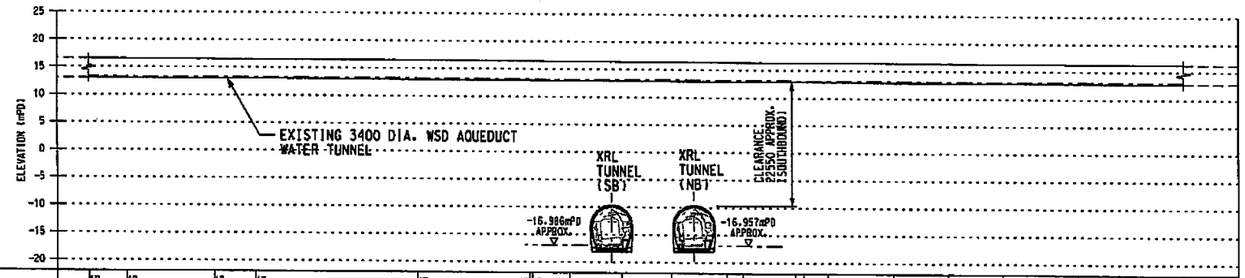
TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
TUNNEL DRAINAGE SCHEMATIC
FOUL WATER

SCALE N/A | DRAWING NO. 824/T/330/OAP/D04/002 | REV. A1

# Appendix F

## Works Contract 824 - WSD Aqueduct As-built Drawings & Inflow Calculation




| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WATER TUNNEL CHAINAGE | | 5319.457 | 5326.400 | | 5342.400 | 5350.000 | | 5376.400 | 5400.000 | 5400.400 | 5407.400 | 5416.900 | 5426.900 | 5435.900 | 5438.900 | 5450.000 | 5454.400 | 5466.400 | 5476.400 | 5486.400 | 5500.000 | 5519.459 |
| EXISTING GROUND LEVEL | | +22.0 | | | | | | | | | | +25.4 | | | | | | | | | | +26.0 |
| INVERT LEVEL | | +13.575 | +13.568 | | +13.551 | | | +13.510 | | +13.587 | +13.578 | +13.569 | +13.559 | +13.548 | +13.545 | | +13.534 | +13.528 | +13.514 | +13.504 | +13.493 | +13.456 |
| GRADIENT | | 1 IN 911.189 FALL | | | | | | | | | | | | | | | | | | | | |
| AS-BUILT LINING TYPE | | 50mm SHOTCRETE | UNLINED | | 50mm SHOTCRETE | UNLINED | | | | 50mm SHOTCRETE | UNLINED | 75mm SHOTCRETE | UNLINED | | 50mm SHOTCRETE | UNLINED | 50mm SHOTCRETE | 75mm SHOTCRETE | 50mm SHOTCRETE | CONCRETE LINING | 70mm SHOTCRETE | |
| CHAINAGE LENGTH (m) | | 6.943 | 16 | | 37 | 21 | | | | 7 | 9.5 | 9 | 10 | | 3 | 9.5 | 6 | 12 | 10 | 10 | 33.059 | |

ELEVATION
SCALE 1:500

NOTES:

1. FOR NOTES, REFER TO DRAWING NO. 824/P/330/OAP/C01/021
2. THE SETTING OUT OF THE WSD TUNNEL IS BASED ON AS-BUILT INFORMATION AND THE TUNNEL LOCATION AND LINING TYPES SHALL BE CONFIRMED BY SURVEYING AND INSPECTION ON SITE.

0 5 10 15 20 25
METRES
1 : 500

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | SCHEME DESIGN ISSUE | TW | 22MAY09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | JM |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 22/MAY/2009 |

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ORIGINATOR: ARUP

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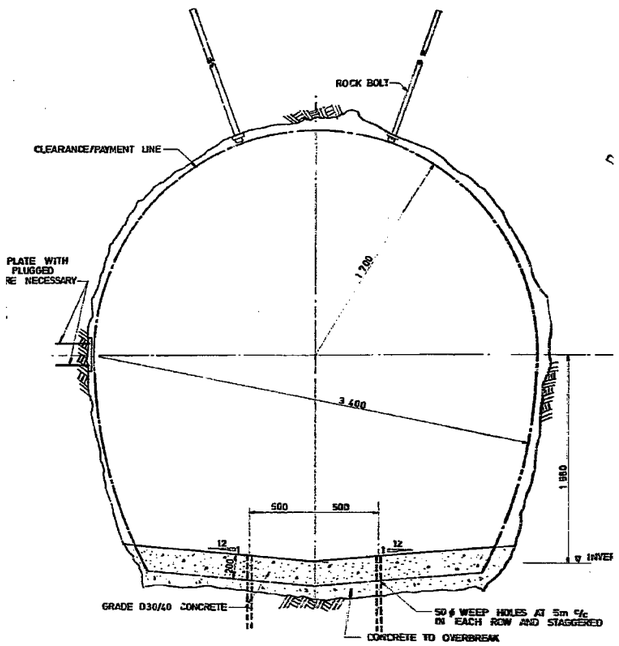
CADD REF. 824_P_330_OAP_C03_341A.dgn

TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
INTERFACE BETWEEN WORKS CONTRACT 824 AND EXISTING WSD AQUEDUCT TUNNEL AT NGAU TAM MEI
PLAN AND SECTION

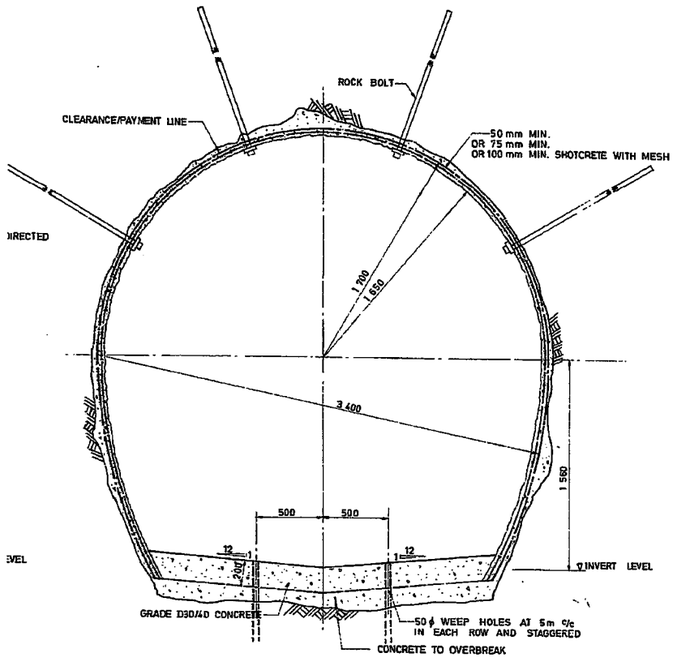
SCALE: 1 : 500 (A1)
DRAWING NO.: 824/P/330/OAP/C03/341
REV.: A

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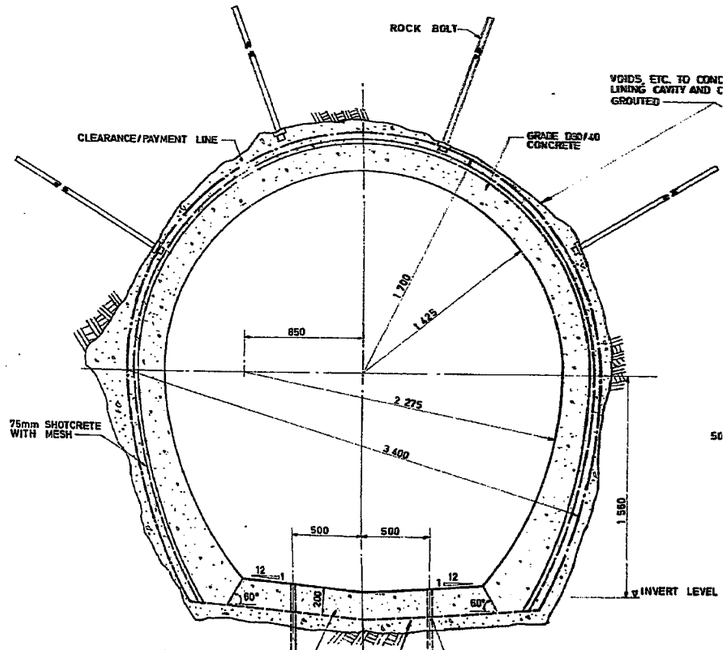
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TYPE 1 :- UNLINED SECTION
SCALE 1 : 20




TYPE 3 :- PATTERNED BOLTS WITH SHOTCRETE AND MESH
SCALE 1 : 20




TYPE 4 :- CONCRETE LINING WITH 75 mm SHOTCRETE AND MESH
SCALE 1 : 20

**As-built cross sections of Western Aqueduct showing installed support details**

**A. Steady State Inflow - 1995 Method**

Zone 2: Tunnel CH 120+100 to 122+000 6232 ft

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_c$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | | |
| b. $F_h$ (Figure 4) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | | |
| c. Percent in interval | 0.0% | 25.0% | 17.0% | 33.0% | 25.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | | |
| d. Tunnel Length, m | 0.0 | 474.9 | 322.9 | 626.8 | 474.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00008 | 0.0003 | 0.0008 | 0.003 | 0.008 | 0.03 | 0.08 | 0.3 | 0.8 | 3 | 8 | 25 | | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 | 1.6 | 5.0 | 15.8 | 49.5 | 158.5 | 495.3 | 1585.0 | 4953.0 | | | |
| g. $\Delta Q_s$, L/min | 0.0 | 7.5 | 16.0 | 99.4 | 235.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 358 | |
| h. $\Delta Q_s$, rounded, L/min | 0 | 10 | 20 | 100 | 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 370 L/min | |
| $\Delta Q_s$, rounded, gpm | 0.0 | 2.6 | 5.3 | 26.4 | 63.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 98 gpm | |

Assumptions:
* Groundwater Elevation at +180 m and average cavern invert at -20m.
Head (ft): 650
*

**A. Steady State Inflow - 2005 Method**

Zone 1: Tunnel CH 120+100 to 122+000 6232 ft

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. $k_c$ scale, cm/sec | 1.E-07 | 5.0 | 1.E-06 | 5.0 | 1.E-05 | 5.0 | 1.E-04 | 5.0 | 1.E-03 | 5.0 | 1.E-02 | 5.0 | | | | |
| b. $F_h$ (Figure 4) | | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | | | |
| c. Percent in interval | 0.0% | 25.0% | 17.0% | 33.0% | 25.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | | |
| d. Tunnel Length, m | 0.0 | 474.9 | 322.9 | 626.8 | 474.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | |
| e. $q_s$/H, L/min/m/m (Figure 4) | 0.0000 | 0.00012 | 0.0004 | 0.0012 | 0.004 | 0.012 | 0.04 | 0.12 | 0.4 | 1.2 | 4 | 12 | 40 | | | |
| f. $q_s$, L/min/m | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 2.4 | 7.9 | 23.8 | 79.2 | 237.7 | 792.5 | 2377.4 | 7924.8 | | | |
| g. $\Delta Q_s$, L/min | 0.0 | 11.3 | 25.6 | 149.0 | 376.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 562 | |
| h. $\Delta Q_s$, rounded, L/min | 0 | 10 | 30 | 150 | 380 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total Qs = | 570 L/min | |
| $\Delta Q_s$, rounded, gpm | 0.0 | 2.6 | 7.9 | 39.6 | 100.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | = | 151 gpm | |

Assumptions:
* Groundwater Elevation at +180m and average cavern invert at -20m.
Head (ft): 650

# Appendix G

## Instrumentation Layout Plan

## NOTES ON MONITORING

1. THE CONTRACTOR SHALL DETERMINE THE EXACT EXTENT AND QUANTITY OF MONITORING AND INSTRUMENTATION BASED ON THE CONDITION SURVEY RESULT. SUCH MONITORING PROPOSAL SHALL BE SUBMITTED TO THE APPROVAL OF THE ENGINEER.
2. THE CONTRACTOR SHALL AGREE THE LOCATIONS OF ALL INSTRUMENTS WITH THE ENGINEER AND RELEVANT LOT OWNERS ON SITE.
3. DETAILS OF SETTING OUT CONTROL POINTS, BENCH MARKS, TEMPORARY BENCH MARKS, ETC. USED FOR MONITORING PURPOSE SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT PRIOR TO THE COMMENCEMENT OF THE SURVEY WORKS.
4. THE CONTRACTOR SHALL SUBMIT AS-BUILT RECORDS OF ALL MONITORING INSTRUMENTS TO THE ENGINEER FOR APPROVAL, INCLUDING COORDINATES, LEVELS, BEARING, PHOTOGRAPHS, ETC. AND ALSO THOSE REQUIRED IN M & W SPECIFICATION CLAUSE 23.11.
5. RESPONSE TESTS SHALL BE CARRIED OUT FOR ALL EXISTING STANDPIPES / PIEZOMETERS WITHIN 3 DAYS OF COMPLETION OF INSTALLATION, AND ON MONTHLY BASIS THEREAFTER. THE CONTRACTOR SHALL REINSTATE OR REPLACE AS NECESSARY ANY MALFUNCTIONING PIEZOMETERS / STANDPIPES TO THE SATISFACTION OF THE ENGINEER.
6. PRIOR TO COMMENCEMENT OF CONSTRUCTION, BACKGROUND MONITORING SHALL BE CARRIED OUT WITH FOUR SETS OF INITIAL READINGS FOR ALL EXISTING AND PROPOSED INSTRUMENTS TAKEN ON WEEKLY BASIS. INITIAL READINGS SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT AT LEAST FOUR WEEKS PRIOR TO COMMENCEMENT OF CONSTRUCTION.
7. MONITORING OF ALL INSTRUMENTS SHALL BE CARRIED OUT BY AN INDEPENDENT SURVEYOR APPROVED BY THE ENGINEER.
8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MAINTENANCE OF ALL THE INSTRUMENTS DURING THE CONTRACT PERIOD. THE CONTRACTOR SHALL REPAIR OR REPLACE ANY DAMAGED INSTRUMENTS AS NECESSARY.
9. INSTRUMENTATION WITHIN MONITORING ZONE VB1 SHALL BE INSTALLED BY THE CONTRACT 825 CONTRACTOR. THE CONTRACTOR MAY INSTALL ADDITIONAL INSTRUMENTATION IF HE SO WISHES. THE AVAILABLE INSTRUMENTATION RECORDS SHALL BE PROVIDED BY THE CONTRACT 825 CONTRACTOR TO THE CONTRACTOR WHEN THE WORK SITE IS HANDED OVER FROM CONTRACT 825 TO CONTRACT 826.
10. THE CONTRACTOR SHALL PROVIDE AND MAINTAIN ALL NECESSARY ACCESS FOR THE CONTRACT 825 CONTRACTOR TO ACCESS HIS INSTRUMENTATION LOCATED WITHIN THE CONTRACTOR'S WORKS AREA AT VB1. ACCESS SHALL BE IN ACCORDANCE WITH APPENDIX Y1 OF THE PS.
11. THE CONTRACTOR SHALL SUBMIT DRAFT MONITORING RESULTS WITHIN 24 HOURS AFTER THE READINGS ARE TAKEN. FORMAL MONITORING RESULTS SHALL BE SUBMITTED ON WEEKLY BASIS.
12. THE CONTRACTOR SHALL ADOPT THE FOLLOWING INSTRUMENT NUMBERING SYSTEM:

XXX-XXXXX-XXXXX-XXX-XX

- XX — INSTRUMENT NUMBER
- XXX — INSTRUMENT TYPE
- XXXXX — STRUCTURE NUMBER IF ANY
- XXXXX — SB CHAINAGE
- XXX — CONTRACT NUMBER

13. ALL MONITORING RESULTS SHALL BE PRESENTED IN A FORMAT APPROVED BY THE ENGINEER. WHICH SHALL AT LEAST INCLUDE DATA AND PLOTS OF READINGS AGAINST TIME. PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL SUBMIT HIS PROPOSED FORMAT OF PRESENTING THE MONITORING RESULTS FOR EACH TYPE OF INSTRUMENT TO THE ENGINEER FOR APPROVAL.
14. MONITORING SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 1

| STRUCTURE | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | 25mm | 40mm | 50mm |
| EXISTING REGISTERED FEATURES (SLOPE AND RETAINING WALL) | 25mm OR 1:600 | 40mm OR 1:375 | 50mm OR 1:300 |
| EXISTING BUILDINGS # (SETTLEMENT) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm |
| UTILITIES * | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |

\# FOR "ALERT", "ACTION", AND "ALARM" RESPONSE VALUES ON BUILDING SETTLEMENT SHALL REFER TABLE 1 EXCEPT THE FOLLOWING:

TABLE 2

| REF. NO. | SOUTHBOUND CHAINAGE | ADDRESS | BUILDING TYPE | BUILDING SETTLEMENT (mm) | | |
|---|---|---|---|---|---|---|
| | | | | ALERT | ACTION | ALARM |
| NB002 | 116+745 | MAI PO | RESIDENTIAL | 15 | 24 | 30 |

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

15. MOVEMENT SHALL BE MONITORED AGAINST ALERT, ACTION, AND ALARM LEVELS IN ACCORDANCE WITH M & W SPECIFICATION CLAUSE 2.18, WHICH ARE SET AS FOLLOWS:

ALERT VALUE — SET AT 0.5 TIMES OF SERVICEABILITY LIMIT

ACTION VALUE — SET AT 0.8 TIMES OF SERVICEABILITY LIMIT

ALARM VALUE — SET AT THE SERVICEABILITY LIMIT.

16. ON REACHING THE "ALERT LEVEL", THE CONTRACTOR SHALL INFORM THE ENGINEER WITHIN 24 HOURS. THE CONTRACTOR SHALL REVIEW THE MOVEMENT, ASSESS THE EFFECTS ON ADJACENT STRUCTURES AND PREDICT FURTHER MOVEMENTS. A "DETAILED PLAN OF ACTION" SHALL BE PROPOSED BY THE CONTRACTOR TO THE SATISFACTION OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE "RESPONSE ACTIONS" IDENTIFIED IN THE "DETAILED PLAN OF ACTION" FOR REACHING ALERT LEVEL.
17. ON REACHING THE "ACTION LEVEL", THE CONTRACTOR SHALL IMMEDIATELY IMPLEMENT THE RESPONSE ACTIONS GIVEN IN THE "DETAILED PLAN OF ACTION" FOR REACHING ACTION LEVEL. WORK MAY THEN ONLY PROCEED IF THE REMEDIAL MEASURES HAVE BEEN IMPLEMENTED AND ARE IN THE OPINION OF THE ENGINEER SHOWN TO BE EFFECTIVE. THE CONTRACTOR SHALL MAKE APPROPRIATE AMENDMENTS TO THE "DETAILED PLAN OF ACTION" WHERE NECESSARY.
18. ON REACHING THE "ALARM LEVEL", THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY. THE CONTRACTOR SHALL IMPLEMENT EMERGENCY RESPONSE ACTIONS INCLUDING SUSPEND ALL CONSTRUCTION ACTIVITIES WITHIN 50m OF THE INSTRUMENTS, UNLESS OTHERWISE AGREED BY THE ENGINEER. THE CONTRACTOR SHALL PROVIDE A REPORT DETAILING THE FULL HISTORY OF MOVEMENTS AND REMEDIAL MEASURES ADOPTED IN RELATION TO THE ACTUAL CONSTRUCTION SEQUENCE. THE REPORT SHALL BE REVIEWED AND INTERPRETATION OF EVENTS GIVEN TO THE ENGINEER WITH RECOMMENDATIONS FOR ENABLING WORK TO PROCEED. WORK MAY ONLY RESUME UPON THE WRITTEN INSTRUCTION OF THE ENGINEER.
19. MINIMUM FREQUENCY OF MONITORING SHALL BE AS FOLLOWS:

TABLE 3

| INSTRUMENT TYPE | DEPTH / LOCATION | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | |
|---|---|---|---|---|---|
| | | | BACKGROUND MONITORING | STANDARD MONITORING | ACTIVE MONITORING |
| OPEN STANDPIPES PIEZOMETERS (PIEZO) | TO BE DETERMINED ON SITE | TO MONITOR CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS IN SOILS / ROCK | MONTHLY FOR AT LEAST ONE YEAR | WEEKLY | DAILY |
| IN-PLACE /VERTICAL INCLINOMETER (IV)) / (INC) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE LATERAL GROUND MOVEMENT | WEEKLY | WEEKLY | DAILY |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR GROUND SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| BUILDING SETTLEMENT POINT (BSP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TILT PLATE (TP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING TILTING | WEEKLY | WEEKLY | DAILY |
| UTILITY SETTLEMENT MARKER (UMP) | ON SELECTED UTILITIES | TO MONITOR UTILITY SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| MAGNETIC PROBE EXTENSOMETER (MPX) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE SOIL SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TELL-TALE | ON BUILDINGS & STRUCTURES | TO MONITOR ANY CRACKS | WEEKLY | WEEKLY | DAILY |

20. BACKGROUND MONITORING SHALL REFER TO THE MONITORING TO BE UNDERTAKEN PRIOR TO ANY CONSTRUCTION WORKS COMMENCE.
21. STANDARD MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE BEYOND 50m AND WITHIN 100m FROM CONSTRUCTION WORKS.
22. ACTIVE MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE WITHIN 50m FROM CONSTRUCTION WORKS.
23. THE CONTRACTOR SHALL INCREASE THE FREQUENCY OF MONITORING AS NECESSARY OR AS INSTRUCTED BY THE ENGINEER.
24. FOR GENERAL MONITORING AND INSTRUMENTATION PLAN, REFER TO DRAWING NOS. 826/T/310/OAP/C06/101 TO 103.
25. FOR TYPICAL DETAILS, REFER TO DRAWING NOS. 826/T/310/OAP/C06/121 TO 126.

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TITLE
CONTRACT 826
HUANGGANG TO MAI PO
MONITORING AND INSTRUMENTATION
GENERAL NOTES

SCALE N.T.S.
DRAWING NO. 826/T/310/OAP/C01/051
REV. A

## NOTES ON MONITORING

1. PRIOR TO THE INSTLLATION OF ALL MONITORING INSTRUMENTS, THE CONTRACTOR SHALL DETERMINE THE EXACT EXTENT AND QUANTITY OF MONITORING AND INSTRUMENTATION BASED ON THE CONDITION SURVEY RESULT. SUCH MONITORING PROPOSAL SHALL BE SUBMITTED TO THE APPROVAL OF THE ENGINEER.
2. THE CONTRACTOR SHALL AGREE THE LOCATIONS OF ALL INSTRUMENTS WITH THE ENGINEER AND RELEVANT LOT OWNERS ON SITE.
3. DETAILS OF SETTING OUT CONTROL POINTS, BENCH MARKS, TEMPORARY BENCH MARKS, ETC. USED FOR MONITORING PURPOSE SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT PRIOR TO THE COMMENCEMENT OF THE SURVEY WORKS.
4. THE CONTRACTOR SHALL SUBMIT AS-BUILT RECORDS OF ALL MONITORING INSTRUMENTS TO THE ENGINEER FOR APPROVAL, INCLUDING COORDINATES, LEVELS, BEARING, PHOTOGRAPHS, ETC. AND ALSO THOSE REQUIRED IN W & W SPECIFICATION CLAUSE 23.11.
5. RESPONSE TESTS SHALL BE CARRIED OUT FOR ALL EXISTING STANDPIPES / PIEZOMETERS WITHIN 3 DAYS OF COMPLETION OF INSTALLATION, AND ON MONTHLY BASIS THEREAFTER. THE CONTRACTOR SHALL REINSTATE OR REPLACE AS NECESSARY ANY MALFUNCTIONING PIEZOMETERS / STANDPIPES TO THE SATISFACTION OF THE ENGINEER.
6. PRIOR TO COMMENCEMENT OF CONSTRUCTION, BACKGROUND MONITORING SHALL BE CARRIED OUT WITH FOUR SETS OF INITIAL READINGS FOR ALL EXISTING AND PROPOSED INSTRUMENTS TAKEN ON WEEKLY BASIS. INITIAL READINGS SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT AT LEAST FOUR WEEKS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION.
7. MONITORING OF ALL INSTRUMENTS SHALL BE CARRIED OUT BY AN INDEPENDENT SURVEYOR APPROVED BY THE ENGINEER.
8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MAINTENANCE OF ALL THE INSTRUMENTS DURING THE CONTRACT PERIOD. THE CONTRACTOR SHALL REPAIR OR REPLACE ANY DAMAGED INSTRUMENTS AS NECESSARY.
9. THE CONTRACTOR SHALL INSTALL AND MONITOR ALL INSTRUMENTATION PRIOR TO AND DURING THE CONSTRUCTION WORKS WITHIN THE COFFERDAM AT VB1. CONTRACT 826 MAY INSTALL ADDITIONAL MONITORING INSTRUMENTATION IF HE SO WISHES. THE CONTRACTOR SHALL PROVIDE THE AVAILABLE MONITORING RECORDS TO THE CONTRACT 826 CONTRACTOR WHEN THE WORK SITE IS HANDED OVER FROM CONTRACT 825 TO CONTRACT 826.
10. THE CONTRACTOR SHALL BE ABLE TO ACCESS HIS INSTRUMENTATION LOCATED WITHIN THE CONTRACT 826 WORKS AREA AT VB1. ACCESS SHALL BE IN ACCORDANCE WITH APPENDIX Y1 OF THE PS.
11. THE CONTRACTOR SHALL SUBMIT DRAFT MONITORING RESULTS WITHIN 24 HOURS AFTER THE READINGS ARE TAKEN. FORMAL MONITORING RESULTS SHALL BE SUBMITTED ON WEEKLY BASIS.
12. THE CONTRACTOR SHALL ADOPT THE FOLLOWING INSTRUMENT NUMBERING SYSTEM:

XXX-XXXXXX-XXXXX-XXX-XX

- XX — INSTRUMENT NUMBER
- XXX — INSTRUMENT TYPE
- XXXXX — STRUCTURE NUMBER IF ANY
- XXXXXX — SB CHAINAGE
- XXX — CONTRACT NUMBER

13. ALL MONITORING RESULTS SHALL BE PRESENTED IN A FORMAT APPROVED BY THE ENGINEER, WHICH SHALL AT LEAST INCLUDE DATA AND PLOTS OF READINGS AGAINST TIME, PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL SUBMIT HIS PROPOSED FORMAT OF PRESENTING THE MONITORING RESULTS FOR EACH TYPE OF INSTRUMENT TO THE ENGINEER FOR APPROVAL.
14. MONITORING OUTSIDE MONITORING ZONE VB1 SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 1

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | 25mm | 40mm | 50mm |
| EXISTING REGISTERED # FEATURES (SLOPE AND RETAINING WALL) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS # (SETTLEMENT) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES * | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| CONVERGENCE ARRAY (DEVIATION FROM DESIGN INTERNAL TUNNEL DIAMETER) | 50% OF THE DESIGN ALLOWED OVALISATION | 80% OF THE DESIGN ALLOWED OVALISATION | 100% OF THE DESIGN ALLOWED OVALISATION |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

C

\# "ALERT", "ACTION", AND "ALARM" RESPONSE VALUES ON BUILDING SETTLEMENT AND LATERAL MOVEMENT ARE SET FOR SOME PARTICULAR BUILDINGS AND STRUCTURES INDIVIDUALITY. DETAILS SHALL REFER TO DRAWING NO. 826/T/320/OAP/C01/052.

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

15. MONITORING WITHIN MONITORING ZONE VB1 SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 2

| STRUCTURE / MONITORING POINT | | ALERT | ACTION | ALARM |
|---|---|---|---|---|
| GROUND SETTLEMENT DUE TO WALL INSTALLATION | | 5mm | 8mm | 10mm |
| GROUND SETTLEMENT DUE TO DEWATERING | | 70mm | 115mm | 145mm |
| GROUND SETTLEMENT DUE TO EXCAVATION | | 50mm | 80mm | 100mm |
| GROUND SETTLEMENT DUE TO SITE FORMATION WORKS | | 25mm | 40mm | 50mm |
| TEMPORARY RETAINING WALL DEFLECTION | | 100mm | 160mm | 200mm |
| GROUNDWATER DRAWDOWN | WITHIN WORK AREA BOUNDARY | 9500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 10500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 11500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| | OUTSIDE WORK AREA BOUNDARY | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| TEMPORARY STRUT FORCE (WHERE Py IS THE ULTIMATE CAPACITY OF THE STRUT) | | 0.50Py | 0.70Py | 0.80Py |
| PIEZOMETRIC HEAD WITHIN THE EXCAVATION AT WALL TOE LEVEL (-49.500) | | 0.80 Pwp | 0.90Pwp | Pwp |

C

Pwp = 9WZ + 4.0H
WHERE 9w (kN/m³) = UNIT WEIGHT OF WATER =10
Z(m) = DEWATERING LEVEL - WALL TOE LEVEL (-49.500)
H(m) = HIGHEST DESIGN GROUNDWATER LEVEL (+4.500) - DEWATERING LEVEL

16. MOVEMENT SHALL BE MONITORED AGAINST ALERT, ACTION, AND ALARM LEVELS IN ACCORDANCE WITH W & W SPECIFICATION CLAUSE 2.18, WHICH ARE SET AS FOLLOWS:

ALERT VALUE SET AT 0.5 TIMES OF SERVICEABILITY LIMIT
ACTION VALUE SET AT 0.8 TIMES OF SERVICEABILITY LIMIT
ALARM VALUE SET AT THE SERVICEABILITY LIMIT.

17. ON REACHING THE "ALERT LEVEL", THE CONTRACTOR SHALL INFORM THE ENGINEER WITHIN 24 HOURS. THE CONTRACTOR SHALL REVIEW THE MOVEMENT, ASSESS THE EFFECTS ON ADJACENT STRUCTURES AND PREDICT FURTHER MOVEMENTS. A "DETAILED PLAN OF ACTION" SHALL BE PROPOSED BY THE CONTRACTOR TO THE SATISFACTION OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE "RESPONSE ACTIONS" IDENTIFIED IN THE "DETAILED PLAN OF ACTION" FOR REACHING ALERT LEVEL.
18. ON REACHING THE "ACTION LEVEL", THE CONTRACTOR SHALL IMMEDIATELY IMPLEMENT THE RESPONSE ACTIONS GIVEN IN THE "DETAILED PLAN OF ACTION" FOR REACHING ACTION LEVEL. WORK MAY THEN ONLY PROCEED IF THE REMEDIAL MEASURES HAVE BEEN IMPLEMENTED AND ARE IN THE OPINION OF THE ENGINEER SHOWN TO BE EFFECTIVE. THE CONTRACTOR SHALL MAKE APPROPRIATE AMENDMENTS TO THE "DETAILED PLAN OF ACTION" WHERE NECESSARY.
19. ON REACHING THE "ALARM LEVEL", THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY. THE CONTRACTOR SHALL IMPLEMENT EMERGENCY RESPONSE ACTIONS INCLUDING SUSPEND ALL CONSTRUCTION ACTIVITIES WITHIN 50m OF THE INSTRUMENTS, UNLESS OTHERWISE AGREED BY THE ENGINEER. THE CONTRACTOR SHALL PROVIDE A REPORT DETAILING THE FULL HISTORY OF MOVEMENTS AND REMEDIAL MEASURES ADOPTED IN RELATION TO THE ACTUAL CONSTRUCTION SEQUENCE. THE REPORT SHALL BE REVIEWED AND INTERPRETATION OF EVENTS GIVEN TO THE ENGINEER WITH RECOMMENDATIONS FOR ENABLING WORK TO PROCEED. WORK MAY ONLY RESUME UPON THE WRITTEN INSTRUCTION OF THE ENGINEER.
20. MINIMUM FREQUENCY OF MONITORING EXCEPT FOR MONITORING ZONE VB1, SHALL BE AS FOLLOWS:

TABLE 3

| INSTRUMENT TYPE | DEPTH/LOCATION | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | |
|---|---|---|---|---|---|
| | | | BACKGROUND MONITORING | STANDARD MONITORING | ACTIVE MONITORING |
| OPEN STANDPIPES PIEZOMETERS (PIEZO) | TO BE DETERMINED ON SITE | TO MONITOR CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS IN SOILS / ROCK | MONTHLY FOR AT LEAST ONE YEAR | WEEKLY | DAILY |
| INPLACE/VERTICAL INCLINOMETER (IVI/INC) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT LEVEL, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE LATERAL GROUND MOVEMENT | WEEKLY | WEEKLY | DAILY |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR GROUND SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| BUILDING SETTLEMENT POINT (BSP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING SETTLEMENT | WEEKLY | WEEKLY | DAILY* |
| TILT PLATE (TP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING TILTING | WEEKLY | WEEKLY | DAILY* |
| UTILITY MONITORING POINT (UMP) | ON SELECTED UTILITIES | TO MONITOR UTILITY SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| MAGNETIC PROBE EXTENSOMETER (MPX) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT LEVEL, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE SOIL SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TELL-TALE | ON BUILDINGS & STRUCTURES | TO MONITOR ANY CRACKS | WEEKLY | WEEKLY | DAILY |
| CONVERGENCE ARRAY | 25m c/c ALONG TBM TUNNEL AND 1 NO. AT THE CENTRE PER CROSS PASSAGE | TO MONITOR DEFORMATION OF PERMANENT TUNNEL LININGS | N/A | WEEKLY | DAILY |

* TWICE DAILY FOR MONITORING POINTS ON SAN TIN HIGHWAY FOOTBRIDGE (NH001) PIERS

21. MINIMUM FREQUENCY OF MONITORING FOR ZONE VB1 SHALL BE AS FOLLOWS:

TABLE 4

| INSTRUMENT TYPE | DEPTH | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | | |
|---|---|---|---|---|---|---|
| | | | DURING WALL INSTALLATION | DURING EXCAVATION | DURING SITE FORMATION WORKS # | ALL OTHER TIMES SUBSEQUENT TO COMPLETION OF ALL SITE FORMATION Δ |
| OPEN STANDPIPE PIEZOMETER (PIEZO)/ OBSERVATION WALLS | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITORING CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS | WEEKLY | DAILY | TWICE A WEEK | EVERY TWO WEEKS |
| VERTICAL INCLINOMETER (INC) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE TEMPORARY RETAINING WALL DEFLECTION | N/A | DAILY | TWICE A WEEK | N/A |
| MAGNETIC PROBE EXTENSSOMETER (MPX) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE SUBSURFACE SOIL SETTLEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR VERTICAL AND HORIZOTAL GROUND MOVEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| STRAIN GAUGE AT TEMPORARY STRUT | N/A | TO MONINTOR STRUT FORCE | N/A | FOUR TIMES DAILY | WEEKLY | N/A |

C

\# SITE FORMATION WORKS INCLUDE ALL BACKFILLING WORKS WITHIN THE MAI PO SHAFT, SLOPEWORKS, RETAINING WALLS, BACKFILLING WORKS FOR THE VENTILATION BUILDING AND ACCESS ROADS, AND ALL ASSOCIATED TEMPORARY WORKS.

Δ MONITORING MAY BE DISCONTINUED ONCE THREE CONSECUTIVE READINGS SHOW THAT MOVEMENTS HAVE STOPPED TO THE SATISFACTION OF THE ENGINEER.

22. BACKGROUND MONITORING SHALL REFER TO THE MONITORING TO BE UNDERTAKEN PRIOR TO ANY CONSTRUCTION WORKS COMMENCE.
23. STANDARD MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE BEYOND 50m AND WITHIN 100m FROM CONSTRUCTION WORKS.
24. ACTIVE MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE WITHIN 50m FROM CONSTRUCTION WORKS.
25. THE CONTRACTOR SHALL INCREASE THE FREQUENCY OF MONITORING AS NECESSARY OR AS INSTRUCTED BY THE ENGINEER.
26. FOR GENERAL MONITORING AND INSTRUMENTATION PLAN, REFER TO DRAWING NOS. 825/T/320/OAP/C05/101-105.
27. FOR TPYICAL DETAILS, REFER TO DRAWING NOS. 825/T/310/OAP/C06/121-127.

## NOTES ON MONITORING OF THE DSD NULLAH

1. GROUND SETTLEMENT POINTS SHALL BE INSTALLED ALONG THE CREST OF THE LOW FLOW CHANNEL.

## NOTES ON MONITORING OF THE HYD SAN TIN HIGHWAY FOOTBRIDGE

1. INSTRUMENTATION ARRANGEMENT FOR FOOTBRIDGE PIERS SHALL REFER TO THE DETAILS SHOWN ON DRG. 825/T/320/OAP/C06/121.

## NOTES ON MONITORING OF REGISTERED FEATURES

1. THE CONTRACTOR SHALL CARRY OUT REGULAR INSPECTION OF ANY REGISTERED GEOTECHNICAL FEATURES LOCATED WITHIN THE ZONE OF INFLUENCE OF THE WORKS. ANY SIGNS OF GEOTECHNICAL DISTRESS INCLUDING SURFACE CRACKING AND NEARBY WATER LEAKAGE SHALL BE DOCUMENTED AND REPORTED TO THE ENGINEER IMMEDIATELY. A REMEDIAL PROPOSAL SHALL BE PREPARED BY THE CONTRACTOR AND SUBMITTED FOR THE APPROVAL OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE PROPOSED REMEDIAL MEASURES UPON GAINING THE APPROVAL FROM THE ENGINEER.
2. PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL APPOINT AN INDEPENDENT REGISTERED PROFESSIONAL ENGINEER (GEOTECHNICAL) (RPE(G)) TO CARRY OUT A DETAILED INSPECTION OF ALL SLOPES, RETAINING WALLS, NATURAL TERRAIN, DISTURBED TERRAIN AND OTHER GEOTECHNICAL FEATURES (WHETHER REGISTERED OR UNREGISTERED) WITHIN THE 5mm SETTLEMENT AND 5mm/s PPV VIBRATION INFLUENCE ZONE AND NOT LESS THAN 50m FROM THE EDGES OF THE PROPOSED TUNNEL STRUCTURES. THESE INSPECTIONS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE REQUIREMENTS OF GEOGUIDE 5, PUBLISHED BY GEO. THE RPE(G) SHALL ADVISE ON THE MONITORING REQUIREMENTS DURING CONSTRUCTION. THE INSPECTION SHALL REVIEW THE CONDITIONS OF FEATURES, IN PARTICULAR ANY SIGNS OF DISTRESS, LOOSE BOULDERS, UNSTABLE ROCK FRAGMENTS AND WEDGES, AND OTHER NATURAL AND MANMADE MATERIALS THAT MAY BE AFFECTED BY CONSTRUCTION ACTIVITIES. THE CONTRACTOR SHALL TAKE APPROPRIATE ACTIONS TO REMOVE OR MITIGATE THE RISK OF INSTABILITY OF THE GEOTECHNICAL FEATURES PRIOR TO COMMENCEMENT OF ANY WORKS. FIVE SETS OF PRE-CONDITION SURVEY REPORTS SHALL BE SUBMITTED TO THE ENGINEER.

A

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TENDER

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|---|---|---|---|---|
| C | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| B | TENDER ADDENDUM NO. 1 ISSUE | AL | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

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TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
MONITORING AND INSTRUMENTATION
GENERAL NOTES

SCALE N.T.S.
DRAWING NO. 825/T/320/OAP/C01/051
REV. C

1.) SETTLEMENT OF THE BELOW LISTED BUILDINGS SHALL BE MONITORED AGAINST THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

| REF. NO. | SOUTHBOUND CHAINAGE | ADDRESS | BUILDING TYPE / DETAILS | BUILDING SETTLEMENT (MM) | | |
|---|---|---|---|---|---|---|
| | | | | ALERT | ACTION | ALARM |
| NB007 | 117+650 | BETWEEN 3, 5 PALM CANYON DRIVE AND CASTLE PEAK ROAD MAI PO | A MIX OF TEMPORARY AND OVERHANGING STRUCTURE | 20 | 32 | 40 |
| NB009 | 117+680 | BETWEEN 3, 5 PALM CANYON DRIVE AND CASTLE PEAK ROAD MAI PO | RESIDENTIAL | 20 | 32 | 40 |
| NB010 | 117+680 | BETWEEN 3, 5 PALM CANYON DRIVE AND CASTLE PEAK ROAD MAI PO | RESIDENTIAL | 20 | 32 | 40 |
| NB013 | 117+870 | 80 CASTLE PEAK ROAD, MAI PO | HOUSE F8,A75-A76,A77-A88, MAPLE GARDEN | 15 | 24 | 30 |
| NB014 | 117+920 | 80 CASTLE PEAK ROAD, MAI PO | HOUSE A43-A52, 55-60, 63-68, MAPLE GARDEN | 15 | 24 | 30 |
| NB015 | 117+940 | 80 CASTLE PEAK ROAD, MAI PO | HOUSE A69-A74, B11-B14, MAPLE GARDEN | 15 | 24 | 30 |
| NB022 | 118+460 | 62D,62E WAI TSAI TSUEN | VILLAGE HOUSE | 15 | 24 | 30 |
| NB023 | 118+440 | 62E WAI TSAI TSUEN | VILLAGE HOUSE | 15 | 24 | 30 |
| NB026 | 118+520 | NEXT TO 41 AND 42 WAI.TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB027 | 118+520 | 41,47 WAI TSAI TSUEN | VILLAGE HOUSE | 15 | 24 | 30 |
| NB029 | 118+540 | 20,25,27 WAI TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB030 | 118+580 | 7,11,12,15,19,33,36 WAI TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB032 | 118+560 | 53,54 WAI TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB033 | 118+600 | 45 WAI TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB034 | 118+600 | NEAR 45 WAI TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB035 | 118+580 | NEAR 56 WAI TSAI TSUEN | VILLAGE HOUSE | 20 | 32 | 40 |
| NB040 | 118+560 | 100 NGAU TAM MEI ROAD | BLOCK A, B YAU MEI GARDEN, WITH PARKING AND TEMPORARY STRUCTURE | 15 | 24 | 30 |
| NB046 | 119+100 | NEAR CHUN SHIN ROAD | VILLAGE HOUSE | 20 | 32 | 40 |
| NB049 | 119+160 | NEAR CHUN SHIN ROAD | VILLAGE HOUSE | 20 | 32 | 40 |
| NB050 | 119+220 | NEAR CHUN SHIN ROAD | VILLAGE HOUSE | 20 | 32 | 40 |
| NB051 | 119+240 | NEAR CHUN SHIN ROAD | VILLAGE HOUSE | 15 | 24 | 30 |
| NB054 | 119+360 | NEAR CHUN SHIN ROAD | VILLAGE HOUSE | 20 | 32 | 40 |
| NB055 | 119+400 | NEAR CHUN SHIN ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB056 | 119+370 | NEAR CHUN SHIN ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB064 | 119+450 | NEAR CHUN SHIN ROAD | WAREHOUSE | 15 | 24 | 30 |
| NB065 | 119+450 | NEAR CHUN SHIN ROAD | RESIDENTIAL | 15 | 24 | 30 |
| NB066 | 119+430 | NEAR CHUK YAU ROAD | VILLAGE HOUSE | 15 | 24 | 30 |
| NB067 | 119+431 | NEAR CHUK YAU ROAD | TEMPORARY STRUCTURE | 15 | 24 | 30 |
| NB068 | 119+430 | NEAR CHUK YAU ROAD | WAREHOUSE | 15 | 24 | 30 |
| NB069 | 119+430 | NEAR CHUK YAU ROAD | WAREHOUSE | 15 | 24 | 30 |
| NB070 | 119+430 | NEAR CHUK YAU ROAD | WAREHOUSE | 15 | 24 | 30 |
| NB071 | 119+520 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB072 | 119+520 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB074 | 119+520 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB075 | 119+520 | NEAR CHUK YAU ROAD | TEMPORARY STRUCTURE | 15 | 24 | 30 |
| NB077 | 119+520 | NEAR CHUK YAU ROAD | RESIDENTIAL | 15 | 24 | 30 |
| NB078 | 119+520 | NEAR CHUK YAU ROAD | TEMPORARY STRUCTURE | 20 | 32 | 40 |
| NB085 | 119+580 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB086 | 119+580 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB086A | 119+580 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB086B | 119+650 | NEAR CHUK YAU ROAD | RESIDENTIAL | 15 | 24 | 30 |
| NB086C | 119+650 | NEAR CHUK YAU ROAD | RESIDENTIAL | 20 | 32 | 40 |
| NB089 | 119+661 | SAI WAH ROAD (NEAR CHUK YAU ROAD) | RESIDENTIAL | 15 | 24 | 30 |
| NB091 | 119+660 | SAI WAH ROAD (NEAR CHUK YAU ROAD) | RESIDENTIAL | 15 | 24 | 30 |

2.) SETTLEMENT OF THE BELOW LISTED STRUCTURES SHALL BE MONITORED AGAINST THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

| REF. No. | SOUTHBOUND CHAINAGE | LOCATION | STRUCTURE TYPE / DETAILS | STRUCTURE SETTLEMENT (mm) | | |
|---|---|---|---|---|---|---|
| | | | | ALERT | ACTION | ALARM |
| NH001 | 117+830 | SAN TIN HIGHWAY | HIGHWAYS FOOTBRIDGE | 13 | 20 | 25 |
| NH002 | 118+810 | NULLAH NEAR YAU TAM MEI TSUEN | HIGHWAYS FOOTBRIDGE | 13 | 20 | 25 |

B

3.) SETTLEMENT OF THE BELOW LISTED REGISTERED FEATURES SHALL BE MONITORED AGAINST THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

| REGISTERED FEATURE# NO | ALERT | ACTION | ALARM |
|---|---|---|---|
| 2SE-C/C116 | 14 mm OR 1:600 | 22 mm OR 1:375 | 28 mm OR 1:300 |
| 2SE-C/R98 | 15 mm OR 1:600 | 24 mm OR 1:375 | 30 mm OR 1:300 |
| 2SE-C/R99 | 15 mm OR 1:600 | 24 mm OR 1:375 | 30 mm OR 1:300 |

# REMARK: LOCATIONS OF THE ABOVE FEATURES SHALL REFER TO DRAWINGS NO. 825/T/320/OAP/C05/301 TO 303

**NOTES:**

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH DRAWING NO. 825/T/320/OAP/C01/051.

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TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
MONITORING AND INSTRUMENTATION
TRIGGER LEVEL FOR EXISTING BUILDINGS AND STRUCTURES MONITORING

SCALE N.T.S.

DRAWING NO. 825/T/320/OAP/C01/052

REV. B

## NOTES ON MONITORING

1. PRIOR TO THE INSTLLATION OF ALL MONITORING INSTRUMENTS, THE CONTRACTOR SHALL DETERMINE THE EXACT EXTENT AND QUANTITY OF MONITORING AND INSTRUMENTATION BASED ON THE CONDITION SURVEY RESULT. SUCH MONITORING PROPOSAL SHALL BE SUBMITTED TO THE APPROVAL OF THE ENGINEER.
2. THE CONTRACTOR SHALL AGREE THE LOCATIONS OF ALL INSTRUMENTS WITH THE ENGINEER AND RELEVANT LOT OWNERS ON SITE.
3. DETAILS OF SETTING OUT CONTROL POINTS, BENCH MARKS, TEMPORARY BENCH MARKS, ETC. USED FOR MONITORING PURPOSE SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT PRIOR TO THE COMMENCEMENT OF THE SURVEY WORKS.
4. THE CONTRACTOR SHALL SUBMIT AS-BUILT RECORDS OF ALL MONITORING INSTRUMENTS TO THE ENGINEER FOR APPROVAL, INCLUDING COORDINATES, LEVELS, BEARING, PHOTOGRAPHS, ETC. AND ALSO THOSE REQUIRED IN M & W SPECIFICATION CLAUSE 23.11.
5. RESPONSE TESTS SHALL BE CARRIED OUT FOR ALL EXISTING STANDPIPES / PIEZOMETERS WITHIN 3 DAYS OF COMPLETION OF INSTALLATION, AND ON MONTHLY BASIS THEREAFTER. THE CONTRACTOR SHALL REINSTATE OR REPLACE AS NECESSARY ANY MALFUNCTIONING PIEZOMETERS / STANDPIPES TO THE SATISFACTION OF THE ENGINEER.
6. PRIOR TO COMMENCEMENT OF CONSTRUCTION, BACKGROUND MONITORING SHALL BE CARRIED OUT WITH FOUR SETS OF INITIAL READINGS FOR ALL EXISTING AND PROPOSED INSTRUMENTS TAKEN ON WEEKLY BASIS. INITIAL READINGS SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT AT LEAST FOUR WEEKS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION.
7. MONITORING OF ALL INSTRUMENTS SHALL BE CARRIED OUT BY AN INDEPENDENT SURVEYOR APPROVED BY THE ENGINEER.
8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MAINTENANCE OF ALL THE INSTRUMENTS DURING THE CONTRACT PERIOD. THE CONTRACTOR SHALL REPAIR OR REPLACE ANY DAMAGED INSTRUMENTS AS NECESSARY.
9. THE CONTRACTOR SHALL SUBMIT ORAFT MONITORING RESULTS WITHIN 24 HOURS AFTER THE READINGS ARE TAKEN. FORMAL MONITORING RESULTS SHALL BE SUBMITTED ON WEEKLY BASIS.
10. THE CONTRACTOR SHALL ADOPT THE FOLLOWING INSTRUMENT NUMBERING SYSTEM:

    XXX-XXXXXX-XXXXX-XXX-XX
    - XX — INSTRUMENT NUMBER
    - XXX — INSTRUMENT TYPE
    - XXXXX — STRUCTURE NUMBER IF ANY
    - XXXXXX — SB CHAINAGE
    - XXX — CONTRACT NUBMER

11. ALL MONITORING RESULTS SHALL BE PRESENTED IN A FORMAT APPROVED BY THE ENGINEER, WHICH SHALL AT LEAST INCLUDE DATA AND PLOTS OF READINGS AGAINST TIME. PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL SUBMIT HIS PROPOSED FORMAT OF PRESENTING THE MONITORING RESULTS FOR EACH TYPE OF INSTRUMENT TO THE ENGINEER FOR APPROVAL.
12. MONITORING OUTSIDE MONITORING ZONE TKP/VB2 SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

**TABLE 1**

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | 25mm | 40mm | 50mm |
| EXISTING REGISTERED # FEATURES (SLOPE AND RETAINING WALL) SETTLEMENT | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS SETTLEMENT | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES SETTLEMENT* | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| CONVERGENCE ARRAY (DEVIATION FROM DESIGN INTERNAL PROFILE POSITION) | 50% OF THE DESIGN ALLOWED DEVIATION | 80% OF THE DESIGN ALLOWED DEVIATION | 100% OF THE DESIGN ALLOWED DEVIATION |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

\# "ALERT, "ACTION", AND "ALARM" RESPONSE VALUES FOR PARTICULAR EXSITING REGISTERED FEATURES SHALL REFER TO TABLE 7.

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS. REFER TO TABLE 6 FOR DETAILS.

13. MONITORING WITHIN MONITORING ZONE TKP SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

**TABLE 2**

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT DUE TO WALL INSTALLATION | 7mm | 12mm | 15mm |
| GROUND SETTLEMENT DUE TO DEWATERING | 7mm | 12mm | 15mm |
| GROUND SETTLEMENT DUE TO EXCAVATION | 18mm | 28mm | 35mm |
| GROUND SETTLEMENT DUE TO SITE FORMATION WORKS | 25mm | 40mm | 50mm |
| TEMPORARY RETAINING WALL DEFLECTION | 35mm | 55mm | 70mm |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| TEMPORARY STRUT FORCE (WHERE Py IS THE ULTIMATE CAPACITY OF THE STRUT) | 0.50Py | 0.70Py | 0.80Py |
| EXISTING REGISTERED # FEATURES (SLOPE AND RETAINING WALL) SETTLEMENT | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |

CONTINUATION OF TABLE 2..

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| EXISTING BUILDINGS SETTLEMENT | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES SETTLEMENT* | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

14. MONITORING WITHIN MONITORING ZONE VB2 SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

**TABLE 3**

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT DUE TO SECANT BORED PILE WALL INSTALLATION | - | - | 5mm |
| GROUND SETTLEMENT DUE TO SHEET PILE WALL INSTALLATION | - | - | 5mm |
| GROUND SETTLEMENT DUE TO CIRCULAR SHAFT EXCAVATION | 13mm | 20mm | 25mm |
| GROUND SETTLEMENT DUE TO RECTANGULAR BASEMENT EXCAVATION | 5mm | 8mm | 10mm |
| TOTAL GROUND SETTLEMENT | 25mm | 40mm | 50mm |
| SECANT BORED PILE WALL DEFLECTION | 28mm | 45mm | 55mm |
| SHEET PILE WALL DEFLECTION | 15mm | 25mm | 30mm |
| GROUND SETTLEMENT DUE TO DEWATERING | - | - | 5mm |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| TEMPORARY STRUT FORCE (WHERE Py IS THE ULTIMATE CAPACITY OF THE STRUT) | 0.50Py | 0.70Py | 0.80Py |
| EXISTING REGISTERED FEATURES # (SLOPE AND RETAINING WALL) SETTLEMENT | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDING SETTLEMENT | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES SETTLEMENT* | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

15. MOVEMENT SHALL BE MONITORED AGAINST ALERT, ACTION, AND ALARM LEVELS IN ACCORDANCE WITH M & W SPECIFICATION CLAUSE 2.18, WHICH ARE SET AS FOLLOWS:

    ALERT VALUE — SET AT 0.5 TIMES OF SERVICEABILITY LIMIT
    ACTION VALUE — SET AT 0.8 TIMES OF SERVICEABILITY LIMIT
    ALARM VALUE — SET AT THE SERVICEABILITY LIMIT.

16. ON REACHING THE "ALERT LEVEL", THE CONTRACTOR SHALL INFORM THE ENGINEER WITHIN 24 HOURS. THE CONTRACTOR SHALL REVIEW THE MOVEMENT, ASSESS THE EFFECTS ON ADJACENT STRUCTURES AND PREDICT FURTHER MOVEMENTS. A "DETAILED PLAN OF ACTION" SHALL BE PROPOSED BY THE CONTRACTOR TO THE SATISFACTION OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE "RESPONSE ACTIONS" IDENTIFIED IN THE "DETAILED PLAN OF ACTION" FOR REACHING ALERT LEVEL.
17. ON REACHING THE "ACTION LEVEL", THE CONTRACTOR SHALL IMMEDIATELY IMPLEMENT THE RESPONSE ACTIONS GIVEN IN THE "DETAILED PLAN OF ACTION" FOR REACHING ACTION LEVEL. WORK MAY THEN ONLY PROCEED IF THE REMEDIAL MEASURES HAVE BEEN IMPLEMENTED AND ARE IN THE OPINION OF THE ENGINEER SHOWN TO BE EFFECTIVE. THE CONTRACTOR SHALL MAKE APPROPRIATE AMENDMENTS TO THE "DETAILED PLAN OF ACTION" WHERE NECESSARY.
18. ON REACHING THE "ALARM LEVEL", THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY. THE CONTRACTOR SHALL IMPLEMENT EMERGENCY RESPONSE ACTIONS INCLUDING SUSPEND ALL CONSTRUCTION ACTIVITIES WITHIN 50m OF THE INSTRUMENTS, UNLESS OTHERWISE AGREED BY THE ENGINEER. THE CONTRACTOR SHALL PROVIDE A REPORT DETAILING THE FULL HISTORY OF MOVEMENTS AND REMEDIAL MEASURES ADOPTED IN RELATION TO THE ACTUAL CONSTRUCTION SEQUENCE. THE REPORT SHALL BE REVIEWED AND INTERPRETATION OF EVENTS GIVEN TO THE ENGINEER WITH RECOMMENDATIONS FOR ENABLING WORK TO PROCEED. WORK MAY ONLY RESUME UPON THE WRITTEN INSTRUCTION OF THE ENGINEER.
19. SHOULD ANY UNDUE SETTLEMENT OR DAMAGE TO ADJACENT ROADS, BUILDINGS, STRUCTURES AND UTILITIES ARE OBSERVED, THE ALARM LEVEL SHOULD BE TRIGGERED.
20. MINIMUM FREQUENCY OF MONITORING OUTSIDE MONITORING ZONE TKP/VB2, SHALL BE AS FOLLOWS:

**TABLE 4**

| INSTRUMENT TYPE | DEPTH/LOCATION | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | |
|---|---|---|---|---|---|
| | | | BACKGROUND MONITORING | STANDARD MONITORING | ACTIVE MONITORING |
| OPEN STANDPIPES PIEZOMETERS (PIEZO) | TO BE DETERMINED ON SITE | TO MONITOR CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS IN SOILS / ROCK | MONTHLY FOR AT LEAST ONE YEAR | WEEKLY | DAILY |
| INPLACE/VERTICAL INCLINOMETER (IVI/INC) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT LEVEL, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE LATERAL GROUND MOVEMENT | WEEKLY | WEEKLY | DAILY |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR GROUND SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| BUILDING SETTLEMENT POINT (BSP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TILT PLATE (TP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING TILTING | WEEKLY | WEEKLY | DAILY |
| UTILITY MONITORING POINT (UMP) | ON SELECTED UTILITIES | TO MONITOR UTILITY SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| MAGNETIC PROBE EXTENSOMETER (MPX) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT LEVEL, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE SOIL SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TELL-TALE | ON BUILDINGS & STRUCTURES | TO MONITOR ANY CRACKS | WEEKLY | WEEKLY | DAILY |
| CONVERGENCE ARRAY | 25m c/c ALONG DRILL AND BLAST TUNNEL AND 1 NO. AT THE CENTRE PER CROSS PASSAGE | TO MONITOR DEFORMATION OF PERMANENT TUNNEL LININGS | N/A | WEEKLY | DAILY |

21. MINIMUM FREQUENCY OF MONITORING FOR ZONE TKP/VB2 SHALL BE AS FOLLOWS:

**TABLE 5**

| INSTRUMENT TYPE | DEPTH | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | | |
|---|---|---|---|---|---|---|
| | | | DURING WALL INSTALLATION | DURING EXCAVATION | DURING SITE FORMATION WORKS # | ALL OTHER TIMES SUBSEQUENT TO COMPLETION OF ALL SITE FORMATION Δ |
| OPEN STANDPIPE PIEZOMETER (PIEZO)/ OBSERVATION WALLS | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITORING CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS | WEEKLY | DAILY | TWICE A WEEK | EVERY TWO WEEKS |
| VERTICAL INCLINOMETER (INC) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE TEMPORARY RETAINING WALL DEFLECTION | N/A | DAILY | TWICE A WEEK | N/A |
| MAGNETIC PROBE EXTENSSOMETER (MPX) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE SUBSURFACE SOIL SETTLEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR VERTICAL AND HORIZOTAL GROUND MOVEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| BUILDING SETTLEMENT POINT (BSP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING SETTLEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| TILT PLATE (TP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING TILTING | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| UTILITY MONITORING POINT (UMP) | ON SELECTED UTILITIES | TO MONITOR UTILITY SETTLEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| TELL-TALE | ON BUILDINGS & STRUCTURES | TO MONITOR ANY CRACKS | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| STRAIN GAUGE AT TEMPORARY STRUT | N/A | TO MONITOR STRUT FORCE | N/A | FOUR TIMES DAILY | WEEKLY | N/A |

\# SITE FORMATION WORKS INCLUDE ALL BACKFILLING WORKS WITHIN THE WAI PO SHAFT, SLOPEWORKS, RETAINING WALLS, BACKFILLING WORKS FOR THE VENTILATION BUILDING AND ACCESS ROADS, AND ALL ASSOCIATED TEMPORARY WORKS.

Δ MONITORING MAY BE DISCONTINUED ONCE THREE CONSECUTIVE READINGS SHOW THAT MOVEMENTS HAVE STOPPED TO THE SATISFACTION OF THE ENGINEER.

22. BACKGROUND MONITORING SHALL REFER TO THE MONITORING TO BE UNDERTAKEN PRIOR TO ANY CONSTRUCTION WORKS COMMENCE.
23. STANDARD MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE BEYOND 50m AND WITHIN 100m FROM CONSTRUCTION WORKS.
24. ACTIVE MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE WITHIN 50m FROM CONSTRUCTION WORKS.
25. THE CONTRACTOR SHALL INCREASE THE FREQUENCY OF MONITORING AS NECESSARY OR AS INSTRUCTED BY THE ENGINEER.
26. FOR MONITORING AND INSTRUMENTATION LAYOUT PLAN, REFER TO DRAWING NOS. 824/T/330/OAP/C06/101, 824/T/NTV/OAP/C06/101-102 AND 824/T/331/OAP/C06/101-108.
27. FOR TYPICAL DETAILS, REFER TO DRAWING NOS. 824/T/330/OAP/C06/121-127.

## NOTES ON MONITORING OF THE WSD WATERMAIN

1. PRIOR TO THE COMMENCEMENT OF EXCAVATION WORKS, THE CONTRACTOR SHALL SUBMIT THE METHOD STATEMENT OF PRECAUTION AND MITIGATION MEASURES AND MONITORING SYSTEM AGAINST POTENTIAL DIFFERENTIAL AND TOTAL VERTICAL SETTLEMENTS IN EXISTING WSD WATERMAINS IN ACCORDANCE WITH 'GUIDELINES FOR EXCAVATION NEAR WATER MAINS' PUBLISHED BY WSD FOR THE APPROVAL OF WSD AND THE ENGINEER.
2. SETTLEMENT OF THE BELOW LISTED UTILITIES SHALL BE MONITORED AGAINST THE FOLLOWING 'ALERT', 'ACTION' AND 'ALARM' RESPONSE VALUES.

**TABLE 6**

| REF. NO. | SOUTHBOUND CHAINAGE | LOCATION | STRUCTURE TYPE/DETAILS | STRUCTURE SETTLEMENT (mm) | | |
|---|---|---|---|---|---|---|
| | | | | ALERT | ACTION | ALARM |
| WSD PIPE | 122+955 | ALONG WSD ACCESS ROAD | WSD WATERMAIN | 13 | 20 | 25 |

## NOTES ON MONITORING OF REGISTERED FEATURES

1. THE CONTRACTOR SHALL CARRY OUT REGULAR INSPECTION OF ANY REGISTERED GEOTECHNICAL FEATURES LOCATED WITHIN THE ZONE OF INFLUENCE OF THE WORKS. ANY SIGNS OF GEOTECHNICAL DISTRESS INCLUDING SURFACE CRACKING AND NEARBY WATER LEAKAGE SHALL BE DOCUMENTED AND REPORTED TO THE ENGINEER IMMEDIATELY. A REMEDIAL PROPOSAL SHALL BE PREPARED BY THE CONTRACTOR AND SUBMITTED FOR THE APPROVAL OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE PROPOSED REMEDIAL MEASURES UPON GAINING THE APPROVAL FROM THE ENGINEER.
2. PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL APPOINT AN INDEPENDENT REGISTERED PROFESSIONAL ENGINEER (GEOTECHNICAL) ((RPE(G))TO CARRY OUT A DETAILED INSPECTION OF ALL SLOPES, RETAINING WALLS, NATURAL TERRAIN, DISTURBED TERRAIN AND OTHER GEOTECHNICAL FEATURES (WHETHER REGISTERED OR UNREGISTERED) WITHIN THE 5mm SETTLEMENT AND 5mm/s PPV VIBRATION INFLUENCE ZONE AND NOT LESS THAN 50m FROM THE EDGES OF THE PROPOSED TUNNEL STRUCTURES. THESE INSPECTIONS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE REQUIREMENTS OF GEOGUIDE 5, PUBLISHED BY GEO. THE RPE(G) SHALL ADVISE ON THE MONITORING REQUIREMENTS DURING CONSTRUCTION. THE INSPECTION SHALL REVIEW THE CONDITIONS OF FEATURES, IN PARTICULAR ANY SIGNS OF DISTRESS, LOOSE BOULDERS, UNSTABLE ROCK FRAGMENTS AND WEDGES, AND OTHER NATURAL AND MANMADE MATERIALS THAT MAY BE AFFECTED BY CONSTRUCTION ACTIVITIES. THE CONTRACTOR SHALL TAKE APPROPRIATE ACTIONS TO REMOVE OR MITIGATE THE RISK OF INSTABILITY OF THE GEOTECHNICAL FEATURES PRIOR TO COMMENCEMENT OF ANY WORKS. FIVE SETS OF PRE-CONDITION SURVEY REPORTS SHALL BE SUBMITTED TO THE ENGINEER.
3. SETTLEMENT OF THE BELOW LISTED REGISTERED FEATURES SHALL BE MONITORED AGAINST THE FOLLOWING 'ALERT', 'ACTION' AND 'ALARM' RESPONSE VALUES.

**TABLE 7**

| REGISTERED FEATURES* | STRUCTURE SETTLEMENT (mm) | | |
|---|---|---|---|
| | ALERT | ACTION | ALARM |
| 2SE-C/C193 | 23 mm OR 1:600 | 36 mm OR 1:375 | 45 mm OR 1:300 |
| 2SE-C/C198 | 15 mm OR 1:600 | 23 mm OR 1:375 | 29 mm OR 1:300 |

* REMARK: LOCATIONS OF THE ABOVE FEATURES SHALL REFER TO DRAWING NO. 824/T/330/DAP/C05/301 TO 302.

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TITLE: CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
MONITORING AND INSTRUMENTATION
GENERAL NOTES

SCALE: N.T.S.

DRAWING NO.: 824/T/330/OAP/C01/051

REV.: A1

## NOTES ON MONITORING

1. PRIOR TO THE INSTALLATION OF ALL MONITORING INSTRUMENTS, THE CONTRACTOR SHALL DETERMINE THE EXACT EXTENT AND QUANTITY OF MONITORING AND INSTRUMENTATION BASED ON THE CONDITION SURVEY RESULT. SUCH MONITORING PROPOSAL SHALL BE SUBMITTED TO THE APPROVAL OF THE ENGINEER.

2. THE CONTRACTOR SHALL AGREE THE LOCATIONS OF ALL INSTRUMENTS WITH THE ENGINEER AND RELEVANT LOT OWNERS ON SITE.

3. DETAILS OF SETTING OUT CONTROL POINTS, BENCH MARKS, TEMPORARY BENCH MARKS, ETC. USED FOR MONITORING PURPOSE SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT PRIOR TO THE COMMENCEMENT OF THE SURVEY WORKS.

4. THE CONTRACTOR SHALL SUBMIT AS-BUILT RECORDS OF ALL MONITORING INSTRUMENTS TO THE ENGINEER FOR APPROVAL, INCLUDING COORDINATES, LEVELS, BEARING, PHOTOGRAPHS, ETC. AND ALSO THOSE REQUIRED IN M & W SPECIFICATION CLAUSE 23.11.

5. RESPONSE TESTS SHALL BE CARRIED OUT FOR ALL EXISTING STANDPIPES / PIEZOMETERS WITHIN 3 DAYS OF COMPLETION OF INSTALLATION, AND ON MONTHLY BASIS THEREAFTER. THE CONTRACTOR SHALL REINSTATE OR REPLACE AS NECESSARY ANY MALFUNCTIONING PIEZOMETERS / STANDPIPES TO THE SATISFACTION OF THE ENGINEER.

6. PRIOR TO COMMENCEMENT OF CONSTRUCTION, BACKGROUND MONITORING SHALL BE CARRIED OUT WITH FOUR SETS OF INITIAL READINGS FOR ALL EXISTING AND PROPOSED INSTRUMENTS TAKEN ON WEEKLY BASIS. INITIAL READINGS SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT AT LEAST FOUR WEEKS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION.

7. MONITORING OF ALL INSTRUMENTS SHALL BE CARRIED OUT BY AN INDEPENDENT SURVEYOR APPROVED BY THE ENGINEER.

8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MAINTENANCE OF ALL THE INSTRUMENTS DURING THE CONTRACT PERIOD. THE CONTRACTOR SHALL REPAIR OR REPLACE ANY DAMAGED INSTRUMENTS AS NECESSARY.

9. THE CONTRACTOR SHALL SUBMIT DRAFT MONITORING RESULTS WITHIN 24 HOURS AFTER THE READINGS ARE TAKEN. FORMAL MONITORING RESULTS SHALL BE SUBMITTED ON WEEKLY BASIS.

10. THE CONTRACTOR SHALL ADOPT THE FOLLOWING INSTRUMENT NUMBERING SYSTEM:

XXX-XXXXXX-XXXXX-XXX-XX

- XX — INSTRUMENT NUMBER
- XXX — INSTRUMENT TYPE
- XXXXX — STRUCTURE NUMBER IF ANY
- XXXXXX — SB CHAINAGE
- XXX — CONTRACT NUMBER

11. ALL MONITORING RESULTS SHALL BE PRESENTED IN A FORMAT APPROVED BY THE ENGINEER, WHICH SHALL AT LEAST INCLUDE DATA AND PLOTS OF READINGS AGAINST TIME, PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL SUBMIT HIS PROPOSED FORMAT OF PRESENTING THE MONITORING RESULTS FOR EACH TYPE OF INSTRUMENT TO THE ENGINEER FOR APPROVAL.

12. MONITORING OUTSIDE MONITORING ZONE ERS & TUT SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 1

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | 25mm | 40mm | 50mm |
| EXISTING REGISTERED FEATURES (SLOPE AND RETAINING WALL) | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS # (SETTLEMENT) | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES * | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| CONVERGENCE ARRAY (DEVIATION FROM DESIGN INTERNAL TUNNEL DIAMETER) | 50% OF THE DESIGN ALLOWED OVALISATION | 80% OF THE DESIGN ALLOWED OVALISATION | 100% OF THE DESIGN ALLOWED OVALISATION |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

\# "ALERT", "ACTION", AND "ALARM" RESPONSE VALUES ON BUILDING SETTLEMENT AND LATERAL MOVEMENT ARE SET FOR SOME PARTICULAR BUILDINGS AND STRUCTURES INDIVIDUALLY. DETAILS SHALL REFER TO DRAWING NO. 823A/T/000/OAP/C01/052.

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

13. MONITORING WITHIN MONITORING ZONE ERS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 2

| STRUCTURE / MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | (A) 35mm<br>(B) 38mm<br>(C) 43mm<br>(D) 50mm<br>(E) 45mm<br>(F) 25mm | (A) 56mm<br>(B) 60mm<br>(C) 68mm<br>(D) 80mm<br>(E) 72mm<br>(F) 40mm | (A) 70mm<br>(B) 75mm<br>(C) 85mm<br>(D) 100mm<br>(E) 90mm<br>(F) 50mm |
| TEMPORARY RETAINING WALL DEFLECTION | (A) 28mm<br>(B) 34mm<br>(C) 35mm<br>(D) 41mm<br>(E) 31mm<br>(F) 29mm | (A) 44mm<br>(B) 54mm<br>(C) 56mm<br>(D) 65mm<br>(E) 50mm<br>(F) 47mm | (A) 55mm<br>(B) 67mm<br>(C) 70mm<br>(D) 81mm<br>(E) 62mm<br>(F) 58mm |
| GROUNDWATER DRAWDOWN | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1600mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 2000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| TEMPORARY STRUT FORCE (WHERE Py IS THE ULTIMATE CAPACITY OF THE STRUT) | 0.50Py | 0.70Py | 0.80Py |
| EXISTING REGISTERED FEATURES (SLOPE AND RETAINING WALL) | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS # (SETTLEMENT) | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES * | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

\# "ALERT", "ACTION", AND "ALARM" RESPONSE VALUES ON BUILDING SETTLEMENT AND LATERAL MOVEMENT ARE SET FOR SOME PARTICULAR BUILDINGS AND STRUCTURES INDIVIDUALLY. DETAILS SHALL REFER TO DRAWING NO. 823A/T/000/OAP/C01/052.

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

14. MONITORING WITHIN MONITORING ZONE TUT SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 2

| STRUCTURE / MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT DUE TO WALL INSTALLATION | 5mm | 8mm | 10mm |
| GROUND SETTLEMENT DUE TO DEWATERING | 5mm | 8mm | 10mm |
| GROUND SETTLEMENT DUE TO EXCAVATION | 25mm | 40mm | 50mm |
| TEMPORARY RETAINING WALL DEFLECTION | 55mm | 85mm | 110mm |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| TEMPORARY STRUT FORCE (WHERE Py IS THE ULTIMATE CAPACITY OF THE STRUT) | 0.50Py | 0.70Py | 0.80Py |
| EXISTING REGISTERED FEATURES (SLOPE AND RETAINING WALL) | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS # (SETTLEMENT) | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES * | 1/3mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

\# "ALERT", "ACTION", AND "ALARM" RESPONSE VALUES ON BUILDING SETTLEMENT AND LATERAL MOVEMENT ARE SET FOR SOME PARTICULAR BUILDINGS AND STRUCTURES INDIVIDUALLY. DETAILS SHALL REFER TO DRAWING NO. 823A/T/000/OAP/C01/052.

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

15. MOVEMENT SHALL BE MONITORED AGAINST ALERT, ACTION, AND ALARM LEVELS IN ACCORDANCE WITH M & W SPECIFICATION CLAUSE 2.18, WHICH ARE SET AS FOLLOWS:

ALERT VALUE — SET AT 0.5 TIMES OF SERVICEABILITY LIMIT
ACTION VALUE — SET AT 0.8 TIMES OF SERVICEABILITY LIMIT
ALARM VALUE — SET AT THE SERVICEABILITY LIMIT.

16. ON REACHING THE "ALERT LEVEL", THE CONTRACTOR SHALL INFORM THE ENGINEER WITHIN 24 HOURS. THE CONTRACTOR SHALL REVIEW THE MOVEMENT, ASSESS THE EFFECTS ON ADJACENT STRUCTURES AND PREDICT FURTHER MOVEMENTS. A "DETAILED PLAN OF ACTION" SHALL BE PROPOSED BY THE CONTRACTOR TO THE SATISFACTION OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE "RESPONSE ACTIONS" IDENTIFIED IN THE "DETAILED PLAN OF ACTION" FOR REACHING ALERT LEVEL.

17. ON REACHING THE "ACTION LEVEL", THE CONTRACTOR SHALL IMMEDIATELY IMPLEMENT THE RESPONSE ACTIONS GIVEN IN THE "DETAILED PLAN OF ACTION" FOR REACHING ACTION LEVEL. WORK MAY THEN ONLY PROCEED IF THE REMEDIAL MEASURES HAVE BEEN IMPLEMENTED AND ARE IN THE OPINION OF THE ENGINEER SHOWN TO BE EFFECTIVE. THE CONTRACTOR SHALL MAKE APPROPRIATE AMENDMENTS TO THE "DETAILED PLAN OF ACTION" WHERE NECESSARY.

18. ON REACHING THE "ALARM LEVEL", THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY. THE CONTRACTOR SHALL IMPLEMENT EMERGENCY RESPONSE ACTIONS INCLUDING SUSPEND ALL CONSTRUCTION ACTIVITIES WITHIN 50m OF THE INSTRUMENTS, UNLESS OTHERWISE AGREED BY THE ENGINEER. THE CONTRACTOR SHALL PROVIDE A REPORT DETAILING THE FULL HISTORY OF MOVEMENTS AND REMEDIAL MEASURES ADOPTED IN RELATION TO THE ACTUAL CONSTRUCTION SEQUENCE. THE REPORT SHALL BE REVIEWED AND INTERPRETATION OF EVENTS GIVEN TO THE ENGINEER WITH RECOMMENDATIONS FOR ENABLING WORK TO PROCEED. WORK MAY ONLY RESUME UPON THE WRITTEN INSTRUCTION OF THE ENGINEER.

19. MINIMUM FREQUENCY OF MONITORING EXCEPT FOR MONITORING ZONE ERS AND TUT, SHALL BE AS FOLLOWS:

TABLE 3

| INSTRUMENT TYPE | DEPTH/LOCATION | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | |
|---|---|---|---|---|---|
| | | | BACKGROUND MONITORING | STANDARD MONITORING | ACTIVE MONITORING |
| OPEN STANDPIPES PIEZOMETERS (PIEZO) | TO BE DETERMINED ON SITE | TO MONITOR CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS IN SOILS / ROCK | MONTHLY FOR AT LEAST ONE YEAR | WEEKLY | DAILY |
| INPLACE/VERTICAL INCLINOMETER (IVI/INC) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT LEVEL, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE LATERAL GROUND MOVEMENT | WEEKLY | WEEKLY | DAILY |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR GROUND SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| BUILDING SETTLEMENT POINT (BSP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TILT PLATE (TP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING TILTING | WEEKLY | WEEKLY | DAILY |
| UTILITY MONITORING POINT (UMP) | ON SELECTED UTILITIES | TO MONITOR UTILITY SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| MAGNETIC PROBE EXTENSOMETER (MPX) | IN ROCK OR AT LEAST 40m BELOW PROPOSED TUNNEL INVERT LEVEL, WHICHEVER SHALLOWER | TO MONITOR SUBSURFACE SOIL SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TELL-TALE | ON BUILDINGS & STRUCTURES | TO MONITOR ANY CRACKS | WEEKLY | WEEKLY | DAILY |
| CONVERGENCE ARRAY | 25m c/c ALONG TBM TUNNEL AND 1 NO. AT THE CENTRE PER CROSS PASSAGE | TO MONITOR DEFORMATION OF PERMANENT TUNNEL LININGS | N/A | WEEKLY | DAILY |

20. MINIMUM FREQUENCY OF MONITORING FOR ZONE ERS AND TUT SHALL BE AS FOLLOWS:

TABLE 4

| INSTRUMENT TYPE | DEPTH | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | | |
|---|---|---|---|---|---|---|
| | | | DURING WALL INSTALLATION | DURING EXCAVATION | DURING BACKFILLING | SUBSEQUENT TO COMPLETION OF BACKFILLING WORKS |
| OPEN STANDPIPE PIEZOMETER (PIEZO)/ OBSERVATION WALLS | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS | WEEKLY | DAILY | TWICE A WEEK | EVERY TWO WEEKS |
| VERTICAL INCLINOMETER (VINC) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE TEMPORARY RETAINING WALL DEFLECTION | N/A | DAILY | TWICE A WEEK | N/A |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR VERTICAL AND HORIZOTAL GROUND MOVEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| STRAIN GAUGE AT TEMPORARY STRUT | N/A | TO MONITOR STRUT FORCE | N/A | FOUR TIMES DAILY | WEEKLY | N/A |
| MAGNETIC PROBE EXTENSOMETER (MPX) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE SUBSURFACE SOIL SETTLEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |

MONITORING MAY BE DISCONTINUED ONCE THREE CONSECUTIVE READINGS SHOW THAT MOVEMENTS HAVE STOPPED TO THE SATISFACTION OF THE ENGINEER.

21. BACKGROUND MONITORING SHALL REFER TO THE MONITORING TO BE UNDERTAKEN PRIOR TO ANY CONSTRUCTION WORKS COMMENCE.

22. STANDARD MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE BEYOND 50m AND WITHIN 100m FROM CONSTRUCTION WORKS.

23. ACTIVE MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE WITHIN 50m FROM CONSTRUCTION WORKS.

24. THE CONTRACTOR SHALL INCREASE THE FREQUENCY OF MONITORING AS NECESSARY OR AS INSTRUCTED BY THE ENGINEER.

25. FOR GENERAL MONITORING AND INSTRUMENTATION PLAN, REFER TO DRAWING NOS. 823A/T/340/OAP/C06/101-102 AND 823A/T/341/OAP/C06/101.

26. FOR TYPICAL DETAILS, REFER TO DRAWING NOS. 823A/T/000/OAP/C06/121-127.

## NOTES ON MONITORING OF THE DSD NULLAH

1. GROUND SETTLEMENT POINTS SHALL BE INSTALLED ALONG THE CREST OF THE LOW FLOW CHANNEL.

## NOTES ON MONITORING OF REGISTERED FEATURES

1. THE CONTRACTOR SHALL CARRY OUT REGULAR INSPECTION OF ANY REGISTERED GEOTECHNICAL FEATURES LOCATED WITHIN THE ZONE OF INFLUENCE OF THE WORKS. ANY SIGNS OF GEOTECHNICAL DISTRESS INCLUDING SURFACE CRACKING AND NEARBY WATER LEAKAGE SHALL BE DOCUMENTED AND REPORTED TO THE ENGINEER IMMEDIATELY. A REMEDIAL PROPOSAL SHALL BE PREPARED BY THE CONTRACTOR AND SUBMITTED FOR THE APPROVAL OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE PROPOSED REMEDIAL MEASURES UPON GAINING THE APPROVAL FROM THE ENGINEER.

2. PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL APPOINT AN INDEPENDENT REGISTERED PROFESSIONAL ENGINEER (GEOTECHNICAL) ((RPE(G))TO CARRY OUT A DETAILED INSPECTION OF ALL SLOPES, RETAINING WALLS, NATURAL TERRAIN, DISTURBED TERRAIN AND OTHER GEOTECHNICAL FEATURES (WHETHER REGISTERED OR UNREGISTERED) WITHIN THE 5mm SETTLEMENT AND 5mm/s PPV VIBRATION INFLUENCE ZONE AND NOT LESS THAN 50m FROM THE EDGES OF THE PROPOSED TUNNEL STRUCTURES. THESE INSPECTIONS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE REQUIREMENTS OF GEOGUIDE 5, PUBLISHED BY GEO. THE RPE(G) SHALL ADVISE ON THE MONITORING REQUIREMENTS DURING CONSTRUCTION. THE INSPECTION SHALL REVIEW THE CONDITIONS OF FEATURES. IN PARTICULAR ANY SIGNS OF DISTRESS, LOOSE BOULDERS, UNSTABLE ROCK FRAGMENTS AND WEDGES, AND OTHER NATURAL AND MANMADE MATERIALS THAT MAY BE AFFECTED BY CONSTRUCTION ACTIVITIES. THE CONTRACTOR SHALL TAKE APPROPRIATE ACTIONS TO REMOVE OR MITIGATE THE RISK OF INSTABILITY OF THE GEOTECHNICAL FEATURES PRIOR TO COMMENCEMENT OF ANY WORKS. FIVE SETS OF PRE-CONDITION SURVEY REPORTS SHALL BE SUBMITTED TO THE ENGINEER.

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| A | BD CONSULTATION SUBMISSION | TW | 21AUG09 | JM |

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| DESIGNED | JY |
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| APPROVED | JM |
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TITLE
CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
MONITORING AND INSTRUMENTATION
GENERAL NOTES

SCALE: N.T.S.
DRAWING NO. 823A/B/000/OAP/C01/051
REV. B

1.) SETTLEMENT OF THE BELOW LISTED BUILDINGS SHALL BE MONITORED AGAINST THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

| REF. No. | SOUTHBOUND CHAINAGE | ADDRESS | BUILDING TYPE / DETAILS | BUILDING SETTLEMENT (mm) | | |
|---|---|---|---|---|---|---|
| | | | | ALERT | ACTION | ALARM |
| NB108 | 122+580 | LIVESTOCK FARM | TSAT SING KONG | 13 | 21 | 26 |
| NB111 | 122+660 | WAREHOUSE | TSAT SING KONG | 13 | 21 | 26 |
| NB112 | 122+720 | FACTORY | TSAT SING KONG | 24 | 38 | 47 |
| NB113 | 122+750 | VILLAGE HOUSE | TSAT SING KONG | 22 | 35 | 44 |
| NB116 | 122+800 | VILLAGE HOUSE | TSAT SING KONG | 14 | 22 | 28 |
| NB117 | 122+790 | VILLAGE HOUSE | TSAT SING KONG | 14 | 23 | 29 |
| NB118 | 122+830 | VILLAGE HOUSE | TSAT SING KONG | 14 | 22 | 27 |
| NB121 | 122+920 | VILLAGE HOUSE | TSAT SING KONG | 14 | 22 | 28 |
| NB128 | 123+290 | VILLAGE HOUSE | KAN TAI ROAD NEAR HUNG MO TAN | 17 | 27 | 33 |
| NB136 | 123+480 | TEMPORARY STRUCTURE | KAN TAI ROAD NEAR HUNG MO TAN | 33 | 53 | 66 |
| NB138 | 123+520 | SHEK KONG VEGETABLE MARKETING CO-OPERATIVE SOCIETY LTD. | KAN TAI ROAD NEAR HUNG MO TAN | 21 | 34 | 43 |
| NB149A | 124+840 | VILLAGE HOUSE | 630 SHEUNG TSUEN | 18 | 29 | 36 |
| NB152 | 125+010 | VILLAGE HOUSE | 509, 510, 510B SHEUNG TSUEN | 14 | 23 | 29 |
| NB153 | 125+060 | VILLAGE HOUSE | 431B TSANG UK TSUEN | 14 | 23 | 28 |
| NB154 | 125+080 | WSD SHEUNG TSUEN PUMPING STATION | NEAR 431B TSANG UK TSUEN | 20 | 32 | 41 |
| NB156 | 125+110 | VILLAGE HOUSE | 427B TSE UK TSUEN | 18 | 28 | 35 |
| NB158 | 125+110 | VILLAGE HOUSE | 428A,429,430,431 TSE UK TSUEN | 16 | 25 | 31 |
| NB161 | 125+160 | VILLAGE HOUSE | 425A, 426A SHEUNG TSUEN | 13 | 21 | 26 |

2.) SETTLEMENT OF THE BELOW LISTED STRUCTURES SHALL BE MONITORED AGAINST THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

| REF. No. | SOUTHBOUND CHAINAGE | ADDRESS | STRUCTURE TYPE / DETAILS | BUILDING SETTLEMENT (mm) | | |
|---|---|---|---|---|---|---|
| | | | | ALERT | ACTION | ALARM |
| NH005 | 124+930 | BRIDGE ACROSS SHEK KONG AIRFIELD ROAD NULLAH NEAR NAM HING WEST ROAD | HIGHWAY VEHICULAR BRIDGE | 25 | 40 | 50 |

**NOTES:**

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH DRAWING NO. 823A/B/000/OAP/C01/051.

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TITLE
CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
MONITORING AND INSTRUMENTATION
TRIGGER LEVEL FOR EXISTING BUILDINGS AND STRUCTURES MONITORING

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| N.T.S. | 823A/B/000/OAP/C01/052 | A |

## NOTES ON MONITORING

1. PRIOR TO THE INSTALLATION OF ALL MONITORING INSTRUMENTS, THE CONTRACTOR SHALL DETERMINE THE EXACT EXTENT AND QUANTITY OF MONITORING AND INSTRUMENTATION BASED ON THE CONDITION SURVEY RESULT. SUCH MONITORING PROPOSAL SHALL BE SUBMITTED TO THE APPROVAL OF THE ENGINEER.

2. THE CONTRACTOR SHALL AGREE THE LOCATIONS OF ALL INSTRUMENTS WITH THE ENGINEER AND RELEVANT LOT OWNERS ON SITE.

3. DETAILS OF SETTING OUT CONTROL POINTS, BENCH MARKS, TEMPORARY BENCH MARKS, ETC. USED FOR MONITORING PURPOSE SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT PRIOR TO THE COMMENCEMENT OF THE SURVEY WORKS.

4. THE CONTRACTOR SHALL SUBMIT AS-BUILT RECORDS OF ALL MONITORING INSTRUMENTS TO THE ENGINEER FOR APPROVAL, INCLUDING COORDINATES, LEVELS, BEARING, PHOTOGRAPHS, ETC. AND ALSO THOSE REQUIRED IN M & W SPECIFICATION CLAUSE 23.11.

5. RESPONSE TESTS SHALL BE CARRIED OUT FOR ALL EXISTING STANDPIPES / PIEZOMETERS WITHIN 3 DAYS OF COMPLETION OF INSTALLATION, AND ON MONTHLY BASIS THEREAFTER. THE CONTRACTOR SHALL REINSTATE OR REPLACE AS NECESSARY ANY MALFUNCTIONING PIEZOMETERS / STANDPIPES TO THE SATISFACTION OF THE ENGINEER.

6. PRIOR TO COMMENCEMENT OF CONSTRUCTION, BACKGROUND MONITORING SHALL BE CARRIED OUT WITH FOUR SETS OF INITIAL READINGS FOR ALL EXISTING AND PROPOSED INSTRUMENTS TAKEN ON WEEKLY BASIS. INITIAL READINGS SHALL BE SUBMITTED TO THE ENGINEER FOR AGREEMENT AT LEAST FOUR WEEKS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION.

7. MONITORING OF ALL INSTRUMENTS SHALL BE CARRIED OUT BY AN INDEPENDENT SURVEYOR APPROVED BY THE ENGINEER.

8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MAINTENANCE OF ALL THE INSTRUMENTS DURING THE CONTRACT PERIOD. THE CONTRACTOR SHALL REPAIR OR REPLACE ANY DAMAGED INSTRUMENTS AS NECESSARY.

9. THE CONTRACTOR SHALL SUBMIT DRAFT MONITORING RESULTS WITHIN 24 HOURS AFTER THE READINGS ARE TAKEN. FORMAL MONITORING RESULTS SHALL BE SUBMITTED ON WEEKLY BASIS.

10. THE CONTRACTOR SHALL ADOPT THE FOLLOWING INSTRUMENT NUMBERING SYSTEM:

XXX-XXXXXX-XXXXX-XXX-XX

- XX — INSTRUMENT NUMBER
- XXX — INSTRUMENT TYPE
- XXXXX — STRUCTURE NUMBER IF ANY
- XXXXXX — SB CHAINAGE
- XXX — CONTRACT NUMBER

11. ALL MONITORING RESULTS SHALL BE PRESENTED IN A FORMAT APPROVED BY THE ENGINEER, WHICH SHALL AT LEAST INCLUDE DATA AND PLOTS OF READINGS AGAINST TIME, PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL SUBMIT HIS PROPOSED FORMAT OF PRESENTING THE MONITORING RESULTS FOR EACH TYPE OF INSTRUMENT TO THE ENGINEER FOR APPROVAL.

12. MONITORING OUTSIDE MONITORING ZONE ERS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 1

| STRUCTURE/MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | 25mm | 40mm | 50mm |
| EXISTING REGISTERED FEATURES (SLOPE AND RETAINING WALL) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS (SETTLEMENT) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES * | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| GROUNDWATER DRAWDOWN | 500mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 800mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

13. MONITORING WITHIN MONITORING ZONE ERS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE FOLLLOWING "ALERT", "ACTION" AND "ALARM" RESPONSE VALUES.

TABLE 2

| STRUCTURE / MONITORING POINT | ALERT | ACTION | ALARM |
|---|---|---|---|
| GROUND SETTLEMENT | (A) 40mm<br>(B) 45mm | (A) 65mm<br>(B) 75mm | (A) 80mm<br>(B) 90mm |
| TEMPORARY RETAINING WALL DEFLECTION | (A) 45mm<br>(B) 60mm | (A) 70mm<br>(B) 95mm | (A) 85mm<br>(B) 115mm |
| GROUNDWATER DRAWDOWN | 1000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 1600mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL | 2000mm WITH REFERENCE TO LOWEST HISTORICAL GROUNDWATER LEVEL |
| TEMPORARY STRUT FORCE (WHERE Py IS THE ULTIMATE CAPACITY OF THE STRUT) | 0.50Py | 0.70Py | 0.80Py |
| EXISTING REGISTERED FEATURES (SLOPE AND RETAINING WALL) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| EXISTING BUILDINGS (SETTLEMENT) | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| UTILITIES * | 13mm OR 1:600 | 20mm OR 1:375 | 25mm OR 1:300 |
| CRACK WIDTH FROM SURFACE-MOUNTED GRID CRACK GAUGE | 2.5mm | 4mm | 5mm |

* OR OTHER VALUES SPECIFIED BY RESPECTIVE UTILITIES UNDERTAKERS, WHICHEVER MORE ONEROUS.

14. MOVEMENT SHALL BE MONITORED AGAINST ALERT, ACTION, AND ALARM LEVELS IN ACCORDANCE WITH M & W SPECIFICATION CLAUSE 2.15, WHICH ARE SET AS FOLLOWS:

ALERT VALUE — SET AT 0.5 TIMES OF SERVICEABILITY LIMIT
ACTION VALUE — SET AT 0.8 TIMES OF SERVICEABILITY LIMIT
ALARM VALUE — SET AT THE SERVICEABILITY LIMIT.

15. ON REACHING THE "ALERT LEVEL", THE CONTRACTOR SHALL INFORM THE ENGINEER WITHIN 24 HOURS. THE CONTRACTOR SHALL REVIEW THE MOVEMENT, ASSESS THE EFFECTS ON ADJACENT STRUCTURES AND PREDICT FURTHER MOVEMENTS. A "DETAILED PLAN OF ACTION" SHALL BE PROPOSED BY THE CONTRACTOR TO THE SATISFACTION OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE "RESPONSE ACTIONS" IDENTIFIED IN THE "DETAILED PLAN OF ACTION" FOR REACHING ALERT LEVEL.

16. ON REACHING THE "ACTION LEVEL", THE CONTRACTOR SHALL IMMEDIATELY IMPLEMENT THE RESPONSE ACTIONS GIVEN IN THE "DETAILED PLAN OF ACTION" FOR REACHING ACTION LEVEL. WORK MAY THEN ONLY PROCEED IF THE REMEDIAL MEASURES HAVE BEEN IMPLEMENTED AND ARE IN THE OPINION OF THE ENGINEER SHOWN TO BE EFFECTIVE. THE CONTRACTOR SHALL MAKE APPROPRIATE AMENDMENTS TO THE "DETAILED PLAN OF ACTION" WHERE NECESSARY.

17. ON REACHING THE "ALARM LEVEL", THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY. THE CONTRACTOR SHALL IMPLEMENT EMERGENCY RESPONSE ACTIONS INCLUDING SUSPEND ALL CONSTRUCTION ACTIVITIES WITHIN 50m OF THE INSTRUMENTS, UNLESS OTHERWISE AGREED BY THE ENGINEER. THE CONTRACTOR SHALL PROVIDE A REPORT DETAILING THE FULL HISTORY OF MOVEMENTS AND REMEDIAL MEASURES ADOPTED IN RELATION TO THE ACTUAL CONSTRUCTION SEQUENCE. THE REPORT SHALL BE REVIEWED AND INTERPRETATION OF EVENTS GIVEN TO THE ENGINEER WITH RECOMMENDATIONS FOR ENABLING WORK TO PROCEED. WORK MAY ONLY RESUME UPON THE WRITTEN INSTRUCTION OF THE ENGINEER.

