Appendix 3.13 – Adjustment Factors for Ground-borne Noise Prediction Model

Adjustment for Source Vibration

Force Density Level (FDL)

The source vibration level (Force Density Level) for the M-stock train previously measured for the M-Stock train was used for the ground borne noise assessment. Since the K-stock train uses disk type braking system instead of the cast iron braking system currently employed by the M-stock train, the source vibration level is likely to be lower than that for the M-stock train Furthermore, the K-stock is also lighter than the M-stock and could result in lower force transmission into the tunnel foundation. Therefore, the use of M-stock train source vibration level represents a conservative approach for the EIA.

The FDL was measured for existing MTR trains running on the Island Line (M-stock). The FDL represents the maximum force envelop for the measurements plus 2 standard deviations. Hence the use of the maximum force density envelop is considered as a "conservative approach" for determination of the ground-borne noise level.

Adjustment for Speed

The levels of ground-borne vibration and noise vary approximately as 20 times the logarithm of speed. Hence to correct the FDL from the reference speed of 80kph, the following adjustment is used:

Speed Adjustment (dB) = 20 log Speed[1] - 38

Adjustment for Wheel and Track Condition

The most important factors affecting the source vibrations are the suspension and track support system, wheel condition and wheel type. Given that the source vibration was determined from measurements for similar EMU, the main source of variation will mostly due to deteriorating wheel and track conditions. The wheel and track condition adjustment factor will take into consideration of the wheel and track conditions during the source vibration measurements.

Since the FDL was measured for trains with somewhat deteriorated rail and wheel conditions[2] under normal operation, no additional rail and wheel correction (i.e. 0dB) is proposed for this study.

Track form Attenuation (TIL)

Track form attenuation represents attenuation due to installation of trackside mitigation measure, e.g. resilient base plate, Low Vibration Trackform (LVT), Isolate Slab Trackform (IST), Floating Slab Trackform (FST) etc.

The approach taken in this study is to try and reduce the number of different trackform types to a minimum, whilst providing the necessary vibration attenuation for satisfaction of the noise and vibration criteria along

[1] Speed in kph.

[2] This is based on observation by test officer for the WIL EIA.

the alignment. The type of vibration mitigating trackform for SIL(E) are listed below:

1. Type 1A: A medium attenuation baseplate or booted dual sleepers based on a bonded or non-bonded compression style baseplate with a resilient elastomeric element, to be fitted atop the concrete sleepers or atop the invert

2. Type 1B: Resiliently supported sleepers whose resilient support pad is manufactured from natural rubber

Type 1A would be adopted along the alignment and could be upgraded to Type 1B if required to achieve compliance with the noise control ordinance.

The required trackform attenuation represents the minimum insertion loss required for the detailed design to achieve compliance with the noise criteria. The following attenuation factor (**Table 1**) based on measurements conducted by MTRC will be used for the study, if applicable.

Table 1: Insertion Loss for Different Track form (TIL)

1/3 Octave Band Centre Frequency (Hz)	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Type 1A	-1	-4	-5	-3	-3	0	-9	-13	-10	-12	-12	-13	-12	-10	-5	-5
Type 1B	0	0	0	5	0	-3	-14	-20	-15	-15	-13	-21	-18	-16	-12	-9

Turnout and cross over correction factor (TOC)

There will be an increase in vibration level when wheel traverse a joint, turnout or a crossing. A TOC correction factor of +10dBA per 1/3 octave band is proposed in accordance with FTA Handbook recommendation.

Vibration Propagation

Tunnel Coupling Factor (TCF)

The weight and size of the structure will affect the vibration radiation characteristic. For SIL(E), the relevant structure types are as follows:

- SOH station – Station on Fill
- From SOH to Ap Lei Chau Drive – Rock Based Tunnel
- Ap Lei Chau Drive to LET portal – Rock Based Tunnel
- From LET portal to WCH – Bridge and Viaduct
- From WCH to Nam Fung Portal – Viaduct
- Nam Fung Portal to Admiralty – Rock Based Tunnel

The correction for Tunnel Structure type applied to tunnels founded on soil. Since the tunnels for SIL(E) are mostly founded in rock, the impedance of the concrete tunnel structure can