18. MINIMUM FREQUENCY OF MONITORING EXCEPT FOR MONITORING ZONE ERS, SHALL BE AS FOLLOWS:

TABLE 3

| INSTRUMENT TYPE | DEPTH/LOCATION | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | |
|---|---|---|---|---|---|
| | | | BACKGROUND MONITORING | STANDARD MONITORING | ACTIVE MONITORING |
| OPEN STANDPIPES PIEZOMETERS (PIEZO) | TO BE DETERMINED ON SITE | TO MONITOR CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS IN SOILS / ROCK | MONTHLY FOR AT LEAST ONE YEAR | WEEKLY | DAILY |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR GROUND SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| BUILDING SETTLEMENT POINT (BSP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TILT PLATE (TP) | ON SELECTED BUILDINGS & STRUCTURE | TO MONITOR BUILDING TILTING | WEEKLY | WEEKLY | DAILY |
| UTILITY MONITORING POINT (UMP) | ON SELECTED UTILITIES | TO MONITOR UTILITY SETTLEMENT | WEEKLY | WEEKLY | DAILY |
| TELL-TALE | ON BUILDINGS & STRUCTURES | TO MONITOR ANY CRACKS | WEEKLY | WEEKLY | DAILY |

19. MINIMUM FREQUENCY OF MONITORING FOR ZONE ERS SHALL BE AS FOLLOWS:

TABLE 4

| INSTRUMENT TYPE | DEPTH | PURPOSE | MINIMUM FREQUENCY OF MONITORING | | | |
|---|---|---|---|---|---|---|
| | | | DURING WALL INSTALLATION | DURING EXCAVATION | DURING BACKFILLING | SUBSEQUENT TO COMPLETION OF BACKFILLING WORKS |
| OPEN STANDPIPE PIEZOMETER (PIEZO)/ OBSERVATION WALLS | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITORING CHANGE IN GROUND WATER LEVEL AND PIEZOMETRIC HEADS | WEEKLY | DAILY | TWICE A WEEK | EVERY TWO WEEKS |
| VERTICAL INCLINOMETER (INC) | TEMPORARY RETAINING WALL TOE LEVEL | TO MONITOR THE TEMPORARY RETAINING WALL DEFLECTION | N/A | DAILY | TWICE A WEEK | N/A |
| GROUND SETTLEMENT POINT (GSP) | ON GROUND SURFACE | TO MONITOR VERTICAL AND HORIZOTAL GROUND MOVEMENT | WEEKLY | DAILY | WEEKLY | EVERY TWO WEEKS |
| STRAIN GAUGE AT TEMPORARY STRUT | N/A | TO MONINTOR STRUT FORCE | N/A | FOUR TIMES DAILY | WEEKLY | N/A |

20. BACKGROUND MONITORING SHALL REFER TO THE MONITORING TO BE UNDERTAKEN PRIOR TO ANY CONSTRUCTION WORKS COMMENCE.

21. STANDARD MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE BEYOND 50m AND WITHIN 100m FROM CONSTRUCTION WORKS.

22. ACTIVE MONITORING FREQUENCY SHOULD BE ADOPTED FOR INSTRUMENTS WHICH ARE WITHIN 50m FROM CONSTRUCTION WORKS.

23. THE CONTRACTOR SHALL INCREASE THE FREQUENCY OF MONITORING AS NECESSARY OR AS INSTRUCTED BY THE ENGINEER.

24. FOR GENERAL MONITORING AND INSTRUMENTATION PLAN, REFER TO DRAWING NOS. 823B/B/350/OAP/C06/101-102.

25. FOR TYPICAL DETAILS, REFER TO DRAWING NOS. 823B/B/350/OAP/C06/121-126.

## NOTES ON MONITORING OF THE DSD NULLAH

1. GROUND SETTLEMENT POINTS SHALL BE INSTALLED ALONG THE CREST OF THE LOW FLOW CHANNEL.

## NOTES ON MONITORING OF REGISTERED FEATURES

1. THE CONTRACTOR SHALL CARRY OUT REGULAR INSPECTION OF ANY REGISTERED GEOTECHNICAL FEATURES LOCATED WITHIN THE ZONE OF INFLUENCE OF THE WORKS. ANY SIGNS OF GEOTECHNICAL DISTRESS INCLUDING SURFACE CRACKING AND NEARBY WATER LEAKAGE SHALL BE DOCUMENTED AND REPORTED TO THE ENGINEER IMMEDIATELY. A REMEDIAL PROPOSAL SHALL BE PREPARED BY THE CONTRACTOR AND SUBMITTED FOR THE APPROVAL OF THE ENGINEER. THE CONTRACTOR SHALL IMPLEMENT THE PROPOSED REMEDIAL MEASURES UPON GAINING THE APPROVAL FROM THE ENGINEER.

2. PRIOR TO COMMENCEMENT OF WORKS, THE CONTRACTOR SHALL APPOINT AN INDEPENDENT REGISTERED PROFESSIONAL ENGINEER (GEOTECHNICAL) (RPE(G)) TO CARRY OUT A DETAILED INSPECTION OF ALL SLOPES, RETAINING WALLS, NATURAL TERRAIN, DISTURBED TERRAIN AND OTHER GEOTECHNICAL FEATURES (WHETHER REGISTERED OR UNREGISTERED) WITHIN THE 5mm SETTLEMENT AND 5mm/s PPV VIBRATION INFLUENCE ZONE AND NOT LESS THAN 50m FROM THE EDGES OF THE PROPOSED TUNNEL STRUCTURES. THESE INSPECTIONS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE REQUIREMENTS OF GEOGUIDE 5, PUBLISHED BY GED. THE RPE(G) SHALL ADVISE ON THE MONITORING REQUIREMENTS DURING CONSTRUCTION. THE INSPECTION SHALL REVIEW THE CONDITIONS OF FEATURES, IN PARTICULAR ANY SIGNS OF DISTRESS, LOOSE BOULDERS, UNSTABLE ROCK FRAGMENTS AND WEDGES, AND OTHER NATURAL AND MANMADE MATERIALS THAT MAY BE AFFECTED BY CONSTRUCTION ACTIVITIES. THE CONTRACTOR SHALL TAKE APPROPRIATE ACTIONS TO REMOVE OR MITIGATE THE RISK OF INSTABILITY OF THE GEOTECHNICAL FEATURES PRIOR TO COMMENCEMENT OF ANY WORKS. FIVE SETS OF PRE-CONDITION SURVEY REPORTS SHALL BE SUBMITTED TO THE ENGINEER.

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| DESIGNED | JY |
| CHECKED | MT |
| APPROVED | JW |
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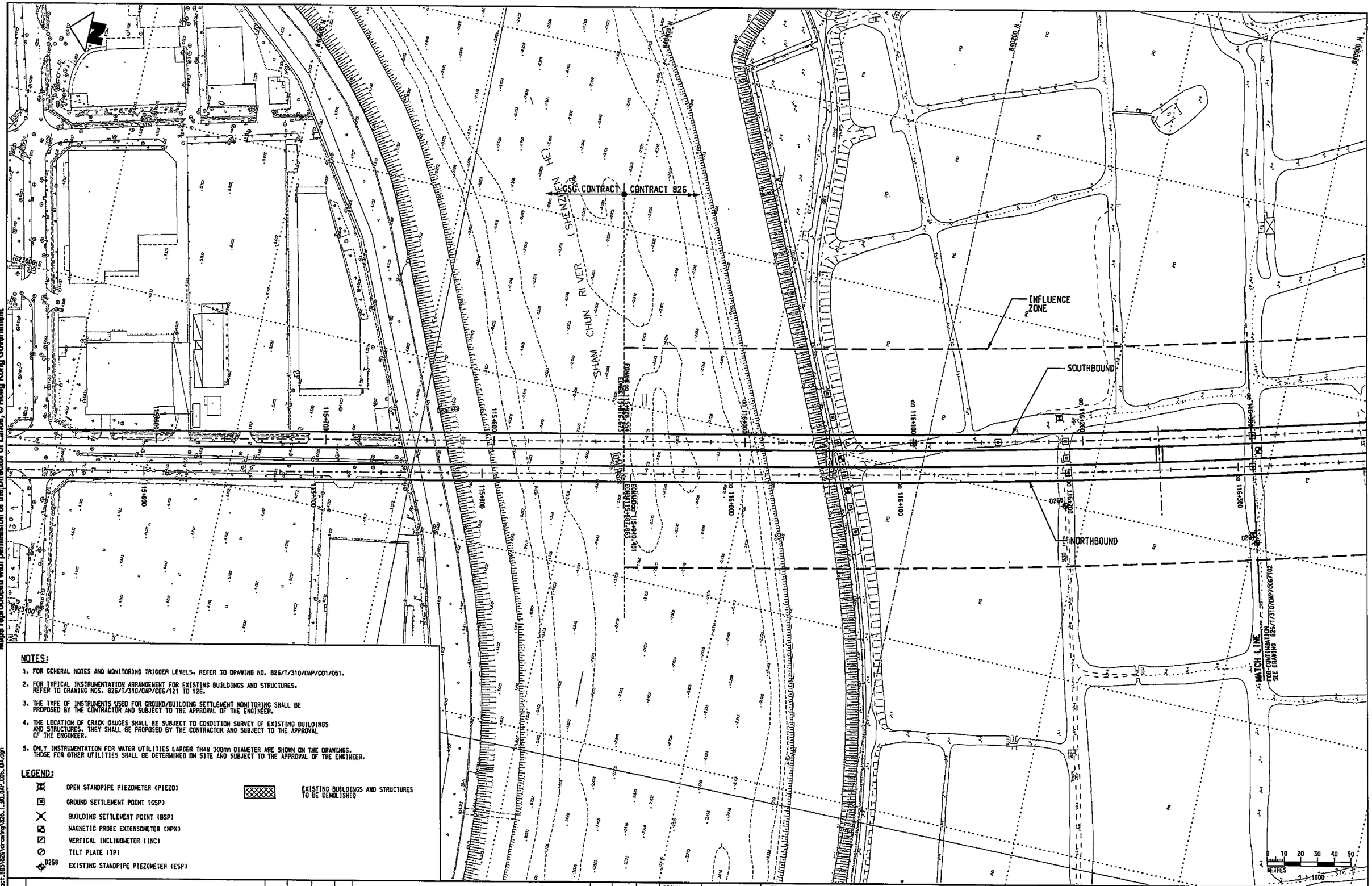
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TITLE
CONTRACT 823B
SHEK KONG STABLING SIDINGS AND ERS
MONITORING AND INSTRUMENTATION
GENERAL NOTES

| SCALE | DRAWING NO. | REV. |
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**NOTES:**

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NO. 826/T/310/DAP/C01/051.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 826/T/310/DAP/C06/121 TO 126.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

**LEGEND:**

- OPEN STANDPIPE PIEZOMETER (PIEZO)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT PLATE (TP)
- D258 EXISTING STANDPIPE PIEZOMETER (ESP)
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | TW | 14AUG09 | JW |

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| DRAWN | HHW |
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CADD REF. 826_T_310_DAP_C06_101A.dgn

TITLE

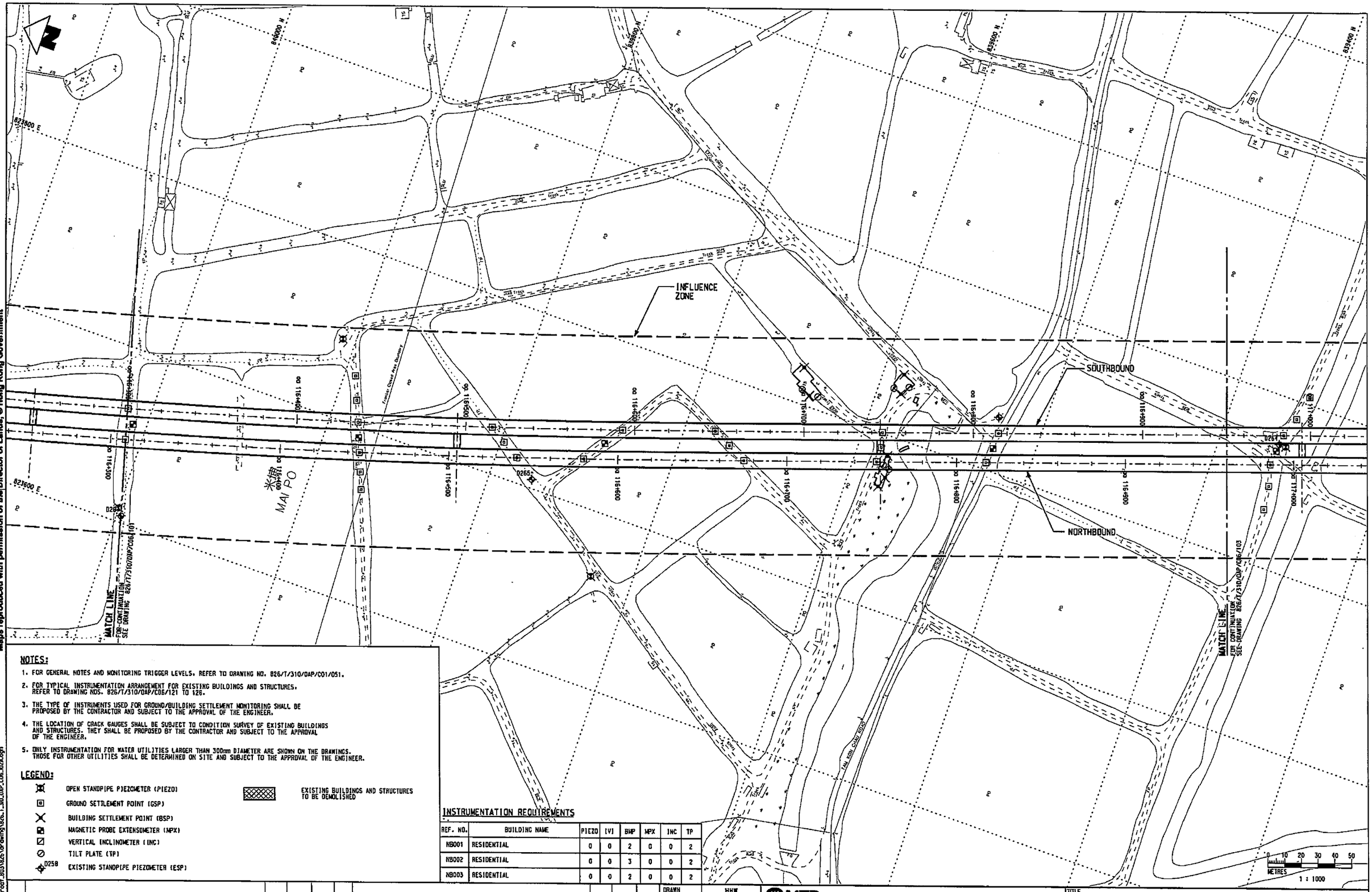
# CONTRACT 826
## HUANGGANG TO MAI PO
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 1

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1: 1000 (A1) | 826/T/310/DAP/C06/101 | A |

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MODIFIED BY: Default PRINTED BY: wilcony 8/02/2009 4:09:00 PM
FILENAME: m:\c803\contract_803\826\drawing\826_T_310_DAP_C06_101A.dgn

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## NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NO. 826/T/310/OAP/C01/051.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 826/T/310/OAP/C06/121 TO 126.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

## LEGEND:

- OPEN STANDPIPE PIEZOMETER (PIEZO)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT PLATE (TP)
- D258 EXISTING STANDPIPE PIEZOMETER (ESP)
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

## INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | (V) | BMP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB001 | RESIDENTIAL | 0 | 0 | 2 | 0 | 0 | 2 |
| NB002 | RESIDENTIAL | 0 | 0 | 3 | 0 | 0 | 2 |
| NB003 | RESIDENTIAL | 0 | 0 | 2 | 0 | 0 | 2 |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | JY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 27MAR2009 |

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EXPRESS RAIL LINK

ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 826_T_310_OAP_C06_102A.dgn

TITLE

# CONTRACT 826
## HUANGGANG TO MAI PO
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN
### SHEET 2

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1: 1000 (A1) | 826/T/310/OAP/C06/102 | A |

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CONTRACT 826 CONTRACT 825

INFLUENCE ZONE

MONITORING ZONE VB1

SOUTHBOUND

NORTHBOUND

VB1 - MPV MAI PO VENTILATION SHAFT

MATCH-LINE FOR CONTINUATION SEE DRAWING 826/T/310/OAP/C06/102

824200 E 839400 N 824000 E 823800 E

SAN TAM ROAD

CASTLE PEAK ROAD

Open Storage

SANTA MONICA AVENUE MONTEREY AVENUE VICTORIA AVENUE PALM AVENUE MARIN AVENUE

0 10 20 30 40 50
METRES
1 1000

## NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NO. 826/T/310/OAP/C01/051.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES. REFER TO DRAWING NOS. 826/T/310/OAP/C06/121 TO 126.
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4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

## LEGEND:

- OPEN STANDPIPE PIEZOMETER (PIEZO)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT PLATE (TP)
- D258 EXISTING STANDPIPE PIEZOMETER (ESP)
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | TW | 14AUG09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | JY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 27MAR2009 |

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EXPRESS RAIL LINK

ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 826_T_310_OAP_C06_103A.dgn

TITLE

# CONTRACT 826
## HUANGGANG TO MAI PO
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 3

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1: 1000 (A1) | 826/T/310/OAP/C06/103 | A |

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CONTRACT 826 | CONTRACT 825

INFLUENCE ZONE

MONITORING ZONE VB1

SOUTHBOUND

NORTHBOUND

NB004 NB005 NB007 NB008 NB009

VB1 MAI PO VENTILATION SHAFT

OPTION 2

0 10 20 30 40 50 METRES

1 1000

**NOTES:**

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 825/T/320/OAP/C01/051 AND 052.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 825/T/320/OAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
6. IF OPTION 2 IS TO BE EXERCISED THEN THIS DRAWING SHALL SUPERSEDE DRAWING NO. 825/T/320/OAP/C06/101. (B)

**LEGEND:**

- OPEN STANDPIPE / PIEZOMETER (PIZED)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 2 ISSUE | TW | 28AUG09 | JM |
| A | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27MAR2009 |

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CADD REF. 825_T_320_OAP_C06_111B.dgn

TITLE

CONTRACT 825

MAI PO TO NGAU TAM MEI

GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

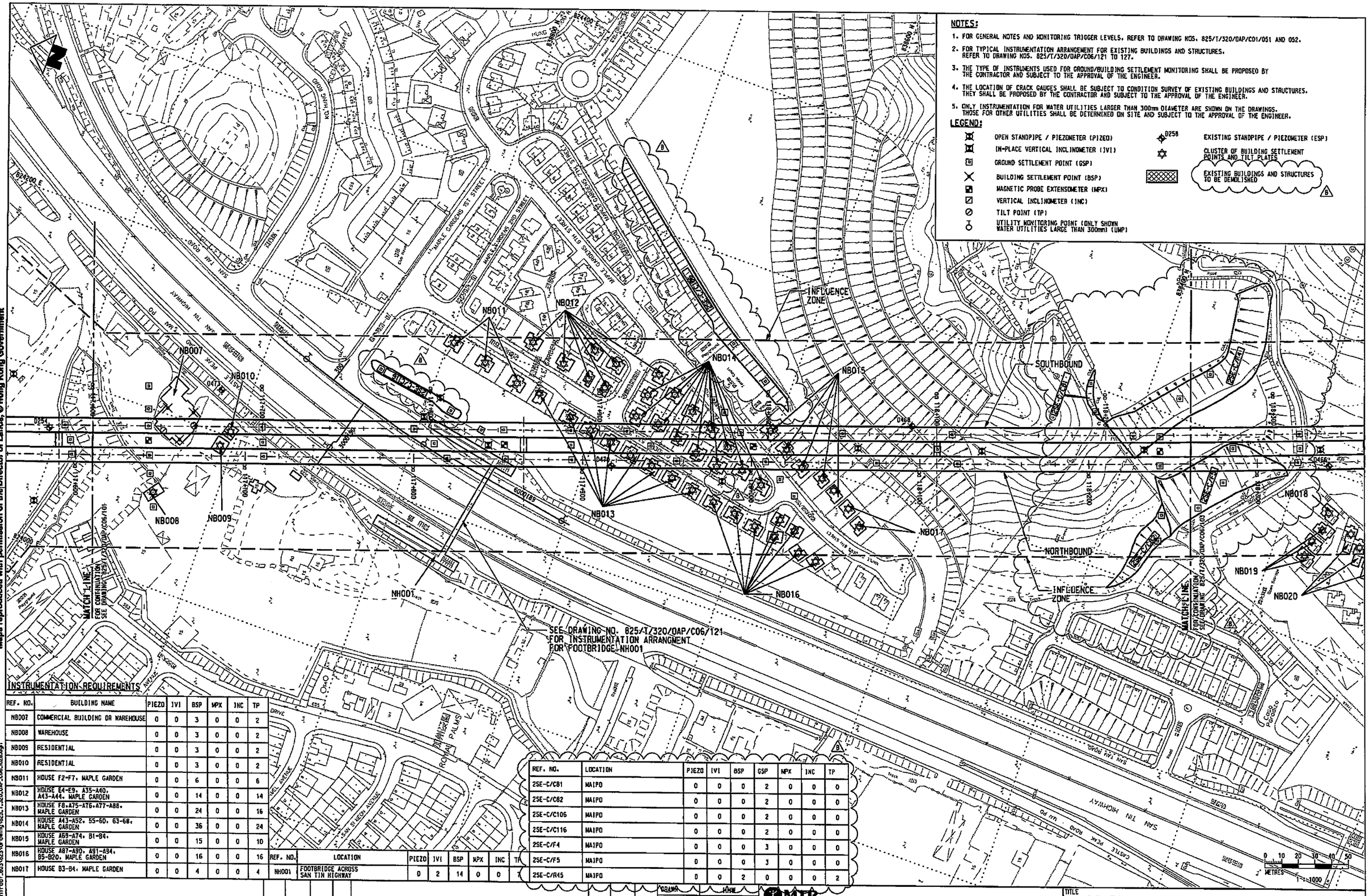
SHEET 1

SCALE 1: 1000 (A1)

DRAWING NO. 825/T/320/OAP/C06/111

REV. B

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FILENAME




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INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB007 | COMMERCIAL BUILDING OR WAREHOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB008 | WAREHOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB009 | RESIDENTIAL | 0 | 0 | 3 | 0 | 0 | 2 |
| NB010 | RESIDENTIAL | 0 | 0 | 3 | 0 | 0 | 2 |
| NB011 | HOUSE F2-F7, MAPLE GARDEN | 0 | 0 | 6 | 0 | 0 | 6 |
| NB012 | HOUSE E4-E9, A35-A40, A43-A44, MAPLE GARDEN | 0 | 0 | 14 | 0 | 0 | 14 |
| NB013 | HOUSE F8,A75-A76,A77-A88, MAPLE GARDEN | 0 | 0 | 24 | 0 | 0 | 16 |
| NB014 | HOUSE A43-A52, 55-60, 63-68, MAPLE GARDEN | 0 | 0 | 36 | 0 | 0 | 24 |
| NB015 | HOUSE A69-A74, B1-B4, MAPLE GARDEN | 0 | 0 | 15 | 0 | 0 | 10 |
| NB016 | HOUSE A87-A90, A91-A94, B5-B20, MAPLE GARDEN | 0 | 0 | 16 | 0 | 0 | 16 |
| NB017 | HOUSE B3-B4, MAPLE GARDEN | 0 | 0 | 4 | 0 | 0 | 4 |

| REF. NO. | LOCATION | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NH001 | FOOTBRIDGE ACROSS SAN TIN HIGHWAY | 0 | 2 | 14 | 0 | 0 | 7 |

| REF. NO. | LOCATION | PIEZO | IVI | BSP | GSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|---|
| 2SE-C/C81 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/C82 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/C106 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/C116 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/F4 | MAIPO | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 2SE-C/F5 | MAIPO | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 2SE-C/R45 | MAIPO | 0 | 0 | 2 | 0 | 0 | 0 | 2 |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

DRAWN HMW
DESIGNED JY
CHECKED PAT
APPROVED JM
DATE 27/MAR/2009

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ORIGINATOR ARUP

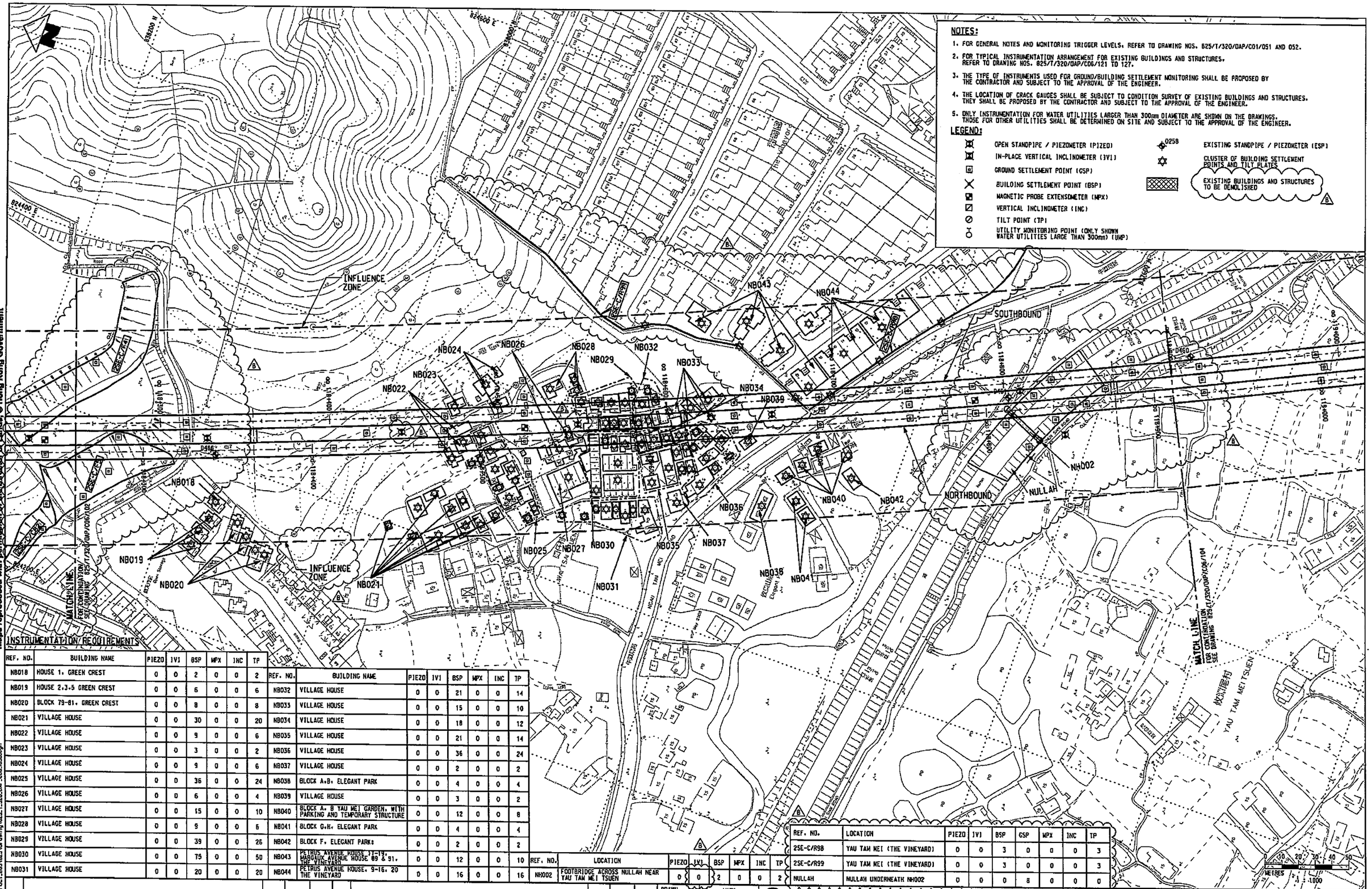
Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_DAP_C06_102B.dgn

TITLE
CONTRACT 825
MAI PO TO NGAU TAM MEI
GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN
SHEET 2

SCALE 1: 1000 (A1)
DRAWING NO. 825/T/320/DAP/C06/102
REV. B

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FILENAME: m:\c803\control_803\825\dr-dwing\825_T_320_DAP_C06_102B.dgn




INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB018 | HOUSE 1, GREEN CREST | 0 | 0 | 2 | 0 | 0 | 2 |
| NB019 | HOUSE 2,3,5 GREEN CREST | 0 | 0 | 6 | 0 | 0 | 6 |
| NB020 | BLOCK 79-81, GREEN CREST | 0 | 0 | 8 | 0 | 0 | 8 |
| NB021 | VILLAGE HOUSE | 0 | 0 | 30 | 0 | 0 | 20 |
| NB022 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB023 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB024 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB025 | VILLAGE HOUSE | 0 | 0 | 36 | 0 | 0 | 24 |
| NB026 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 4 |
| NB027 | VILLAGE HOUSE | 0 | 0 | 15 | 0 | 0 | 10 |
| NB028 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB029 | VILLAGE HOUSE | 0 | 0 | 39 | 0 | 0 | 26 |
| NB030 | VILLAGE HOUSE | 0 | 0 | 75 | 0 | 0 | 50 |
| NB031 | VILLAGE HOUSE | 0 | 0 | 20 | 0 | 0 | 20 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB032 | VILLAGE HOUSE | 0 | 0 | 21 | 0 | 0 | 14 |
| NB033 | VILLAGE HOUSE | 0 | 0 | 15 | 0 | 0 | 10 |
| NB034 | VILLAGE HOUSE | 0 | 0 | 18 | 0 | 0 | 12 |
| NB035 | VILLAGE HOUSE | 0 | 0 | 21 | 0 | 0 | 14 |
| NB036 | VILLAGE HOUSE | 0 | 0 | 36 | 0 | 0 | 24 |
| NB037 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB038 | BLOCK A,B, ELEGANT PARK | 0 | 0 | 4 | 0 | 0 | 4 |
| NB039 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB040 | BLOCK A, B YAU MEI GARDEN, WITH PARKING AND TEMPORARY STRUCTURE | 0 | 0 | 12 | 0 | 0 | 8 |
| NB041 | BLOCK G,H, ELEGANT PARK | 0 | 0 | 4 | 0 | 0 | 4 |
| NB042 | BLOCK F, ELEGANT PARK | 0 | 0 | 2 | 0 | 0 | 2 |
| NB043 | PETRUS AVENUE HOUSE, 77-79, MARGUX AVENUE HOUSE 89 & 91, THE VINEYARD | 0 | 0 | 12 | 0 | 0 | 10 |
| NB044 | PETRUS AVENUE HOUSE, 9-16, 20 THE VINEYARD | 0 | 0 | 16 | 0 | 0 | 16 |

| REF. NO. | LOCATION | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NH002 | FOOTBRIDGE ACROSS NULLAH NEAR YAU TAM MEI TSUEN | 0 | 0 | 2 | 0 | 0 | 2 |

| REF. NO. | LOCATION | PIEZO | IVI | BSP | GSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|---|
| 2SE-C/R98 | YAU TAM MEI (THE VINEYARD) | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| 2SE-C/R99 | YAU TAM MEI (THE VINEYARD) | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| NULLAH | NULLAH UNDERNEATH NH002 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JW |
| A | TENDER ISSUE | TW | 02JUL09 | JW |

| | |
|---|---|
| DRAWN | HHM |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_DAP_C06_103B.dgn

TITLE: CONTRACT 825
MAI PO TO NGAU TAM MEI
GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN
SHEET 3

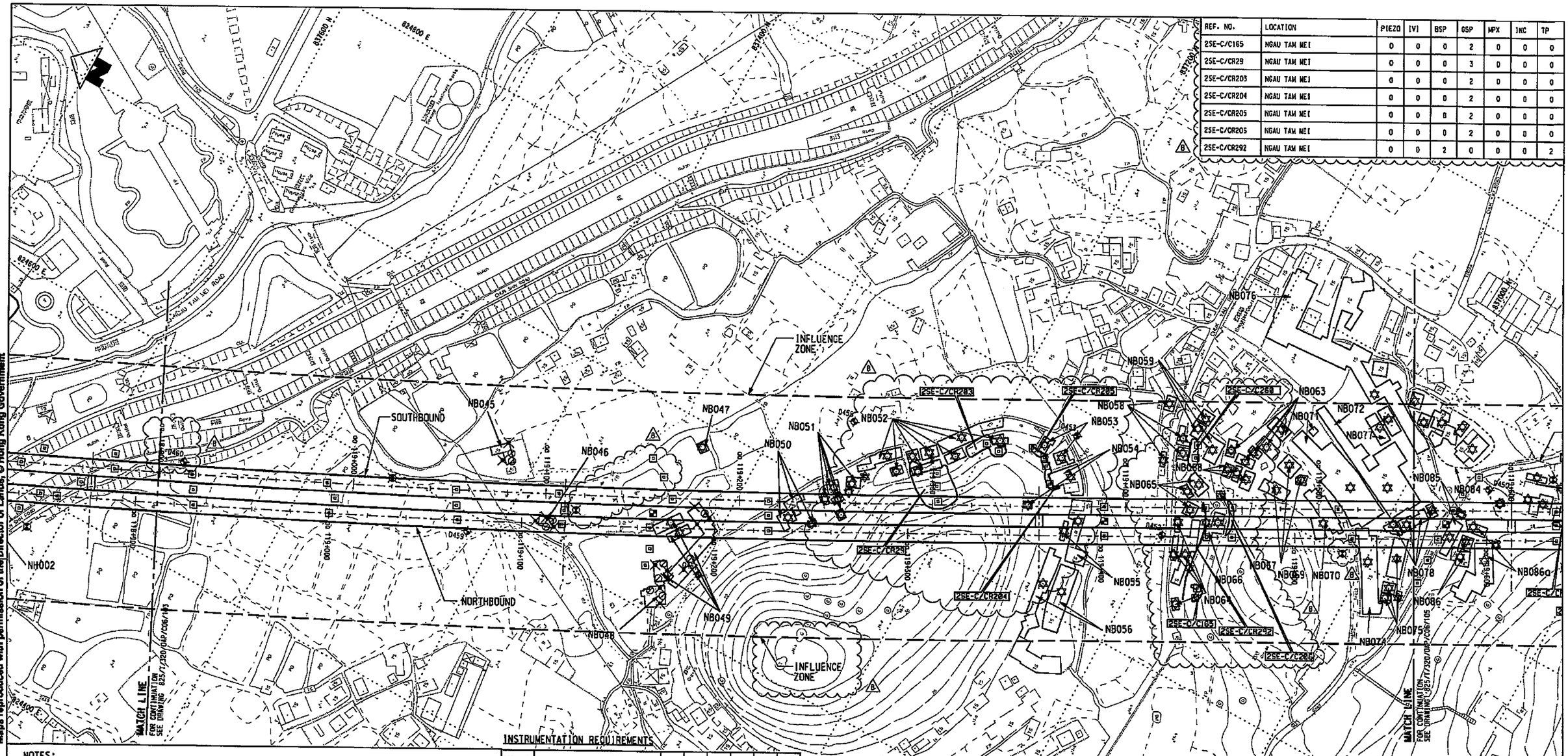
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DRAWING NO. 825/T/320/DAP/C06/103

REV. B

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PRINTED BY: williamw 1/23/2009 9:40:41 AM




| REF. NO. | LOCATION | PIEZO | IVI | BSP | GSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|---|
| 2SE-C/C165 | NGAU TAM MEI | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/CR29 | NGAU TAM MEI | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 2SE-C/CR203 | NGAU TAM MEI | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/CR204 | NGAU TAM MEI | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/CR205 | NGAU TAM MEI | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/CR206 | NGAU TAM MEI | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/CR292 | NGAU TAM MEI | 0 | 0 | 2 | 0 | 0 | 0 | 2 |

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NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 825/T/320/DAP/C01/051 AND 052.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 825/T/320/DAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
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LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB045 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB046 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB047 | TEMPORARY STRUCTURE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB048 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB049 | VILLAGE HOUSE | 0 | 0 | 12 | 0 | 0 | 8 |
| NB050 | VILLAGE HOUSE | 0 | 0 | 15 | 0 | 0 | 10 |
| NB051 | VILLAGE HOUSE | 0 | 0 | 15 | 0 | 0 | 10 |
| NB052 | VILLAGE HOUSE | 0 | 0 | 22 | 0 | 0 | 16 |
| NB053 | RESIDENTIAL | 0 | 0 | 5 | 0 | 0 | 4 |
| NB054 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 4 |
| NB055 | RESIDENTIAL | 0 | 0 | -12 | 0 | 0 | 8 |
| NB056 | RESIDENTIAL | 0 | 0 | 6 | 0 | 0 | 4 |
| NB058 | RESIDENTIAL | 0 | 0 | 9 | 0 | 0 | 8 |
| NB059 | TEMPORARY STRUCTURE | 0 | 0 | 7 | 0 | 0 | 6 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB063 | WAREHOUSE | 0 | 0 | 11 | 0 | 0 | 10 |
| NB064 | RESIDENTIAL | 0 | 0 | 14 | 0 | 0 | 10 |
| NB065 | RESIDENTIAL | 0 | 0 | 9 | 0 | 0 | 6 |
| NB066 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB067 | TEMPORARY STRUCTURE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB068 | WAREHOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB069 | WAREHOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB070 | WAREHOUSE | 0 | 0 | 6 | 0 | 0 | 4 |
| NB071 | RESIDENTIAL | 0 | 0 | 6 | 0 | 0 | 6 |
| NB072 | RESIDENTIAL | 0 | 0 | 3 | 0 | 0 | 2 |
| NB074 | RESIDENTIAL | 0 | 0 | 3 | 0 | 0 | 2 |
| NB075 | TEMPORARY STRUCTURE | 0 | 0 | 12 | 0 | 0 | 8 |
| NB076 | RESIDENTIAL | 0 | 0 | 8 | 0 | 0 | 8 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB077 | RESIDENTIAL | 0 | 0 | 9 | 0 | 0 | 6 |
| NB078 | TEMPORARY STRUCTURE | 0 | 0 | 12 | 0 | 0 | 8 |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JM |
| A | TENDER ISSUE | TW | 02JUL09 | JM |

| | |
|---|---|
| DRAWN | HHW |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 27/MAR/2009 |

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ORIGINATOR ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_DAP_C06_104B.dgn

TITLE

# CONTRACT 825
## MAI PO TO NGAU TAM MEI
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

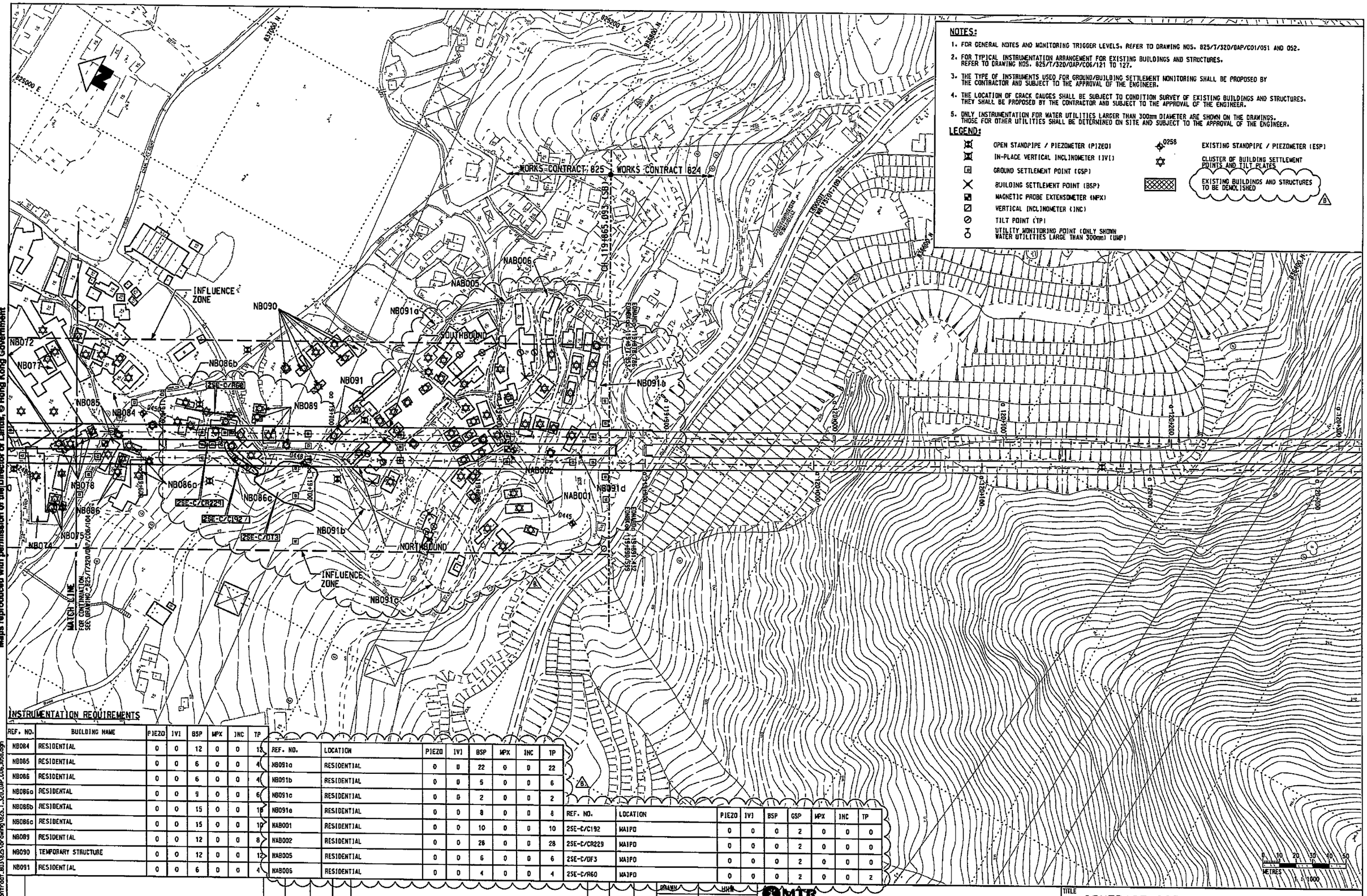
SHEET 4

SCALE 1: 1000 (A1)

DRAWING NO. 825/T/320/DAP/C06/104

REV. B

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NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 825/T/320/DAP/C01/051 AND 052.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 825/T/320/DAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- 0258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB084 | RESIDENTIAL | 0 | 0 | 12 | 0 | 0 | 12 |
| NB085 | RESIDENTIAL | 0 | 0 | 6 | 0 | 0 | 4 |
| NB086 | RESIDENTIAL | 0 | 0 | 6 | 0 | 0 | 4 |
| NB086a | RESIDENTAL | 0 | 0 | 9 | 0 | 0 | 6 |
| NB086b | RESIDENTAL | 0 | 0 | 15 | 0 | 0 | 10 |
| NB086c | RESIDENTIAL | 0 | 0 | 15 | 0 | 0 | 10 |
| NB089 | RESIDENTIAL | 0 | 0 | 12 | 0 | 0 | 8 |
| NB090 | TEMPORARY STRUCTURE | 0 | 0 | 12 | 0 | 0 | 12 |
| NB091 | RESIDENTIAL | 0 | 0 | 6 | 0 | 0 | 4 |

| REF. NO. | LOCATION | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB091a | RESIDENTIAL | 0 | 0 | 22 | 0 | 0 | 22 |
| NB091b | RESIDENTIAL | 0 | 0 | 5 | 0 | 0 | 6 |
| NB091c | RESIDENTIAL | 0 | 0 | 2 | 0 | 0 | 2 |
| NB091e | RESIDENTIAL | 0 | 0 | 8 | 0 | 0 | 8 |
| NAB001 | RESIDENTIAL | 0 | 0 | 10 | 0 | 0 | 10 |
| NAB002 | RESIDENTIAL | 0 | 0 | 28 | 0 | 0 | 28 |
| NAB005 | RESIDENTIAL | 0 | 0 | 6 | 0 | 0 | 6 |
| NAB006 | RESIDENTIAL | 0 | 0 | 4 | 0 | 0 | 4 |

| REF. NO. | LOCATION | PIEZO | IVI | BSP | GSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|---|
| 2SE-C/C192 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/CR229 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/DF3 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 2SE-C/R60 | MAIPO | 0 | 0 | 0 | 2 | 0 | 0 | 2 |

TENDER

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| B | TENDER ADDENDUM NO. 1 ISSUE | TW | 03AUG09 | JW |
| A | TENDER ISSUE | TW | 02JUL09 | JW |

| | |
|---|---|
| DRAWN | HHH |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JW |
| DATE | 27/MAR/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 825_T_320_DAP_C06_105B.dgn

TITLE

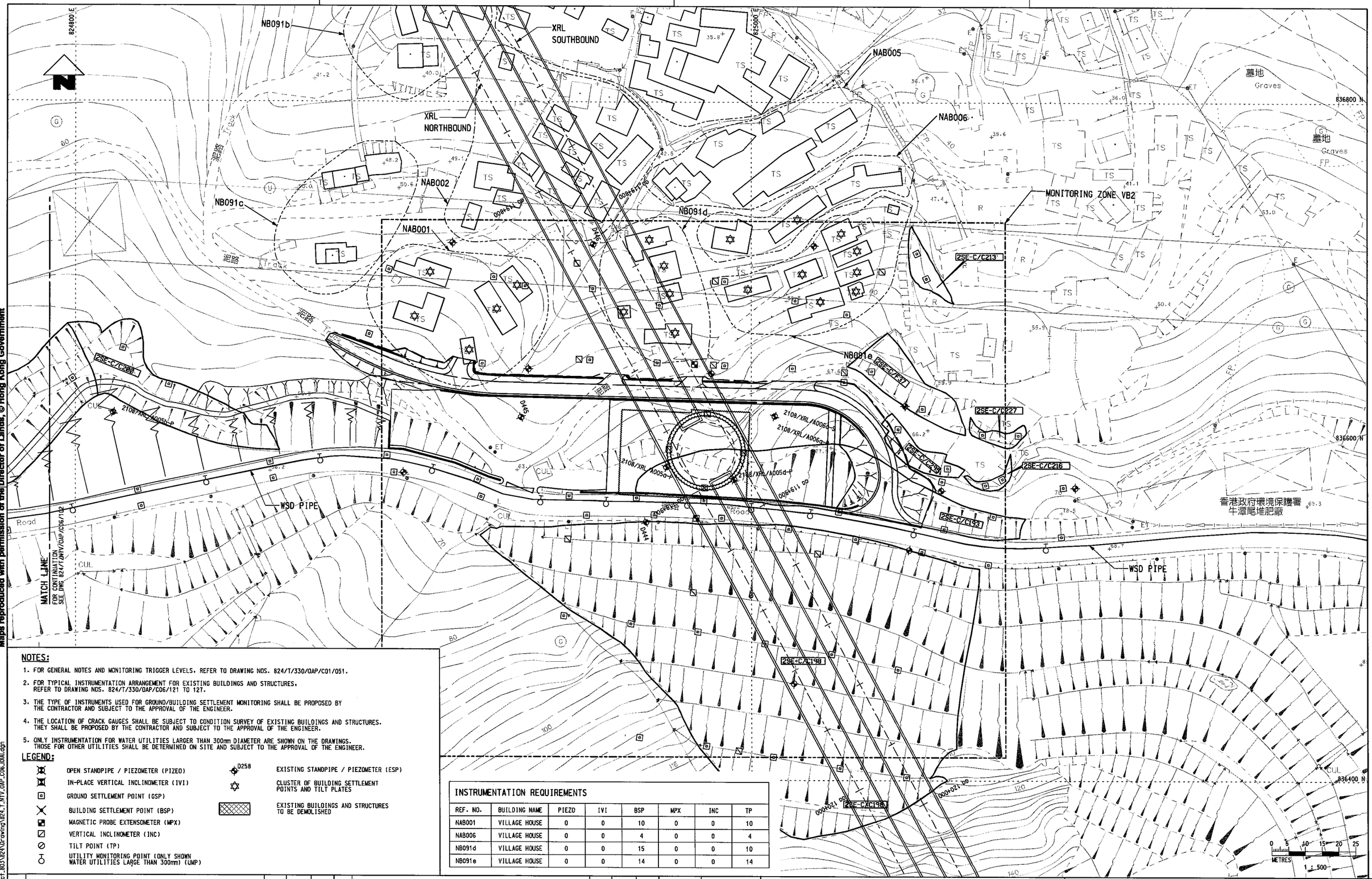
# CONTRACT 825
## MAI PO TO NGAU TAM MEI
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 5

| SCALE | DRAWING NO. | REV. |
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## NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 824/T/330/OAP/C01/051.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 824/T/330/OAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

## LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

## INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NAB001 | VILLAGE HOUSE | 0 | 0 | 10 | 0 | 0 | 10 |
| NAB006 | VILLAGE HOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB091d | VILLAGE HOUSE | 0 | 0 | 15 | 0 | 0 | 10 |
| NB091e | VILLAGE HOUSE | 0 | 0 | 14 | 0 | 0 | 14 |

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 13NOV09 | JM |

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|---|---|
| DRAWN | AC |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 13/NOV/2009 |

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ORIGINATOR
ARUP
Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

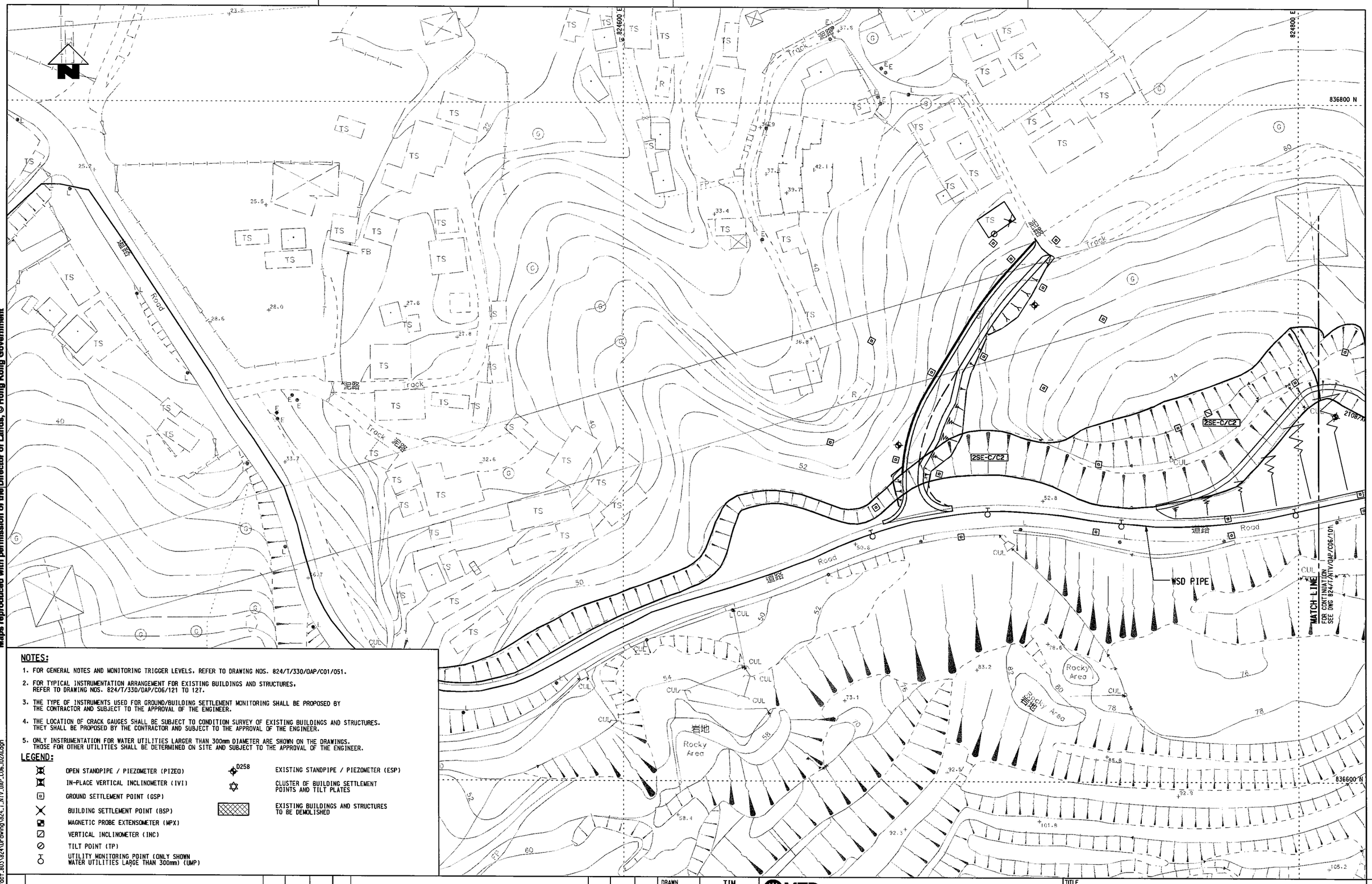
CADD REF. 824_T_NTV_OAP_C06_101A1.dgn

TITLE
CONTRACT 824
NGAU TAM MEI TO TAI KONG PO
NGAU TAM MEI VENTILATION BUILDING VB2 – GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN
SHEET 1

SCALE 1 : 500 (A1) | DRAWING NO. 824/T/NTV/OAP/C06/101 | REV. A1

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## NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 824/T/330/OAP/C01/051.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 824/T/330/OAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

## LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- 0258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 13NOV09 | JM |

ACP

| | |
|---|---|
| DRAWN | TIM |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 13/NOV/2009 |

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CADD REF. 824_T_NTV_OAP_C06_102A1.dgn

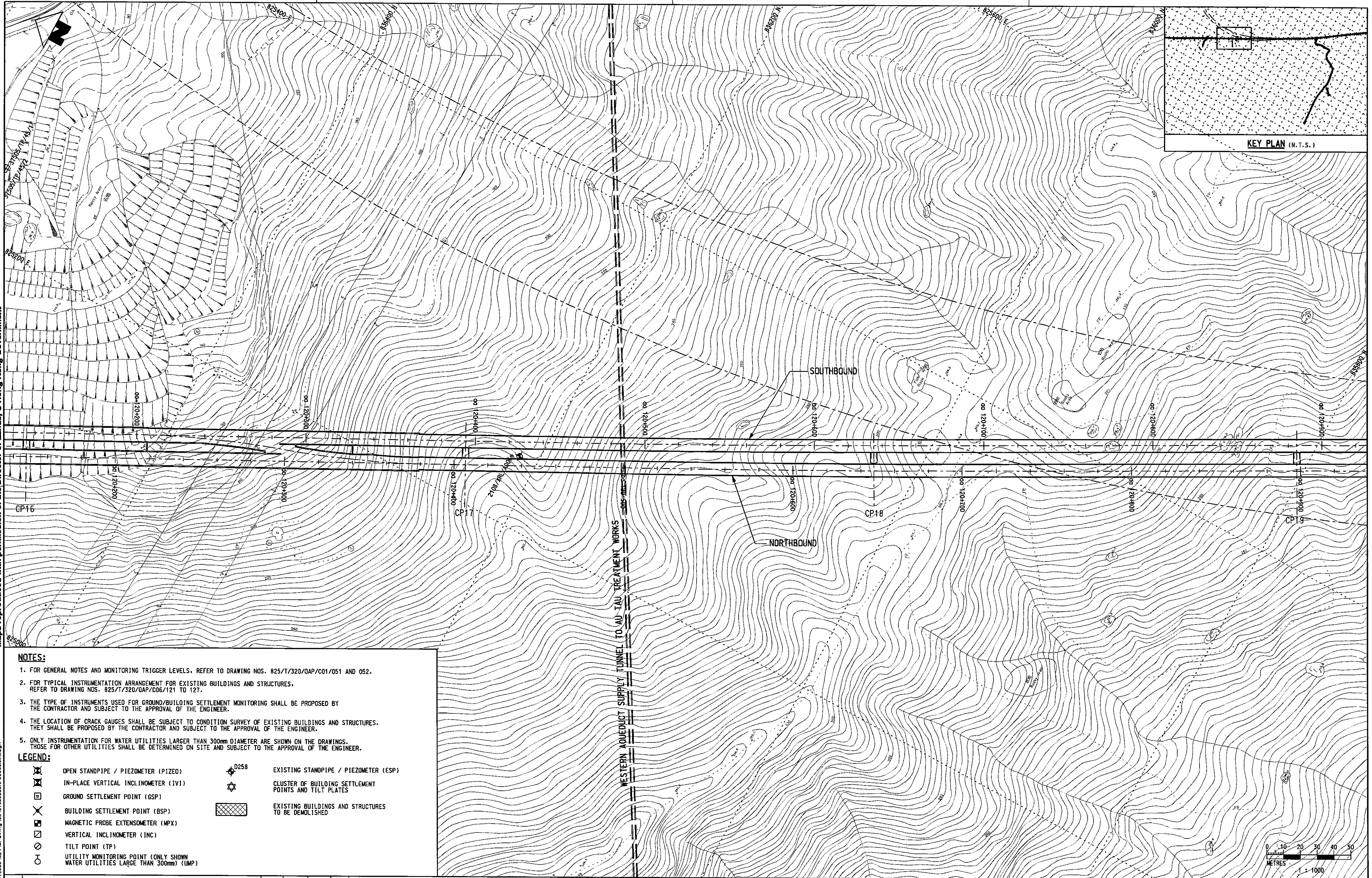
TITLE

# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
### NGAU TAM MEI VENTILATION BUILDING VB2 - GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN SHEET 2

| SCALE | DRAWING NO. | REV. |
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## NOTES:

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 825/T/320/OAP/C01/051 AND 052.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 825/T/320/OAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

## LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 13NOV09 | JM |

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|---|---|
| DRAWN | HHW |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 13/NOV/2009 |

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ORIGINATOR ARUP

Supported by :
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Urbis, BMT Asia

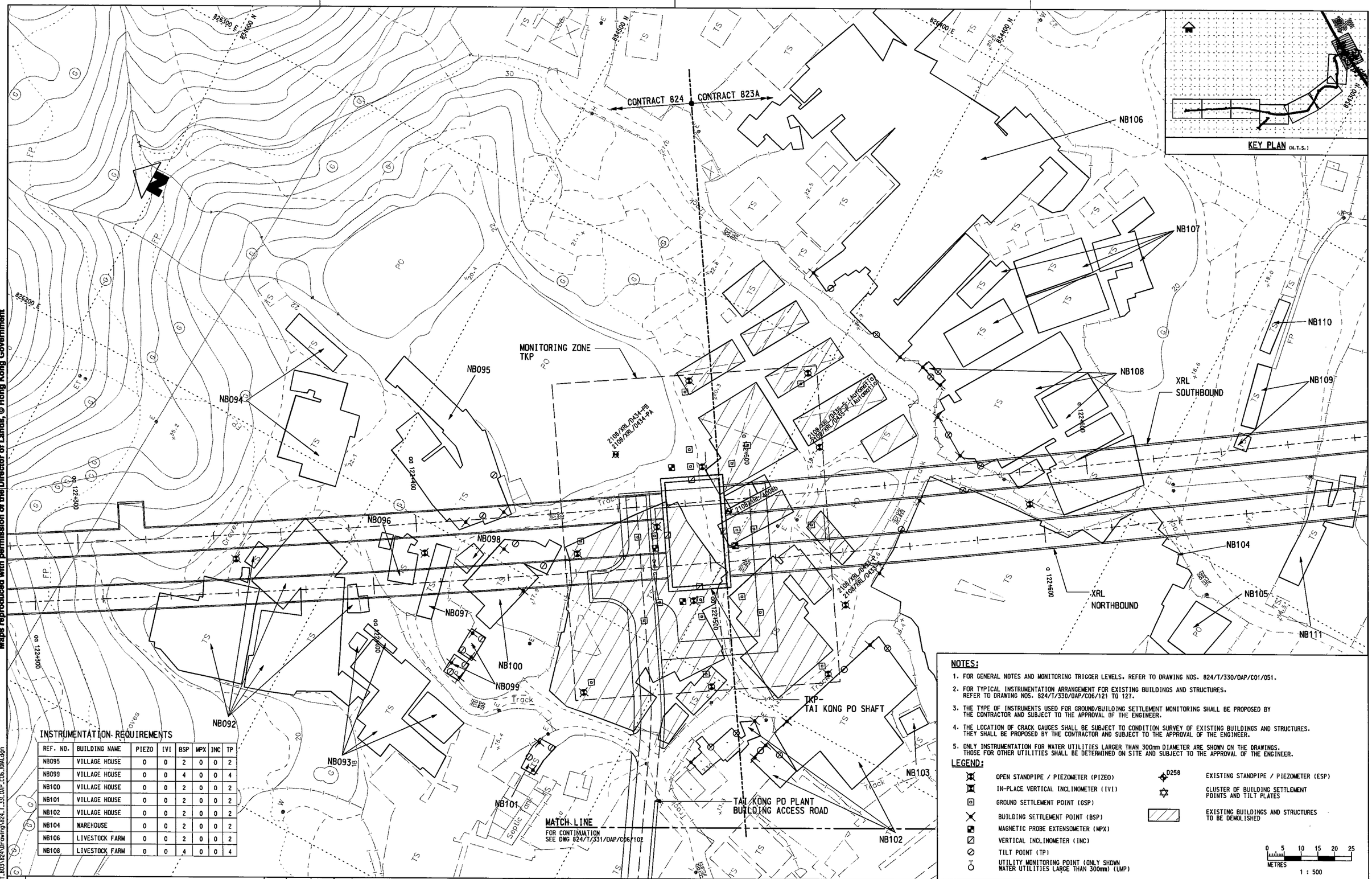
CADD REF. 824_T_330_OAP_C06_101A1.dgn

TITLE
# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SCALE 1: 1000 (A1) | DRAWING NO. 824/T/330/OAP/C06/101 | REV. A1

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## INSTRUMENTATION REQUIREMENTS

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB095 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB099 | VILLAGE HOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB100 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB101 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB102 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB104 | WAREHOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB106 | LIVESTOCK FARM | 0 | 0 | 2 | 0 | 0 | 2 |
| NB108 | LIVESTOCK FARM | 0 | 0 | 4 | 0 | 0 | 4 |

**NOTES:**

1. FOR GENERAL NOTES AND MONITORING TRIGGER LEVELS, REFER TO DRAWING NOS. 824/T/330/OAP/C01/051.
2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 824/T/330/OAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

**LEGEND:**

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

METRES 0 5 10 15 20 25

1 : 500

ACP

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A1 | TENDER DRAWINGS ACPS ISSUE | TW | 13NOV09 | JM |

| | |
|---|---|
| DRAWN | TIM |
| DESIGNED | JY |
| CHECKED | PAT |
| APPROVED | JM |
| DATE | 13/NOV/2009 |

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ORIGINATOR: ARUP

Supported by : Atkins, TFP Farrells, DLS, Knight Frank, SIYUAN, Urbis, BMT Asia

CADD REF. 824_T_331_OAP_C06_101A1.dgn

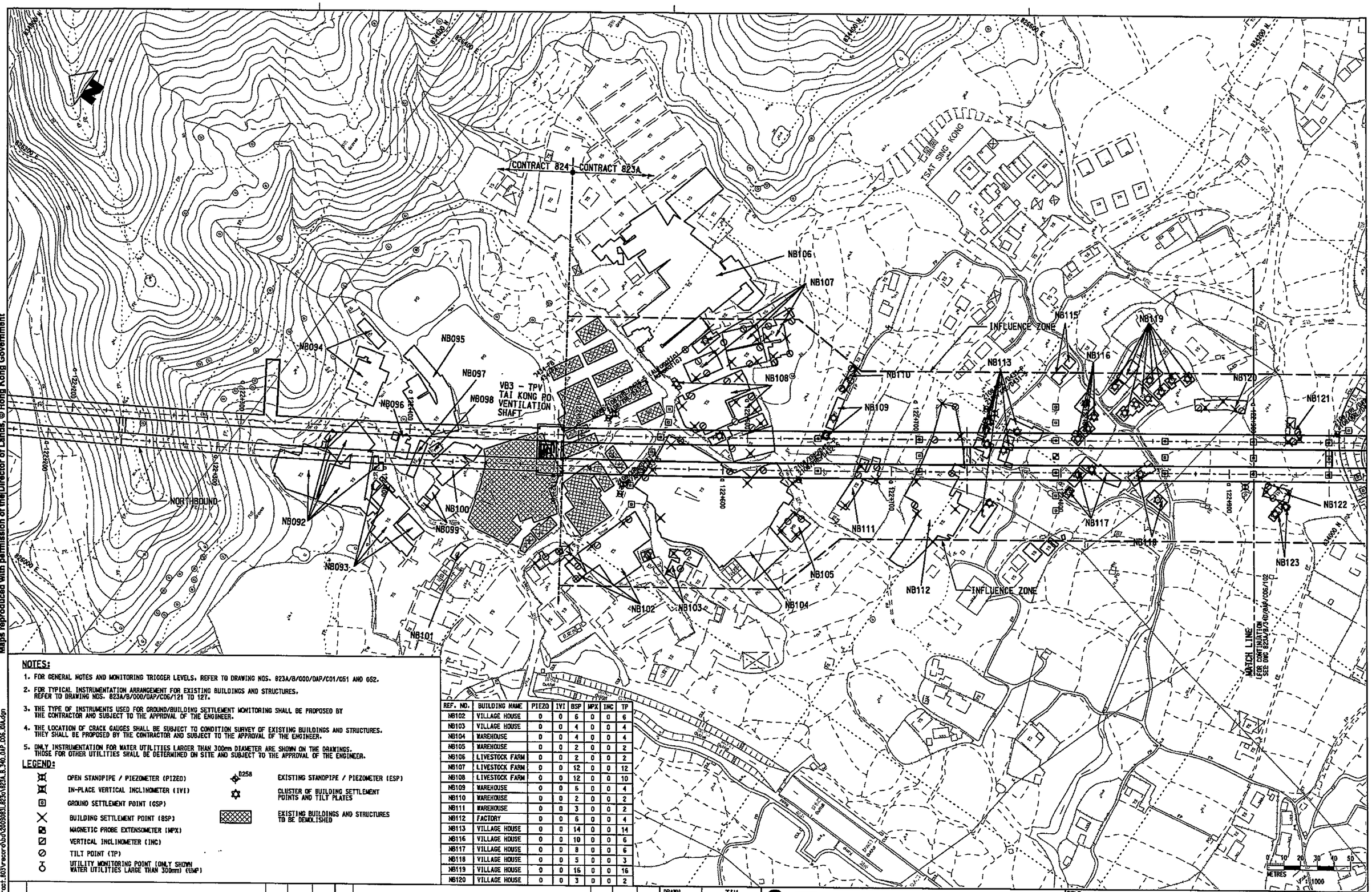
TITLE

# CONTRACT 824
## NGAU TAM MEI TO TAI KONG PO
### TAI KONG PO PLANT BUILDING TKP – GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN SHEET 1

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1: 500 (A1) | 824/T/331/OAP/C06/101 | A1 |

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NOTES:

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2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 823A/B/000/DAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES. THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- EXISTING STANDPIPE / PIEZOMETER (ESP) (0258)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB102 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 6 |
| NB103 | VILLAGE HOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB104 | WAREHOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB105 | WAREHOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB106 | LIVESTOCK FARM | 0 | 0 | 2 | 0 | 0 | 2 |
| NB107 | LIVESTOCK FARM | 0 | 0 | 12 | 0 | 0 | 12 |
| NB108 | LIVESTOCK FARM | 0 | 0 | 12 | 0 | 0 | 10 |
| NB109 | WAREHOUSE | 0 | 0 | 5 | 0 | 0 | 4 |
| NB110 | WAREHOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB111 | WAREHOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB112 | FACTORY | 0 | 0 | 6 | 0 | 0 | 4 |
| NB113 | VILLAGE HOUSE | 0 | 0 | 14 | 0 | 0 | 14 |
| NB116 | VILLAGE HOUSE | 0 | 0 | 10 | 0 | 0 | 6 |
| NB117 | VILLAGE HOUSE | 0 | 0 | 8 | 0 | 0 | 6 |
| NB118 | VILLAGE HOUSE | 0 | 0 | 5 | 0 | 0 | 3 |
| NB119 | VILLAGE HOUSE | 0 | 0 | 16 | 0 | 0 | 16 |
| NB120 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |

BD CONSULTATION SUBMISSION

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | BD CONSULTATION SUBMISSION | TW | 21AUG09 | JM |

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|---|---|
| DRAWN | TIM |
| DESIGNED | JY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 05/JUN/2009 |

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CADD REF. 823A_B_340_DAP_C06_101A.dgn

TITLE

# CONTRACT 823A

## TAI KONG PO TO TSE UK TSUEN

### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 1

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1: 1000 (A1) | 823A/B/340/DAP/C06/101 | A |

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**NOTES:**

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2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 823A/B/000/OAP/C06/121 TO 127.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
4. THE LOCATION OF CRACK GAUGES SHALL BE SUBJECT TO CONDITION SURVEY OF EXISTING BUILDINGS AND STRUCTURES, THEY SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
5. ONLY INSTRUMENTATION FOR WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. THOSE FOR OTHER UTILITIES SHALL BE DETERMINED ON SITE AND SUBJECT TO THE APPROVAL OF THE ENGINEER.

**LEGEND:**

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- 0258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB121 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB122 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB123 | VILLAGE HOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB126 | FACTORY | 0 | 0 | 2 | 0 | 0 | 2 |
| NB127 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB128 | FACTORY | 0 | 0 | 3 | 0 | 0 | 2 |
| NB129 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB130 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB136 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 2 |
| NB138 | SHEK KONG VEGETABLE MARKETING CO-OPERATIVE SOCIETY LTD. | 0 | 0 | 3 | 0 | 0 | 2 |

| REF. NO. | STRUCTURE NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NH003 | BRIDGE ACROSS KAM TIN RIVER AT KAM TIN ROAD | 0 | 0 | 2 | 0 | 0 | 2 |
| NH004 | BRIDGE ACROSS KAM TIN RIVER AT WANG TOI SHAN SHAN TSUEN ROAD | 0 | 0 | 2 | 0 | 0 | 2 |

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| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | BD CONSULTATION SUBMISSION | TW | 21AUG09 | JW |

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|---|---|
| DRAWN | TIM |
| DESIGNED | JY |
| CHECKED | JB. |
| APPROVED | JW |
| DATE | 05/JUN/2009 |

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TITLE

# CONTRACT 823A
## TAI KONG PO TO TSE UK TSUEN
### GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 2

| SCALE | DRAWING NO. | REV. |
|---|---|---|
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PRINTED BY: williamw
07/09/2009 02:29:59 PM

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## NOTES:

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2. FOR TYPICAL INSTRUMENTATION ARRANGEMENT FOR EXISTING BUILDINGS AND STRUCTURES, REFER TO DRAWING NOS. 823B/B/350/DAP/C06/121 TO 126.
3. THE TYPE OF INSTRUMENTS USED FOR GROUND/BUILDING SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR AND SUBJECT TO THE APPROVAL OF THE ENGINEER.
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## LEGEND:

- OPEN STANDPIPE / PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

CONTRACT 823A
CONTRACT 823B
PROJECT BOUNDARY
PROPOSED WORKS SITE
SOUTHBOUND
NORTHBOUND
PROPOSED ERS
MONITORING ZONE ERS (A)
NB136
NB138
NB139
NB140
NB141
NB142
NB143
NB144
NH004
MATCH LINE
FOR CONTINUATION SEE DWG B23B/B/350/DAP/C06/102
METRES

| REF. NO. | STRUCTURE NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB138 | SHEK KONG VEGETABLE MARKETING CO-OPERATIVE SOCIETY LTD. | 0 | 0 | 3 | 0 | 0 | 2 |
| NB139 | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NH004 | BRIDGE ACROSS KAM TIN RIVER AT WANG TOI SHAN SHAN TSUEN ROAD | 0 | 0 | 2 | 0 | 0 | 2 |

BD CONSULTATION SUBMISSION

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | BD CONSULTATION SUBMISSION | TW | 07OCT09 | JM |

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|---|---|
| DRAWN | TIM |
| DESIGNED | JY |
| CHECKED | MT |
| APPROVED | JM |
| DATE | 07/OCT/2009 |

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TITLE
CONTRACT 823B
SHEK KONG STABLING SIDINGS AND ERS
GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN
SHEET 1

SCALE 1: 1000 (A1) | DRAWING NO. 823B/B/350/OAP/C06/101 | REV. A

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FILENAME: MAY2803\CONTRACT_823\RECORD\DGN\2009\0907\B23B_B350_OAP_C06_101A.dgn

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PROJECT BOUNDARY

NB144 NB145 NB146 NB147 NB148 NB149A NB149B

CONTRACT 823B CONTRACT 823A

MONITORING ZONE ERS (A)

MONITORING ZONE ERS (B)

MATCH-LINE FOR CONTINUATION SEE DWG 823B/B/350/OAP/C06/101

NORTHBOUND

SOUTHBOUND

KEI LING KEI ROAD

| REF. NO. | STRUCTURE NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB147 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 3 |
| NB148 | FARMHOUSE | 0 | 0 | 4 | 0 | 0 | 2 |

**NOTES:**

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**LEGEND:**

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- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

0 10 20 30 40 50 METRES

1 : 1000

BD CONSULTATION SUBMISSION

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | BD CONSULTATION SUBMISSION | TW | 07OCT09 | JM |

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| DRAWN | TIM |
| DESIGNED | JY |
| CHECKED | MT |
| APPROVED | JM |
| DATE | 07/OCT/2009 |

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TITLE

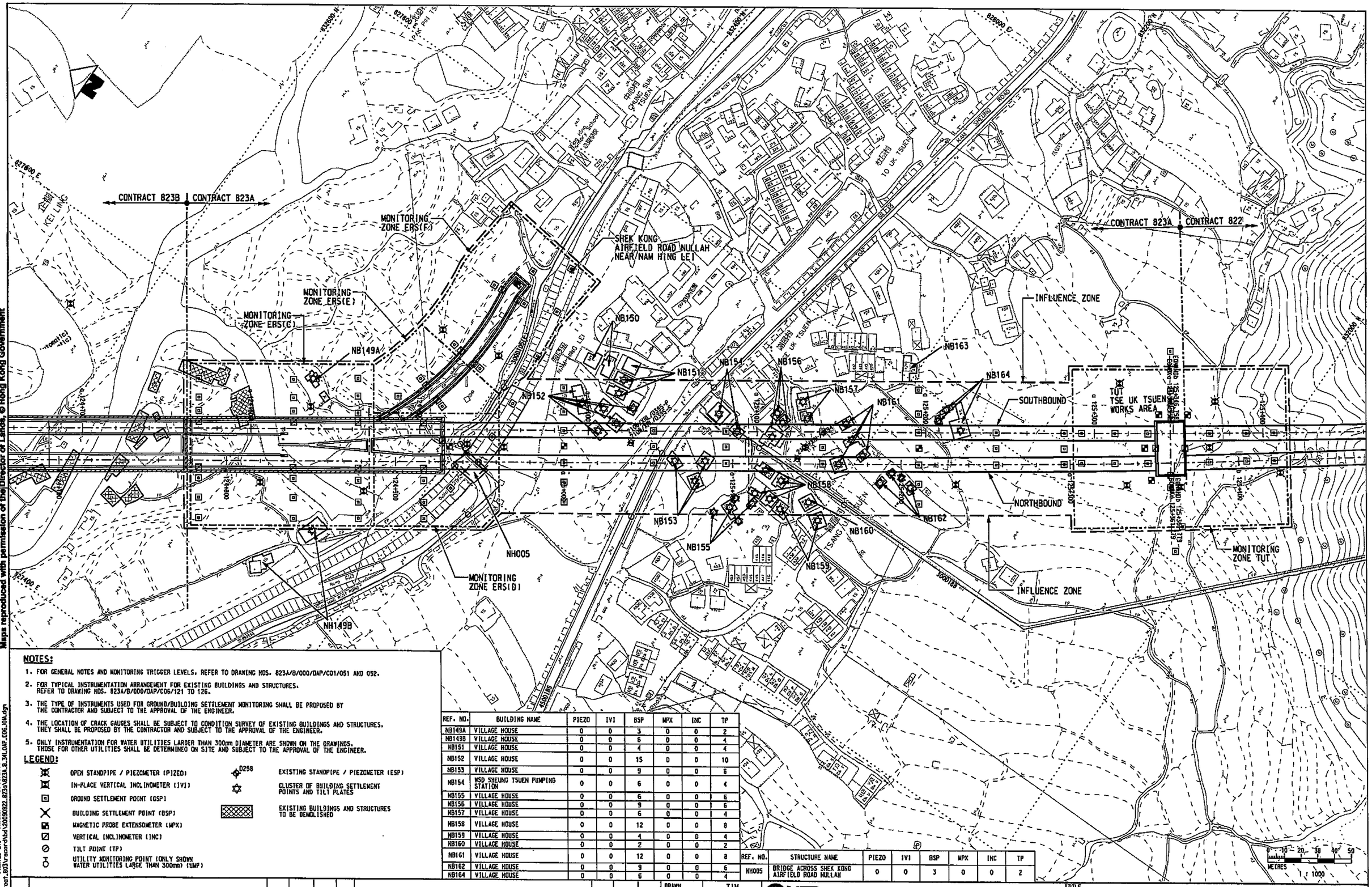
CONTRACT 823B
SHEK KONG STABLING SIDINGS AND ERS
GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 2

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1: 1000 (A1) | 823B/B/350/OAP/C06/102 | A |

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- GROUND SETTLEMENT POINT (GSP)
- BUILDING SETTLEMENT POINT (BSP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILT POINT (TP)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- D258 EXISTING STANDPIPE / PIEZOMETER (ESP)
- CLUSTER OF BUILDING SETTLEMENT POINTS AND TILT PLATES
- EXISTING BUILDINGS AND STRUCTURES TO BE DEMOLISHED

| REF. NO. | BUILDING NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NB149A | VILLAGE HOUSE | 0 | 0 | 3 | 0 | 0 | 2 |
| NB149B | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 4 |
| NB151 | VILLAGE HOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB152 | VILLAGE HOUSE | 0 | 0 | 15 | 0 | 0 | 10 |
| NB153 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB154 | WSD SHEUNG TSUEN PUMPING STATION | 0 | 0 | 6 | 0 | 0 | 4 |
| NB155 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 6 |
| NB156 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB157 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 4 |
| NB158 | VILLAGE HOUSE | 0 | 0 | 12 | 0 | 0 | 8 |
| NB159 | VILLAGE HOUSE | 0 | 0 | 4 | 0 | 0 | 4 |
| NB160 | VILLAGE HOUSE | 0 | 0 | 2 | 0 | 0 | 2 |
| NB161 | VILLAGE HOUSE | 0 | 0 | 12 | 0 | 0 | 8 |
| NB162 | VILLAGE HOUSE | 0 | 0 | 9 | 0 | 0 | 6 |
| NB164 | VILLAGE HOUSE | 0 | 0 | 6 | 0 | 0 | 4 |

| REF. NO. | STRUCTURE NAME | PIEZO | IVI | BSP | MPX | INC | TP |
|---|---|---|---|---|---|---|---|
| NH005 | BRIDGE ACROSS SHEK KONG AIRFIELD ROAD NULLAH | 0 | 0 | 3 | 0 | 0 | 2 |

BD CONSULTATION SUBMISSION

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | BD CONSULTATION SUBMISSION | TW | 21AUG09 | JW |

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| DRAWN | TJM |
| DESIGNED | JY |
| CHECKED | JB |
| APPROVED | JM |
| DATE | 05/JUN/2009 |

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TITLE

CONTRACT 823A
TAI KONG PO TO TSE UK TSUEN
GEOTECHNICAL INSTRUMENTATION LAYOUT PLAN

SHEET 3

SCALE 1: 1000 (A1)

DRAWING NO. 823A/B/341/OAP/C06/101

REV. A

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MTR Corporation Limited

# HONG KONG SECTION OF GUANGZHOU - SHENZHEN - HONG KONG EXPRESS RAIL LINK

(No. EP-349/2009)

## Hydrogeological Impact Assessment Report

Certified by: Glenn Fromme

Position: Environmental Team Leader

Date: 14 APR 2010

MTR Corporation Limited

# HONG KONG SECTION OF GUANGZHOU – SHENZHEN – HONG KONG EXPRESS RAIL LINK

(No. EP-349/2009)

## Supplementary Information on Updated Hydrogeological Impact Assessment Reports

Verified by: _____

Position: Independent Environmental Checker

Date: 30 July 2010

MTR Corporation Limited

# HONG KONG SECTION OF GUANGZHOU - SHENZHEN - HONG KONG EXPRESS RAIL LINK

(No. EP-349/2009)

## Supplementary Information on Updated Hydrogeological Impact Assessment Reports

Certified by: _____

Position: Environmental Team Leader

Date: 26 JUL 2010

**Summary on the findings of updated Hydrogeological Impact Assessment (HIA)**

## 1. Introduction

Hydrogeological Impact Assessment (HIA) was conducted during the EIA stage (hereinafter referred as "previous HIA") to assess the potential impact of tunnel works under the XRL on the surface water and groundwater. The assessment was based on qualitative approach which covered potential hydrogeological impact due to groundwater drawdown/dewatering of surface features. Based on the assessment result, a number of precautionary measures were identified to minimize the potential hydrogeolical impact due to construction. It was concluded in the assessment that with the adoption of appropriate construction control/practices during construction, no adverse impact to groundwater table is anticipated.

In accordance with the EP Condition 2.10, an updated HIA (hereinafter referred as "updated HIA") was carried out to re-affirm the findings of the EIA Report with respect to the extent of the environmental impacts as a result of the potential hydrology and groundwater level changes. The assessment in the updated HIA was based on quantitative approach to provide a more precise result in the potential groundwater level changes.

## 2. Summary of the findings of the Previous HIA

The previous HIA covered various construction methods to be adopted for tunneling and shaft construction, covering Cut-and-Cover, Drill and Blast and bored tunneling. No significant risk of groundwater drawdown with respect to the use of these construction methods was identified in the previous HIA, provided that the following precautionary and mitigation measures proposed are implemented:

Cut-and-Cover (Section 6.1.4 and 7.1 of Previous HIA):

- Toe grouting shall be applied to lengthen the effective flow path of groundwater from outside and thus control the amount of water inflow to the excavation.

- Recharge wells shall be installed as necessary outside the excavation to pump water obtained from the excavation back into the ground.

- Groundwater monitoring during pre-construction and construction stage

Drill and Blast (Section 6.1.3 and 7.1 of Previous HIA):

- An observational method is to be adopted to monitor the effects to the groundwater table to determine the need for further grouting works locally . Transmissive features are anticipated and grouting will be required to seal such features prior to the tunnel excavation intersecting them.

- Pre-excavation probing at locations where any highly transmissive features are anticipated will be required. Post grouting will be undertaken as necessary before the lining is constructed.

Bored tunneling method (Section 6.1.2 and 7.1 of Previous HIA):

- The use of TBM construction method and the selection of an impermeable "undrained" tunnel lining should preclude groundwater inflow into the tunnels. No potential water drawdown is anticipated and groundwater monitoring were identified in the previous HIA report.

**3. Summary of the findings of the updated HIA**

a) Bored tunneling method (TBM) (Chapter 5 of the updated HIA report for Tunnel (North))

The potential impact to groundwater drawdown due to TBM operation in Northern tunnel sections (Tai Kong Po to Tse Uk Tsuen Tunnels, Mai Po to Ngau Tam Mei Tunnels and Border to Mai Po Tunnels) were covered in the updated HIA report. As the hydrostatic pressure is effectively supported by the pressure maintained in front of the TBM head, only insignificant impact was identified due to TBM operation. The un-drained design of TBM lining would not cause any groundwater drawdown after installation of lining. The assessment result is in line with the previous HIA report that no significant groundwater impact would arise due to TBM operation. Based on the assessment result, no specific mitigation measure would be required. Groundwater monitoring with respective Alert-Action-Alarm (AAA) values for contingency actions was recommended during TBM tunneling.

b) Drill and Blast tunneling method (Updated HIA report for Works Contract 821 and 822, Chapter 8 of the updated HIA for Tunnel (North),

Hydrogeological numerical model (SEEP/W) was conducted to analysis the groundwater inflow during construction of D&B tunnel from Pat Heung to Shek Yam.

The modeling results revealed the limited groundwater flow within the bedrock, where the tunnel is situated, is independent from the high groundwater flow within the high permeability superficial groundwater system. The assessment concluded that impact to near surface groundwater table due to D&B tunnel excavation within rock would be insignificant which agrees with the findings in the previous HIA.

The same model was conducted for D&B tunnel in Kwai Chung North to assess the potential drawdown of the water table above rockhead level due to tunnel excavation. Maximum groundwater drawdown of only 1.5m within the superficial deposits was identified in the report.

For D&B tunnel from Ngau Tam Mei to Tai Kong Po, semi-empirical and numerical estimation on inflow were conducted from which the inflow control criteria for pre-excavation and post-excavation were derived. No significant hydrogeological impact was identified in the updated HIA report with the implementation of mitigation measures.

The following mitigation measures were proposed for the D&B tunneling work in the updated HIA report:

-Comprehensive groundwater monitoring programme for baseline and construction period
-Pre-excavation probing, pre-excavation and post-excavation grouting using the specified inflow criteria in the Report

c) Cut-and-Cover tunnel and shaft (Chapter 6&7 of the updated HIA for Tunnel (North)

Quantitative groundwater drawdown assessment (PLAXIS) was conducted for the shaft excavation (Mai Po Ventilation Shaft, Ngau Tam Mei Ventilation Shaft, Tai Kong Po Emergency Access Point and Tse Uk Tsuen Works Shaft). Groundwater drawdown immediately behind the D-wall in various degrees was identified in the assessment. Nonetheless, it was identified in Chapter 7 of the updated HIA report that the excavations for the shaft will only require temporary dewatering during their construction and any groundwater drawdown would typically be limited to 2m within the site area. The drawdown is temporary as in long term the box is sealed and groundwater level will recover with full hydrostatic head outside. The findings in updated HIA agrees with the findings of Previous HIA.

Regarding the possible long term damming effect due to the construction of the impermeable cut & cover box, a 3D MODFLOW groundwater model has been developed to assess the impact of groundwater regime in the Shek Kong area. With the D-Wall in place and ground level of the SSS adjusted to its final formation level, groundwater levels are found to be not significantly impacted.

The following mitigation measures were proposed for the C&C tunneling work in the updated HIA report:

- Toe grouting shall be implemented to control the amount of water inflow to the excavation.
- Recharge wells shall be installed as necessary outside the excavation to pump water obtained from the excavation back into the ground.
- Subsequent to the completion of diaphragm wall construction and toe grouting and prior to the commencement of excavation work, a full scale pumping test will be undertaken to verify the water cut-off effectiveness and the effects of dewatering on adjacent structures.

**4. Potential ecological impact**

With reference to Chapter 3 of the EIA report, potential drawdown in groundwater table could result in dewatering of surface water features which could result in potential ecological impact. Based on the assessment result of the updated HIA reported, the potential risk of groundwater drawdown is similar to that identified in the previous HIA, with the implementation of the above-mentioned groundwater monitoring and mitigation measures. In view of the findings from the updated HIA report, it is concluded that the ecological impact due to groundwater drawdown identified in the EIA report is valid with no adverse ecological impact.

**5. Conclusions**

The potential hydrogeological impact of various tunnel/shaft construction methods were assessed in the updated HIA report. The quantitative hydrogeological impact assessment result in the updated HIA report generally agrees with the findings of previous HIA report with no significant impact to the groundwater table anticipated, provided that the groundwater monitoring and mitigation measures proposed for various tunnel/shaft construction methods in the updated HIA report are properly implemented at the construction stage. Based on the review of previous and updated HIA, the conclusion identified in the EIA report that there is no adverse ecological impact due to groundwater drawdown is still valid.

# Express Rail Link

# Consultancy Agreement No. C802

# Detailed Design for Tunnels and Associated Structures (South)

## Works Contract 822 – Tai Mo Shan Tunnel

## Hydrogeological Impact Assessment

ATKINS

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Appendix A XRL Works Contract 822 – Draft Particular Specification for WSD Interfaces
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## ABBREVIATIONS

| | |
|---|---|
| ARUP | Ove Arup & Partners HK Ltd |
| ATK | Atkins China Ltd |
| BD | Buildings Department |
| CCT | Cut and Cover Tunnel |
| CCTV | Closed circuit Television |
| CEDD | Civil Engineering and Development Department |
| CLPP | China Light and Power |
| DSD | Drainage Services Department |
| DSM | MTRCL Design Standard Manual |
| EAP | Emergency Access Point |
| EBS | Existing Building Structure |
| EEP | Emergency Evacuation Point |
| EIA | Environmental Impact Assessment |
| EIAO | Environmental Impact Assessment Ordinance |
| EPBM | Earth Pressure Balance Machine |
| ERS | Emergency Rescue Siding |
| EVA | Emergency Vehicular Access |
| FUT | Futian Station |
| GEO | Geotechnical Engineering Office |
| GIU | Geotechnical Information Unit |
| GSM-R | Global System for Mobile - Radio |
| HGV | Huang Gang Park Ventilation Building (VB0) |
| HKSAR | Hong Kong Special Administrative Region |
| HTW | Hoi Ting Road Works Area |
| HV | High Voltage |
| HyD | Highways Department |
| ID | Inner diameter |
| KCV | Kwai Chung Ventilation Building (VB6) |
| KSL | Kowloon Southern Link |
| KTW | Kam Tin Road Works Area |
| LKM | Lam Kam Road Magazine |
| LV | Low Voltage |
| MD | Marine Department |

| | |
|---|---|
| MKV | Mong Kok West Ventilation Building (VB8) |
| MLW | Mei Lai Road Works Area |
| MPV | Mai Po Ventilation Building (VB1) |
| MTRCL | MTR Corporation Limited |
| NAC | Nam Cheong Station |
| NB | North Bound Track |
| NCB | Nam Cheong Barge Point |
| NCO | Noise control Ordinance |
| NCV | Nam Cheong Ventilation Building (VB7) |
| NPW | Nam Cheong Park Works Area |
| NSR | Noise Sensitive Receivers |
| NTV | Ngau Tam Mei Ventilation Building (VB2) |
| NWDSM | New Works Design Standard Manual |
| OD | Outer Diameter |
| OHL | Overhead Lines |
| PA | Public Announcement |
| PHV | Pat Heung Ventilation Building (VB4) |
| PLA | Peoples Liberation Army |
| PPFS | Preliminary Project Feasibility Study |
| PTI | Public Transport Interchange |
| RC | Reinforced Concrete |
| RCB | Rambler Channel Barge Point |
| RDO | Railway Development Office |
| RMB | Running Maintenance Building |
| SB | South Bound Track |
| SKM | So Kwun Wat Magazine |
| SLB | Siu Lam Barge Point |
| SMR | Sham Mong Road |
| SMV | Shing Mun Ventilation Building (VB5) |
| SYW | Shek Yam Works Area |
| TBM | Tunnel Boring Machine |
| TCL | Tung Chung Line |
| TSSC | Trackside Safety and Security Committee |
| TKT | Tai Kok Tsui |
| TMB | Tuen Mun Barge Point |

| | |
|---|---|
| TPV | Tai Kong Po Ventilation Building (VB3) |
| TUW | Tse Uk Tsuen Works Area |
| TVS | Tunnel Ventilation System |
| TWL | Tsuen Wan Line |
| UIC | International Union of Railways |
| UPVC | Unplasticised Polyvinyl Chloride |
| URA | Urban Redevelopment Authority |
| VB | Ventilation Building |
| VSR | Visually Sensitive Receivers |
| WKT | West Kowloon Terminus |
| WR | West Rail Line |
| WSD | Water Supplies Department |
| XRL | Express Rail Link |
| 4DI | Fourth Survey and Design Institute |

## EXECUTIVE SUMMARY

This Hydrogeological Impact Assessment (HIA) Report studies the hydrogeological impact of the tunnelling works on the Tai Mo Shan area for the potential receptors in the vicinity of the XRL tunnels under Works Contract of 822. Particular reference is made to interfaces with WSD facilities.

The proposed XRL Tai Mo Shan Tunnels pass 800m to the west of the Shing Mun Reservoir Catchment and 1000m to the west of the reservoir itself. The alignment passes at depth (typically 100 to 600m) below an indirect catchment (S10.3) which flows towards the south into the Shing Mun Reservoir Catchwater. The alignment also passes under the Tai Mo Shan Catchwater Tunnel with a vertical separation of 67m. The proposed tunnels are drained, pressure relieved tunnels.

A detailed hydrogeological assessment is presented which includes calculations and numerical modelling using the software SEEP/W.

Significant reference is made in the report to the West Rail Tai Lam Tunnel. This tunnel was constructed on a parallel alignment through similar geology and with similar interfaces with WSD interfaces (except that the tunnel passed directly beneath the Ho Pui Reservoir). The Tai Lam Tunnel was also designed and constructed as a pressure relieved tunnel. The tunnel was excavated adopting inflow control criteria agreed with WSD and the water inflows were successfully limited to below the criteria by grouting. This is demonstrated by presentation of construction records and records of inflows to the permanent works.

The yields of the impounding reservoirs in Hong Kong come almost entirely from surface runoff. A small amount will come from groundwater, although the catchwaters that gather from the indirect catchments are not specifically designed to collect groundwater.

The hydrogeological modelling demonstrates that the tunnel is located within low permeability bedrock at depth, and which is 100 to 2000 times less permeable than the near surface superficial material. The modelling demonstrates that flow within the near surface deposits (a very small percentage of which may contribute to the reservoir yield) is unaffected by excavation of the tunnel at depth. The models show no discernable impact on the water table, during the wet or dry season. The models also show that the location of spring lines would not be impacted and therefore related habitats would be similarly unaffected.

The report assesses the impact of more permeable geological features located within the low permeability rock mass at depth on the predicted tunnel inflows. The frequency of these features is assessed from the alignment geological model and with detailed reference to the construction records of the Tai Lam Tunnel, where such features were successfully grouted. An outline specification is included in the report which defines criteria that will be used to locate such features ahead of the face and treat them if inflows from probeholes exceed the specified criteria.

The proposed criteria are more stringent than those applied to the Tai Lam Tunnel and they will be applied to the full tunnel alignment, which was not the case for Tai Lam Tunnel.

The adoption of tighter inflow control criteria is for several reasons, but primarily to ensure that the features are identified and treated ahead of the excavation, reducing the risk of difficult post excavation grouting that could impact the project programme.

# 1. INTRODUCTION

## 1.1 Scope and Purpose of this Report

This report assesses the hydrogeological setting for the Tai Mo Shan Tunnel, which is to be constructed as part of the proposed Express Rail Link, under works contract 822.

The report reviews the hydrogeological setting, possible impacts of the proposed tunnel design concept on WSD facilities and outlines the proposed engineering mitigation measures that will be imposed on construction.

The aim of the report is to establish a basis for Water Services Department to agree in principle to the proposed construction concepts.

## 1.2 Project Background

The Railway Development Strategy 2000 (RDS-2000) identified the Regional Express Line as one of the future rail corridors required to meet anticipated transport demand in the HKSAR. In November 2004 Government invited KCR to study the viability of this rail link; in July 2005, following the conclusion of their study KCR submitted its report on the matter, the Express Rail Link (ERL) Study Report.

The 2005 ERL study report examined the Hong Kong section of the proposed Hong Kong Guangzhou Express Rail Link, a variant to the ERL envisaged in RDS-2000. The ERL study established that the terminus of the Express Rail Link should be located at West Kowloon and that options existed for either a dedicated rail corridor or a shared use corridor that utilized existing / proposed KCR lines, namely West Rail and the Kowloon Southern Link.

In February 2006 KCR were invited to proceed with further planning of ERL; the study brief required examination of shared and dedicated corridor options and also the accommodation of changes in planning requirements within the Mainland to provide for an additional ERL station near Yitian Road Futian Station (FUT), in Shenzhen's Futian District and of the proposed Pearl River Delta Rapid Transit System that was being studied in the Mainland.

In November 2006 KCR appointed consultant to carry out a project feasibility study for ERL; the final report was issued in September 2007. This study concluded that although the shared corridor option was viable in the short term the anticipated demand for cross boundary travel would be such that the shared route would be unable to meet demand in the longer term; consequently, the report recommended that the dedicated option be taken forward.

In May 2008, Arup-Atkins JV was appointed by MTRCL to carry out the preliminary design for the ERL tunnels (hereafter renamed as XRL) and associated structures from Mai Po to West Kowloon under Consultancy Agreement NEX/2102.

ATK was appointed as the design Consultant to MTRCL on Express Rail Link Detailed Design Consultancy Agreement No.C802 – XRL Tunnels and Associated Structures (South) on 16 January 2009.

## 1.3 Project Overview

The Guangzhou-Shenzhen-Hong Kong Express Rail Link is a committed cross Boundary transport infrastructure project, which will provide high speed rail services between Hong Kong and Guangzhou, and a connection to the national high-speed passenger rail network serving major mainland cities outside of Guangdong province. This network, which will comprise some 12,000 km, is now under construction in the Mainland. It is understood that the section from Guangzhou to Shenzhen (Futian) will commence operation in 2010. The Hong Kong section of the Guangzhou-Shenzhen-Hong Kong Passenger Line is scheduled for urgent implementation following the announcement by the Chief Executive of the HKSAR in the 2007-08 Policy Address.

The XRL, measuring about 26 km from West Kowloon to the Boundary, will use a dedicated railway corridor to ensure that a high line capacity can be achieved and to ensure operational compatibility with the Mainland. The line will be within tunnels to be constructed by a combination of drill-and-blast, mined using tunnel boring machines and cut-and-cover techniques. Seven access shafts and seven construction adits have been identified along the route to facilitate construction. In total there will be eight ventilation buildings at approximately 5km centres, located at Mai Po, Ngau Tam Mei, Tai Kong Po, Pat Heung, Shing Mun, Kwai Chung, Nam Cheong and Mong Kok West respectively. The ventilation buildings will also be utilised as EAP for the emergency services. For the detailed design the tunnels have been divided into two packages: northern and southern package based on a split on the south side of the Kam Tin Valley. The southern package will consist of some 15km of running tunnel, four ventilation buildings and all the necessary construction access and support facilities.

The C802 consultancy agreement comprises the design of running tunnels from north of the WKT to the PHV, including associated structures enabling, such as ventilation buildings shafts/adits, roadworks, drainage and the necessary works. The Project is divided into five works contract packages, comprised of two initial works packages, 802 – Nam Cheong Property Foundations and 805 – Sham Mong Road Obstruction Removal, and three tunnelling works packages, 822 – Pat Heung to Shek Yam (Tai Mo Shan Tunnels), 821 – Shek Yam to Mei Lei Road (Kwai Chung Tunnels) and 820 – Mei Lai Road to Hoi Ting Road (Kowloon Tunnels).

## 1.4 Alignment Description – 822 Pat Heung to Shek Yam (Tai Mo Shan Tunnel)

The project comprises approximately 26km of tunnel from the Huang Gang Ventilation Shaft (HGV) north of the Boundary between the Shenzhen Special Economic Zone (SEZ) and the Hong Kong Special Administrative Region to a new terminus station in West Kowloon.

The southern section of the alignment commences from a shaft constructed on the northern flanks of Tai Mo Shan. A few hundred meters to the north of the shaft are various connections with adits from the Pat Heung Ventilation Building which is sited to the east of Tse Uk Tsuen and some distance from the alignment.

The alignment thereafter continues beneath the natural terrain of Tai Mo Shan (Elevation +957mPD) for some 7km, after which it passes beneath the western end of the Shing Mun Valley. The single twin track tunnel in this section is formed using drill and blast techniques. The Shing Mun Ventilation Building, approximately 50m to the west of the drill and blast running tunnels, is sited at an elevation of approximate +98mPD; here the ventilation connection will be via a deep vertical shaft and a short section of adit, both formed using drill and blast construction.

At Shek Yam, a temporary construction adit will provide access from the works area to the drill and blast running tunnels immediately to the west of the site. The contract boundary with the C821 - Shek Yam to Mei Lei Road (Kwai Chung Tunnels) contract to the west will be close to the connection with the construction adit. At this location cover to ground level is greater than 80m.

To the south the alignment proceeds with the adjacent C821 contract, below the heavily urbanized and industrialized environment of Kwai Chung, where it follows the Castle Peak Road highway corridor.

This report considers only the Tai Mo Shan drill and blast tunnel, which is shown on Figure 1 and the interfaces with WSD facilities are shown on Figure 2.

## 1.5 Previous Hydrogeological Studies

A HIA Report comprising one of the suite of Geotechnical Report submissions required under the scope of the consultancy agreement for the Express Rail Link — Preliminary Design Service of XRL Tunnels and Associated Structures (Consultancy Agreement NEX/2102) was submitted in December 2008.

The other reports within the suite are the Geotechnical Engineering Report (GER), Ground Movements Report (GMR), Geotechnical Instrumentation Report (GIR), Site Impact Assessment Report (SIAR), Natural Terrain Hazard Study Report (NTHSR), Structural Appraisal Report (SAR) and Blasting Assessment Report (BAR).

The main objective of the Preliminary Design HIA was to review the hydrogeological conditions along the entire alignment of the proposed XRL project, specifically the definition of the existing groundwater and hydrological systems and provide recommendations for further studies to be carried out following the completion of additional investigation and monitoring works.

## 1.6 Proposed Construction Concept for Tai Mo Shan Tunnel

The selected design concept for the Tai Mo Shan Tunnel is a pressure relieved tunnel, whereby the groundwater pressure on to the final lining is relieved by allowing limited drainage to the tunnel invert, which is taken via the tunnel drainage system to a sump situated at a low point, from where it is discharged.

The design is therefore a balance between ensuring pressure relief whilst limiting inflows into the permanent tunnel to acceptable levels.

WSD have raised concern that inflows might by sufficiently large so as to impact on their reservoir catchment system, beneath which the alignment passes.

So called drained tunnels (i.e. pressure relieved) have been commonly used in Hong Kong for large span tunnels in high cover settings, as they are often the only economically viable option. This option was previously selected for the West Rail Tai Lam Tunnel, which runs parallel to the proposed XRL alignment, some 3 kilometres to the west, and was also used for the recently completed Eagles Nest Highway Tunnel.

The Tai Mo Shan Tunnel is similar to the existing West Rail Tai Lam Tunnel, passing through similar geology (subject to confirmation), but passing under higher cover and therefore anticipated to encounter higher piezometric heads thus making the adoption of an undrained tunnel system impractical.

# 2. PRECEDENT

## 2.1 Inflow to Tunnel Excavations in Rock

Historical examples of groundwater inflows which have forced long delays or even abandonment of tunnels are numerous and many are well known. As a single instance from the 19th Century, completion of the 6.5km long Severn Railway Tunnel was delayed for several years by 'The Great Spring' which represented extremely localised inflow over a 3-4m length beneath the land, whereas the tunnel had been successfully driven beneath the estuary of the River Severn. Pumped inflows which continue today range between 470 and 1260 l/s from this short length in a conglomerate. Other examples include CERN (1991) Storebaelt (1991). The Saurdal-Sandsetu tunnel experienced 830 l/s.

There is also experience in Hong Kong, notably SSDS, where high inflows were experienced that could not be adequately controlled with the available equipment, in this case in three of five subsea tunnels.

However for the majority of tunnels in Hong Kong only limited inflows were encountered over long lengths of the excavations, due to the generally low hydraulic conductivity of the rock mass. Data available from four relatively recently completed MTRC tunnels illustrates the typical variation of conditions encountered. These are summarised in the Table below:

Table 2.1 : Summary of Recorded Inflows into Recent MTR Tunnels

| Tunnel Project | Length of Drained Tunnel | Final Groundwater inflows | |
|---|---|---|---|
| | | $m^3$/day | l/min/m |
| Pak Shing Kok | 1178 | 298.5 | 0.2 |
| Tai Yam Teng Tunnel | 716 | 105.2 | 0.1 |
| Black Hill Tunnels | 1650 | 68 | 0.03 |
| Quarry Bay Congestion Relief Works | 1800 | 6.2 | 0.002 |

Pak Shing Kok encountered high inflows in a series of adjacent bifurcation caverns located with shallow cover and beneath a river with a base flow that historically was maintained throughout the year. No grouting was carried out during excavation of the tunnels, although grouting was undertaken after completion of the final lining to lower the inflows in to the permanent works. Throughout the rest of the tunnel only localised minor inflows and seepages were observed, but again no systemic probing and grouting was undertaken. Despite this the total final inflows are relatively small, equating to 0.2l/min/m. For tunnels that have not encountered high localised inflows, such as those within the granitic rock mass encountered at Quarry Bay Extension, the final inflows were very low.

Similar precedent experience can be seen from Singapore where military caverns in the massive granite pluton were dry whereas nearby sewerage tunnels suffered inflows within the more weathered rock closer to surface.

The same was true of the storm water storage cavern on Jersey, which was substantially dry whereas the tunnels conveying stormwater encountered inflow problems.

Several already constructed drained tunnels in Hong Kong pass close to major WSD impounding reservoirs, much closer than the proposed XRL alignment. The Shing Mun Highway tunnel is one example. Also the recently completed Eagles Nest Tunnel was constructed below and parallel to the Kowloon Reservoir, and within the margins of the Tolo Fault. The tunnel was designed and constructed as a drained tunnel and it is understood that the final inflow criteria have been met by successfully grouting limited lengths of tunnel. The West Rail Tai Lam Tunnel passed directly below the Ho Pui Reservoir, but inflows were successfully reduced to inflow levels agreed in advance with WSD. Further details on the Tai Lam Tunnel are provided in the following section of this report.

Examples from other projects in Hong Kong are summarised in the overleaf table:

Table 2.2 : Summary Table of HK Tunnel Projects

| Tunnel Project | Length (km) | Geological Terrain | Excavation Method | Water Inflow Issues | Ground Treatment |
|---|---|---|---|---|---|
| MTRC - MIS, TWE, ISL | 28.0 | Granite | Drill & Blast | Generally none to minor even adjacent to reclamation areas at 150-300m from sea; except at one location at North Point where a fracture zone connecting the tunnels to the sea gave very large water inflows. | Extensive ground treatment employed at North Point tunnels. |
| WSD Western Aqueducts Low Wu to Tai Lam Chung | 19.0 | Granite, Granodiorities, Sedimentary, volcanics | Drill & Blast | Generally none to minor, excepting one notable high inflow zone in a large shear zone in volcanic rocks. | Post grouting carried out with variable success. |
| WSD Western Aqueducts Tsing Tam to Yau Kom Tau (nearby open reservoir) | 5.0 | Granite Granodiorities, Sedimentary, volcanics | Drill & Blast | Generally none to moderate except at locations where large water inflows occurred in areas of high overburden cover where fracture zones or open joints connected the tunnels with a local reservoir. | -- |
| WSD Pak Kong to Junk Bay | 6.0 | Granite, volcanics | Drill & Blast | Generally none to minor but very high initial inflows (60 l/s) at granite/volcanics interface, with an inflow reduction factor of 50%. | Extensive post grouting at granite/volcanic interface with little success. |
| WSD Lantau Aqueduct | 7.0 | Granite with Rhyolite Dyke Swarm | TBM, Open Type | Several zones of initially large water inflows occurred at open joints giving a cumulative outflow from the tunnel of 40 l/s reducing with time. | -- |
| Hong Kong Cable Tunnel (Bowen Road to Wah Fu) | 3.1 | Volcanics | Drill & Blast | None to minor. Total flows about 1 l/s. | -- |
| Hong Kong Electric Cable Tunnel (Nam Fung Road to Parker) (nearby reservoir) | 5.5 | Granite | TBM, Open Type | High initial water inflows (up to 40 l/s) where fracture zones or open joints connected the tunnel with Tai Tam Reservoir, and feeder valleys. | Extensive post grouting to suppress water inflows. Process involved 'chasing' inflows into adjacent sections of tunnel. |
| Hong Kong University Sewerage Tunnel | 1.5 | Volcanics | Drill & Blast | Generally none to minor. High water inflow (47 l/s) at fracture zone reducing by 50% in one month and by 80% ultimately. | -- |

| Tunnel Project | Length (km) | Geological Terrain | Excavation Method | Water Inflow Issues | Ground Treatment |
|---|---|---|---|---|---|
| Hong Kong Gas (Braemar Hill) | 2.6 | Granite | TBM, Open Type | None to minor. | -- |
| Tolo Effluent Export Scheme | 7.5 | Granite, Granodiorities | TBM, Double Shielded | Generally none to minor with infrequent high initial inflows (cumulating to 40 l/s) at fracture zones or open joints. | -- |
| Route 3 - Cheung Ching Tunnels | 1.5 | Volcanics/ Granite | Drill & Blast | None to minor. | -- |
| Tate's Cairn Tunnel | 4.8 | Granite | Drill & Blast | Generally none to minor. Total flows at portals about 8 l/s during construction. | -- |
| Castle Peak NWNT Sewerage Project | 9.0 | Granite | Drill & Blast | Generally none to minor. | -- |
| DSD-SSDS Outfall (Subaqueous) | 1.5 | Granite | TBM, Open Type | Generally minor to moderate inflows. | Much grouting prior to and subsequent to tunnel lining erection. |
| DSD-SSDS Contracts 13 & 14 (Subaqueous) | 2.4 (21.6 remaining) | Mainly granite, some volcanics | 5 No. TBMs Open Type | Large inflows on 3 out of 5 no. drives where fracture zones or open joints connect tunnels with sea. Inflows of 17-25 l/s recorded at some localities with little effective reduction with time. | Extensive post grouting to meet high watertightness specification. |

## 2.2 Analysis of West Rail Tai Lam Tunnel (DB350)

### 2.2.1 Overview

The West Rail Tai Lam Tunnel passes through the Country Park parallel to the proposed XRL alignment, but some 3 to 4km to the south and west. The Tai Lam Tunnel passes through similar geological conditions as expected to be encountered by XRL, including the same major fault zones (Sham Tseng Fault in particular) and a similar proportion of principal lithologies (granitic and volcanic rock types). The reason for the similarity and hence the relevance of the Tai Lam Tunnel data to the Tai Mo Shan Tunnel is the dominant north east striking trend of the major regional geological structure and lithological boundaries, which thus broadly extrapolate between the two alignments. This is illustrated on Figure 3.

The Tai Lam Tunnel was constructed as a single twin track excavation by drill and blast and was designed as a pressure relieved drained tunnel, the same concept as the proposed Tai Mo Shan Tunnel. Construction records for the tunnel are available that record data on the ground conditions encountered and the water inflows recorded. The Tunnel was completed in 2001 and data is available on water inflows into the permanently lined tunnel, recorded at the tunnel sump.

### 2.2.2 Groundwater Inflow Control – Specification

The Tai Lam Tunnel passes close (24m) beneath WSD Water Tunnel No. 3, beneath Catchwater No. 10, directly below Ho Pui Reservoir and a further catchwater close to the northern portal. During the preliminary design there were discussions with WSD on the interfaces including a presentation to the Director, on both blasting impacts and also on water inflow control. Following this a specification was developed, to the approval of WSD, that included the following controls :

- 20 litres /minute through any probe hole ahead of tunnel face
- 50 litres/minute at the tunnel face and within 25 meters of the face over any 50 meters length of tunnel

Notes :

1. The 50 litres/minute criteria equates to 2 litres/minute/metre
2. These criteria were relaxed during construction after further discussion with WSD

The specification imposed these constraints in WSD Drainage Mitigation Zones, defined as 170m either side of Ho Pui Reservoir and 60m either side (measured horizontally) of WSD water tunnels and catchwaters.

If water inflows greater than 20 litres / minute were encountered in a probe hole grouting ahead of the tunnel excavation face (pre-excavation grouting) was to be undertaken.

Elsewhere the final inflows had to comply with a final tunnel inflow of less than 0.55 l/min/m.

### 2.2.3 Encountered Conditions

The inflows encountered by probe holes drilled ahead of the face were recorded throughout the tunnel length and are shown on the as built records.

A summary of these records is illustrated on Figures 4 and 5 for the north and south halves of the tunnel respectively[1].

The key features of the inflows were as follows :

- Inflows from probeholes drilled ahead of the excavation were typically associated with specific discrete, transmissive, geological structures, that were subsequently encountered by the excavation and are recorded on the geological records.
- The discrete transmissive structures tended to cross cut the alignment at a high angle particularly in the northern half of the tunnel, consistent with main geological structural trend[2].
- Inflows from probeholes associated with the discrete structure tended to reduce significantly with time (often reducing to low values within an hour), These are illustrated in Figure 6.
- Some sustained inflows were encountered. For example associated with the Sham Tseng Fault (approximately 350 l/min) were not recorded to reduce with time, but where subsequently treated via grouting.

The majority of the inflows were less than 20l/min (although many of the measurements were qualitative (slight, moderate and high) and actual values in l/min have been inferred.

### 2.2.4 Grouting

Grouting was undertaken according to the specification at the WSD interface zones and also at fault structures (including the Sham Tseng Fault) to reduce sustained high inflows encountered there.

The extent of grouting undertaken is shown in Figure 4 and these are also summarised in more detail in Table 2.5.

According to the as constructed records only limited grouting was undertaken over an estimated length of between 2% and 5% of the alignment depending on assumptions of the thickness of the geological structures grouted.

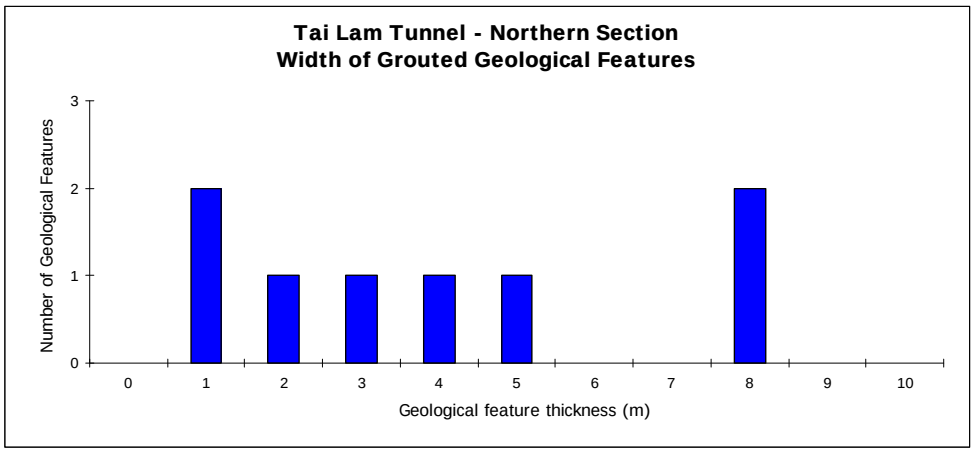
Grouting was undertaken only in the northern section of the alignment, at locations of higher inflow beneath Ho Pui Reservoir amounting to a conservative total of 90m (1.6% of the alignment) and at the Sham Tseng and other faults (187m, 3.35% of the alignment).

[1] The records used both qualitative and quantitative terms to describe the inflows. Figures 4 and 5 show an assumed inflow for the qualitative description, based on the average inflow of those that have both qualitative and quantitative values.

2 Structures parallel to the tunnel excavation are much more problematical to treat via grouting to reduce inflows.

From a more detailed assessment of the records and as summarised in Table 2.5 it is evident that the higher inflows were actually associated with relatively narrow features and inflow did not occur throughout the broader zones as described in the summary records. Assessment of the length of broad zones therefore needs to be compared with the length (cumulative width) of the transmissive features, which represent a more realistic assessment of grout requirements.

Volumes of grout required to reduce the inflows to acceptable amounts would relate to the width and nature of these 'narrow' features, which are shown in the Figure below :




The location of the discrete transmissive features, associated with each of the broader zones is shown in Figure 5.

For two zones (one of which was the Sham Tseng Fault, the second an un named fault structure) the close spacing of transmissive structure required a zone of grouting up to 8m in width. The photograph below illustrates the Tai Lam Tunnel at the Sham Tseng Fault, the peripheral grout tubes can be seen.




A summary of the inflow zones and associated discrete features are summarised in the following tables 2.3 and 2.4 :

Table 2.3 : Tai Lam Tunnel – Estimate of Grouting Extent Undertaken Based on Width of Zones of Higher Flow

| Zone of Tunnel where grouting was undertaken | Number of Zones | Total Tunnel Length (m) | % of tunnel length |
|---|---|---|---|
| Total tunnel length intersected by zones described as having enhanced inflow.<br><br>(all in the northern half of the tunnel alignment) | 10 | 191 | 3.5 |

Table 2.4 : Tai Lam Tunnel – Estimate of Grouting Extent Undertaken Based on Width of Geological Structures Within Higher Flow Zones

| Zone of Tunnel where grouting was undertaken | Number of Features | Total Width of Features (m) | % of tunnel length |
|---|---|---|---|
| Total tunnel length intersected by Discrete Transmissive Features within zones described as having enhanced flow. | 12 | 30 | 0.5 |

These tables indicate that approximately 15% of the length of the broad zones of inflow associated with geological structure required grouting to reduce inflows to within acceptable levels.

The records also give an indication of the reduction of inflow as a result of the pre excavation grouting of each of the transmissive features. The inflows recorded from the face and sidewall after excavation are listed in Table 2.5. This indicates an average initial sustained inflow from the probe holes that intersected transmissive structures to be 400 l/min (100 to 800 l/min). These flows reduced to a typical average of less than 20 l/min (0 to 40 l/min), with only one feature with a high residual flow of 150 l/min.

The duration of the grouting works required to achieve these final inflows was in some cases significant. For example between Chainage 1465 and 1488 an initial inflow of 350 l/min was encountered. Grouting at this Chainage was undertaken over a 12 day period and succeeded in reducing the inflow to 50l/min (i.e. 2.1 l/min/m).

Table 2.5 : West Rail – Tai Lam Tunnel Schedule of Grouted Features and Associated Geological Structures

| Tai Lam Tunnel - Northern Section (CH1000 - CH3955) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone Grouted | | | Geological Features Encountered | | | | |
| Chainage to (m) | Chainage from (m) | Length (m) | Number | Width (m) | Recorded Initial Inflow (l/min) | Recorded Reduced Inflow (l/min) | Description |
| 1465 | 1488 | 23 | ? | ? | 350 | 50 | Records do not show any significant geological features at this chainage. Zone grouted over 12 days. |
| 1514 | 1574 | 60 | 2 | 0.4 | 260 | 150 | Feature 1: 400mm wide subvertical shear zone comprising disintegrated rock with some mineralization. Dip / dip direction 85/005. |
| | | | | 8 | 800 | 0 | Feature 2: 6 - 8m wide faulted zone comprising grey and pink granite with widely to very closely spaced ('sugar cubed') slickensided and smooth planar joints. Internal 250 - 750mm thick zone of fault gouge. Noted that no water inflow observed. Dip / dip direction 80/166. |
| 1777 | 1788 | 11 | 0 | | 400 | 0 | Records do not show any significant geological features at this chainage. Grouting undertaken from probehole at CH1729 prior to excavation through zone. |
| 1925 | 1937 | 12 | 1 | 1.5 | 240 | 10 | 1.0 - 1.5m wide sub-vertical fault zone comprising light grey fault gouge, sub-angular tuff gravel breccia and highly fracture in-situ tuff. Dip / dip direction 84/168. |
| 1937 | 1954 | 17 | 1 | 3 | 400 | 20 | 2.0 - 3.0m wide steeply inclined fault zone comprising fault gouge, breccia and highly fractured tuff. Moderate water inflow (20 l/min) with occasional material outwash observed. Dip / dip direction 78/181) |
| 1994 | 2002 | 8 | 1 | 4 | 400 | 40 | 2.0 - 4.0m wide sub-vertical shear zone comprising tuff with closely spaced slickensided, undulating and planar joints generally tightly healed with calcite. Dip / dip direction 85/160. |
| 2144 | 2148 | 4 | 0 | | 300 | Moderate | Records do not show any significant geological features at this chainage. Grouting undertaken from probehole at CH2114 prior to excavation through zone. |
| 2174 | 2183 | 9 | 1 | 0.5 | 800 | 10 | 500mm wide minor subevertical shear zone comprising brecciated tuff with abundant calcite mineralisation. Dip / dip direction 69/204. |

| Tai Lam Tunnel - Northern Section (CH1000 - CH3955) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone Grouted | | | Geological Features Encountered | | | | |
| Chainage to (m) | Chainage from (m) | Length (m) | Number | Width (m) | Recorded Initial Inflow (l/min) | Recorded Reduced Inflow (l/min) | Description |
| 3334 | 3370 | 36 | 2 | 5 | 350 | 20 | Feature 1: 0.3 - 5.0m wide sub-vertical fault zone comprising fault breccia with minor sand and clay infill. Dip / dip direction 80/060. |
| | | | | 8 | 20 | 20 | Feature 2: 8.0m wide major fault comprising weak crushed rock with very closely spaced sheared jointing with talc and clay coatings. Dip / dip direction 80/150. |
| 3740 | 3751 | 11 | 3 | 0.2 | 100 | Slight | No feature described in text however the discontinuities sketch shows 3 approximately 45 degree dipping joints directly above grouted zone. |
| Total (m) | | 191 | | 30.6 | | | |
| Section Length (m) | | 2955 | | 2955 | | | |
| % of Tunnel Section | | 6.46 | | 1.04 | | | |
| % of Total Tunnel Alignment | | 3.46 | | 0.56 | | | |

### 2.2.5 Final Long Term Inflows

The tunnel sump for the WR Tai Lam tunnel is installed with 3 pumps, each rated at 45.5 l/s. The sump serves approximately 5 km of the tunnel.

During the period August 2003 to March 2009 (approx 2040 days) , the total running hours of the 3 pumps was 30935 hours (about 15 hours daily). Based on the pump capacity, the discharge rate is about 29l/s.

From previous on-site measurement some years ago, the inflow rate at the sump was measured at between 31 and 38l/s with a typical value of 33 l/s. The inflow rate was constant with only little fluctuation recorded after a rain storm, confirming the conclusions that flow into the tunnels is largely independent of flow in the superficial aquifers. The data is illustrated on Figure 7.

Considering the pump discharge rate would be higher (say by 10~20%) due to lower resistance in the pumping main, when not all 3 pumps are running simultaneously, the two figures compare very well.

Hence with 33 l/s for 5 km tunnel, the inflow rate for the completed Tai Lam tunnel is about 0.0066 l/s per metre of tunnel, or 0.4l/min/m of tunnel. This represents an extremely useful guide to achievable long terms inflows to Tai Mo Shan Tunnel.

## 2.3 General Implications of Precedent for Tai Mo Shan Tunnel

Based upon the large amount of experience of tunnelling within the granitic rock masses in Hong Kong (more than 100 kilometres of tunnel) it is clear that site specific details are very influential on the response of this environment to tunnel excavation and induced flows. The precedent experience suggests the following:

- Generally low to very low inflows are to be expected along much of the tunnel alignment. However inflows vary according to rock mass conditions, cover (stress) weathering state and proximity to recharge sources.
- Encountered inflows associated with specific structures of limited width generally should reduce with time.
- Systematic grouting is not typically required (or undertaken) for long lengths of tunnel excavation.
- Higher, potentially problematical inflows are typically associated with discrete transmissive structure including, faults and dykes. Inflows may not abate with time from these features however they can be pre-grouted successfully.
- HK precedent experience suggests inflows to rock excavations are controllable by drilling and grouting methods when conducted adequately and with appropriate equipment, prior to excavation. With post excavation grouting the desired results prove more difficult to achieve.
- Adequate pre-grouting to tight criteria can impact significantly on the construction programme.

The inflow criteria agreed with WSD for Tai Lam Tunnel were achieved using conventional techniques, but this had significant programme implications at some chainages. Care needs to be taken in selecting inflow criteria for XRL, to ensure they are achievable in terms of methodology, cost and programme.

# 3. DESCRIPTION OF WSD INSTALLATIONS AND SURFACE WATER GATHERING GROUNDS

## 3.1 The proposed Tai Mo Shan Tunnel will interface with the following WSD installations :

- Shing Mun Reservoir indirect catchment (Reference Number S10.3)
- Shing Mun Catchwater
- Tai Lam Chung Reservoir indirect catchment (Reference Number S13.3-11)
- Tai Lam Chung Reservoir Catchwater

The locations of these interfaces are shown on Figure 2.

## 3.2 Shing Mun Catchwater

Shing Mun Catchwater collects surface water from the S10.3 catchment and transfers it to Shing Mun Reservoir to the east.

The catchwater is an open concrete channel at this location and passes above the tunnel alignment with a vertical separation of more than 170m. The interface is shown on Figure 8.

## 3.3 Shing Mun (Jubilee) Reservoir indirect catchment (Reference Number S10.3)

The proposed Tai Mo Shan Tunnel passes at a distance of more than one kilometre to the east of the Shing Mun Reservoir and approximately 800m from the associated surface water catchment. Water is gathered from an adjacent catchment, Number S.10.3 and transferred to the Reservoir via an open channel catchwater, Shing Mun Catchwater.

The proposed Tai Mo Shan Tunnel alignment passes under catchment S.10.3 for a distance of approximately 3.5km. Cover to ground surface within this section varies from 100m to 650m. The interface is shown on Figure 9 and 10.

The West Rail Tai Lam Tunnel passes under this same catchment some 3km to the west.

The area of the S10.3 catchment is 1262.41 ha.

## 3.4 Tai Lam Chung Reservoir indirect catchment (Reference Number S13.3-11)

Further to the north the alignment passes under catchment S15.3-11 for a distance of approximately 2km, with a similar cover to ground level of 100m to 650m.

The surface water from the catchment drains to Tai Lam Cheung Reservoir as shown in Figure 9 and 10.

## 3.5 Tai Lam Chung Reservoir Catchwater

Close to the northern portal the alignment passes beneath the Tai Lam Chung Reservoir Catchwater, with a vertical separation of 170m.

The catchwater is in tunnel at this location, as shown on Figure 11.

# 4. REGIONAL HYDROLOGICAL DATA

Basic hydrological data along the XRL alignment has been obtained from the Geotechnical Engineering Office (GEO), the Hong Kong Observatory (HKO) and the Water Supplies Department (WSD). The data collected includes rainfall records, evaporation records and catchment yield records, each of which are discussed in more detail in the following sections.

## 4.1 Rainfall Records

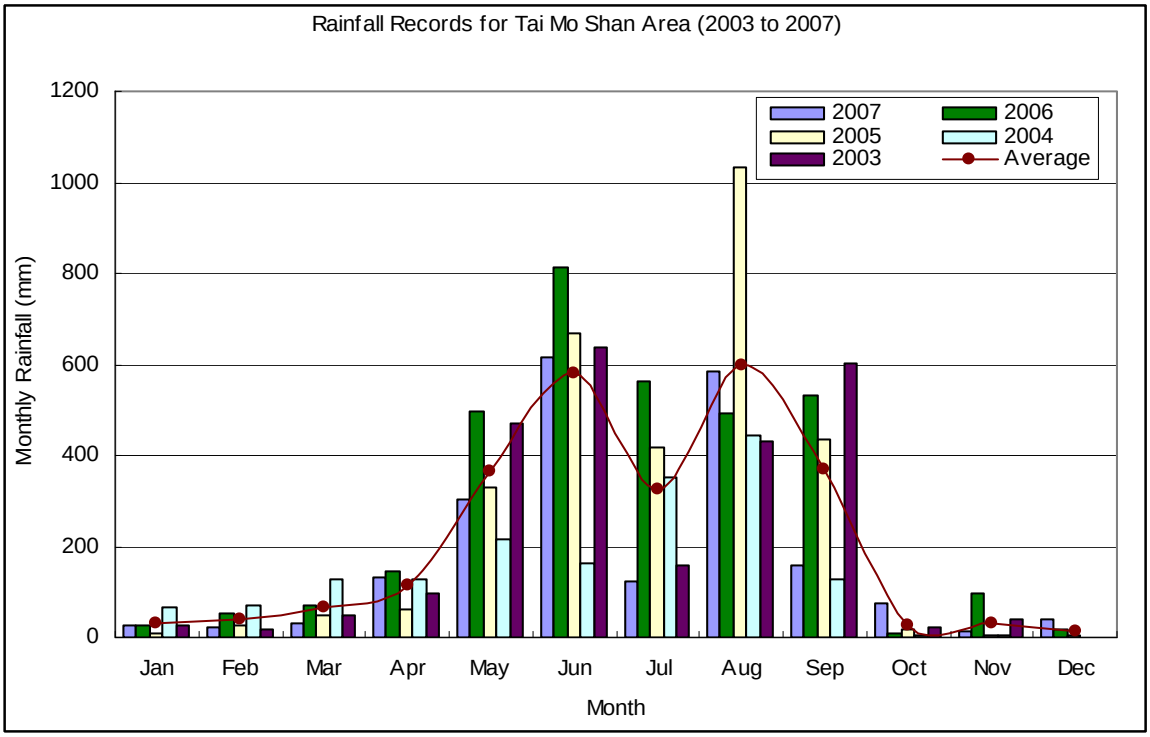
The relevant rainfall data collected includes readings taken at GEO Rain Gauge Nos. N14, N36, N37 & N40, which are located between Kadoorie Agriculture Research Centre in Shek Kong in the north and Shing Mun Country Park Visitor Centre in the south. A summary of the rain gauge locations and monthly monitoring results for the period 2003 to 2007 are provided in the tables below:

Table 4.1 : Rain Gauge Location

| Rain Gauge Number | Rain Gauge Location |
|---|---|
| N14 | Wireless Station, Tai Mo Shan |
| N36 | Kadoorie Agriculture Research Centre, Shek Kong |
| N37 | Twisk Country Park Management Centre, Tsuen Wan |
| N40 | Shing Mun Country Park Visitor Centre, Kwai Chung |

Table 4.2 : Average Rainfall Reading

| Year | Recorded Monthly Rainfall (mm) based on average reading from N14, N36, N37 & N40 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| 2007 | 27 | 21 | 31 | 130 | 303 | 614 | 125 | 585 | 156 | 74 | 15 | 41 |
| 2006 | 25 | 55 | 69 | 146 | 497 | 814 | 564 | 491 | 534 | 8 | 97 | 17 |
| 2005 | 9 | 28 | 49 | 61 | 330 | 667 | 416 | 1033 | 436 | 16 | 4 | 6 |
| 2004 | 66 | 73 | 125 | 128 | 214 | 164 | 354 | 444 | 129 | 4 | 3 | 1 |
| 2003 | 26 | 16 | 50 | 97 | 469 | 639 | 158 | 432 | 602 | 23 | 38 | 1 |
| Av. | 30 | 38 | 65 | 112 | 363 | 579 | 323 | 597 | 371 | 25 | 31 | 13 |



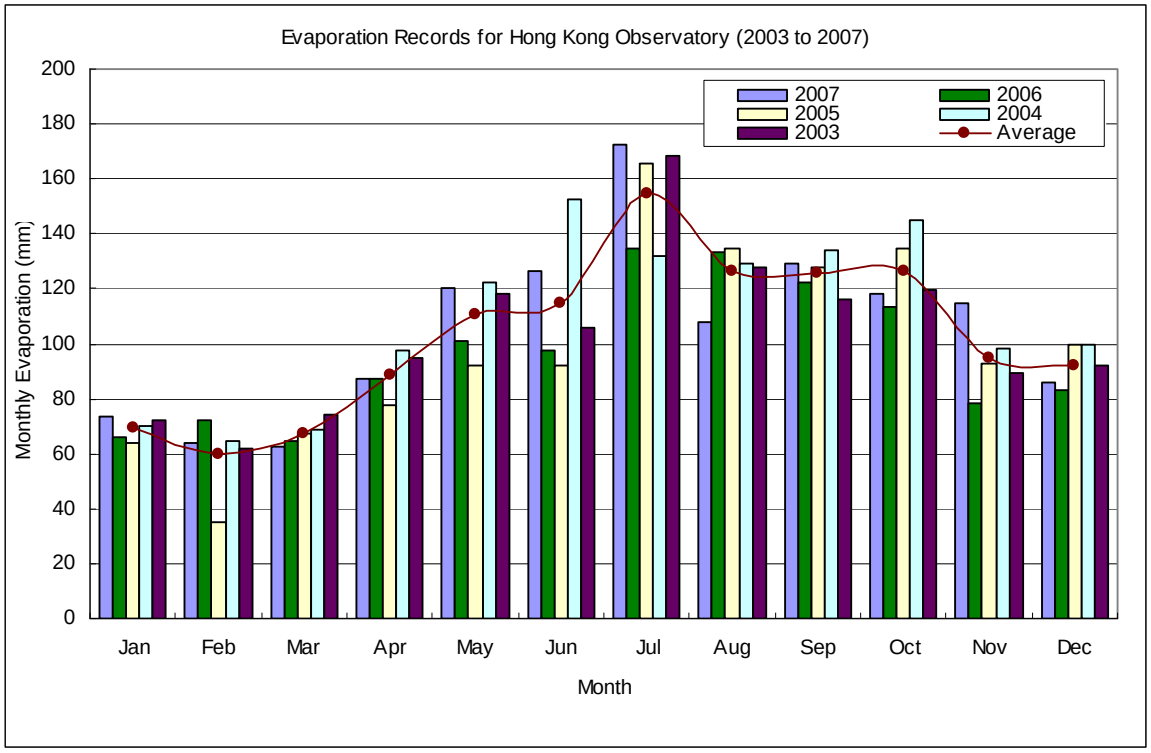

The above data indicates that the drainage catchments along the XRL alignment will typically have a total input to the hydrological system between 1700 mm and 3300 mm per annum, with an average annual rainfall in the order of 2500 mm.

## 4.2 Evaporation

Whilst no direct monitoring of evaporation rates has been carried out in close proximity to the alignment, the records of monitoring at the Hong Kong Observatory record an average annual evaporation of about 1200 mm. The relevant monitoring records used to determine this value are summarized in the following table:

Table 4.3 : Recorded Monthly Evaporation

| Year | Recorded Monthly Evaporation (mm) based on readings from the HKO | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| 2007 | 74 | 64 | 63 | 88 | 120 | 127 | 172 | 108 | 129 | 118 | 115 | 86 |
| 2006 | 66 | 72 | 64 | 87 | 101 | 98 | 135 | 134 | 122 | 113 | 79 | 83 |
| 2005 | 64 | 35 | 67 | 78 | 92 | 92 | 166 | 135 | 128 | 135 | 93 | 99 |
| 2004 | 70 | 65 | 69 | 98 | 123 | 153 | 132 | 129 | 134 | 145 | 98 | 99 |
| 2003 | 73 | 62 | 74 | 95 | 118 | 106 | 168 | 128 | 116 | 120 | 90 | 92 |
| Av. | 69 | 60 | 67 | 89 | 111 | 115 | 155 | 127 | 126 | 126 | 95 | 92 |



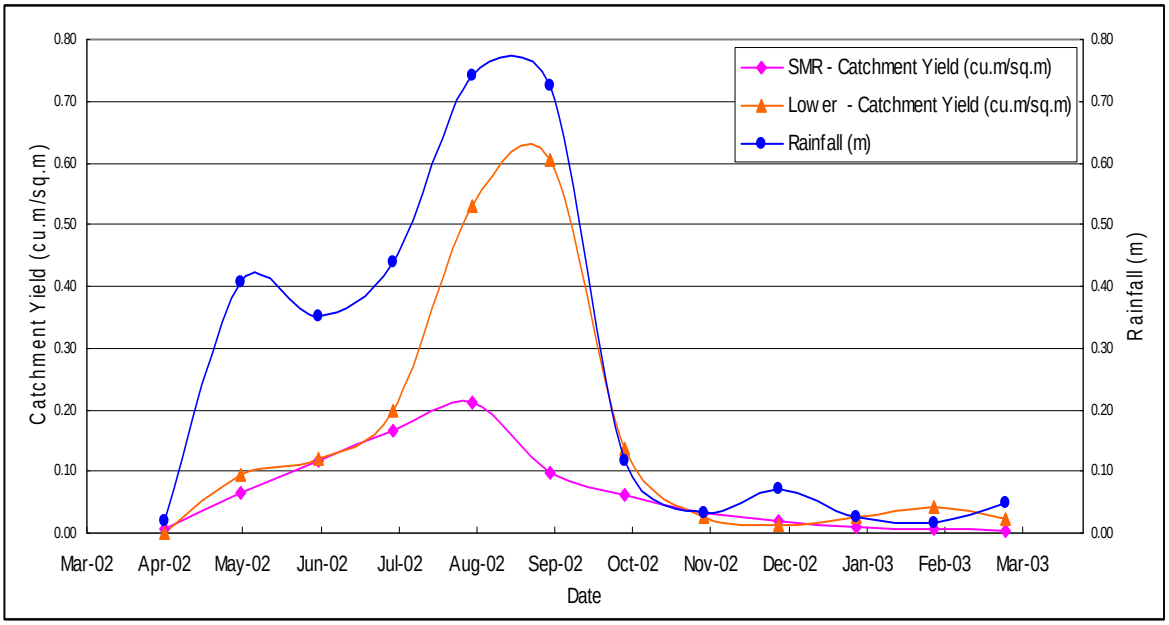

This data indicates that the water balance for any standing water within catchments in the vicinity of XRL is likely to be positive between April and September (precipitation exceeds evaporation) and negative between October and March (evaporation exceeds precipitation). This observation correlates reasonably well with the reductions in groundwater levels noted in many of the observation wells during the dry-season. However, it should be noted that much of the rainfall within the catchment areas would not provide a source for evaporation as it would be lost to the system either as direct surface run-off or through infiltration and recharge of the groundwater aquifers.

## 4.3 Surface Run-off

In addition to the above records of rainfall and evaporation, crude estimates of surface run-off have also been made based on the catchment yield data provided by WSD for the Shing Mun Reservoir (SMR) and Lower Shing Mun Reservoir (LSMR) for the period 2002-2003. A summary of the catchment yield characteristics for these areas is provided in the table below.

Table 4.4 : Summary of Catchment Yields based on WSD Monitoring Data for the Period 2002-2003

| Area | Catchment Yield (thousands of cu.m) per Hectare for 2002-2003 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar |
| SMR | 158 | 1597 | 2889 | 4120 | 5238 | 2389 | 1525 | 824 | 464 | 242 | 153 | 61 |
| LSMR | 0 | 1870 | 2382 | 3934 | 10489 | 12008 | 2721 | 515 | 287 | 500 | 825 | 465 |
| Aver. | 79 | 1734 | 2635 | 4027 | 7863 | 7199 | 2123 | 669 | 375 | 371 | 489 | 263 |




Based on the individual catchment characteristics for each monitoring area, it is apparent that (excluding the effects of evaporation) the total input into each catchment per annum after run-off equates to 791 mm (SMR) and 1816 mm (LSMR). This suggests that approximately 25% to 60% of precipitation is lost as direct surface run-off, although as can be seen on the above plot, this figure typically has notable increases (up to as much as 80% of precipitation) in the months of August and September when rainfall intensities are often at their highest. The above data largely corresponds with the DSD's Stormwater Drainage Manual (2000), which suggests a runoff coefficient between 0.25 to 0.35 for steep grassland (heavy soil) and for steep natural slopes or areas where a shallow soil surface is underlain by impervious rock, a higher runoff coefficient of 0.4 to 0.9 may be applied.

Based on the above figures it is reasonable to estimate that the total groundwater recharge from rainfall for the catchments in the vicinity of XRL is in the order of 1000 mm per annum, excluding any effect from evaporation.

## 4.4 CATCHMENT DATA

Data has been provided by WSD on the following :

- Shing Mun Reservoir - Yield Data (1974 to 2004)
- Shing Mun Reservoir Catchwater - Flow (1977 to 2004)
- Shing Mun Level Water Data (2007 to 2009)
- Catchment Surface Areas

The data is summarised as follows :

| | |
|---|---|
| Shing Mun Reservoir Average Yield | 33.2 million $m^3$/yr |
| Shing Mun Reservoir Catchment Average Yield | 15.2 million $m^3$/yr |

The data indicates that in a typical year Shing Mun Catchwater provides 45% of the yield of the Reservoir.

Comparison of rainfall data for catchwater S10.3 with flow data for the Shing Mun Catchwater is provided in Figure 12. This indicates that flow in the catchwater varies through the year according to the rainfall, however the significant majority of flow in the catchwater will be derived from surface runoff from the catchment and via the surface water network.

The flow is characterised by very short duration peak flows following soon after the peak rainfall event. Estimations of runoff for the catchment suggest a typical maximum to be approximately 60%, although this will vary through the year. A small percentage of the contribution of flow in the catchwater will be provided by flow from groundwater, via the stream channels. This is likely to be less than 10% of the catchment yield once evaporation has been considered.

Analysis of the catchwater data indicates that during peak rainfall periods, typically in June and August the available runoff exceeds the capacity of the catchwater system and drains to the lower, generally urbanised lower catchment areas.

# 5. SEEP/W ANALYSIS

## 5.1 Conceptual Hydrogeological Model

The catchments along the Tai Mo Shan alignment comprise steep natural terrain slopes that flow to the south. The terrain is intersected by stream channels, a few of which have small base flows through the dry season. The streams gather the surface water run off during the rainfall events and flow downstream, typically being intersected by the catchwaters

A conceptual model of a typical catchment slope and associated catchwater is included as Figure 13 and 14.

Based on an assessment of the distribution of superficial deposits and a review of the locations of inferred spring lines it is apparent the groundwater is flowing from the higher elevation areas to the lower elevation areas and a spring line occurs within most valleys.

During the wet season the groundwater recharges from the permeation of rainfall through the superficial deposits and weathered rock within the areas of predominantly natural habitat (vegetated hill slopes) and agricultural land. The bedrock underneath the weathered rock reduces in permeability with depth such that the base of the model can effectively be assumed as a no flow boundary.

In the wet season a spring line can be expected to occur at a height above the stream bed (Figure 13) and this will become lower during the dry season (Figure 14), as the water table declines. At all times of the year the water table in the superficial deposits remains above stream level (or above reservoir level for the adjacent S10.2 catchment).

Groundwater divides can be found along the principal ridge lines that form Tai Mo Shan. The groundwater divide acts as a no flow boundary to ground and surface water flow.

Flow “refraction” is expected to take place with the large majority of flow occurring in the higher conductivity layers and with flow towards these conductive layers from the layers of lesser conductivity. This process includes flow from the rock mass to the upper more permeable zones in the lower areas of the catchment, but the quantities of flow are small. In general, flow takes place from the upper areas of the model, concentrated in the more conductive layers, towards the lower elevation areas of the model to the stream channels, and associated valleys.

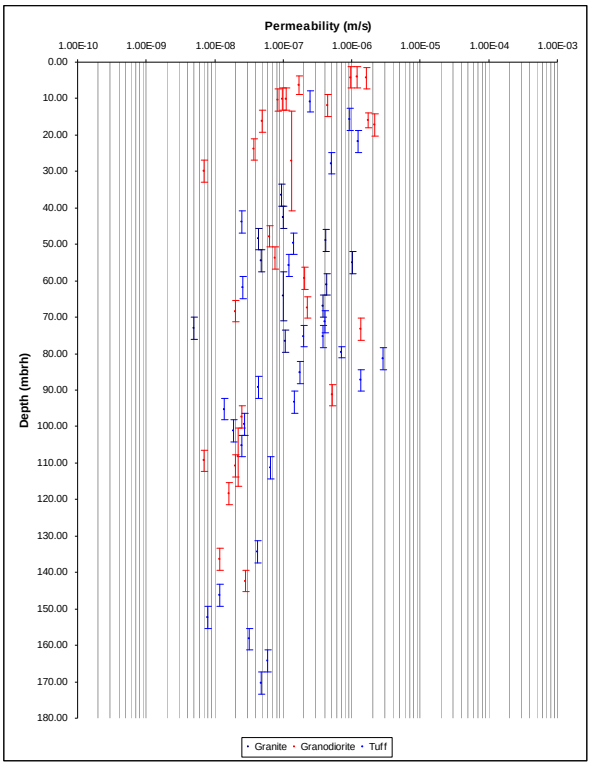
A similar system applies in the dry season; however, with negligible recharge reduced flows and a decline in the groundwater table are likely to occur. However a water table is expected to be maintained within the side slopes to the valleys through out the year.

In general the magnitude of flow in the bedrock is limited when compared to the flow through the superficial materials due to the very large contrast in transmissivity.

## 5.2 Permeability

Due to the cover to the alignment and length of tunnel, comprehensive permeability characterisation of the range of rock mass types is not possible.

Lugeon (water inflow) testing in boreholes was undertaken as part of the preliminary design and is summarised in the Plot below. Additional testing is currently ongoing to supplement this data.




The plot shows the depth interval over which in the lugeon testing was undertaken and is colour coded according to the lithology.

Back calculation of the inflow to Tai Lam Tunnel provides a useful value for the bulk permeability of the rock mass, in which the more permeable transmissive zones, including the major fault zones have been grouted. The final inflow of 0.4l/min/m indicates a grouted rock mass permeability in the region of 2 x $10^{-8}$m/s.

In addition to the above works, it is noted that a number of studies have previously been conducted into the variations of permeability with depth and, in particular, within the completely weathered Grade V unit and within the upper partially weathered rock mass zones. Such variation relates to the following attributes and their particular depth dependencies:

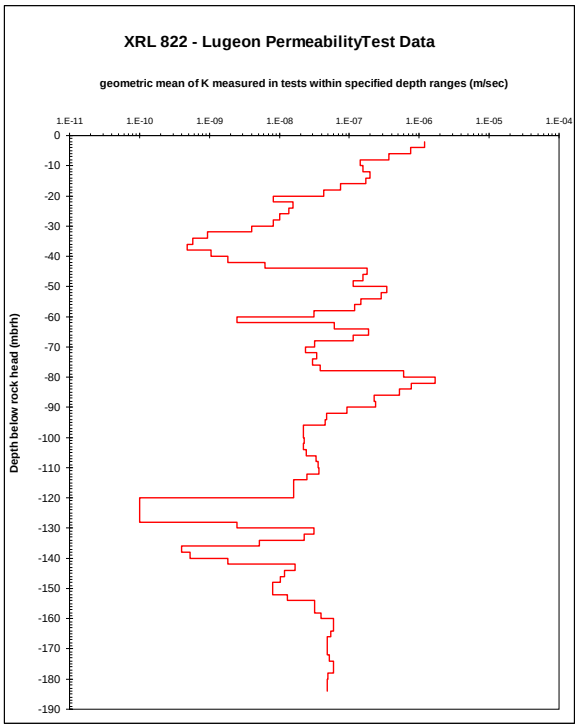
- Porosity development due to leaching of fines (increasing with depth)
- Reduction in clay content with depth - Typically from 20% or more at the top to 0 - 5% at base of saprolite
- Preferential weathering of structure reducing in effect with depth below rockhead

- Increase in confinement and reduction in permeability with depth[3].

The study of precedent, presented in Section 2, has indicated that grouting of transmissive structure is feasible using conventional methods. For the Tai Mo Shan Tunnel a comprehensive approach to investigation and treatment of such features will be undertaken ahead of the main excavation to treat transmissive features. The aim will be to treat them to a level such that their permeability will be similar to the surrounding rock mass, to ensure that the hydraulic isolation provided by the otherwise low permeability rock mass.

For the relatively unweathered rock masses, that are expected at tunnel level for the majority of the alignment, a grouted permeability will be assumed for final inflow prediction, whereby transmissive structures are assumed to have been treated.

A plot of all available data within the contract boundary, plotted in relation to rock head and plotted as average values over 1m depth intervals is provided below.




This is a summary plot that contains all lithologies (there is insufficient data to present a plot for each lithology).

Whilst a broad indication of the variation of permeability with depth relative to rockhead is provided, by the above plot, any specific trends are obscured by the following:

- Combination of data from several geographical areas and lithologies
- Long test lengths for the packer tests
- Data from test lengths of both typical rock mass conditions and fractured zones of rock
- Lugeon testing was generally targeted at more permeable zones

Based on a detailed review of the data carried out in the context of published data and data from other HK projects, the following preliminary design permeability profile is proposed for the Tai Mo Shan Tunnel :

Table 5.1 : Hydrogeological Parameters for Soils and Rocks

| Soil / Rock Type or Zone | Recommended Design Permeability, k (m/s) |
|---|---|
| Colluvium | $3 \times 10^{-5}$ |
| CDG (>10m above rock head) | $1 \times 10^{-6}$ |
| CDG & HDG (typically 0 to 10m above rockhead) | $1 \times 10^{-5}$ |
| M/SDG (Upper 10m of Bedrock Profile) | $6 \times 10^{-7}$ |
| M/SDG (10m to 30m below Bedrock Level) | $5 \times 10^{-8}$ |
| M/SDG (>30m below Bedrock Level) | $5 \times 10^{-9}$ to $1 \times 10^{-8}$ |

The profile of permeability illustrates that there is a very large difference in the permeability of some of the superficial deposits versus those for the rock mass at depth, by a factor of up to 2000 ($1 \times 10^{-5}$ compared to $5 \times 10^{-9}$m/s).

The proposed values intentionally do not consider locally enhanced permeability associated with isolated transmissive features, which will be treated via grouting following a carefully specified procedure. The values are thus intended to represent upper bound values for the background permeability associated with the typical rock mass conditions.

## 5.3 Modelling Scope and Results

Hydrogeological numerical modelling has been undertaken using the software SEEP/W. This is a finite element software package commonly used to analyse groundwater seepage problems within unsaturated-saturated materials. SEEP/W's formulation allows the user to consider analyses ranging from simple, saturated steady-state problems to saturated-unsaturated time-dependent problems. The analysis is carried out based upon Darcy's Law. The output from SEEP/W consists of a graphical representation of the ground water model superimposed on the geological conditions. The output also simulates the position of the groundwater table as a result of water draining into the tunnels.

The purpose of the modelling programme was to assess the influence of a tunnel at depth, excavated within a low permeability rock mass, at a distance beneath more permeable near surface materials, as described in the conceptual hydrogeological model.

To do this a simplified model representative of a catchment slope and valley, with steep topography, typical of the S10.3 catchment, was adopted. A permeability profile consistent with that presented in Section 5.2 was included in the model. The model is shown in **Figure 13**.

Four main modelling scenarios were examined, details are given in **Figures 15 to 18**, and a summary of the models and the key findings is provided below :

Table 5.2 : Model Descriptions and Findings

| Model No. | Model Descriptions | Results - Key Findings |
|---|---|---|
| 1 | Steady state<br><br>5 layers (tunnel horizon permeability 5x10-9m/s)<br><br>Wet season with infiltration<br><br>Without tunnel opening | Simulates the spring line location and high water table during wet season without tunnel opening.<br><br>Large majority of flow is taking place within the superficial materials |
| 2 | Steady state<br><br>5 layers (tunnel horizon permeability 5x10-9m/s)<br><br>Wet season with infiltration<br><br>With tunnel opening | Model 2 is the same as Model 1, but with the tunnel open.<br><br>Opening of the tunnel has no discernable impact on the groundwater head or groundwater level within the superficial deposits. The location of the spring is unaffected. The flow regime in the superficial and weathered rock remains the same as the model without tunnel opening.<br><br>Head distribution in the low permeability rock mass at depth is modified, resulting from depressurisation around the tunnel. |
| 3 | Steady state<br><br>4 layers (tunnel horizon permeability 5x10-8m/s)<br><br>Wet season with infiltration<br><br>With tunnel opening | Model 3 is the same as Model 2, except that the low permeability rock mass at depth around the tunnel opening has been increased to 5x10-8m/s.<br><br>Despite increasing the permeability at the tunnel horizon by an order of magnitude there is almost no impact on the water table elevation or any impact on the location of the spring line. The head distribution within the low permeability rock mass at depth is more modified than for Model 2. |
| 4 | Transient State<br><br>5 layers<br><br>Water table established during wet season infiltration<br><br>Subsequently dry season modelled (6 month without infiltration)<br><br>With tunnel opening | Model 4 is a transient model, undertaken to asses the amount the water table is drawn down in the dry season.<br><br>The model indicates that during the dry season the water table declines and the spring line moves down slope as would be expected.<br><br>The model is a good check for the permeability profiles assumed (if the permeabilites were too high the model would completely drain during the modelled dry season, and if the permeabilites were too low there would be no or limited response to the dry season period). |

Adopting the permeability profiles described in this section of the report, the models in general agree with the conceptual hydrogeological models outlined above.

The models illustrate that the limited flow within the low permeability bedrock at depth is largely independent from the relatively high flows within the high permeability superficial groundwater system, due to the large contrast in permeability.

The SEEP/W models demonstrate that most of the groundwater flow is taking place in the higher permeability superficial deposits (and more weathered rock).

The models demonstrate that any impact of the tunnel excavation at depth, within fresh and slightly weathered low permeability rock, on the near surface groundwater table, would be insignificant, in terms of water table elevation, flows and spring line location both in the wet and dry season.

# 6. INFLOW PREDICTIONS

## 6.1 Inflows - Steady State Calculations – Alignment Models

### 6.1.1 Assumptions

Nearly all available methods relating to the estimation of groundwater flows into an excavation rely on a number of simplifying assumptions, the most pertinent of which are summarised below:

- The rock mass is homogenous and has isotropic permeability
- Steady state flow conditions are in effect; and
- The tunnel boundary is modelled as a free flow boundary

It is noted that due to these assumptions, the predicted water inflows into a tunnel provide an approximation only.

In order to provide some indication of the reliability of the predictions four separate methods have been used, although they are all susceptible to the same assumptions, except McFeat-Smith which is an empirically based system (but based on limited data).

### 6.1.2 Methodology

Preliminary estimations of potential groundwater inflow into the caverns have been made using the following methods

- Goodman Equation (1965)
- Heuer's amendment of the Goodman Equation (1995 & 2005), with additional modifications based on Raymer (2001)
- Heuer's Statistical Approach (1995)
- McFeat-Smith (1999)

The rate of groundwater inflow into an excavation is a time dependent function that will reduce with time as the hydrogeological regime responds to changes in head around the excavation (referred to as early, mid and late time by Raymer 2005).

The method by McFeat-Smith makes some allowance for this, however the other methods do not. Goodman in particular assumes no reduction in head and therefore represents an upper bound assessment for anything other than immediate (early) flow rates. From Hong Kong experience, a conservative estimate of the reduction in rate is 40 to 60% of the initial recorded inflow.

### 6.1.3 Predicted Inflow Rates

#### 6.1.3.1 Predicted Initial Tunnel Water Inflow

The distribution of permeability along the alignment has been based on the alignment geological model, which identifies variations due to weathering and inferred major geological structure. The groundwater head has been varied along the alignment according to the topographic setting.

Two sets of analyses have been undertaken. The effect of discrete transmissive geological features such as faults are included in the first assessment, summarised in Table 6.1. For the second set of analyses, the transmissive features are assumed to have been successfully treated by pre-excavation grouting and are assumed to have permeability equivalent to the background permeability in the inflow calculations, the results are summarised in Table 6.2.

This approach has been adopted to predict inflow to the openings resulting from the background permeability and heads in order to establish the likely range of inflow. The results of the assessments for the tunnels are summarised in the following tables, with full calculations included in Appendix B.

Table 6.1 : Summary of Predicted Groundwater Inflows (without grouting)

| Location | Average Tunnel Water Inflow (L/min/m) Predicted using | | |
|---|---|---|---|
| | Goodman/ Heuer/ Raymer | IMS - Initial | IMS - Final |
| Total Length (7550m) | 1.68 | 0.80 | 0.45 |
| Within Tai Lam Chung Reservoir's Indirect Catchment (2100m) | 1.47 | 0.80 | 0.43 |
| Within Shing Mun Reservoir's Indirect Catchment (3520m) | 1.73 | 0.80 | 0.49 |

Table 6.2 : Summary of Predicted Groundwater Inflows (with grouting)

| Location | Average Tunnel Water Inflow (L/min/m) Predicted using | | |
|---|---|---|---|
| | Goodman/ Heuer/ Raymer | IMS - Initial | IMS - Final |
| Total Length (7550m) | 0.28 | 0.22 | 0.12 |
| Within Tai Lam Chung Reservoir's Indirect Catchment (2100m) | 0.28 | 0.27 | 0.17 |
| Within Shing Mun Reservoir's Indirect Catchment (3520m) | 0.34 | 0.23 | 0.14 |

The above estimates show reasonable correlation between the values identified using the Goodman, Heuer/Raymer, IMS – Initial and Final.

## 6.2 Inflows - Steady State Calculations – Probeholes

Steady state inflow calculations for an advance probe hole, with a diameter of 60mm, have also been undertaken. The calculated inflows have been compared with maximum allowable inflows and related grouting criteria to assess the extent of tunnel that might require grouting.

Based on the probehole inflow calculations, some transmissive zones have been identified with high initial inflow potential, these are listed in Table 6.3. Predicted inflows from these features exceed the grouting criteria (presented in Section 8.3 below), for probehole with inflows that exceed 5 l/min over any 20m length of probehole.

Table 6.3 : Potential High Inflow Zones (Major Geological Structures)

| Chainage (from) | Chainage (to) | Length (m) | Features |
|---|---|---|---|
| 125+644 | 125+648 | 4 | Basalt Dyke |
| 125+709 | 125+712 | 3 | Dacite Dyke |
| 125+860 | 125+875 | 15 | Photolineament |
| 126+140 | 126+145 | 5 | Inferred Fault |
| 126+170 | 126+174 | 4 | Shear Zone |
| 126+590 | 126+595 | 5 | Inferred Fault |
| 126+613 | 126+643 | 30 | Contact zone of Jmt/Jts (Granitic/ Volcanic) |
| 126+900 | 126+975 | 75 | Sham Tseng Fault zone |
| 127+450 | 127+475 | 25 | Fault zones |
| 128+460 | 128+485 | 25 | Contact of Jts/Jty (Volcanic/ Volcanic) |
| 129+170 | 129+195 | 25 | Inferred Fault |
| 129+670 | 129+695 | 25 | Photolineament |
| 129+950 | 129+965 | 15 | Inferred Fault |
| 130+210 | 130+230 | 20 | Inferred Fault |
| 130+580 | 130+595 | 15 | Photolineament |
| 130+870 | 130+885 | 15 | Inferred Fault |
| 131+672 | 131+679 | 7 | Inferred fault |
| 131+786 | 131+790 | 4 | Inferred Fault |
| 131+882 | 131+885 | 3 | Basalt Dyke |
| 131+931 | 131+976 | 45 | Inferred Fault |

| Chainage (from) | Chainage (to) | Length (m) | Features |
|---|---|---|---|
| 132+025 | 132+060 | 35 | Contact of Jty/Jmt (Volcanic/ Granitic) |
| 132+121 | 132+173 | 52 | Inferred fault |
| 132+410 | 132+430 | 20 | Contact of Jmt/Jkn (Volcanic/ Granitic) |
| 132+830 | 132+840 | 10 | Inferred Fault |
| 132+885 | 132+910 | 25 | Dyke |
| | Total Length | 507 | (6% of total length) |

From inspection of the Tai Lam Tunnel records the length of grouting required within potential high inflow zones (i.e. major geological structures) required to reduce inflows to acceptable levels was a maximum of 8m. Inspection of the more detailed geological records suggests that relatively narrow transmissive features occur within broader geological structures. From the Tai Lam West Rail Tunnel data summarised in Tables 2.3 and 2.4 only 15% of the broader zones required grouting. This would indicate that approximately 77m of the Tai Mo Shan major geological structures (i.e. 15% of 507m) would require grouting.

Additional narrow transmissive features that have not been specifically identified in the alignment geological model, but would also require grouting, also need to be allowed for in grouting estimates. These are discussed in Section 8.3.

## 6.3 Inflow Predictions Based on Precedent – Tai Lam Tunnel

The final inflow to the Tai Lam Tunnel has been measured by recording flow into the tunnel sump to be 0.4l/min/m, as summarised in Section 2 and Figure 7.

Back calculation from this figure, indicates a bulk permeability of the rock mass along the alignment (including the small percentage of grouted tunnel) to be in the region of $2 \times 10^{-8}$ m/s and consistent with the assumptions adopted in the above assessments.

A flow of 0.4l/min/m for the Tai Mo Shan Tunnel would result in an annual inflow into the permanent tunnel of 1.15 million $m^3$ / year over full tunnel length.

Inflow over the length of tunnel beneath catchment S10.3 would be as follows:

Table 6.4 : Inflow over the length of tunnel beneath Indirect Shing Mun Reservoir Catchment

| | Final Groundwater inflows 0.4 l/min/m | % of Shing Mun Reservoir Yield |
|---|---|---|
| Total annual inflow for tunnel within Shing Mun Reservoir Catchment S10.3 | 0.72 million $m^3$ / year | 2.2 % |

Table 6.4 does not imply that the yield of Shing Mun reservoir will be reduced by 2.2%, this is because the hydrogeological system in the low permeability rock mass at tunnel level is largely independent from the surface runoff and near surface groundwater recharge to the reservoir.

# 7. EVALUATION OF IMPACT ON WSD FACILITIES

## 7.1 Catchment S10.3 and Shing Mun Reservoir

### 7.1.1 Impact on Shing Mun Reservoir Yield

Prediction of inflows using conservative values of permeability, and comprehensive back analysis of the inflows encountered during construction and final inflows to the Tai Lam Tunnel, indicate that a final inflow of 0.4 l/min/m should be easily achievable using conventional methods.

The element of the reservoir yield that could conceivably be influenced by the Tai Mo Shan Tunnel is the contribution from the S10.3 catchment (which lies above the proposed alignment), via Shing Mun Reservoir Catchwater. Inflow to the tunnel over this section of the alignment at 0.4 l/min/m would amount to 0.72 million m3 /year, which equates to approximately 2.2% of the annual reservoir yield.

Reference should be made to Section 5 of this report describing the conceptual geological model and the associated hydrogeological modelling. This infers that there is limited interaction between discharge to the catchwater and flow in the rock mass surrounding the tunnel. This is due to the high percentage of runoff in the catchment and the significant permeability contrast between the superficial material and the underlying rock mass.

Analysis of catchment S10.3 and associated flow in the catchwater suggests a very large majority of flow in the catchwater is derived from runoff which would be unaffected by any future inflows to the tunnel.

### 7.1.2 Impact on Superficial Aquifers and Related Habitats

Flow to the future tunnel would be derived from the superficial aquifer, WSD have expressed concern that this could result in a decline of the water table and influence reservoir yields.

Reference to the project hydrogeological conceptual model indicates that during the wet season recharge from rainfall is such that the superficial aquifers are fully recharged. The water tables decline naturally in the dry season, with only a few streams maintaining a base flow.

Decline of the water table within a typical catchment has been modelled via a simplified SEEP/W. This analysis suggests that any additional dry season decline in the water table as a result of flow to the tunnel would be very limited and would not therefore detrimentally impact on habitats within the habitats of the stream courses or lower catchment areas

To ensure that the impacts are limited, grouting of permeable, transmissive geological structures along the tunnel alignment should be undertaken where encountered.

## 7.2 Shing Mun Catchwater

Due to the large vertical separation and lined open channel construction of the Shing Mun Catchwater no impacts have been identified by this study and no particular mitigation measures are deemed necessary other than those included within the MTR standard specification.

## 7.3 Tai Lam Chung Reservoir indirect catchment (Reference Number S13.3-11)

The influence of the proposed project on the Tai Lam Chung Reservoir indirect Catchment are similar to those relating to Shing Mun Reservoir and Catchment Number S10.3, however the length of the tunnel beneath the catchement is less and the contribution of the S13.3-11 as a percentage of the annual yield of Tai Lam Chung Reservoir is also smaller.

However it is proposed that grouting of transmissive features should be undertaken according to the same criteria developed for the tunnel section below S10.3.

## 7.4 Tai Lam Chung Reservoir Catchwater

The vertical separation between the proposed alignment and the catchwater is 67.3m. Inflow control requirements will be required over this section of the alignment.

# 8. PROPOSED MITIGATION STRATEGY

## 8.1 Inflow Control Requirement

Studies of precedent practice, including construction of the Tai Lam Tunnel, demonstrate that pre-grouting ahead of the tunnel excavation to pre defined inflow trigger levels is a practical and effective means of controlling inflow.

The difficulty is setting target inflow criteria that are necessary, but also achievable within the available construction programme.

Analysis of the Tai Lam Tunnel data indicates that to achieve a final inflow of 0.4 l/min/m approximately 12 features were grouted, with a grouted width of approximately 30m (or a maximum of 190m, if the broader higher inflow zones are considered). This was achieved with an inflow criteria applied only to the WSD Drainage Mitigation Zones (DMZ), which did not include the length of tunnel below the S10.3 catchment. Additional grouting was however undertaken by the contractor to control sustained high localised flows associated with faults, outside the DMZ, in order to comply with the final inflow criteria of 0.55 l/min/m.

MTR recognise that a degree of specified inflow control over the full alignment is beneficial in order to limit long term inflows in terms of the following:

- To control inflow in poor ground (fault zones in particular) to prevent instability and allow safe construction of the temporary and permanent support.
- To ensure that high flow zones are pre-grouted ahead of the tunnel excavation
- To limit impact on WSD facilities
- To limit long term pumping costs thereby reducing maintenance costs to acceptable levels

## 8.2 Grouting Methodology

The advantages of successful pre-grouting works are well demonstrated by the extensive experience of drill and blast tunnelling in Hong Kong, and on MTR projects in particular. Several recent cases where high post excavation inflows have been encountered have proven extremely difficult to resolve via post excavation grouting, and solutions become even more complex once the final lining has been installed.

Specification of a relatively tight criterion in terms of inflow from probeholes is therefore beneficial to ensure inflow criteria for the final excavated tunnel are achieved.

Figure 19 illustrates a typical arrangement for grouting from a 16m span excavation. These concepts are currently being developed in relation to the XRL tunnel geometries and the range of ground conditions anticipated. The general approach will be as follows :

- Investigation - probing
- Treatment of transmissive flowing features identified by probing observations
- Systematic Grouting in areas of enhanced permeability (expected at portals and fault zones)
- Cut-off Membranes with Post Grouting Facility (Contingency Measure)

This will be achieved via a systematic and carefully specified protocol of grouting. In outline this will comprise a procedure summarised below.

The number of probe holes will vary according to the particular risks associated with an alignment interval, but will comprise a minimum of a single probe hole drilled a minimum of 20m ahead of the face at any one time. If inflow criteria from the probehole(s) are exceeded the probehole(s) will be pressure grouted according to the specification. A minimum array of primary grout holes will then be drilled around the full circumference of the tunnel and grouted according to the contractors proposed methods and in accordance with the specification. An array of primary check holes will then subsequently be drilled and water outflows checked against the probe hole criteria. If any of the check hole flows exceed the criteria a secondary array of grout holes would be drilled and the procedure repeated.

Details of the grouting sequence and design will vary according to the ground conditions encountered. A number of designs (3 to 4) will therefore be developed by the contractor with a fully prepared methodology and design for each, that would include specification of the following :

- Inclination and length of the grout holes from the tunnel axis
- Number and layout of grout holes
- Grout mix design including specification of additives and setting times
- Grout Pressures
- 'Stop Grout' Criteria

## 8.3 Draft Inflow Criteria

### 8.3.1 Assessment of Inflow Criteria - Tai Lam Tunnel Data

The Tai Lam Tunnel data has been used to assess the implications for Tai Mo Shan tunnel of adopting a tighter inflow control specification than was adopted for the Tai Lam Tunnel.

The following tables summarise the number of grouting that would have been required in the Tai Lam Tunnel if a criteria of 5l/min over any 20m length of probe hole had been applied to the full alignment below the catchment.

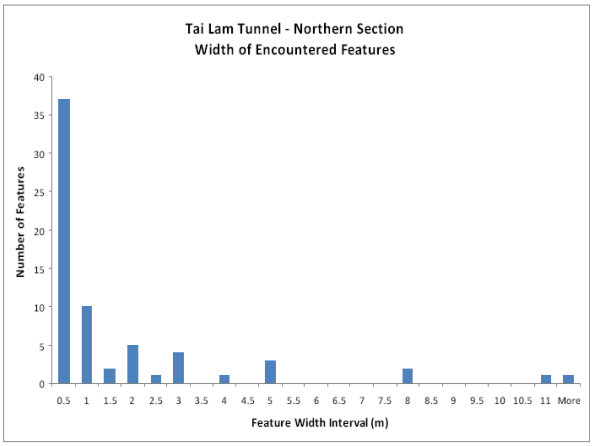
Table 8.1 : Tai Lam Tunnel – Estimate of Grouting Extent That Would have been Required if probe hole inflow of 5l/min/20m had been applied based on width of Zones of Higher Flow

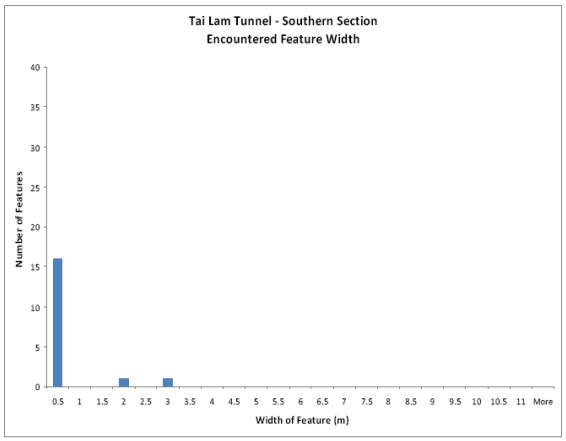
| Zone of Tunnel where grouting would be required | Number of Zones |
|---|---|
| Total tunnel length intersected by zones described as having enhanced inflow . | 69 |

Of the 69 features (see table 8.1) encountered in the probes or subsequently in the tunnel excavation approximately 75% were recorded in the northern half of the project. The reasons for this appear to be related to the occurrence of structural zones that comprised a higher concentration of all types of inflow features, these included the Sham Tseng Fault Zone and a structural zone beneath Ho Pui Reservoir.

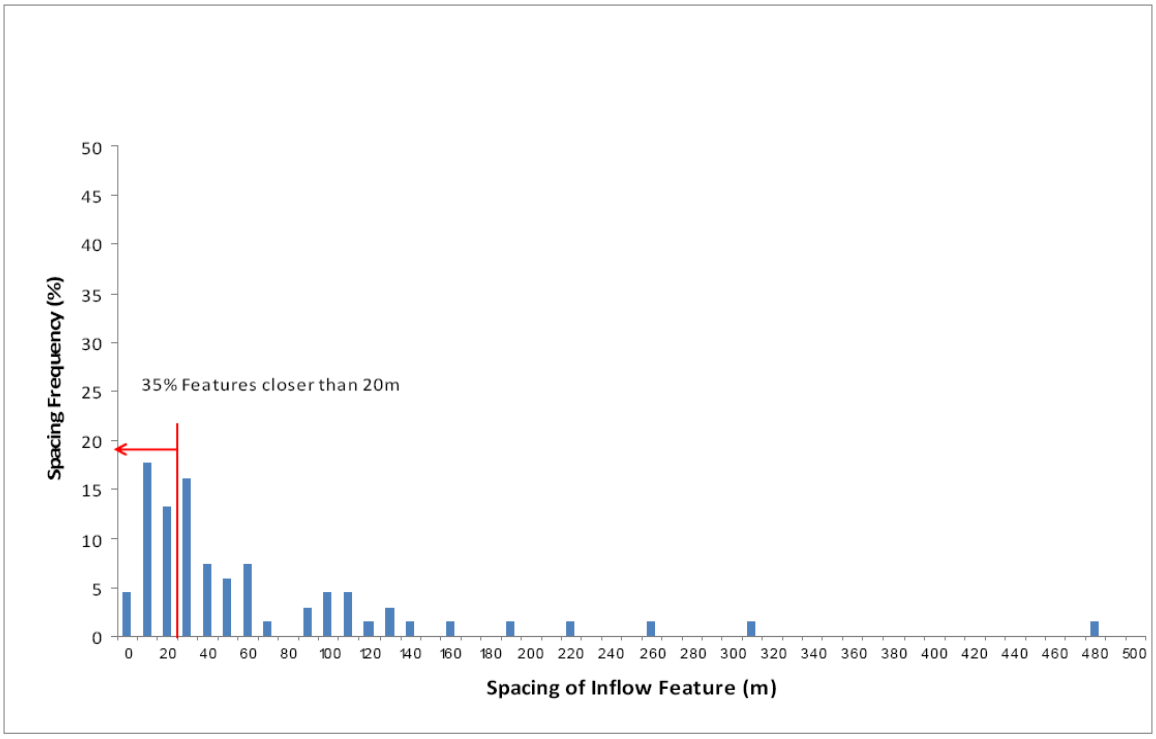
In addition to the above, a further 15 zones of moderate inflow and 1 of high inflow were recorded in the post excavation face but had no (logged) inflow structure associated with them and no available quantitative record of the inflow. These are assumed to represent relatively dispersed inflow that would not have failed the proposed inflow criteria.

Frequency plots of the feature thickness as encountered in the northern and southern sections of the alignment are shown below:




Also a plot of spacing of transmissive features encountered in Tai Lam Tunnel (West Rail) is shown below:




Of the total 69 features identified with an inflow of greater than 5L/min, approximately 35% are spaced at less than 20m from another feature and therefore more than one feature would be treated within a single grout zone (see above feature spacing plot). In addition, it is conservatively estimated that the flow from a further 10 to 25% would reduce to below the threshold of 5L/min within a 20m probehole. A reasonable estimate of the number of features wthat would have required treatment via pre-excavation grouting, if a probehole criteria of 5 L/min/m has been adopted, is 35 to 40 features.

### 8.3.2 Proposed Inflow Criteria

The following criteria is proposed for the full length of the Tai Mo Shan Tunnel :

- Pre-excavation grouting shall be carried out ahead of the excavation according to the following criteria :

  Water flowing from a probehole drilled ahead of the face exceeds 5 l/min (for a single probe hole) or a total of 10 l/min (for more than one probehole), measured over a minimum of 20m length and measured a minimum of 1 hour after termination of drilling.

- After excavation and prior to construction of the final lining the following criteria shall apply :

  Cumulative water inflows, flowing from a 25 metre length of completed tunnel excavation exceeds 50 litres/minute. Post excavation grouting will be carried out and the final lining not constructed until the criteria has been met.

- Final inflows to the completed tunnel shall not exceed 400l/min for 1000m of completed tunnel.

An initial draft particular specification for the C822 contract to apply at all WSD interfaces, as described in the specification is provided in Appendix A.

### 8.3.3 Predicted Extent of Grouting - Tai Mo Shan Tunnel - Summary

From the alignment geological model for Tai Mo Shan Tunnel there are 25 major geological structures expected that have predicted inflows higher than the probehole inflow criteria of 5 l/min for a 20m length (refer to Table 6.3). Using the Tai Lam data a conservative estimate of the extent of grouting required, related to discrete features within these broader zones is 15%, hence 77m of tunnel, derived as fifteen percent of 507m, is expected to require grouting.

In addition to the features identified by the geological model a further 17 minor, but transmissive features are expected to be encountered. This number has been derived from assessment of the Tai Lam Tunnel data.

Table 8.2 : XRL - Tai Mo Shan Tunnel, Schedule of Features

| | Number of Zones / Features | Feature width (Grouting requirement) | Broad geological structural zone |
|---|---|---|---|
| Major geological structures | 25 | 77m | 507m |
| Minor transmissive features | 17 | 8.5m (0.5m per feature) | n/a |

It should be recognised that these estimates are uncertain for a number of reasons, including uncertainty with the alignment geological model and the applicability of the Tai Lam Tunnel data to the Tai Mo Shan alignment.

These estimates will therefore be reviewed once the Tai Mo Shan alignment geological model has been updated, after completion of the ongoing site investigation. Full reference should be made to the Geotechnical Interpretative Report for an assessment of the geological risks, but these include :

- faulting sub parallel to the alignment
- transmissive discontinuities sub parallel to the alignment
- high frequency of transmissive structures (faults and more minor transmissive discontinuities)
- higher frequency of transmissive dykes
- higher frequency of transmissive zones within the tuff sequence, including contacts, sandstone and conglomeratic horizons
- geothermal water systems that could give rise to higher sustained inflows (as encountered on the Butterfly Valley project).

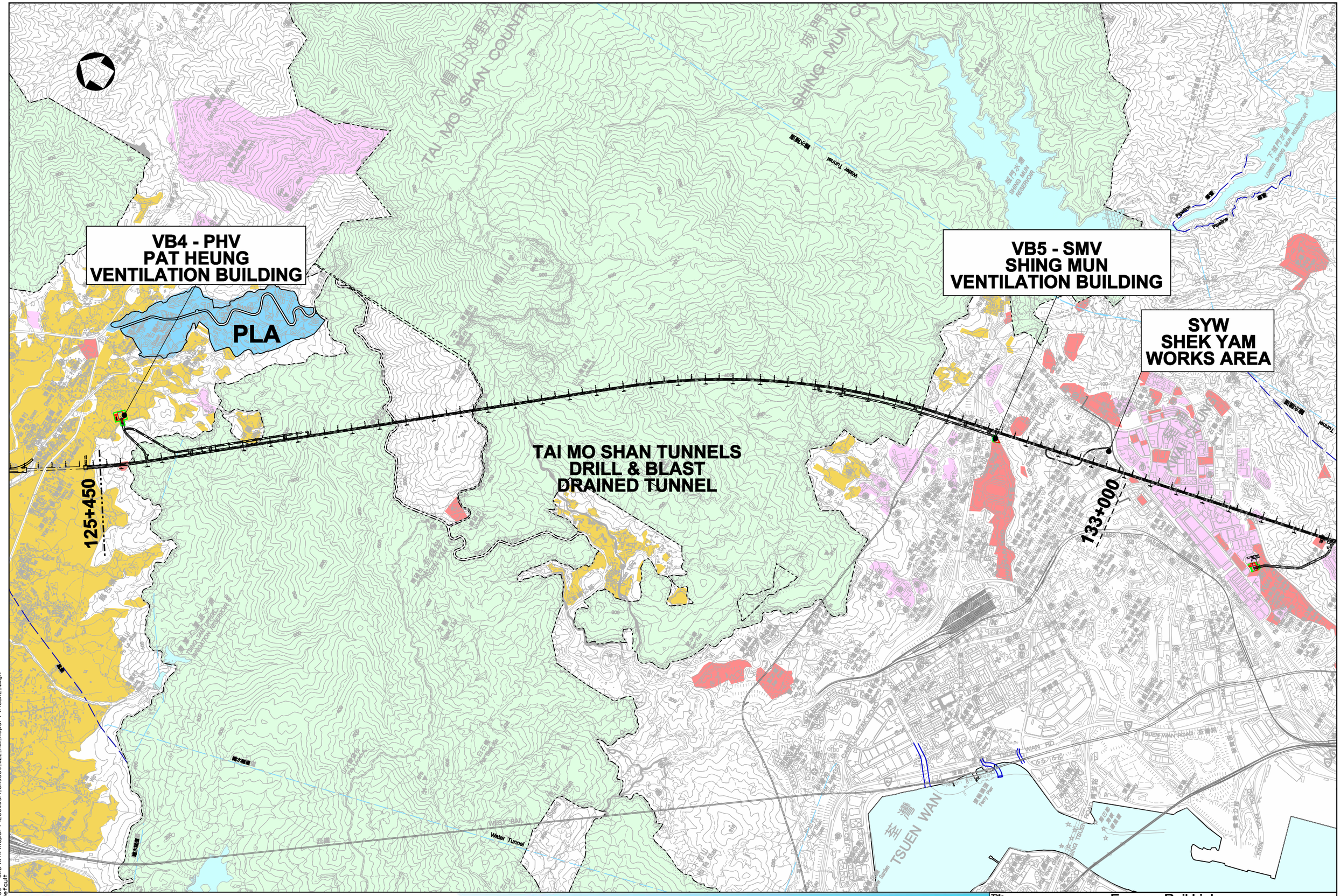
A preliminary assessment of the risks infers the following range :

| | Number of Zones / Features | Feature width (Grouting requirement) | Broad geological structural zone |
|---|---|---|---|
| Major geological structures | 15 to 25 | 60 to 100m | 400 to 650m |
| Minor transmissive features | 15 to 30 | 7.5 to 30m | n/a |

## 8.4 Grouting Designs

Indicative grout designs for the range of expected rock mass conditions will be developed as a part of the detailed design for the Tai Mo Shan Tunnel.

# FIGURES




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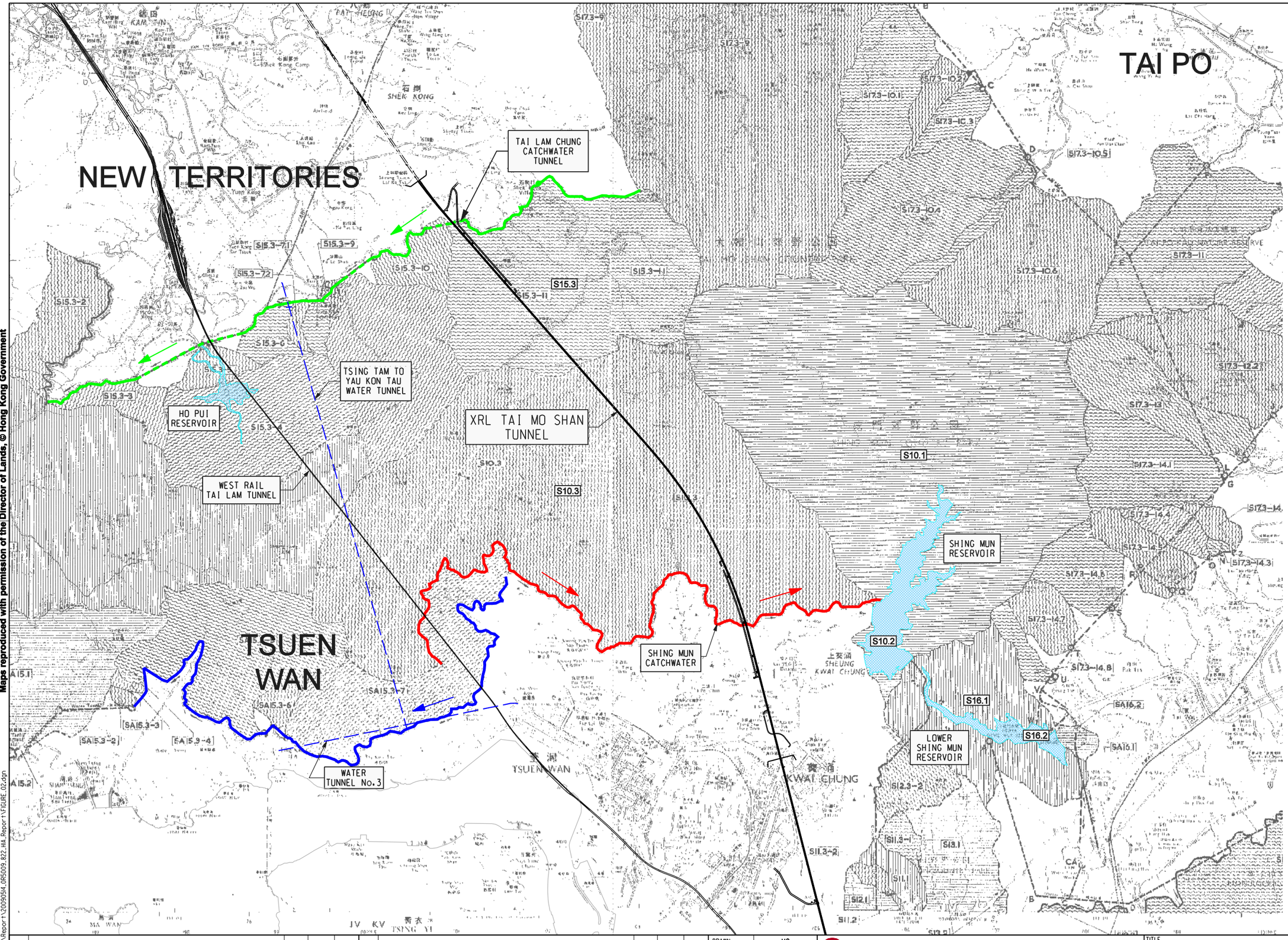
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Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

Title
# Express Rail Link
## Summary Alignment Drawing

| Figure No. | Date |
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| Figure 1 | May 2009 |




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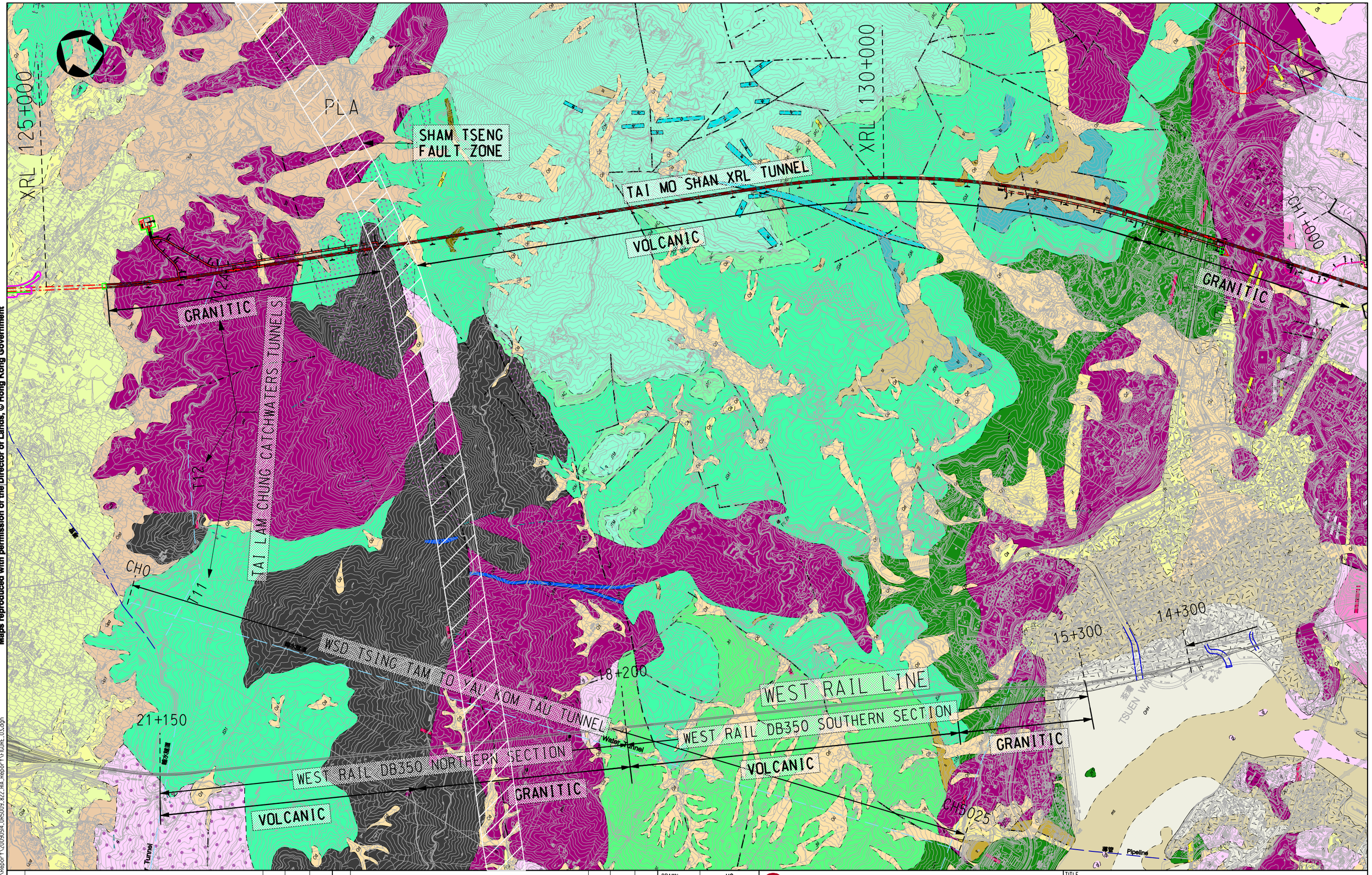
TITLE

# CONTRACT 822

## PAT HEUNG TO SHEK YAM

TAI MO SHAN TUNNEL & WEST RAIL TAI LAM TUNNEL INTERFACE WITH WSD FACILITES

| SCALE | DRAWING NO. | REV. |
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|---|---|
| DRAWN | VC |
| DESIGNED | TC |
| CHECKED | BM |
| APPROVED | TM |
| DATE | 14/MAY/2009 |

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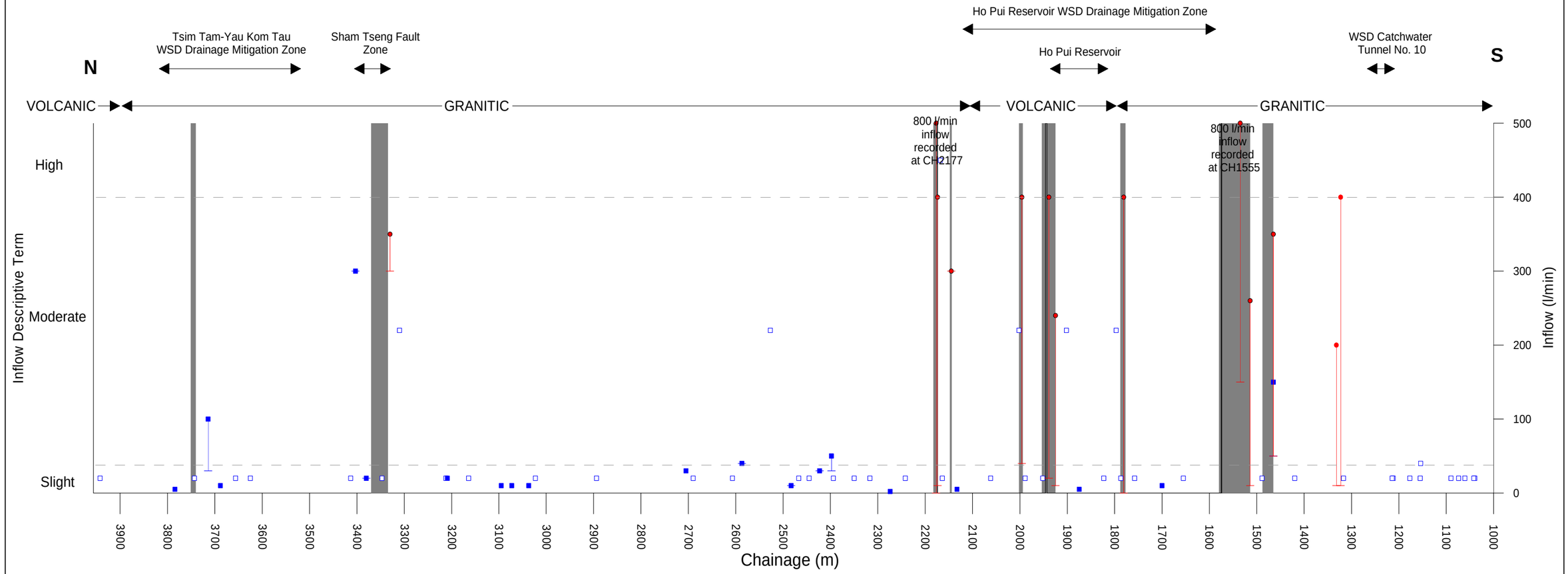
ORIGINATOR ATKINS

Supported by
Arup, TFP Farrells, DLS
Kenneth Ng

CADD REF. FIGURE_03.dgn

TITLE
CONTRACT 822
PAT HEUNG TO SHEK YAM
GEOLOGICAL MAP FOR XRL
TAI MO SHAN TUNNEL & WEST RAIL TAI LAM TUNNEL

SCALE 1:10000 (A1) | DRAWING NO. FIGURE_03 | REV. –




**Notes**

1. Data extracted from As-Built Geological Records (Nishimatsu and Maunsell Consultants Asia Ltd)

2. Inflows are those recorded from probeholes and excavation logging

**Inflow Ranges**

| | Range | Mid-Point |
|---|---|---|
| Slight | 0 - 40 | 20 |
| Moderate | 40 - 400 | 220 |
| High | >400 | 450 |

**LEGEND:**

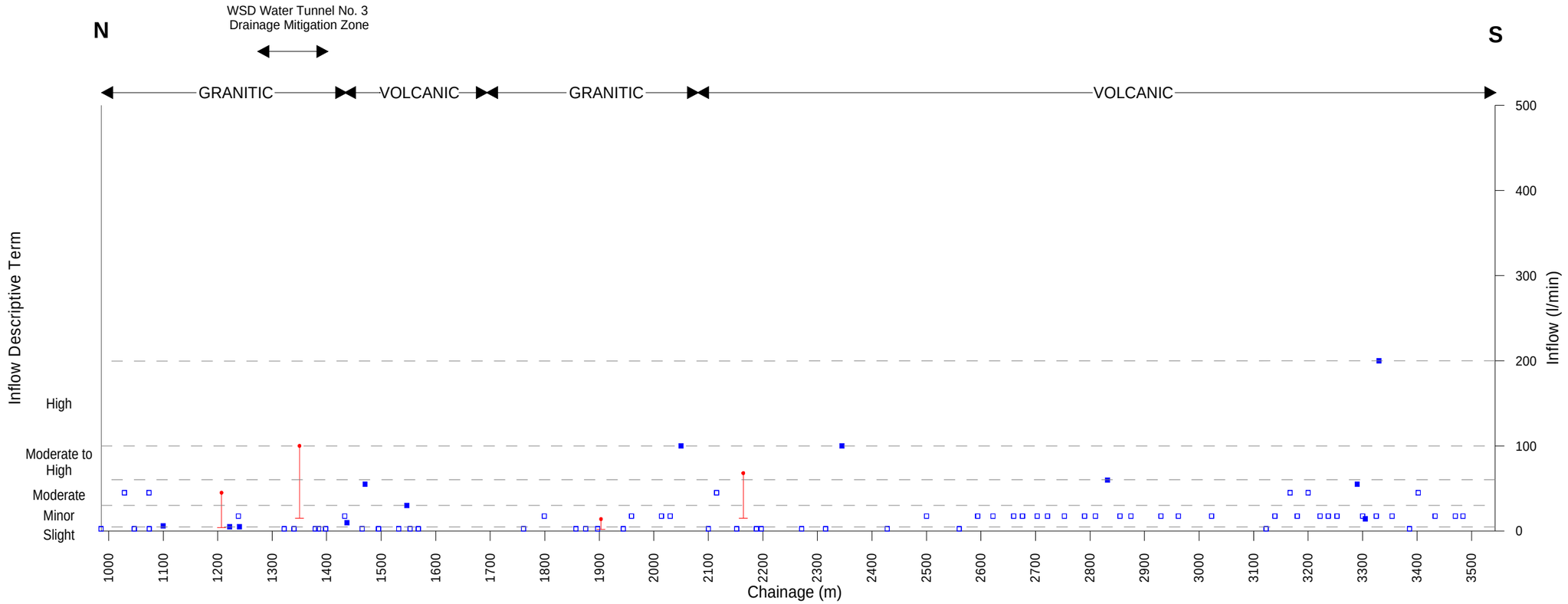
- Measured tunnel inflow from probehole showing reduction over time
- Measured tunnel inflow from probehole showing reduction after grouting (reduction in flow logged post excavation)
- Measured tunnel inflow from excavation logging
- Measured tunnel inflow from excavation logging showing reduction over time
- Descriptive Tunnel Inflow (Flow Range Mid-Point Used for Plot)
- Grouted Zone
- Geological feature encountered within grouted zone


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Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

| | | | |
|---|---|---|---|
| Figure Title | Tai Lam Tunnel - Recorded Tunnel Inflows – Northern Section | | |
| Figure No | 4 | Date | MAY 2009 |




**Notes**

1. Data extracted from As-Built Geological Records (Dragages and Maunsell Consultants Asia Ltd)

2. Inflows are those recorded from probeholes and excavation logging

**Inflow Ranges**

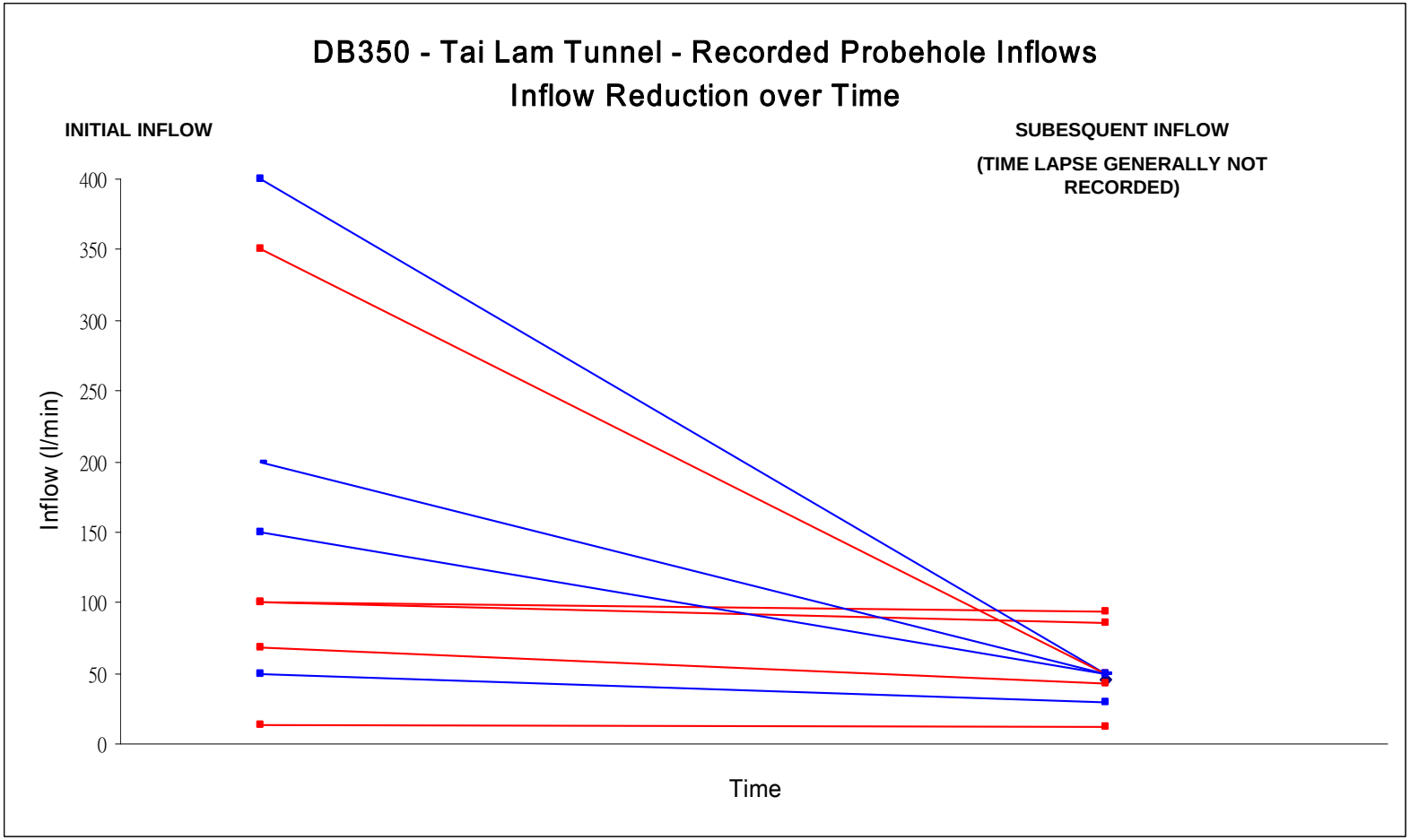
| | Range | Mid-Point |
|---|---|---|
| Slight | 0 - 5 | 2.5 |
| Minor | 5 - 30 | 17.5 |
| Moderate | 30 - 60 | 45 |
| Moderate to High | 60 - 100 | 80 |
| High | 100 - 200 | 150 |

**LEGEND:**

- Measured tunnel inflow from probehole showing reduction over time
- Measured tunnel inflow from probehole showing reduction after grouting (reduction in flow logged post excavation)
- Measured tunnel inflow from excavation logging
- Measured tunnel inflow from excavation logging showing reduction over time
- Descriptive Tunnel Inflow (Flow Range Mid-Point Used for Plot)
- Grouted Zone
- Geological feature encountered within grouted zone

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Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

| | | | |
|---|---|---|---|
| Figure Title | Tai Lam Tunnel - Recorded Tunnel Inflows – Southern Section | | |
| Figure No | 5 | Date | MAY 2009 |



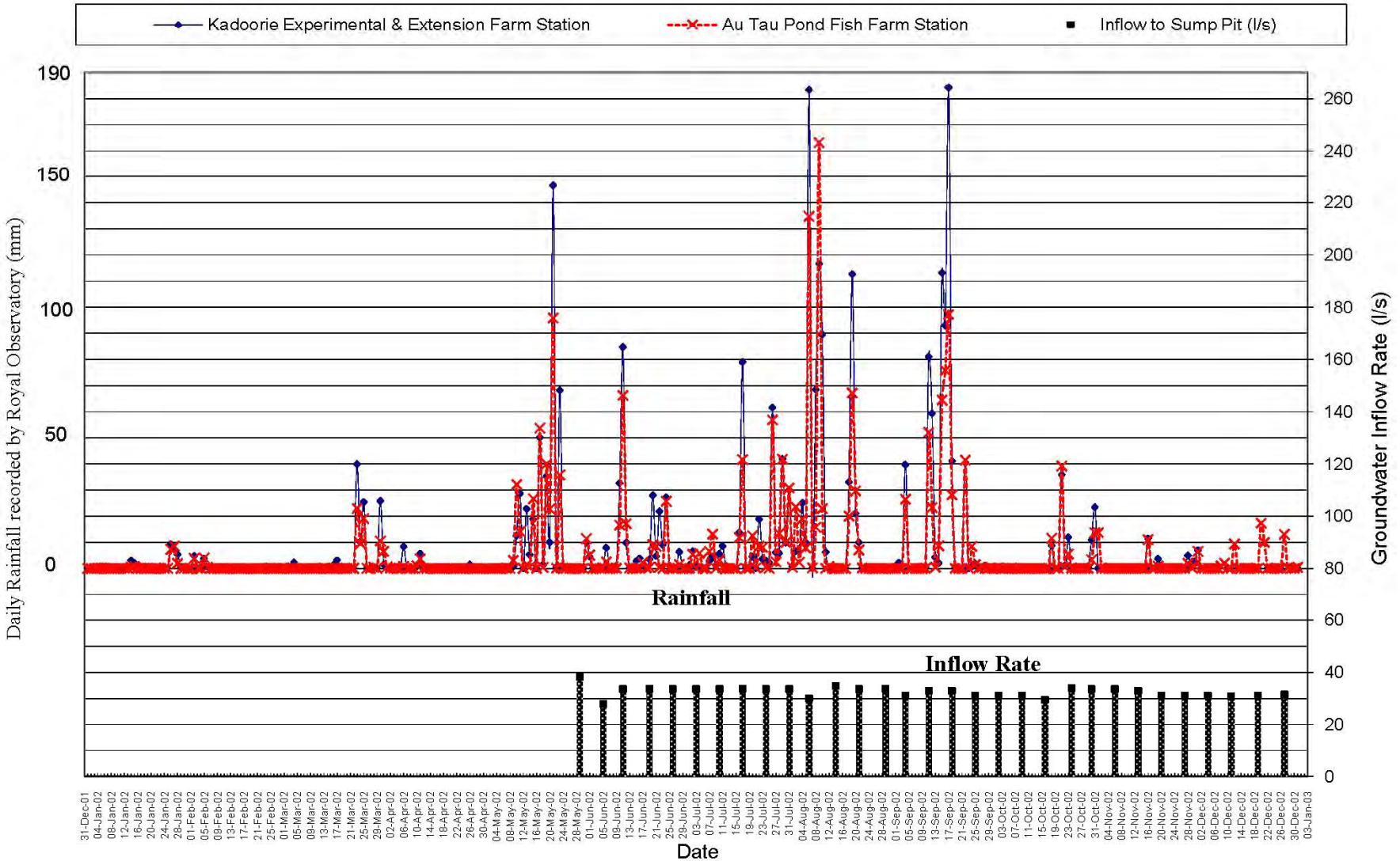

**Notes**

1. Data extracted from As-Built Geological Records (Nishimatsu – Dragages and Maunsell Consultants Asia Ltd)
2. Inflow reduction times generally not stated

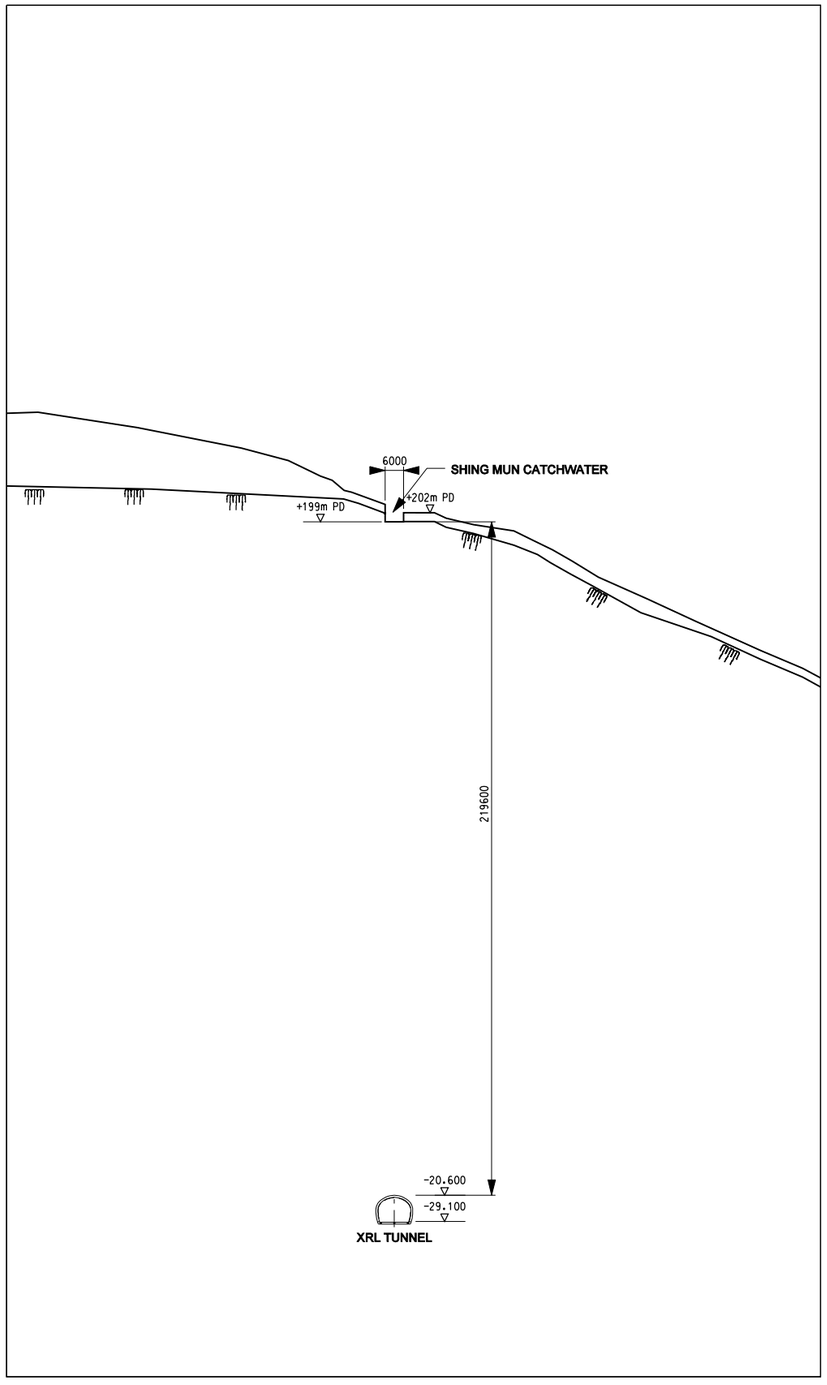
**Legend**

- Southern Section (Dragages)
- Northern Section (Nishimatsu)

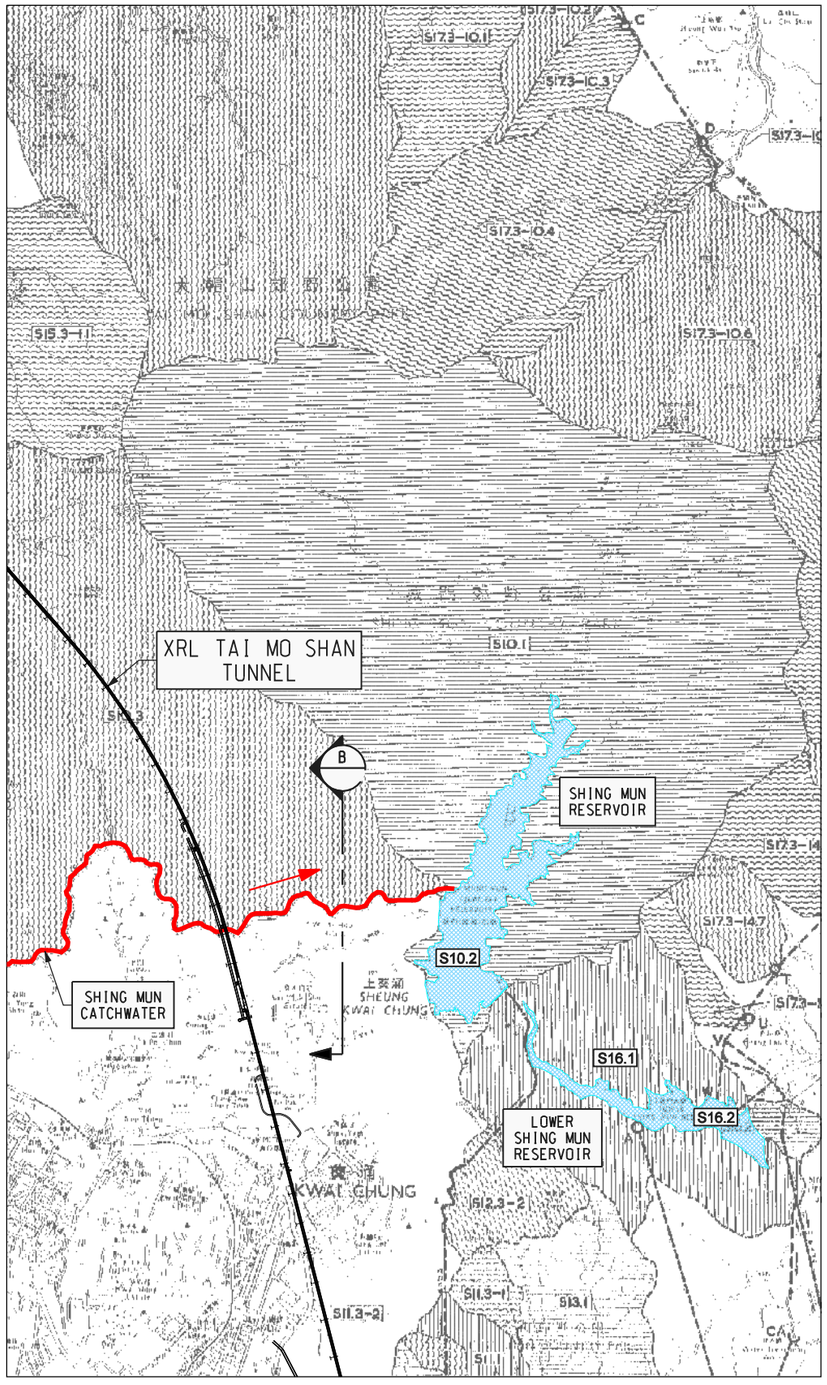
# Groundwater Inflow in Tai Lam Tunnel Sump Pit vs Rainfall



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SECTION B
SCALE 1:1000




PLAN
SCALE 1:20000

LEGEND:

RESERVOIR

DIRECTION OF FLOW IN CATCHWATER

0 20 40 60 80 100
METRES
1 : 2000

0 200 400 600 800 1000
METRES
1 : 20000

PLOT DRV: Z:\03 - CAD\CAD_Admin\PLOTDRIVER\PDF_Color_150dpi_080923.plt
MODEL NAME: Default PRINTED BY: vinchon 18/05/2009 3:49:50 PM
FILENAME: Z:\03 - CAD\ATK\Report\2009594_0R5009_822_HIA_Report\FIGURE_08.dgn

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| REV | DESCRIPTION | BY | DATE | APPROVED |
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| | |
|---|---|
| DRAWN | VC |
| DESIGNED | TC |
| CHECKED | BM |
| APPROVED | TM |
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CADD REF. FIGURE_08.dgn

TITLE
CONTRACT 822
PAT HEUNG TO SHEK YAM
INTERFACE WITH SHING MUN CATCHWATER

SCALE AS SHOWN (A1)
DRAWING NO. FIGURE_08
REV. –

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NEW TERRITORIES

TAI PO

TSUEN WAN

HO PUI RESERVOIR

XRL TAI MO SHAN TUNNEL

SHING MUN RESERVOIR

LOWER SHING MUN RESERVOIR

LEGEND:

- INDIRECT CATCHMENT AREA FOR TAM LAM CHUNG RESERVOIR
- INDIRECT CATCHMENT AREA FOR SHING MUN RESERVOIR
- DIRECT CATCHMENT AREA FOR SHING MUN RESERVOIR
- DIRECT CATCHMENT AREA FOR LOWER SHING MUN RESERVOIR
- INDIRECT CATCHMENT AREA FOR LOWER SHING MUN RESERVOIR
- RESERVOIR
- DIRECTION OF FLOW IN CATCHWATER
- 822 CONTRACT BOUNDARY

0 200 400 600 800 1000
METRES
1 : 20000

PLOT DRV: Z:\03 - CAD\CAD_Admin\PLOTDRVER\PDF_Color_150dpi_080923.plt
MODELNAME: Default PRINTED BY: vinchan 18/05/2009 3:48:53 PM
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| DRAWN | VC |
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CADD REF. FIGURE_09.dgn

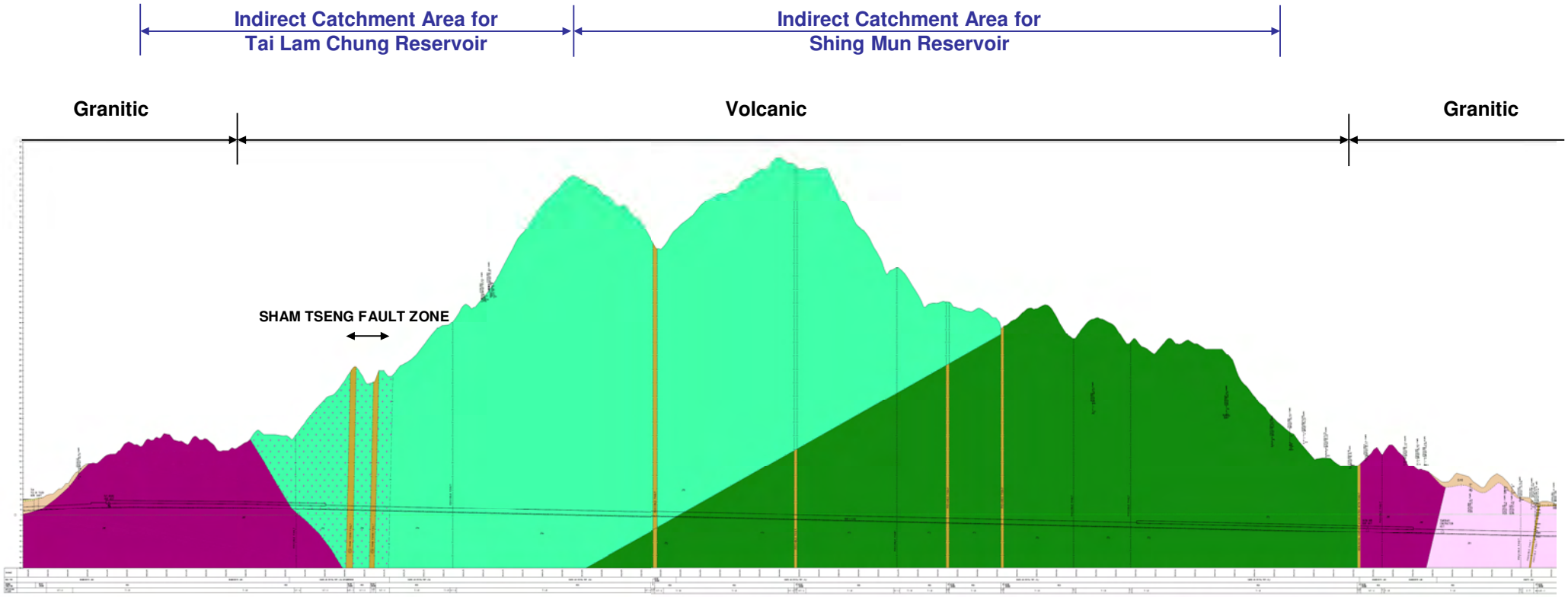
TITLE

# CONTRACT 822

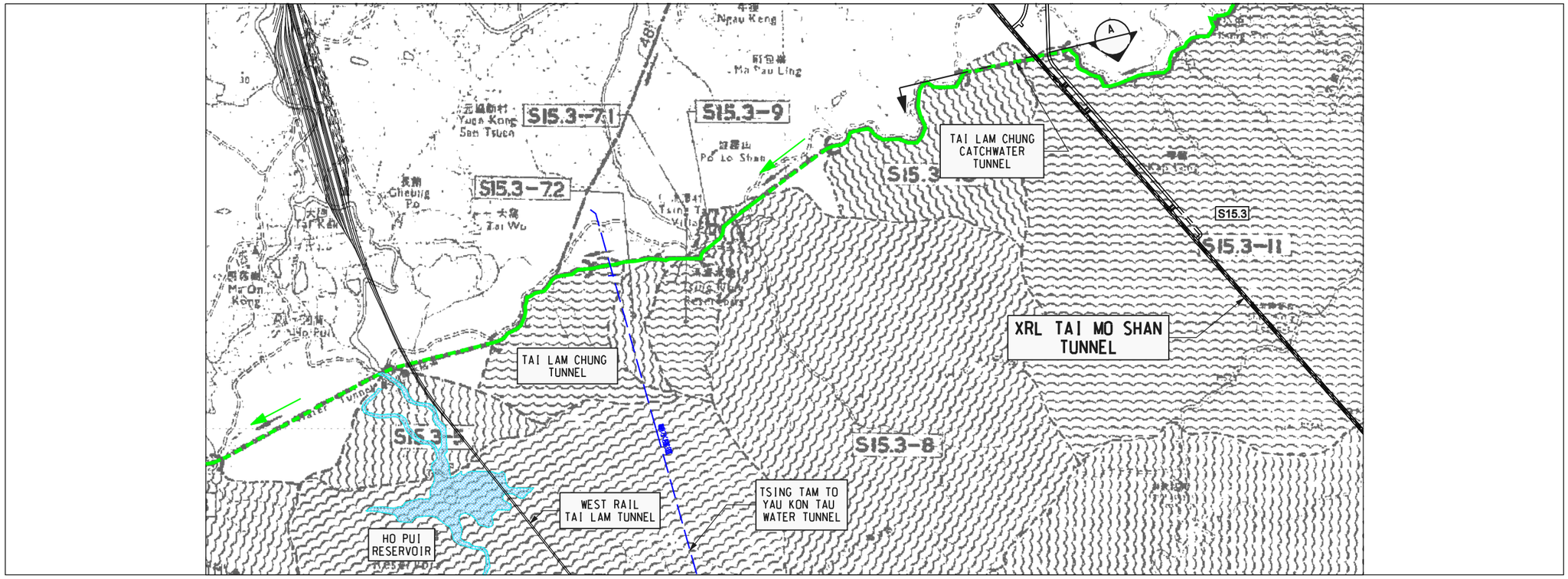
## PAT HEUNG TO SHEK YAM

INTERFACE WITH WSD CATCHMENTS CATCHWATERS AND FACILITIES

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1:20000 (A1) | FIGURE_09 | – |


Indirect Catchment Area for
Tai Lam Chung Reservoir
Indirect Catchment Area for
Shing Mun Reservoir
Granitic
Volcanic
Granitic
SHAM TSENG FAULT ZONE

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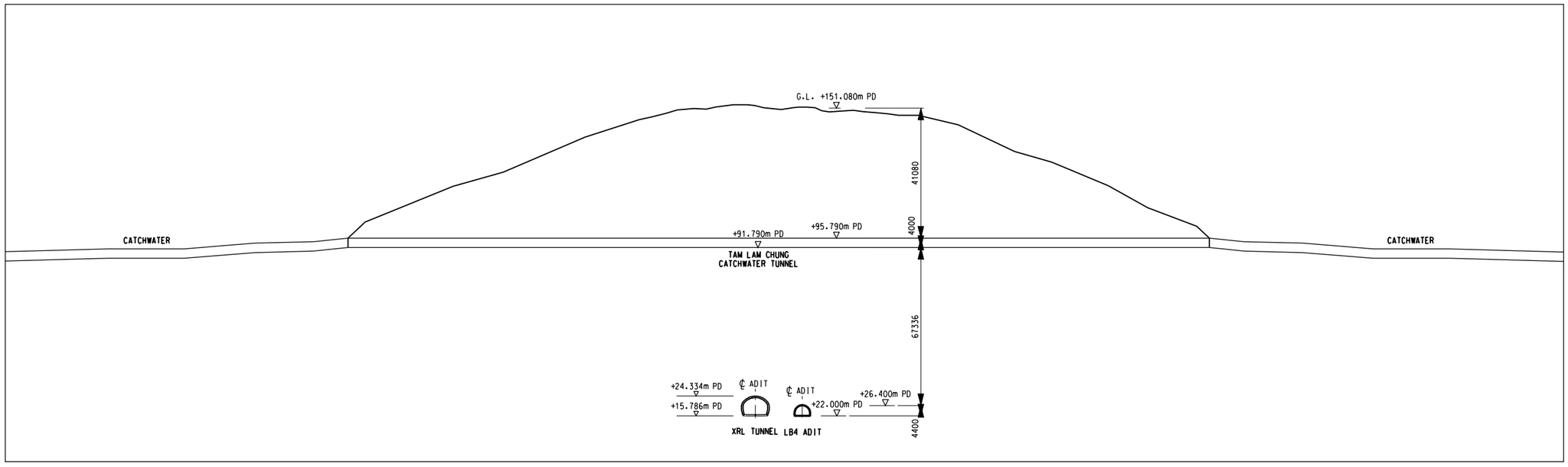



LEGEND:

RESERVOIR

DIRECTION OF FLOW IN CATCHWATER

PLAN
SCALE 1:10000




SECTION A
SCALE 1:1000

0 10 20 30 40 50 METRES 1 : 1000

0 100 200 300 400 500 METRES 1 : 10000

| REV | DESCRIPTION | BY | DATE | APPROVED | REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| DRAWN | VC |
| DESIGNED | TC |
| CHECKED | BM |
| APPROVED | TM |
| DATE | 14/MAY/2009 |

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CADD REF. FIGURE_11.dgn

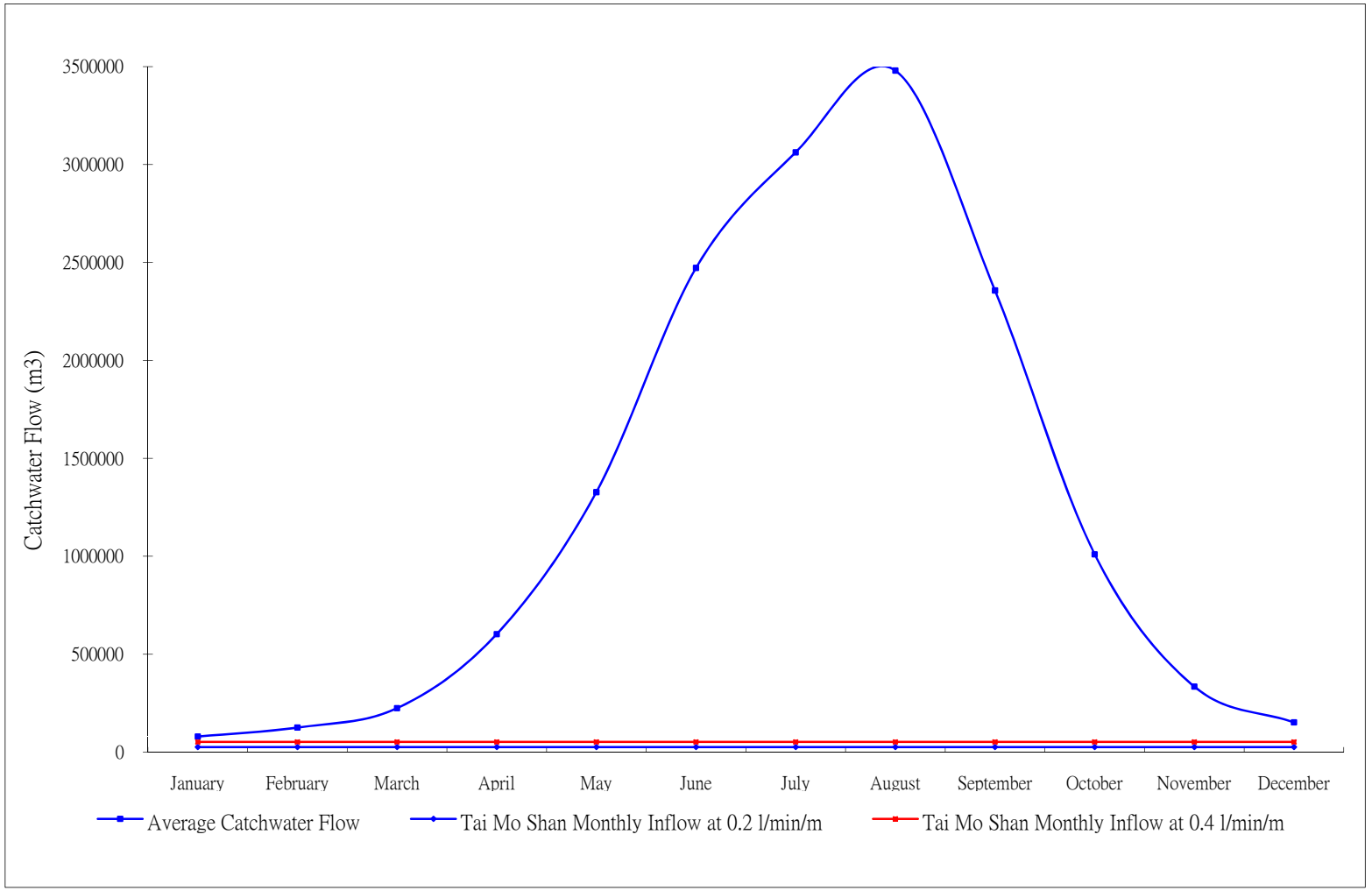
TITLE
CONTRACT 822
PAT HEUNG TO SHEK YAM
INTERFACE WITH TAI LAM CHUNG CATCHWATER TUNNEL

SCALE AS SHOWN (A1)

DRAWING NO. FIGURE_11

REV. –

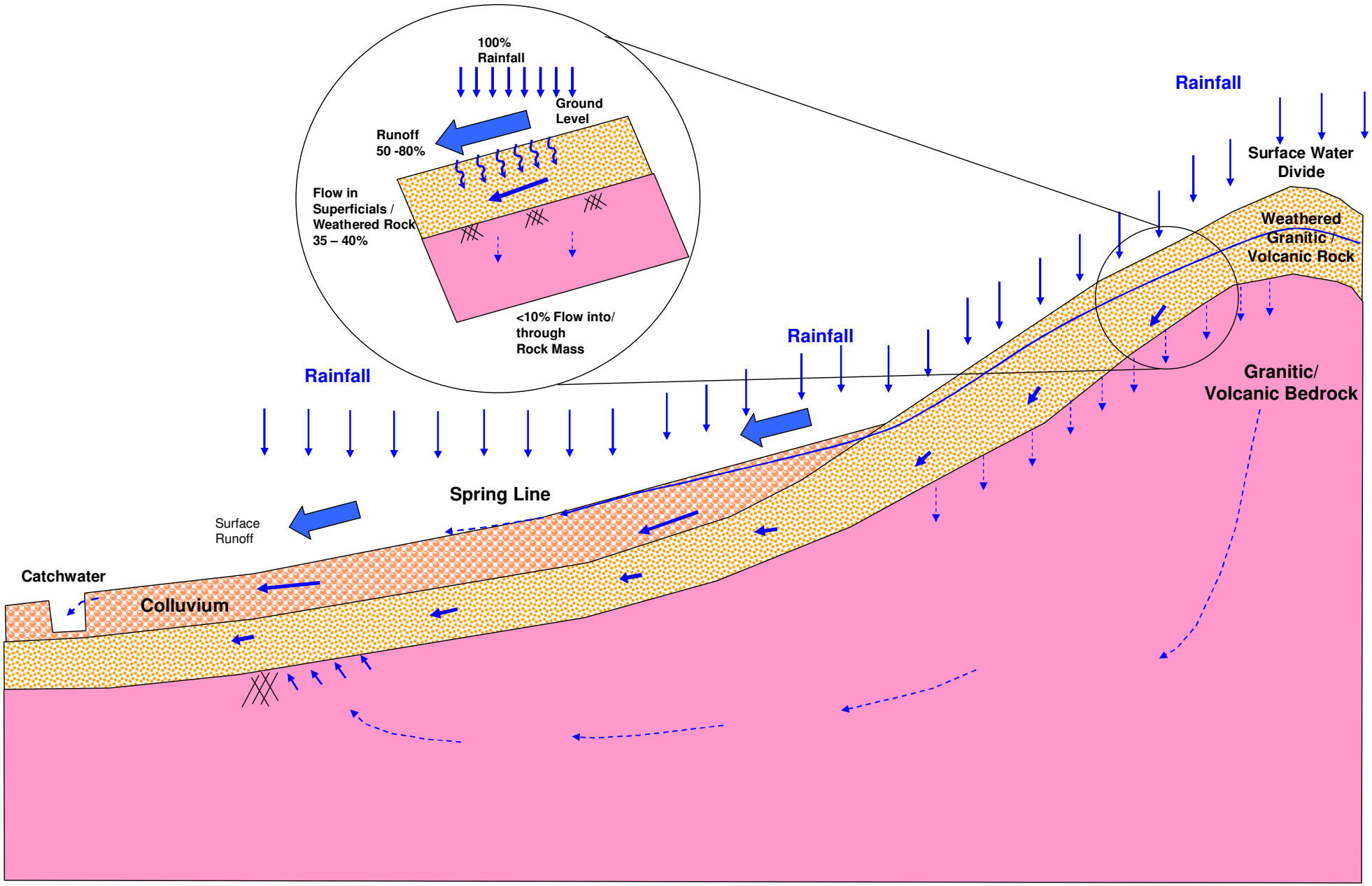
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MODEL NAME: Default PRINTED BY: vinchan 18/05/2009 3:45:13 PM
FILENAME: Z:\03 - CAD\ATK\Report\2009054_095009_822_HIA_Report\FIGURE_11.dgn




**NOTES:**

1. Average Rainfall Data 1997 - 2008 (HKO Records)

2. Average Catchwater Flow 1977 - 2004 (WSD Records)



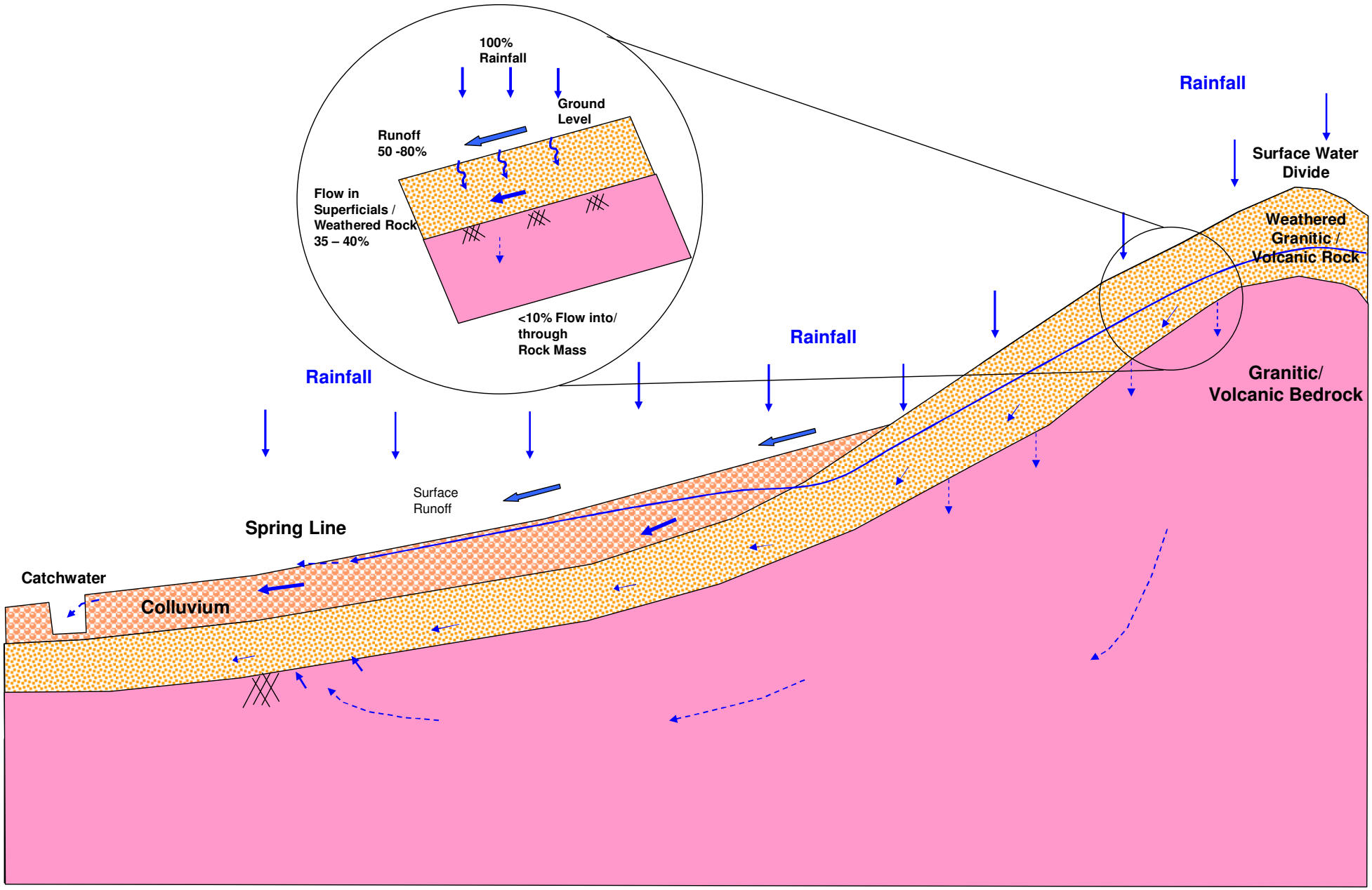

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XRL C802

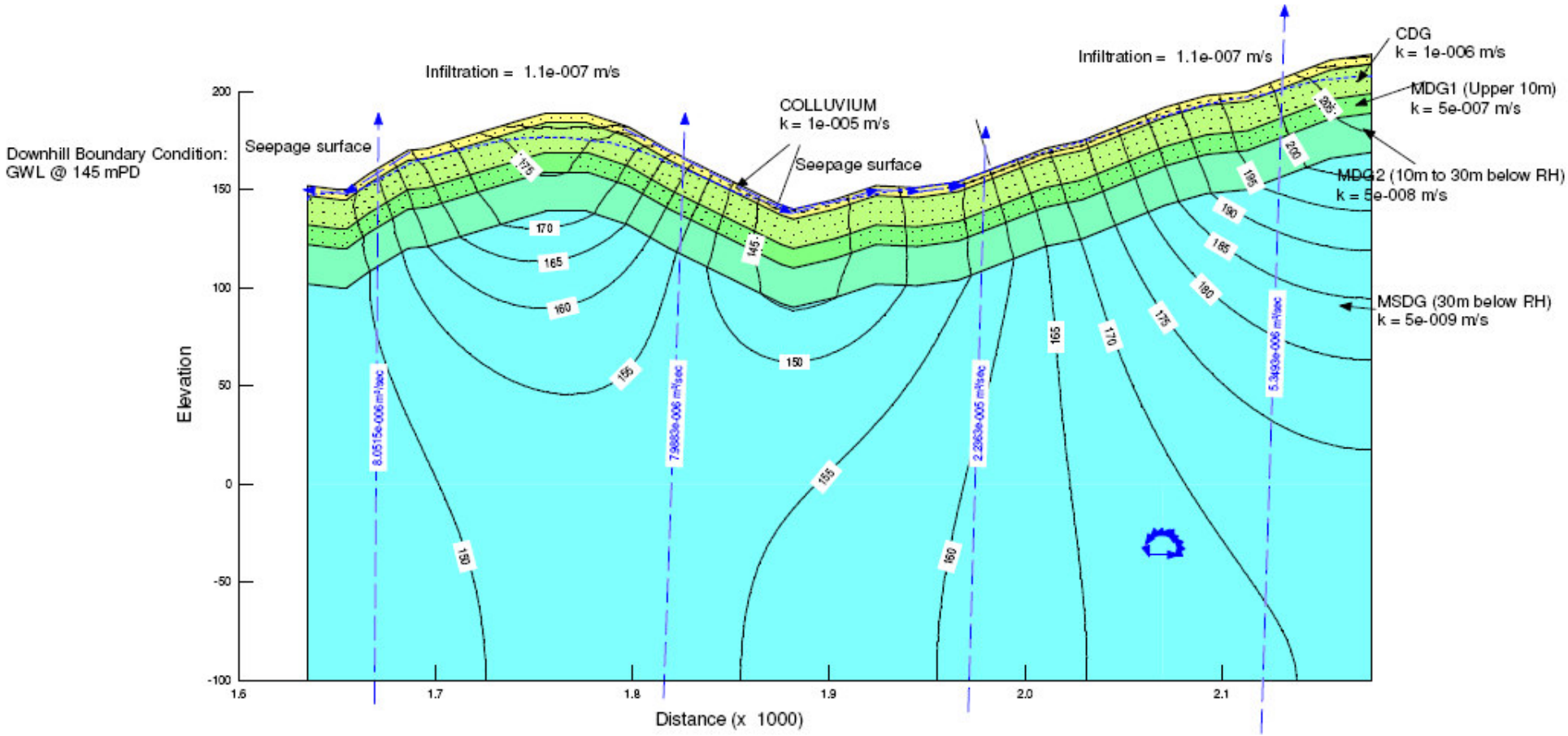
Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

| | | | |
|---|---|---|---|
| Figure Title | Hydrogeology Conceptual Model (Wet Season) | | |
| Figure No | 13 | Date | JUNE 2009 |


100%
Rainfall
Ground
Level
Runoff
50 -80%
Flow in
Superficials /
Weathered Rock
35 – 40%
<10% Flow into/
through
Rock Mass
Rainfall
Rainfall
Rainfall
Surface Water
Divide
Weathered
Granitic /
Volcanic Rock
Granitic/
Volcanic Bedrock
Surface
Runoff
Spring Line
Catchwater
Colluvium
Not To Scale

Title: MTRC - XRL C802 Hydrogeological Analysis
Comments: A-A (scale 1:4000 - Extent: 1624 to 2150)
File Name: A A-Existing_Infiltration(09_05_19)-CDG_iter-1.gsz
Date: 19/05/2009

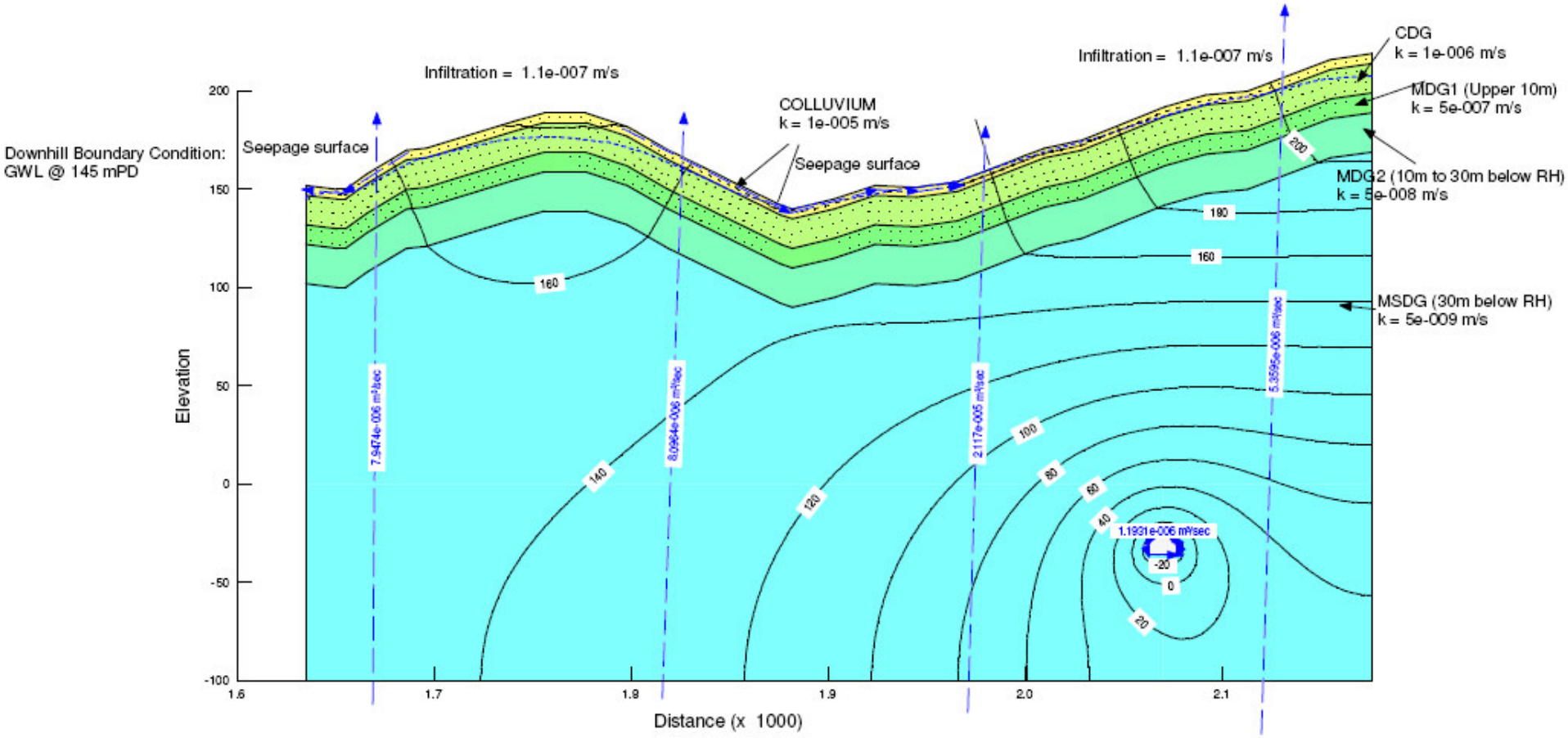
Assumptions: (3 Rock Layers)
1. Model extent from x = 1617 to 2176m
2. Colluvium thickness assumed to be 5m
3. CDG thickness is assumed to be 15m.
4. k values are not finalised (up to 2009-04-29 k database)
5. Left hand boundary assumed to at the base of the reservoir and right hand boundary assumed to be groundwater divide/ no flow boundary.
6. Rainfall infilatration is applied to the high topographic areas.




| | | | |
|---|---|---|---|
| MTR ATKINS Supported by Arup, TFP Farrells, DLS, Knight Frank, BMT, Kenneth NG | Consultancy Agreement No. C802<br>Express Rail Link<br>Detailed Design for Tunnels & Associated Structures (South) | Figure Title | SEEP/W Model No.1 |
| | | Figure No 15 | Date JUNE 2009 |

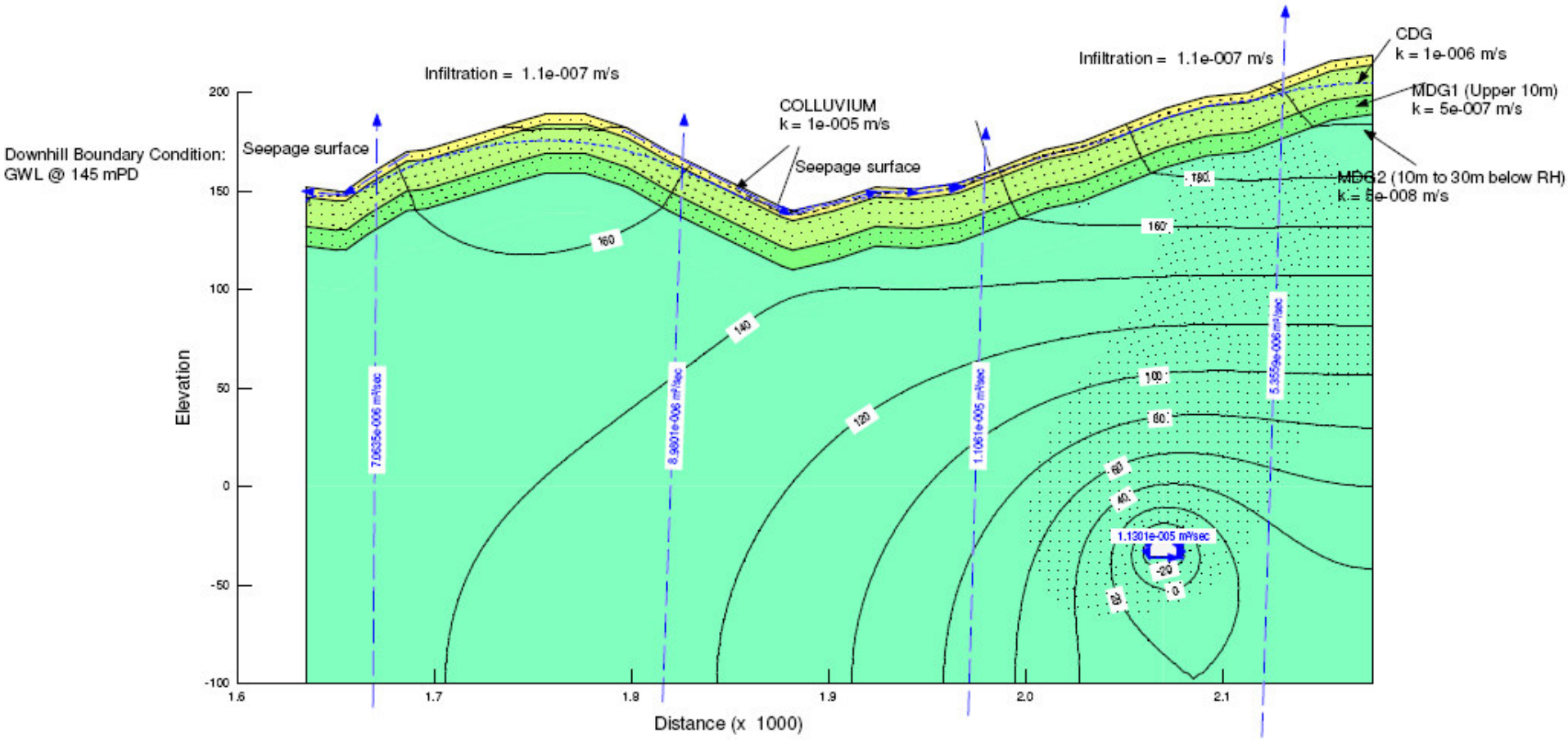
Title: MTRC - XRL C802 Hydrogeological Analysis
Comments: A-A (scale 1:4000 - Extent: 1624 to 2150)
File Name: A A-Tunnel_Infiltration(09_05_19)-CDG_iter-1.gsz
Date: 19/05/2009

Assumptions: (3 Rock Layers)
1. Model extent from x = 1617 to 2176m
2. Colluvium thickness assumed to be 5m
3. CDG thickness is assumed to be 15m.
4. k values are not finalised (up to 2009-04-29 k database)
5. Left hand boundary assumed to at the base of the reservoir and right hand boundary assumed to be groundwater divide/ no flow boundary.
6. Rainfall infilatration is applied to the high topographic areas.



Title: MTRC - XRL C802 Hydrogeological Analysis
Comments: A-A (scale 1:4000 - Extent: 1624 to 2150)
File Name: A A-Tunnel_Infiltration(09_05_19)-MSDG_iter-1.gsz
Date: 19/05/2009

Assumptions: (3 Rock Layers)
1. Model extent from x = 1617 to 2176m
2. Colluvium thickness assumed to be 5m
3. CDG thickness is assumed to be 15m.
4. k values are not finalised (up to 2009-04-29 k database)
5. Left hand boundary assumed to at the base of the reservoir and right hand boundary assumed to be groundwater divide/ no flow boundary.
6. Rainfall infilatration is applied to the high topographic areas.



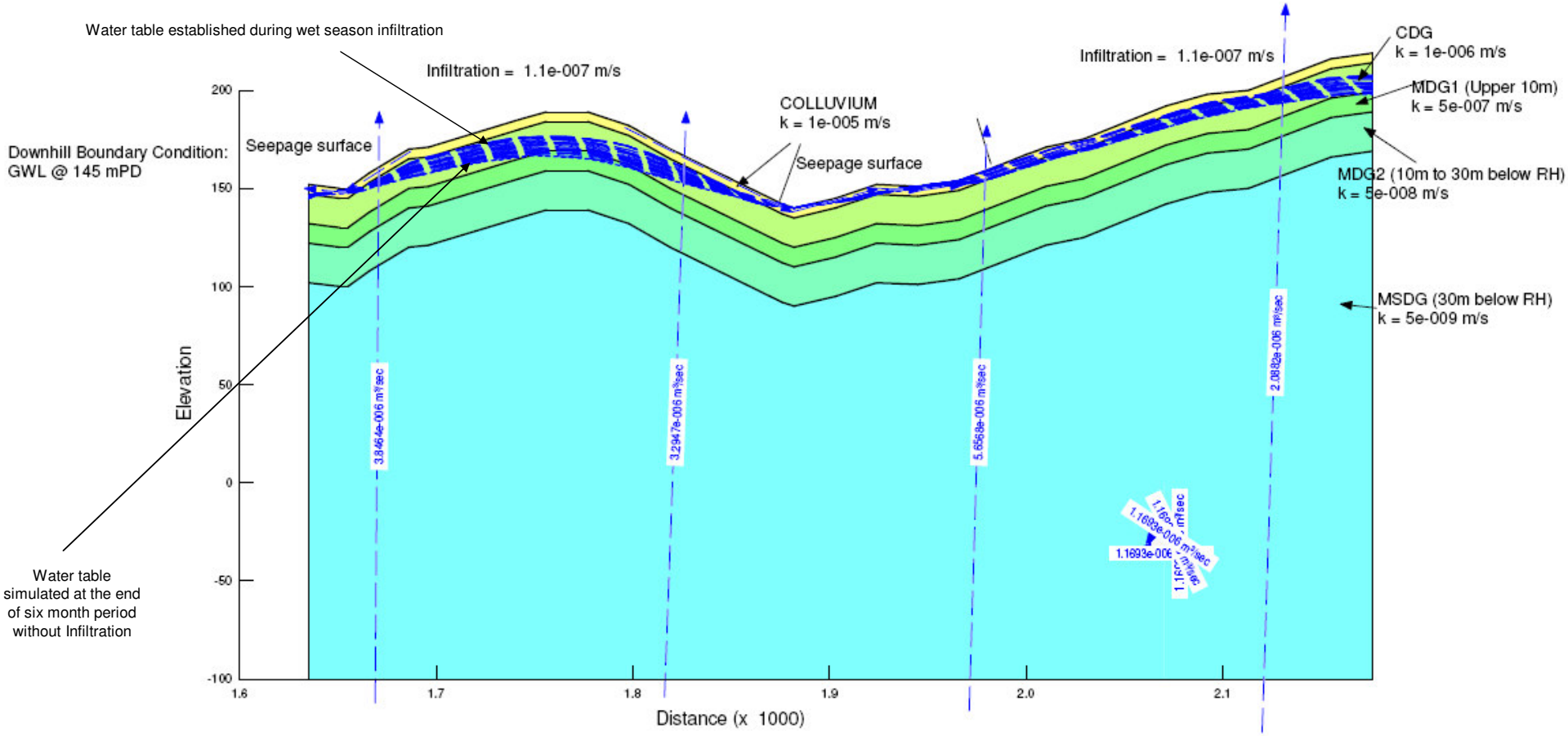

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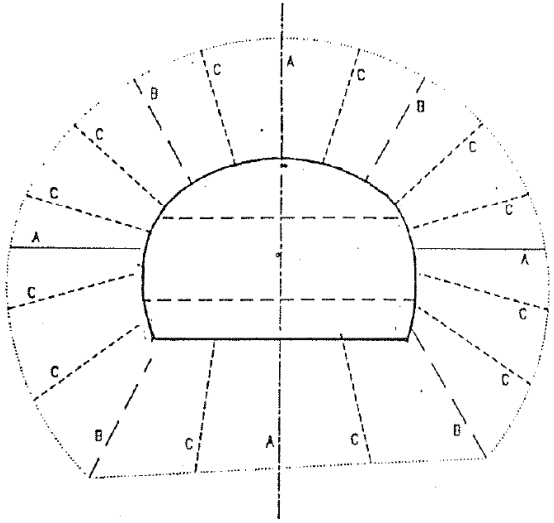
| Figure Title | SEEP/W Model No.3 | |
|---|---|---|
| Figure No | 17 | Date JUNE 2009 |

Title: MTRC - XRL C802 Hydrogeological Analysis
Comments: A-A (scale 1:4000 - Extent: 1624 to 2150)
File Name: Transient_A A-Tunnel_Infiltration(09_05_19)-CDG.gsz
Date: 19/05/2009

Assumptions: (3 Rock Layers)
1. Model extent from x = 1617 to 2176m
2. Colluvium thickness assumed to be 5m
3. CDG thickness is assumed to be 15m.
4. k values are not finalised (up to 2009-04-29 k database)
5. Left hand boundary assumed to at the base of the reservoir and right hand boundary assumed to be groundwater divide/ no flow boundary.
6. Rainfall infilatration is applied to the high topographic areas.




| | | | |
|---|---|---|---|
| MTR ATKINS<br>Supported by<br>Arup, TFP Farrells, DLS, Knight Frank, BMT, Kenneth NG | Consultancy Agreement No. C802<br>Express Rail Link<br>Detailed Design for Tunnels & Associated Structures (South) | Figure Title | SEEP/W Model No.4 |
| | | Figure No 18 | Date JUNE 2009 |

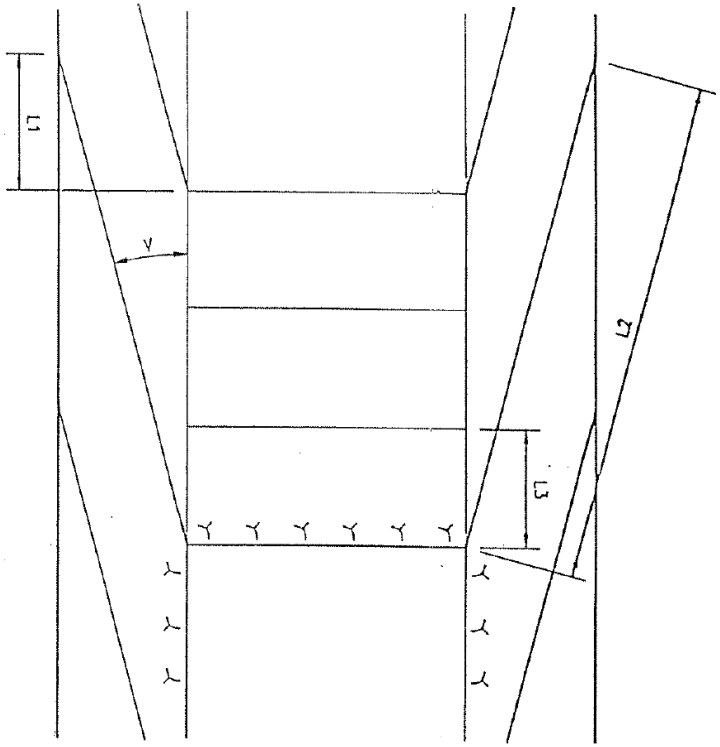



SECTION

A = Probe holes and basic grouting fan

B = Basic grouting fan

C = Additional holes in conductive area only




PLAN

<100 l/min
Grouting method 1

| w/c-ratio | max quantity cement * |
|---|---|
| 3:1 | 100 Kg |
| 2:1 | 200 Kg |
| 1:1 | 200 Kg |
| 0.75:1 | 400 Kg |
| 0.5:1 | to completion |

>100 l/min
Grouting method 2

| w/c-ratio | max quantity cement * |
|---|---|
| 1:1 | 200 Kg |
| 0.75:1 | 400 Kg |
| 0.5:1 | to completion |

* If no significant increase in back pressure

Grouting holes

| L1(m) | L2(m) | L3(m) | V(°) |
|---|---|---|---|
| >6 | 21.6 | 4.9 | 15 |

# APPENDIX A

# DRAFT PART SPECIFICATION FOR WSD INTERFACES

*Water Ingress*

P11.19 Where the tunnel lining is designed as a drained lining, controlling infiltration of groundwater in to tunnels, adits, or caverns during the excavation and lining phase shall be undertaken. The flow of ground water into the drained completed lining system shall be limited to ensure that potentially damaging impacts of groundwater drawdown do not occur and to ensure that the final inflows into the tunnel drains are within limits associated with the capacity of the drainage system. The contractor shall demonstrate in a timely manner that within section of the tunnels the following criteria are complied with :

I) Drawdown of the water table is consistent with the limits of this contract;

II) That any observed drawdown and predicted final drawdown will not induce unacceptable ground movement, have any adverse impact on habitats or reduce recharge to WSD impounding reservoirs;

III) That effective contingency measures are available and if appropriate already in place; and

IV) That the contact limits for final inflow to the completed tunnel will not be exceeded.

The requirements of this Specification with respect to the maximum allowable inflow rate into a probe hole, tunnel, adit or cavern during the excavation phase may be relaxed at the discretion of the Engineer. Any relaxation to the criteria shall only be granted on the basis of a comprehensive package of monitoring data, including inflow data, piezometric response, settlement data (where applicable) and interpreted presentation of the encountered geological conditions. The package should demonstrate how the requirements listed above are achieve however no such relaxation is guaranteed to be granted by the Engineer.

P11.20 Drilling plant shall be fitted with measure while drilling equipment and this data shall be used by the contractor to update and develop the geological model. The information shall be used to ensure that an up to dated geological interpretation is available at all times to form a basis for decision making in relation to the grouting works.

*Water Ingress - Probehole Criteria*

P11.21 Probe drilling shall be carried out ahead of all excavated face at all times, the drill patterns shall consist of a minimum of 3 holes but increasing to 6 where the rock mass deteriorates or where large amount of water are identified. The probe holes shall be in accordance with the requirements of the M&W specification and shall be a minimum of 20m in length.

P11.22 Where water flowing from a probe hole drilled ahead of the face exceeds 5 l/min (for a single probe hole) or a total of 10 l/min (for more than one probehole), measured over a minimum of 20m length and measured a minimum of 1 hour after termination of drilling, pre excavation grouting shall be undertaken until the criteria has been achieved.

P11.23 The probehole inflow grouting criteria shall be constantly reviewed and adjusted upwards or downwards as necessary, in accordance with **Clause P1.1** and subject to Approval as experience is gained during the tunnel and cavern excavation. The Contractor shall establish the probing requirements taking account of the excavation sequence, number of probeholes tunnel size and other variables. However, the probehole criteria shall be set so as to minimise the possibility of a requirement for post excavation grouting and to ensure that the criteria for inflow to the completed tunnel is complied with.

*Water Ingress - Post Excavation Criteria*

P11.24 Following excavation and prior to construction of the final tunnel lining the cumulative water inflows over a 25 metres length of completed tunnel excavation shall be measured. Where this value exceeds 50 litres/minute post excavation grouting shall be undertaken until the criteria have been achieved and construction of the tunnel final lining can commence.

P11.25 The post excavation criteria shall not be relied upon to determine compliance with the final inflow criteria, which shall be assessed separately and controlled primarily via the probehole criteria

P11.26 A system of V-notch weirs or similar measures shall be installed along the tunnel, cavern or adit to confirm compliance with the post excavation inflow criteria.

*Water Ingress - Final Inflow Criteria*

P11.27 For the completed (lined) tunnel, the water inflows shall not exceed 400l/min for 1000m of completed tunnel.

P11.28 Ongoing assessment of the pre final lining residual inflows shall be maintained and examined, and the probehole criteria and post excavation criteria adjusted as necessary, subject to Approval.

P11.29 The required system of V-notch weirs or similar measures shall also be used to assess compliance with the final inflow criteria.

*Water Ingress - Submissions*

P11.30 The Contractor shall propose a grouting regime to the Engineer for Approval. This shall include the following :

Pre-Excavation Grouting

a. The number, pattern, orientation, diameter, length of probeholes ahead of the face, for the range of ground conditions that will require grouting.

b. The method of grout injection, the number, pattern, orientation, diameter, length of grout holes, the grout mix and mixing method for the range of ground conditions that will require grouting. List of plant to be used.

c. Details of related procedures including the proposed ‘stop criteria’ which shall be used to assess when grouting should be ceased in a grout hole

d. Number and layout of grout check holes.

e. Procedures shall be detailed to be adopted in the event that very poor rock mass conditions are encountered close to the face. The equipment and materials for such works shall be available on site at all times.

Post Excavation Grouting

d. Details of post-excavation grouting shall vary according to the specific conditions which shall be considered on a case by case basis. However generic designs shall be developed and shall include method of grout injection, the number, pattern, orientation, diameter, length of grout holes, the grout mix and mixing method for the range of ground conditions that will require grouting. List of plant to be used.

P11.31 Procedures

Site procedures for the implementation of the grouting works shall be developed by the contractor for Approval. The document shall demonstrate a co-ordinated and integrated team with flow of information and clear decision making roles.

*Records*

P11.32 The Contractor's tunnelling records shall include quantified assessments of water inflow from probeholes. The inflows shall be recorded at intervals and the lapsed time since drilling of the probehole recorded. The length and diameter position of the probehole shall be stated together with the number of other probeholes drilled ahead of the face at the time.

P11.33 Quantitative records of post excavation inflows shall also be maintained. The location of inflows from the face, from unlined excavations including from the crown, sidewall and invert shall also be recorded.

P11.34 Background levels of water inflow shall be established to aid the identification of higher inflows. Zones of water inflow above the background level shall be identified and quantified and related to geological features.

# APPENDIX B

# TUNNEL INFLOW PREDICTIONS

Inflow Assessment Model - includes geological features

Information of XRL Tai Mo Shan Tunnels 7550 m

Catchment

| | | | |
|---|---|---|---|
| Length of Tai Mo Shan Tunnels within Indirect Catchment of Tai Lam Chung Reservoir | = | 2100 m | (XRL Chainage from 126+000 to 128+100) |
| Length of Tai Mo Shan Tunnels within Indirect Catchment of Shing Mun Reservoir | = | 3520 m | (XRL Chainage from 128+100 to 131+600) |

| Total Inflow | L/min | L/min/m |
|---|---|---|
| Goodman | 12,717 | 1.68 |
| Heuer | 12,702 | 1.68 |
| IMS Initial (Average) | 6,017 | 0.80 |
| IMS final (Average) | 3,363 | 0.45 |

Inflow within Tai Lam Chung Reservoir Catchment

| | L/min | L/min/m |
|---|---|---|
| Goodman | 3078 | 1.47 |
| Heuer | 3074 | 1.46 |
| IMS Initial (Average) | 1672 | 0.80 |
| IMS final (Average) | 904 | 0.43 |

Inflow within Shing Mun Reservoir Catchment

| | L/min | L/min/m |
|---|---|---|
| Goodman | 6106 | 1.73 |
| Heuer | 6099 | 1.73 |
| IMS Initial (Average) | 2825 | 0.80 |
| IMS final (Average) | 1739 | 0.49 |

| | Sheet No. 1 of 6 | Rev. | Job No. |
|---|---|---|---|
| | Chainage 125450 to 126643 | | |

| Job Title: | XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |
|---|---|---|---|---|---|---|---|

Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 125450 | 125510 | 125570 | 125600 | 125630 | 125644 | 125648 | 125690 | 125709 | 125712 | 125750 | 125810 | 125860 | 125875 | 125930 | 125990 | 126000 | 126050 | 126110 | 126170 | 126174 | 126230 | 126290 | 126350 | 126410 | 126470 | 126530 | 126590 | 126595 | 126613 | Tunnel Length |
| To (m) | 125510 | 125570 | 125600 | 125630 | 125644 | 125648 | 125690 | 125709 | 125712 | 125750 | 125810 | 125860 | 125875 | 125930 | 125990 | 126000 | 126050 | 126110 | 126170 | 126174 | 126230 | 126290 | 126350 | 126410 | 126470 | 126530 | 126590 | 126595 | 126613 | 126643 | 1193 |
| Length (m) | 60 | 60 | 30 | 30 | 14 | 4 | 42 | 19 | 3 | 38 | 60 | 50 | 15 | 55 | 60 | 10 | 50 | 60 | 60 | 4 | 56 | 60 | 60 | 60 | 60 | 60 | 60 | 5 | 18 | 30 | Average Values |
| Feature / BH No. | | | | | | f20 | D383 (2) | D384 (2) | | | | | f19 | | | | | | D382 (2) | | | | | | | | D381 (3) | | | f18 | |
| Rock type/ feature type | Jmt | Jmt | Jmt | Jmt | Jmt | Basalt Dyke | Jmt | Jmt | Dacite Dyke | Jmt | Jmt | Jmt | Inferred Fault | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Shear Zone | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | ntact of Jmt/Uts | |
| Water Level above tunnel (m) | 22.45 | 44.49 | 61.04 | 63.72 | 63.72 | 63.72 | 63.72 | 76.90 | 92.06 | 92.06 | 92.06 | 94.77 | 94.77 | 101.35 | 108.59 | 113.04 | 101.23 | 101.23 | 108.20 | 105.07 | 105.07 | 87.68 | 86.22 | 95.60 | 113.61 | 115.12 | 115.87 | 112.08 | 112.08 | 112.08 | 90.65 |
| WL above rock head (m) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | |
| Thickness of Rock Cover (m) | 17.45 | 39.49 | 56.04 | 58.72 | 58.72 | 58.72 | 58.72 | 71.90 | 87.06 | 87.06 | 87.06 | 89.77 | 89.77 | 96.35 | 103.59 | 108.04 | 96.23 | 96.23 | 103.20 | 100.07 | 100.07 | 82.68 | 81.22 | 90.60 | 108.61 | 110.12 | 110.87 | 107.08 | 107.08 | 107.08 | |
| Permeability (m/s) | 5.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 5.0E-08 | 5.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 5.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-06 | 2.00E-07 |
| Tunnel Radius | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 9.93 |
| IMS Rock Class | 2 | 1 | 1 | 1 | 1 | 4 | 2 | 2 | 4 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 | 1.70 |
| Vent Adit/ Single Track | ST | ST | ST | ST | | | | | | | | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | |
| Horizontal Distance to (sf) | 80 | 60 | 30 | 30 | 30 | 30 | 35 | 10 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 50 | 30 | 30 | 0 | |
| *Head Factor* | *0.224493* | *0.444936836* | *0.610413442* | *0.637152763* | *0.637152763* | *0.637152763* | *0.637152763* | *0.763904811* | *0.920573097* | *0.920573097* | *0.920573097* | *0.947720308* | *0.947720308* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0.876841* | *0.862153* | *0.95596578* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *Horizontal Separation* | *0.552786* | *0.612701665* | *0.726138721* | *0.726138721* | *0.726138721* | *0.726138721* | *0.704196011* | *0.84188612* | *1* | *1* | *1* | *1* | *1* | *0.704196011* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0.841886117* | *0.841886117* | *1* | *0.646447* | *0.726139* | *0.726138721* | *1* | |
| *R* | *0.086868* | *0.190829478* | *0.310271385* | *0.323862905* | *0.323862905* | *0.323862905* | *0.314076304* | *0.45321565* | *0.644401168* | *0.644401168* | *0.644401168* | *0.663404216* | *0.663404216* | *0.492937208* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.613789* | *0.603507* | *0.563370023* | *0.589320282* | *0.1* | *0.452513* | *0.508297* | *0.508297105* | *0.7* | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | 20.34 | 4.88 | 2.86 | 2.93 | 1.19 | 34.11 | 17.91 | 9.12 | 32.43 | 4.11 | 6.49 | 6.40 | 192.13 | 7.35 | 8.38 | 1.43 | 6.67 | 8.01 | 41.78 | 54.68 | 7.65 | 7.33 | 7.25 | 7.73 | 8.62 | 8.70 | 8.74 | 42.75 | 2.56 | 427.45 | **992** l/min |
| **Heuer / Raymer Eqn** | 20.31 | 4.87 | 2.86 | 2.93 | 1.19 | 34.07 | 17.89 | 9.11 | 32.40 | 4.10 | 6.48 | 6.40 | 191.91 | 7.34 | 8.37 | 1.43 | 6.67 | 8.00 | 41.74 | 54.61 | 7.65 | 7.32 | 7.24 | 7.72 | 8.61 | 8.69 | 8.73 | 42.70 | 2.56 | 426.97 | **991** l/min |
| **Factored Heuer/Raymer** | 2.54 | 0.61 | 0.36 | 0.37 | 0.15 | 4.26 | 2.24 | 1.14 | 4.05 | 0.51 | 0.81 | 0.80 | 23.99 | 0.92 | 1.05 | 0.18 | 0.83 | 1.00 | 5.22 | 6.83 | 0.96 | 0.91 | 0.91 | 0.96 | 1.08 | 1.09 | 1.09 | 5.34 | 0.32 | 53.37 | **124** l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 7.3 | 6.9 | 5.6 | 5.8 | 2.7 | 47.9 | 18.5 | 12.1 | 71.5 | 14.7 | 23.2 | 19.9 | 366.2 | 16.3 | 25.2 | 4.2 | 21.0 | 25.2 | 58.8 | 103.6 | 23.5 | 22.1 | 21.7 | 20.3 | 21.2 | 3.6 | 16.3 | 31.0 | 5.5 | 777.0 | 1800.8 l/min |
| *Average* | 5.5 | 5.2 | 4.2 | 4.4 | 2.0 | 31.1 | 13.9 | 9.0 | 46.4 | 11.0 | 17.4 | 14.9 | 238.8 | 12.2 | 18.9 | 3.2 | 15.8 | 18.9 | 44.1 | 67.2 | 17.6 | 16.6 | 16.3 | 15.2 | 15.9 | 2.7 | 12.2 | 16.6 | 4.1 | 504.0 | **1205.3 l/min** |
| *Low* | 3.6 | 3.4 | 2.8 | 2.9 | 1.4 | 14.2 | 9.2 | 6.0 | 21.3 | 7.3 | 11.6 | 10.0 | 109.5 | 8.1 | 12.6 | 2.1 | 10.5 | 12.6 | 29.4 | 30.8 | 11.8 | 11.0 | 10.9 | 10.1 | 10.6 | 1.8 | 8.1 | 2.3 | 2.7 | 231.0 | 609.8 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 0.6 | 1.3 | 1.7 | 1.9 | 0.9 | 15.5 | 5.8 | 5.5 | 46.1 | 9.5 | 14.9 | 13.2 | 244.3 | 8.0 | 17.6 | 2.9 | 14.7 | 17.6 | 41.2 | 72.5 | 16.5 | 13.6 | 13.1 | 11.4 | 12.5 | 0.4 | 7.4 | 15.8 | 2.8 | 543.9 | 1173.1 l/min |
| *Average* | 0.5 | 1.0 | 1.3 | 1.4 | 0.7 | 10.1 | 4.4 | 4.1 | 29.9 | 7.1 | 11.2 | 9.9 | 158.4 | 6.0 | 13.2 | 2.2 | 11.0 | 13.2 | 30.9 | 47.0 | 12.3 | 10.2 | 9.8 | 8.6 | 9.4 | 0.3 | 5.5 | 8.5 | 2.1 | 352.8 | **783.0 l/min** |
| *Low* | 0.3 | 0.7 | 0.9 | 0.9 | 0.4 | 4.6 | 2.9 | 2.7 | 13.7 | 4.7 | 7.5 | 6.6 | 72.6 | 4.0 | 8.8 | 1.5 | 7.4 | 8.8 | 20.6 | 21.6 | 8.2 | 6.8 | 6.6 | 5.7 | 6.3 | 0.2 | 3.7 | 1.2 | 1.4 | 161.7 | 392.9 l/min |

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 . k . (z + h1) \pi}{2.3 \log (r / 2z)}$ *

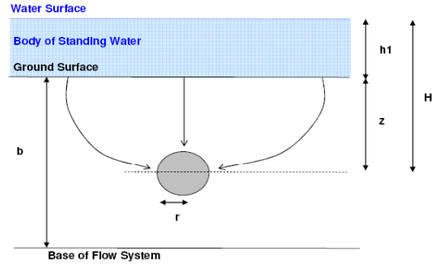
*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 . \pi . k . H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)

* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

**Goodmans Model Definition**



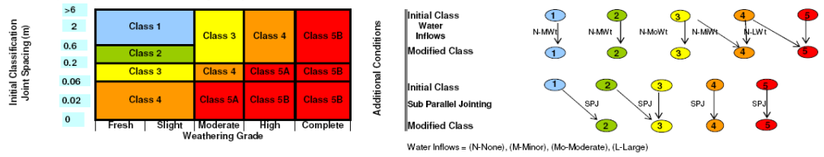

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| IMS - | 101 | Initial |
| | 66 | Final |
| Goodman - | 83 | |
| Heuer / Raymer - | 83 | |
| Factored Heuer / Raymer - | 10 | |

IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**







Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | |
|---|---|---|---|---|---|
| | Sheet No. 2 of 6 | | Rev. | | Job No. |
| | Chainage 126643 to 128485 | | | | |
| Job Title: XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: 13-May-09 |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 126643 | 126650 | 126710 | 126770 | 126830 | 126890 | 126900 | 126975 | 127010 | 127050 | 127070 | 127130 | 127190 | 127250 | 127310 | 127365 | 127400 | 127450 | 127475 | 127520 | 127610 | 127710 | 127810 | 127910 | 128010 | 128110 | 128210 | 128310 | 128410 | 128460 | | | |
| To (m) | *126650* | *126710* | *126770* | *126830* | *126890* | *126900* | *126975* | *127010* | *127050* | *127070* | *127130* | *127190* | *127250* | *127310* | *127365* | *127400* | *127450* | *127475* | *127520* | *127610* | *127710* | *127810* | *127910* | *128010* | *128110* | *128210* | *128310* | *128410* | *128460* | *128485* | | | |
| Length (m) | *7* | *60* | *60* | *60* | *60* | *10* | *75* | *35* | *40* | *20* | *60* | *60* | *60* | *60* | *55* | *35* | *50* | *25* | *45* | *90* | *100* | *100* | *100* | *100* | *100* | *100* | *100* | *100* | *50* | *25* | | | |
| Feature / BH No. | | | | | | | f17 | f17 | f17 | | | | | | | | | f16 | | | | | | | | | | | | f15 | | | |
| Rock type | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Sham Tseng Fault zone* | *Sham Tseng Fault zone* | *Sham Tseng Fault zone* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | | | *Fault zone* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *contact of Jts/Jty* | | | |
| Water Level above tunnel (m) | 112.08 | 127.86 | 158.45 | 183.06 | 199.75 | 230.62 | 230.62 | 239.32 | 219.23 | 219.23 | 240.41 | 239.13 | 257.27 | 278.46 | 307.47 | 325.93 | 335.93 | 343.87 | 370.58 | 370.58 | 412.95 | 479.00 | 536.53 | 581.87 | 610.86 | 597.18 | 572.05 | 547.69 | 500.73 | 500.73 | | | |
| WL above rock head (m) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | | | |
| Thickness of Rock Cover (m) | 107.08 | 122.86 | 153.45 | 178.06 | 194.75 | 225.62 | 225.62 | 234.32 | 214.23 | 214.23 | 235.41 | 234.13 | 252.27 | 273.46 | 302.47 | 320.93 | 330.93 | 338.87 | 365.58 | 365.58 | 407.95 | 474.00 | 531.53 | 576.87 | 605.86 | 592.18 | 567.05 | 542.69 | 495.73 | 495.73 | | | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | | | |
| Tunnel Radius | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | | |
| IMS Rock Class | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | | | |
| Vent Adit/ Single Track | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | | | | | | | | | | | | | | | | | | | | | | | | | |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | | | |
| Horizontal Distance to (sf) | 10 | 10 | 80 | 120 | 120 | 120 | 100 | 35 | 0 | 0 | 0 | 0 | 50 | 30 | 60 | 30 | 20 | 0 | 65 | 15 | 10 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | | | |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | |
| *Horizontal Separation* | *0.841886117* | *0.841886* | *0.552786* | *0.452277* | *0.452277* | *0.452277442* | *0.5* | *0.704196011* | *1* | *1* | *1* | *1* | *0.646446609* | *0.726138721* | *0.612702* | *0.726139* | *0.776393* | *1* | *0.596887* | *0.806351* | *0.841886* | *1* | *1* | *1* | *0.776393* | *1* | *1* | *1* | *1* | *1* | | | |
| *R* | *0.589320282* | *0.58932* | *0.38695* | *0.316594* | *0.316594* | *0.31659421* | *0.35* | *0.070419601* | *0.7* | *0.7* | *0.7* | *0.7* | *0.452512627* | *0.508297105* | *0.428891* | *0.508297* | *0.543475* | *0.7* | *0.417821* | *0.564446* | *0.58932* | *0.7* | *0.7* | *0.7* | *0.543475* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Goodman Eqn | 1.00 | 9.32 | 10.78 | 11.92 | 12.68 | 2.34 | 1757.60 | 8.43 | 8.04 | 4.02 | 12.94 | 12.88 | 13.62 | 14.47 | 14.31 | 9.53 | 13.93 | 709.51 | 13.54 | 27.08 | 32.75 | 36.83 | 40.31 | 43.02 | 44.73 | 43.93 | 42.44 | 40.98 | 19.08 | 953.83 | 0.00 | 0.00 | 0.00 |
| Heuer / Raymer Eqn | 1.00 | 9.31 | 10.77 | 11.91 | 12.67 | 2.34 | 1755.62 | 8.42 | 8.04 | 4.02 | 12.92 | 12.87 | 13.60 | 14.45 | 14.30 | 9.52 | 13.92 | 708.72 | 13.52 | 27.05 | 32.72 | 36.79 | 40.27 | 42.97 | 44.68 | 43.88 | 42.39 | 40.94 | 19.06 | 952.76 | 0.00 | 0.00 | 0.00 |
| Factored Heuer/Raymer | 0.12 | 1.16 | 1.35 | 1.49 | 1.58 | 0.29 | 219.45 | 1.05 | 1.00 | 0.50 | 1.62 | 1.61 | 1.70 | 1.81 | 1.79 | 1.19 | 1.74 | 88.59 | 1.69 | 3.38 | 4.09 | 4.60 | 5.03 | 5.37 | 5.59 | 5.48 | 5.30 | 5.12 | 2.38 | 119.09 | 0.00 | 0.00 | 0.00 |
| IMS - Initial Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *High* | 2.5 | 21.2 | 13.9 | 11.4 | 11.4 | 1.9 | 971.3 | 1.5 | 16.8 | 8.4 | 25.2 | 25.2 | 16.3 | 18.3 | 14.2 | 10.7 | 16.3 | 647.5 | 11.3 | 30.5 | 35.4 | 42.0 | 42.0 | 42.0 | 32.6 | 42.0 | 42.0 | 42.0 | 21.0 | 647.5 | 0.0 | 0.0 | 0.0 |
| *Average* | 1.9 | 15.9 | 10.4 | 8.5 | 8.5 | 1.4 | 630.0 | 1.1 | 12.6 | 6.3 | 18.9 | 18.9 | 12.2 | 13.7 | 10.6 | 8.0 | 12.2 | 420.0 | 8.5 | 22.9 | 26.5 | 31.5 | 31.5 | 31.5 | 24.5 | 31.5 | 31.5 | 31.5 | 15.8 | 420.0 | 0.0 | 0.0 | 0.0 |
| *Low* | 1.2 | 10.6 | 7.0 | 5.7 | 5.7 | 0.9 | 288.8 | 0.7 | 8.4 | 4.2 | 12.6 | 12.6 | 8.1 | 9.1 | 7.1 | 5.3 | 8.2 | 192.5 | 5.6 | 15.2 | 17.7 | 21.0 | 21.0 | 21.0 | 16.3 | 21.0 | 21.0 | 21.0 | 10.5 | 192.5 | 0.0 | 0.0 | 0.0 |
| IMS - Final Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *High* | 1.5 | 12.5 | 5.4 | 3.6 | 3.6 | 0.6 | 339.9 | 0.1 | 11.8 | 5.9 | 17.6 | 17.6 | 7.4 | 9.3 | 6.1 | 5.4 | 8.9 | 453.3 | 4.7 | 17.2 | 20.8 | 29.4 | 29.4 | 29.4 | 17.7 | 29.4 | 29.4 | 29.4 | 14.7 | 453.3 | 0.0 | 0.0 | 0.0 |
| *Average* | 1.1 | 9.4 | 4.0 | 2.7 | 2.7 | 0.5 | 220.5 | 0.1 | 8.8 | 4.4 | 13.2 | 13.2 | 5.5 | 7.0 | 4.6 | 4.1 | 6.6 | 294.0 | 3.5 | 12.9 | 15.6 | 22.1 | 22.1 | 22.1 | 13.3 | 22.1 | 22.1 | 22.1 | 11.0 | 294.0 | 0.0 | 0.0 | 0.0 |
| *Low* | 0.7 | 6.3 | 2.7 | 1.8 | 1.8 | 0.3 | 101.1 | 0.1 | 5.9 | 2.9 | 8.8 | 8.8 | 3.7 | 4.7 | 3.0 | 2.7 | 4.4 | 134.8 | 2.4 | 8.6 | 10.4 | 14.7 | 14.7 | 14.7 | 8.9 | 14.7 | 14.7 | 14.7 | 7.4 | 134.8 | 0.0 | 0.0 | 0.0 |

**Totals**

| | |
|---|---|
| **Tunnel Length** | |
| | 1842 |
| **Average Values** | |
| | 344.32 |
| | 1.09E-07 |
| | 8.07 |
| | 1.30 |

| | | |
|---|---|---|
| **Initial Water Inflow** | | |
| 3,966 | l/min | |
| 3,961 | l/min | |
| 495 | l/min | |
| **Initial Water Inflow** | | |
| 2864.1 | l/min | |
| **1918.4** | **l/min** | |
| 972.7 | l/min | |
| **Final Water Inflow** | | |
| 1615.2 | l/min | |
| **1085.1** | **l/min** | |
| 555.0 | l/min | |

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

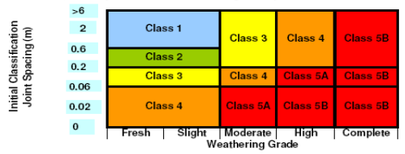
*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

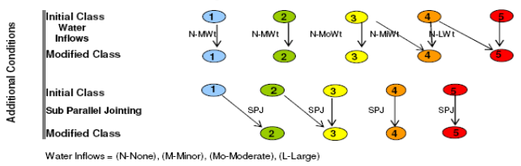
q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

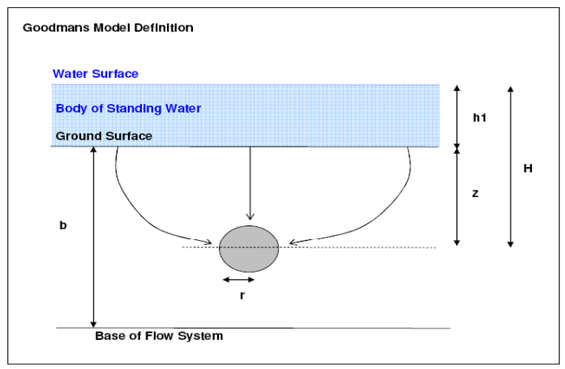
**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)




**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **104** | **Initial** |
| | **59** | **Final** |
| **Goodman -** | **215** | |
| **Heuer / Raymer -** | **215** | |
| **Factored Heuer / Raymer -** | **27** | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sheet No. 3 of 6 | | Rev. | | Job No. | |
| | | Chainage 128485 to 130870 | | | | | |
| Job Title: | XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Totals** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 128485 | 128510 | 128610 | 128710 | 128810 | 128910 | 129010 | 129110 | 129170 | 129195 | 129290 | 129370 | 129470 | 129570 | 129670 | 129695 | 129770 | 129870 | 129950 | 129965 | 129970 | 130070 | 130170 | 130210 | 130230 | 130270 | 130370 | 130470 | 130570 | 130580 | 130595 | 130670 | 130770 | 130870 | **Tunnel Length** |
| To (m) | *128510* | *128610* | *128710* | *128810* | *128910* | *129010* | *129110* | *129170* | *129195* | *129290* | *129370* | *129470* | *129570* | *129670* | *129695* | *129770* | *129870* | *129950* | *129965* | *129970* | *130070* | *130170* | *130210* | *130230* | *130270* | *130370* | *130470* | *130570* | *130580* | *130595* | *130670* | *130770* | *130870* | 2385 |
| Length (m) | *25* | *100* | *100* | *100* | *100* | *100* | *100* | *60* | *25* | *95* | *80* | *100* | *100* | *100* | *25* | *75* | *100* | *80* | *15* | *5* | *100* | *100* | *40* | *20* | *40* | *100* | *100* | *100* | *10* | *15* | *75* | *100* | *100* | **Average Values** |
| Feature / BH No. | | | | | | | | | *f14* | | | | | | *f13* | | | | *f12* | | | | | *f11* | | | | | | *f10* | | | | |
| Rock type | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Inferred Fault* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Photolineament* | *Jty* | *Jty* | *Jty* | *Inferred fault* | *Jty* | *Jty* | *Jty* | *Jty* | *Inferred Fault* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Photolineament* | *Jty* | *Jty* | *Jty* | |
| Water Level above tunnel (m) | 500.72793 | 507.1048 | 545.3517 | 579.0662 | 594.9412 | 622.28591 | 646.101587 | 650.49 | 650.49 | 638.6717 | 637.1 | 587.730752 | 529.129512 | 470.87741 | 447.827118 | 447.8271 | 402.4285 | 393.0523 | 393.0523 | 393.0523 | 382.9249 | 379.6184 | 359.6996 | 359.6996 | 359.6996 | 372.074 | 388.1705 | 363.4088 | 343.6738 | 343.673845 | 367.6564 | 367.6564 | 344.9689 | |
| WL above rock head (m) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 465.76 |
| Thickness of Rock Cover (m) | 495.72793 | 502.1048 | 540.3517 | 574.0662 | 589.9412 | 617.28591 | 641.101587 | 645.49 | 645.49 | 633.6717 | 632.1 | 582.730752 | 524.129512 | 465.87741 | 442.827118 | 442.8271 | 397.4285 | 388.0523 | 388.0523 | 388.0523 | 377.9249 | 374.6184 | 354.6996 | 354.6996 | 354.6996 | 367.074 | 383.1705 | 358.4088 | 338.6738 | 338.673845 | 362.6564 | 362.6564 | 339.9689 | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.60E-07 |
| Tunnel Radius | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 11 | 11 | 7.24 |
| IMS Rock Class | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1.45 |
| Vent Adit/ Single Track | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 130700 SM VA |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | |
| Horizontal Distance to (sf) | 0 | 10 | 0 | 50 | 150 | 150 | 50 | 0 | 5 | 0 | 30 | 0 | 0 | 0 | 20 | 70 | 0 | 30 | 110 | 110 | 160 | 50 | 10 | 0 | 0 | 50 | 0 | 0 | 20 | 0 | 0 | 40 | 0 | |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *Horizontal Separation* | *1* | *0.841886* | *1* | *0.646447* | *0.387628* | *0.3876276* | *0.6464466* | *1* | *0.8881966* | *1* | *0.7261387* | *1* | *1* | *1* | *0.7763932* | *0.58167* | *1* | *0.726139* | *0.475596* | *0.475596* | *0.367544* | *0.646447* | *0.841886* | *1* | *1* | *0.646447* | *1* | *1* | *0.776393* | *1* | *1* | *0.683772* | *1* | |
| *R* | *0.7* | *0.58932* | *0.7* | *0.452513* | *0.271339* | *0.2713393* | *0.4525126* | *0.1* | *0.62173762* | *0.7* | *0.5082971* | *0.7* | *0.7* | *0.7* | *0.54347524* | *0.407169* | *0.7* | *0.508297* | *0.332917* | *0.332917* | *0.257281* | *0.452513* | *0.58932* | *0.7* | *0.7* | *0.452513* | *0.1* | *0.7* | *0.543475* | *0.7* | *0.7* | *0.478641* | *0.7* | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| Goodman Eqn | 9.54 | 38.54 | 40.84 | 42.85 | 43.79 | 45.40 | 46.80 | 28.23 | 1176.41 | 44.05 | 37.02 | 43.37 | 39.87 | 36.33 | 872.94 | 26.19 | 32.10 | 25.21 | 472.60 | 1.58 | 30.87 | 30.66 | 11.76 | 587.88 | 11.76 | 30.18 | 31.20 | 29.63 | 2.84 | 425.52 | 22.43 | 33.13 | 31.57 | 4,383 l/min |
| Heuer / Raymer Eqn | 9.53 | 38.50 | 40.80 | 42.80 | 43.74 | 45.35 | 46.75 | 28.20 | 1175.09 | 44.00 | 36.98 | 43.32 | 39.82 | 36.29 | 871.96 | 26.16 | 32.06 | 25.18 | 472.06 | 1.57 | 30.83 | 30.62 | 11.74 | 587.22 | 11.74 | 30.15 | 31.16 | 29.60 | 2.83 | 425.05 | 22.40 | 33.09 | 31.53 | 4,378 l/min |
| Factored Heuer/Raymer | 1.19 | 4.81 | 5.10 | 5.35 | 5.47 | 5.67 | 5.84 | 3.53 | 146.89 | 5.50 | 4.62 | 5.41 | 4.98 | 4.54 | 109.00 | 3.27 | 4.01 | 3.15 | 59.01 | 0.20 | 3.85 | 3.83 | 1.47 | 73.40 | 1.47 | 3.77 | 3.90 | 3.70 | 0.35 | 53.13 | 2.80 | 4.14 | 3.94 | 547 l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 10.5 | 35.4 | 42.0 | 27.2 | 16.3 | 16.3 | 27.2 | 3.6 | 575.1 | 39.9 | 24.4 | 42.0 | 42.0 | 42.0 | 502.7 | 18.3 | 42.0 | 24.4 | 194.8 | 1.0 | 15.4 | 27.2 | 14.1 | 518.0 | 16.8 | 27.2 | 6.0 | 42.0 | 3.3 | 388.5 | 31.5 | 28.7 | 42.0 | 2877.6 l/min |
| *Average* | 7.9 | 26.5 | 31.5 | 20.4 | 12.2 | 12.2 | 20.4 | 2.7 | 373.0 | 29.9 | 18.3 | 31.5 | 31.5 | 31.5 | 326.1 | 13.7 | 31.5 | 18.3 | 119.9 | 0.7 | 11.6 | 20.4 | 10.6 | 336.0 | 12.6 | 20.4 | 4.5 | 31.5 | 2.4 | 252.0 | 23.6 | 21.5 | 31.5 | **1938.4 l/min** |
| *Low* | 5.3 | 17.7 | 21.0 | 13.6 | 8.1 | 8.1 | 13.6 | 1.8 | 171.0 | 20.0 | 12.2 | 21.0 | 21.0 | 21.0 | 149.5 | 9.2 | 21.0 | 12.2 | 54.9 | 0.5 | 7.7 | 13.6 | 7.1 | 154.0 | 6.4 | 13.6 | 3.0 | 21.0 | 1.6 | 115.5 | 15.8 | 14.4 | 21.0 | 999.1 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 7.4 | 20.8 | 29.4 | 12.3 | 4.4 | 4.4 | 12.3 | 0.4 | 357.6 | 27.9 | 12.4 | 29.4 | 29.4 | 29.4 | 273.2 | 7.5 | 29.4 | 12.4 | 61.5 | 0.3 | 4.0 | 12.3 | 8.3 | 362.6 | 11.8 | 12.3 | 0.6 | 29.4 | 1.8 | 272.0 | 22.1 | 13.7 | 29.4 | 1741.9 l/min |
| *Average* | 5.5 | 15.6 | 22.1 | 9.2 | 3.3 | 3.3 | 9.2 | 0.3 | 231.9 | 20.9 | 9.3 | 22.1 | 22.1 | 22.1 | 177.2 | 5.6 | 22.1 | 9.3 | 39.9 | 0.2 | 3.0 | 9.2 | 6.3 | 235.2 | 8.8 | 9.2 | 0.5 | 22.1 | 1.3 | 176.4 | 16.5 | 10.3 | 22.1 | **1172.0 l/min** |
| *Low* | 3.7 | 10.4 | 14.7 | 6.1 | 2.2 | 2.2 | 6.1 | 0.2 | 106.3 | 14.0 | 6.2 | 14.7 | 14.7 | 14.7 | 81.2 | 3.7 | 14.7 | 6.2 | 18.3 | 0.2 | 2.0 | 6.1 | 4.2 | 107.8 | 5.9 | 6.1 | 0.3 | 14.7 | 0.9 | 80.9 | 11.0 | 6.9 | 14.7 | 802.0 l/min |

**Average Estimated Inflow in terms of L/Min/100m:** IMS - 81 Initial; 49 Final; Goodman - 184; Heuer / Raymer - 184; Factored Heuer / Raymer - 23

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

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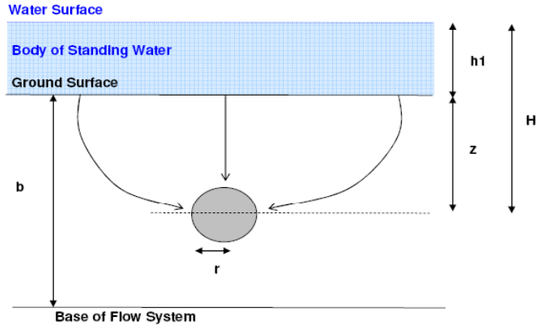
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* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

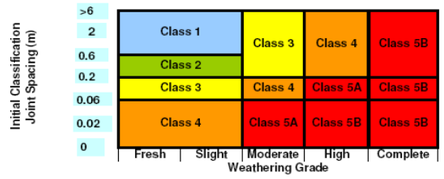
**Goodmans Model Definition**

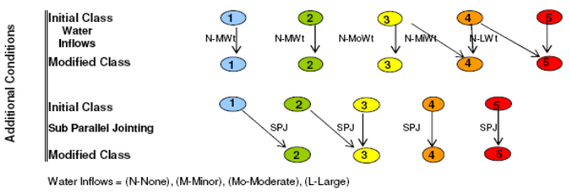



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**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sheet No. 4 of 6 | | Rev. | | Job No. | |
| | | Chainage 130870 to 132060 | | | | | |
| Job Title: | XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 130870 | 130885 | 130970 | 131020 | 131080 | 131140 | 131200 | 131260 | 131320 | 131380 | 131440 | 131500 | 131560 | 131620 | 131672 | 131679 | 131740 | 131786 | 131790 | 131860 | 131882 | 131885 | 131920 | 131931 | 131976 | 131980 | 132025 | 132040 | | | | Tunnel Length |
| To (m) | *130885* | *130970* | *131020* | *131080* | *131140* | *131200* | *131260* | *131320* | *131380* | *131440* | *131500* | *131560* | *131620* | *131672* | *131679* | *131740* | *131786* | *131790* | *131860* | *131882* | *131885* | *131920* | *131931* | *131976* | *131980* | *132025* | *132040* | *132060* | | | | 1190 |
| Length (m) | *15* | *85* | *50* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *52* | *7* | *61* | *46* | *4* | *70* | *22* | *3* | *35* | *11* | *45* | *4* | *45* | *15* | *20* | | | | Average Values |
| Rock type | *f9* *Inferred fault* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *f8* *Inferred fault* | *Jty* | *Jty* | *D365 (3)* *Jty* | *Jty* | *Jty* | *f7 / D364 (3)* *Basalt Dyke* | *Jty* | *Jty* | *f6 / D363 (4/5)* *Inferred Fault* | *Jty* | *Jty* | *f5* *Contact of Jty/Jmt* | *f5 / D362 (4/5) / D361 (3)* *Contact of Jty/Jmt* | | | |
| Water Level above tunnel (m) | 323.04 | 323.04 | 309.12 | 326.13 | 326.88 | 330.37 | 323.92 | 321.30 | 313.31 | 285.29 | 247.61 | 220.59 | 195.81 | 175.79 | 175.79 | 158.78 | 132.30 | 132.30 | 113.87 | 109.10 | 109.10 | 109.10 | 103.66 | 103.66 | 103.66 | 105.23 | 105.23 | 117.89 | | | | 203.64 |
| WL above rock head (m) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | | | | |
| Thickness of Rock Cover (m) | 318.04 | 318.04 | 304.12 | 321.13 | 321.88 | 325.37 | 318.92 | 316.30 | 308.31 | 280.29 | 242.61 | 215.59 | 190.81 | 170.79 | 170.79 | 153.78 | 127.30 | 127.30 | 108.87 | 104.10 | 104.10 | 104.10 | 98.66 | 98.66 | 98.66 | 100.23 | 100.23 | 112.89 | | | | |
| Permeability (m/s) | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 3.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-06 | | | | 2.33E-07 |
| Tunnel Radius | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | | | | 11.00 |
| IMS Rock Class | 4.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 4.00 | 1.00 | 1.00 | 3.00 | 1.00 | 1.00 | 4.00 | 1.00 | 1.00 | 4.00 | 1.00 | 1.00 | 4.00 | 4.00 | | | | 1.71 |
| Vent Adit/ Single Track | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | | | | |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | | | |
| Horizontal Distance to (sf) | 10 | 10 | 0 | 20 | 0 | 30 | 90 | 150 | 150 | 100 | 30 | 20 | 20 | 20 | 25 | 30 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | | |
| *Horizontal Separation* | *0.84188612* | *0.841886* | *1* | *0.776393* | *1* | *0.7261387* | *0.5256584* | *0.3876276* | *0.387628* | *0.5* | *0.7261387* | *0.7763932* | *0.7763932* | *0.776393* | *0.75* | *0.726139* | *0.646447* | *0.646447* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | | |
| *R* | *0.58932028* | *0.58932* | *0.7* | *0.543475* | *0.7* | *0.5082971* | *0.3679608* | *0.2713393* | *0.271339* | *0.35* | *0.5082971* | *0.5434752* | *0.5434752* | *0.543475* | *0.525* | *0.508297* | *0.452513* | *0.452513* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | | | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| Goodman Eqn | 450.73 | 25.54 | 14.54 | 18.16 | 18.19 | 18.34 | 18.07 | 17.96 | 17.62 | 16.43 | 14.81 | 13.62 | 12.50 | 10.04 | 135.17 | 10.97 | 7.31 | 19.07 | 10.08 | 3.08 | 42.01 | 4.90 | 1.49 | 609.81 | 0.54 | 6.16 | 205.23 | 294.49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2,017 l/min |
| Heuer / Raymer Eqn | 450.22 | 25.51 | 14.52 | 18.14 | 18.17 | 18.31 | 18.05 | 17.94 | 17.60 | 16.42 | 14.79 | 13.60 | 12.49 | 10.03 | 135.02 | 10.96 | 7.30 | 19.05 | 10.07 | 3.08 | 41.96 | 4.90 | 1.49 | 609.13 | 0.54 | 6.15 | 205.00 | 294.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2,015 l/min |
| Factored Heuer/Raymer | 56.28 | 3.19 | 1.82 | 2.27 | 2.27 | 2.29 | 2.26 | 2.24 | 2.20 | 2.05 | 1.85 | 1.70 | 1.56 | 1.25 | 16.88 | 1.37 | 0.91 | 2.38 | 1.26 | 0.38 | 5.25 | 0.61 | 0.19 | 76.14 | 0.07 | 0.77 | 25.63 | 36.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 252 l/min |
| IMS - Initial Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Initial Water Inflow |
| *High* | 327.1 | 30.1 | 21.0 | 19.6 | 25.2 | 18.3 | 13.2 | 9.8 | 9.8 | 12.6 | 18.3 | 19.6 | 19.6 | 17.0 | 136.0 | 18.6 | 12.5 | 22.1 | 4.2 | 1.3 | 11.1 | 2.1 | 0.7 | 166.5 | 0.2 | 2.7 | 55.5 | 74.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1068.4 l/min |
| *Average* | 212.2 | 22.5 | 15.8 | 14.7 | 18.9 | 13.7 | 9.9 | 7.3 | 7.3 | 9.5 | 13.7 | 14.7 | 14.7 | 12.7 | 88.2 | 14.0 | 9.4 | 11.9 | 3.2 | 1.0 | 7.2 | 1.6 | 0.5 | 108.0 | 0.2 | 2.0 | 36.0 | 48.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 718.6 l/min |
| *Low* | 97.2 | 15.0 | 10.5 | 9.8 | 12.6 | 9.1 | 6.6 | 4.9 | 4.9 | 6.3 | 9.1 | 9.8 | 9.8 | 8.5 | 40.4 | 9.3 | 6.2 | 1.6 | 2.1 | 0.7 | 3.3 | 1.1 | 0.3 | 49.5 | 0.1 | 1.4 | 16.5 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 368.7 l/min |
| IMS - Final Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Final Water Inflow |
| *High* | 192.8 | 17.7 | 14.7 | 10.6 | 17.6 | 9.3 | 4.9 | 2.7 | 2.7 | 4.4 | 9.3 | 10.6 | 10.6 | 9.2 | 71.4 | 9.5 | 5.7 | 10.0 | 0.4 | 0.1 | 1.1 | 0.2 | 0.1 | 16.7 | 0.0 | 0.3 | 5.6 | 7.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 445.4 l/min |
| *Average* | 125.0 | 13.3 | 11.0 | 8.0 | 13.2 | 7.0 | 3.7 | 2.0 | 2.0 | 3.3 | 7.0 | 8.0 | 8.0 | 6.9 | 46.3 | 7.1 | 4.2 | 5.4 | 0.3 | 0.1 | 0.7 | 0.2 | 0.0 | 10.8 | 0.0 | 0.2 | 3.6 | 4.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 302.1 l/min |
| *Low* | 57.3 | 8.9 | 7.4 | 5.3 | 8.8 | 4.7 | 2.4 | 1.3 | 1.3 | 2.2 | 4.7 | 5.3 | 5.3 | 4.6 | 21.2 | 4.7 | 2.8 | 0.7 | 0.2 | 0.1 | 0.3 | 0.1 | 0.0 | 5.0 | 0.0 | 0.1 | 1.7 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 158.7 l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| IMS - | 60 | Initial |
| | 25 | Final |
| Goodman - | 169 | |
| Heuer / Raymer - | 169 | |
| Factored Heuer / Raymer - | 21 | |

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

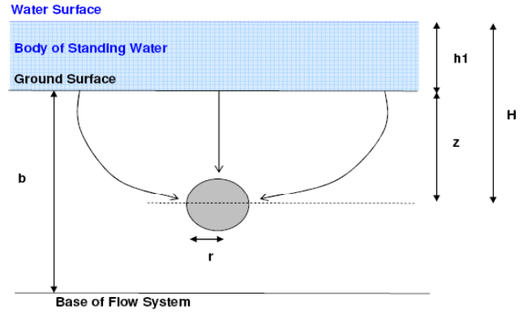
*(Goodman, 1965)* $q = \frac{2 \cdot k \cdot (z + h1)\ \pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \frac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

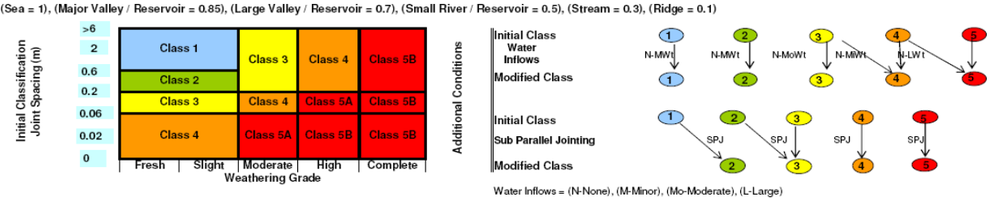
**Goodmans Model Definition**




IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | |
|---|---|---|---|
| | Sheet No. 5 of 6 | Rev. | Job No. |
| | Chainage 132060 to 132430 | | |
| Job Title: XRL Tai Mo Shan Tunnels | Input by: HC | Ckd by: TC | Date: 13-May-09 |

Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 132060 | 132100 | 132121 | 132160 | 132173 | 132220 | 132280 | 132340 | 132400 | 132410 | 132430 | **Tunnel Length** |
| **To (m)** | 132100 | 132121 | 132160 | 132173 | 132220 | 132280 | 132340 | 132400 | 132410 | 132430 | 0 | 370 |
| **Length (m)** | 40 | 21 | 39 | 13 | 47 | 60 | 60 | 60 | 10 | 20 | 0 | **Average Values** |
| **Feature / BH No.** | | | f4 / D360 (4/5) | f4 | | | | | | f3 | | |
| **Rock type** | Jmt | Jmt | Inferred fault | Inferred fault | Jmt | Jmt | Jmt | Jmt | Jmt | contact of Jmt/Jkn | | |
| **Water Level above tunnel (m)** | 117.88569 | 133.1587674 | 133.1587674 | 142.8025387 | 142.8025 | 129.38116 | 105.030914 | 98.2452643 | 83.07332 | 83.07332015 | | 116.86 |
| **WL above rock head (m)** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | |
| **Thickness of Rock Cover (m)** | 112.88569 | 128.1587674 | 128.1587674 | 137.8025387 | 137.8025 | 124.38116 | 100.030914 | 93.2452643 | 78.07332 | 78.07332015 | | |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | | 3.07E-07 |
| **Tunnel Radius** | 11 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | 7.40 |
| **IMS Rock Class** | 1 | 1 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 4 | | 1.90 |
| **Vent Adit/ Single Track** | 132100 SM Vent Adit | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| *Horizontal Distance to (sf)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Head Factor* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.9824526 | 0.830733 | 0.830733202 | 0 | |
| *Horizontal Separation* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| *R* | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0982453 | 0.083073 | 0.08307332 | 0 | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | 5.89 | 2.93 | 544.36 | 190.75 | 6.90 | 8.21 | 7.09 | 6.78 | 1.01 | 201.96 | 0.00 | **976 l/min** |
| **Heuer / Raymer Eqn** | 5.88 | 2.93 | 543.75 | 190.54 | 6.89 | 8.20 | 7.09 | 6.77 | 1.01 | 201.73 | 0.00 | **975 l/min** |
| **Factored Heuer/Raymer** | 0.74 | 0.37 | 67.97 | 23.82 | 0.86 | 1.02 | 0.89 | 0.85 | 0.13 | 25.22 | 0.00 | **122 l/min** |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 2.4 | 1.3 | 144.3 | 48.1 | 2.8 | 3.6 | 3.6 | 3.5 | 0.5 | 61.5 | 0.0 | 271.6 l/min |
| *Average* | 1.8 | 0.9 | 93.6 | 31.2 | 2.1 | 2.7 | 2.7 | 2.7 | 0.4 | 39.9 | 0.0 | **178.0 l/min** |
| *Low* | 1.2 | 0.6 | 42.9 | 14.3 | 1.4 | 1.8 | 1.8 | 1.8 | 0.2 | 18.3 | 0.0 | 84.3 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 0.2 | 0.1 | 14.4 | 4.8 | 0.3 | 0.4 | 0.4 | 0.3 | 0.0 | 5.1 | 0.0 | 26.1 l/min |
| *Average* | 0.2 | 0.1 | 9.4 | 3.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.0 | 3.3 | 0.0 | **17.1 l/min** |
| *Low* | 0.1 | 0.1 | 4.3 | 1.4 | 0.1 | 0.2 | 0.2 | 0.2 | 0.0 | 1.5 | 0.0 | 8.1 l/min |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | | | | | | | | | | | | | | | | | | | | | | |
| **To (m)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Length (m)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Horizontal Distance to (sf)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Head Factor* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Horizontal Separation* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *R* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Goodman Eqn** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Heuer / Raymer Eqn** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Factored Heuer/Raymer** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *High* (Initial) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Average* (Initial) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Low* (Initial) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *High* (Final) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Average* (Final) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Low* (Final) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **48** | **Initial** |
| | **5** | **Final** |
| **Goodman -** | **264** | |
| **Heuer / Raymer -** | **263** | |
| **Factored Heuer / Raymer -** | **33** | |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

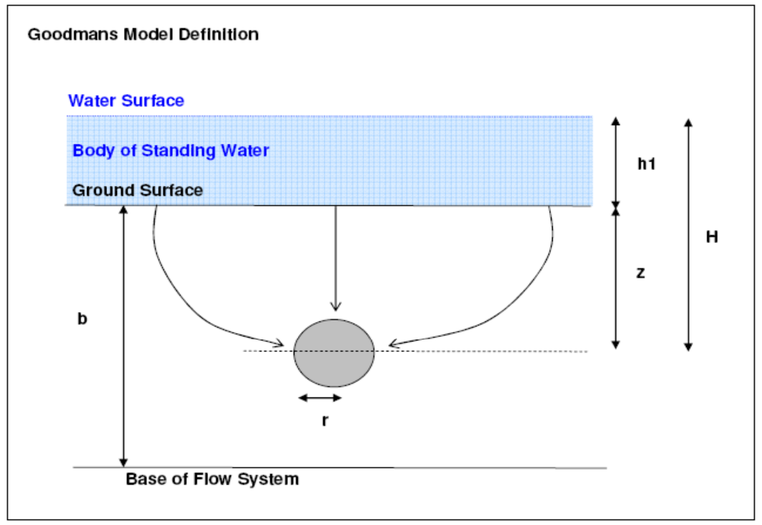
Where:

*(Goodman, 1965)* $$q = \frac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}\ ^{*}$$

*(Heuer, 1995 & Raymer, 2001)* $$q = \frac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

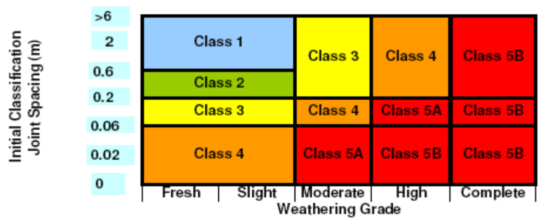
q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965)
However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

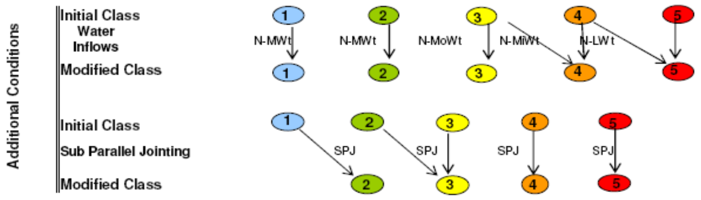



IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sheet No. 6 of 6 | | Rev. | | Job No. | |
| | | Chainage 132430 to 133000 | | | | | |
| Job Title: | XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | **Totals** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 132430 | 132460 | 132500 | 132580 | 132640 | 132700 | 132760 | 132820 | 132830 | 132835 | 132840 | 132880 | 132885 | 132910 | 132940 | **Tunnel Length** |
| To (m) | 132460 | 132500 | 132580 | 132640 | 132700 | 132760 | 132820 | 132830 | 132835 | 132840 | 132880 | 132885 | 132910 | 132940 | 133000 | 570 |
| Length (m) | 30 | 40 | 80 | 60 | 60 | 60 | 60 | 10 | 5 | 5 | 40 | 5 | 25 | 30 | 60 | **Average Values** |
| Feature / BH No. | | | | | | | | | D350 (4/5) | f2 | | | f1 / D348 (4/5) | | | |
| Rock type | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | inferred fault | Jkn | Jkn | dyke | Jkn | Jkn | |
| Water Level above tunnel (m) | 83.07332 | 79.03082 | 93.11501 | 83.83335 | 72.9504 | 91.648998 | 78.8720172 | 52.3616501 | 52.36165006 | 52.36165 | 52.36165 | 46.81034048 | 46.8103405 | 46.81034 | 44.54121 | |
| WL above rock head (m) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 65.13 |
| Thickness of Rock Cover (m) | 78.07332 | 74.03082 | 88.11501 | 78.83335 | 67.9504 | 86.648998 | 73.8720172 | 47.3616501 | 47.36165006 | 47.36165 | 47.36165 | 41.81034048 | 41.8103405 | 41.81034 | 39.54121 | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 2.08E-07 |
| Tunnel Radius | 7 | 7 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11.33 |
| IMS Rock Class | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 1 | 4 | 1 | 1 | 1.60 |
| Vent Adit/ Single Track | | | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | |
| Source Size Factor (sf) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| *Horizontal Distance to (sf)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Head Factor* | *0.8307332* | *0.790308* | *0.93115* | *0.838334* | *0.729504* | *0.91649* | *0.7887202* | *0.5236165* | *0.523616501* | *0.523617* | *0.5236165* | *0.468103405* | *0.4681034* | *0.468103* | *0.445412* | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *R* | *0.0830733* | *0.079031* | *0.093115* | *0.083833* | *0.07295* | *0.091649* | *0.078872* | *0.0523617* | *0.05236165* | *0.052362* | *0.0523617* | *0.04681034* | *0.0468103* | *0.04681* | *0.044541* | |

| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Goodman Eqn** | 3.03 | 3.91 | 10.46 | 7.37 | 6.81 | 7.77 | 7.11 | 0.96 | 47.83 | 47.83 | 3.83 | 0.46 | 227.50 | 2.73 | 5.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **383** | **l/min** |
| **Heuer / Raymer Eqn** | 3.03 | 3.91 | 10.45 | 7.36 | 6.80 | 7.76 | 7.11 | 0.96 | 47.77 | 47.77 | 3.82 | 0.45 | 227.25 | 2.73 | 5.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **383** | **l/min** |
| **Factored Heuer/Raymer** | 0.38 | 0.49 | 1.31 | 0.92 | 0.85 | 0.97 | 0.89 | 0.12 | 5.97 | 5.97 | 0.48 | 0.06 | 28.41 | 0.34 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **48** | **l/min** |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** | |
| *High* | 1.5 | 1.9 | 4.5 | 3.0 | 2.6 | 3.3 | 2.8 | 0.3 | 9.7 | 9.7 | 1.3 | 0.1 | 43.3 | 0.8 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 86.5 | l/min |
| *Average* | 1.1 | 1.4 | 3.4 | 2.3 | 2.0 | 2.5 | 2.1 | 0.2 | 6.3 | 6.3 | 0.9 | 0.1 | 26.1 | 0.6 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **58.5** | **l/min** |
| *Low* | 0.7 | 0.9 | 2.2 | 1.5 | 1.3 | 1.6 | 1.4 | 0.2 | 2.9 | 2.9 | 0.6 | 0.1 | 12.9 | 0.4 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.5 | l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** | |
| *High* | 0.1 | 0.1 | 0.4 | 0.3 | 0.2 | 0.3 | 0.2 | 0.0 | 0.5 | 0.5 | 0.1 | 0.0 | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | l/min |
| *Average* | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.0 | 0.3 | 0.3 | 0.0 | 0.0 | 1.3 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **3.4** | **l/min** |
| *Low* | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **10** | **Initial** |
| | **1** | **Final** |
| **Goodman -** | **67** | |
| **Heuer / Raymer -** | **67** | |
| **Factored Heuer / Raymer -** | **8** | |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

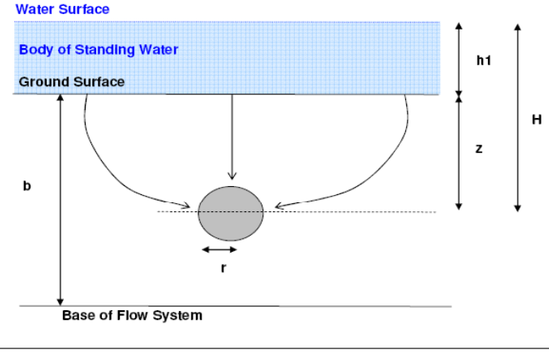
*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)

* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size difference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

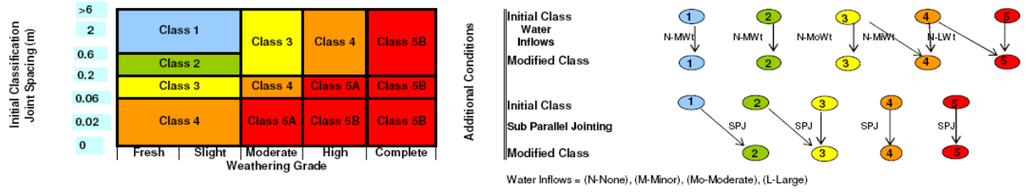
**Goodmans Model Definition**




IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**



Inflow Assessment Model - without geological features

Information of XRL Tai Mo Shan Tunnels 7550 m

Catchment

| | | | | |
|---|---|---|---|---|
| Length of Tai Mo Shan Tunnels within Indirect Catchment of Tai Lam Chung Reservoir | = | 2100 | m | (XRL Chainage from 126+000 to 128+100) |
| Length of Tai Mo Shan Tunnels within Indirect Catchment of Shing Mun Reservoir | = | 3520 | m | (XRL Chainage from 128+100 to 131+600) |

| Total Inflow | L/min | L/min/m |
|---|---|---|
| Goodman | 2,129 | 0.28 |
| Heuer | 2,126 | 0.28 |
| IMS Initial (Average) | 1,631 | 0.22 |
| IMS final (Average) | 933 | 0.12 |

Inflow within Tai Lam Chung Reservoir Catchment

| | L/min | L/min/m |
|---|---|---|
| Goodman | 581 | 0.28 |
| Heuer | 581 | 0.28 |
| IMS Initial (Average) | 576 | 0.27 |
| IMS final (Average) | 353 | 0.17 |

Inflow within Shing Mun Reservoir Catchment

| | L/min | L/min/m |
|---|---|---|
| Goodman | 1215 | 0.35 |
| Heuer | 1214 | 0.34 |
| IMS Initial (Average) | 824 | 0.23 |
| IMS final (Average) | 484 | 0.14 |

| | Sheet No. 1 of 6 | Rev. | Job No. |
|---|---|---|---|
| | Chainage 125450 to 126643 | | |
| Job Title: XRL Tai Mo Shan Tunnels | Input by: HC | Ckd by: TC | Date: 13-May-09 |

Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Totals** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 125450 | 125510 | 125570 | 125600 | 125630 | 125644 | 125648 | 125690 | 125709 | 125712 | 125750 | 125810 | 125860 | 125875 | 125930 | 125990 | 126000 | 126050 | 126110 | 126170 | 126174 | 126230 | 126290 | 126350 | 126410 | 126470 | 126530 | 126590 | 126595 | 126613 | **Tunnel Length** |
| **To (m)** | 125510 | 125570 | 125600 | 125630 | 125644 | 125648 | 125690 | 125709 | 125712 | 125750 | 125810 | 125860 | 125875 | 125930 | 125990 | 126000 | 126050 | 126110 | 126170 | 126174 | 126230 | 126290 | 126350 | 126410 | 126470 | 126530 | 126590 | 126595 | 126613 | 126643 | 1193 |
| **Length (m)** | 60 | 60 | 30 | 30 | 14 | 4 | 42 | 19 | 3 | 38 | 60 | 50 | 15 | 55 | 60 | 10 | 50 | 60 | 60 | 4 | 56 | 60 | 60 | 60 | 60 | 60 | 60 | 5 | 18 | 30 | **Average Values** |
| **Feature / BH No.** | | | | | | f20 | D383 (2) | D384 (2) | | | | | f19 | | | | | | D382 (2) | | | | | | | | D381 (3) | | | f18 | |
| **Rock type/ feature type** | Jmt | Jmt | Jmt | Jmt | Jmt | *Basalt Dyke* | Jmt | Jmt | *Dacite Dyke* | Jmt | Jmt | Jmt | *Inferred Fault* | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | *Shear Zone* | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | Jmt | *ntact of Jmt/Uts* | |
| **Water Level above tunnel (m)** | 22.45 | 44.49 | 61.04 | 63.72 | 63.72 | 63.72 | 63.72 | 76.90 | 92.06 | 92.06 | 92.06 | 94.77 | 94.77 | 101.35 | 108.59 | 113.04 | 101.23 | 101.23 | 108.20 | 105.07 | 105.07 | 87.68 | 86.22 | 95.60 | 113.61 | 115.12 | 115.87 | 112.08 | 112.08 | 112.08 | 90.65 |
| **WL above rock head (m)** | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | |
| **Thickness of Rock Cover (m)** | 17.45 | 39.49 | 56.04 | 58.72 | 58.72 | 58.72 | 58.72 | 71.90 | 87.06 | 87.06 | 87.06 | 89.77 | 89.77 | 96.35 | 103.59 | 108.04 | 96.23 | 96.23 | 103.20 | 100.07 | 100.07 | 82.68 | 81.22 | 90.60 | 108.61 | 110.12 | 110.87 | 107.08 | 107.08 | 107.08 | |
| **Permeability (m/s)** | 5.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 5.0E-08 | 5.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 5.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-08 | 3.50E-08 |
| **Tunnel Radius** | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 9.93 |
| **IMS Rock Class** | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1.20 |
| **Vent Adit/ Single Track** | ST | ST | ST | ST | | | | | | | | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | |
| **Source Size Factor (sf)** | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | |
| **Horizontal Distance to (sf)** | 80 | 60 | 30 | 30 | 30 | 30 | 35 | 10 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 50 | 30 | 30 | 0 | |
| *Head Factor* | *0.224493* | *0.444936836* | *0.610413442* | *0.637152763* | *0.637152763* | *0.637152763* | *0.637152763* | *0.763904811* | *0.920573097* | *0.920573097* | *0.920573097* | *0.947720308* | *0.947720308* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0.876841* | *0.862153* | *0.95596578* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *Horizontal Separation* | *0.552786* | *0.612701665* | *0.726138721* | *0.726138721* | *0.726138721* | *0.726138721* | *0.704196011* | *0.84188612* | *1* | *1* | *1* | *1* | *1* | *0.704196011* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0.841886117* | *0.841886117* | *1* | *0.646447* | *0.726139* | *0.726138721* | *1* | |
| *R* | *0.086868* | *0.190829478* | *0.310271385* | *0.323862905* | *0.323862905* | *0.323862905* | *0.314076304* | *0.45321565* | *0.644401168* | *0.644401168* | *0.644401168* | *0.663404216* | *0.663404216* | *0.492937208* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.613789* | *0.603507* | *0.563370023* | *0.589320282* | *0.1* | *0.452513* | *0.508297* | *0.508297105* | *0.7* | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | 20.34 | 4.88 | 2.86 | 2.93 | 1.19 | 0.34 | 17.91 | 9.12 | 0.32 | 4.11 | 6.49 | 6.40 | 1.92 | 7.35 | 8.38 | 1.43 | 6.67 | 8.01 | 41.78 | 0.55 | 7.65 | 7.33 | 7.25 | 7.73 | 8.62 | 8.70 | 8.74 | 42.75 | 2.56 | 4.27 | 259 l/min |
| **Heuer / Raymer Eqn** | 20.31 | 4.87 | 2.86 | 2.93 | 1.19 | 0.34 | 17.89 | 9.11 | 0.32 | 4.10 | 6.48 | 6.40 | 1.92 | 7.34 | 8.37 | 1.43 | 6.67 | 8.00 | 41.74 | 0.55 | 7.65 | 7.32 | 7.24 | 7.72 | 8.61 | 8.69 | 8.73 | 42.70 | 2.56 | 4.27 | 258 l/min |
| **Factored Heuer/Raymer** | 2.54 | 0.61 | 0.36 | 0.37 | 0.15 | 0.04 | 2.24 | 1.14 | 0.04 | 0.51 | 0.81 | 0.80 | 0.24 | 0.92 | 1.05 | 0.18 | 0.83 | 1.00 | 5.22 | 0.07 | 0.96 | 0.91 | 0.91 | 0.96 | 1.08 | 1.09 | 1.09 | 5.34 | 0.32 | 0.53 | 32 l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 7.3 | 6.9 | 5.6 | 5.8 | 2.7 | 0.8 | 18.5 | 12.1 | 1.2 | 14.7 | 23.2 | 19.9 | 6.0 | 16.3 | 25.2 | 4.2 | 21.0 | 25.2 | 58.8 | 1.7 | 23.5 | 22.1 | 21.7 | 20.3 | 21.2 | 3.6 | 16.3 | 31.0 | 5.5 | 12.6 | 454.7 l/min |
| *Average* | 5.5 | 5.2 | 4.2 | 4.4 | 2.0 | 0.6 | 13.9 | 9.0 | 0.9 | 11.0 | 17.4 | 14.9 | 4.5 | 12.2 | 18.9 | 3.2 | 15.8 | 18.9 | 44.1 | 1.3 | 17.6 | 16.6 | 16.3 | 15.2 | 15.9 | 2.7 | 12.2 | 16.6 | 4.1 | 9.5 | 334.4 l/min |
| *Low* | 3.6 | 3.4 | 2.8 | 2.9 | 1.4 | 0.4 | 9.2 | 6.0 | 0.6 | 7.3 | 11.6 | 10.0 | 3.0 | 8.1 | 12.6 | 2.1 | 10.5 | 12.6 | 29.4 | 0.8 | 11.8 | 11.0 | 10.9 | 10.1 | 10.6 | 1.8 | 8.1 | 2.3 | 2.7 | 6.3 | 214.1 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 0.6 | 1.3 | 1.7 | 1.9 | 0.9 | 0.3 | 5.8 | 5.5 | 0.7 | 9.5 | 14.9 | 13.2 | 4.0 | 8.0 | 17.6 | 2.9 | 14.7 | 17.6 | 41.2 | 1.2 | 16.5 | 13.6 | 13.1 | 11.4 | 12.5 | 0.4 | 7.4 | 15.8 | 2.8 | 8.8 | 265.7 l/min |
| *Average* | 0.5 | 1.0 | 1.3 | 1.4 | 0.7 | 0.2 | 4.4 | 4.1 | 0.6 | 7.1 | 11.2 | 9.9 | 3.0 | 6.0 | 13.2 | 2.2 | 11.0 | 13.2 | 30.9 | 0.9 | 12.3 | 10.2 | 9.8 | 8.6 | 9.4 | 0.3 | 5.5 | 8.5 | 2.1 | 6.6 | 195.9 l/min |
| *Low* | 0.3 | 0.7 | 0.9 | 0.9 | 0.4 | 0.1 | 2.9 | 2.7 | 0.4 | 4.7 | 7.5 | 6.6 | 2.0 | 4.0 | 8.8 | 1.5 | 7.4 | 8.8 | 20.6 | 0.6 | 8.2 | 6.8 | 6.6 | 5.7 | 6.3 | 0.2 | 3.7 | 1.2 | 1.4 | 4.4 | 126.1 l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **28** | **Initial** |
| | **16** | **Final** |
| **Goodman -** | **22** | |
| **Heuer / Raymer -** | **22** | |
| **Factored Heuer / Raymer -** | **3** | |

**Note :-**
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

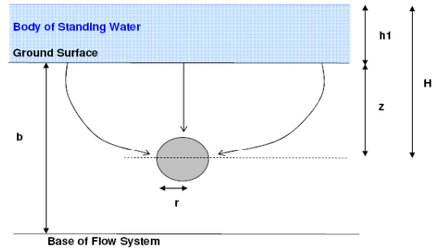
*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1) \cdot \pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

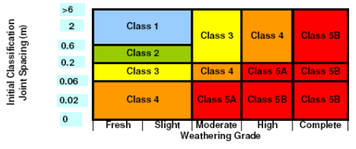
**Goodmans Model Definition**

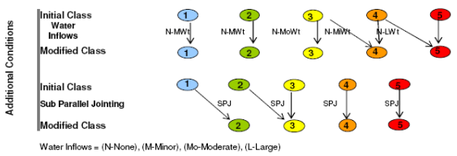



IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | |
|---|---|---|---|---|---|
| | Sheet No. 2 of 6 | | Rev. | | Job No. |
| | Chainage 126643 to 128485 | | | | |
| Job Title: XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: 13-May-09 |

Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 126643 | 126650 | 126710 | 126770 | 126830 | 126890 | 126900 | 126975 | 127010 | 127050 | 127070 | 127130 | 127190 | 127250 | 127310 | 127365 | 127400 | 127450 | 127475 | 127520 | 127610 | 127710 | 127810 | 127910 | 128010 | 128110 | 128210 | 128310 | 128410 | 128460 | | | |
| To (m) | *126650* | *126710* | *126770* | *126830* | *126890* | *126900* | *126975* | *127010* | *127050* | *127070* | *127130* | *127190* | *127250* | *127310* | *127365* | *127400* | *127450* | *127475* | *127520* | *127610* | *127710* | *127810* | *127910* | *128010* | *128110* | *128210* | *128310* | *128410* | *128460* | *128485* | | | |
| Length (m) | *7* | *60* | *60* | *60* | *60* | *10* | *75* | *35* | *40* | *20* | *60* | *60* | *60* | *60* | *55* | *35* | *50* | *25* | *45* | *90* | *100* | *100* | *100* | *100* | *100* | *100* | *100* | *100* | *50* | *25* | | | |
| Feature / BH No. | | | | | | | f17 | f17 | f17 | | | | | | | | | f16 | | | | | | | | | | | | f15 | | | |
| Rock type | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Sham Tseng Fault zone* | *Sham Tseng Fault zone* | *Sham Tseng Fault zone* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | | | *Fault zone* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *Jts* | *contact of Jts/Jty* | | | |
| Water Level above tunnel (m) | 112.08 | 127.86 | 158.45 | 183.06 | 199.75 | 230.62 | 230.62 | 239.32 | 219.23 | 219.23 | 240.41 | 239.13 | 257.27 | 278.46 | 307.47 | 325.93 | 335.93 | 343.87 | 370.58 | 370.58 | 412.95 | 479.00 | 536.53 | 581.87 | 610.86 | 597.18 | 572.05 | 547.69 | 500.73 | 500.73 | | | |
| WL above rock head (m) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | | | |
| Thickness of Rock Cover (m) | 107.08 | 122.86 | 153.45 | 178.06 | 194.75 | 225.62 | 225.62 | 234.32 | 214.23 | 214.23 | 235.41 | 234.13 | 252.27 | 273.46 | 302.47 | 320.93 | 330.93 | 338.87 | 365.58 | 365.58 | 407.95 | 474.00 | 531.53 | 576.87 | 605.86 | 592.18 | 567.05 | 542.69 | 495.73 | 495.73 | | | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | | | |
| Tunnel Radius | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | | |
| IMS Rock Class | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| Vent Adit/ Single Track | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | PH VT | | | | | | | | | | | | | | | | | | | | | | | | | |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | | | |
| Horizontal Distance to (sf) | 10 | 10 | 80 | 120 | 120 | 120 | 100 | 35 | 0 | 0 | 0 | 0 | 50 | 30 | 60 | 30 | 20 | 0 | 65 | 15 | 10 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | | | |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | |
| *Horizontal Separation* | *0.841886117* | *0.841886* | *0.552786* | *0.452277* | *0.452277* | *0.452277442* | *0.5* | *0.704196011* | *1* | *1* | *1* | *1* | *0.646446609* | *0.726138721* | *0.612702* | *0.726139* | *0.776393* | *1* | *0.596887* | *0.806351* | *0.841886* | *1* | *1* | *1* | *0.776393* | *1* | *1* | *1* | *1* | *1* | | | |
| *R* | *0.589320282* | *0.58932* | *0.38695* | *0.316594* | *0.316594* | *0.31659421* | *0.35* | *0.070419601* | *0.7* | *0.7* | *0.7* | *0.7* | *0.452512627* | *0.508297105* | *0.428891* | *0.508297* | *0.543475* | *0.7* | *0.417821* | *0.564446* | *0.58932* | *0.7* | *0.7* | *0.7* | *0.543475* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Goodman Eqn | 1.00 | 9.32 | 10.78 | 11.92 | 12.68 | 2.34 | 17.58 | 8.43 | 8.04 | 4.02 | 12.94 | 12.88 | 13.62 | 14.47 | 14.31 | 9.53 | 13.93 | 7.10 | 13.54 | 27.08 | 32.75 | 36.83 | 40.31 | 43.02 | 44.73 | 43.93 | 42.44 | 40.98 | 19.08 | 9.54 | 0.00 | 0.00 | 0.00 |
| Heuer / Raymer Eqn | 1.00 | 9.31 | 10.77 | 11.91 | 12.67 | 2.34 | 17.56 | 8.42 | 8.04 | 4.02 | 12.92 | 12.87 | 13.60 | 14.45 | 14.30 | 9.52 | 13.92 | 7.09 | 13.52 | 27.05 | 32.72 | 36.79 | 40.27 | 42.97 | 44.68 | 43.88 | 42.39 | 40.94 | 19.06 | 9.53 | 0.00 | 0.00 | 0.00 |
| Factored Heuer/Raymer | 0.12 | 1.16 | 1.35 | 1.49 | 1.58 | 0.29 | 2.19 | 1.05 | 1.00 | 0.50 | 1.62 | 1.61 | 1.70 | 1.81 | 1.79 | 1.19 | 1.74 | 0.89 | 1.69 | 3.38 | 4.09 | 4.60 | 5.03 | 5.37 | 5.59 | 5.48 | 5.30 | 5.12 | 2.38 | 1.19 | 0.00 | 0.00 | 0.00 |
| IMS - Initial Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *High* | 2.5 | 21.2 | 13.9 | 11.4 | 11.4 | 1.9 | 15.8 | 1.5 | 16.8 | 8.4 | 25.2 | 25.2 | 16.3 | 18.3 | 14.2 | 10.7 | 16.3 | 10.5 | 11.3 | 30.5 | 35.4 | 42.0 | 42.0 | 42.0 | 32.6 | 42.0 | 42.0 | 42.0 | 21.0 | 10.5 | 0.0 | 0.0 | 0.0 |
| *Average* | 1.9 | 15.9 | 10.4 | 8.5 | 8.5 | 1.4 | 11.8 | 1.1 | 12.6 | 6.3 | 18.9 | 18.9 | 12.2 | 13.7 | 10.6 | 8.0 | 12.2 | 7.9 | 8.5 | 22.9 | 26.5 | 31.5 | 31.5 | 31.5 | 24.5 | 31.5 | 31.5 | 31.5 | 15.8 | 7.9 | 0.0 | 0.0 | 0.0 |
| *Low* | 1.2 | 10.6 | 7.0 | 5.7 | 5.7 | 0.9 | 7.9 | 0.7 | 8.4 | 4.2 | 12.6 | 12.6 | 8.1 | 9.1 | 7.1 | 5.3 | 8.2 | 5.3 | 5.6 | 15.2 | 17.7 | 21.0 | 21.0 | 21.0 | 16.3 | 21.0 | 21.0 | 21.0 | 10.5 | 5.3 | 0.0 | 0.0 | 0.0 |
| IMS - Final Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *High* | 1.5 | 12.5 | 5.4 | 3.6 | 3.6 | 0.6 | 5.5 | 0.1 | 11.8 | 5.9 | 17.6 | 17.6 | 7.4 | 9.3 | 6.1 | 5.4 | 8.9 | 7.4 | 4.7 | 17.2 | 20.8 | 29.4 | 29.4 | 29.4 | 17.7 | 29.4 | 29.4 | 29.4 | 14.7 | 7.4 | 0.0 | 0.0 | 0.0 |
| *Average* | 1.1 | 9.4 | 4.0 | 2.7 | 2.7 | 0.5 | 4.1 | 0.1 | 8.8 | 4.4 | 13.2 | 13.2 | 5.5 | 7.0 | 4.6 | 4.1 | 6.6 | 5.5 | 3.5 | 12.9 | 15.6 | 22.1 | 22.1 | 22.1 | 13.3 | 22.1 | 22.1 | 22.1 | 11.0 | 5.5 | 0.0 | 0.0 | 0.0 |
| *Low* | 0.7 | 6.3 | 2.7 | 1.8 | 1.8 | 0.3 | 2.8 | 0.1 | 5.9 | 2.9 | 8.8 | 8.8 | 3.7 | 4.7 | 3.0 | 2.7 | 4.4 | 3.7 | 2.4 | 8.6 | 10.4 | 14.7 | 14.7 | 14.7 | 8.9 | 14.7 | 14.7 | 14.7 | 7.4 | 3.7 | 0.0 | 0.0 | 0.0 |

**Totals**

| | |
|---|---|
| **Tunnel Length** | |
| | 1842 |
| **Average Values** | |
| | 344.32 |
| | 1.00E-08 |
| | 8.07 |
| | 1.00 |

| | | |
|---|---|---|
| **Initial Water Inflow** | | |
| **Goodman Eqn** | **579** | **l/min** |
| **Heuer / Raymer Eqn** | **578** | **l/min** |
| **Factored Heuer/Raymer** | **72** | **l/min** |
| **Initial Water Inflow** | | |
| *High* | 634.6 | l/min |
| *Average* | **475.9** | **l/min** |
| *Low* | 317.3 | l/min |
| **Final Water Inflow** | | |
| *High* | 389.0 | l/min |
| *Average* | **291.8** | **l/min** |
| *Low* | 194.5 | l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **26** | **Initial** |
| | **16** | **Final** |
| **Goodman -** | **31** | |
| **Heuer / Raymer -** | **31** | |
| **Factored Heuer / Raymer -** | **4** | |

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

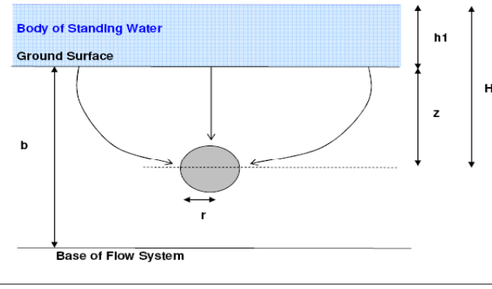
*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

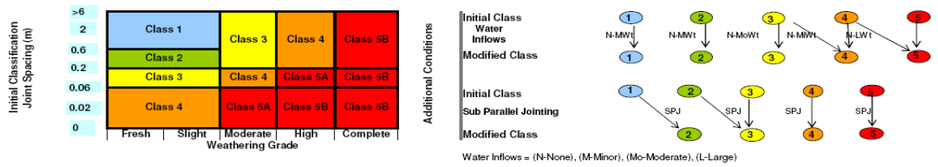
IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Goodmans Model Definition**




**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**







Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sheet No. 3 of 6 | | Rev. | | Job No. | | |
| | Chainage 128485 to 130870 | | | | | | |
| Job Title: XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 | |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 128485 | 128510 | 128610 | 128710 | 128810 | 128910 | 129010 | 129110 | 129170 | 129195 | 129290 | 129370 | 129470 | 129570 | 129670 | 129695 | 129770 | 129870 | 129950 | 129965 | 129970 | 130070 | 130170 | 130210 | 130230 | 130270 | 130370 | 130470 | 130570 | 130580 | 130595 | 130670 | 130770 | Tunnel Length |
| To (m) | 128510 | 128610 | 128710 | 128810 | 128910 | 129010 | 129110 | 129170 | 129195 | 129290 | 129370 | 129470 | 129570 | 129670 | 129695 | 129770 | 129870 | 129950 | 129965 | 129970 | 130070 | 130170 | 130210 | 130230 | 130270 | 130370 | 130470 | 130570 | 130580 | 130595 | 130670 | 130770 | 130870 | 2385 |
| Length (m) | 25 | 100 | 100 | 100 | 100 | 100 | 100 | 60 | 25 | 95 | 80 | 100 | 100 | 100 | 25 | 75 | 100 | 80 | 15 | 5 | 100 | 100 | 40 | 20 | 40 | 100 | 100 | 100 | 10 | 15 | 75 | 100 | 100 | Average Values |
| Feature / BH No. | | | | | | | | | f14 | | | | | | f13 | | | | f12 | | | | | f11 | | | | | | f10 | | | | |
| Rock type | Jty | Jty | Jty | Jty | Jty | Jty | Jty | Jty | Inferred Fault | Jty | Jty | Jty | Jty | Jty | Photolineament | Jty | Jty | Jty | Inferred fault | Jty | Jty | Jty | Jty | Inferred Fault | Jty | Jty | Jty | Jty | Jty | Photolineament | Jty | Jty | Jty | |
| Water Level above tunnel (m) | 500.72793 | 507.1048 | 545.3517 | 579.0662 | 594.9412 | 622.28591 | 646.101587 | 650.49 | 650.49 | 638.6717 | 637.1 | 587.730752 | 529.129512 | 470.87741 | 447.827118 | 447.8271 | 402.4285 | 393.0523 | 393.0523 | 393.0523 | 382.9249 | 379.6184 | 359.6996 | 359.6996 | 359.6996 | 372.074 | 388.1705 | 363.4088 | 343.6738 | 343.673845 | 367.6564 | 367.6564 | 344.9689 | 465.76 |
| WL above rock head (m) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| Thickness of Rock Cover (m) | 495.72793 | 502.1048 | 540.3517 | 574.0662 | 589.9412 | 617.28591 | 641.101587 | 645.49 | 645.49 | 633.6717 | 632.1 | 582.730752 | 524.129512 | 465.87741 | 442.827118 | 442.8271 | 397.4285 | 388.0523 | 388.0523 | 388.0523 | 377.9249 | 374.6184 | 354.6996 | 354.6996 | 354.6996 | 367.074 | 383.1705 | 358.4088 | 338.6738 | 338.673845 | 362.6564 | 362.6564 | 339.9689 | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.00E-08 |
| Tunnel Radius | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 11 | 11 | 7.24 |
| IMS Rock Class | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.00 |
| Vent Adit/ Single Track | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 130700 SM VA |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | |
| Horizontal Distance to (sf) | 0 | 10 | 0 | 50 | 150 | 150 | 50 | 0 | 5 | 0 | 30 | 0 | 0 | 0 | 20 | 70 | 0 | 30 | 110 | 110 | 160 | 50 | 10 | 0 | 0 | 50 | 0 | 0 | 20 | 0 | 0 | 40 | 0 | |
| *Head Factor* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| *Horizontal Separation* | 1 | 0.841886 | 1 | 0.646447 | 0.387628 | 0.3876276 | 0.6464466 | 1 | 0.8881966 | 1 | 0.7261387 | 1 | 1 | 1 | 0.7763932 | 0.58167 | 1 | 0.726139 | 0.475596 | 0.475596 | 0.367544 | 0.646447 | 0.841886 | 1 | 1 | 0.646447 | 1 | 1 | 0.776393 | 1 | 1 | 0.683772 | 1 | |
| *R* | 0.7 | 0.58932 | 0.7 | 0.452513 | 0.271339 | 0.2713393 | 0.4525126 | 0.1 | 0.62173762 | 0.7 | 0.5082971 | 0.7 | 0.7 | 0.7 | 0.54347524 | 0.407169 | 0.7 | 0.508297 | 0.332917 | 0.332917 | 0.257281 | 0.452513 | 0.58932 | 0.7 | 0.7 | 0.452513 | 0.1 | 0.7 | 0.543475 | 0.7 | 0.7 | 0.478641 | 0.7 | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| Goodman Eqn | 9.54 | 38.54 | 40.84 | 42.85 | 43.79 | 45.40 | 46.80 | 28.23 | 11.76 | 44.05 | 37.02 | 43.37 | 39.87 | 36.33 | 8.73 | 26.19 | 32.10 | 25.21 | 4.73 | 1.58 | 30.87 | 30.66 | 11.76 | 5.88 | 11.76 | 30.18 | 31.20 | 29.63 | 2.84 | 4.26 | 22.43 | 33.13 | 31.57 | 883 l/min |
| Heuer / Raymer Eqn | 9.53 | 38.50 | 40.80 | 42.80 | 43.74 | 45.35 | 46.75 | 28.20 | 11.75 | 44.00 | 36.98 | 43.32 | 39.82 | 36.29 | 8.72 | 26.16 | 32.06 | 25.18 | 4.72 | 1.57 | 30.83 | 30.62 | 11.74 | 5.87 | 11.74 | 30.15 | 31.16 | 29.60 | 2.83 | 4.25 | 22.40 | 33.09 | 31.53 | 882 l/min |
| Factored Heuer/Raymer | 1.19 | 4.81 | 5.10 | 5.35 | 5.47 | 5.67 | 5.84 | 3.53 | 1.47 | 5.50 | 4.62 | 5.41 | 4.98 | 4.54 | 1.09 | 3.27 | 4.01 | 3.15 | 0.59 | 0.20 | 3.85 | 3.83 | 1.47 | 0.73 | 1.47 | 3.77 | 3.90 | 3.70 | 0.35 | 0.53 | 2.80 | 4.14 | 3.94 | 110 l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 10.5 | 35.4 | 42.0 | 27.2 | 16.3 | 16.3 | 27.2 | 3.6 | 9.3 | 39.9 | 24.4 | 42.0 | 42.0 | 42.0 | 8.2 | 18.3 | 42.0 | 24.4 | 3.0 | 1.0 | 15.4 | 27.2 | 14.1 | 8.4 | 16.8 | 27.2 | 6.0 | 42.0 | 3.3 | 6.3 | 31.5 | 28.7 | 42.0 | 743.7 l/min |
| *Average* | 7.9 | 26.5 | 31.5 | 20.4 | 12.2 | 12.2 | 20.4 | 2.7 | 7.0 | 29.9 | 18.3 | 31.5 | 31.5 | 31.5 | 6.1 | 13.7 | 31.5 | 18.3 | 2.2 | 0.7 | 11.6 | 20.4 | 10.6 | 6.3 | 12.6 | 20.4 | 4.5 | 31.5 | 2.4 | 4.7 | 23.6 | 21.5 | 31.5 | 557.8 l/min |
| *Low* | 5.3 | 17.7 | 21.0 | 13.6 | 8.1 | 8.1 | 13.6 | 1.8 | 4.7 | 20.0 | 12.2 | 21.0 | 21.0 | 21.0 | 4.1 | 9.2 | 21.0 | 12.2 | 1.5 | 0.5 | 7.7 | 13.6 | 7.1 | 4.2 | 8.4 | 13.6 | 3.0 | 21.0 | 1.6 | 3.2 | 15.8 | 14.4 | 21.0 | 371.8 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 7.4 | 20.8 | 29.4 | 12.3 | 4.4 | 4.4 | 12.3 | 0.4 | 5.8 | 27.9 | 12.4 | 29.4 | 29.4 | 29.4 | 4.4 | 7.5 | 29.4 | 12.4 | 1.0 | 0.3 | 4.0 | 12.3 | 6.3 | 5.9 | 11.8 | 12.3 | 0.6 | 29.4 | 1.8 | 4.4 | 22.1 | 13.7 | 29.4 | 436.6 l/min |
| *Average* | 5.5 | 15.6 | 22.1 | 9.2 | 3.3 | 3.3 | 9.2 | 0.3 | 4.3 | 20.9 | 9.3 | 22.1 | 22.1 | 22.1 | 3.3 | 5.6 | 22.1 | 9.3 | 0.7 | 0.2 | 3.0 | 9.2 | 6.3 | 4.4 | 8.8 | 9.2 | 0.5 | 22.1 | 1.3 | 3.3 | 16.5 | 10.3 | 22.1 | 327.5 l/min |
| *Low* | 3.7 | 10.4 | 14.7 | 6.1 | 2.2 | 2.2 | 6.1 | 0.2 | 2.9 | 14.0 | 6.2 | 14.7 | 14.7 | 14.7 | 2.2 | 3.7 | 14.7 | 6.2 | 0.5 | 0.2 | 2.0 | 6.1 | 4.2 | 2.9 | 5.9 | 6.1 | 0.3 | 14.7 | 0.9 | 2.2 | 11.0 | 6.9 | 14.7 | 218.3 l/min |

**Average Estimated Inflow in terms of L/Min/100m:** IMS - 23 Initial, 14 Final; Goodman - 37; Heuer / Raymer - 37; Factored Heuer / Raymer - 5

Note :-

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \frac{2 . k . (z + h1) \pi}{2.3 \log (r / 2z)}$ *

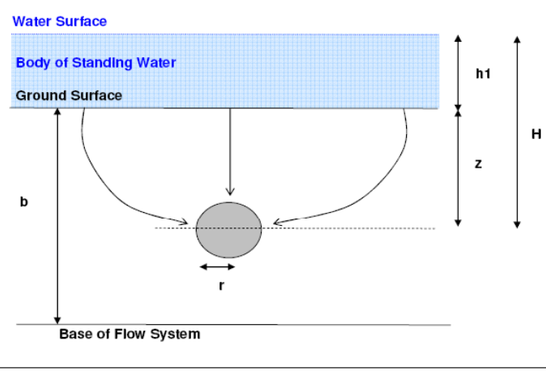
*(Heuer, 1995 & Raymer, 2001)* $q = \frac{2 . \pi . k . H}{\ln (2z / r)}$

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)

* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

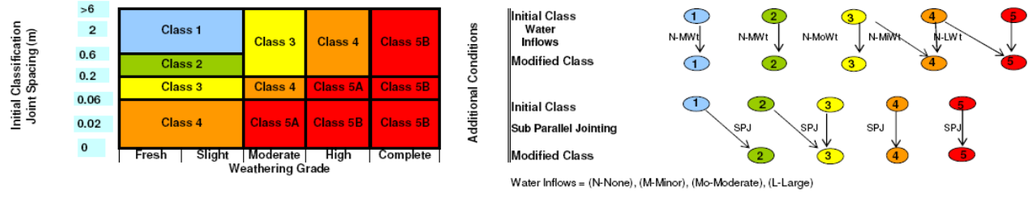
**Goodmans Model Definition**




IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sheet No. 4 of 6 | | Rev. | | Job No. | |
| | | Chainage 130870 to 132060 | | | | | |
| Job Title: | XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 130870 | 130885 | 130970 | 131020 | 131080 | 131140 | 131200 | 131260 | 131320 | 131380 | 131440 | 131500 | 131560 | 131620 | 131672 | 131679 | 131740 | 131786 | 131790 | 131860 | 131882 | 131885 | 131920 | 131931 | 131976 | 131980 | 132025 | 132040 | | | | Tunnel Length |
| To (m) | *130885* | *130970* | *131020* | *131080* | *131140* | *131200* | *131260* | *131320* | *131380* | *131440* | *131500* | *131560* | *131620* | *131672* | *131679* | *131740* | *131786* | *131790* | *131860* | *131882* | *131885* | *131920* | *131931* | *131976* | *131980* | *132025* | *132040* | *132060* | | | | 1190 |
| Length (m) | *15* | *85* | *50* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *60* | *52* | *7* | *61* | *46* | *4* | *70* | *22* | *3* | *35* | *11* | *45* | *4* | *45* | *15* | *20* | | | | Average Values |
| Rock type | *f9 Inferred fault* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *Jty* | *f8 Inferred fault* | *Jty* | *Jty* | *D365 (3) Jty* | *Jty* | *Jty* | *f7 / D364 (3) Basalt Dyke* | *Jty* | *Jty* | *f6 / D363 (4/5) Inferred Fault* | *Jty* | *Jty* | *f5 Contact of Jty/Jmt* | *f5 / D362 (4/5) / D361 (3) Contact of Jty/Jmt* | | | |
| Water Level above tunnel (m) | 323.04 | 323.04 | 309.12 | 326.13 | 326.88 | 330.37 | 323.92 | 321.30 | 313.31 | 285.29 | 247.61 | 220.59 | 195.81 | 175.79 | 175.79 | 158.78 | 132.30 | 132.30 | 113.87 | 109.10 | 109.10 | 109.10 | 103.66 | 103.66 | 103.66 | 105.23 | 105.23 | 117.89 | | | | 203.64 |
| WL above rock head (m) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | | | | |
| Thickness of Rock Cover (m) | 318.04 | 318.04 | 304.12 | 321.13 | 321.88 | 325.37 | 318.92 | 316.30 | 308.31 | 280.29 | 242.61 | 215.59 | 190.81 | 170.79 | 170.79 | 153.78 | 127.30 | 127.30 | 108.87 | 104.10 | 104.10 | 104.10 | 98.66 | 98.66 | 98.66 | 100.23 | 100.23 | 112.89 | | | | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 3.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | | | | 2.04E-08 |
| Tunnel Radius | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | | | | 11.00 |
| IMS Rock Class | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | | | | 1.07 |
| Vent Adit/ Single Track | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | SM VA | | | | |
| Source Size Factor (sf) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | | | |
| Horizontal Distance to (sf) | 10 | 10 | 0 | 20 | 0 | 30 | 90 | 150 | 150 | 100 | 30 | 20 | 20 | 20 | 25 | 30 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | | |
| *Horizontal Separation* | *0.84188612* | *0.841886* | *1* | *0.776393* | *1* | *0.7261387* | *0.5256584* | *0.3876276* | *0.387628* | *0.5* | *0.7261387* | *0.7763932* | *0.7763932* | *0.776393* | *0.75* | *0.726139* | *0.646447* | *0.646447* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | | |
| *R* | *0.58932028* | *0.58932* | *0.7* | *0.543475* | *0.7* | *0.5082971* | *0.3679608* | *0.2713393* | *0.271339* | *0.35* | *0.5082971* | *0.5434752* | *0.5434752* | *0.543475* | *0.525* | *0.508297* | *0.452513* | *0.452513* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | | | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| Goodman Eqn | 4.51 | 25.54 | 14.54 | 18.16 | 18.19 | 18.34 | 18.07 | 17.96 | 17.62 | 16.43 | 14.81 | 13.62 | 12.50 | 10.04 | 1.35 | 10.97 | 7.31 | 19.07 | 10.08 | 3.08 | 0.42 | 4.90 | 1.49 | 6.10 | 0.54 | 6.16 | 2.05 | 2.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **297** l/min |
| Heuer / Raymer Eqn | 4.50 | 25.51 | 14.52 | 18.14 | 18.17 | 18.31 | 18.05 | 17.94 | 17.60 | 16.42 | 14.79 | 13.60 | 12.49 | 10.03 | 1.35 | 10.96 | 7.30 | 19.05 | 10.07 | 3.08 | 0.42 | 4.90 | 1.49 | 6.09 | 0.54 | 6.15 | 2.05 | 2.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **296** l/min |
| Factored Heuer/Raymer | 0.56 | 3.19 | 1.82 | 2.27 | 2.27 | 2.29 | 2.26 | 2.24 | 2.20 | 2.05 | 1.85 | 1.70 | 1.56 | 1.25 | 0.17 | 1.37 | 0.91 | 2.38 | 1.26 | 0.38 | 0.05 | 0.61 | 0.19 | 0.76 | 0.07 | 0.77 | 0.26 | 0.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **37** l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 5.3 | 30.1 | 21.0 | 19.6 | 25.2 | 18.3 | 13.2 | 9.8 | 9.8 | 12.6 | 18.3 | 19.6 | 19.6 | 17.0 | 2.2 | 18.6 | 12.5 | 22.1 | 4.2 | 1.3 | 0.2 | 2.1 | 0.7 | 2.7 | 0.2 | 2.7 | 0.9 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 310.8 l/min |
| *Average* | 4.0 | 22.5 | 15.8 | 14.7 | 18.9 | 13.7 | 9.9 | 7.3 | 7.3 | 9.5 | 13.7 | 14.7 | 14.7 | 12.7 | 1.7 | 14.0 | 9.4 | 11.9 | 3.2 | 1.0 | 0.1 | 1.6 | 0.5 | 2.0 | 0.2 | 2.0 | 0.7 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **228.4** l/min |
| *Low* | 2.7 | 15.0 | 10.5 | 9.8 | 12.6 | 9.1 | 6.6 | 4.9 | 4.9 | 6.3 | 9.1 | 9.8 | 9.8 | 8.5 | 1.1 | 9.3 | 6.2 | 1.6 | 2.1 | 0.7 | 0.1 | 1.1 | 0.3 | 1.4 | 0.1 | 1.4 | 0.5 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 146.0 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 3.1 | 17.7 | 14.7 | 10.6 | 17.6 | 9.3 | 4.9 | 2.7 | 2.7 | 4.4 | 9.3 | 10.6 | 10.6 | 9.2 | 1.2 | 9.5 | 5.7 | 10.0 | 0.4 | 0.1 | 0.0 | 0.2 | 0.1 | 0.3 | 0.0 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 155.4 l/min |
| *Average* | 2.3 | 13.3 | 11.0 | 8.0 | 13.2 | 7.0 | 3.7 | 2.0 | 2.0 | 3.3 | 7.0 | 8.0 | 8.0 | 6.9 | 0.9 | 7.1 | 4.2 | 5.4 | 0.3 | 0.1 | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **114.4** l/min |
| *Low* | 1.6 | 8.9 | 7.4 | 5.3 | 8.8 | 4.7 | 2.4 | 1.3 | 1.3 | 2.2 | 4.7 | 5.3 | 5.3 | 4.6 | 0.6 | 4.7 | 2.8 | 0.7 | 0.2 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 73.4 l/min |

**Average Estimated Inflow in terms of L/Min/100m:** IMS - 19 Initial; 10 Final

Goodman - 25

Heuer / Raymer - 25

Factored Heuer / Raymer - 3

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

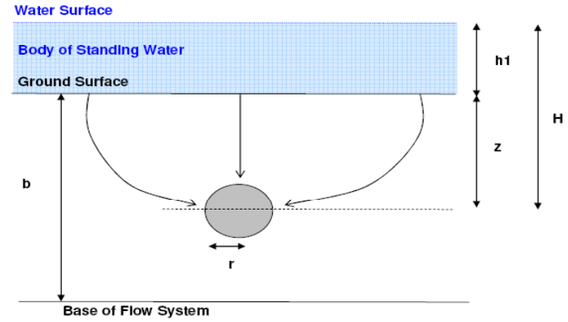
*(Goodman, 1965)* $q = \frac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \frac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

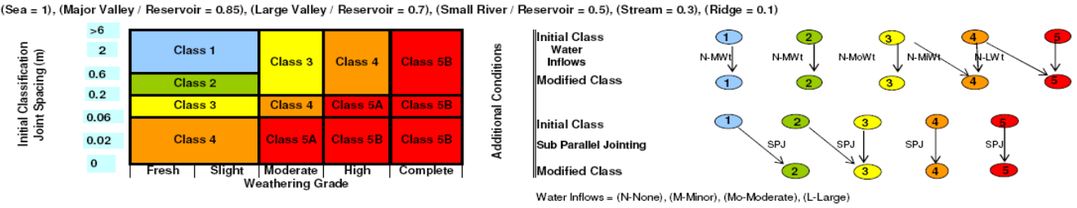
**Goodmans Model Definition**




IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | |
|---|---|---|---|---|---|
| | Sheet No. 5 of 6 | Rev. | | Job No. | |
| | Chainage 132060 to 132430 | | | | |
| Job Title: XRL Tai Mo Shan Tunnels | Input by: HC | Ckd by: | TC | Date: | 13-May-09 |

Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 132060 | 132100 | 132121 | 132160 | 132173 | 132220 | 132280 | 132340 | 132400 | 132410 | 132430 |
| **To (m)** | *132100* | *132121* | *132160* | *132173* | *132220* | *132280* | *132340* | *132400* | *132410* | *132430* | *0* |
| **Length (m)** | *40* | *21* | *39* | *13* | *47* | *60* | *60* | *60* | *10* | *20* | *0* |
| **Feature / BH No.** | | | *f4 / D360 (4/5)* | *f4* | | | | | | *f3* | |
| **Rock type** | *Jmt* | *Jmt* | *Inferred fault* | *Inferred fault* | *Jmt* | *Jmt* | *Jmt* | *Jmt* | *Jmt* | *contact of Jmt/Jkn* | |
| **Water Level above tunnel (m)** | 117.88569 | 133.1587674 | 133.1587674 | 142.8025387 | 142.8025 | 129.38116 | 105.030914 | 98.2452643 | 83.07332 | 83.07332015 | |
| **WL above rock head (m)** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| **Thickness of Rock Cover (m)** | 112.88569 | 128.1587674 | 128.1587674 | 137.8025387 | 137.8025 | 124.38116 | 100.030914 | 93.2452643 | 78.07332 | 78.07332015 | |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | |
| **Tunnel Radius** | 11 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Vent Adit/ Single Track** | 132100 SM Vent Adit | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| *Horizontal Distance to (sf)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0.9824526* | *0.830733* | *0.830733202* | *0* |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *R* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.0982453* | *0.083073* | *0.08307332* | *0* |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | |
| **Goodman Eqn** | 5.89 | 2.93 | 5.44 | 1.91 | 6.90 | 8.21 | 7.09 | 6.78 | 1.01 | 2.02 | 0.00 |
| **Heuer / Raymer Eqn** | 5.88 | 2.93 | 5.44 | 1.91 | 6.89 | 8.20 | 7.09 | 6.77 | 1.01 | 2.02 | 0.00 |
| **Factored Heuer/Raymer** | 0.74 | 0.37 | 0.68 | 0.24 | 0.86 | 1.02 | 0.89 | 0.85 | 0.13 | 0.25 | 0.00 |
| **IMS - Initial Water Inflow** | | | | | | | | | | | |
| *High* | 2.4 | 1.3 | 2.3 | 0.8 | 2.8 | 3.6 | 3.6 | 3.5 | 0.5 | 1.0 | 0.0 |
| *Average* | 1.8 | 0.9 | 1.8 | 0.6 | 2.1 | 2.7 | 2.7 | 2.7 | 0.4 | 0.7 | 0.0 |
| *Low* | 1.2 | 0.6 | 1.2 | 0.4 | 1.4 | 1.8 | 1.8 | 1.8 | 0.2 | 0.5 | 0.0 |
| **IMS - Final Water Inflow** | | | | | | | | | | | |
| *High* | 0.2 | 0.1 | 0.2 | 0.1 | 0.3 | 0.4 | 0.4 | 0.3 | 0.0 | 0.1 | 0.0 |
| *Average* | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.0 | 0.1 | 0.0 |
| *Low* | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | | | | | | | | | | | | | | | | | | | | | | |
| **To (m)** | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| **Length (m)** | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *Horizontal Distance to (sf)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Head Factor* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *R* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| **Goodman Eqn** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Heuer / Raymer Eqn** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Factored Heuer/Raymer** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *IMS Initial High* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *IMS Initial Average* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *IMS Initial Low* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *IMS Final High* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *IMS Final Average* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *IMS Final Low* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Totals**

| | | |
|---|---|---|
| **Tunnel Length** | 370 | |
| **Average Values** | | |
| Water Level above tunnel (m) | 116.86 | |
| Permeability (m/s) | 1.00E-08 | |
| Tunnel Radius | 7.40 | |
| IMS Rock Class | 1.00 | |
| **Initial Water Inflow** | | |
| Goodman Eqn | **48** | **l/min** |
| Heuer / Raymer Eqn | **48** | **l/min** |
| Factored Heuer/Raymer | **6** | **l/min** |
| **Initial Water Inflow** (IMS) | | |
| High | 21.8 | l/min |
| Average | **16.4** | **l/min** |
| Low | 10.9 | l/min |
| **Final Water Inflow** (IMS) | | |
| High | 2.2 | l/min |
| Average | **1.6** | **l/min** |
| Low | 1.1 | l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **4** | **Initial** |
| | **0** | **Final** |
| **Goodman -** | **13** | |
| **Heuer / Raymer -** | **13** | |
| **Factored Heuer / Raymer -** | **2** | |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow" by Heuer, R.E. (1995), and "Predicting Groundwater Inflow into Hard Rock Tunnels"* by Raymer, J.H. (2001),

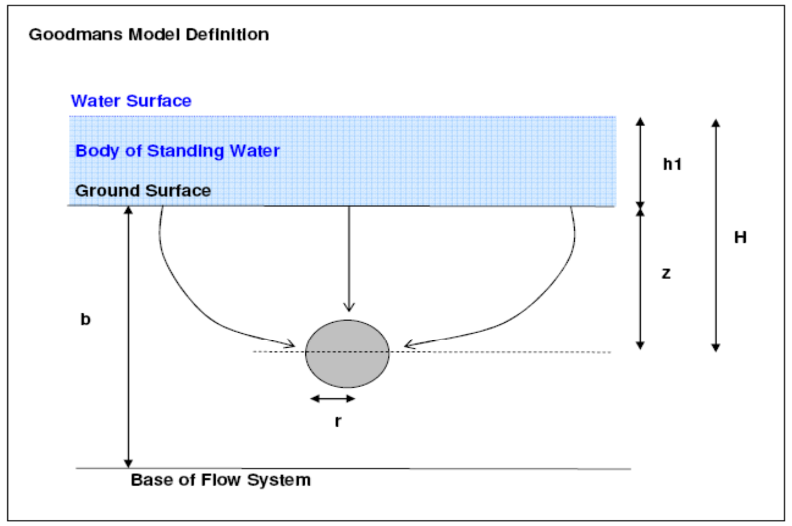
Where:

*(Goodman, 1965)* $$q = \frac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}\ {}^{*}$$

*(Heuer, 1995 & Raymer, 2001)* $$q = \frac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

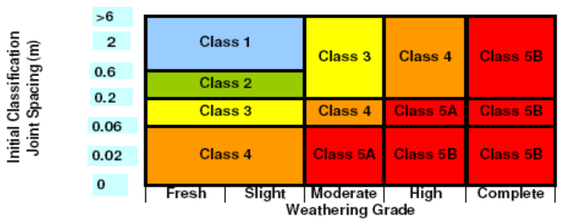
q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965). However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

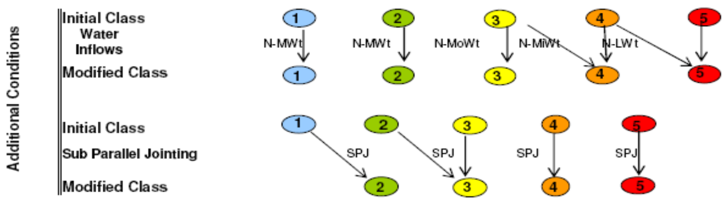



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The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to BLUE cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sheet No. 6 of 6 | | Rev. | | Job No. | |
| | | Chainage 132430 to 133000 | | | | | |
| Job Title: | XRL Tai Mo Shan Tunnels | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |

## Summary of Predicted Groundwater Inflow for Contract 822

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 132430 | 132460 | 132500 | 132580 | 132640 | 132700 | 132760 | 132820 | 132830 | 132835 | 132840 | 132880 | 132885 | 132910 | 132940 | Tunnel Length |
| To (m) | *132460* | *132500* | *132580* | *132640* | *132700* | *132760* | *132820* | *132830* | *132835* | *132840* | *132880* | *132885* | *132910* | *132940* | *133000* | 570 |
| Length (m) | *30* | *40* | *80* | *60* | *60* | *60* | *60* | *10* | *5* | *5* | *40* | *5* | *25* | *30* | *60* | Average Values |
| Feature / BH No. | | | | | | | | | *D350 (4/5)* | *f2* | | | *f1 / D348 (4/5)* | | | |
| Rock type | *Jkn* | *Jkn* | *Jkn* | *Jkn* | *Jkn* | *Jkn* | *Jkn* | *Jkn* | *Jkn* | *inferred fault* | *Jkn* | *Jkn* | *dyke* | *Jkn* | *Jkn* | |
| Water Level above tunnel (m) | 83.07332 | 79.03082 | 93.11501 | 83.83335 | 72.9504 | 91.648998 | 78.8720172 | 52.3616501 | 52.36165006 | 52.36165 | 52.36165 | 46.81034048 | 46.8103405 | 46.81034 | 44.54121 | |
| WL above rock head (m) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 65.13 |
| Thickness of Rock Cover (m) | 78.07332 | 74.03082 | 88.11501 | 78.83335 | 67.9504 | 86.648998 | 73.8720172 | 47.3616501 | 47.36165006 | 47.36165 | 47.36165 | 41.81034048 | 41.8103405 | 41.81034 | 39.54121 | |
| Permeability (m/s) | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.00E-08 |
| Tunnel Radius | 7 | 7 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11.33 |
| IMS Rock Class | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.00 |
| Vent Adit/ Single Track | | | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | SYCA | |
| Source Size Factor (sf) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| *Horizontal Distance to (sf)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Head Factor* | *0.8307332* | *0.790308* | *0.93115* | *0.838334* | *0.729504* | *0.91649* | *0.7887202* | *0.5236165* | *0.523616501* | *0.523617* | *0.5236165* | *0.468103405* | *0.4681034* | *0.468103* | *0.445412* | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *R* | *0.0830733* | *0.079031* | *0.093115* | *0.083833* | *0.07295* | *0.091649* | *0.078872* | *0.0523617* | *0.05236165* | *0.052362* | *0.0523617* | *0.04681034* | *0.0468103* | *0.04681* | *0.044541* | |

| Calculated Inflow (L/min) for: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Initial Water Inflow | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goodman Eqn | 3.03 | 3.91 | 10.46 | 7.37 | 6.81 | 7.77 | 7.11 | 0.96 | 0.48 | 0.48 | 3.83 | 0.46 | 2.28 | 2.73 | 5.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 63 | l/min |
| Heuer / Raymer Eqn | 3.03 | 3.91 | 10.45 | 7.36 | 6.80 | 7.76 | 7.11 | 0.96 | 0.48 | 0.48 | 3.82 | 0.45 | 2.27 | 2.73 | 5.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 63 | l/min |
| Factored Heuer/Raymer | 0.38 | 0.49 | 1.31 | 0.92 | 0.85 | 0.97 | 0.89 | 0.12 | 0.06 | 0.06 | 0.48 | 0.06 | 0.28 | 0.34 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8 | l/min |
| IMS - Initial Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Initial Water Inflow | |
| *High* | 1.5 | 1.9 | 4.5 | 3.0 | 2.6 | 3.3 | 2.8 | 0.3 | 0.2 | 0.2 | 1.3 | 0.1 | 0.7 | 0.8 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.8 | l/min |
| *Average* | 1.1 | 1.4 | 3.4 | 2.3 | 2.0 | 2.5 | 2.1 | 0.2 | 0.1 | 0.1 | 0.9 | 0.1 | 0.5 | 0.6 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 18.6 | l/min |
| *Low* | 0.7 | 0.9 | 2.2 | 1.5 | 1.3 | 1.6 | 1.4 | 0.2 | 0.1 | 0.1 | 0.6 | 0.1 | 0.4 | 0.4 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.4 | l/min |
| IMS - Final Water Inflow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Final Water Inflow | |
| *High* | 0.1 | 0.1 | 0.4 | 0.3 | 0.2 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | l/min |
| *Average* | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | l/min |
| *Low* | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| IMS - | 3 | Initial |
| | 0 | Final |
| Goodman - | 11 | |
| Heuer / Raymer - | 11 | |
| Factored Heuer / Raymer - | 1 | |

Note :-

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" *by Heuer, R.E. (1995), and "Predicting Groundwater Inflow into Hard Rock Tunnels"* by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

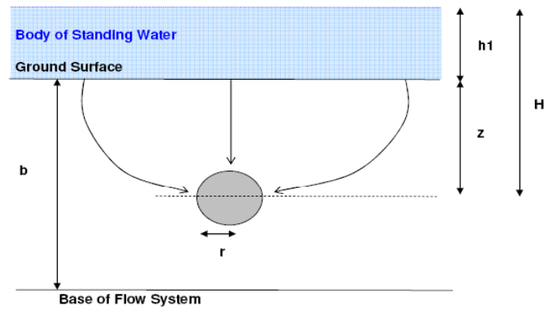
*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)

* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

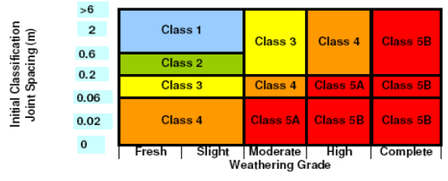
**Goodmans Model Definition**

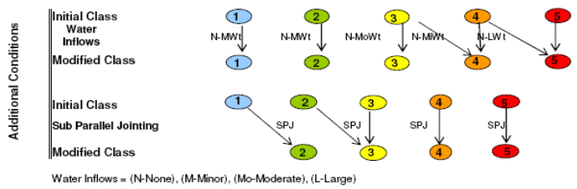



IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

# Express Rail Link

# Consultancy Agreement No. C802

# Detailed Design for Tunnels and Associated Structures (South)

# Works Contract 821

# Hydrogeological Impact Assessment

# Kwai Chung Tunnels - Drill and Blast Sections

ATKINS

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Appendix E Layout of Monitoring Points

## ABBREVIATIONS

| | |
|---|---|
| BD | Buildings Department |
| CEDD | Civil Engineering and Development Department |
| CLP | China Light and Power |
| DSD | Drainage Services Department |
| DSM | MTRCL Design Standard Manual |
| EBS | Existing Building Structure |
| GEO | Geotechnical Engineering Office |
| GIU | Geotechnical Information Unit |
| HDD | Horizontal Directional Drillhole |
| HIA | Hydrogeological Impact Assessment |
| HKSAR | Hong Kong Special Administrative Region |
| HyD | Highways Department |
| IMS | Ian McFeat-Smith groundwater inflow calculation method |
| KCV | Kwai Chung Ventilation Building (VB6) |
| KGR | Kowloon Group Reservoirs |
| LDS | Lantau Dyke Swarm |
| LMF | Lead Mine Pass Fault |
| LSMR | Lower Shing Mun Reservoir |
| MTRCL | MTR Corporation Limited |
| NB | North Bound Track |
| NWDSM | New Works Design Standard Manual |
| RDO | Railway Development Office |
| SB | South Bound Track |
| SMR | Sham Mong Road |
| SSDS | Strategic Sewage Disposal Scheme |
| TBM | Tunnel Boring Machine |
| TCF | Tolo Channel Fault |
| TVS | Tunnel Ventilation System |
| TWL | Tsuen Wan Line |
| VB | Ventilation Building |
| WKT | West Kowloon Terminus |
| WR | West Rail Line |
| WSD | Water Supplies Department |
| XRL/ERL | Express Rail Link |

## EXECUTIVE SUMMARY

This Hydrogeological Impact Assessment (HIA) Report studies the hydrogeological impact of the proposed tunnelling works in the Kwai Chung area on the potential receptors in the vicinity of the XRL tunnels under Works Contract 821.

The proposed XRL Kwai Chung Tunnels pass south from Shek Yam under the urbanised section of Kwai Chung following the Castle Peak Road highway corridor. Particular consideration is given to interfaces with existing buildings and structures in this section of the alignment.

South of the Kwai Chung Valley ground level rises to greater than 200mPD, in an area located between Ha Kwai Chung (to the west) and the Kowloon Reservoirs (to the east), in the vicinity of Lai King Hill. The Reservoirs are located more than 400m from the alignment and will not be impacted by construction of XRL.

Ground level then drops to a low point of approximately 40mPD in a section of the alignment beneath Ching Cheung Road in the vicinity of the Tolo Fault, were particular attention has been paid to the anticipated ground conditions. Elevation rises again briefly before descending to Lai Chi Kok and the interface with Contract 820.

The proposed tunnels are drained, pressure relieved tunnels, except for a short section within the Tolo Fault which may be undrained if high residual inflows are encountered.

Review of a number of previous Hong Kong projects is made, with particular reference to Tunnel F of the SSDS project. This tunnel encountered some of the same ground conditions as will be encountered in the Kwai Chung Tunnels (including the Tolo Channel Fault) and is therefore a useful source of reference. There are however significant differences between the two projects in terms of the hydrogeological setting and the proposed methods of construction. The impacts experienced in response construction of Tunnel F and the potential impacts from the proposed Kwai Chung Tunnel therefore differ significantly.

A hydrogeological assessment has been undertaken which includes calculations and numerical modelling using the software SEEP/W of the Kwai Chung North section of the alignment. The models indicate that with a conservative assumed permeability of $1 \times 10^{-8}$m/s for the pre-grouted rock mass surrounding the tunnel, drawdown of the water table will be less than 1.5m.

The geological assessment for this section of the alignment suggests that there are no compressible clay materials within 500m of the alignment and predicted settlements caused by the modelled magnitude of drawdown are therefore less than 10mm. These would be expected to occur during the construction period and results in a ‘very slight’ risk of damage to even the most sensitive structures. However as a precautionary measure mandatory pre-grouting (ahead of the excavation) for this section of the alignment (133+300 to 133+660) will be required. In addition a tighter final inflow criteria will also be applied in this section of the alignment to be consistent with the calculated inflows.

Indicative grouting arrangements necessary for the range of ground conditions expected in order to meet the specified inflow criteria are provided in the report (further development of the arrangements in terms of grout types and procedures will be required by the contractor, particularly for the major fault zones).

# 1. INTRODUCTION

## 1.1 Scope of Report

This report assesses the hydrogeological setting for the Kwai Chung Tunnels, which is to be constructed as part of the proposed Express Rail Link, under works contract 821.

The report reviews the hydrogeological setting, possible impacts of the proposed tunnel design concept in the vicinity of the XRL alignment and outlines the proposed engineering mitigation measures that will be required.

This report describes the following:

- interpreted geological and hydrogeological conditions;
- estimated rates of groundwater inflow into the tunnels
- summary of potential impact of predicted drawdown on surrounding structures and utilities;
- available mitigation options and the need for pre-excavation grouting;
- proposed specification, control and mitigation implementation procedures;

## 1.2 Project Background

The Railway Development Strategy 2000 (RDS-2000) identified the Regional Express Line as one of the future rail corridors required to meet anticipated transport demand in the HKSAR. In November 2004 Government invited KCR to study the viability of this rail link; in July 2005, following the conclusion of their study KCR submitted its report on the matter, the Express Rail Link (ERL) Study Report.

The 2005 ERL study report examined the Hong Kong section of the proposed Hong Kong Guangzhou Express Rail Link, a variant to the ERL envisaged in RDS-2000. The ERL study established that the terminus of the Express Rail Link should be located at West Kowloon and that options existed for either a dedicated rail corridor or a shared use corridor that utilized existing / proposed KCR lines, namely West Rail and the Kowloon Southern Link.

In February 2006 KCR were invited to proceed with further planning of ERL; the study brief required examination of shared and dedicated corridor options and also the accommodation of changes in planning requirements within the Mainland to provide for an additional ERL station near Yitian Road Futian Station (FUT), in Shenzhen's Futian District and of the proposed Pearl River Delta Rapid Transit System that was being studied in the Mainland.

In November 2006 KCR appointed consultant to carry out a project feasibility study for ERL; the final report was issued in September 2007. This study concluded that although the shared corridor option was viable in the short term the anticipated demand for cross boundary travel would be such that the shared route would be unable to meet demand in the longer term; consequently, the report recommended that the dedicated option be taken forward.

In May 2008, Arup-Atkins JV was appointed by MTRCL to carry out the preliminary design for the ERL tunnels (hereafter renamed as XRL) and associated structures from Mai Po to West Kowloon under Consultancy Agreement NEX/2102.

Atkins was appointed as the design Consultant to MTRCL on Express Rail Link Detailed Design Consultancy Agreement No.C802 – XRL Tunnels and Associated Structures (South) on 16 January 2009.

## 1.3 Project Overview

The Guangzhou-Shenzhen-Hong Kong Express Rail Link is a committed cross Boundary transport infrastructure project, which will provide high speed rail services between Hong Kong and Guangzhou, and a connection to the national high-speed passenger rail network serving major mainland cities outside Guangdong province. This network, which will comprise some 12,000 km, is now under construction in the Mainland. It is understood that the section from Guangzhou to Shenzhen (Futian) will commence operation in 2010. The Hong Kong section of the Guangzhou-Shenzhen-Hong Kong Passenger Line is scheduled for urgent implementation following the announcement by the Chief Executive of the HKSAR in the 2007-08 Policy Address.

The XRL, measuring about 26 km from West Kowloon to the Boundary, will use a dedicated railway corridor to ensure that a high line capacity can be achieved and to ensure operational compatibility with the Mainland. The line will be within tunnels to be constructed by a combination of drill-and-blast, mined using tunnel boring machines and cut-and-cover techniques. Seven access shafts and seven construction adits have been identified along the route to facilitate construction. In total there will be eight ventilation buildings at approximately 5km centres, located at Mai Po, Ngau Tam Mei, Tai Kong Po, Pat Heung, Shing Mun, Kwai Chung, Nam Cheong and Mong Kok West respectively. The ventilation buildings will also be utilised as EAP for the emergency services. For the detailed design the tunnels have been divided into two packages: northern and southern package based on a split on the south side of the Kam Tin Valley. The southern package will consist of some 15km of running tunnel, four ventilation buildings and all the necessary construction access and support facilities.

The C802 consultancy agreement comprises the design of running tunnels from north of the WKT to the PHV, including associated structures enabling, such as ventilation buildings shafts/adits, roadworks, drainage and the necessary works. The Project is divided into five works contract packages, comprised of two initial works packages, 802 – Nam Cheong Property Foundations and 805 – Sham Mong Road Obstruction Removal, and three tunnelling works packages, 822 – Pat Heung to Shek Yam (Tai Mo Shan Tunnels), 821 – Shek Yam to Mei Lei Road (Kwai Chung Tunnels) and 820 – Mei Lai Road to Hoi Ting Road (Kowloon Tunnels).

## 1.4 Alignment Description – 821 – Shek Yam to Mei Lei Road (Kwai Chung Tunnels)

The project comprises approximately 26km of tunnel from the Huang Gang Ventilation Shaft (HGV) north of the Boundary between the Shenzhen Special Economic Zone (SEZ) and the Hong Kong Special Administrative Region to a new terminus station in West Kowloon.

At Shek Yam, a temporary construction adit will provide access from the works area to the drill and blast running tunnels immediately to the west of the site. The contract boundary with the 821 - Shek Yam to Mei Lei Road (Kwai Chung Tunnels) contract to the west will be close to the connection with the construction adit. At this location cover to ground level is greater than 80m.

To the south the alignment proceeds within the 821 contract, below the heavily urbanized and industrialized environment of Kwai Chung North, where it follows the Castle Peak Road highway corridor. To the south the ground level rises steeply within the Ha Kwai Chung area, before descending into Lai Chi Kok area.

This report considers only the Kwai Chung drill and blast tunnel, the alignment is shown on Figure 1.1.

## 1.5 Sources of Information

### 1.5.1 Previous Hydrogeological Studies

A HIA Report comprising one of the suite of Geotechnical Report submissions required under the scope of the consultancy agreement for the Express Rail Link — Preliminary Design Service of XRL Tunnels and Associated Structures (Consultancy Agreement NEX/2102) was submitted in December 2008.

The other reports within the suite are the Geotechnical Engineering Report (GER), Ground Movements Report (GMR), Geotechnical Instrumentation Report (GIR), Site Impact Assessment Report (SIAR), Natural Terrain Hazard Study Report (NTHSR), Structural Appraisal Report (SAR) and Blasting Assessment Report (BAR).

The main objective of the Preliminary Design HIA was to review the hydrogeological conditions along the entire alignment of the proposed XRL project, specifically the definition of the existing groundwater and hydrological systems and provide recommendations for further studies to be carried out following the completion of additional investigation and monitoring works.

### 1.5.2 Borehole Information in Kwai Chung North area

Borehole information in the Kwai Chung North area (as indicated in Figure 3.2) is provided by Geotechnical Engineering Office (GEO) of the Government of the Hong Kong Administrative Region.

## 1.6 Proposed construction concept for Kwai Chung Tunnels

The selected design concept for the Kwai Chung Tunnel is a pressure relieved ("drained") tunnel for the majority of the tunnel length, whereby the groundwater pressure on to the final lining is relieved by allowing limited drainage to the tunnel invert, which is taken via the tunnel drainage system to a sump situated at a low point, from where it is discharged.

Contract 821 will comprise a single, twin track tunnel (span approximately 15m) extending from the Shek Yam Construction adit towards the south. A bifurcation cavern will be formed from approximate chainages 135+730 to 136+980 where the tunnel will divide into two single track 7m span tunnels. The maximum span of the bifurcation cavern will be approximately 19.5m.

The design concept includes for a short undrained section of single track tunnel within the influence zone of the Tolo Channel Fault. This precaution is in case inflows cannot be easily controlled by pre-grouting in this section of the alignment to levels consistent with the final inflow criteria. The tunnel will be sized so as to accommodate an undrained lining, although a drained tunnel may be constructed if groundwater inflows are adequately controlled. For either construction option pre-excavation grouting will be required to allow safe excavation of the tunnel.

Typical tunnel cross sections are shown in Figure 1.2.

# 2. PRECEDENT

## 2.1 Inflow to Tunnel Excavations in Rock

Historical examples of groundwater inflows which have forced long delays or even abandonment of tunnels are numerous and many are well known. As a single instance from the 19th Century, completion of the 6.5km long Severn Railway Tunnel was delayed for several years by 'The Great Spring' which represented extremely localised inflow over a 3-4m length beneath the land, whereas the tunnel had been successfully driven beneath the estuary of the River Severn. Pumped inflows which continue today range between 470 and 1260 l/s from this short length in a conglomerate. Other examples include the Saurdal-Sandsetu tunnel which experienced 830 l/s.

There is also experience in Hong Kong, notably SSDS, where high inflows were experienced that could not be adequately controlled with the available equipment, in this case in three of five subsea tunnels.

However for the majority of tunnels in Hong Kong only limited inflows were encountered over long lengths of the excavations, due to the generally low hydraulic conductivity of the rock mass. Data available from five relatively recently completed MTRC tunnels illustrates the typical variation of conditions encountered. These are summarised in the Table below:

Table 2.1 Summary of Recorded Inflows into Recent MTR Tunnels

| Tunnel Project | Length of Drained Tunnel | Final Groundwater inflows | |
|---|---|---|---|
| | | m3/day | l/min/m |
| West Rail Tai Lam Tunnel | 5140 | 2960.6 | 0.4 |
| Pak Shing Kok | 1178 | 298.5 | 0.2 |
| Tai Yam Teng Tunnel | 716 | 105.2 | 0.1 |
| Black Hill Tunnels | 1650 | 68 | 0.03 |
| Quarry Bay Congestion Relief Works | 1800 | 6.2 | 0.002 |

Pak Shing Kok encountered high inflows in a series of adjacent bifurcation caverns located with shallow cover and beneath a river with a high base flow that historically was maintained throughout the year. No grouting was carried out during excavation of the tunnels, although grouting was undertaken after completion of the final lining to lower the inflows in to the permanent works. Throughout the rest of the tunnel only localised minor inflows and seepages were observed, but again no systemic probing and grouting was undertaken. Despite this the total final inflows are relatively small, equating to 0.2l/min/m. For tunnels that have not encountered high localised inflows, such as those within the granitic rock mass encountered at Quarry Bay Extension, the final inflows were very low.

Similar precedent experience can be seen from Singapore where military caverns in the massive granite pluton were dry and nearby sewerage tunnels suffered inflows within the weathered and fractured rock.

The same was true of the storm water storage cavern on Jersey, which was substantially dry whereas the tunnels conveying stormwater encountered inflow problems.

Initially the West Rail Tai Lam Tunnel adopted a probehole criteria of 20 litres/min. This was later relaxed to 50 litres/min from any probehole. In response to these criteria pre excavation grouting was undertaken at 9 locations to treat 11 geological features with high associated inflows.

Analysis of the available records indicates that this was inadequate to control the final inflows to the required 0.55 litres/min/m, and extensive programmes of post excavation grouting were required to reduce the inflows.

The final inflows recorded in the sumps after completion of the project equate approximately to 0.4l/min/m.

## 2.2 SSDS Tunnel F

### 2.2.1 Overview

Tunnel F was excavated from Tsing Yi, under the Rambler Channel to Stone Cutters, with a total length of 3.6km The alignment is shown on Figure 2.1. The tunnel was 3.35m in diameter and was excavated using a Robbins open face hard rock TBM, with a cast in situ lining and two drills mounted on a rotating wheel located 18m back from the face. Alterations to the TBM during excavation of the tunnel collared the drill at 5m behind the face. The tunnel was constructed at an elevation of -125 to -132mPD.

### 2.2.2 Geology

Tunnel F of the DSD SSDS project traversed some of the same geology as expected to be encountered in the proposed 821 tunnels. In particular it crossed the following :

- Lead Mine Pass Fault (LMF)
- Lantau Dyke Swarm (LDS)
- Tolo Channel Fault (TCF)

The alignment intersected the TCF diagonally suggesting some local variation in the strike of the zone.

The TCF comprised a complex zone defined as being 268m in width with a repeating succession of mostly poor and very poor rock mass conditions with some better rock mass conditions in between.

Between the TCF and the LMF the tunnel encountered a dyke swarm for approximately 120m, this was associated with very high inflows and poor rock mass conditions. The dykes were mainly rhyolites and due to their rapid cooling tend to have a well developed joint system that gives rise to a blocky rockmass, requiring specific support and also gives rise to high permeability and inflows. Joints associated with these dykes were observed to be open 'forming a network of voids'. Mafic dykes are not recorded in the literature as being a specific problem within this section of the alignment.

The LMF comprised a 20m wide zone of very poor rock mass conditions (the quality of the rock adjacent to this is not known) and hand mine techniques were used to traverse this section.

### 2.2.3 Hydrogeology

Details of the inflows along Tunnel F are not published however it is stated that inflow from the dyke swarm was in the order of thousands of litres per minute. Water inflows associated with the TFZ were also reported as very high.

At the end of tunnelling the inflow to the tunnel was 1.4l/min/m.

### 2.2.4 Inflow Control

Due largely to the distance of the TBM mounted probe drills from the face at the commencement of the project much of the inflow control via grouting had to be left until after excavation which only managed to partially control the inflow.

In the areas requiring the most extensive grouting the grout hole layout comprised 20 holes around the full perimeter, drilled 36m ahead of the face (i.e. 54m in length). The holes were stage grouted with grout quantities averaging 5,000 kg/m of tunnel for most of the length of the TCF. Typically there were 20 probe holes which suggests 5,000kg per probehole. 300 days were apparently required to treat the zones of excessive water inflow. The statistics improved once the drill collaring location was relocated to 5m behind the face.

### 2.2.5 Implications of Drawdown

For tunnel F and some other SSDS tunnels significant drawdown and some settlement resulted from the tunnel inflows. This impacts where enhanced by the presence of overlying marine deposits that both inhibited recharge, thereby causing more widespread drawdown whilst suffering consolidation settlement where they occurred beneath reclamation fill. This situation is not expected to occur for 821 as marine deposits do not occur within 500m of the alignment.

Examples from other projects in Hong Kong are summarised in the following table:

Table 2.2 Summary Table of HK Tunnel Projects

| Tunnel Project | Length (km) | Geological Terrain | Excavation Method | Water Inflow Issues | Ground Treatment |
|---|---|---|---|---|---|
| MTRC - MIS, TWE, ISL | 28.0 | Granite | Drill & Blast | Generally none to minor even adjacent to reclamation areas at 150-300m from sea; except at one location at North Point where a fracture zone connecting the tunnels to the sea gave very large water inflows. | Extensive ground treatment employed at North Point tunnels. |
| WSD Western Aqueducts Low Wu to Tai Lam Chung | 19.0 | Granite, Granodiorities, Sedimentary, volcanics | Drill & Blast | Generally none to minor, excepting one notable high inflow zone in a large shear zone in volcanic rocks. | Post grouting carried out with variable success. |
| WSD Western Aqueducts Tsing Tam to Yau Kom Tau (nearby open reservoir) | 5.0 | Granite Granodiorities, Sedimentary, volcanics | Drill & Blast | Generally none to moderate except at locations where large water inflows occurred in areas of high overburden cover where fracture zones or open joints connected the tunnels with a local reservoir. | -- |
| WSD Pak Kong to Junk Bay | 6.0 | Granite, volcanics | Drill & Blast | Generally none to minor but very high initial inflows (60 l/s) at granite/volcanics interface, with an inflow reduction factor of 50%. | Extensive post grouting at granite/volcanic interface with little success. |
| WSD Lantau Aqueduct | 7.0 | Granite with Rhyolite Dyke Swarm | TBM, Open Type | Several zones of initially large water inflows occurred at open joints giving a cumulative outflow from the tunnel of 40 l/s reducing with time. | -- |
| Hong Kong Cable Tunnel (Bowen Road to Wah Fu) | 3.1 | Volcanics | Drill & Blast | None to minor. Total flows about 1 l/s. | -- |
| Hong Kong Electric Cable Tunnel (Nam Fung Road to Parker) (nearby reservoir) | 5.5 | Granite | TBM, Open Type | High initial water inflows (up to 40 l/s) where fracture zones or open joints connected the tunnel with Tai Tam Reservoir, and feeder valleys. | Extensive post grouting to suppress water inflows. Process involved 'chasing' inflows into adjacent sections of tunnel. |

| Tunnel Project | Length (km) | Geological Terrain | Excavation Method | Water Inflow Issues | Ground Treatment |
|---|---|---|---|---|---|
| Hong Kong University Sewerage Tunnel | 1.5 | Volcanics | Drill & Blast | Generally none to minor. High water inflow (47 l/s) at fracture zone reducing by 50% in one month and by 80% ultimately. | -- |
| Hong Kong Gas (Braemar Hill) | 2.6 | Granite | TBM, Open Type | None to minor. | -- |
| Tolo Effluent Export Scheme | 7.5 | Granite, Granodiorities | TBM, Double Shielded | Generally none to minor with infrequent high initial inflows (cumulating to 40 l/s) at fracture zones or open joints. | -- |
| Route 3 - Cheung Ching Tunnels | 1.5 | Volcanics/ Granite | Drill & Blast | None to minor. | -- |
| Tate's Cairn Tunnel | 4.8 | Granite | Drill & Blast | Generally none to minor. Total flows at portals about 8 l/s during construction. | -- |
| Castle Peak NWNT Sewerage Project | 9.0 | Granite | Drill & Blast | Generally none to minor. | -- |
| DSD-SSDS Outfall (Subaqueous) | 1.5 | Granite | TBM, Open Type | Generally minor to moderate inflows. | Much grouting prior to and subsequent to tunnel lining erection. |
| DSD-SSDS Contracts 13 & 14 (Subaqueous) | 2.4 (21.6 remaining) | Mainly granite, some volcanics | 5 No. TBMs Open Type | Large inflows on 3 out of 5 no. drives where fracture zones or open joints connect tunnels with sea. Inflows of 17-25 l/s recorded at some localities with little effective reduction with time. | Extensive post grouting to meet high watertightness specification. |

Based upon the large amount of experience of tunnelling within the granitic rock masses in Hong Kong (more than 100 kilometres of tunnel) it is clear that site specific details are very influential on the response of this environment to tunnel excavation and induced flows. This suggests the following:

- Inflows vary according to rock mass conditions including lithology, cover (stress and head) weathering state and proximity to recharge sources.
- Higher, potentially problematical inflows are typically associated with anomalous geological conditions, associated with discrete transmissive structure, dykes, faults, or influence of the weathering profile.
- When these conditions are combined with proximity to a recharge source the inflows tend to be sustained. In the absence of a nearby recharge source drawdown may be caused by inflows if left uncontrolled.
- Pre-excavation grouting is not typically required for long lengths of tunnel excavation, except in very sensitive urban settings where stringent inflow criteria may apply.
- Post-excavation grouting tends to be difficult to control and implement and time consuming.
- HK precedent experience suggests inflows to tunnels in rock are controllable by pre-excavation drilling and grouting methods when adequately designed and implemented with appropriate equipment, prior to excavation. However there are a number of Hong Kong examples where pre-excavation grouting was not adequately specified or implemented which led to high final inflows and the need to undertake programmes of post excavation grouting.

# 3. GEOLOGICAL AND HYDROGEOLOGICAL SETTING

## 3.1 Overview

A Geological Longitudinal Section along the alignment is included as Figure 3.1.

The contract boundary with 822 is to the north of Kwai Chung at Chainage 133+000, where the alignment passes beneath Sheung Kwai Chung where ground level reaches a maximum of approximately 80mPD. From here the alignment continues to the south and crosses near the head of the Kwai Chung Valley where ground level is at 15 to 30mPD for a distance of 750m.

South of the valley ground level rises again to greater than 200mPD, in an area located between Ha Kwai Chung (to the west) and the Kowloon Reservoirs (to the east), in the vicinity of Lai King Hill. Ground level then drops to a low point of approximately 40mPD in a section of the alignment beneath Ching Cheung Road in the vicinity of the Tolo Fault. Elevation rises again briefly before descending to Lai Chi Kok. The contract boundary with 820 is at Chainage 136+800.

The alignment can be subdivided according to the topographic setting as summarised in table 3.1

Table 3.1 Topographic Settings of Kwai Chung Tunnels

| | | Approximate Chainages | | Approximate Crown Level (mPD) | Typical Rock head level (mPD) | Typical Groundwater level (mPD) | Water Head (m) |
|---|---|---|---|---|---|---|---|
| | | From | To | | | | |
| Kwai Chung North | | 133+000 | 133+750 | -32 | 0 | 10 | 40 |
| Kwai Chung South | Lai King Hill | 133+750 | 136+300 | -28 | >180 | >250 | >180 |
| | Ching Cheung Road - Tolo Channel Fault | 136+300 | 136+650 | -24 | 30 (lower bound) | 15 - 30 | >50 |

Track level reaches a low point at chainage 133+025, where the proposed tunnel will pass beneath the existing Kwai Chung cable tunnel, track level at this location is -42mPD. Tunnel crown level will therefore be at approximately -32mPD for all of this section of the alignment. The alignment then rises in order to pass over the DSD Lai Chi Kok drainage tunnel at chainage 136+950, within the adjacent contract 820.

The alignment is within granitic rock types throughout this section of the alignment. A contact between granodiorite and finer grained granite (Shatin Granite) is expected close to the northern contract boundary. There is a faulted contact between the Shatin Granite and the Kowloon Granite, at the location of the Tolo Fault.

The 821 alignment is intersected by a number of faults as indicated in the alignment geological long sections. Two regional faults will intersect the alignment as follows :

Lead Mine Pass Fault – Chainage 133+450

Tolo Channel Fault – Chainage 136+300 to 136+650

To the north of the Tolo Channel Fault a high frequency of dykes is anticipated, comprising rhyolite (fine grained) dykes of the Lantau Dyke Swarm. These have not been identified clearly by the project site investigation but are known to be present to the north of the Tolo Fault and were encountered in the SSDS Tunnel F at that location. High water inflows can be expected to be associated with the rhyolite dykes and dyke margins.

## 3.2 Kwai Chung

Kwai Chung North Tunnel lies within a relatively low lying area (typical ground level +15 to +25mPD). Key features of this section of the alignment are provided below.

Despite the tunnel alignment being located at some depth, in a rock mass with typically limited weathering, the water table is located within the superficial materials that vary in thickness between approximately 10 to 20m. The water table is below rock head to the north of chainage 133+060 and to the south of chainage 133+700, within these areas the saturated thickness in the superficial deposits is zero and water drawdown induced settlement is not an inflow control constraint. However between these chainages the saturated thickness varies from less than 5m to greater than 15m.

A comprehensive study of the distribution of superficial deposits in the Kwai Chung area has been undertaken using both the project site investigation data but also all available data from the GIU. The superficial deposits recorded in the GIU boreholes logs have recently been classified by the GEO. This data has been plotted as a GIS plot in Figure 3.2. This study demonstrates that marine deposits (comprising sensitive clay materials) have not been encountered in boreholes closer than 500m from the alignment. Alluvial materials extend further up the valley and are conservatively assessed to be present above the alignment between chainages 133+200 to 133+500. Borehole data suggests the alluvium is granular in composition at this location. It is therefore assumed for design purposes that drawdown induced settlement can be calculated using elastic constants with no time dependent consolidation settlement likely.

There are a variety of existing structures in this area, with a variety of foundations, these are considered in more detail in Section 7 and 8.

Between chainages 133+450 to 133+470 the tunnel will cross the Lead Mine Pass fault. Associated with this is a zone of thicker weathered materials and poor rock mass conditions are anticipated, at least over a zone of 20m wide, but additional subparallel transmissive structure may also be present including dykes.

## 3.3 Lai King Hill

The section of the alignment beneath Lai King Hill has a high cover of over 100m, typically greater than 200m. Superficial deposits are likely to be of limited thickness with only a limited saturated thickness within these materials. There are only a few structures above this section of the alignment, including some concrete lined WSD reservoirs, however due to the vertical separation they will not impose any constraint on the proposed works.

This section of the alignment passes approximately 400m to the west of the Kowloon Reservoirs, the alignment does not pass beneath any direct or indirect catchments to these reservoirs.

- Kowloon Reception Reservoir (Catchment S12.2 – more than 400m to the east)
- Kowloon Reception Reservoir direct catchment S12.1 (more than 200m to the east)
- Kowloon Reception Reservoir indirect catchment S12.3-1 (about 200m to the east)

The locations of the proposed Kwai Chung Tunnels and Kowloon Group Reservoirs are shown on Figure 3.3.

A high frequency of rhyolite dykes may be encountered in this section of the alignment, and high inflows may be associated with these features, that will require treatment.

## 3.4 Ching Cheung Road and the Tolo Channel Fault

### 3.4.1 Available Data

It is known that the alignment will be intersected by the Tolo Fault approximately between the chainages 153+150 to 136+500.

An HDD hole has been drilled as part of the XRL project specific site investigation. There were significant restrictions on the location of the drilling rig, which was eventually situated close to chainage 136+450, but at a location approximately 100m to the west of the alignment, as shown on Figure 3.4. The aim of the hole was to penetrate the full thickness of the TCF however due to restrictions in location of the hole it may have only been possible to drill through a portion of the fault as explained further below.

From ground level the HDD alignment was downwards at approximately 30 degrees, until it reached tunnel elevation at chainage 136+220, by which time it had also converged on the centre line of the southbound tunnel.

### 3.4.2 Rock Mass Classes

From inspection of the logs and core photographs four rock mass classes have been identified as follows:

Table 3.2 Tolo Channel Fault Zones – Rock Mass Classes

| Rock Mass Class | Key Attributes | RQD Range (typical) | Core Loss Range (typical) |
|---|---|---|---|
| RM01 | Typical rock mass conditions | 90 - 100 (95) | 0 |
| RM02 | Limited or no alteration high fracture frequency and lower RQDs. Very limited core loss | 45 - 65 (55) | <5% |
| RM03 | Frequent non intact and core loss zones | 30 - 50 (40) | 20% |
| RM04 | Completely altered rock material with associated non intact core or core loss | 0 - 30 (10) | 30% |

NOTE
1 Core loss is based on an assessment of the HDD hole 002.

RM01 comprises slightly weathered and fresh rock material with moderately widely spaced discontinuities, there is typically no core loss and major throughgoing structure is not characteristic. Water inflows would be expected to be limited to singular transmissive joints.

RM02 comprises closely and very closely spaced subvertical discontinuities trending parallel to the main fault zone, which are often chlorite infilled. Less than 5% core loss is typical within this class as identified in DD02. Due to the high frequency of discontinuities high inflows would be expected from these zones. RM02 tends to occur as discrete zones cross cutting through RM01 conditions.

RM03 is characterised by a very high frequency of core loss zones resulting in average core loss of 20% of the rock mass. Core loss zones are discrete and up to 0.5m in width comprising completely altered material, some of the zones have been partially cored in DD02 and were retrieved as non intact broken core with some clay material. The intervening rock material is typically moderately weathered to slightly weathered[1]. Large ground water inflows are possible from this rock mass class.

[1] Weathering state not described on borehole log

RM04 is also characterised by a high frequency of core loss zones resulting in substantial average core loss comprising 30% of the rock mass. Core loss zones are discrete and up to 2m in width and presumed to comprise completely altered and sheared material. Intervening rock mass is typically moderately weathered[1], moderately strong with closely and very closely spaced chlorite infilled discontinuities. Significant instability and high water inflows are possible from this rock mass.

### 3.4.3 Distribution of Classes and Proposed Alignment Model

The logged distribution of the rock mass classes is as follows :

Table 3.3 Tolo Channels Fault Zone – Distribution of Rock Mass Classes

| Approx. Chainage (m) | | Width | Rock Mass Class | Key Features | Interpretation |
|---|---|---|---|---|---|
| From | To | | | | |
| 136+440 | 136+412 | 28 | - | Fault not sampled | Sub areal Weathering profile |
| 136+412 | 136+382 | 30 | 3 | Classes 3 and 4 | Central Fault Zone |
| 136+382 | 136+355 | 27 | 4 | | |
| 136+355 | 136+337 | 18 | 3 | | |
| 136+337 | 136+331 | 6 | 1 | Classes 1, 2 and 3 | Outer Fault Zone |
| 136+331 | 136+325 | 6 | 3 | | |
| 136+325 | 136+322 | 3 | 2 | | |
| 136+322 | 136+315 | 7 | 1 | | |
| 136+315 | 136+309 | 6 | 3 | | |
| 136+309 | 136+306 | 3 | 2 | | |
| 136+306 | 136+280 | 26 | 1 | | Fault Zone Margin |
| 136+280 | 136+243 | 37 | 2 | Parallel Structure | |
| 136+243 | 136+192 | 51 | 1 | | |
| 136+192 | 136+165 | 27 | 2 | Parallel Structure | |
| 136+165 | 136+131 | 34 | 1 | | |
| 136+131 | 136+125 | 6 | 2 | Parallel Structure | |
| 136+125 | 135+885 | 240 | 1 | | |

NOTE
1 Full extent of fault not intersected by borehole

The distribution of the rock mass classes as encountered in DD02 is shown on Figure 3.5. Figure 3.6 presents an alignment interpretation of the anticipated rock mass classes versus chainage in and adjacent to the TCF.

These interpretations illustrate that the southern end of the fault zone width may not have been encountered by DD02, and an assumed distribution of classes for this area, based on the distribution encountered on the northern side of the fault zone, is shown on Figure 3.5.

In broad terms the TCF is anticipated to comprise a Central Fault Zone of very poor rock mass conditions (RM03 and RM04) flanked by an Outer Fault Zone which comprises intermittent good and poor rock mass conditions (RM01, 02 and 03). Beyond this is a broader zone in which discrete zones of closely spaced structure (RM02)[2] located in an otherwise competent rock mass (RM01) will be encountered trending parallel to the main fault.

The inferred alignment distribution is therefore as follows :

Table 3.4 Tolo Channel Fault – Broad Structural Subdivision

| | Chainage | Width (m) | | Source |
|---|---|---|---|---|
| Zone Containing Parallel Structure | 136+126 - 136+306 | 180 | 180 | From DD02 |
| Outer Fault Zone | 136+306 - 136+337 | 140 | 31 | From DD02 |
| Central Fault Zone | 136+337 - 136+412 | | 75 | From DD02 |
| Outer Fault Zone | 136+412 - 136+442 | | 30 | Conjectured |
| Zone Containing Parallel Structure | 136+442 - 136+662 | 180 | 180 | Conjectured |

Table 3 indicates that the width of the outer and central fault zone, with associated adverse tunnelling conditions is approximately 140m, with further subparallel zones being encountered for a distance of 180m to the north and (presumed) to the south. There is a risk that 140m is an underestimate for the main part of the fault zone as it is possible that not all the central zone was intersected by DD02, the fault zone being recoded as 268m wide in tunnel F.

For construction planning (and for consideration in preparing the Geotechnical Baseline Report - GBR) the following model is proposed:

[2] The core has not been inspected and to date a detailed check of the logging has not been completed. It is possible that the RM02 zones are closely fractured ryhollite dykes.

Table 3.5 Tolo Channel Fault – Broad Structural Subdivision – Revised for GBR

| | Chainage | Width (m) | | Source |
|---|---|---|---|---|
| Zone Containing Parallel Structure | 136+126 - 136+306 | 180 | 180 | From DD02 |
| Outer Fault Zone | 136+306 - 136+337 | 266 | 31 | From DD02 |
| Central Fault Zone | 136+337 - 136+512 | | 175 | From DD02 |
| Outer Fault Zone | 136+512 - 136+572 | | 60 | Conjectured |
| Zone Containing Parallel Structure | 136+572 - 136+752 | 180 | 180 | Conjectured |

This suggests a total zone fault zone of 266m, consistent with the Tunnel F information and an overall width of 627m.

# 4. REGIONAL HYDROLOGICAL DATA

Basic hydrological data along the alignment of the XRL has been obtained from the Geotechnical Engineering Office (GEO), the Hong Kong Observatory (HKO) and the Water Supplies Department (WSD). The data collected includes rainfall records, evaporation records and catchment yield records, each of which are discussed in more detail in the following sections.

## 4.1 Rainfall Records

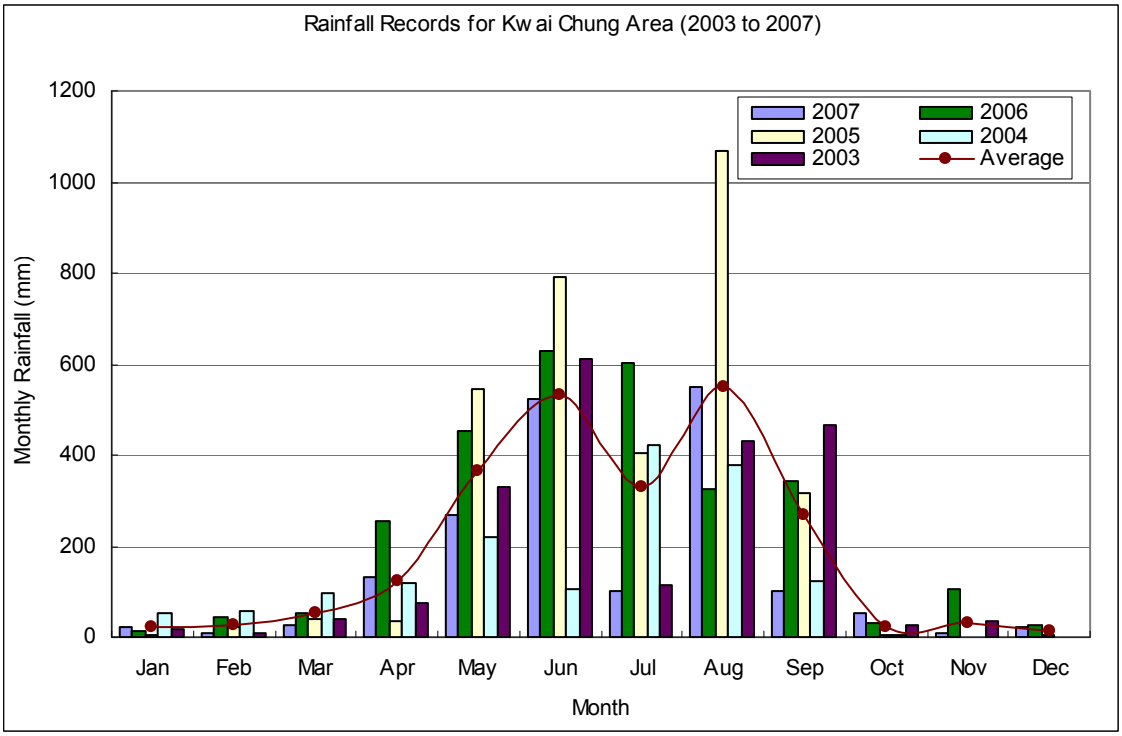
The relevant rainfall data collected includes readings taken at GEO Rain Gauge Nos. N04, N06, K06 & K10, which are located between Lei Pui Street, Shek Lei in the north and West Kowloon Northern Sewage Pumping Station in the south. The data collected extends from the coastline in the west to the So Uk Estate in the east. A summary of the rain gauge locations and monthly monitoring results for the period 2003 to 2007 are provided in the tables below:

Table 4.1 Rain Gauge Location

| Rain Gauge Number | Rain Gauge Location |
|---|---|
| N04 | Kai Kwong Lau, Cho Yiu Estate |
| N06 | C.N.E.C. Christian College, 6 Lei Pui Street, Shek Lei |
| K06 | Carnation House, So Uk Estate |
| K10 | West Kowloon Northern Sewage Pumping Station |

Table 4.2 Average Rainfall Reading

| Year | Recorded Monthly Rainfall (mm) based on average reading from N04, N06, K06 & K10 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| 2007 | 23 | 8 | 24 | 133 | 269 | 522 | 100 | 551 | 102 | 53 | 7 | 24 |
| 2006 | 14 | 42 | 53 | 253 | 452 | 630 | 603 | 326 | 344 | 33 | 107 | 28 |
| 2005 | 5 | 21 | 40 | 35 | 544 | 793 | 402 | 1069 | 317 | 4 | 1 | 6 |
| 2004 | 55 | 58 | 96 | 120 | 222 | 107 | 421 | 380 | 124 | 3 | 0 | 0 |
| 2003 | 18 | 8 | 40 | 77 | 329 | 610 | 114 | 430 | 464 | 26 | 33 | 1 |
| Av. | 23 | 27 | 51 | 124 | 363 | 532 | 328 | 551 | 270 | 24 | 30 | 12 |



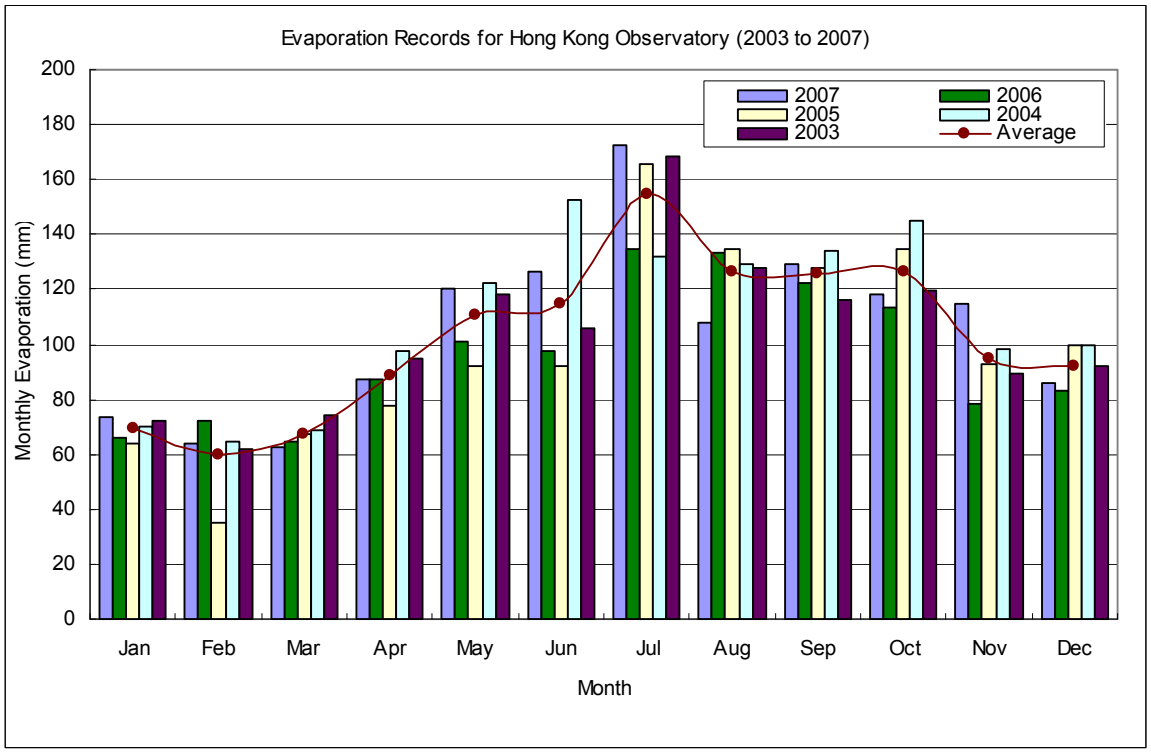

The above data indicates that the drainage catchments along the alignment of the XRL typically have a total input to the hydrological system between 1600 mm and 3200 mm per annum, with an average annual rainfall in the order of 2300 mm.

## 4.2 Evaporation

Whilst no direct monitoring of evaporation rates has been carried out in close proximity to the alignment, the records of monitoring at the Hong Kong Observatory record an average annual evaporation of about 1200 mm. The relevant monitoring records used to determine this value are summarized in the following table:

Table 4.3 Recorded Monthly Evaporation

| Year | Recorded Monthly Evaporation (mm) based on readings from the HKO | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| 2007 | 74 | 64 | 63 | 88 | 120 | 127 | 172 | 108 | 129 | 118 | 115 | 86 |
| 2006 | 66 | 72 | 64 | 87 | 101 | 98 | 135 | 134 | 122 | 113 | 79 | 83 |
| 2005 | 64 | 35 | 67 | 78 | 92 | 92 | 166 | 135 | 128 | 135 | 93 | 99 |
| 2004 | 70 | 65 | 69 | 98 | 123 | 153 | 132 | 129 | 134 | 145 | 98 | 99 |
| 2003 | 73 | 62 | 74 | 95 | 118 | 106 | 168 | 128 | 116 | 120 | 90 | 92 |
| Av. | 69 | 60 | 67 | 89 | 111 | 115 | 155 | 127 | 126 | 126 | 95 | 92 |



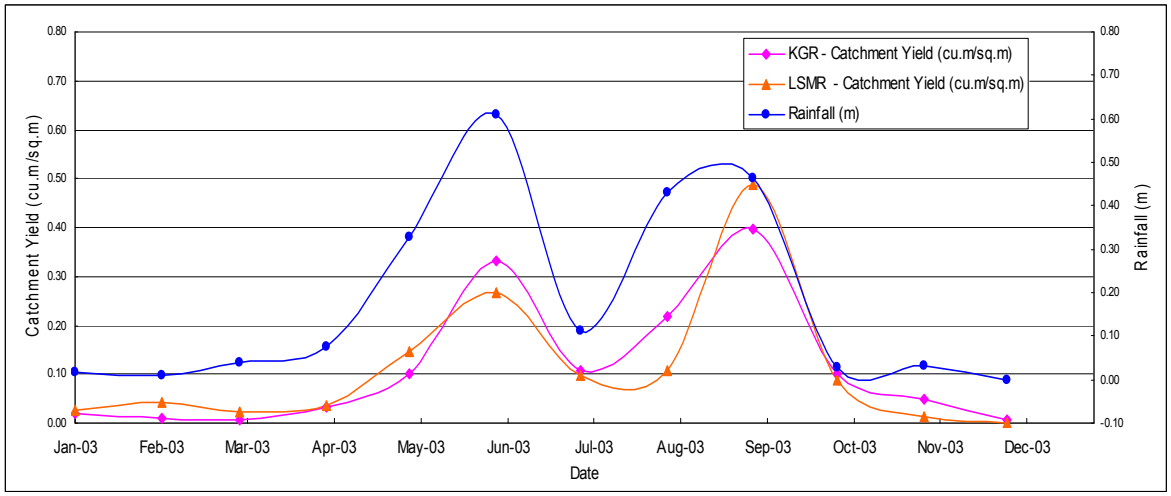

This data indicates that the water balance for any standing water within catchments in the vicinity of the XRL is likely to be positive between April and September (precipitation exceeds evaporation) and negative between October and March (evaporation exceeds precipitation). This observation correlates reasonably well with the reductions in groundwater levels noted in many of the observation wells during the dry-season. However, it should be noted that much of the rainfall within the catchment areas would not provide a source for evaporation as it would be lost to the system either as direct surface run-off or through infiltration and recharge of the groundwater aquifers.

## 4.3 Surface Run-off

In addition to the above records of rainfall and evaporation, crude estimates of surface run-off have also been made based on the catchment yield data published by WSD for the Kowloon Group Reservoirs (KGR) and Lower Shing Mun Reservoir (LSMR) for the period 2003. A summary of the catchment yield characteristics for these areas is provided in the table below.

Table 4.4 Summary of Catchment Yields based on WSD Monitoring Data for the Period 2003

| Area | Catchment Yield (thousands of cu.m) per Hectare for 2003 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| KRG | 113 | 54 | 29 | 188 | 576 | 1919 | 617 | 1250 | 2289 | 578 | 272 | 42 |
| LSMR | 500 | 825 | 465 | 711 | 2880 | 5304 | 1935 | 2156 | 9667 | 1735 | 234 | 20 |
| Av. | 113 | 54 | 29 | 188 | 576 | 1919 | 617 | 1250 | 2289 | 578 | 272 | 42 |




Based on the individual catchment characteristics for each monitoring area, it is apparent that (excluding the effects of evaporation) the total input into each catchment per annum after run-off equates to 1374 mm (KGR) and 1333 mm (LSMR). This suggests that approximately 62% to 63% of precipitation is lost as direct surface run-off, although as can be seen on the above plot, this figure typically has notable increases (up to as much as 80% of precipitation) in the months of August and September when rainfall intensities are often at their highest. The above data largely corresponds with the DSD's Stormwater Drainage Manual (2000), which suggests a runoff coefficient between 0.25 to 0.35 for steep grassland (heavy soil) and for steep natural slopes or areas where a shallow soil surface is underlain by impervious rock, a higher runoff coefficient of 0.4 to 0.9 may be applied.

Based on the above figures it is reasonable to estimate that the total groundwater recharge from rainfall for the catchments in the vicinity of the XRL is in the order of 920 mm per annum, excluding any effect from evaporation. The Stormwater Drainage Manual also suggests a run-off coefficient of 0.95 for hard surfaced developed areas, which corresponds to 65 mm recharge from rainfall within the urban area in Kwai Chung.

# 5. SEEP/W ANALYSIS – KWAI CHUNG NORTH

## 5.1 Introduction

Kwai Chung North has been identified as the only section of the alignment having a potential risk of damage to structures caused by drawdown. To evaluate this risk hydrogeological analyses have been undertaken to assess the possible magnitude of drawdown to serve as a basis for assessing the impacts on buildings and structures.

## 5.2 Conceptual Model

### 5.2.1 Sub-regional (Wide area) Model

The hydrogeological concept for the region is summarised in Figure 5.1. The model depicted is a wet season model with recharge to the superficial deposits and rock taking place in the natural exposed slopes. The right hand edge represents the catchment boundary (no flow) and the left hand the sea. The granitic rock reduces in permeability with depth such that the base of the model can be assumed as a no flow boundary.

Flow 'refraction' is expected to take place with the majority of flow taking place in the higher transmissivity layers and flow towards these layers from the adjacent layers of lesser conductivity. This process includes flow from the rockmass to the upper more permeable zones. For presentation not all weathering zones are shown in the conceptual model.

In general, flow takes place from the right hand of the model, concentrated in the more transmissive layers towards the left hand of the model and the sea.

The marine deposits are of low permeability and therefore inhibit discharge of the system, and act has a confining layer.

The same system applies in the dry season, but with negligible recharge and reduced flows and a decline in the water table.

The model described above is representative of a section along the central axis of the Kwai Chung Valley, however due to the geometry of the Valley, there will also be flow towards the cross section, with convergent flow down the full length of the valley. Actual recharge will therefore be greater than represented by a two dimensional model, in this respect a 2D model will be inherently conservative.

### 5.2.2 Local Scale Models

#### 5.2.2.1 Hydrogeological Profile

The typical hydrogeological sequence applicable to the Kwai Chung North tunnels is summarised as follows, with each of the units varying in both composition and thickness:

- superficial deposits (colluvium/fill)
- weathered rock (saprolite)
- rockhead interface zone
- fresh rock profile

The review of GI logs, inspection of rock cores and review of all data has identified the presence of two zones with potential to influence groundwater flows. These consist of a coarse grained and porous highly and completely decomposed layer in the area above rockhead and an interface zone in the upper part of the rock mass, resulting from preferential weathering along sub-horizontal discontinuities and to a smaller extent the sub-verticals.

These zones both have potential for high hydraulic conductivity due to the process of accumulation of water at the soil / rock interface and lateral flow dictated by the underlying, and generally lower permeability, granitic rock mass.

The rock mass in which the tunnel will be formed comprises a fractured crystalline media with an inherently low porosity and hydraulic conductivity. The predominant factor controlling groundwater flow through the rock mass will be the presence of open discontinuities forming networks, in particular those sub-vertical transmissive discontinuities with connectivity to the overlying superficial deposits and high permeability zones.

#### 5.2.2.2 Major Geological Structure

Structure at various scales is anticipated to occur within the rock mass in the vicinity of the tunnels.

The currently available site investigation data has identified zones of closely spaced discontinuities which may be persistent. These structures may be more permeable than the typical rock mass conditions forming enhanced conduits of flow, although clay infill has been noted in some zones, reducing the significance of such features.

In addition the Lead Mine Pass Fault is expected to be encountered comprising a zone of perhaps 20m thickness, and related sub parallel transmissive structures expected within a broader zone.

In addition dykes of the Lantau Dyke Swarm are anticipated, although the frequency and location is uncertain.

## 5.3 Water Table Elevation

The water table elevation has been recorded in borehole monitoring installations along the alignment in Kwai Chung North (see table 5.1), the location of these is shown in Figure 5.2. Standpipes have recorded levels of the water table in the superficial deposits. This data is presented as a contour plot in Figure 5.3, which illustrates the level within the superficial deposits, at the central part of the valley to be relatively consistent and at approximately +10mPD.

The water table is therefore expected to be above rock head between chainages 133+060 to 133+700, however there is limited saturated thickness above rockhead north of chainage 133+300 and south of 135+660.

There is also some data on water pressure (head) within the rock mass below rock head. These levels are much more variable. In general the heads are similar to or slightly above the levels in the superficial deposits, as would be expected from the conceptual model. A borehole slightly further to the south, at the edge of the valley, encountered artesian conditions in the rock mass.

Within the central section of the valley two boreholes recorded much lower heads in the rock than expected, as follows :

Piezometer D346 - -4mPD

Piezometer D347 - -13mPD

Both these boreholes are close to the existing CLP cable tunnel, with piezometer tips located at a similar elevation to the tunnel. D347, which records the lower levels, is located just 25m from the tunnel and the recorded head is approximately 8m above the CLP tunnel crown. This indicates that the CLP is drained and is causing significant depressurisation in the adjacent rock mass, but apparently with very limited impact on the water table.

Table 5.1 Summary of Kwai chung Groundwater Monitoring Records

| Hole No. | Easting | Northing | Piezometer (P) / Standpipe (S) | GL (mPD) | Maximum Water Level(mPD) | Minimum Water Level(mPD) | Variability of GWL (m) | Pipe Tip - Depth (m) |
|---|---|---|---|---|---|---|---|---|
| A040 | 832159.94 | 824513.306 | S | 89.76 | 86.02 | 85.68 | 0.34 | 88.00 |
| A050 | 832593.95 | 822127.22 | P | 6.41 | 2.65 | 2.42 | 0.23 | 10.50 |
| A050 | 832593.95 | 822127.22 | P | 6.41 | 2.6 | 2.34 | 0.26 | 19.00 |
| B015a | 831951.995 | 825576.365 | P | 30.72 | DRY | DRY | DRY | 14.50 |
| B021 | 832159.191 | 824615.796 | S | 80.05 | DRY | DRY | DRY | 4.00 |
| B021 | 832159.191 | 824615.796 | P | 80.05 | 71.34 | 68.67 | 2.67 | 13.50 |
| B028 | 832582.76 | 822621.88 | S | 66.67 | 47.78 | 46.05 | 1.73 | 5.00 |
| B028 | 832582.76 | 822621.88 | P | 66.67 | 66.67 | 45.95 | 20.72 | 27.00 |
| B031 | 832775.44 | 822154.22 | P | 34.59 | DRY | DRY | DRY | 15.00 |
| B031 | 832775.44 | 822154.22 | P | 34.59 | 14.95 | 13.06 | 1.89 | 40.00 |
| C006 | 831861.193 | 824297.571 | P | 74.34 | 62.979 | 61.219 | 1.76 | 35.00 |
| D308 | 832588.1 | 822113.3 | S | 6.32 | 2.7 | 2.28 | 0.42 | 6.55 |

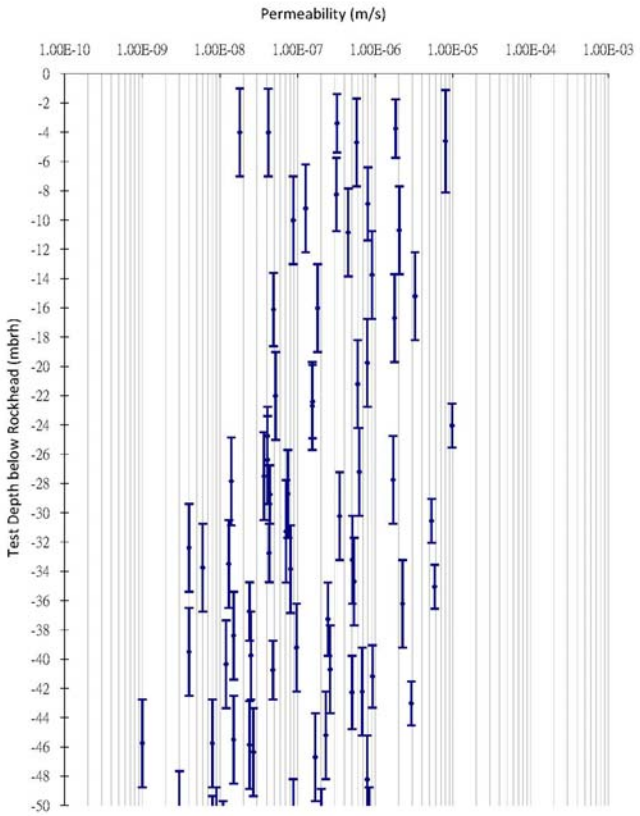
| Hole No. | Easting | Northing | Piezometer (P) / Standpipe (S) | GL (mPD) | Maximum Water Level(mPD) | Minimum Water Level(mPD) | Variability of GWL (m) | Pipe Tip - Depth (m) |
|---|---|---|---|---|---|---|---|---|
| D308 | 832588.1 | 822113.3 | P | 6.32 | 2.66 | 2.34 | 0.32 | 25.00 |
| D310 | 832678.11 | 822204.98 | S | 52.2 | 28.28 | 22.58 | 5.7 | 58.00 |
| D311 | 832567.55 | 822156.02 | P | 6.4 | 2.79 | 2.38 | 0.41 | 5.00 |
| D311 | 832567.55 | 822156.02 | S | 6.4 | 2.82 | 2.39 | 0.43 | 13.00 |
| D312 | 832672.61 | 822434.49 | S | 43.24 | DRY | DRY | DRY | 15.00 |
| D312 | 832672.61 | 822434.49 | P | 43.24 | 27.93 | 26.89 | 1.04 | 37.00 |
| D315 | 832713.424 | 822540.362 | S | 58.21 | 49.23 | 48.55 | 0.68 | 20.50 |
| D315 | 832713.424 | 822540.362 | P | 58.21 | 41.22 | 30.73 | 10.49 | 39.00 |
| D317 | 832646.13 | 822683.78 | S | 83.76 | 47.24 | 40.78 | 6.46 | 95.00 |
| D320 | 832608.11 | 822896.49 | S | 122.79 | 96.45 | 71.17 | 25.28 | 142.00 |
| D321 | 832515.9 | 823012.99 | S | 103.67 | 98.35 | 79.58 | 18.77 | 118.00 |
| D327 | 831871.98 | 824421 | S | 67.9 | 63.9 | 62.87 | 1.03 | 10.00 |
| D327 | 831871.98 | 824421 | P | 67.9 | 53.58 | 51.49 | 2.09 | 76.50 |
| D329 | 831793.42 | 824512.35 | S | 12.62 | 11.56 | 11.11 | 0.45 | 30.00 |
| D330 | 831738.69 | 824462.96 | S | 12.77 | 6.75 | 5.84 | 0.91 | 30.00 |
| D330 | 831738.69 | 824462.96 | P | 12.77 | 6.62 | 5.75 | 0.87 | 7.00 |
| D331 | 832122.48 | 824589 | S | 61.5 | 49.91 | 48.69 | 1.22 | 85.00 |
| D335 | 832043.4 | 824897.67 | P | 38.36 | 16.43 | 16.01 | 0.42 | 59.50 |
| D335 | 832043.4 | 824897.67 | S | 38.36 | 20.88 | 17.22 | 3.66 | 30.00 |
| D337 | 831999.3 | 825055.02 | S | 28 | 13.71 | 12.64 | 1.07 | 52.50 |
| D339 | 831974.66 | 825203.1 | S | 19.74 | 16.07 | 14.72 | 1.35 | 43.00 |
| D340 | 831978.19 | 825244.4 | S | 17.76 | 14.68 | 14.09 | 0.59 | 7.50 |
| D340 | 831978.19 | 825244.4 | P | 17.76 | 14.43 | 13.77 | 0.66 | 15.00 |
| D343 | 831959.35 | 825357.82 | S | 13.57 | 10.99 | 10.58 | 0.41 | 10.00 |
| D343 | 831959.35 | 825357.82 | P | 13.57 | 4.19 | 3.85 | 0.34 | 54.00 |

| Hole No. | Easting | Northing | Piezometer (P) / Standpipe (S) | GL (mPD) | Maximum Water Level(mPD) | Minimum Water Level(mPD) | Variability of GWL (m) | Pipe Tip - Depth (m) |
|---|---|---|---|---|---|---|---|---|
| D345 | 831861.41 | 825530.66 | S | 11.65 | 8.54 | 5.23 | 3.31 | 32.00 |
| D346 | 831872.46 | 825607.85 | S | 13.07 | 10.86 | 9.17 | 1.69 | 5.00 |
| D346 | 831872.46 | 825607.85 | P | 13.07 | 5.23 | -4.31 | 9.54 | 40.00 |
| D347 | 831849.95 | 825669.22 | P | 14.33 | -11.09 | -13.88 | 2.79 | 40.60 |

## 5.4 Permeability

Lugeon (water inflow) testing in boreholes was undertaken as part of the preliminary and detailed design and is summarised in the Figure below. Additional testing is currently ongoing to supplement this data.

Plot of Lugeon Testing Versus Depth

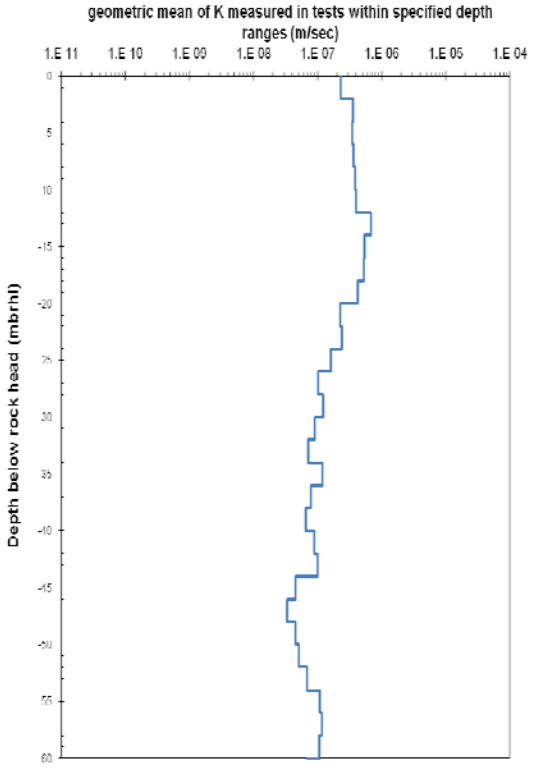



The plot shows the depth interval over which in the lugeon testing was undertaken.

The study of precedent, presented in Section 2, has indicated that grouting of transmissive structure is feasible using conventional methods. For the Kwai Chung Tunnel a comprehensive approach to investigation and treatment of such features will be undertaken ahead of the main excavation to treat transmissive features. The aim will be to treat them to a level such that their permeability will be similar to the surrounding rock mass, to ensure (or engineer) the hydraulic isolation provided by the otherwise low permeability rock mass.

For the relatively unweathered rock masses, that are expected at tunnel level for the majority of the alignment, a grouted permeability will be assumed for analysis, whereby transmissive structures are assumed to have been treated By pre-excavation grouting.

A design value for the rock mass at depth, unaffected by local transmissive structure has been assessed from the site specific data. A plot of all available data within the contract boundary, plotted in relation to rock head and plotted as average values over 1m depth intervals is provided below.




Whilst a broad indication of the variation in permeability with depth relative to rockhead is provided, by the above plot, any specific trends are likely to be obscured by the following:

- Data from test lengths of both typical rock mass conditions and fractured zones of rock
- Lugeon testing was generally targeted at more permeable zones

Work undertaken for the MTRC West Island Line by Atkins-Arup JV, comprising continuous lugeon testing of boreholes (overlapping 3m test lengths for the full depth of selected boreholes) derived a median permeability one order of magnitude lower than a lugeon data set from the same source rock mass derived from targeting transmissive features. Continuous testing on selected boreholes is also being undertaken as part of the ongoing investigation for this project.

Based on a detailed review of the data carried out in the context of published data and data from other HK projects, the following design permeability profile is proposed for the Kwai Chung Tunnel:

Table 5.2 Hydrogeological Parameters for Soils and Rocks

| Soil / Rock Type or Zone | Typical Design Permeability, k (m/s) |
|---|---|
| Fill | 5 x 10-5 to 2.5 x 10-3 |
| Marine Deposits - Clay | 1 x 10-7 |
| Alluvium | 3.9x10-6 |
| Colluvium | 1 x 10-5 |
| CDG (>10m above rock head) | 1.8 x 10-6 |
| CDG & HDG (typically 0 to 10m above rockhead) | 1 x 10-5 |
| M/SDG (Upper 20m of Bedrock Profile) | 1 x 10-7 |
| M/SDG (20m to 40m below Bedrock Level) | 1 x 10-8 |
| M/SDG (>40m below Bedrock Level) | 5 x 10-9 to 2 x 10-8 |

The profile of permeability illustrates that there is a very large difference in the permeability of some of the superficial deposits versus those for the rock mass at depth, by a factor of up to 2000 (1 x 10-5 compared to 5 x 10-9m/s).

The proposed values intentionally do not consider locally enhanced permeability associated with isolated transmissive features, which will be treated via grouting following a carefully specified procedure. The values are thus intended to represent upper bound values for the background permeability associated with the typical or treated rock mass conditions.

## 5.5 Modelling Scope

Hydrogeological numerical modelling has been undertaken using the software SEEP/W. This is a finite element software package commonly used to analyse groundwater seepage within unsaturated-saturated materials. SEEP/W's formulation allows the user to consider analyses ranging from simple, saturated steady-state conditions to saturated-unsaturated time-dependent conditions. The analysis is carried out based upon Darcy's Law. The output from SEEP/W consists of a graphical representation of the ground water model superimposed on the geological conditions. The output also simulates the position of the groundwater table as a result of water draining into the tunnels.

The purpose of the modelling programme was to assess the influence of a tunnel at depth, excavated within a low permeability rock mass, at a distance beneath more permeable near surface materials, as described in the conceptual hydrogeological model.

To do this a simplified cross sectional model along the full length of the Kwai Chung valley was developed, as illustrated in Figure 5.4.

The section crosses the alignment at chainage CH 133+460, in the vicinity of the Lead Mine Pass Fault, although the fault is not explicitly modelled, as this is assumed to have been treated via pre excavation grouting.

A difficulty with developing a functional model with this particular geometry is the contrast between the upper catchment 'slope model', upstream of the alignment, (characterised by natural terrain above the development line), and the very long shallow gradient 'valley model' downstream from the alignment. The two systems need to balance in terms of flux with the output from the upper system providing the input to the lower. However the extremely shallow gradients of the valley section of the model have very low heads and hence a low flux, for the permeabilities expected. The lower system is therefore unlikely to be able to transmit the groundwater flow arising from the upper slope model, thus giving rise to a large spring zone where the water table breaks the surface.

The three key controlling attributes are the following

- Permeability
- Recharge
- Water Table Elevation

The permeability has been measured and is known, within certain ranges, from published data, however the permeability of the both the fill and the colluvium can vary significantly and can have very high values.

Recharge is known in terms of average rainfalls, however recharge to the groundwater is less certain, and can be influenced by the steepness of local topography, three dimensional effects of water being lost to other catchments and the position of the development line, which is relatively high in relation to the surface water divide for this model.

The water table is known along the alignment, but there is less data in the higher catchment areas.

To investigate possible variations in the above three scenarios have been modelled as follows :

### Scenario A

| | |
|---|---|
| Permeability | Fixed at expected values (typical values) |
| Recharge/flux | Fixed at expected values (as 25 percent of rainfall) |
| Water Table | Allowed to equilibrate according to the model calculations |

### Scenario B

| | |
|---|---|
| Permeability | Permeability increased in the near surface materials (colluvium and fill)surface to a point that a water table develops below ground level with no seepage surface at ground level. |
| Recharge/flux | Fixed at expected values (as 25 percent of rainfall) |
| Water Table | Water table formed at the measured elevations (around 10mPD) |

### Scenario C

| | |
|---|---|
| Permeability | Fixed at expected values (upper bound) |
| Recharge/flux | Limited to prevent a seepage zone forming |
| Water Table | Water table formed at the measured elevations (around 10mPD) |

**Assumptions**

The model has adopted the following conditions in order to simulate groundwater flows into and around the excavations:

- Constant head boundary has been set at the lower limits of the model. The groundwater levels at these locations have been established based on model calibration with regard to the minimum groundwater levels recorded at tunnel location during the project specific long-term monitoring works (Jan 09 to May 09). The constant head boundary at the right hand side is set to be 0mPD to represent the mean sea level.
- The modelling has been undertaken for steady state condition.
- A no flow boundary has been set at the base of model and on the left hand side boundary. A total length of 216m x 1m of recharge area for water input into the model.
- The pressure head around the boundary of the proposed tunnel excavation has been set at atmospheric pressure in order to simulate fully pressure relieved conditions.
- Perfect hydraulic continuity has been assumed between the various layers in the models.

- The assessment assumes greenfield conditions. That is, the possible influence of external factors such as existing deep foundations, leakage of existing utilities, are not considered.

Other parameters have been modified as below:

### Scenario A

- Permeability for fill and colluvium = 6.6 x10-5m/s and 1x10-5m/s respectively
- Recharge = 1x10-7 m/s
- Water flux = 2.16x10-5m3/s

### Scenario B

- Permeability for fill and collvuium = 8x10-4m/s
- Recharge = 1 x10-7 m/s
- Water flux = 2.16x10-5m3/s

### Scenario C

- Permeability for fill and collvuium = 5 x10-5m/s
- Recharge = 1x10-7 m/s
- Water flux = $1.08x10^{-5}/m^3/s$

## 5.6 Modelling Results

The results can be summarised as follows:

Table 5.3 Summary Table of SEEP/W Analysis

| Scenario | Tunnel Open / Closed | Flux | Inflow | Water Table Position | Drawdown |
|---|---|---|---|---|---|
| A | Closed | $2.16x10^{-5}m^3/s$ | - | 15.42 | - |
| A | Open | $2.16x10^{-5}m^3/s$ | $1.84x10^{-6}m^3/s/m$ (0.11l/min/m) | 14.05 | 1.37 |
| B | Closed | $2.16x10^{-5}m^3/s$ | - | 10.86 | - |
| B | Open | $2.16x10^{-5}m^3/s$ | $1.71x10^{-6}m^3/s/m$ (0.10l/min/m) | 9.41 | 0.45 |
| C | Closed | $1.08x10^{-5}m^3/s$ | - | 9.97 | - |
| C | Open | $1.08x10^{-5}m^3/s$ | $1.69 x10^{-6}m^3/s/m$ (0.10l/min/m) | 9.94 | 0.03 |

### Scenario A

Adopting the permeability profiles described in this section of the report, the model in general agree with the conceptual hydrogeological models outlined above, although extensive seepage zones develop.

As a consequence a large percentage of the available recharge is lost to the surface.

Once the tunnel is opened, depressurisation occurs in the rock mass surrounding the tunnel, caused by limited inflow from the low permeability rock mass surround into the tunnel. Drawdown of the water table in the superficial deposits will only occur above the tunnel once the surface outflow from the model (seepage) has stopped and a water table has developed. This process takes time (model steps) to develop and reduces the drawdown that is modelled. This may however be an accurate simulation of the situation that exists on site.

A maximum drawdown of **1.37m** is predicted.

### Scenario B

Scenario B develops a water table in the superficial deposits by allowing a high flux in the upper level materials, comprising colluvium and fill, due to very high assigned permeability. The simulated high permeability upper layers do not however support a high water table as they tend to drain and therefore a lower water table than recorded in practice tends to form near the base of the fill material.

A maximum drawdown of **0.45m** is predicted.

### Scenario C

A water table close to the observed level is established by allowing half quantity of the flux into the models and the upper level materials comprising relatively permeable materials (fill). The combination of low flux and relatively permeable do not support a high water table either. .

A maximum drawdown of **0.03m** is predicted.

### General Conclusions

The SEEP/W models demonstrate that most of the groundwater flow is taking place in the higher permeability superficial deposits (and more weathered rock). It is possible that very high flux is occurring in the near surface materials or that some flow that would otherwise form a seepage area (in the absence of the urbanisation) is draining into the surface water runoff drainage system.

The models demonstrate that groundwater drawdown of groundwater within the superficial deposits is likely to occur during excavation of the tunnels. The models suggest that this could be up to as maximum **of 1.5m**.

Greater drawdown of the water table would occur if transmissive features including joints, dykes and faults are not successfully pre-grouted ahead of the excavation.

# 6. INFLOW PREDICTIONS

## 6.1 Inflows - Steady State Calculations – Alignment Models

### 6.1.1 Assumptions

Methods relating to the estimation of groundwater flows into an excavation rely on a number of simplifying assumptions, the most pertinent of which are summarised below:

- The rock mass is homogenous and has isotropic permeability
- Steady state flow conditions are in effect; and
- The tunnel boundary is modelled as a free flow boundary

It is noted that due to these assumptions, the predicted water inflows into a tunnel provide an approximation only.

In order to provide some indication of the reliability of the predictions four separate methods have been used, although they are all susceptible to the same assumptions, except McFeat-Smith which is an empirically based system (but based on limited HK data).

### 6.1.2 Methodology

Preliminary estimations of potential groundwater inflow into the caverns have been made using the following methods

- Goodman Equation (1965)
- Heuer's amendment of the Goodman Equation (1995 & 2005), with additional modifications based on Raymer (2001)
- Heuer's Statistical Approach (1995)
- McFeat-Smith (1999)

The rate of groundwater inflow into an excavation is a time dependent function that will reduce with time as the hydrogeological regime responds to changes in head around the excavation (referred to as early, mid and late time by Raymer 2005).

The method by McFeat-Smith makes some allowance for this, however the other methods do not. Goodman in particular assumes no reduction in head and therefore represents an upper bound assessment for anything other than immediate (early) flow rates. From Hong Kong experience, a conservative estimate of the reduction in rate is 40 to 60% of the initial recorded inflow.

### 6.1.3 Predicted Inflow Rates

#### 6.1.3.1 Predicted Initial Tunnel Water Inflow

The distribution of permeability along the alignment has been based on the alignment geological model, which identifies variations due to weathering and inferred major geological structure. The groundwater head has been varied along the alignment according to the topographic setting.

Two sets of analyses have been undertaken. The effect of discrete transmissive geological features such as faults are included in the first assessment, summarised in Table 6.1. For the second set of analyses, the transmissive features are assumed to have been successfully treated by pre-excavation grouting and are assumed to have permeability equivalent to the background permeability in the inflow calculations, the results are summarised in Table 6.2.

This approach has been adopted to predict inflow to the openings resulting from the background permeability and heads in order to establish the likely range of inflow. The results of the assessments for the tunnels are summarised in the following tables, with full calculations included in Appendix B.

Table 6.1 Summary of Predicted Groundwater Inflows (without grouting)

| Location | Average Tunnel Water Inflow (L/min/m) Predicted using | | |
|---|---|---|---|
| | Goodman/ Heuer/ Raymer | IMS - Initial | IMS - Final |
| Kwai Chung North (1638m) | 0.92 | 0.25 | 0.03 |
| Kwai Chung South (2082m) | 2.01 | 0.43 | 0.07 |

Table 6.2 Summary of Predicted Groundwater Inflows (with grouting)

| Location | Average Tunnel Water Inflow (L/min/m) Predicted using | | |
|---|---|---|---|
| | Goodman/ Heuer/ Raymer | IMS - Initial | IMS – Final |
| Kwai Chung North (1638m) | 0.13 | 0.05 | 0.01 |
| Kwai Chung South (2082m) | 0.20 | 0.07 | 0.01 |

The above estimates show reasonable correlation between the values identified using the Goodman, Heuer/Raymer, IMS – Initial and Final.

## 6.2 Inflows - Steady State Calculations – Probeholes

Steady state inflow calculations for an advance probe hole, with a diameter of 60mm, have also been undertaken. The calculated inflows have been compared with maximum allowable inflows and related grouting criteria to assess the extent of tunnel that might require grouting.

Based on the probehole inflow calculations, some transmissive zones have been identified with high initial inflow potential, these are listed in Tables 6.3 and 6.4. Predicted inflows from these features exceed the grouting criteria (defined in Section 10).

Table 6.3 Kwai Chung North Potential High Inflow Zones (Major Geological Structures)

| Chainage (from) | Chainage (to) | Intersection Width (m) | Features |
|---|---|---|---|
| 133150 | 133153 | 3 | Inferred Fault |
| 133222 | 133247 | 25 | Granodiorite Dyke F1 |
| 133300 | 133410 | 110 | Systematic Grouting Zone<br>Inferred Fault |
| 133410 | 133500 | 90 | Systematic Grouting Zone<br>(Lead Mine Pass Fault, Basalt Dyke/ Breccia Zone) |
| 133500 | 133660 | 160 | Systematic Grouting Zone<br>(Fault Breccia and Inferred Fault) |
| 133720 | 133723 | 3 | Inferred Fault |
| 133807 | 133810 | 3 | Inferred Fault |
| 133914 | 133917 | 3 | Inferred Fault |
| 134000 | 134003 | 3 | Inferred Fault |
| 134248 | 134285 | 37 | Granodiorite Dyke Zone - F5 |
| 134590 | 134595 | 5 | Photolineament (Gf/Gc) - F6 |

Table 6.4 Kwai Chung South Potential High Inflow Zones (Major Geological Structures)

| Chainage (from) | Chainage (to) | Intersection Width (m) | Features |
|---|---|---|---|
| 134910 | 134942 | 32 | Inferred fault F7 |
| 135020 | 135030 | 10 | contact of Gc(Jkt) /Gf-m(Jkn) F8 |
| 135140 | 135156 | 16 | Contact of Rhyolite F9 |
| 135160 | 135190 | 30 | Inferred Fault |
| 135645 | 135648 | 3 | Inferred Fault (Intense microfracture) F10 |
| 135754 | 135756 | 2 | Inferred fault F11 |
| 135924 | 135947 | 23 | Rhyolite dyke F12 |
| 136118 | 136130 | 12 | Contact of Jkn/Jkt F13 |
| 136163 | 136167 | 24 | Minor Fault Tolo Channel Fault F14 |
| 136291 | 136398 | 107 | Tolo Channel Fault Zone F14 |
| 136487 | 136519 | 32 | Tolo Channel Fault Zone F15 |
| 136540 | 136544 | 4 | Inferred Fault |
| 136565 | 136570 | 5 | Inferred Fault |
| 136585 | 136600 | 15 | Contact of Jkt/Klk F17 |

Additional narrow transmissive features that have not been specifically identified in the alignment geological model, but would also require grouting, also need to be allowed for in grouting estimates. These are discussed in Section 10.2.

# 7. LOCATION OF SENSITIVE STRUCTURES

## 7.1 Kwai Chung North Chainages CH133+000 to CH134+638

Table 7.1 Sensitive Structures at Kwai Chung North

| Ref. No. | Chainage (Southbound) | Building | Address | Foundation Type |
|---|---|---|---|---|
| SB018 | 133+200 | Yau Shing Building | 501-511 Castle Peak Road | R.C.C. Pile 14" x 14" |
| SB020 | 133+180 | Kar Po Mansion | 499 Castle Peak Road | Driven RC Pile with external circular tube |
| SB021 | 133+220 | Cheong Nin Building | 1013-1033 Kwai Chung Road | Franki Pile |
| SB025 | 133+280 | Hung Wan Building | 480 Castle Peak Road - Kwai Chung | R.C.C. Pile 12"x12", 14"x13" |
| SB026 | 133+310 | Tung Po Building | 466 Castle Peak Road - Kwai Chung | R.C.C. Pile 12"x12", 14"x14" |
| SB028 | 133+220 | Chun Po Building | 1011 Kwai Chung Road | R.C.C. Pile 14" x 14" |
| SB030 | 133+350 | Ming Yin Building | 4 Ping Lai Path | R.C.C. Pile 14" x 14" |
| SB031 | 133+370 | Ming Tong Building | 3 Ping Fu Path | R.C.C. Pile 14" x 14" |
| SB032 | 133+350 | Gold Peak Building | 30-34 Kwai Wing Road | Franki Pile |
| SB033 | 133+390 | Ming Tak Building | 4 Ping Fu Path | R.C.C. Pile 14" x 14" |
| SB034 | 133+390 | Kin Ming Building | 33 Ta Chuen Ping Street | R.C.C. Pile 14" x 14" |
| SB037 | 133+420 | Wai Yin Building | 430-436 Castle Peak Road - Kwai Chung | Precast R.C.C |
| SB043 | 133+320 | On Fat Industrial Building | 12-18 Kwai Wing Road | Franki Pile |
| SB045 | 133+480 | So Tao Centre | 11-15 Kwai Sau Road | Driven-H Piles |
| SB047 | 133+520 | Hensey Industrial Building | 433-441 Castle Peak Road - Kwai Chung | PIP Pile |
| SB050 | 133+590 | SKH Lady MacLehose Centre | 22 Wo Yi Hop Road | Driven-H Piles |
| SH001 | 131+930 | HyD N619 | (see Appendix C) | Retaining Wall in Shallow Footing |
| SH006 | 133+620 | HyD NF51 | (see Appendix C) | PIP/ Footing |

The location of these structures is shown on Figures in Appendix C. The sensitive structures, that are founded on driven piles are concentrated in an area between Chainage 133+100 and 133+620 and therefore they are more likely to be impacted by any settlement due to groundwater drawdown.

# 8. GROUND MOVEMENT PREDICTION

## 8.1 Construction Works

The works Contract 821 section involves the following construction works which may produce ground movements affecting the adjacent buildings

- Drill and Blast Tunnels - Shek Yam to Mei Lai Road Tunnels (Kwai Chung Tunnels - Ch133+000 to Ch136+780), including less than 16m mechanical excavation at Kwai Chung Ventilation adit.
- Cut and Cover Tunnels – Mei Lai Road plus connecting adit (Ch136+580)

The adits will generally be designed as drill and blast tunnel although short sections of soft / poor ground, generally less than 50m in length, are expected at the adit portals. Soft ground mining techniques in conjunction with heavy ground reinforcement is anticipated for the excavation of these soft / mixed ground sections.

## 8.2 General Ground Movement Prediction Method

For drill and blast tunnels the ground movements can be attributed to the following activities:

- Stress relief and rock mass deformation due to excavation in rock; and

Groundwater drawdown within the overlying strata during excavation and due to the long term effects of adopting a drained tunnel solution.

## 8.3 Methodology in Assessing Ground Movements Induced Drill and Blast Tunnelling

### 8.3.1 Stress Relief in Rock Mass

When an underground opening is excavated in a stressed rock mass the stresses in the vicinity of the new opening are re-distributed and higher stresses are induced around the opening. Due to the change of stress, elastic and/or plastic deformation of the rock mass surrounding the opening will occur which may result in induced ground settlements at surface.

As rock tunnelling will generally be carried out in competent rock with the amount of rock cover varying from 10m to approximate seventy metres, ground settlement due to the deformation and ground loss around the opening is considered to be minor.

A conservative allowance of 5mm should be allowed for within the 20m wide zone represented by the Lead Mine Pass Fault. Deformation of the tunnel profile of up to 20mm could occur and it is just possible that a small percentage of this will be seen at the surface. 5mm is considered a conservative allowance.

### 8.3.2 Groundwater Drawdown

Lowering of the groundwater table during excavation of the tunnel will occur equally whether the tunnel is drained or undrained in the long term.

Any dewatering of the overlying strata caused by lowering of the groundwater table will increase the effective stress in any compressible soils resulting in settlement of the soil and, thus, ground movements.

No consolidation settlement sensitive materials are expected within a distance of 500m from the alignment and therefore outside the zone of influence. Only short term (immediate) elastic settlement is therefore expected.

The deformation of the compressible layers is inversely proportional to the materials' elastic modulus. Therefore the consolidation settlements of Completely Decomposed Granite/Volcanic (CDG/V), Alluvium and Marine Deposits layers are expected to be more significant than those for Moderately Decomposed Granite/Volcanic (MDG/V) and Slightly Decomposed Granite/Volcanic (SDG/V).

The consolidation settlement due to dewatering has then been estimated using elastic theory as detailed below:

$$\delta = m_v H \Delta\sigma$$

| | | | |
|---|---|---|---|
| Where | $m_v$ | = | Coefficient of Volume Change = 1/ E |
| | E | = | Elastic Modulus (kPa) |
| | H | = | Thickness of soil stratum (m) |
| | $\Delta\sigma$ . | = | Change of Vertical Effective Stress (kPa) |

The drawdown is anticipated to be a maximum of 1.5m as long as pre-excavation grouting is implemented and the transmissive features adequately treated. No long term consolidation settlement is expected.

Based on the SEEP/W model results, the maximum drawdown has been predicted as 1.5m. For the design purpose, 2m drawdown has been used for settlement calculations. The ground settlements have been calculated at 8 chainage locations.

Settlement predictions using the elastic theory and a conservative assessment of the SPT 'N' value profile have been undertaken at these 8 chainage locations within Kwai Chung North and the assumptions and results are summarised on the following Table 8.1

Table 8.1 Estimated Ground Settlements

| Location | Assumed Rock Cover | Saturated Thickness above Rock | Predicted Groundwater drawdown above Rock | Calculated Settlement due to groundwater drawdown (mm) |
|---|---|---|---|---|
| Ch133+030 | 49 | 0 | 2 | 0 |
| Ch133+100 | 43 | 3 | 2 | 6 |
| Ch133+240 | 40 | 5 | 2 | 6 |
| Ch133+300 | 41 | 7 | 2 | 9 |
| Ch133+450 | 34 | 18 | 2 | 8 |
| Ch133+550 | 45 | 5 | 2 | 4 |
| Ch133+650 | 42 | 6 | 2 | 2 |
| Ch-133+730 | 50 | 0 | 2 | 0 |

Contour plans of settlement due to groundwater drawdown are presented in Appendix C.

# 9. BUILDING DAMAGE ASSESSMENT AND RISK EVALUATION

In order to carry out building impact assessment, buildings adjacent to the proposed alignment needed to be classified in terms of potential risk of damage based on categories proposed by Burland et al. (1977). The risk of damage categories include: Negligible, Very Slight, Slight, Moderate, Severe and Very Severe. These categories along with a description of typical damage and likely forms of repair for typical masonry structures and typical values of maximum settlement and slope for damage risk assessment are defined by Rankin (1988). Boscardin and Cording (1989) showed that these categories of damage are related to the magnitude of the maximum tensile strain induced on the structure.

A staged approach has been adopted to assess the degree of damage to the buildings due to ground movements. The approach includes preliminary assessment, second-stage assessment and detailed evaluation due to tunnelling based on CIRIA Report “Building Response to Tunnelling, Volume 1: Projects and Methods Case Studies from the Construction of the Jubilee Line Extension, London 2001”. The following sections describe the process for the various stages.

The methodology is written up in full in the Existing Building Impact Report.

The sensitive structures listed in Table 7.1 have been assessed in the light of the predicted ground movements summarised in Section 8.

Building impact assessment for the nearby existing buildings has been carried out to assess the degree of damage associated with the estimated ground movement shown on Table 8.1 which is less than 10mm. Therefore, all buildings within the chainage Ch133+000 to Ch133+700 have been classified as having ‘Very Slight’ risk of damage under the Stage 1 assessment. As the estimated ground movement and slope of ground are less than 10mm and 1 / 500 respectively, second-stage assessment and structural assessment are not required.

It is therefore concluded that the impact of groundwater drawdown due to tunnel excavation along works contract 821 alignment on all the nearby existing buildings is acceptable.

# 10. CONCLUSIONS AND MITIGATION REQUIREMENTS

## 10.1 Grouting Pre Excavation Designs and Classes

Indicative designs of grout layouts for the single track tunnel are included in **Appendix D.** The grouting classes A to D are selected according to the expected ground conditions or amounts of inflow recorded from probe holes, or where specified in the contract. A represents a relatively low level of grouting, with the number or probe holes, grout holes and check holes increasing from Class A to D.

The Contractor will be required to employ appropriately qualified and experienced specialists to develop detailed grouting designs to fulfil the requirements of the specification.

## 10.2 Grouting Estimates

At particular locations along the alignment grouting will need to be undertaken to control inflow for the following key reasons :

- To control drawdown in the superficial deposits in order to control settlements and building damage
- To control inflow in major fault zones in order to allow safe excavation of the tunnel
- To limit inflow from discrete transmissive features in order that the final inflow criteria are met.

Each of these will require sections of the alignment to be pre-grouted, estimates of these are summarised in Tables 10.1 and 10.2.

The general grouting criteria to be applied is summarised in Table 10.3.

The section of the alignment within Kwai Chung North between chainages 133+300 and 133+660 has been found by this study to include :

- Major Geological Structures
- Saturated thicknesses of greater than 10m in the superficial deposits
- Sensitive Structures

Within this length of the alignment the contract will specify that systematic grouting will be undertaken. This means that between these chainages grouting will be mandatory irrespective of recorded inflow from probeholes. In addition more stringent inflow criteria shall apply, as summarised in Table 10.4.

There are two major fault zones within this section of the alignment, the Lead Mine Pass Fault and the Tolo Fault. The Lead Mine Pass fault is within Kwai Chung North, were the more stringent inflow criteria shall apply. The Tolo Channel Fault is in a section of the alignment where there are no constraints in terms of potential impact, other than allowing safe construction and ensuring that the final long term inflow criteria is complied with, however a drained lining for this section of the alignment has been allowed for to ensure that the final inflow requirement to the overall tunnel is complied with.

The number of expected transmissive features has been evaluated and summarised in Section 6. These have been used in Tables 10.1 and 10.2 to determine the grouting lengths required.

Table 10.1 Kwai Chung North Potential High Inflow Zones
(Major Geological Structures – read in conjunction with Table 6.3)

| Features | Intersection Width (m) | Assumed Number of 20m Grout Rounds |
|---|---|---|
| Inferred Fault | 3 | 1 |
| Granodiorite Dyke F1 | 25 | 2 |
| Systematic Grouting Zone | 110 | 18 |
| Systematic Grouting Zone | 90 | |
| Systematic Grouting Zone | 160 | |
| Inferred Fault | 3 | 1 |
| Inferred Fault | 3 | 1 |
| Inferred Fault | 3 | 1 |
| Inferred Fault | 3 | 1 |
| Inferred Fault | 5 | 1 |
| Inferred Fault | 4 | 1 |
| Granodiorite Dyke Zone - F5 | 37 | 2 |
| Photolineament (Gf/Gc) - F6 | 5 | 1 |
| Additional Dykes | | 5 |
| Additional Transmissive Joints | | 5 |
| TOTAL | | 40 |

Table 10.2 Kwai Chung South Potential High Inflow Zones
(Major Geological Structures – read in conjunction with Table 6.4)

| Features | Intersection Width (m) | Assumed Number of 20m Grout Rounds |
|---|---|---|
| Inferred fault F7 | 32 | 2 |
| contact of Gc(Jkt) /Gf-m(Jkn) F8 | 10 | 1 |
| Contact of Rhyolite F9 | 16 | 1 |
| Inferred Shear Zone | 30 | 2 |
| Inferred Fault (Intense microfracture) | 3 | 1 |
| Inferred fault F11/ D321 | 2 | 1 |
| Inferred Fault | 3 | 1 |
| Rhyolite dyke F12/ D318 | 16 | 1 |
| Contact of Jkn/Jkt F13 | 12 | 1 |
| Tolo Channel Fault Zone F14/F15 | 166 | 9 |
| Inferred Fault | 4 | 1 |
| Inferred Fault | 5 | 1 |
| Contact of Jkt/Klk F16 | 15 | 1 |
| Additional dykes | | 6 |
| Additional Transmissive discontinuities | | 6 |
| TOTAL | | 35 |

## 10.3 Proposed Grouting Criteria

Table 10.3 Proposed Inflow Control Criteria Contract 821 Typical Criteria

| Criteria Type | Criteria |
|---|---|
| Single Probehole (L/min/m) | 5L/min/20m 0.25 |
| Combined Flow From Probeholes (L/min/m) | 10L/min/20m 0.5 |
| Post Excavation (L/min/m) | 50L/min/25m 2 |
| Final Inflow (L/min/m) | 40L/min/100m 0.4 |

Table 10.4 Proposed Inflow Control Criteria Contract 821 Kwai Chung North Tunnel 133+300 to 133+660

| | 133+300 to 133+410 | 133+410 to 133+500 | 133+500 to 133+660 |
|---|---|---|---|
| Single Probehole (L/min/m) | 3L/min/20m 0.15 | 1L/min/20m 0.05 | 3L/min/20m 0.15 |
| Combined Flow From Probeholes (L/min/m) | 6L/min/20m 0.3 | 2L/min/20m 0.1 | 6L/min/20m 0.3 |
| Post Excavation (L/min/m) | 25Lmin/25m 1 | 15L/min/25m 0.6 | 25Lmin/25m 1 |
| Final Inflow (L/min/m) | 20L/min/100m 0.2 | 10L/min/100m 0.1 | 20L/min/100m 0.2 |

## 10.4 Monitoring of Existing Structures

Instrumentation and monitoring has been proposed to monitor the effects of cavern construction on nearby EBS. Instrumentations near the cavern will basically include:

- Groundwater monitoring equipped with piezometers and standpipes shall be continued using the existing monitoring points installed as a part of the site investigation stages and the proposed additional boreholes.
- Building settlement markers – to monitor the movement of the existing buildings affected by the works.
- Ground settlement markers – to monitor the ground surface movement. Utility settlement markers – to monitor the movement of sensitive utilities affected by the works.
- Tiltmeters – to monitor the tilting of structures.
- Vibration monitoring using seismograph – to monitor the vibration of structures due to the construction works.

Drawings indicating the layout of the monitoring points is shown in Figures in Appendix E and further details are provided in the **Existing Building Impact Report.**

## 11. REFERENCES

1. Burland,J.B., Standing,J.R., Jardine,F.M., editor, (2001) Building response to tunnelling: case studies from the Jubilee Line Extension, London: volume 1: projects and methods, London, CIRIA and Thomas Telford.

2. GEO, (2008) Catalogue of Hong Kong Tunnels.

3. Goodman et al (1965) Groundwater Inflows during Tunnel Driving. Bulletin of Engineering Geology.

4. Heuer, R.E. (1995) Estimating Rock Tunnel Water Inflow. Proc. of 1995 Conference on Rock Excavation and Tunnelling (RETC).

5. Heuer, R.E. (2005) Estimating Rock Tunnel Water Inflow – Part II. Proc. of 2005 Conference on Rock Excavation and Tunnelling (RETC).

6. McFeat-Smith et al (1999) Water Inflows in Bored Tunnel Driven in Hong Kong: Prediction, Construction Issues and Control Measures. Proc. of Conference on Urban Ground Engineering, Hong Kong. Thomas Telford.

7. McLearle, D., Foreman, W., Hansmire, W., Tong, E. (2001) Hong Kong Strategic Sewage Disposal Scheme Stage I Deep Tunnels, 2001 Proc. of 2001 Conference on Rock Excavation and Tunnelling (RETC).

8. MTR Corporation (2008). Design Standards Manual Section 4 – Civil Engineering (Rev. A2)

9. MTR Corporation (2009) Ground Engineering Reports. XRL. Agreement no. C802.

10. MTR Coporation (2009) Existing Building Impact Report. XRL. Agreement no. C802.

11. Preene et al (2000) CIRIA Report C515 - Groundwater control – design and practice.

12. Rankin, W.J. (1988): Ground movements resulting from urban tunnelling; predictions and effects. Engineering Geology Special Publication No. 5, pp79-92.

13. Raymer, J.H. (2001) Predicting Groundwater Inflows into Hard Rock Tunnels: Estimating the High End of the Permeability Distribution. Proc. of 2001 Conference on Rock Excavation and Tunnelling (RETC).

14. Raymer, J.H. (2005) Groundwater Inflow into Hard Rock Tunnels: A New Look at Inflow Equations. Proc. of 2005 Conference on Rock Excavation and Tunnelling (RETC).

15. S. H. Someville, CIRIA Report 113: Control of Groundwater for Temporary Works.

# FIGURES

VB5 - SMV
SHING MUN
VENTILATION BUILDING

SYW
SHEK YAM
WORKS AREA

822

821

VB6 - KCV
KWAI CHUNG
VENTILATION BUILDING

MLW
MEI LAI ROAD
WORKS AREA

VB7 - NCV
NAM CHEONG
VENTILATION BUILDING

821

820

133+000

SHEK YAM
WORKS AREA ADIT
(SYW ADIT)

KWAI CHUNG NORTH

134+638

KWAI CHUNG SOUTH

SHING MUN
VENTILATION DUCTS
(SMV DUCTS)

CONTRACT 821
KWAI CHUNG TUNNELS (KCT)

136+780

TSUEN WAN

KWAI TSING CONTAINER TERMINALS

STONECUTTERS ISLAND

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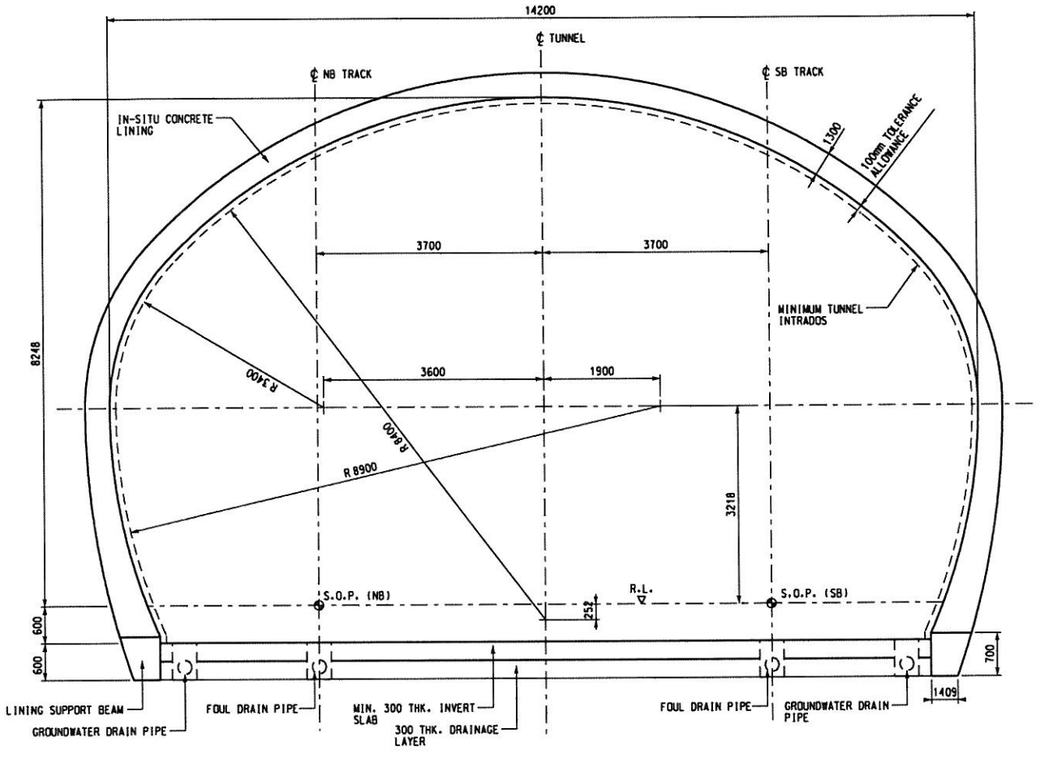
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Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

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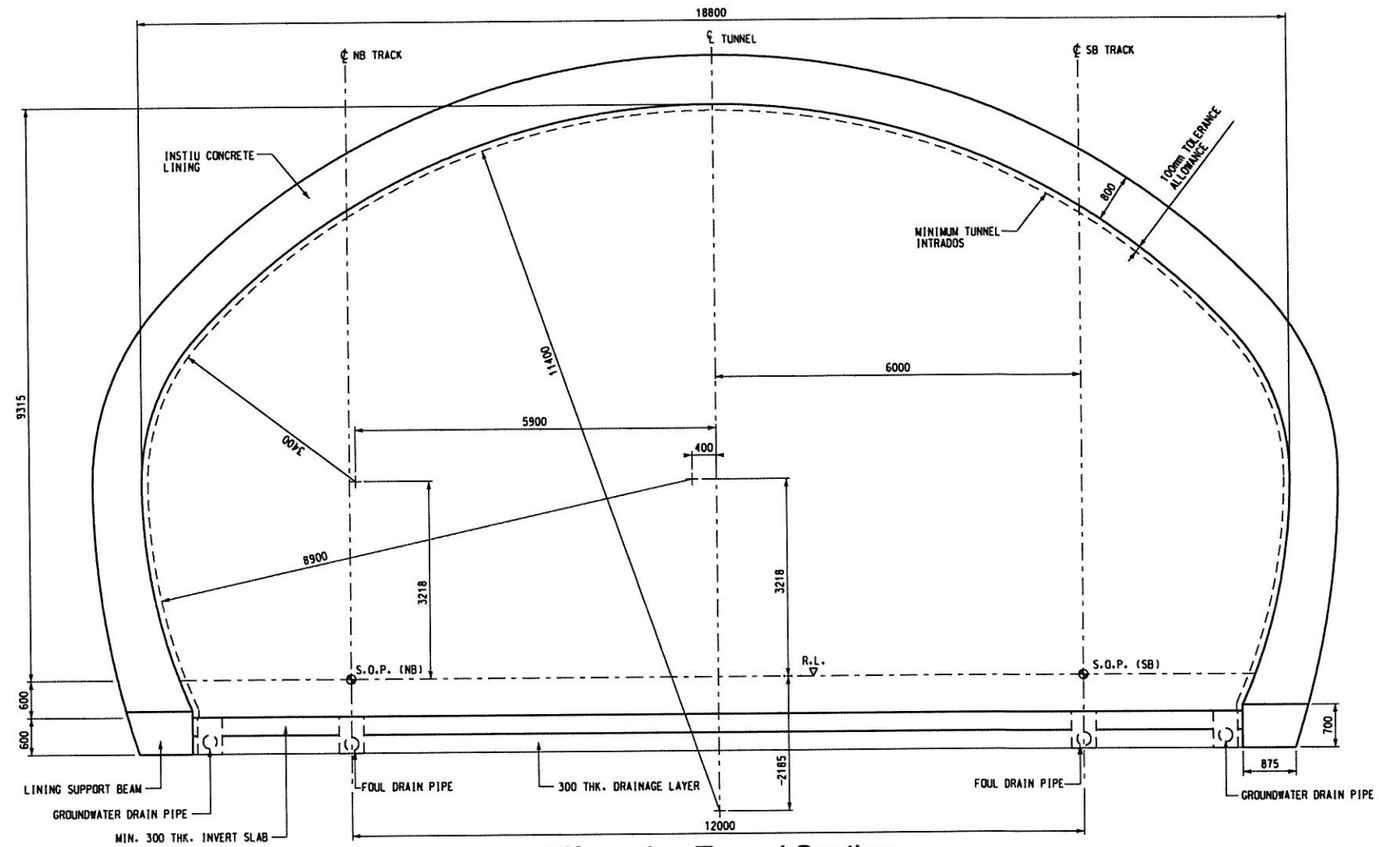
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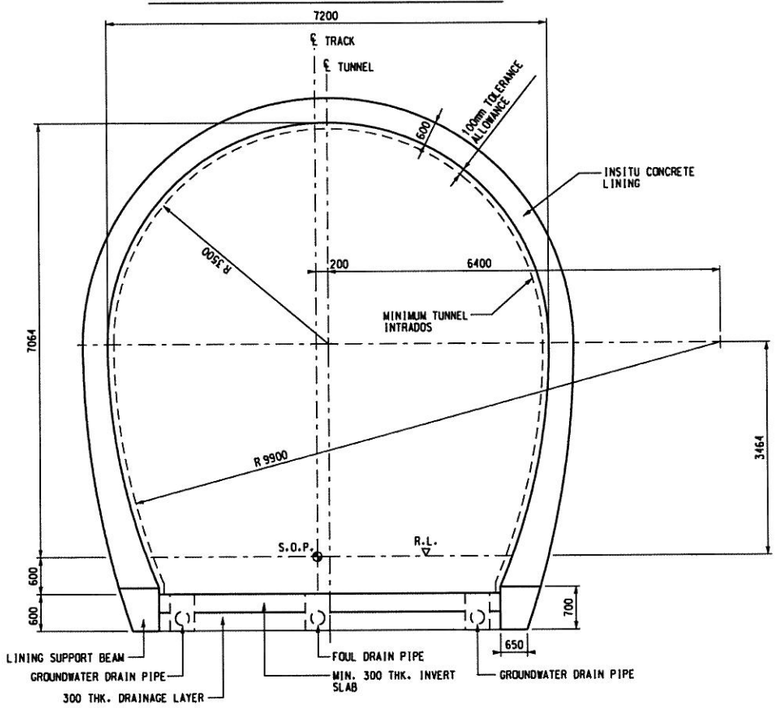
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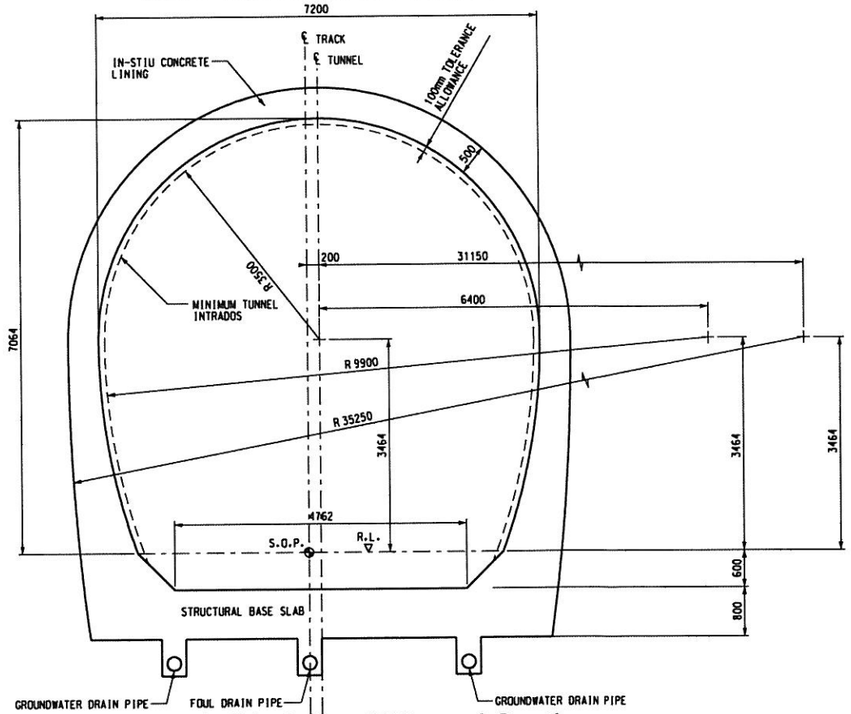

## Twin Track Tunnel Section




## Bifurcation Tunnel Section

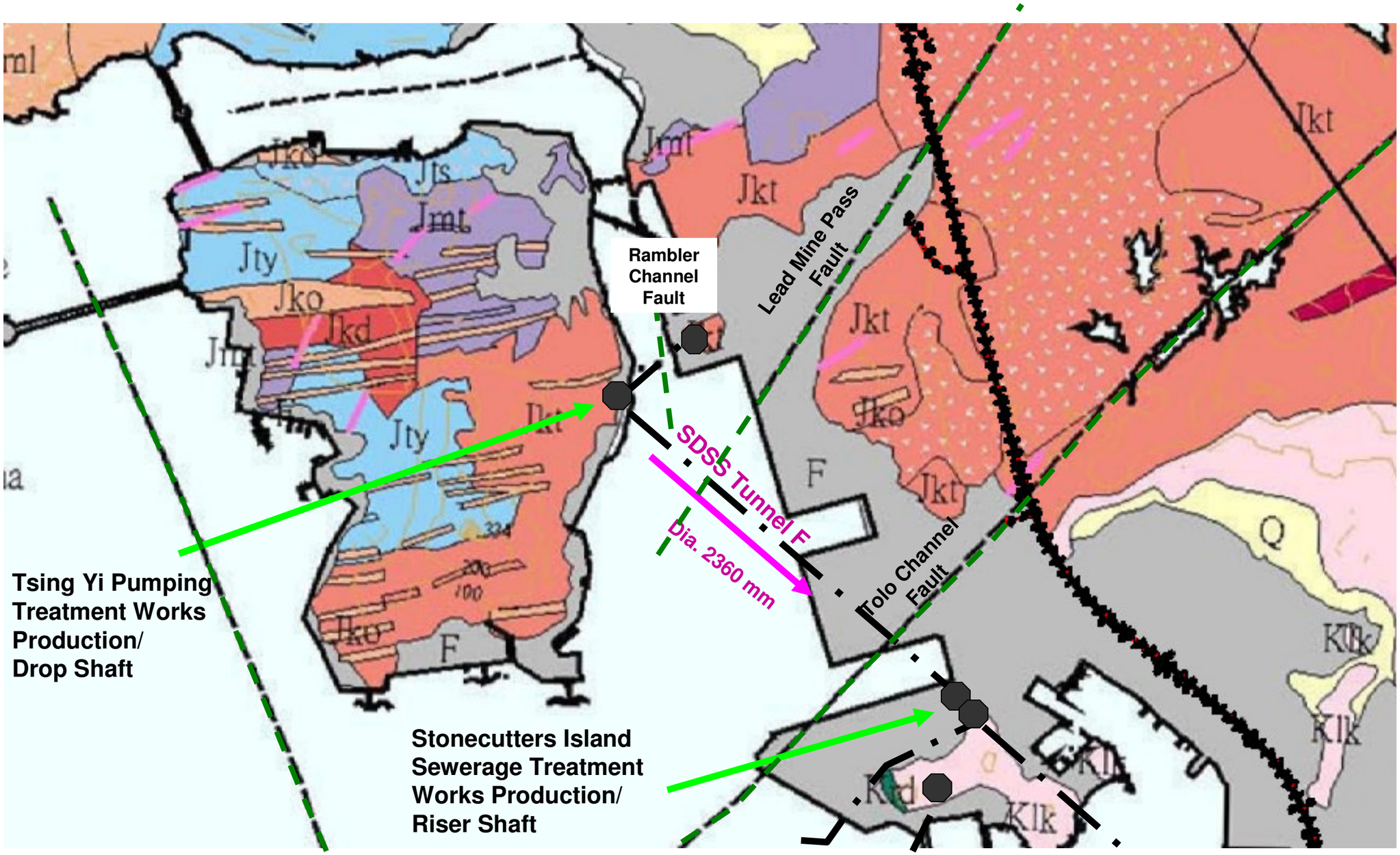



## Single Track "Drained" Tunnel Section




## Single Track "Undrained" Tunnel Section

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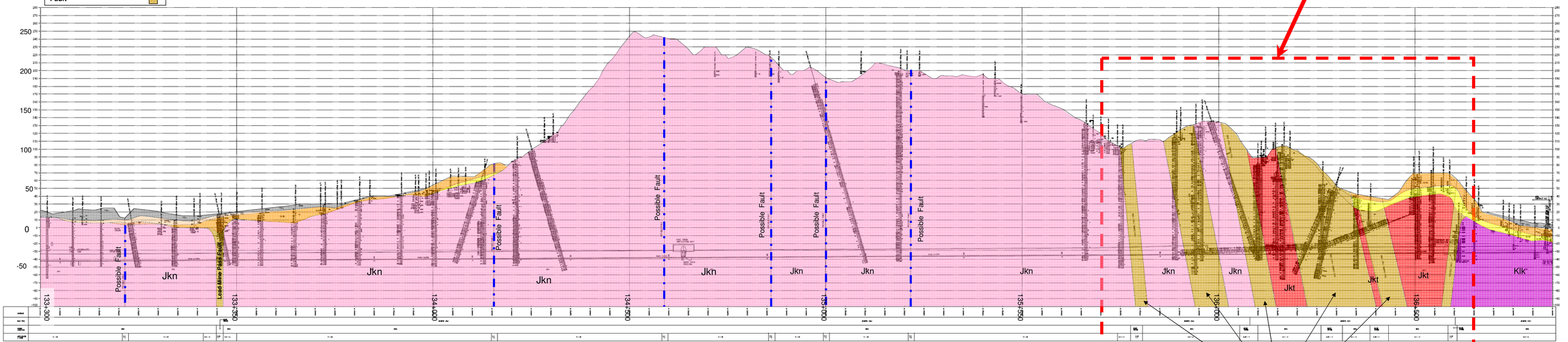
- Geological Fault
- SDSS Tunnel
- Tunnel flow direction
- Sewerage Treatment Works/ Shafts

Extract of Geological Map of Hong Kong, 1 :100,000 scale. (GEO, 2006)

**Klk** – Kowloon Granite
**Jkt** – Shatin Granite
**Jkn** – Needle Hill Granite

**FILL**
**C/HDG**
**COLLUVIUM**
**MIXED GROUND**
**Fault**

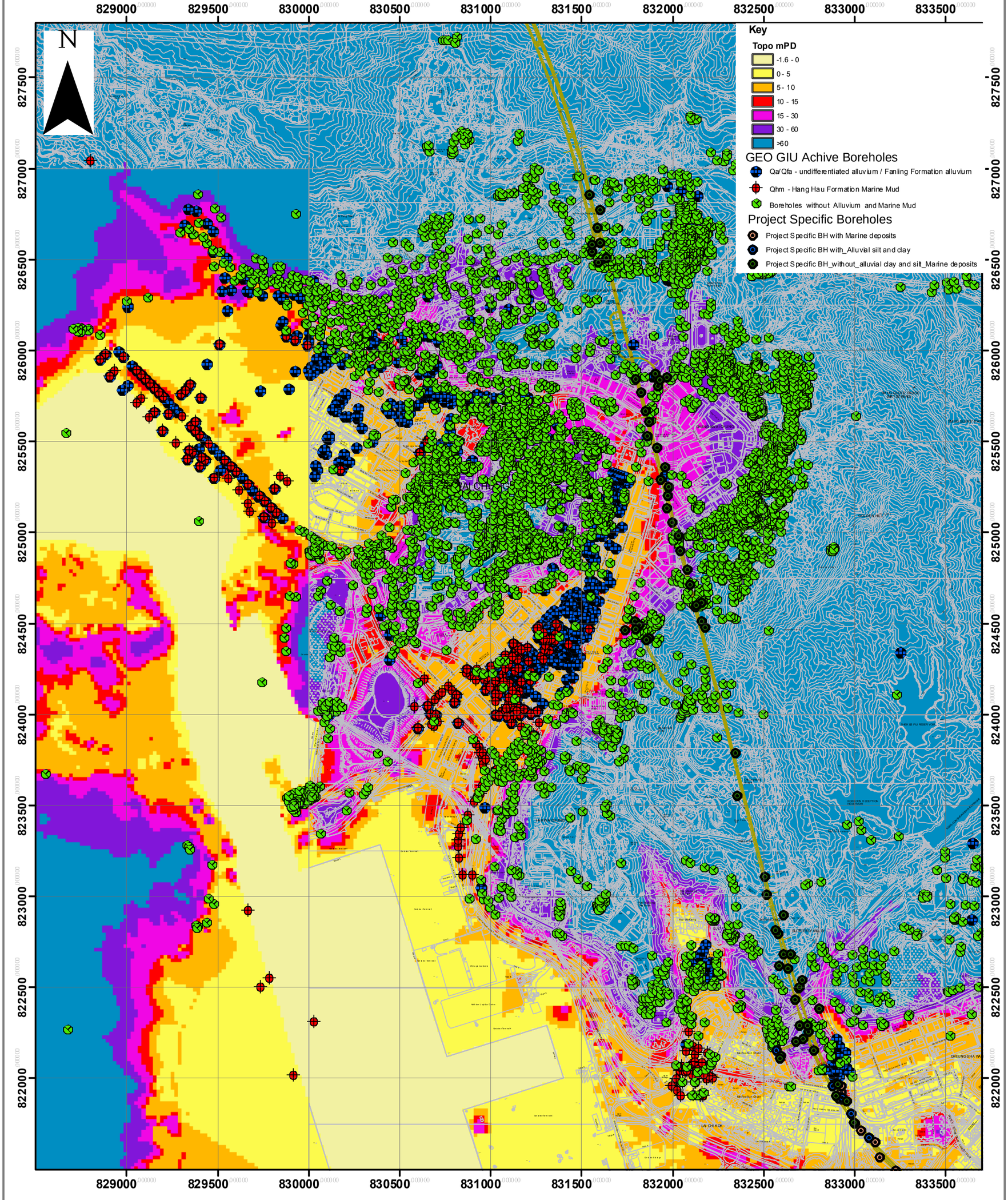
Refer to Figures 3.4 to 3.6 for updated geological interpretation




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| | |
|---|---|
| Figure Title | Geological Longitudinal Section |
| Figure No | 3.1 |
| Date | July 2009 |




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Figure Title

Kwai Chung North - GIS Plot -
Distribution of Superficial Deposit Type

Figure No. 3.2

Date July 2009

LIEGEND:

- DIRECT CATCHMENT AREA FOR KOWLOON RESERVOIR
- INDIRECT CATCHMENT AREA FOR KOWLOON RESERVOIR
- DIRECT CATCHMENT AREA FOR KOWLOON RECEPTION RESERVOIR
- INDIRECT CATCHMENT AREA FOR KOWLOON RECEPTION RESERVOIR
- DIRECT CATCHMENT AREA FOR SHEK LI PUI RESERVOIR
- INDIRECT CATCHMENT AREA FOR SHEK LI PUI RESERVOIR
- DIRECT CATCHMENT AREA FOR KOWLOON BYEWASH RESERVOIR
- RESERVOIR

SHING MUN RESERVOIR

KOWLOON RESERVOIR

KOWLOON RECEPTION RESERVOIR

KOWLOON BYEWASH RESERVOIR

CONTRACT 821 KWAI CHUNG TUNNELS (KCT)

KOWLOON

0 100 200 300 400 500
METRES
1 : 10000

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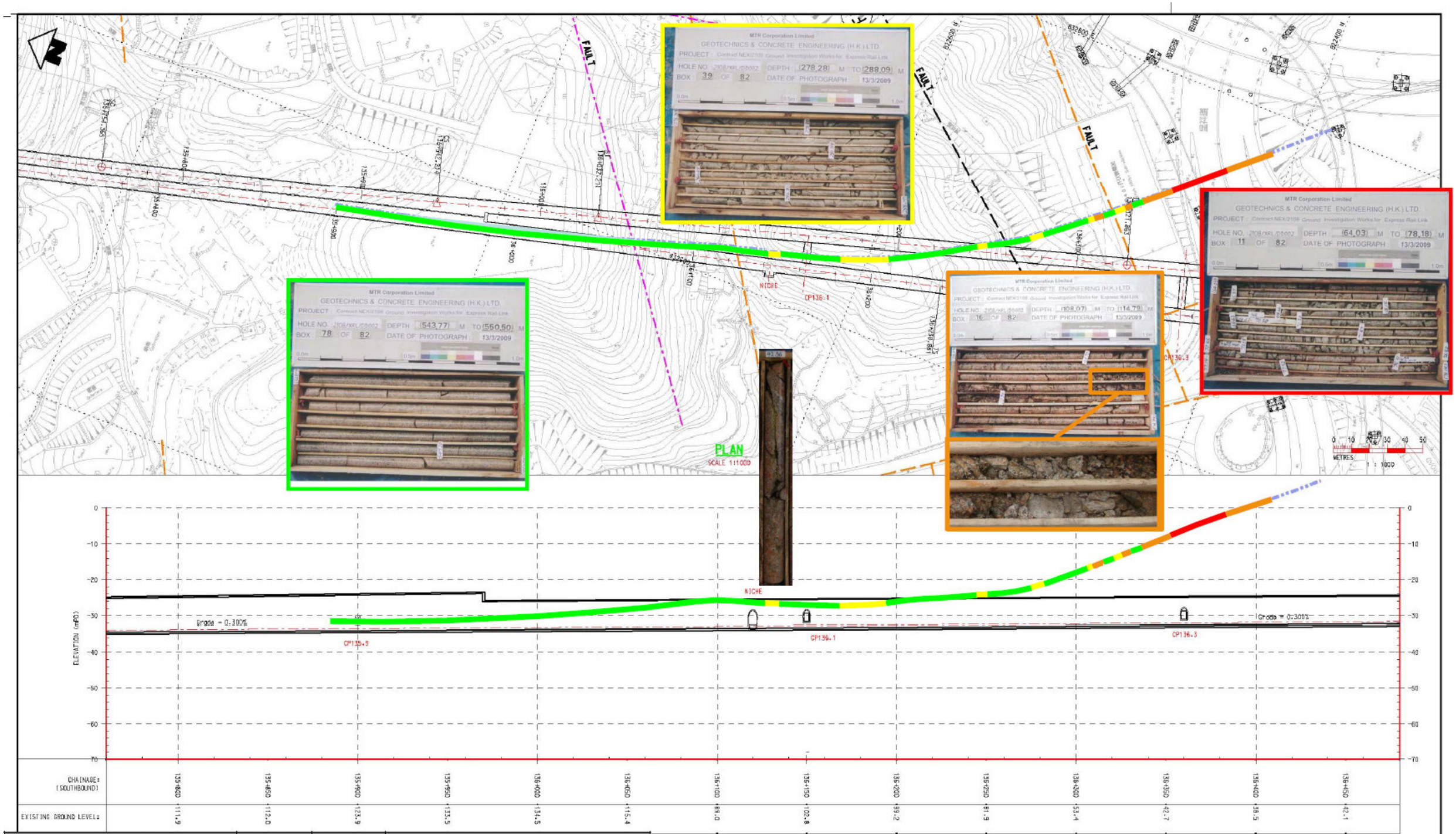
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Title: Interface with WSD Facilites

Figure No.: Figure 3.3

Date: July 2009

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| Rock Mass Class | TCR (%) | RQD(%) | Sub-Vertical Spacing (m) |
|---|---|---|---|
| RMC01 | 100 | 95 - 100 | Moderately Spaced |
| RMC02 | 100 | 55 - 65 | Moderately to closely spaced |
| RMC03 | 76 | 30 - 50 | Closely to very closely spaced |
| RMC04 | 69 | 0 - 20 | Very closely to extremely closely spaced |

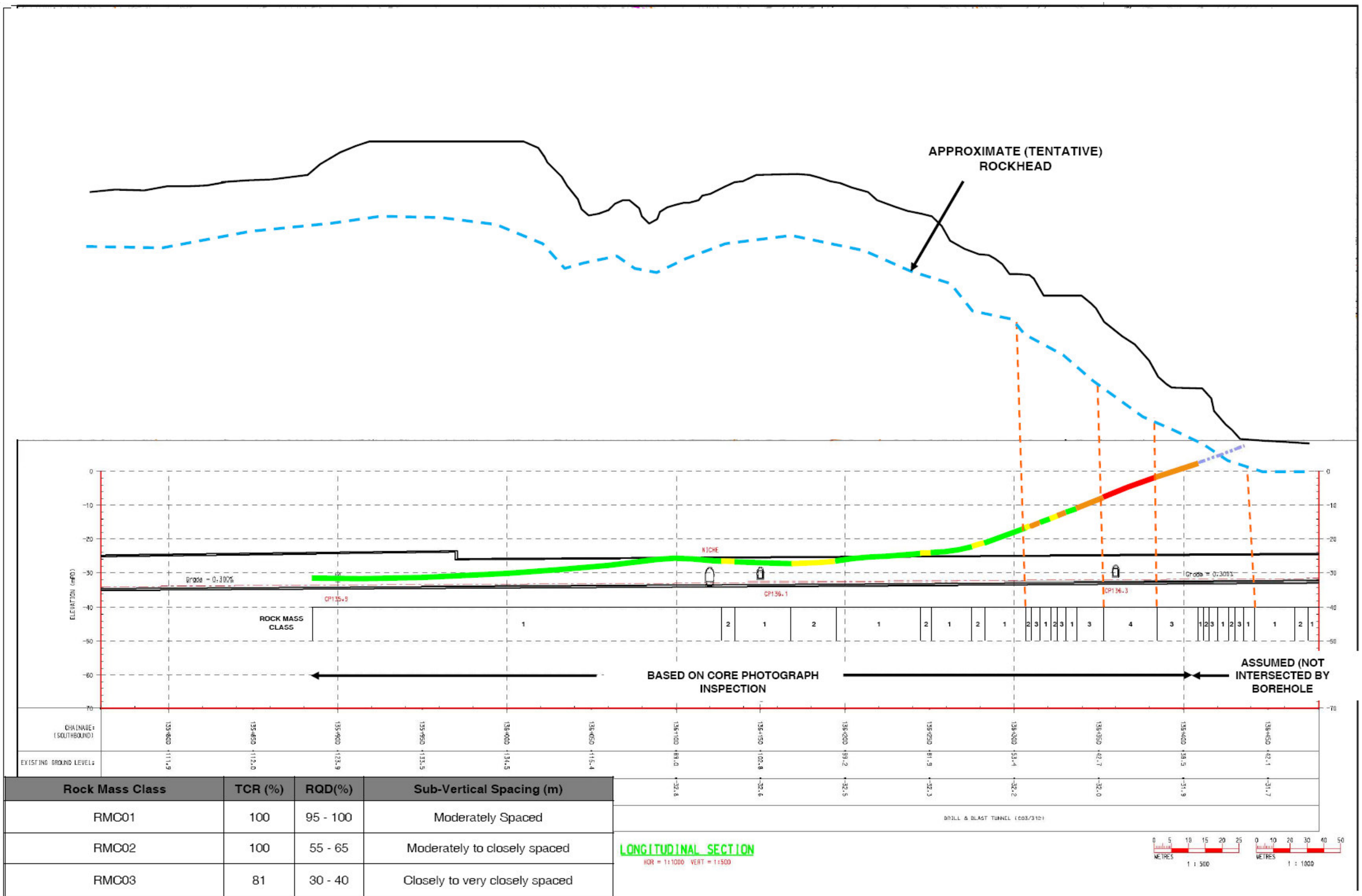
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| | | | |
|---|---|---|---|
| Figure Title | Tolo Fault – Location Plan and Section of HDD Borehole DD02 | | |
| Figure No | 3.4 | Date | July 2009 |




| Rock Mass Class | TCR (%) | RQD(%) | Sub-Vertical Spacing (m) |
|---|---|---|---|
| RMC01 | 100 | 95 - 100 | Moderately Spaced |
| RMC02 | 100 | 55 - 65 | Moderately to closely spaced |
| RMC03 | 81 | 30 - 40 | Closely to very closely spaced |
| RMC04 | 69 | 0 - 20 | Very closely to extremely closely spaced |

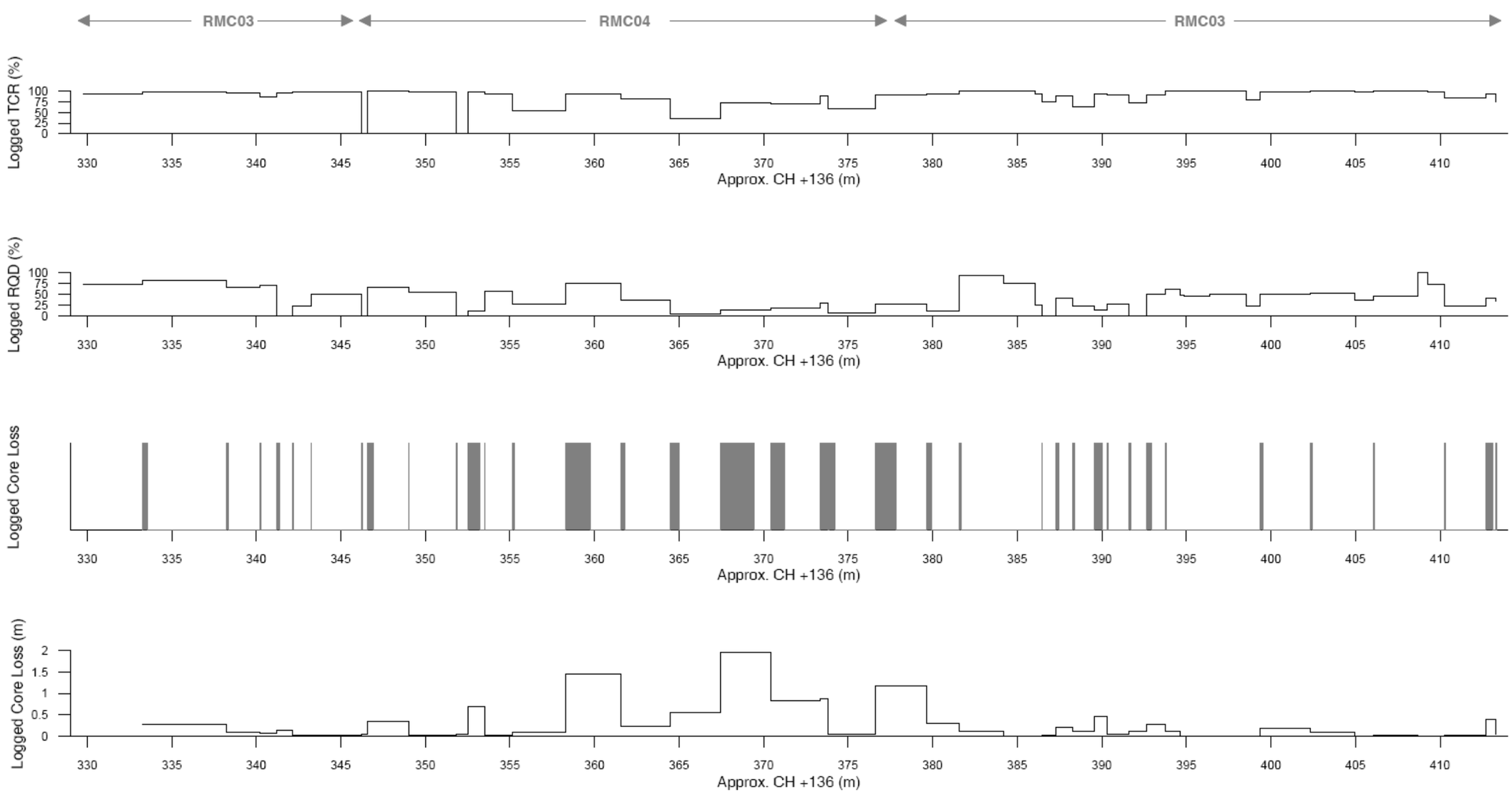
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| Figure Title | Tolo Fault – Rock Mass Conditions Encountered in HDD borehole | | |
| Figure No | 3.5 | Date | July 2009 |

FIGURE 4



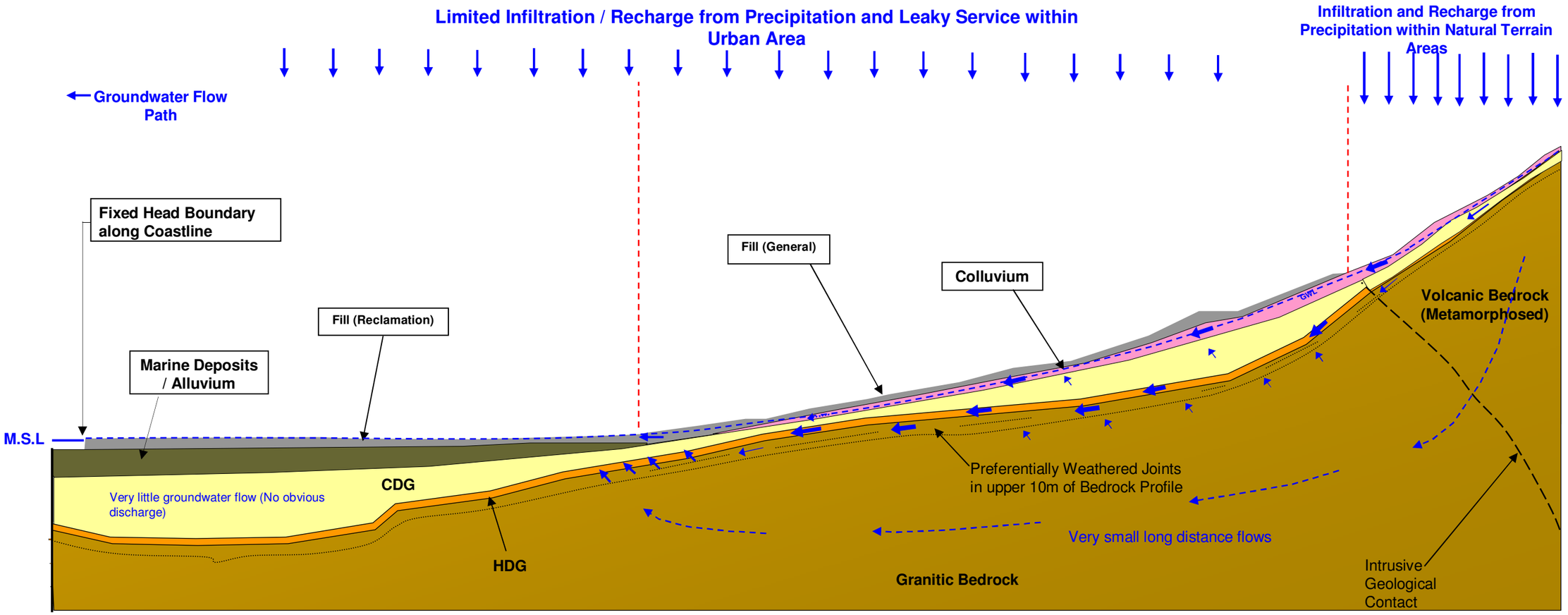

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| | | | |
|---|---|---|---|
| Figure Title | Tolo Fault – Distribution of Anticipated Rock Mass Classes | | |
| Figure No | 3.6 | Date | July 2009 |


Limited Infiltration / Recharge from Precipitation and Leaky Service within Urban Area
Infiltration and Recharge from Precipitation within Natural Terrain Areas
Groundwater Flow Path
Fixed Head Boundary along Coastline
Fill (Reclamation)
Fill (General)
Colluvium
Volcanic Bedrock (Metamorphosed)
Marine Deposits / Alluvium
M.S.L
CDG
Very little groundwater flow (No obvious discharge)
Preferentially Weathered Joints in upper 10m of Bedrock Profile
Very small long distance flows
HDG
Granitic Bedrock
Intrusive Geological Contact

N

Key

Piezometers

Standpipes

0 250 500 Meters

KWAI CHUNG

D352P D352S D350S D353S D354S D348P D347P D346P D346S D345S D343P D343S D340P D340S D339S D337S D335S D335P D331S D329S D330P D330S D327P D327S

| Hole No. | Easting | Northing | P / S | GL | Maximum Water Level(mPD) | Minimum Water Level(mPD) | Variability of GWL (m) | Pipe Tip (mbgl) | Materials |
|---|---|---|---|---|---|---|---|---|---|
| D327 | 831871.98 | 824421 | S | 67.9 | 63.9 | 62.87 | 1.03 | 10.00 | Fill, MDG |
| D327 | 831871.98 | 824421 | P | 67.9 | 53.58 | 51.49 | 2.09 | 76.50 | SDG |
| D329 | 831793.42 | 824512.35 | S | 12.62 | 11.56 | 11.11 | 0.45 | 30.00 | CDG |
| D330 | 831738.69 | 824462.96 | S | 12.77 | 6.75 | 5.84 | 0.91 | 30.00 | CDG |
| D330 | 831738.69 | 824462.96 | P | 12.77 | 6.62 | 5.75 | 0.87 | 7.00 | CDG |
| D331 | 832122.48 | 824589 | S | 61.5 | 49.91 | 48.69 | 1.22 | 85.00 | MDG, SDG |
| D335 | 832043.4 | 824897.67 | P | 38.36 | 16.43 | 16.01 | 0.42 | 59.50 | SDG |
| D335 | 832043.4 | 824897.67 | S | 38.36 | 20.88 | 17.22 | 3.66 | 30.00 | MDG, SDG |
| D337 | 831999.3 | 825055.02 | S | 28 | 13.71 | 12.64 | 1.07 | 52.50 | MSG, SDG |
| D339 | 831974.66 | 825203.1 | S | 19.74 | 16.07 | 14.72 | 1.35 | 43.00 | HDG,MDG,SDG |
| D340 | 831978.19 | 825244.4 | S | 17.76 | 14.68 | 14.09 | 0.59 | 7.50 | Quartz,Quartzphyric rhyolite |
| D340 | 831978.19 | 825244.4 | P | 17.76 | 14.43 | 13.77 | 0.66 | 15.00 | Feldsparhyric Rhyolite |
| D343 | 831959.35 | 825357.82 | S | 13.57 | 10.99 | 10.58 | 0.41 | 10.00 | FILL,COLL |
| D343 | 831959.35 | 825357.82 | P | 13.57 | 4.19 | 3.85 | 0.34 | 54.00 | MDG |
| D345 | 831861.41 | 825530.66 | S | 11.65 | 8.54 | 5.23 | 3.31 | 32.00 | |
| D346 | 831872.46 | 825607.85 | S | 13.07 | 10.86 | 9.17 | 1.69 | 5.00 | FILL,COLL |
| D346 | 831872.46 | 825607.85 | P | 13.07 | 5.23 | -4.31 | 9.54 | 40.00 | SDG |
| D347 | 831849.95 | 825669.22 | P | 14.33 | -11.09 | -13.88 | 2.79 | 40.60 | SDG |
| D348 | 831826.784 | 825770.429 | P | 21.43 | 15.77 | 12.83 | 2.94 | 48.00 | CDG |
| D350 | 831796.47 | 825842.35 | S | 32.54 | 27.13 | 23.31 | 3.82 | 57.50 | |
| D352 | 831903.46 | 825874.99 | S | 37.85 | DRY | DRY | DRY | 11.50 | RS,CDG |
| D352 | 831903.46 | 825874.99 | P | 37.85 | 25.89 | 25.43 | 0.46 | 17.50 | MDG |
| D353 | 831969.42 | 825851.68 | S | 21.84 | 21.35 | 20.63 | 0.72 | 50.00 | |
| D354 | 831931.07 | 825837.88 | S | 21.76 | 21.28 | 20.31 | 0.97 | 6.70 | MSG, SDG |

MTR

XRL

Consultancy Agreement No. C802
Express Rail Link : Detailed Design for Tunnels & Associated Structures (South)

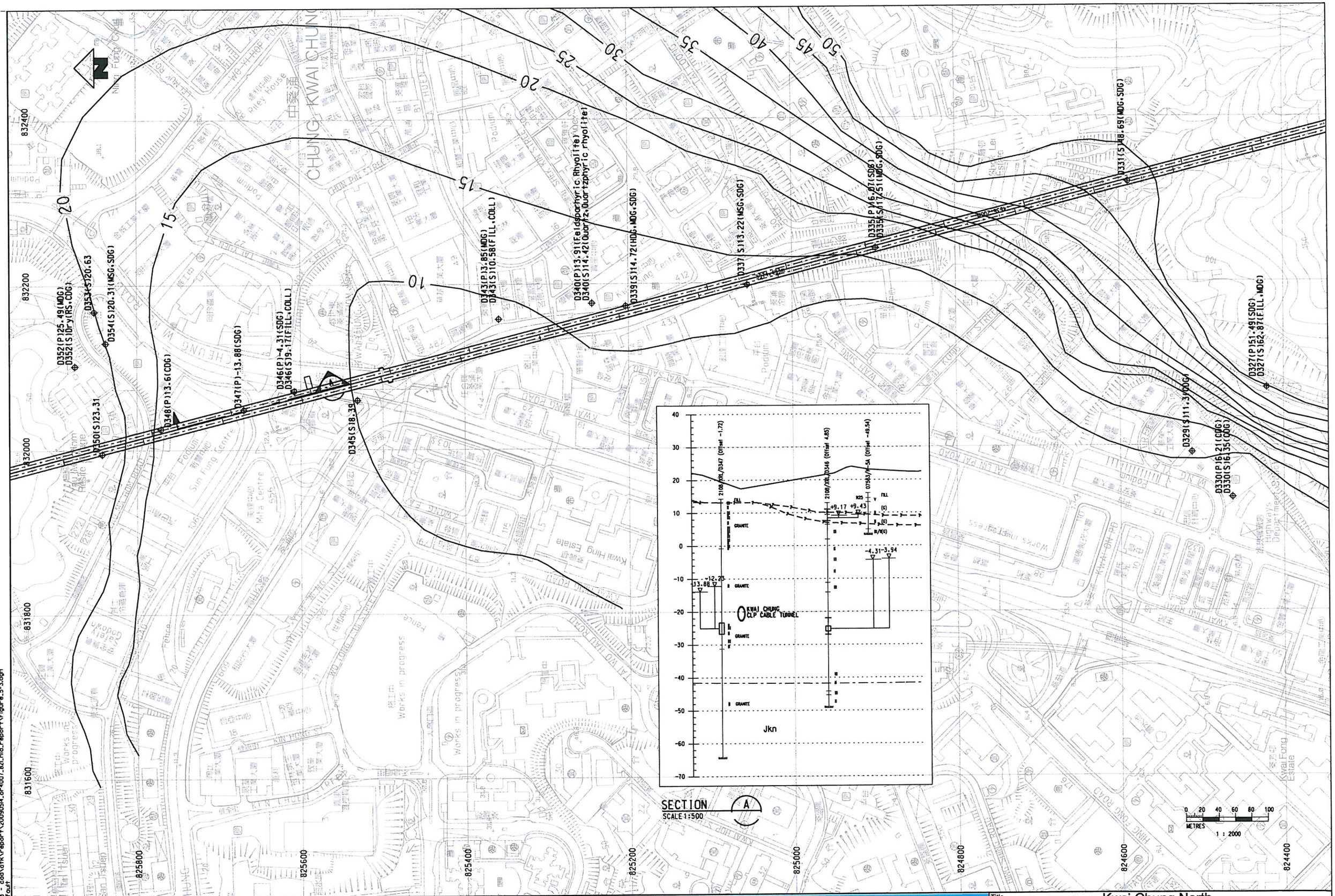
ATKINS

Supported by
Arup, TFP Farrells, DLS, Knight Frank, BMT, Kenneth Ng

Figure Title: Kwai Chung North - Groundwater Level Monitoring Point

Figure No. 5 .2

Date July 2009





MTR ATKINS

Supported by
Arup, TFP Farrells, DLS, Kenneth Ng

Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)


Title: Kwai Chung North - Groundwater Level Contour

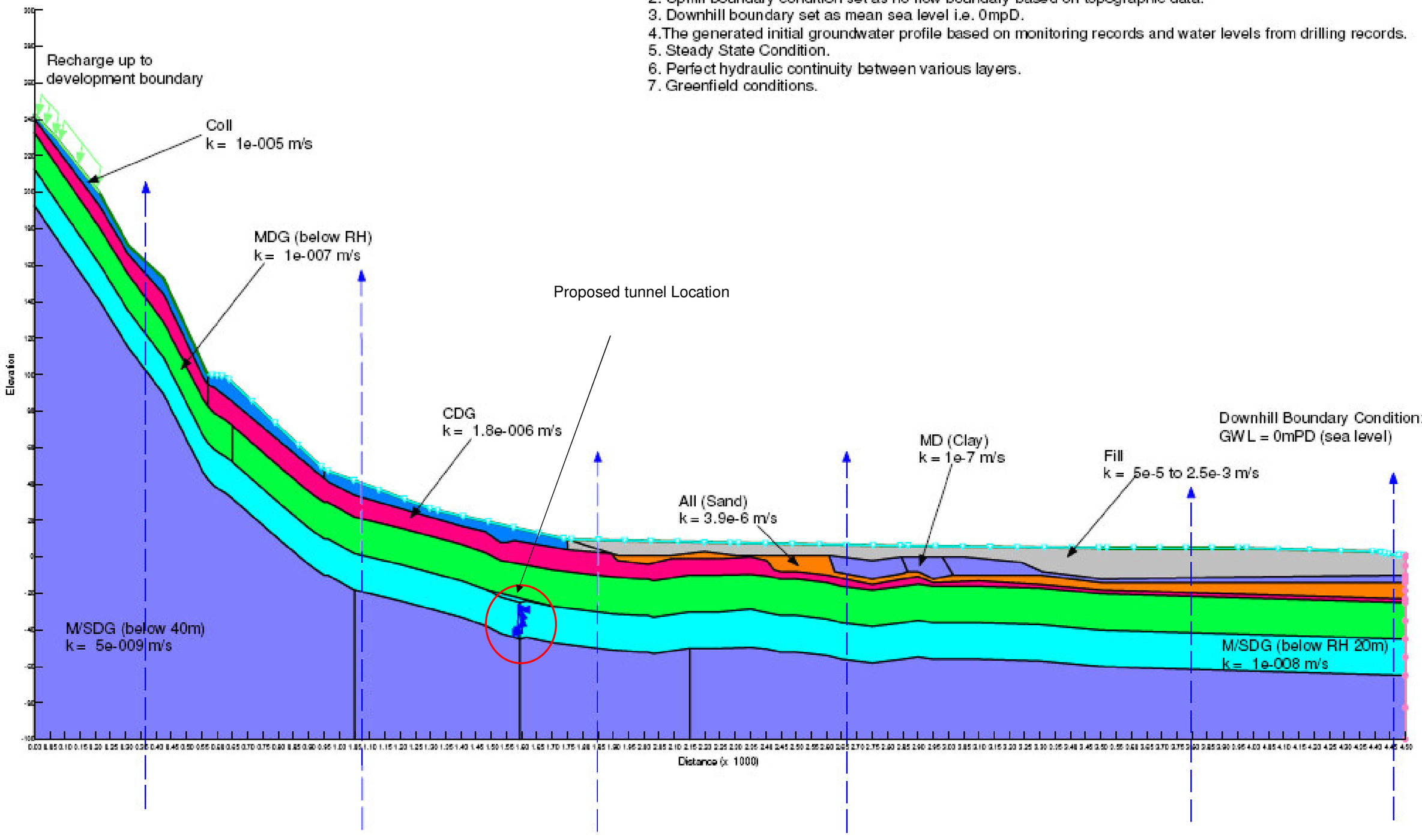
Figure No. Figure 5.3

Date July 2009


PLOT DRIVER:DGN -"C:\DOCUMENTS AND SETTINGS\ADMINISTRATOR\DESKTOP\ERL_EDMW_WINDOWS.DBC\PSCRIPT.PRS"
PLOTTED:Wednesday, 15/07/2009 11:11:15
FILENAME: z:\03 - geo\gik\report\20090514_or4007.82l_hla_report\Figure.5-3.dgn
MODEL NAME:Default

Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 15/07/2009
File Name: General Model B-B.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)

Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m.
2. Uphill boundary condition set as no flow boundary based on topographic data.
3. Downhill boundary set as mean sea level i.e. 0mpD.
4.The generated initial groundwater profile based on monitoring records and water levels from drilling records.
5. Steady State Condition.
6. Perfect hydraulic continuity between various layers.
7. Greenfield conditions.




MTR ATKINS

Supported by
Arup, TFP Farrells, DLS, Knight Frank, BMT, Kenneth NG

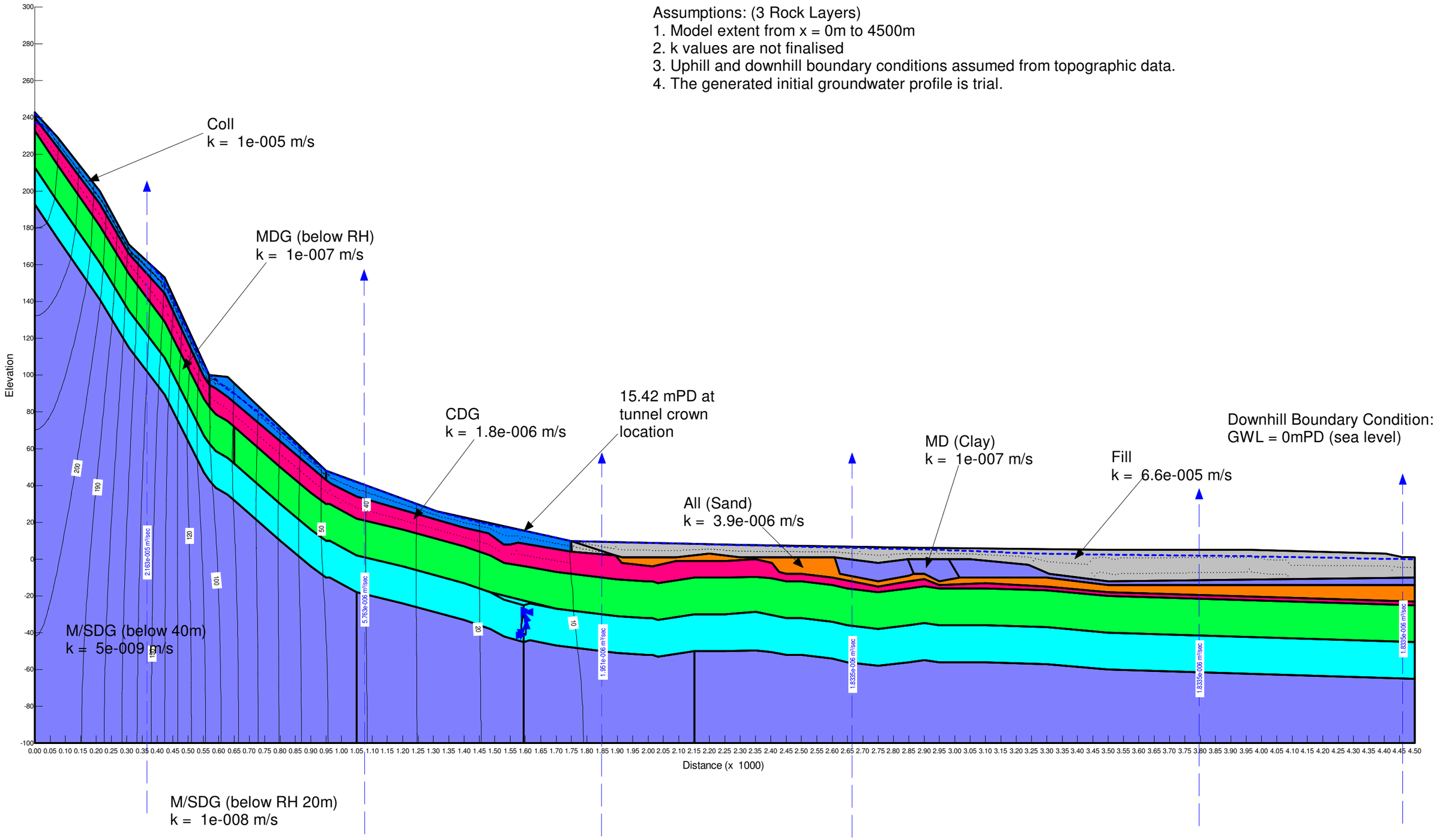
Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

| | | | |
|---|---|---|---|
| Figure Title | Kwai Chung North – Hydrogeological SEEP/W Model | | |
| Figure No | 5.4 | Date | July 2009 |

# APPENDIX A

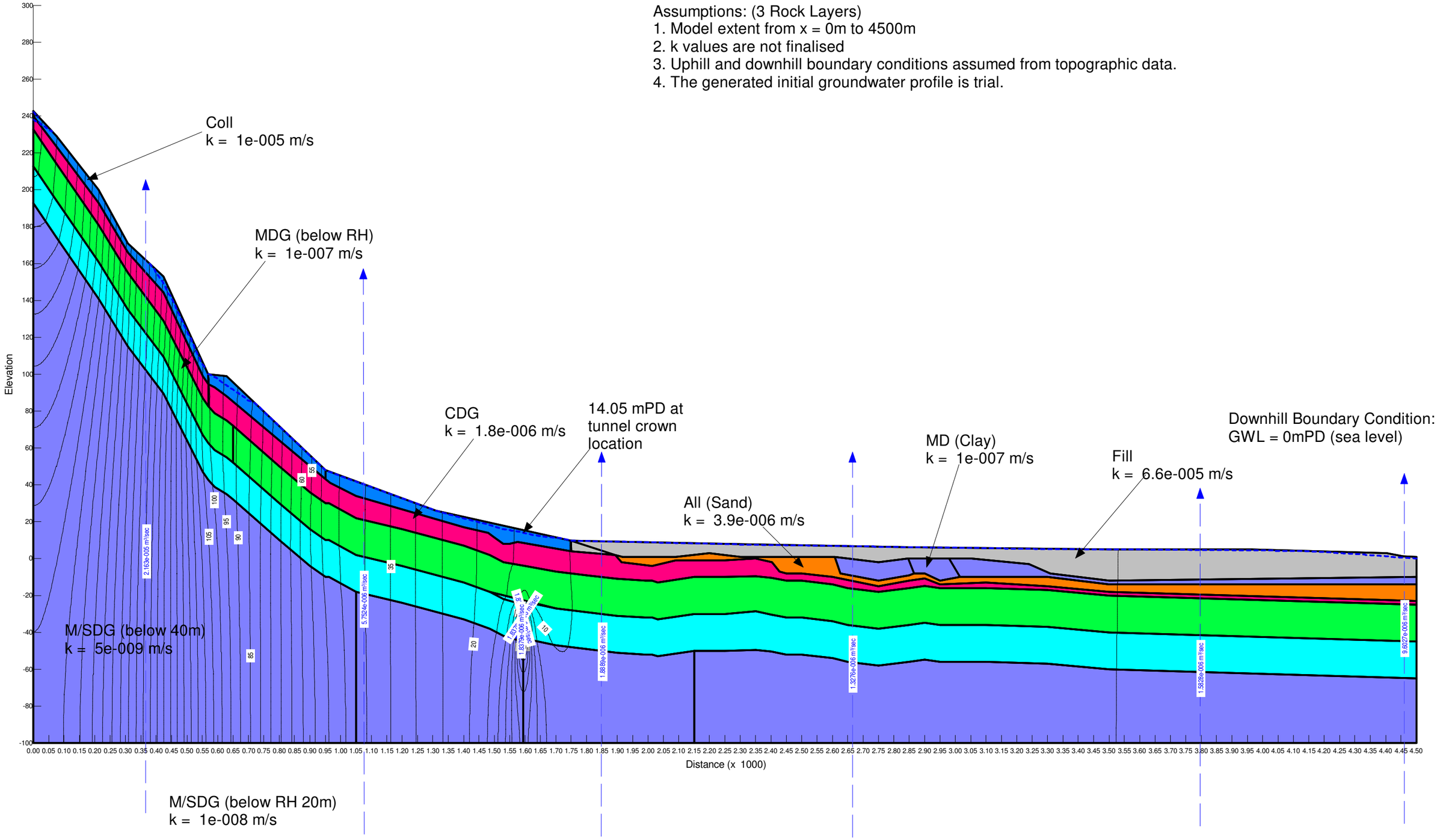
# SEEP MODELLING OUTPUT

Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 19/05/2009
File Name: B_B Existing with Rainfall and outflow (09-05-19)8.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)




Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m
2. k values are not finalised
3. Uphill and downhill boundary conditions assumed from topographic data.
4. The generated initial groundwater profile is trial.

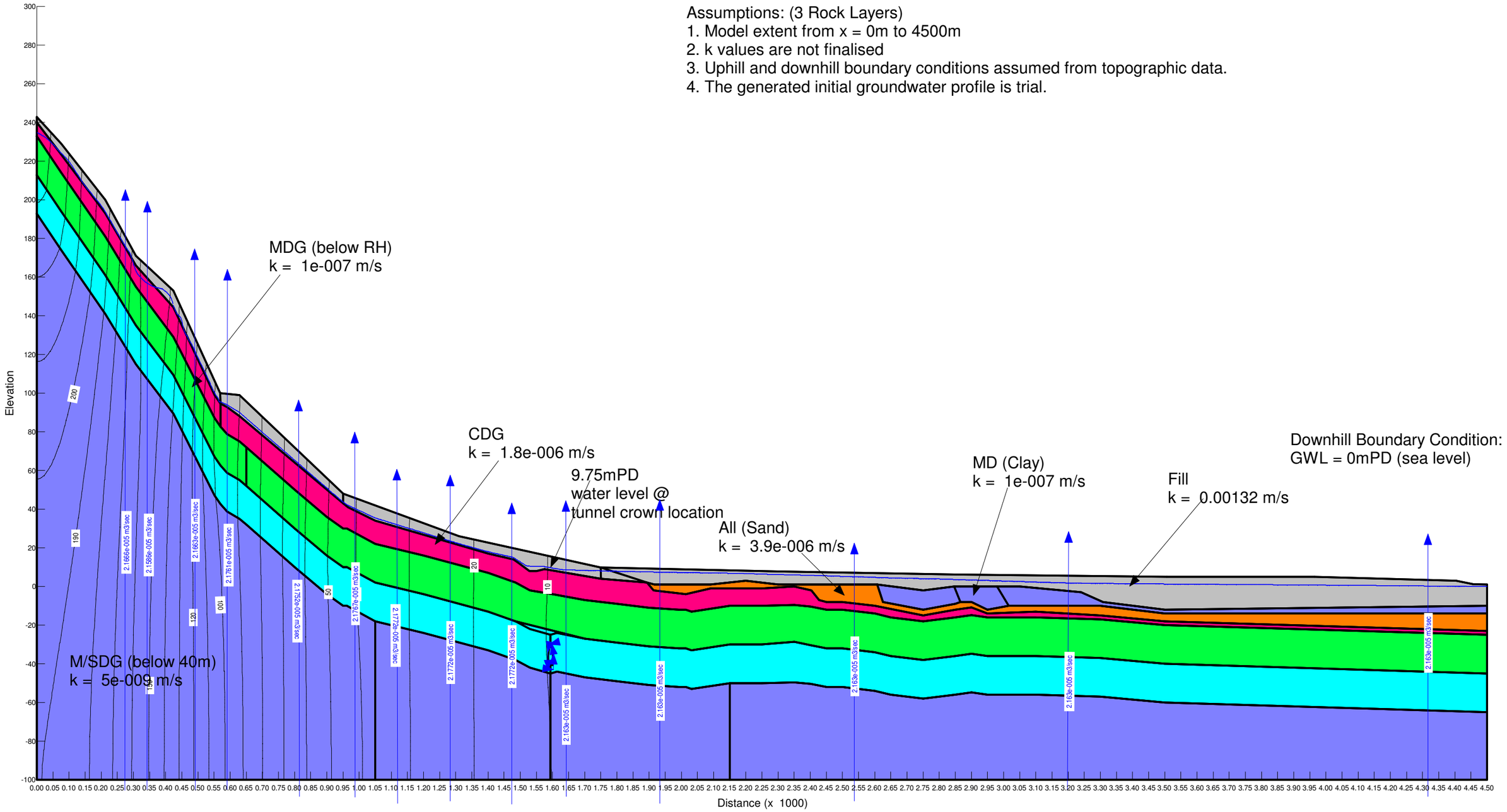
Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 2009/7/8
File Name: B_B Tunnel with Rainfall and outflow (09-07-07)8a.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)




Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m
2. k values are not finalised
3. Uphill and downhill boundary conditions assumed from topographic data.
4. The generated initial groundwater profile is trial.

Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 2009/7/8
File Name: B_B Existing with Rainfall and outflow (09-07-08)8b.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)

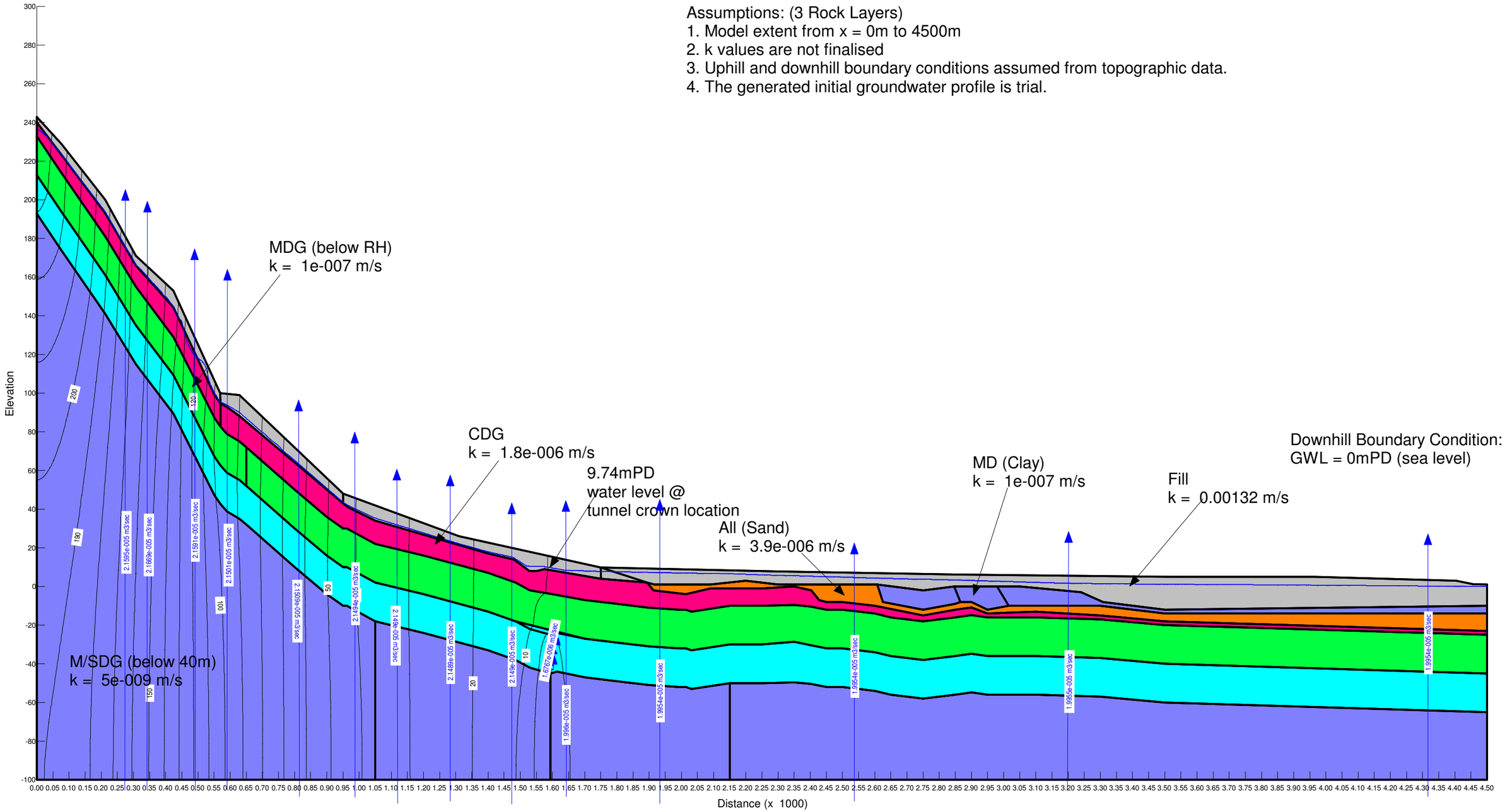
Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m
2. k values are not finalised
3. Uphill and downhill boundary conditions assumed from topographic data.
4. The generated initial groundwater profile is trial.




M/SDG (below RH 20m)
k = 1e-008 m/s

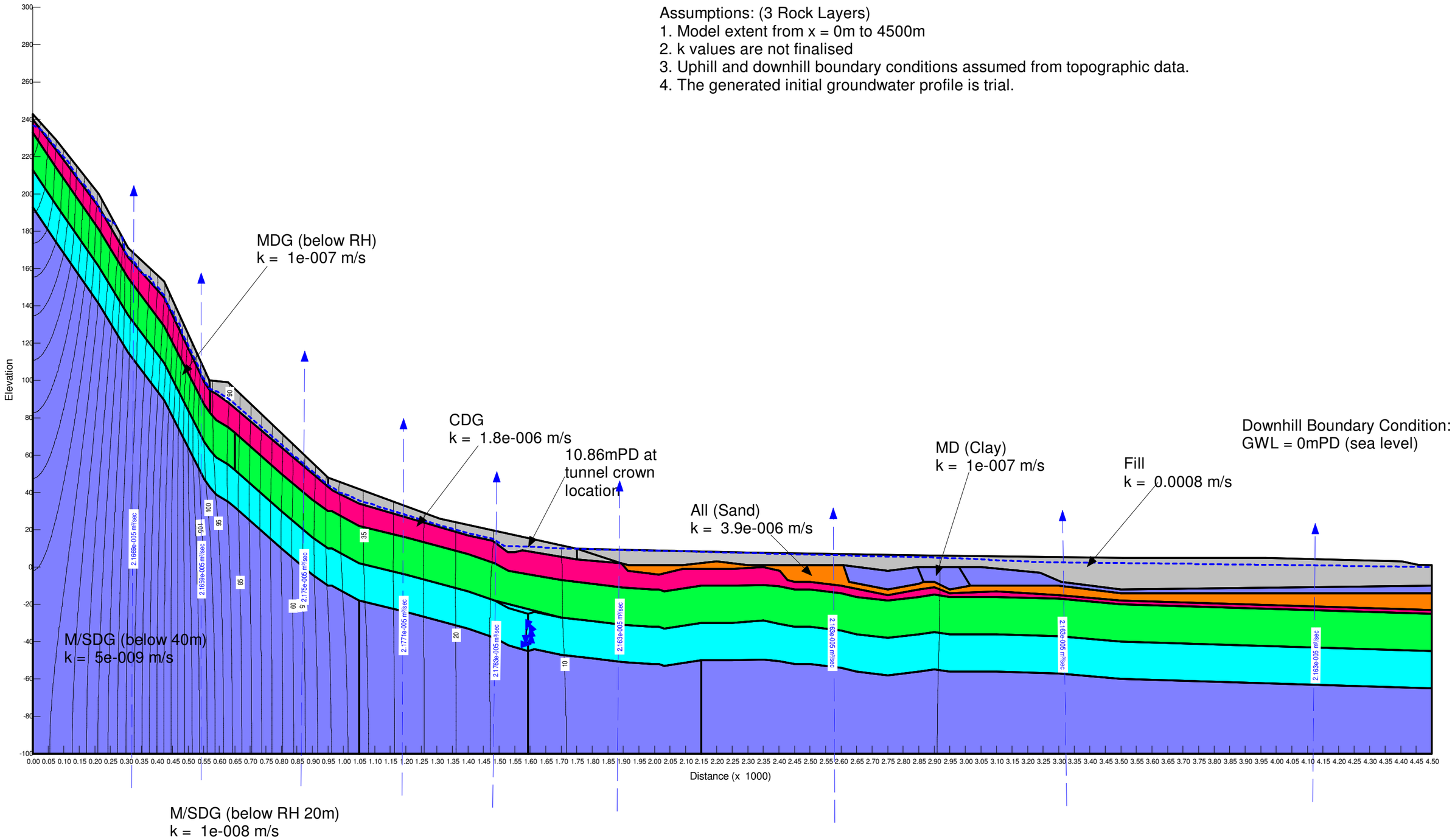
Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 2009/7/8
File Name: B_B Tunnel with Rainfall and outflow (09-07-08)8b.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)

Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m
2. k values are not finalised
3. Uphill and downhill boundary conditions assumed from topographic data.
4. The generated initial groundwater profile is trial.



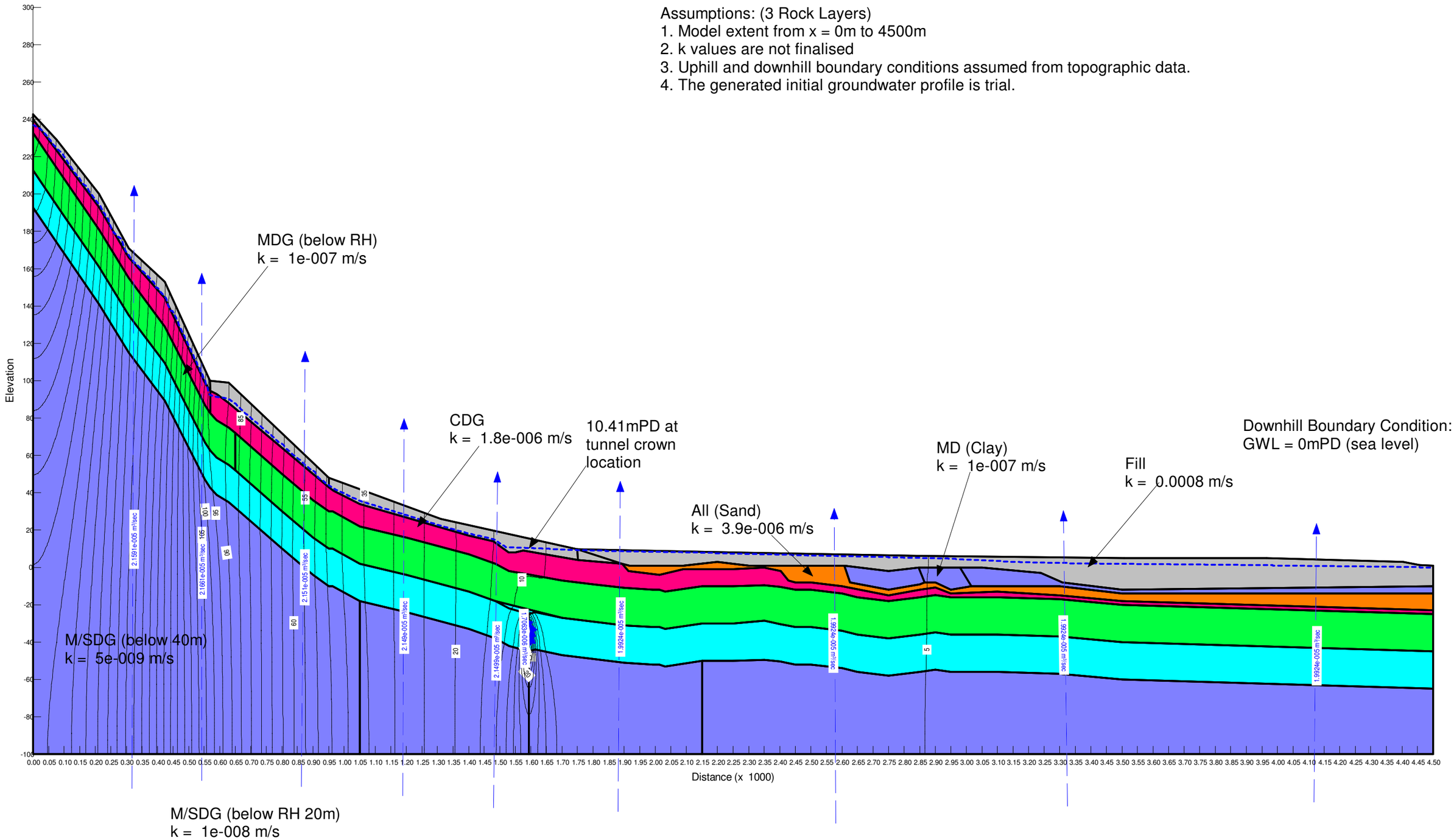
Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 2009/7/12
File Name: B_B Existing with Rainfall and outflow (09-07-10)8c.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)

Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m
2. k values are not finalised
3. Uphill and downhill boundary conditions assumed from topographic data.
4. The generated initial groundwater profile is trial.



Title: MTRC - XRL C802 Hydrogeological Analysis
Date: 2009/7/12
File Name: B_B Tunnel with Rainfall and outflow (09-07-10)8c.gsz
Comments: B-B (H. scale 1:12,000 & V. scale 1: 2000) - Existing (09-04-29)

Assumptions: (3 Rock Layers)
1. Model extent from x = 0m to 4500m
2. k values are not finalised
3. Uphill and downhill boundary conditions assumed from topographic data.
4. The generated initial groundwater profile is trial.



# APPENDIX B

# INFLOW CALCULATIONS

Inflow Assessment Model - includes geological features

Information of XRL Kwai Chung North Tunnels 1590 m

| Total Inflow | L/min | L/min/m |
|---|---|---|
| Goodman | 1,573 | 0.99 |
| Heuer | 1,571 | 0.99 |
| IMS Initial (Average) | 449 | 0.28 |
| IMS final (Average) | 58 | 0.04 |

| | | | |
|---|---|---|---|
| | Sheet No. 1 of 3 | Rev. | Job No. |
| | Chainage 133000 to 133551 | | |
| Job Title: XRL Kwai Chung Tunnels North | Input by: HC | Ckd by: TC | Date: 10-Jun-09 |

Summary of Predicted Groundwater Inflow for Contract 821

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 133000 | 133030 | 133060 | 133090 | 133120 | 133150 | 133153 | 133180 | 133210 | 133222 |
| **To (m)** | *133030* | *133060* | *133090* | *133120* | *133150* | *133153* | *133180* | *133210* | *133222* | *133240* |
| **Length (m)** | *30* | *30* | *30* | *30* | *30* | *3* | *27* | *30* | *12* | *18* |
| **Feature / BH No.** | | | | | | D345 (4) | | | | F1 / D344 (3/4) |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Granodiorite Dyke |
| **Water Level above tunnel (m)** | 49.00 | 48.00 | 46.00 | 46.00 | 44.00 | 45.00 | 45.00 | 45.00 | 45.00 | 45.42 |
| **WL above rock head (m)** | 0.00 | 0.00 | 3.00 | 3.00 | 2.00 | 3.00 | 3.00 | 4.00 | 5.00 | 5.00 |
| **Thickness of Rock Cover (m)** | 49.00 | 48.00 | 43.00 | 43.00 | 42.00 | 42.00 | 42.00 | 41.00 | 40.00 | 40.42 |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 4 |
| **Vent Adit/ Single Track** | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Head Factor* | *0.49* | *0.48* | *0.46* | *0.46* | *0.44* | *0.45* | *0.45* | *0.45* | *0.45* | *0.45417* |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *R* | *0.049* | *0.048* | *0.046* | *0.046* | *0.044* | *0.045* | *0.045* | *0.045* | *0.045* | *0.045417* |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | |
| **Goodman Eqn** | **2.32** | **2.30** | **2.31** | **2.31** | **2.23** | **22.81** | **2.05** | **2.31** | **0.93** | **140.55** |
| **Heuer / Raymer Eqn** | **2.32** | **2.29** | **2.30** | **2.30** | **2.23** | **22.79** | **2.05** | **2.30** | **0.93** | **140.40** |
| **Factored Heuer/Raymer** | **0.29** | **0.29** | **0.29** | **0.29** | **0.28** | **2.85** | **0.26** | **0.29** | **0.12** | **17.55** |
| **IMS - Initial Water Inflow** | | | | | | | | | | |
| *High* | **0.9** | **0.9** | **0.8** | **0.8** | **0.8** | **5.0** | **0.7** | **0.8** | **0.3** | **30.2** |
| *Average* | **0.7** | **0.6** | **0.6** | **0.6** | **0.6** | **3.2** | **0.5** | **0.6** | **0.2** | **19.6** |
| *Low* | **0.4** | **0.4** | **0.4** | **0.4** | **0.4** | **1.5** | **0.4** | **0.4** | **0.2** | **9.0** |
| **IMS - Final Water Inflow** | | | | | | | | | | |
| *High* | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.2** | **0.0** | **0.0** | **0.0** | **1.4** |
| *Average* | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.9** |
| *Low* | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.4** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 133240 | 133247 | 133270 | 133300 | 133340 | 133343 | 133360 | 133390 | 133420 | 133432 |
| **To (m)** | *133247* | *133270* | *133300* | *133340* | *133343* | *133360* | *133390* | *133420* | *133432* | *133450* |
| **Length (m)** | *7* | *23* | *30* | *40* | *3* | *17* | *30* | *30* | *12* | *18* |
| **Feature / BH No.** | F1 | | | | D343 (4) | | | | | F2 |
| **Rock type/ feature type** | Granodiorite Dyke | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Lead Mine Pass fault |
| **Water Level above tunnel (m)** | 45.83 | 45.83 | 45.74 | 46.00 | 46.00 | 46.00 | 46.50 | 48.00 | 50.00 | 50.00 |
| **WL above rock head (m)** | 4.83 | 5.00 | 5.00 | 5.00 | 8.94 | 8.94 | 10.53 | 12.12 | 16.00 | 16.00 |
| **Thickness of Rock Cover (m)** | 41.00 | 40.83 | 40.74 | 41.00 | 37.06 | 37.06 | 35.97 | 35.88 | 34.00 | 34.00 |
| **Permeability (m/s)** | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **IMS Rock Class** | 4 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 4 |
| **Vent Adit/ Single Track** | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Head Factor* | *0.45827* | *0.45827* | *0.45737* | *0.46* | *0.46* | *0.46* | *0.465* | *0.48* | *0.5* | *0.5* |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *R* | *0.045827* | *0.045827* | *0.045737* | *0.046* | *0.046* | *0.046* | *0.0465* | *0.048* | *0.05* | *0.05* |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | |
| **Goodman Eqn** | **54.80** | **1.80** | **2.35** | **3.14** | **24.70** | **1.40** | **2.53** | **2.62** | **1.12** | **167.97** |
| **Heuer / Raymer Eqn** | **54.73** | **1.80** | **2.35** | **3.14** | **24.67** | **1.40** | **2.53** | **2.61** | **1.12** | **167.78** |
| **Factored Heuer/Raymer** | **6.84** | **0.23** | **0.29** | **0.39** | **3.08** | **0.17** | **0.32** | **0.33** | **0.14** | **20.97** |
| **IMS - Initial Water Inflow** | | | | | | | | | | |
| *High* | **11.9** | **0.6** | **0.8** | **1.1** | **5.1** | **0.5** | **0.8** | **0.9** | **0.4** | **33.3** |
| *Average* | **7.7** | **0.5** | **0.6** | **0.8** | **3.3** | **0.4** | **0.6** | **0.6** | **0.3** | **21.6** |
| *Low* | **3.5** | **0.3** | **0.4** | **0.6** | **1.5** | **0.2** | **0.4** | **0.4** | **0.2** | **9.9** |
| **IMS - Final Water Inflow** | | | | | | | | | | |
| *High* | **0.5** | **0.0** | **0.0** | **0.1** | **0.2** | **0.0** | **0.0** | **0.0** | **0.0** | **1.7** |
| *Average* | **0.4** | **0.0** | **0.0** | **0.0** | **0.2** | **0.0** | **0.0** | **0.0** | **0.0** | **1.1** |
| *Low* | **0.2** | **0.0** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.0** | **0.5** |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 133450 | 133458 | 133480 | 133496 | 133499 | 133510 | 133540 | 133549 | 133551 | | | | | | | | |
| **To (m)** | *133458* | *133480* | *133496* | *133499* | *133510* | *133540* | *133549* | *133551* | | | | | | | | | |
| **Length (m)** | *8* | *22* | *16* | *3* | *11* | *30* | *9* | *2* | | | | | | | | | |
| **Feature / BH No.** | F2 / D340 (2) | | | F3 / D339 (4) | | | | F4 / D338(3) | | | | | | | | | |
| **Rock type/ feature type** | Lead Mine Pass fault | Jkn | Jkn | Basalt Dyke/Brecciated Zone | | Jkn | Jkn | Fault Breccia | | | | | | | | | |
| **Water Level above tunnel (m)** | 50.00 | 50.00 | 50.61 | 50.61 | 50.61 | 50.52 | 49.50 | 49.00 | | | | | | | | | |
| **WL above rock head (m)** | 16.00 | 10.00 | 10.61 | 8.61 | 8.61 | 5.52 | 4.50 | 5.00 | | | | | | | | | |
| **Thickness of Rock Cover (m)** | 34.00 | 40.00 | 40.00 | 42.00 | 42.00 | 45.00 | 45.00 | 44.00 | | | | | | | | | |
| **Permeability (m/s)** | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | | | | | | | | | |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | | | | | | | | |
| **IMS Rock Class** | 4 | 1 | 1 | 4 | 1 | 1 | 1 | 4 | | | | | | | | | |
| **Vent Adit/ Single Track** | | | | | | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | | | | | | | | |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| *Head Factor* | *0.5* | *0.5* | *0.50607* | *0.50607* | *0.50607* | *0.50517* | *0.495* | *0.49* | | | | | | | | | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | | | | | | | |
| *R* | *0.05* | *0.05* | *0.050607* | *0.050607* | *0.050607* | *0.050517* | *0.0495* | *0.049* | | | | | | | | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | |
| **Goodman Eqn** | **74.65** | **1.90** | **1.40** | **25.65** | **0.94** | **2.48** | **0.73** | **16.22** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |
| **Heuer / Raymer Eqn** | **74.57** | **1.90** | **1.40** | **25.62** | **0.94** | **2.48** | **0.73** | **16.20** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |
| **Factored Heuer/Raymer** | **9.32** | **0.24** | **0.17** | **3.20** | **0.12** | **0.31** | **0.09** | **2.03** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | |
| *High* | **14.8** | **0.7** | **0.5** | **5.6** | **0.3** | **0.9** | **0.3** | **3.6** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| *Average* | **9.6** | **0.5** | **0.4** | **3.6** | **0.3** | **0.7** | **0.2** | **2.4** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| *Low* | **4.4** | **0.3** | **0.2** | **1.7** | **0.2** | **0.5** | **0.1** | **1.1** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | |
| *High* | **0.7** | **0.0** | **0.0** | **0.3** | **0.0** | **0.0** | **0.0** | **0.2** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| *Average* | **0.5** | **0.0** | **0.0** | **0.2** | **0.0** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| *Low* | **0.2** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |

**Totals**

| | | |
|---|---|---|
| **Tunnel Length** | | |
| 551 | | |
| **Average Values** | | |
| Water Level above tunnel (m) | 47.47 | |
| Permeability (m/s) | 2.93E-07 | |
| Tunnel Radius | 9.00 | |
| IMS Rock Class | 1.86 | |
| **Initial Water Inflow** | | |
| Goodman Eqn | **567** | **l/min** |
| Heuer / Raymer Eqn | **566** | **l/min** |
| Factored Heuer/Raymer | **71** | **l/min** |
| **Initial Water Inflow** | | |
| High | 123.4 | l/min |
| Average | **81.4** | **l/min** |
| Low | 39.5 | l/min |
| **Final Water Inflow** | | |
| High | 5.9 | l/min |
| Average | **3.9** | **l/min** |
| Low | 1.9 | l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **15** | **Initial** |
| | **1** | **Final** |
| **Goodman -** | **103** | |
| **Heuer / Raymer -** | **103** | |
| **Factored Heuer / Raymer -** | **13** | |

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow" by Heuer, R.E. (1995), and "Predicting Groundwater Inflow into Hard Rock Tunnels"* by Raymer, J.H. (2001),

Where:

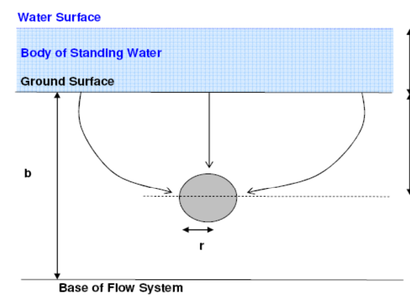
*(Goodman, 1965)* $q = \frac{2 . k . (z + h1) \pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \frac{2 . \pi . k . H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

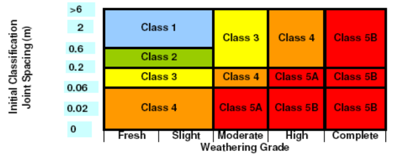
**Goodmans Model Definition**

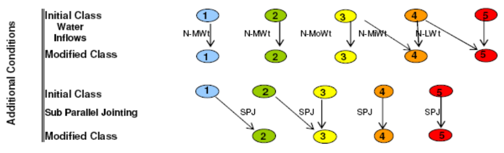



IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | |
|---|---|---|---|
| | Sheet No. 2 of 3 | Rev. | Job No. |
| | Chainage 133551 to 133810 | | |
| Job Title: XRL Kwai Chung Tunnels North | Input by: HC | Ckd by: TC | Date: 07-Jul-09 |

Summary of Predicted Groundwater Inflow for Contract 821

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 133551 | 133570 | 133600 | 133644 | 133647 | 133660 | 133690 | 133720 | 133723 | 133750 | 133780 | 133807 | **Tunnel Length** |
| **To (m)** | *133570* | *133600* | *133644* | *133647* | *133660* | *133690* | *133720* | *133723* | *133750* | *133780* | *133807* | *133810* | 259 |
| **Length (m)** | *19* | *30* | *44* | *3* | *13* | *30* | *30* | *3* | *27* | *30* | *27* | *3* | **Average Values** |
| **Feature / BH No.** | | | | D337 (3) | | | | D336 (3) | | | | D335(3) | |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | |
| **Water Level above tunnel (m)** | 49.00 | 47.84 | 47.25 | 47.25 | 48.00 | 48.00 | 49.50 | 50.00 | 50.00 | 50.00 | 51 | 51 | 49.07 |
| **WL above rock head (m)** | 5.00 | 5.00 | 5.00 | 5.00 | 6.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| **Thickness of Rock Cover (m)** | 44.00 | 42.84 | 42.25 | 42.25 | 42.00 | 45.00 | 50.00 | 54.89 | 54.89 | 60.80 | 65.71 | 65.71 | |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.58E-07 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9.00 |
| **IMS Rock Class** | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 1.50 |
| **Vent Adit/ Single Track** | | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Head Factor* | *0.49* | *0.47837* | *0.47247* | *0.4725* | *0.48* | *0.48* | *0.495* | *0.5* | *0.5* | *0.5* | *0.51* | *0.51* | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *R* | *0.049* | *0.047837* | *0.047247* | *0.04725* | *0.048* | *0.048* | *0.0495* | *0.05* | *0.05* | *0.05* | *0.051* | *0.051* | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | **1.54** | **2.40** | **3.50** | **14.33** | **1.05** | **2.36** | **2.35** | **14.91** | **2.24** | **2.64** | **2.50** | **16.65** | **66 l/min** |
| **Heuer / Raymer Eqn** | **1.54** | **2.40** | **3.50** | **14.32** | **1.05** | **2.36** | **2.35** | **14.89** | **2.23** | **2.64** | **2.49** | **16.63** | **66 l/min** |
| **Factored Heuer/Raymer** | **0.19** | **0.30** | **0.44** | **1.79** | **0.13** | **0.29** | **0.29** | **1.86** | **0.28** | **0.33** | **0.31** | **2.08** | **8 l/min** |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | **0.6** | **0.9** | **1.2** | **1.7** | **0.4** | **0.9** | **0.9** | **1.8** | **0.8** | **0.9** | **0.8** | **1.9** | 12.8 l/min |
| *Average* | **0.4** | **0.6** | **0.9** | **0.9** | **0.3** | **0.6** | **0.7** | **1.0** | **0.6** | **0.7** | **0.6** | **1.0** | **8.4 l/min** |
| *Low* | **0.3** | **0.4** | **0.6** | **0.1** | **0.2** | **0.4** | **0.4** | **0.1** | **0.4** | **0.5** | **0.4** | **0.1** | 4.1 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | **0.0** | **0.0** | **0.1** | **0.1** | **0.0** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.1** | 0.6 l/min |
| *Average* | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.1** | **0.4 l/min** |
| *Low* | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | 0.2 l/min |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Goodman Eqn** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Heuer / Raymer Eqn** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Factored Heuer/Raymer** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *High* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Average* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Low* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *High* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Average* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Low* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **3** | **Initial** |
| | **0** | **Final** |
| **Goodman -** | **26** | |
| **Heuer / Raymer -** | **26** | |
| **Factored Heuer / Raymer -** | **3** | |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" *by Heuer, R.E. (1995), and "Predicting Groundwater Inflow into Hard Rock Tunnels"* by Raymer, J.H. (2001),

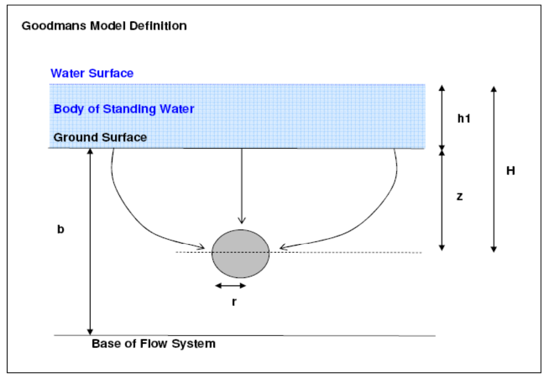
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*(Heuer, 1995 & Raymer, 2001)* $$q = \frac{2 . \pi . k . H}{\ln (2z / r)}$$

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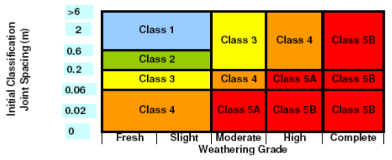
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k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
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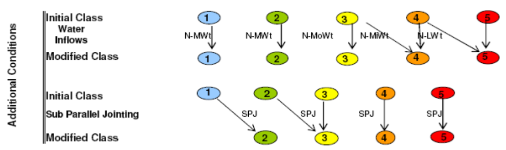



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The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf)** = **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class** =




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | |
|---|---|---|---|
| | Sheet No. 3 of 3 | Rev. | Job No. |
| | Chainage 133810 to 134638 | | |
| Job Title: XRL Kwai Chung Tunnels North | Input by: HC | Ckd by: TC | Date: 10-Jun-09 |
| | Summary of Predicted Groundwater Inflow for Contract 821 | | |

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Totals** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 133810 | 133840 | 133870 | 133900 | 133914 | 133917 | 133930 | 133960 | 133990 | 134000 | 134003 | 134050 | 134080 | 134110 | 134150 | 134155 | 134170 | 134226 | 134230 | 134248 | 134260 | 134285 | 134290 | 134320 | 134350 | 134380 | 134410 | 134440 | 134470 | 134500 | 134530 | 134560 | 134590 | 134595 | 134620 | 134638 | |
| **To (m)** | 133840 | 133870 | 133900 | 133914 | 133917 | 133930 | 133960 | 133990 | 134000 | 134003 | 134050 | 134080 | 134110 | 134150 | 134155 | 134170 | 134226 | 134230 | 134248 | 134260 | 134285 | 134290 | 134320 | 134350 | 134380 | 134410 | 134440 | 134470 | 134500 | 134530 | 134560 | 134590 | 134595 | 134620 | 134638 | 0 | **Tunnel Length** |
| **Length (m)** | 30 | 30 | 30 | 14 | 3 | 13 | 30 | 30 | 10 | 3 | 47 | 30 | 30 | 40 | 5 | 15 | 56 | 4 | 18 | 12 | 25 | 5 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 5 | 25 | 18 | 0 | 828 |
| **Feature / BH No.** | | | | | D334 (3) | | | | | D333 (3) | | | | | | D332 (3) / D331 (2) | D330 (4) / D328 (4) | | | D327 (4) | D325 (1) | F5 | F5 | | | | | | | | | | | f6 | | | | | **Average Values** |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | GD dyke zone | GD dyke zone | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Photolineament (GI/Gc) | Jkn | Jkn | Jkn | |
| **Water Level above tunnel (m)** | 51.50 | 53.00 | 55.00 | 57.00 | 57.00 | 57.00 | 59.00 | 62.00 | 62.00 | 66.00 | 66.00 | 70.00 | 75.00 | 79.00 | 80.00 | 80.00 | 89.00 | 89.00 | 98.00 | 98.00 | 109.00 | 109.00 | 123.00 | 132.00 | 150.00 | 170.00 | 204.06 | 226.93 | 250.62 | 266.72 | 268.03 | 267.94 | 266.51 | 266.51 | 260.61 | | 127.84 |
| **WL above rock head (m)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | | |
| **Thickness of Rock Cover (m)** | 69.62 | 70.53 | 72.44 | 74.35 | 74.35 | 74.35 | 74.35 | 75.00 | 75.00 | 80.00 | 80.00 | 85.00 | 87.00 | 94.72 | 101.63 | 101.63 | 114.54 | 115.45 | 125.36 | 125.36 | 123.00 | 123.00 | 132.46 | 145.17 | 166.89 | 185.37 | 204.06 | 226.93 | 245.62 | 261.72 | 263.03 | 262.94 | 261.51 | 261.51 | 255.61 | | |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 5.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-06 | 1.0E-06 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | | 1.86E-07 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 10 | 11 | 12 | | 9.17 |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 4 | 1 | 1 | 4 | 1 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | | 1.57 |
| **Vent Adit/ Single Track** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 80 | 45 | 45 | 15 | 0 | 40 | 50 | 50 | 35 | 30 | 0 | 60 | 85 | 100 | 0 | 0 | 0 | 0 | 100 | 75 | 60 | 35 | | |
| *Head Factor* | *0.515* | *0.53* | *0.55* | *0.57* | *0.57* | *0.57* | *0.59* | *0.62* | *0.62* | *0.66* | *0.66* | *0.7* | *0.75* | *0.79* | *0.8* | *0.8* | *0.89* | *0.89* | *0.98* | *0.98* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0.5* | *0.552786405* | *0.664589803* | *0.66459* | *0.806350833* | *1* | *0.683772* | *0.646447* | *0.6464466* | *0.704196* | *0.726139* | *1* | *0.612701665* | *0.539022777* | *0.5* | *1* | *1* | *1* | *1* | *0.5* | *0.566987298* | *0.612702* | *0.7042* | *1* | |
| *R* | *0.0515* | *0.053* | *0.055* | *0.057* | *0.057* | *0.057* | *0.059* | *0.062* | *0.062* | *0.066* | *0.066* | *0.07* | *0.1125* | *0.131010378* | *0.159501553* | *0.159502* | *0.215295672* | *0.267* | *0.201029* | *0.190055* | *0.193934* | *0.211259* | *0.217842* | *0.3* | *0.1838105* | *0.161706833* | *0.15* | *0.1* | *0.1* | *0.1* | *0.1* | *0.15* | *0.170096189* | *0.18381* | *0.21126* | *0* | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | 2.88 | 2.90 | 2.95 | 1.40 | 18.01 | 1.30 | 3.00 | 3.02 | 1.01 | 18.88 | 4.93 | 3.28 | 3.33 | 23.47 | 61.52 | 1.85 | 7.48 | 53.71 | 2.56 | 170.64 | 350.82 | 0.70 | 4.43 | 4.73 | 5.23 | 5.64 | 6.06 | 6.55 | 7.09 | 7.43 | 7.46 | 7.46 | 127.10 | 6.51 | 4.72 | 0.00 | 940 l/min |
| **Heuer / Raymer Eqn** | 2.87 | 2.90 | 2.95 | 1.40 | 17.99 | 1.30 | 3.00 | 3.01 | 1.00 | 18.86 | 4.93 | 3.27 | 3.32 | 23.44 | 61.45 | 1.84 | 7.47 | 53.65 | 2.56 | 170.45 | 350.43 | 0.70 | 4.43 | 4.73 | 5.22 | 5.64 | 6.05 | 6.55 | 7.09 | 7.42 | 7.45 | 7.45 | 126.95 | 6.50 | 4.71 | 0.00 | 939 l/min |
| **Factored Heuer/Raymer** | 0.36 | 0.36 | 0.37 | 0.17 | 2.25 | 0.16 | 0.37 | 0.38 | 0.13 | 2.36 | 0.62 | 0.41 | 0.42 | 2.93 | 7.68 | 0.23 | 0.93 | 6.71 | 0.32 | 21.31 | 43.80 | 0.09 | 0.55 | 0.59 | 0.65 | 0.70 | 0.76 | 0.82 | 0.89 | 0.93 | 0.93 | 0.93 | 15.87 | 0.81 | 0.59 | 0.00 | 117 l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 0.9 | 1.0 | 1.0 | 0.5 | 2.1 | 0.4 | 1.1 | 1.1 | 0.4 | 2.4 | 1.9 | 1.3 | 2.0 | 7.3 | 29.5 | 1.4 | 7.2 | 39.5 | 2.2 | 84.4 | 179.4 | 0.6 | 3.9 | 5.4 | 3.3 | 2.9 | 2.7 | 1.8 | 1.8 | 1.8 | 1.8 | 2.7 | 31.5 | 2.8 | 2.3 | 0.0 | 432.2 l/min |
| *Average* | 0.7 | 0.7 | 0.7 | 0.4 | 1.1 | 0.3 | 0.8 | 0.8 | 0.3 | 1.3 | 1.4 | 0.9 | 1.5 | 5.5 | 19.1 | 1.1 | 5.4 | 25.6 | 1.6 | 54.7 | 116.4 | 0.5 | 2.9 | 4.1 | 2.5 | 2.2 | 2.0 | 1.4 | 1.4 | 1.4 | 1.4 | 2.0 | 20.4 | 2.1 | 1.7 | 0.0 | 286.3 l/min |
| *Low* | 0.5 | 0.5 | 0.5 | 0.2 | 0.2 | 0.2 | 0.5 | 0.6 | 0.2 | 0.2 | 0.9 | 0.6 | 1.0 | 3.7 | 8.8 | 0.7 | 3.6 | 11.7 | 1.1 | 25.1 | 53.3 | 0.3 | 2.0 | 2.7 | 1.7 | 1.5 | 1.4 | 0.9 | 0.9 | 0.9 | 0.9 | 1.4 | 9.4 | 1.4 | 1.1 | 0.0 | 140.4 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 | 0.1 | 0.1 | 0.2 | 1.0 | 4.7 | 0.2 | 1.6 | 10.6 | 0.4 | 16.0 | 34.8 | 0.1 | 0.9 | 1.6 | 0.6 | 0.5 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 5.4 | 0.5 | 0.5 | 0.0 | 81.9 l/min |
| *Average* | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.7 | 3.1 | 0.2 | 1.2 | 6.8 | 0.3 | 10.4 | 22.6 | 0.1 | 0.6 | 1.2 | 0.5 | 0.4 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 3.5 | 0.4 | 0.4 | 0.0 | 54.1 l/min |
| *Low* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.5 | 1.4 | 0.1 | 0.8 | 3.1 | 0.2 | 4.8 | 10.3 | 0.1 | 0.4 | 0.8 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 1.6 | 0.3 | 0.2 | 0.0 | 26.4 l/min |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

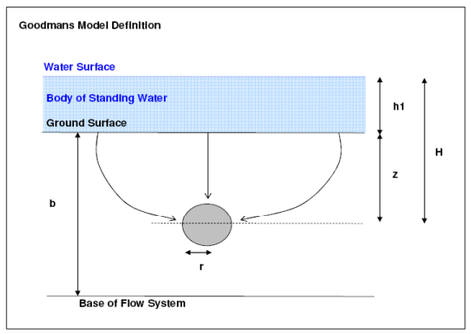
*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)

* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Goodmans Model Definition**

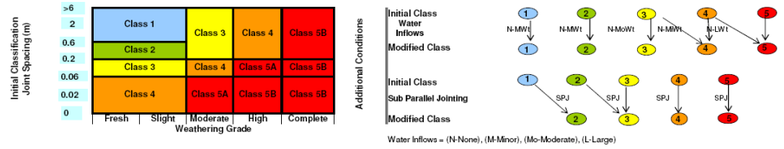



**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| IMS - | 35 | Initial |
| | 7 | Final |
| Goodman - | 114 | |
| Heuer / Raymer - | 113 | |
| Factored Heuer / Raymer - | 14 | |

**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

Inflow Assessment Model - includes geological features
Information of XRL Kwai Chung South Tunnels 2082 m

| Total Inflow | L/min | L/min/m |
|---|---|---|
| Goodman | 3,868 | 1.86 |
| Heuer | 3,864 | 1.86 |
| IMS Initial (Average) | 852 | 0.41 |
| IMS final (Average) | 150 | 0.07 |

| | | | |
|---|---|---|---|
| | Sheet No. 1 of 4 | Rev. | Job No. |
| | Chainage 134638 to 135490 | | |
| Job Title: XRL Kwai Chung Tunnels South | Input by: HC | Ckd by: TC | Date: 13-May-09 |

Summary of Predicted Groundwater Inflow for Contract 821

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 134638 | 134650 | 134680 | 134710 | 134740 | 134770 | 134800 | 134830 | 134860 | 134890 | 134910 | 134920 |
| **To (m)** | 134650 | 134680 | 134710 | 134740 | 134770 | 134800 | 134830 | 134860 | 134890 | 134910 | 134920 | 134942 |
| **Length (m)** | 12 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 20 | 10 | 22 |
| **Feature / BH No.** | | | | | | | | | | | f7 | f7 |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | inferred fault | inferred fault |
| **Water Level above tunnel (m)** | 260.61 | 248.89 | 249.51 | 250.52 | 241.96 | 244.63 | 249.42 | 245.34 | 235.16 | 222.42 | 222.42 | 219.83 |
| **WL above rock head (m)** | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| **Thickness of Rock Cover (m)** | 255.61 | 243.89 | 244.51 | 245.52 | 236.96 | 239.63 | 244.42 | 240.34 | 230.16 | 217.42 | 217.42 | 214.83 |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-06 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 |
| **Vent Adit/ Single Track** | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| **Horizontal Distance to (sf)** | 20 | 50 | 50 | 20 | 0 | 20 | 50 | 50 | 25 | 10 | 0 | 0 |
| *Head Factor* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Horizontal Separation* | 0.776393 | 0.646446609 | 0.646446609 | 0.776393202 | 1 | 0.776393202 | 0.646446609 | 0.64644661 | 0.75 | 0.841886117 | 1 | 1 |
| *R* | 0.232918 | 0.193933983 | 0.193933983 | 0.232917961 | 0.3 | 0.232917961 | 0.193933983 | 0.19393398 | 0.225 | 0.252565835 | 0.3 | 0.3 |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | |
| **Goodman Eqn** | 2.92 | 7.06 | 7.07 | 7.09 | 6.91 | 6.97 | 7.07 | 6.98 | 6.77 | 4.33 | 216.48 | 472.17 |
| **Heuer / Raymer Eqn** | 2.92 | 7.05 | 7.06 | 7.08 | 6.90 | 6.96 | 7.06 | 6.98 | 6.76 | 4.32 | 216.24 | 471.64 |
| **Factored Heuer/Raymer** | 0.36 | 0.88 | 0.88 | 0.89 | 0.86 | 0.87 | 0.88 | 0.87 | 0.84 | 0.54 | 27.03 | 58.95 |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | |
| *High* | 1.7 | 3.5 | 3.5 | 4.2 | 5.4 | 4.2 | 3.5 | 3.5 | 4.1 | 3.0 | 111.0 | 244.2 |
| *Average* | 1.3 | 2.6 | 2.6 | 3.1 | 4.1 | 3.1 | 2.6 | 2.6 | 3.0 | 2.3 | 72.0 | 158.4 |
| *Low* | 0.8 | 1.7 | 1.7 | 2.1 | 2.7 | 2.1 | 1.7 | 1.7 | 2.0 | 1.5 | 33.0 | 72.6 |
| **IMS - Final Water Inflow** | | | | | | | | | | | | |
| *High* | 0.4 | 0.7 | 0.7 | 1.0 | 1.6 | 1.0 | 0.7 | 0.7 | 0.9 | 0.8 | 33.3 | 73.3 |
| *Average* | 0.3 | 0.5 | 0.5 | 0.7 | 1.2 | 0.7 | 0.5 | 0.5 | 0.7 | 0.6 | 21.6 | 47.5 |
| *Low* | 0.2 | 0.3 | 0.3 | 0.5 | 0.8 | 0.5 | 0.3 | 0.3 | 0.5 | 0.4 | 9.9 | 21.8 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 134942 | 134950 | 134980 | 135010 | 135020 | 135030 | 135040 | 135070 | 135100 | 135130 | 135140 | 135156 |
| **To (m)** | 134950 | 134980 | 135010 | 135020 | 135030 | 135040 | 135070 | 135100 | 135130 | 135140 | 135156 | 135160 |
| **Length (m)** | 8 | 30 | 30 | 10 | 10 | 10 | 30 | 30 | 30 | 10 | 16 | 4 |
| **Feature / BH No.** | | D324(2/1) | | | f8 | | | | | | f9 | |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | | comtact of Gc(Jkt) /Gf-m(Jkn) | | Jkn | Jkn | Jkn | Jkn | Contact of Rhyolite | Jkn |
| **Water Level above tunnel (m)** | 219.83 | 223.30 | 219.52 | 210.79 | 210.79 | 210.79 | 207.16 | 209.69 | 220.31 | 228.24 | 228.24 | 228.24 |
| **WL above rock head (m)** | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| **Thickness of Rock Cover (m)** | 214.83 | 218.30 | 214.52 | 205.79 | 205.79 | 205.79 | 202.16 | 204.69 | 215.31 | 223.24 | 223.24 | 223.24 |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 4 | 1 |
| **Vent Adit/ Single Track** | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| **Horizontal Distance to (sf)** | 4 | 50 | 75 | 80 | 80 | 70 | 50 | 20 | 0 | 10 | 18 | 20 |
| *Head Factor* | 0.9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Horizontal Separation* | 0.9 | 0.646446609 | 0.566987 | 0.552786 | 0.552786405 | 0.58167 | 0.646447 | 0.7763932 | 1 | 0.841886 | 0.787867966 | 0.776393202 |
| *R* | 0.27 | 0.193933983 | 0.170096 | 0.165836 | 0.165835921 | 0.174501 | 0.193934 | 0.232918 | 0.3 | 0.252566 | 0.23636039 | 0.232917961 |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | |
| **Goodman Eqn** | 1.72 | 6.51 | 6.43 | 2.08 | 208.11 | 2.08 | 6.16 | 6.22 | 6.45 | 2.21 | 353.02 | 0.88 |
| **Heuer / Raymer Eqn** | 1.72 | 6.51 | 6.42 | 2.08 | 207.87 | 2.08 | 6.16 | 6.21 | 6.44 | 2.20 | 352.63 | 0.88 |
| **Factored Heuer/Raymer** | 0.21 | 0.81 | 0.80 | 0.26 | 25.98 | 0.26 | 0.77 | 0.78 | 0.81 | 0.28 | 44.08 | 0.11 |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | |
| *High* | 1.3 | 3.5 | 3.1 | 1.0 | 61.4 | 1.0 | 3.5 | 4.2 | 5.4 | 1.5 | 139.9 | 0.6 |
| *Average* | 1.0 | 2.6 | 2.3 | 0.7 | 39.8 | 0.8 | 2.6 | 3.1 | 4.1 | 1.1 | 90.8 | 0.4 |
| *Low* | 0.6 | 1.7 | 1.5 | 0.5 | 18.2 | 0.5 | 1.7 | 2.1 | 2.7 | 0.8 | 41.6 | 0.3 |
| **IMS - Final Water Inflow** | | | | | | | | | | | | |
| *High* | 0.3 | 0.7 | 0.5 | 0.2 | 10.2 | 0.2 | 0.7 | 1.0 | 1.6 | 0.4 | 33.1 | 0.1 |
| *Average* | 0.3 | 0.5 | 0.4 | 0.1 | 6.6 | 0.1 | 0.5 | 0.7 | 1.2 | 0.3 | 21.5 | 0.1 |
| *Low* | 0.2 | 0.3 | 0.3 | 0.1 | 3.0 | 0.1 | 0.3 | 0.5 | 0.8 | 0.2 | 9.8 | 0.1 |

| | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 135160 | 135190 | 135220 | 135250 | 135280 | 135310 | 135340 | 135370 | 135400 | 135430 | 135460 | **Tunnel Length** |
| **To (m)** | 135190 | 135220 | 135250 | 135280 | 135310 | 135340 | 135370 | 135400 | 135430 | 135460 | 135490 | 852 |
| **Length (m)** | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | **Average Values** |
| **Feature / BH No.** | D323 (2) | | | | | | | | | | | |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | |
| **Water Level above tunnel (m)** | 226.37 | 221.50 | 219.51 | 215.16 | 213.06 | 215.31 | 215.6555 | 214.8038 | 213.3638 | 208.531 | 198.98176 | 224.85 |
| **WL above rock head (m)** | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5 | 5 | 5 | 5 | 5 | |
| **Thickness of Rock Cover (m)** | 221.37 | 216.50 | 214.51 | 210.16 | 208.06 | 210.31 | 210.6555 | 209.8038 | 208.3638 | 203.531 | 193.98176 | |
| **Permeability (m/s)** | 5.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1E-08 | 1E-08 | 1E-08 | 1E-08 | 1E-08 | 1.24E-07 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9.00 |
| **IMS Rock Class** | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.37 |
| **Vent Adit/ Single Track** | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | |
| **Horizontal Distance to (sf)** | 50 | 75 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 20 | |
| *Head Factor* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| *Horizontal Separation* | 0.646446609 | 0.566987298 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 | 0.6464 | 0.7763932 | |
| *R* | 0.193933983 | 0.170096189 | 0.15 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1939 | 0.232918 | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | 32.90 | 6.47 | 6.43 | 6.34 | 6.29 | 6.34 | 6.35 | 6.33 | 6.30 | 6.19 | 5.99 | 1,450 l/min |
| **Heuer / Raymer Eqn** | 32.86 | 6.47 | 6.42 | 6.33 | 6.29 | 6.33 | 6.34 | 6.32 | 6.29 | 6.19 | 5.98 | 1,448 l/min |
| **Factored Heuer/Raymer** | 4.11 | 0.81 | 0.80 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.77 | 0.75 | 181 l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 8.1 | 3.1 | 2.7 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 3.5 | 4.2 | 650.4 l/min |
| *Average* | 6.1 | 2.3 | 2.0 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 2.6 | 3.1 | 431.4 l/min |
| *Low* | 4.1 | 1.5 | 1.4 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.7 | 2.1 | 212.4 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 1.6 | 0.5 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.7 | 1.0 | 169.1 l/min |
| *Average* | 1.2 | 0.4 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.7 | 111.6 l/min |
| *Low* | 0.8 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.5 | 54.2 l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| IMS - | 51 | Initial |
| | 13 | Final |
| Goodman - | 170 | |
| Heuer / Raymer - | 170 | |
| Factored Heuer / Raymer - | 21 | |

**Note :-**
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

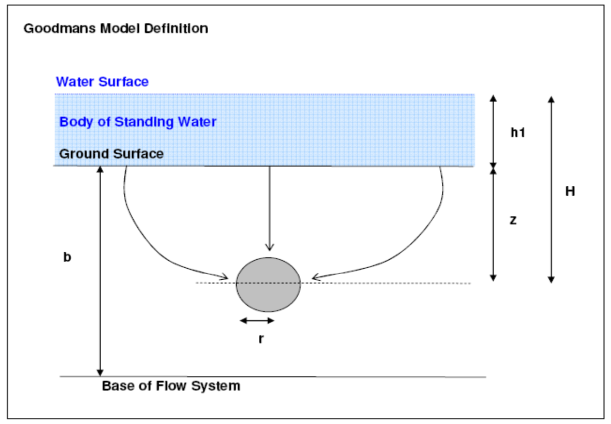
Where:

*(Goodman, 1965)* $$q = \frac{2 \cdot k \cdot (z + h1)\, \pi}{2.3 \log (r / 2z)} \;*$$

*(Heuer, 1995 & Raymer, 2001)* $$q = \frac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

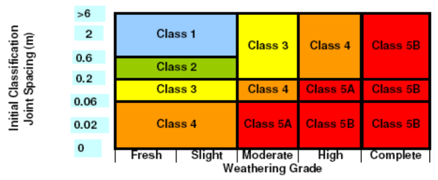
q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965)
However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

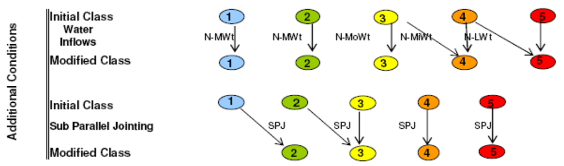



IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

| | | | | |
|---|---|---|---|---|
| | Sheet No. 2 of 4 | Rev. | | Job No. |
| | Chainage 135490 to 136130 | | | |
| Job Title: XRL Kwai Chung Tunnels South | Input by: HC | Ckd by: TC | | Date: 10-Jun-09 |
| | Summary of Predicted Groundwater Inflow for Contract 821 | | | |

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 135+660 | | |
| **From (m)** | 135490 | 135520 | 135550 | 135580 | 135610 | 135640 | 135645 | 135648 | 135670 | 135700 |
| **To (m)** | *135520* | *135550* | *135580* | *135610* | *135640* | *135645* | *135648* | *135670* | *135700* | *135730* |
| **Length (m)** | *30* | *30* | *30* | *30* | *30* | *5* | *3* | *22* | *30* | *30* |
| **Feature / BH No.** | | | | | | | f10/ D322 (3) | | | |
| **Rock type/ feature type** | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Inferred Fault (Intense micrfracture) | Jkn | Jkn | Jkn |
| **Water Level above tunnel (m)** | 190.25 | 187.95 | 169.15 | 161.73 | 152.66 | 122.00 | 122.00 | 122.00 | 120.00 | 118.00 |
| **WL above rock head (m)** | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Thickness of Rock Cover (m)** | 185.25 | 182.95 | 177.35 | 169.15 | 161.73 | 152.66 | 152.66 | 152.66 | 144.21 | 130.55 |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 |
| **Vent Adit/ Single Track** | ST | | | | | | | | | |
| **Source Size Factor (sf)** | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 |
| **Horizontal Distance to (sf)** | 0 | 20 | 50 | 0 | 0 | 0 | 50 | 100 | 80 | 50 |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *Horizontal Separation* | *1* | *0.776393202* | *0.646446609* | *1* | *1* | *1* | *0.646446609* | *0.5* | *0.552786405* | *0.646446609* |
| *R* | *0.3* | *0.232917961* | *0.193933983* | *0.1* | *0.1* | *0.1* | *0.193933983* | *0.15* | *0.165835921* | *0.193933983* |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | |
| **Goodman Eqn** | 5.79 | 5.74 | 5.47 | 5.28 | 5.11 | 0.82 | 49.05 | 3.60 | 4.71 | 4.39 |
| **Heuer / Raymer Eqn** | 5.79 | 5.74 | 5.46 | 5.27 | 5.11 | 0.82 | 48.99 | 3.59 | 4.70 | 4.38 |
| **Factored Heuer/Raymer** | 0.72 | 0.72 | 0.68 | 0.66 | 0.64 | 0.10 | 6.12 | 0.45 | 0.59 | 0.55 |
| **IMS - Initial Water Inflow** | | | | | | | | | | |
| *High* | 5.4 | 4.2 | 3.5 | 1.8 | 1.8 | 0.3 | 21.5 | 2.0 | 3.0 | 3.5 |
| *Average* | 4.1 | 3.1 | 2.6 | 1.4 | 1.4 | 0.2 | 14.0 | 1.5 | 2.2 | 2.6 |
| *Low* | 2.7 | 2.1 | 1.7 | 0.9 | 0.9 | 0.2 | 6.4 | 1.0 | 1.5 | 1.7 |
| **IMS - Final Water Inflow** | | | | | | | | | | |
| *High* | 1.6 | 1.0 | 0.7 | 0.2 | 0.2 | 0.0 | 4.2 | 0.3 | 0.5 | 0.7 |
| *Average* | 1.2 | 0.7 | 0.5 | 0.1 | 0.1 | 0.0 | 2.7 | 0.2 | 0.4 | 0.5 |
| *Low* | 0.8 | 0.5 | 0.3 | 0.1 | 0.1 | 0.0 | 1.2 | 0.1 | 0.2 | 0.3 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 135+890 | | | | |
| **From (m)** | 135730 | 135754 | 135756 | 135760 | 135790 | 135820 | 135850 | 135880 | 135890 | 135893 | 135910 | 135924 |
| **To (m)** | *135754* | *135756* | *135760* | *135790* | *135820* | *135850* | *135880* | *135890* | *135893* | *135910* | *135924* | *135940* |
| **Length (m)** | *24* | *2* | *4* | *30* | *30* | *30* | *30* | *10* | *3* | *17* | *14* | *16* |
| **Feature / BH No.** | | f11/ D321 | | | | | | | D320 (3) | | | f12 |
| **Rock type/ feature type** | Jkn | Inferred fault | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | Rhyolite Dyke |
| **Water Level above tunnel (m)** | 115.00 | 115.00 | 115.00 | 112.00 | 112.00 | 110.00 | 109.00 | 107.00 | 107.00 | 107.00 | 105.00 | 105.00 |
| **WL above rock head (m)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Thickness of Rock Cover (m)** | 120.38 | 120.38 | 120.38 | 116.92 | 122.37 | 124.60 | 125.44 | 132.95 | 132.95 | 132.95 | 141.17 | 141.17 |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 6.0E-07 | 1.0E-08 | 1.0E-08 | 1.0E-06 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **IMS Rock Class** | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 4 |
| **Vent Adit/ Single Track** | | | | | | | | | | | | |
| **Source Size Factor (sf)** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Horizontal Distance to (sf)** | 30 | 5 | 0 | 15 | 45 | 75 | 100 | 0 | 0 | 0 | 0 | 0 |
| *Head Factor* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *Horizontal Separation* | *0.726138721* | *0.888196601* | *1* | *0.806350833* | *0.66459* | *0.566987* | *0.5* | *1* | *1* | *1* | *1* | *1* |
| *R* | *0.217841616* | *0.26645898* | *0.3* | *0.24190525* | *0.199377* | *0.170096* | *0.15* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | |
| **Goodman Eqn** | 3.32 | 27.65 | 0.55 | 4.06 | 4.19 | 4.25 | 4.27 | 1.48 | 26.68 | 2.52 | 2.16 | 247.38 |
| **Heuer / Raymer Eqn** | 3.31 | 27.62 | 0.55 | 4.06 | 4.19 | 4.24 | 4.26 | 1.48 | 26.65 | 2.52 | 2.16 | 247.11 |
| **Factored Heuer/Raymer** | 0.41 | 3.45 | 0.07 | 0.51 | 0.52 | 0.53 | 0.53 | 0.19 | 3.33 | 0.31 | 0.27 | 30.89 |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | |
| *High* | 3.1 | 19.7 | 0.7 | 4.4 | 3.6 | 3.1 | 2.7 | 0.6 | 3.7 | 1.0 | 0.8 | 59.2 |
| *Average* | 2.4 | 12.8 | 0.5 | 3.3 | 2.7 | 2.3 | 2.0 | 0.5 | 2.0 | 0.8 | 0.6 | 38.4 |
| *Low* | 1.6 | 5.9 | 0.4 | 2.2 | 1.8 | 1.5 | 1.4 | 0.3 | 0.3 | 0.5 | 0.4 | 17.6 |
| **IMS - Final Water Inflow** | | | | | | | | | | | | |
| *High* | 0.7 | 5.3 | 0.2 | 1.1 | 0.7 | 0.5 | 0.4 | 0.1 | 0.4 | 0.1 | 0.1 | 5.9 |
| *Average* | 0.5 | 3.4 | 0.2 | 0.8 | 0.5 | 0.4 | 0.3 | 0.0 | 0.2 | 0.1 | 0.1 | 3.8 |
| *Low* | 0.3 | 1.6 | 0.1 | 0.5 | 0.4 | 0.3 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 1.8 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 135940 | 135947 | 135970 | 136000 | 136030 | 136060 | 136090 | 136118 | 136130 | | | | |
| **To (m)** | *135947* | *135970* | *136000* | *136030* | *136060* | *136090* | *136118* | *136130* | *0* | *0* | *0* | *0* | *0* |
| **Length (m)** | *7* | *23* | *30* | *30* | *30* | *30* | *28* | *12* | *0* | *0* | *0* | *0* | *0* |
| **Feature / BH No.** | f12/ D318 (3) | D319 (1) | | | | | *D316 (2) / D317 (1/2)* | f13 | | | | | |
| **Rock type/ feature type** | Rhyolite Dyke | Jkn | Jkn | Jkn | Jkn | Jkn | Jkn | ontact of Jkn/Jkt | | | | | |
| **Water Level above tunnel (m)** | 102.00 | 102.00 | 98.00 | 93.00 | 87.00 | 83.00 | 78.00 | 74.00 | | | | | |
| **WL above rock head (m)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| **Thickness of Rock Cover (m)** | 145.82 | 145.82 | 148.15 | 146.23 | 137.43 | 118.10 | 102.88 | 104.97 | | | | | |
| **Permeability (m/s)** | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | | | | | |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | | | | |
| **IMS Rock Class** | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | | | | | |
| **Vent Adit/ Single Track** | | | ST | ST | ST | ST | ST | ST | | | | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | | | | |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| *Head Factor* | *1* | *1* | *0.98* | *0.93* | *0.87* | *0.83* | *0.78* | *0.74* | | | | | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | | | | |
| *R* | *0.1* | *0.1* | *0.098* | *0.093* | *0.087* | *0.083* | *0.078* | *0.074* | | | | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | |
| **Goodman Eqn** | 110.75 | 3.64 | 4.80 | 4.76 | 4.55 | 4.09 | 3.47 | 150.94 | | | | | |
| **Heuer / Raymer Eqn** | 110.63 | 3.63 | 4.80 | 4.75 | 4.55 | 4.09 | 3.47 | 150.77 | | | | | |
| **Factored Heuer/Raymer** | 13.83 | 0.45 | 0.60 | 0.59 | 0.57 | 0.51 | 0.43 | 18.85 | | | | | |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | |
| *High* | 25.9 | 1.4 | 1.8 | 1.7 | 1.6 | 1.5 | 1.3 | 32.9 | | | | | |
| *Average* | 16.8 | 1.0 | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 21.3 | | | | | |
| *Low* | 7.7 | 0.7 | 0.9 | 0.8 | 0.8 | 0.7 | 0.7 | 9.8 | | | | | |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | |
| *High* | 2.6 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 2.4 | | | | | |
| *Average* | 1.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.6 | | | | | |
| *Low* | 0.8 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.7 | | | | | |

**Totals**

| Row | Totals | |
|---|---|---|
| **Tunnel Length** | 640 | |
| **Average Values** | | |
| Water Level above tunnel (m) | 116.72 | |
| Permeability (m/s) | 1.95E-07 | |
| Tunnel Radius | 9.00 | |
| IMS Rock Class | 1.57 | |
| **Initial Water Inflow** | | |
| Goodman Eqn | **705** | **l/min** |
| Heuer / Raymer Eqn | **705** | **l/min** |
| Factored Heuer/Raymer | **88** | **l/min** |
| **Initial Water Inflow** | | |
| High | 217.5 | l/min |
| Average | **146.2** | **l/min** |
| Low | 74.9 | l/min |
| **Final Water Inflow** | | |
| High | 30.5 | l/min |
| Average | **20.8** | **l/min** |
| Low | 11.0 | l/min |

**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **23** | **Initial** |
| | **3** | **Final** |
| **Goodman -** | **110** | |
| **Heuer / Raymer -** | **110** | |
| **Factored Heuer / Raymer -** | **14** | |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

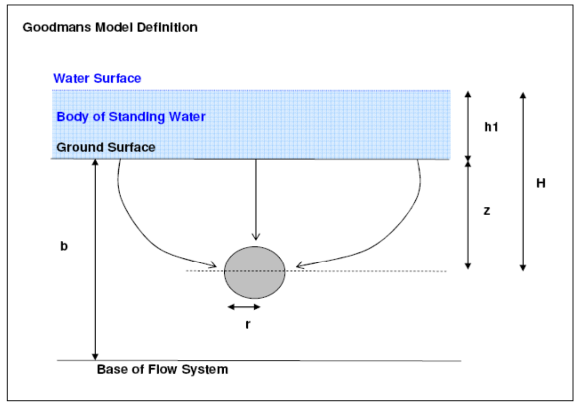
Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\, \pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

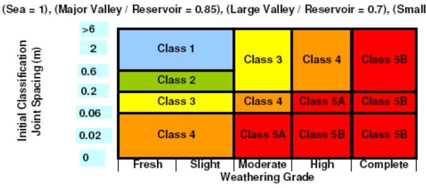
q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965)
However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)*. As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

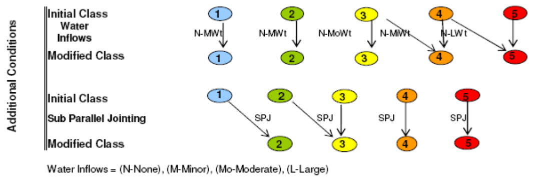



IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

**IMS Rock Class =**



| | | | | | |
|---|---|---|---|---|---|
| | Sheet No. 3 of 4 | | Rev. | | Job No. |
| | Chainage 136130 to 136600 | | | | |
| Job Title: XRL Kwai Chung Tunnels South | Input by: | HC | Ckd by: | TC | Date: 13-May-09 |

Summary of Predicted Groundwater Inflow for Contract 821

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | | | | | | | | | | | | | | | | | **Totals** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From (m)** | 136130 | 136150 | 136180 | 136210 | 136240 | 136270 | 136291 | 136300 | 136330 | 136360 | 136390 | 136398 | 136420 | 136450 | 136480 | 136487 | 136510 | 136519 | 136540 | 136544 | 136565 | 136570 | 136573 | 136585 | 136600 | **Tunnel Length** |
| **To (m)** | *136150* | *136180* | *136210* | *136240* | *136270* | *136291* | *136300* | *136330* | *136360* | *136390* | *136398* | *136420* | *136450* | *136480* | *136487* | *136510* | *136519* | *136540* | *136544* | *136565* | *136570* | *136573* | *136585* | *136600* | *0* | 470 |
| **Length (m)** | *20* | *30* | *30* | *30* | *30* | *21* | *9* | *30* | *30* | *30* | *8* | *22* | *30* | *30* | *7* | *23* | *9* | *21* | *4* | *21* | *5* | *3* | *12* | *15* | *0* | **Average Values** |
| **Feature / BH No.** | | | | | | | F15 / D315 (3/4) | F15 | F15/ D312 (2/3) | F15 | F15 | | | | | F15 / D313 (4)/ D309 (3) | F15 | | D307(4) | | A51 (3/4) | D311 (3) | | f16 | | |
| **Rock type/ feature type** | Jkt | Jkt | Jkt | Jkt | Jkt | Jkt | Tolo Channel Faul Zone | Tolo Channel Faul Zone | Tolo Channel Faul Zone | Tolo Channel Faul Zone | Tolo Channel Faul Zone | Jkt | Jkt | Jkt | Jkt | Tolo Channel Faul Zone | Tolo Channel Faul Zone | Jkt | Jkt | Jkt | Jkt | Jkt | Jkt | Contact of Jkt/HK | | |
| **Water Level above tunnel (m)** | 74.00 | 73.00 | 73.00 | 73.00 | 70.00 | 69.00 | 69.00 | 66.00 | 64.00 | 62.00 | 60.00 | 60.00 | 60.00 | 62.00 | 63.61 | 63.61 | 66.52 | 66.52 | 67.43 | 67.43 | 67.43 | 65.00 | 65.00 | 65.00 | | |
| **WL above rock head (m)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 12.00 | 14.00 | 10.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 66.36 |
| **Thickness of Rock Cover (m)** | 104.97 | 113.83 | 113.40 | 107.90 | 95.00 | 80.00 | 80.00 | 65.00 | 52.00 | 48.00 | 50.00 | 50.00 | 67.00 | 62.00 | 63.61 | 63.61 | 66.52 | 66.52 | 67.43 | 67.43 | 67.43 | 65.00 | 65.00 | 65.00 | | |
| **Permeability (m/s)** | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-06 | 1.0E-06 | 1.0E-06 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-08 | 1.0E-06 | 1.0E-06 | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-06 | 6.0E-07 | 1.0E-08 | 1.0E-06 | | 4.47E-07 |
| **Tunnel Radius** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9.00 |
| **IMS Rock Class** | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 4 | 1 | 4 | 3 | 1 | 4 | | 2.33 |
| **Vent Adit/ Single Track** | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | ST | | |
| **Source Size Factor (sf)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | |
| **Horizontal Distance to (sf)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| *Head Factor* | *0.74* | *0.73* | *0.73* | *0.73* | *0.7* | *0.69* | *0.69* | *0.66* | *0.64* | *0.62* | *0.6* | *0.6* | *0.6* | *0.6* | *0.62* | *0.6361* | *0.6361* | *0.66517* | *0.66517* | *0.67427* | *0.67427* | *0.67427* | *0.65* | *0.65* | *0.65* | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *R* | *0.074* | *0.073* | *0.073* | *0.073* | *0.07* | *0.069* | *0.069* | *0.066* | *0.064* | *0.062* | *0.06* | *0.06* | *0.06* | *0.062* | *0.06361* | *0.06361* | *0.066517* | *0.066517* | *0.067427* | *0.067427* | *0.067427* | *0.065* | *0.065* | *0.065* | | |
| **Calculated Inflow (L/min) for:** | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| **Goodman Eqn** | 2.52 | 3.99 | 3.98 | 3.85 | 3.53 | 2.20 | 94.42 | 279.85 | 296.11 | 296.56 | 75.23 | 2.07 | 2.81 | 2.68 | 0.63 | 208.47 | 83.89 | 1.96 | 37.60 | 1.97 | 47.00 | 16.54 | 1.10 | 137.80 | | 1,607 l/min |
| **Heuer / Raymer Eqn** | 2.51 | 3.98 | 3.97 | 3.84 | 3.52 | 2.20 | 94.31 | 279.53 | 295.78 | 296.23 | 75.15 | 2.07 | 2.81 | 2.67 | 0.63 | 208.24 | 83.79 | 1.96 | 37.56 | 1.97 | 46.95 | 16.52 | 1.10 | 137.65 | | 1,605 l/min |
| **Factored Heuer/Raymer** | 0.31 | 0.50 | 0.50 | 0.48 | 0.44 | 0.28 | 11.79 | 34.94 | 36.97 | 37.03 | 9.39 | 0.26 | 0.35 | 0.33 | 0.08 | 26.03 | 10.47 | 0.24 | 4.70 | 0.25 | 5.87 | 2.06 | 0.14 | 17.21 | | 201 l/min |
| **IMS - Initial Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | **Initial Water Inflow** |
| *High* | 0.9 | 1.3 | 1.3 | 1.3 | 1.3 | 0.9 | 23.0 | 73.3 | 71.0 | 68.3 | 17.8 | 0.8 | 1.1 | 1.1 | 0.3 | 54.1 | 22.2 | 0.5 | 10.0 | 0.8 | 12.5 | 2.4 | 0.5 | 36.1 | | 403.4 l/min |
| *Average* | 0.7 | 1.0 | 1.0 | 1.0 | 0.9 | 0.7 | 14.9 | 47.5 | 46.1 | 44.6 | 11.5 | 0.6 | 0.8 | 0.8 | 0.2 | 35.1 | 14.4 | 0.6 | 6.5 | 0.6 | 8.1 | 1.3 | 0.4 | 23.4 | | 262.7 l/min |
| *Low* | 0.4 | 0.7 | 0.7 | 0.7 | 0.6 | 0.4 | 6.8 | 21.8 | 21.1 | 20.5 | 5.3 | 0.4 | 0.5 | 0.6 | 0.1 | 16.1 | 6.6 | 0.4 | 3.0 | 0.4 | 3.7 | 0.2 | 0.2 | 10.7 | | 121.9 l/min |
| **IMS - Final Water Inflow** | | | | | | | | | | | | | | | | | | | | | | | | | | **Final Water Inflow** |
| *High* | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.6 | 4.8 | 4.5 | 4.3 | 1.1 | 0.0 | 0.1 | 0.1 | 0.0 | 3.4 | 1.5 | 0.1 | 0.7 | 0.1 | 0.8 | 0.2 | 0.0 | 2.3 | | 26.1 l/min |
| *Average* | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 1.0 | 3.1 | 2.9 | 2.8 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 1.0 | 0.0 | 0.4 | 0.0 | 0.5 | 0.1 | 0.0 | 1.5 | | 17.0 l/min |
| *Low* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.4 | 1.4 | 1.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.4 | 0.0 | 0.2 | 0.0 | 0.3 | 0.0 | 0.0 | 0.7 | | 7.9 l/min |

**Note :-**

Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\ \pi}{2.3 \log (r / 2z)}$ *

*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

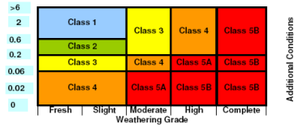
q = Steady state rate of inflow per unit length of tunnel (cu.m/s)
k = Permeability of Rock Mass (m/s)
z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)

* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

IMS Method based upon IMS rockmass classification system and empirical data for Hong Kong ONLY. Method reproduced from paper, "Water Inflows in Bored Tunnels driven in Hong Kong : Prediction, Construction Issues and Control Measures", International Confer
The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Water Source (sf) =** **(Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)**

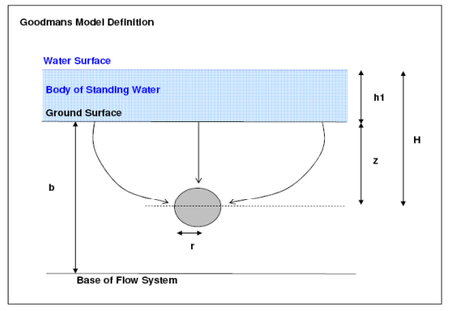
**IMS Rock Class =**







Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)




**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| **IMS -** | **56** | **Initial** |
| | **4** | **Final** |
| **Goodman -** | **342** | |
| **Heuer / Raymer -** | **341** | |
| **Factored Heuer / Raymer -** | **43** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Sheet No. 4 of 4 | | Rev. | | Job No. | |
| | Chainage 136600 to 136780 | | | | | |
| Job Title: XRL Kwai Chung Tunnels South | Input by: | HC | Ckd by: | TC | Date: | 13-May-09 |
| Summary of Predicted Groundwater Inflow for Contract 821 | | | | | | |

**Geological Unit** **Granitic/ Volcanic within Hard Rock Portion of Main Tunnel**

| | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| From (m) | 136600 | 136615 | 136620 | 136630 | 136660 | 136690 | 136720 | 136750 | 136780 | Tunnel Length |
| To (m) | *136615* | *136620* | *136630* | *136660* | *136690* | *136720* | *136750* | *136780* | *0* | 180 |
| Length (m) | *15* | *5* | *10* | *30* | *30* | *30* | *30* | *30* | *0* | Average Values |
| Feature / BH No. | | D308 (4) | | | | | | | | |
| Rock type/ feature type | Klk | Klk | Klk | Klk | Klk | Klk | Klk | Klk | | |
| Water Level above tunnel (m) | 48.00 | 48.00 | 48.00 | 45.00 | 44.00 | 38.00 | 33.00 | 29.00 | | 41.63 |
| WL above rock head (m) | 16.00 | 16.00 | 16.00 | 8.00 | 16.00 | 16.00 | 15.00 | 15.00 | | |
| Thickness of Rock Cover (m) | 32.00 | 32.00 | 32.00 | 37.00 | 28.00 | 22.00 | 18.00 | 14.00 | | |
| Permeability (m/s) | 1.0E-08 | 1.0E-06 | 1.0E-08 | 1.0E-08 | 5.0E-08 | 5.0E-08 | 5.0E-08 | 5.0E-08 | | 1.54E-07 |
| Tunnel Radius | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9.00 |
| IMS Rock Class | 1 | 4 | 1 | 1 | 2 | 2 | 2 | 2 | | 1.88 |
| Vent Adit/ Single Track | ST | ST | ST | ST | ST | ST | ST | ST | | |
| Source Size Factor (sf) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | |
| Horizontal Distance to (sf) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| *Head Factor* | *0.48* | *0.48* | *0.48* | *0.45* | *0.44* | *0.38* | *0.33* | *0.29* | | |
| *Horizontal Separation* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | | |
| *R* | *0.048* | *0.048* | *0.048* | *0.045* | *0.044* | *0.038* | *0.033* | *0.029* | | |

| Calculated Inflow (L/min) for: | | | | | | | | | | | | | | | | | | | | Initial Water Inflow | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goodman Eqn | 1.39 | 46.17 | 0.92 | 2.42 | 13.63 | 13.56 | 13.48 | 14.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 106 | l/min |
| Heuer / Raymer Eqn | 1.38 | 46.12 | 0.92 | 2.42 | 13.61 | 13.54 | 13.46 | 14.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 106 | l/min |
| Factored Heuer/Raymer | 0.17 | 5.77 | 0.12 | 0.30 | 1.70 | 1.69 | 1.68 | 1.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13 | l/min |
| IMS - Initial Water Inflow | | | | | | | | | | | | | | | | | | | | Initial Water Inflow | |
| *High* | 0.4 | 8.9 | 0.3 | 0.8 | 1.8 | 1.6 | 1.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.5 | l/min |
| *Average* | 0.3 | 5.8 | 0.2 | 0.6 | 1.4 | 1.2 | 1.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.4 | l/min |
| *Low* | 0.2 | 2.6 | 0.1 | 0.4 | 0.9 | 0.8 | 0.7 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.4 | l/min |
| IMS - Final Water Inflow | | | | | | | | | | | | | | | | | | | | Final Water Inflow | |
| *High* | 0.0 | 0.4 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | l/min |
| *Average* | 0.0 | 0.3 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | l/min |
| *Low* | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | l/min |

Note :-
Method based upon the papers, "*Groundwater Inflows during Tunnel Driving*" by Goodman, R.E., Moye, D.G., Van Schalkwyk, A., & Javandel, T. (1965), "*Estimating Rock Tunnel Water Inflow*" by Heuer, R.E. (1995), and "*Predicting Groundwater Inflow into Hard Rock Tunnels*" by Raymer, J.H. (2001),

Where:

*(Goodman, 1965)* $q = \dfrac{2 \cdot k \cdot (z + h1)\,\pi}{2.3 \log (r / 2z)}$ *

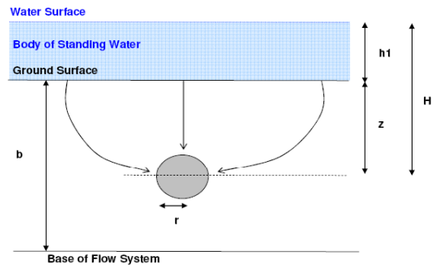
*(Heuer, 1995 & Raymer, 2001)* $q = \dfrac{2 \cdot \pi \cdot k \cdot H}{\ln (2z / r)}$

*Note: In his paper Raymer recommends factoring the results of the above Eqn by 1/8*

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z = Distance from tunnel centre line to ground surface (m)
H = Water head (m)
r = Tunnel radius (m)
h1 = Depth of standing water above ground surface (m)
* The Eqn shown is presented in its original form, as published in Goodman (1965) However, experience has shown that the function *2.3 log (r/2z)* typically results in negative parameters due to the size diference between the tunnel radius and the tunnel depth. As such, all later publications and citations of the Goodman Eqn have inversed the bracketed portion of the equation to *(2z/r)* . As this results in a more meaningful output, the same amendment has been made within this spreadsheet.

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The horizontal separation is assumed to be the same distance as the depth for estimating purposes. Zone of influence should be assessed specifically for actual site
Data input required to **BLUE** cells only

**Goodmans Model Definition**

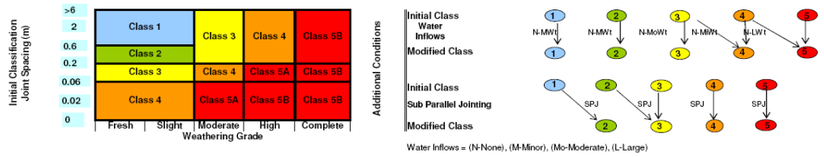



**Average Estimated Inflow in terms of L/Min/100m:**

| | | |
|---|---|---|
| IMS - | 6 | Initial |
| | 0 | Final |
| Goodman - | 59 | |
| Heuer / Raymer - | 59 | |
| Factored Heuer / Raymer - | 7 | |

**Water Source (sf) =** (Sea = 1), (Major Valley / Reservoir = 0.85), (Large Valley / Reservoir = 0.7), (Small River / Reservoir = 0.5), (Stream = 0.3), (Ridge = 0.1)

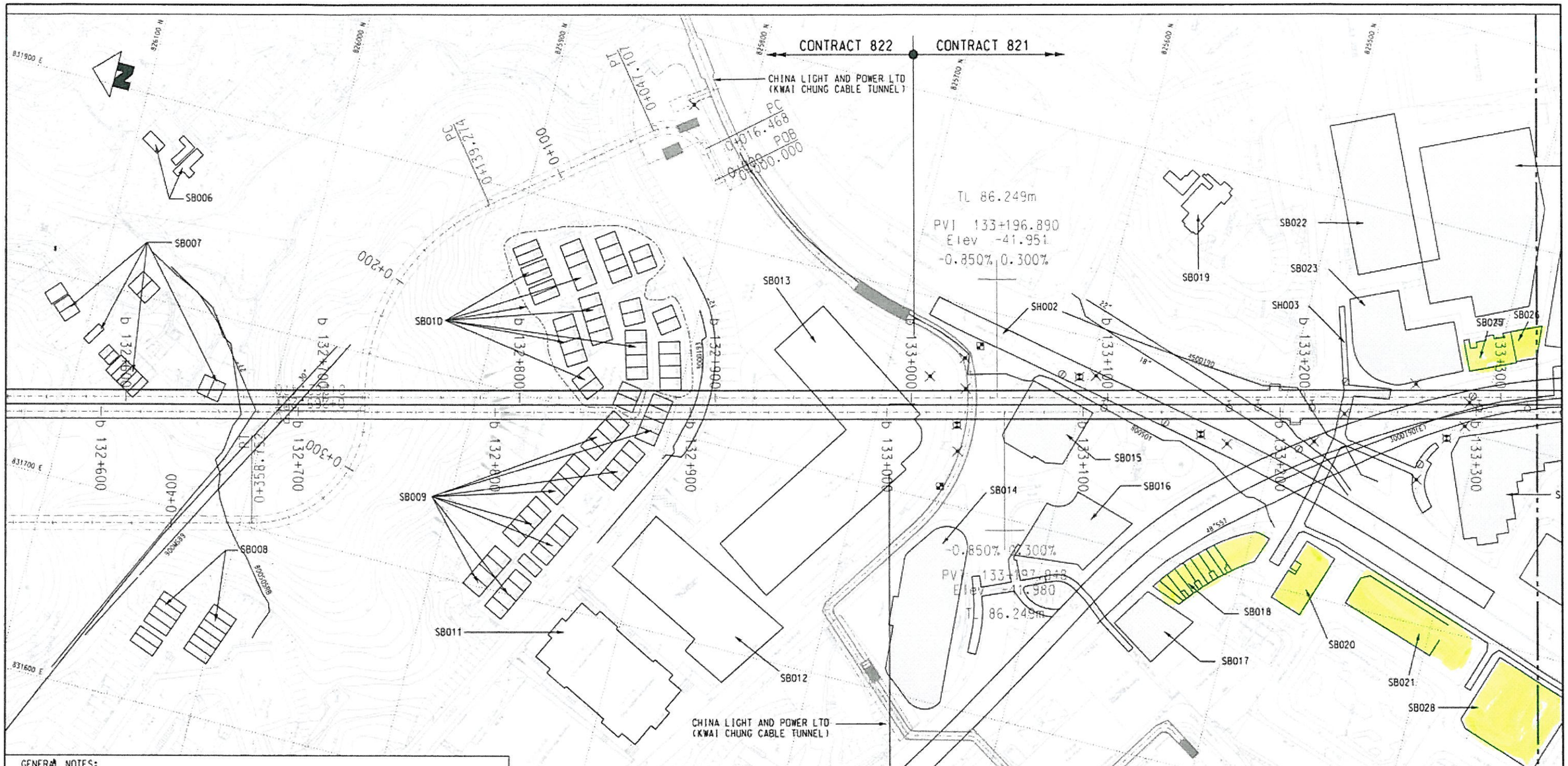
**IMS Rock Class =**




Water Inflows = (N-None), (M-Minor), (Mo-Moderate), (L-Large)

# APPENDIX C

# LOCATION OF EXISITING BUILDINGS AND STRUCTURES AND SETTLEMENT CONTOUR




GENERAL NOTES:

1. THE INSTRUMENTATION NUMBER TYPE AND LOCATION SHOWN ARE INTERIM AND WILL BE SUBJECT TO FURTHER DESIGN DEVELOPMENT.
2. THE INSTRUMENT LOCATIONS SHOWN IN THESE DRAWINGS ARE INDICATIVE ONLY. THE FREQUENCY OF MONITORING SHALL BE VARIED DEPENDING ON THE TYPE OF INSTRUMENT AND THE RELATIONSHIP BETWEEN THE INSTRUMENT AND AREAS OF CURRENT ACTIVITY. THE INSTRUMENTATION FOR MONITORING ADJACENT BUILDINGS, STRUCTURES AND UTILITIES WILL NEED TO BE AGREED WITH THE OWNERS OR INTERESTED PARTIES.
3. THE LOCATION OF THE CRACK GAUGES WILL BE SUBJECT TO BUILDING CONDITION SURVEY. CRACK GAUGES ARE NOT SHOWN AS THEY WILL NEED TO BE DEFINED FOLLOWING THE RESULTS OF THE BUILDING CONDITION SURVEYS.
4. ONLY WATER UTILITIES LARGER THAN 300mm DIAMETER ARE SHOWN ON THE DRAWINGS. OTHER UTILITIES SHOULD REFER TO SITE IMPACT ASSESSMENT REPORT OR TO BE DETERMINED ON SITE.

LEGEND:

- OPEN STANDPIPE PIEZOMETER (PIZEO)
- IN-PLACE VERTICAL INCLINOMETER (IVI)
- DEFORMATION MONITORING POINT (DMP)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- VERTICAL INCLINOMETER (INC)
- TILTMETER (TM)
- AUTOMATIC DEFORMATION MONITORING SYSTEM (ADMS)
- SURFACE-MOUNTED VIBRATING WIRE STRAIN GAUGE, SPOT WELDED TYPE (VWSG)
- UTILITY MONITORING POINT (ONLY SHOWN WATER UTILITIES LARGE THAN 300mm) (UMP)
- ON-SOIL VIBRATION MONITORING (OSVM) (IN URBAN AREA)

- PROPOSED XRL ALIGNMENT
- EBS CLASSIFIED AS NEGLIGIBLE TO VERY SLIGHT IN DAMAGE CLASSIFICATION
- EBS CLASSIFIED AS SLIGHT IN DAMAGE CLASSIFICATION
- EBS CLASSIFIED AS MODERATE TO VERY SEVERE IN DAMAGE CLASSIFICATION
- EBS WITHIN BLASTING INFLUENCE ZONE
- EXISTING HISTORICAL BUILDING
- EBS TO BE DEMOLISHED OR MODIFIED

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB014 | MITA CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB015 | FANG BROTHERS TEXTURES LIMITED | 0 | 0 | 0 | 0 | 0 | 0 |
| SB016 | NAN SING INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB017 | CHEONG WANG MANSION | 0 | 0 | 0 | 0 | 0 | 0 |
| SB018 | KAU SHING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB019 | THE SALVATION ARMY KWAI CHUNG GIRL'S HOME | 0 | 0 | 0 | 0 | 0 | 0 |
| SB020 | KAR PO MANSION | 0 | 0 | 0 | 0 | 0 | 0 |
| SB021 | CHEONG NIN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB022 | EDWICK INDUSTRIAL CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB023 | HUTCHISON ESTATE - BLOCK A | 0 | 0 | 0 | 0 | 0 | 0 |
| | HUTCHISON ESTATE - PODIUM | 0 | 0 | 0 | 0 | 0 | 0 |
| | HUTCHISON ESTATE - BLOCK B | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB024 | VIGOR INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB025 | HUNG WAN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB026 | TUNG PO BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB027 | YAM HOP HING (K.C.) INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | ADDRESS | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SH002 | KWAI CHUNG ROAD BRIDGE | 0 | 0 | 2 | 0 | 0 | 2 |
| SH003 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD AND KWAI CHUNG ROAD | 0 | 0 | 2 | 0 | 0 | 2 |
| SH004 | CASTLE PEAK ROAD BRIDGE | 0 | 0 | 2 | 0 | 0 | 2 |

MTR ATKINS

Supported by
Arup, TFP Farrells, DLS, Kenneth Ng

Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

Title: Location Plan of Sensitive Structure

Figure No.: Appendix C

Date: August 2009

UserWorkspace C:\Documents and Settings\kluser\Application Data\Bentley\Workspace\projects\MTR.GEOuserLibrary C:\Documents and Settings\kluser\Application Data\Bentley\Workspace\projects\MTR-XRAIL.pcf
PLOT DRIVER\\foodkb1020\Matrix\Geo Tech\ENG\CAD\GEOTECHNICAL\020-MTR\MTR\LAD.ADMIN\REFERENCE\PLOT CONFIG\A3 COLOUR.plt
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MODEL NAME: Default

| REF. NO. | ADDRESS | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SH005 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD - KWAI CHUNG (NEAR PING FU PATH) | 0 | 0 | 2 | 0 | 0 | 2 |
| SH006 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD - KWAI CHUNG (NEAR WO YIP HOP ROAD) | 0 | 0 | 2 | 0 | 0 | 2 |
| SH007 | STAIRCASE CONNECT CASTLE PEAK ROAD TO NORTH OF WAH TAT INDUSTRIAL CENTRE | 0 | 0 | 2 | 0 | 0 | 2 |
| SH008 | STAIRCASE CONNECT CASTLE PEAK ROAD TO SOUTH OF WAH TAT INDUSTRIAL CENTRE | 0 | 0 | 2 | 0 | 0 | 2 |
| SH009 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD - KWAI CHUNG (NEAR YIP SHING STREET) | 0 | 0 | 2 | 0 | 0 | 2 |
| SH010 | YIP SHING STREET BRIDGE | 0 | 0 | 2 | 0 | 0 | 2 |

Key

Sensitive Structure

20

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- EXISTING HISTORICAL BUILDING
- EBS TO BE DEMOLISHED OR MODIFIED

N 825400
N 825100
N 824800
E 832100
E 832000
E 831900
E 831800
E 831500

SB024 SB025 SB026 SB027 SB029 SB030 SB031 SB032 SB033 SB034 SB035 SB036 SB037 SB038 SB039 SB040 SB041 SB042 SB043 SB044 SB045 SB046 SB047 SB048 SB049 SB050 SB051 SB052 SB053 SB054 SB055 SB056 SB057 SB058 SB059 SB060 SB061 SB062 SB063 SB064 SB065 SB066 SB067 SB068

SH004 SH005 SH006 SH007 SH008 SH009 SH010

NORTHBOUND

300D190(E) 300C10BRA 48"S57(W440912) 48"S57 12" 2974.403m 4556.203m

b 133+300 b 133+400 b 133+500 b 133+600 b 133+700 b 133+800 b 133+900 b 134+000 b 134+100

MATCH LINE FOR CONTINUATION SEE DWG FIGURE 7.1

MATCH LINE FOR CONTINUATION SEE DWG FIGURE 7.3

0 10 20 30 40 50 METRES

1 : 1000

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB029 | KWAI FUNG HOUSE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB030 | MING YIN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB031 | MING TONG BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB032 | GOLD PEAK BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB033 | MING TAK BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB034 | KIN MING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB035 | RYODEN INDUSTRIAL CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB036 | MERCANTILE INDUSTRIAL & WAREHOUSE BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB037 | WAI YIN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB038 | FANG BROTHERS KNITTING LIMITED | 0 | 0 | 0 | 0 | 0 | 0 |
| SB039 | KAM BUN INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB040 | PO SING CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB041 | KWAI SING CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB042 | SHUI SUM INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB043 | ON FAT INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB044 | STAR CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB045 | SO TAO CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB046 | TAI TAK INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB047 | HENSEY INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB048 | VANTA INDUSTRIAL CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB049 | PO KAI MANSION | 0 | 0 | 0 | 0 | 0 | 0 |
| SB050 | SKH LADY MACLEHOSE CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB051 | KAM PUI BUILDING & CHEONG PING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB052 | KWAI WAH BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB053 | KWAI CHUNG GEE CHANG HOUSE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB054 | KWAI YING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB056 | KWAI CHUNG COLD STORAGE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB057 | SOUTH CHINA COLD STORAGE BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB058 | GOLD KING INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB059 | BOLDWIN INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB060 | WAH SING INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB061 | WAH TAT INDUSTRIAL BUILDING - BLOCK B | 0 | 0 | 0 | 0 | 0 | 0 |
| SB062 | WAH TAT INDUSTRIAL BUILDING - BLOCK A | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB055 | KWAI CHUNG BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB063 | WAH TAT INDUSTRIAL BUILDING - BLOCK C | 0 | 0 | 0 | 0 | 0 | 0 |
| SB064 | MAI ON INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB065 | MAI LUEN INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB066 | SHEK YAT HOUSE, SHEK LEI ESTATE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB067 | GREENKNOLL COURT - BLOCK 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SB068 | GREENKNOLL COURT - BLOCK 2 | 0 | 0 | 0 | 0 | 0 | 0 |

MTR ATKINS

Supported by Arup, TFP Farrells, DLS, Kenneth Ng

XRL

Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

Title: Location Plan of Sensitive Structure

Figure No.: Appendix C

Date: August 2009

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FILENAME:\\fpedxb1000\Metro\Geo Tech\ENG\CAD\GEOTECHNICAL\020-MTR\MTR\REP\C821& C822\C82\Figure 7.2.dgn
MODEL NAME:DisTourf

**NOTE:**

1. FOR GENERAL NOTE AND LEGEND, REFER TO FIGURE A.

CONTRACT 822 | CONTRACT 821

832000 E
831800 E
831600 E
826000 N
825800 N
825600 N

SHEK YAM CONSTRUCTION ADIT

PT 0+047.107
PC 0+139.274
PC 0+016.468
POB 0+000.000
PT 0+358.470
PC 0+262.470

TL 86.249m
PVI 133+196.890
Elev -41.951
-0.850% 0.300%

-0.850% 0.300%
PVI 133+197.948
Elev -41.980
TL 86.249m

b 132+600
b 132+700
b 132+800
b 132+900
b 133+000
b 133+100
b 133+200
b 133+300

KWAI CHUNG ROAD
CASTLE PEAK ROAD - KWAI CHUNG

MATCH LINE
FOR CONTINUATION
SEE FIGURE 3.2

Key
Predicted Settlement Contour in mm

0 10 20 30 40 50
METRES
1 : 1000

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FILENAME: \\Feadkb000\Metro\Geo Tech\ENG\CAD\GEOTECHNICAL\020-MTR\MTR\REP\C821& C822\C82I\FIGURE 3.1.dgn
MODEL NAME: Default

MTR ATKINS
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XRL
Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

Title: Predicted Settlement Contour Due to Groundwater Drawdown
Figure No. Appendix C
Date August 2009

**NOTE:**

1. FOR GENERAL NOTE AND LEGEND, REFER TO FIGURE A.

N

825400 N

825200 N

825000 N

824800 N

824600 N

832000 E

831800 E

SHEK PAI STREET

KWAI CHUNG ROAD

b 133+300

b 133+400

b 133+500

b 133+600

b 133+700

b 133+800

b 133+900

b 134+000

4536.205m

MATCH LINE
FOR CONTINUATION
SEE FIGURE 3.1

MATCH LINE
FOR CONTINUATION
SEE FIGURE 3.3

Key

Predicted Settlement Contour in mm

0 10 20 30 40 50
METRES
1 : 1000

MTR ATKINS

Supported by
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XRL

Consultancy Agreement No. C802
Express Rail Link
Detailed Design for Tunnels & Associated Structures (South)

Title: Predicted Settlement Contour Due to Groundwater Drawdown

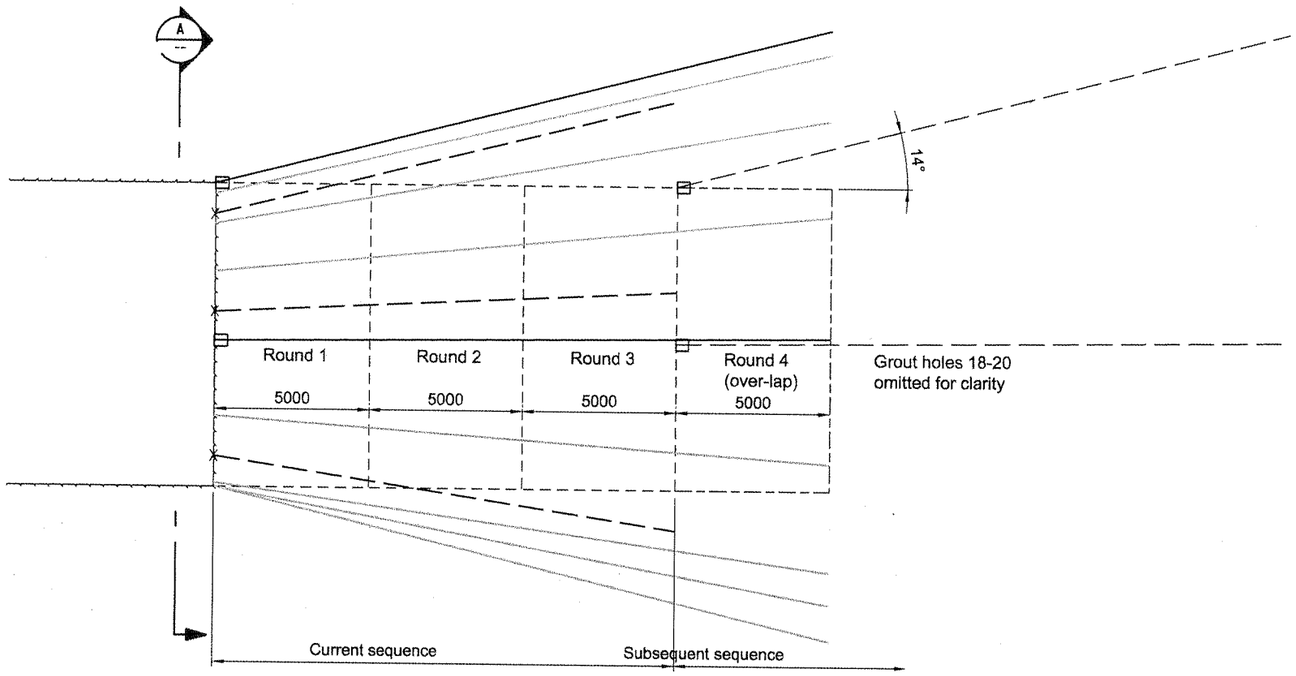
Figure No. Appendix C

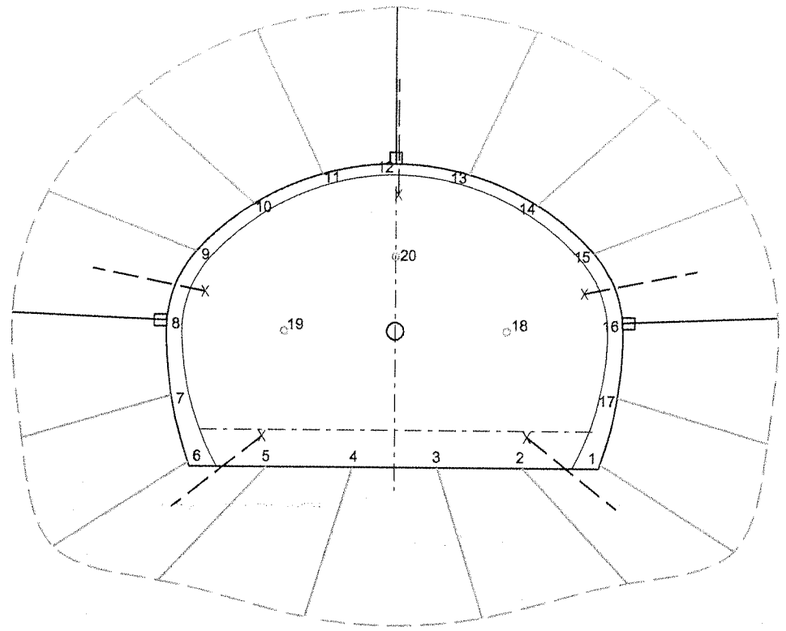
Date August 2009

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FILENAME: \\Feadxb000\Metro\Geo Tech\ENG\CAD\GEOTECHNICAL\020-MTR\MTR\REP\C821& C822\C82\FIGURE 3.2.dgn
MODEL NAME: Default

# APPENDIX D

# INDICATIVE GROUT LAYOUTS




SECTION A
SCALE 1:100

LEGEND:

| | | |
|---|---|---|
| ⊟——— | PROBE & GROUT HOLES | 3NO. |
| O ——— | GROUT HOLES | 17NO. |
| ✳—— —— | CONTROL HOLES | 5NO. |

INDICATIVE GROUTING DETAILS
START PRESSURE (SEE NOTE 3)

| | |
|---|---|
| 20-100M ROCK COVER | 20 BAR |
| 100-200M ROCK COVER | 40 BAR |
| >200M ROCK COVER | 60 BAR |

STOP PRESSURE (SEE NOTE 4)

| | |
|---|---|
| 20-100M ROCK COVER | 60 BAR |
| 100-200M ROCK COVER | 75 BAR |
| >200M ROCK COVER | 90 BAR |

VOLUME AND GROUT MIX PER HOLE

| | | |
|---|---|---|
| 0-300 KG | MC - WCR | 1.0 |
| 300-600 KG | MC - WCR | 0.8 |
| 600-1000 KG | MC - WCR | 0.7 |
| >1000 KG | MC - WCR | 0.6+ACC |

MC DENOTES MICRO CEMENT
WCR DENOTES WATER CEMENT RATIO
ACC DENOTES SETTING ACCELERATOR

NOTES:

1. DRAWING TO BE READ IN ACCORDANCE WITH DRAWINGS 822/B/360/ATK/T04/401 AND 402. (NOTES FOR TEMPORARY ROCK SUPPORT)
2. ROUND LENGTH TO BE VARIED ACCORDING TO EXCAVATION AND TEMPORARY SUPPORT SEQUENCE REQUIREMENTS.
3. MINIMUM OF 5.0M OVERLAP BETWEEN EACH PROBING AND GROUTING ARRAY SHALL BE MAINTAINED.
4. START PRESSURE IS THE PUMP PRESSURE SETTING AT THE COMMENCEMENT OF PUMPING. ONCE GROUT PUMPING RATE REDUCES, PRESSURE SHALL BE INCREMENTALLY INCREASED.
5. GROUTING OF ANY INDIVIDULE HOLE SHALL BE STOPPED ONCE EITHER THE STOP PRESSURE IS REACHED OR THE ASSIGNED MAXIMUM VOLUME OF GROUT HAS BEEN REACHED.
6. GROUT PATTERN SHOWN FOR TYPICAL TWIN TRACK TUNNEL SECTION. PROBE GROUT AND CONTROL HOLES SHALL BE ADJUSTED FOR OTHER TUNNEL TYPES TO PROVIDE SUFFICIENT COVERAGE.

0 1 2 3 4 5
METRES
1 : 100

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | ALE | 03AUG09 | TM |

| | |
|---|---|
| DRAWN | ALE |
| DESIGNED | MC |
| CHECKED | HR |
| APPROVED | TM |
| DATE | 27/JUL/2009 |

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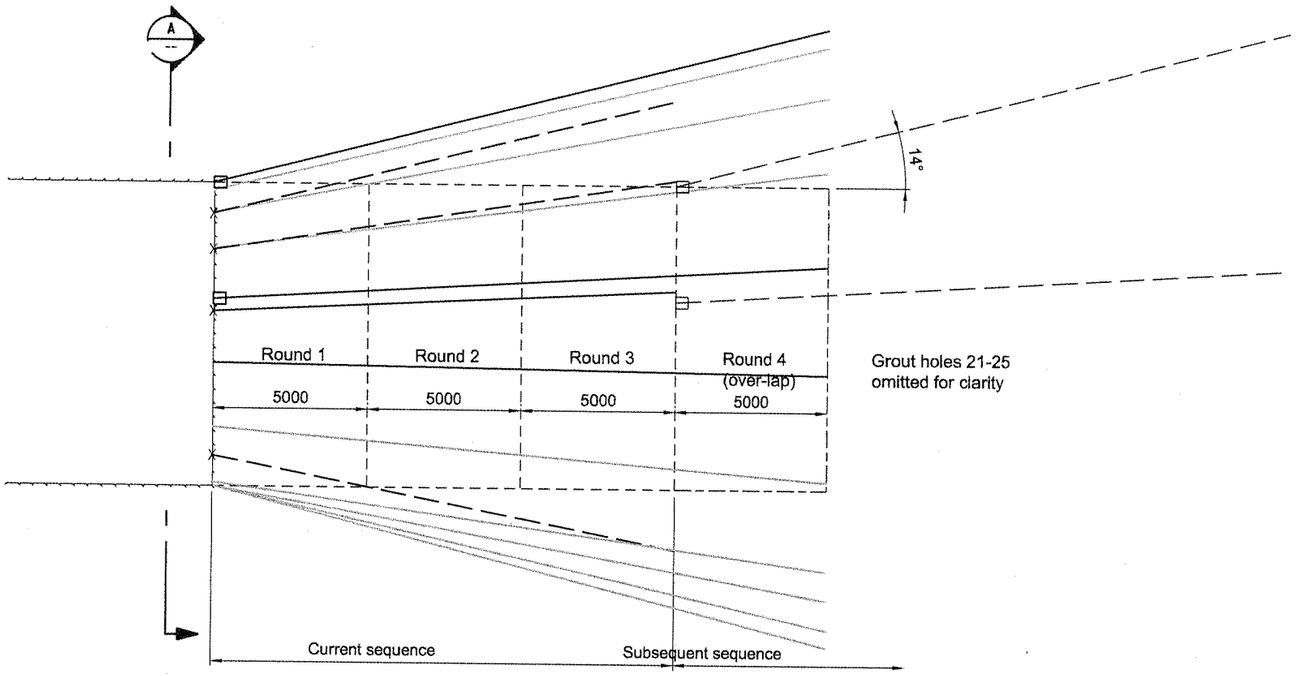
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EXPRESS RAIL LINK
ORIGINATOR
ATKINS
Supported by Arup, TFP Farrells, DLS Kenneth Ng
CADD REF. 822_T_360_ATK_T04_451A.dgn

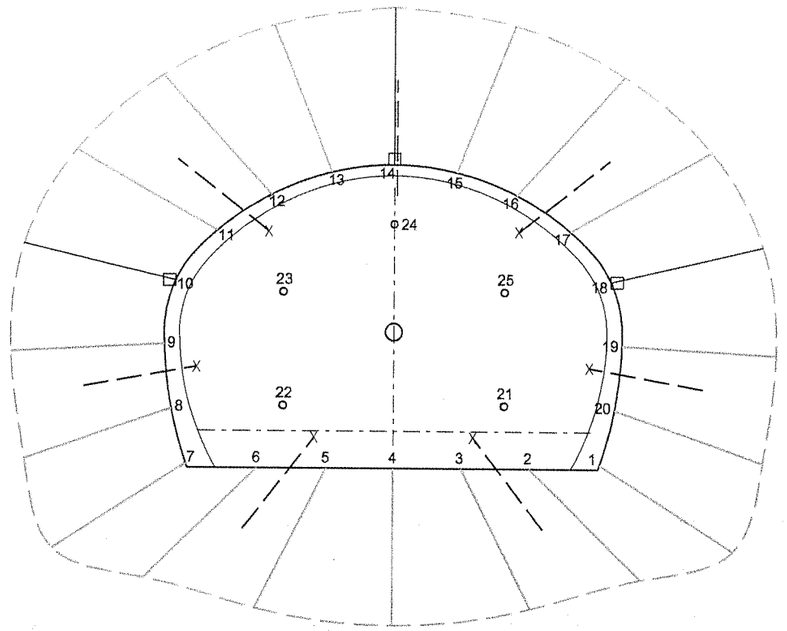
TITLE
CONTRACT 822
TSE UK TSUEN TO SHEK YAM TUNNELS
DRILL AND BLAST TUNNELS
GROUTING CLASSES
PATTERN A

SCALE 1 : 100 (A1)
DRAWING NO. 822/T/360/ATK/T04/451
REV. A

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SECTION A
SCALE 1:100

LEGEND:

| | | |
|---|---|---|
| ⊟——— | PROBE & GROUT HOLES | 3NO. |
| O ——— | GROUT HOLES | 22NO. |
| *—— | CONTROL HOLES | 7NO. |

INDICATIVE GROUTING DETAILS
START PRESSURE (SEE NOTE 3)

| | |
|---|---|
| 20-100M ROCK COVER | 20 BAR |
| 100-200M ROCK COVER | 40 BAR |
| >200M ROCK COVER | 60 BAR |

STOP PRESSURE (SEE NOTE 4)

| | |
|---|---|
| 20-100M ROCK COVER | 60 BAR |
| 100-200M ROCK COVER | 75 BAR |
| >200M ROCK COVER | 90 BAR |

VOLUME AND GROUT MIX PER HOLE

| | | |
|---|---|---|
| 0-300 KG | MC - WCR | 1.0 |
| 300-600 KG | MC - WCR | 0.8 |
| 600-1000 KG | MC - WCR | 0.7 |
| >1000 KG | MC - WCR | 0.6+ACC |

MC DENOTES MICRO CEMENT
WCR DENOTES WATER CEMENT RATIO
ACC DENOTES SETTING ACCELERATOR

NOTES:

1. DRAWING TO BE READ IN ACCORDANCE WITH DRAWINGS 822/B/360/ATK/T04/401 AND 402. (NOTES FOR TEMPORARY ROCK SUPPORT)
2. ROUND LENGTH TO BE VARIED ACCORDING TO EXCAVATION AND TEMPORARY SUPPORT SEQUENCE REQUIREMENTS.
3. MINIMUM OF 5.0M OVERLAP BETWEEN EACH PROBING AND GROUTING ARRAY SHALL BE MAINTAINED.
4. START PRESSURE IS THE PUMP PRESSURE SETTING AT THE COMMENCEMENT OF PUMPING. ONCE GROUT PUMPING RATE REDUCES, PRESSURE SHALL BE INCREMENTALLY INCREASED.
5. GROUTING OF ANY INDIVIDULE HOLE SHALL BE STOPPED ONCE EITHER THE STOP PRESSURE IS REACHED OR THE ASSIGNED MAXIMUM VOLUME OF GROUT HAS BEEN REACHED.
6. GROUT PATTERN SHOWN FOR TYPICAL TWIN TRACK TUNNEL SECTION. PROBE GROUT AND CONTROL HOLES SHALL BE ADJUSTED FOR OTHER TUNNEL TYPES TO PROVIDE SUFFICIENT COVERAGE.

0 1 2 3 4 5
METRES
1 : 100

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | ALE | 03AUG09 | TM |

| | |
|---|---|
| DRAWN | ALE |
| DESIGNED | MC |
| CHECKED | HR |
| APPROVED | TM |
| DATE | 27/JUL/2009 |

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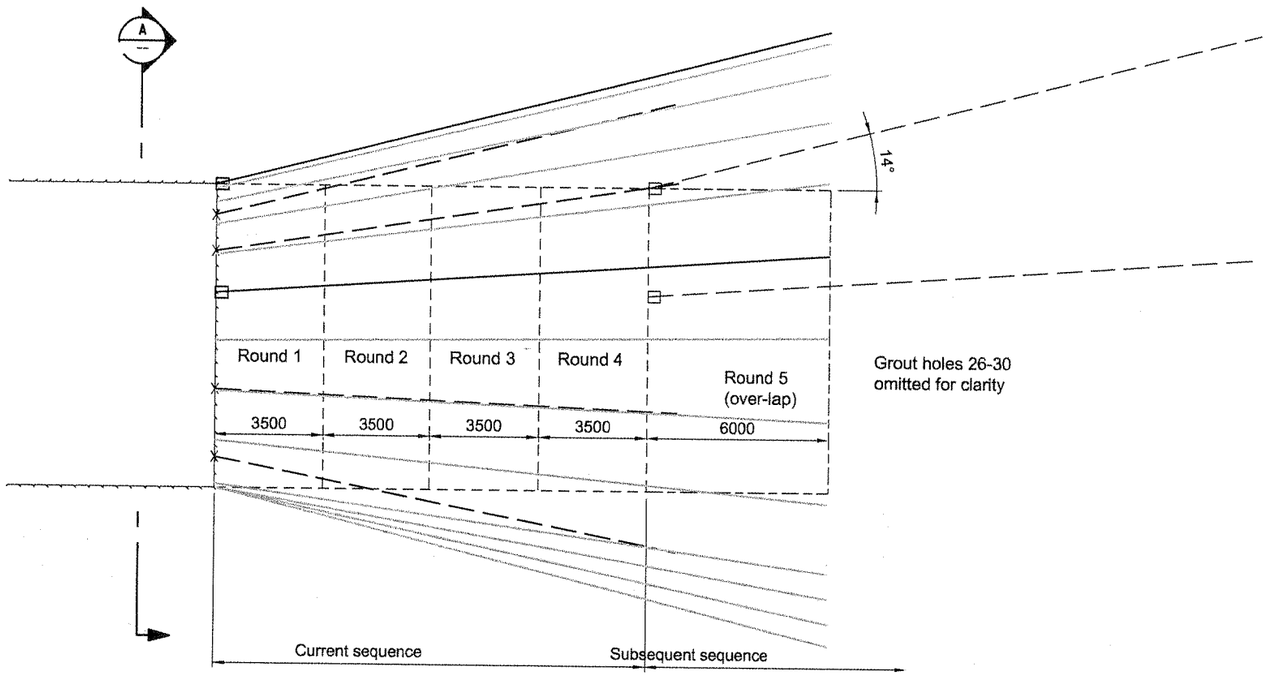
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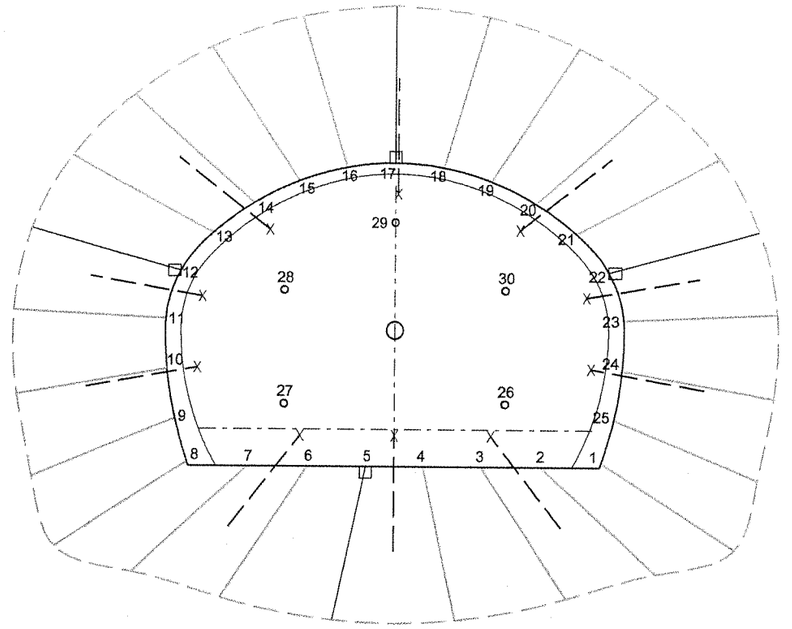
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CONTRACT 822
TSE UK TSUEN TO SHEK YAM TUNNELS
DRILL AND BLAST TUNNELS
GROUTING CLASSES
PATTERN B

SCALE 1 : 100 (A1)
DRAWING NO. 822/T/360/ATK/T04/452
REV. A

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SECTION A
SCALE 1:100

LEGEND:

| | | |
|---|---|---|
| ⊟——— | PROBE & GROUT HOLES | 4NO. |
| O —— | GROUT HOLES | 26NO. |
| ×—— | CONTROL HOLES | 10NO. |

INDICATIVE GROUTING DETAILS

START PRESSURE (SEE NOTE 3)

| | |
|---|---|
| 20-100M ROCK COVER | 20 BAR |
| 100-200M ROCK COVER | 40 BAR |
| ₵200M ROCK COVER | 60 BAR |

STOP PRESSURE (SEE NOTE 4)

| | |
|---|---|
| 20-100M ROCK COVER | 60 BAR |
| 100-200M ROCK COVER | 75 BAR |
| ₵200M ROCK COVER | 90 BAR |

VOLUME AND GROUT MIX PER HOLE

| | | |
|---|---|---|
| 0-300 KG | MC - WCR | 1.0 |
| 300-600 KG | MC - WCR | 0.8 |
| 600-1000 KG | MC - WCR | 0.7 |
| ₵1000 KG | MC - WCR | 0.6+ACC |

MC DENOTES MICRO CEMENT
WCR DENOTES WATER CEMENT RATIO
ACC DENOTES SETTING ACCELERATOR

NOTES:

1. DRAWING TO BE READ IN ACCORDANCE WITH DRAWINGS 822/B/360/ATK/T04/401 AND 402. (NOTES FOR TEMPORARY ROCK SUPPORT)
2. ROUND LENGTH TO BE VARIED ACCORDING TO EXCAVATION AND TEMPORARY SUPPORT SEQUENCE REQUIREMENTS.
3. MINIMUM OF 5.0M OVERLAP BETWEEN EACH PROBING AND GROUTING ARRAY SHALL BE MAINTAINED.
4. START PRESSURE IS THE PUMP PRESSURE SETTING AT THE COMMENCEMENT OF PUMPING. ONCE GROUT PUMPING RATE REDUCES, PRESSURE SHALL BE INCREMENTALLY INCREASED.
5. GROUTING OF ANY INDIVIDULE HOLE SHALL BE STOPPED ONCE EITHER THE STOP PRESSURE IS REACHED OR THE ASSIGNED MAXIMUM VOLUME OF GROUT HAS BEEN REACHED.
6. GROUT PATTERN SHOWN FOR TYPICAL TWIN TRACK TUNNEL SECTION. PROBE GROUT AND CONTROL HOLES SHALL BE ADJUSTED FOR OTHER TUNNEL TYPES TO PROVIDE SUFFICIENT COVERAGE.

0 1 2 3 4 5 METRES
1 : 100

| REV | DESCRIPTION | BY | DATE | APPROVED |
|---|---|---|---|---|
| A | TENDER ISSUE | ALE | 03AUG09 | TM |

| | |
|---|---|
| DRAWN | ALE |
| DESIGNED | MC |
| CHECKED | HR |
| APPROVED | TM |
| DATE | 27/JUL/2009 |

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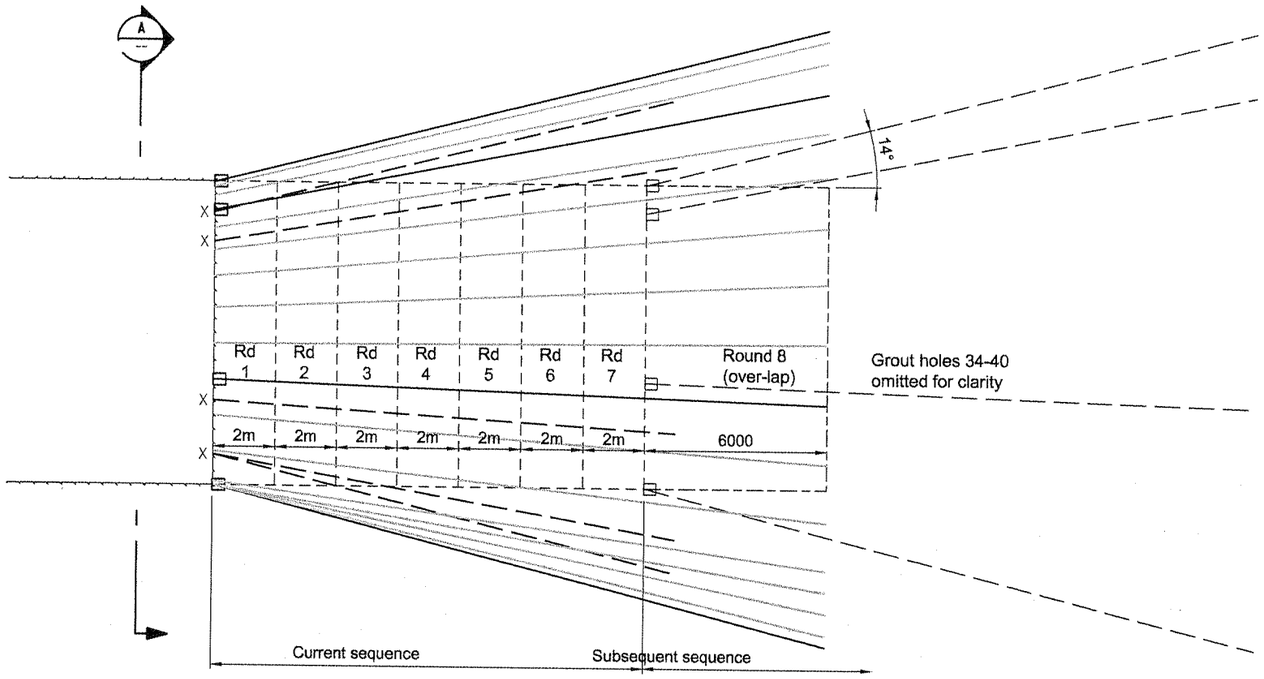
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ORIGINATOR ATKINS Supported by Arup, TFP Farrells, DLS Kenneth Ng
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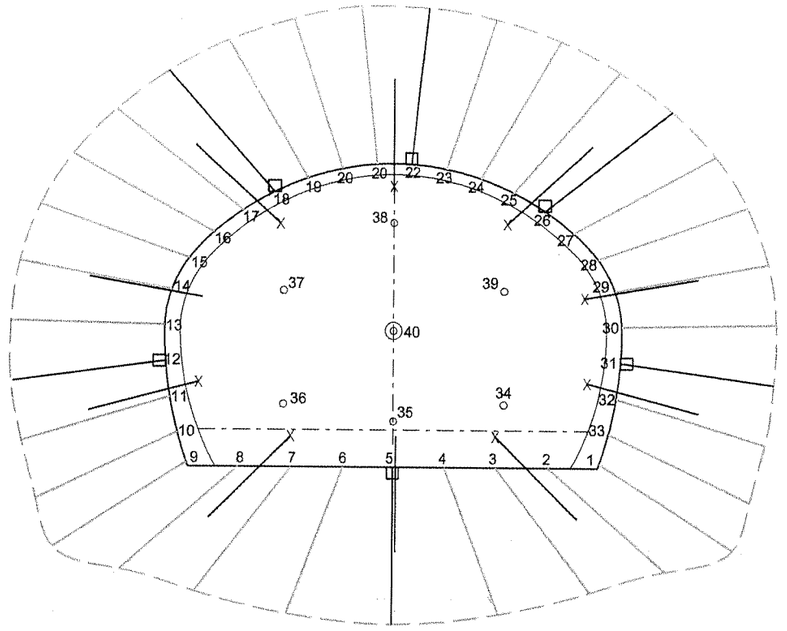
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TSE UK TSUEN TO SHEK YAM TUNNELS
DRILL AND BLAST TUNNELS
GROUTING CLASSES
PATTERN C

SCALE 1 : 100 (A1) | DRAWING NO. 822/T/360/ATK/T04/453 | REV. A

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SECTION A
SCALE 1:100

LEGEND:

| | | |
|---|---|---|
| ⊟——— | PROBE & GROUT HOLES | 6NO. |
| O ——— | GROUT HOLES | 34NO. |
| ×— — | CONTROL HOLES | 10NO. |

INDICATIVE GROUTING DETAILS

START PRESSURE (SEE NOTE 3)

| | |
|---|---|
| 20-100M ROCK COVER | 20 BAR |
| 100-200M ROCK COVER | 40 BAR |
| >200M ROCK COVER | 60 BAR |

STOP PRESSURE (SEE NOTE 4)

| | |
|---|---|
| 20-100M ROCK COVER | 60 BAR |
| 100-200M ROCK COVER | 75 BAR |
| >200M ROCK COVER | 90 BAR |

VOLUME AND GROUT MIX PER HOLE

| | | |
|---|---|---|
| 0-300 KG | MC - WCR | 1.0 |
| 300-600 KG | MC - WCR | 0.8 |
| 600-1000 KG | MC - WCR | 0.7 |
| >1000 KG | MC - WCR | 0.6+ACC |

MC DENOTES MICRO CEMENT
WCR DENOTES WATER CEMENT RATIO
ACC DENOTES SETTING ACCELERATOR

NOTES:

1. DRAWING TO BE READ IN ACCORDANCE WITH DRAWINGS 822/B/360/ATK/T04/401 AND 402. (NOTES FOR TEMPORARY ROCK SUPPORT)
2. ROUND LENGTH TO BE VARIED ACCORDING TO EXCAVATION AND TEMPORARY SUPPORT SEQUENCE REQUIREMENTS.
3. MINIMUM OF 5.0M OVERLAP BETWEEN EACH PROBING AND GROUTING ARRAY SHALL BE MAINTAINED.
4. START PRESSURE IS THE PUMP PRESSURE SETTING AT THE COMMENCEMENT OF PUMPING. ONCE GROUT PUMPING RATE REDUCES, PRESSURE SHALL BE INCREMENTALLY INCREASED.
5. GROUTING OF ANY INDIVIDULE HOLE SHALL BE STOPPED ONCE EITHER THE STOP PRESSURE IS REACHED OR THE ASSIGNED MAXIMUM VOLUME OF GROUT HAS BEEN REACHED.
6. GROUT PATTERN SHOWN FOR TYPICAL TWIN TRACK TUNNEL SECTION. PROBE GROUT AND CONTROL HOLES SHALL BE ADJUSTED FOR OTHER TUNNEL TYPES TO PROVIDE SUFFICIENT COVERAGE.

0 1 2 3 4 5 METRES
1 : 100

| REV | DESCRIPTION | BY | DATE | APPROVED |
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| A | TENDER ISSUE | ALE | 03AUG09 | TM |

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| DRAWN | ALE |
| DESIGNED | MC |
| CHECKED | HR |
| APPROVED | TM |
| DATE | 27/JUL/2009 |

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ORIGINATOR ATKINS Supported by Arup, TFP Farrells, DLS Kenneth Ng
CADD REF. 822_T_360_ATK_T04_454A.dgn

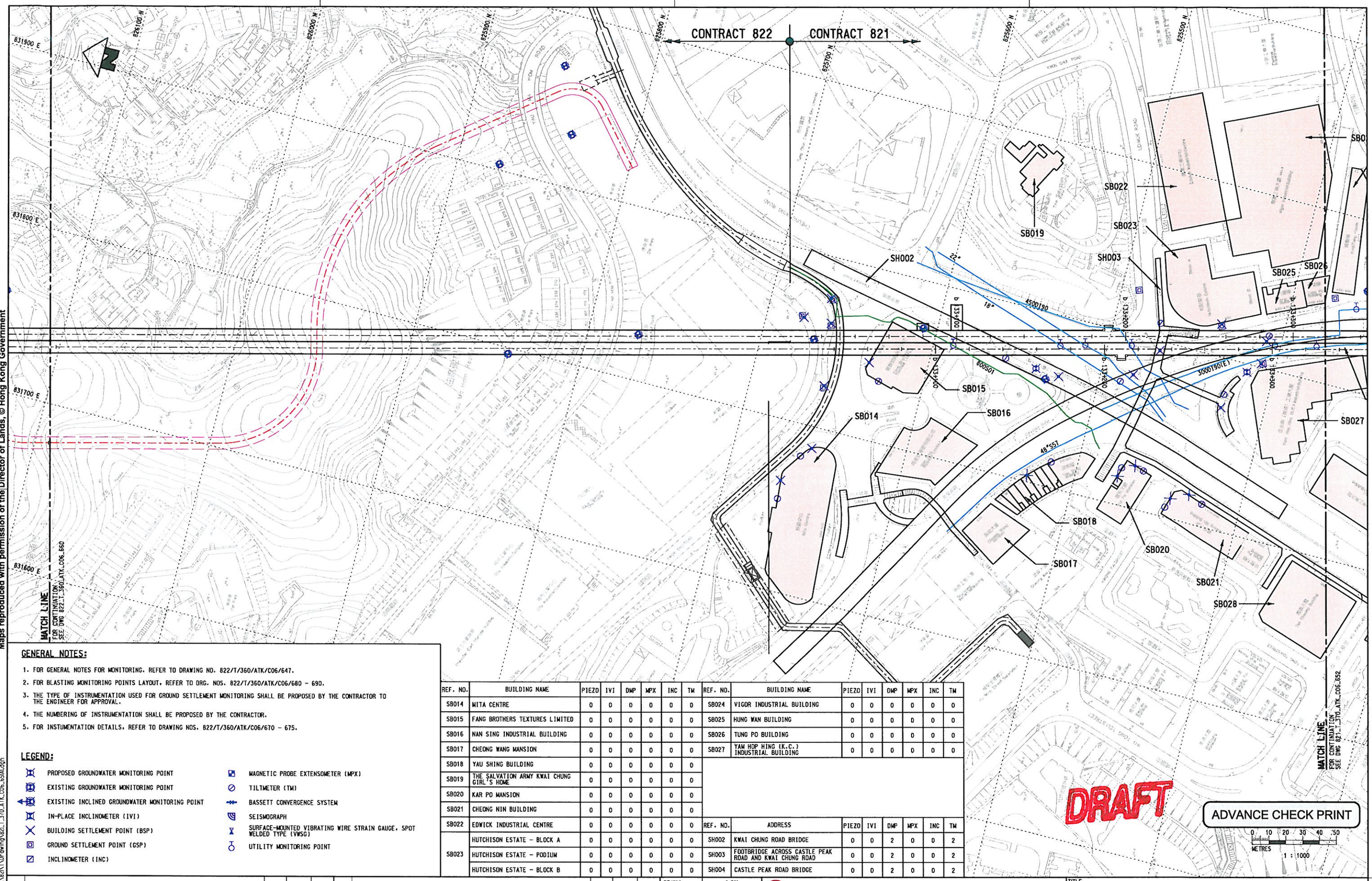
TITLE
CONTRACT 822
TSE UK TSUEN TO SHEK YAM TUNNELS
DRILL AND BLAST TUNNELS
GROUTING CLASSES
PATTERN D

SCALE 1 : 100 (A1)
DRAWING NO. 822/T/360/ATK/T04/454
REV. A

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# APPENDIX E

# LAYOUT OF MONITORING POINTS




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## GENERAL NOTES:

1. FOR GENERAL NOTES FOR MONITORING, REFER TO DRAWING NO. 822/T/360/ATK/C06/647.
2. FOR BLASTING MONITORING POINTS LAYOUT, REFER TO DRG. NOS. 822/T/360/ATK/C06/680 – 690.
3. THE TYPE OF INSTRUMENTATION USED FOR GROUND SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR TO THE ENGINEER FOR APPROVAL.
4. THE NUMBERING OF INSTRUMENTATION SHALL BE PROPOSED BY THE CONTRACTOR.
5. FOR INSTUMENTATION DETAILS, REFER TO DRAWING NOS. 822/T/360/ATK/C06/670 – 675.

## LEGEND:

- PROPOSED GROUNDWATER MONITORING POINT
- EXISTING GROUNDWATER MONITORING POINT
- EXISTING INCLINED GROUNDWATER MONITORING POINT
- IN-PLACE INCLINOMETER (IVI)
- BUILDING SETTLEMENT POINT (BSP)
- GROUND SETTLEMENT POINT (GSP)
- INCLINOMETER (INC)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- TILTMETER (TM)
- BASSETT CONVERGENCE SYSTEM
- SEISMOGRAPH
- SURFACE-MOUNTED VIBRATING WIRE STRAIN GAUGE, SPOT WELDED TYPE (VWSG)
- UTILITY MONITORING POINT

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB014 | MITA CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB015 | FANG BROTHERS TEXTURES LIMITED | 0 | 0 | 0 | 0 | 0 | 0 |
| SB016 | NAN SING INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB017 | CHEONG WANG MANSION | 0 | 0 | 0 | 0 | 0 | 0 |
| SB018 | YAU SHING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB019 | THE SALVATION ARMY KWAI CHUNG GIRL'S HOME | 0 | 0 | 0 | 0 | 0 | 0 |
| SB020 | KAR PO MANSION | 0 | 0 | 0 | 0 | 0 | 0 |
| SB021 | CHEONG NIN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB022 | EDWICK INDUSTRIAL CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB023 | HUTCHISON ESTATE – BLOCK A | 0 | 0 | 0 | 0 | 0 | 0 |
| | HUTCHISON ESTATE – PODIUM | 0 | 0 | 0 | 0 | 0 | 0 |
| | HUTCHISON ESTATE – BLOCK B | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB024 | VIGOR INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB025 | HUNG WAN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB026 | TUNG PO BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB027 | YAW HOP HING (K.C.) INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |

| REF. NO. | ADDRESS | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SH002 | KWAI CHUNG ROAD BRIDGE | 0 | 0 | 2 | 0 | 0 | 2 |
| SH003 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD AND KWAI CHUNG ROAD | 0 | 0 | 2 | 0 | 0 | 2 |
| SH004 | CASTLE PEAK ROAD BRIDGE | 0 | 0 | 2 | 0 | 0 | 2 |

| REV | DESCRIPTION | BY | DATE | APPROVED |
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| DRAWN | LCH |
| DESIGNED | FEC |
| CHECKED | WDE |
| APPROVED | TM |
| DATE | 03/MAR/2009 |

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Supported by Arup, TFP Farrells, DLS Kenneth Ng

CADD REF. 821_T_370_ATK_C06_651A1.dgn

TITLE

# CONTRACT 821
## SHEK YAM TO MEI LAI ROAD TUNNELS

**GEOTECHNICAL INSTRUMENTATION**
**SHEET 1**

| SCALE | DRAWING NO. | REV. |
|---|---|---|
| 1 : 1000 (A1) | 821/T/370/ATK/C06/651 | A1 |

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PRINTED BY: lesleywu 10/08/2009 10:29:03

| REF. NO. | ADDRESS | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SH005 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD – KWAI CHUNG (NEAR PING FU PATH) | 0 | 0 | 2 | 0 | 0 | 2 |
| SH006 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD – KWAI CHUNG (NEAR WO YIP HOP ROAD) | 0 | 0 | 2 | 0 | 0 | 2 |
| SH007 | STAIRCASE CONNECT CASTLE PEAK ROAD TO NORTH OF WAH TAT INDUSTRIAL CENTRE | 0 | 0 | 2 | 0 | 0 | 2 |
| SH008 | STAIRCASE CONNECT CASTLE PEAK ROAD TO SOUTH OF WAH TAT INDUSTRIAL CENTRE | 0 | 0 | 2 | 0 | 0 | 2 |
| SH009 | FOOTBRIDGE ACROSS CASTLE PEAK ROAD – KWAI CHUNG (NEAR YIP SHING STREET) | 0 | 0 | 2 | 0 | 0 | 2 |
| SH010 | YIP SHING STREET BRIDGE | 0 | 0 | 2 | 0 | 0 | 2 |

## GENERAL NOTES:

1. FOR GENERAL NOTES FOR MONITORING. REFER TO DRAWING NO. 822/T/360/ATK/C06/647.
2. FOR BLASTING MONITORING POINTS LAYOUT, REFER TO DRG. NOS. 822/T/360/ATK/C06/680 – 690.
3. THE TYPE OF INSTRUMENTATION USED FOR GROUND SETTLEMENT MONITORING SHALL BE PROPOSED BY THE CONTRACTOR TO THE ENGINEER FOR APPROVAL.
4. THE NUMBERING OF INSTRUMENTATION SHALL BE PROPOSED BY THE CONTRACTOR.
5. FOR INSTUMENTATION DETAILS, REFER TO DRAWING NOS. 822/T/360/ATK/C06/670 – 675.

## LEGEND:

- PROPOSED GROUNDWATER MONITORING POINT
- EXISTING GROUNDWATER MONITORING POINT
- EXISTING INCLINED GROUNDWATER MONITORING POINT
- IN-PLACE INCLINOMETER (IVI)
- BUILDING SETTLEMENT POINT (BSP)
- GROUND SETTLEMENT POINT (GSP)
- INCLINOMETER (INC)
- MAGNETIC PROBE EXTENSOMETER (MPX)
- TILTMETER (TM)
- BASSETT CONVERGENCE SYSTEM
- SEISMOGRAPH
- SURFACE-MOUNTED VIBRATING WIRE STRAIN GAUGE, SPOT WELDED TYPE (VWSG)
- UTILITY MONITORING POINT

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DRAFT
ADVANCE CHECK PRINT

0 10 20 30 40 50
METRES
1 : 1000

MATCH LINE
FOR CONTINUATION
SEE DWG 821_T_370_ATK_C06_651

MATCH LINE
FOR CONTINUATION
SEE DWG 821_T_370_ATK_C06_653

| REF. NO. | BUILDING NAME | PIEZO | IVI | DMP | MPX | INC | TM |
|---|---|---|---|---|---|---|---|
| SB029 | KWAI FUNG HOUSE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB030 | WING YIN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB031 | WING TONG BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB032 | GOLD PEAK BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB033 | WING TAK BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB034 | KIN WING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB035 | RYODEN INDUSTRIAL CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB036 | MERCANTILE INDUSTRIAL & WAREHOUSE BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB037 | WAI YIN BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB038 | FANG BROTHERS KNITTING LIMITED | 0 | 0 | 0 | 0 | 0 | 0 |
| SB039 | KAM BUN INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB040 | PO SING CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB041 | KWAI SING CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB042 | SHUI SUM INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB043 | ON FAT INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB044 | STAR CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB045 | SO TAO CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB046 | TAI TAK INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB047 | HENSEY INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB048 | VANTA INDUSTRIAL CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB049 | PO KAI MANSION | 0 | 0 | 0 | 0 | 0 | 0 |
| SB050 | SKH LADY MACLEHOSE CENTRE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB051 | KAM PUI BUILDING & CHEONG PING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB052 | KWAI WAH BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB053 | KWAI CHUNG GEE CHANG HOUSE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB054 | KWAI YING BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB055 | KWAI CHUNG BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB056 | KWAI CHUNG COLD STORAGE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB057 | SOUTH CHINA COLD STORAGE BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB058 | GOLD KING INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB059 | BOLDWIN INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB060 | WAH SING INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB061 | WAH TAT INDUSTRIAL BUILDING – BLOCK B | 0 | 0 | 0 | 0 | 0 | 0 |
| SB062 | WAH TAT INDUSTRIAL BUILDING – BLOCK A | 0 | 0 | 0 | 0 | 0 | 0 |
| SB063 | WAH TAT INDUSTRIAL BUILDING – BLOCK C | 0 | 0 | 0 | 0 | 0 | 0 |
| SB064 | MAI ON INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB065 | MAI LUEN INDUSTRIAL BUILDING | 0 | 0 | 0 | 0 | 0 | 0 |
| SB066 | SHEK YAT HOUSE, SHEK LEI ESTATE | 0 | 0 | 0 | 0 | 0 | 0 |
| SB067 | GREENKNOLL COURT – BLOCK 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| SB068 | GREENKNOLL COURT – BLOCK 2 | 0 | 0 | 0 | 0 | 0 | 0 |

| REV | DESCRIPTION | BY | DATE | APPROVED |
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| A1 | FIRST ISSUE | LCH | 02OCT09 | TM |

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| DESIGNED | FEC |
| CHECKED | WDE |
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| DATE | 03/MAR/2009 |

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TITLE
CONTRACT 821
SHEK YAM TO MEI LAI ROAD TUNNELS
GEOTECHNICAL INSTRUMENTATION
SHEET 2

SCALE 1 : 1000 (A1) | DRAWING NO. 821/T/370/ATK/C06/652 | REV. A1

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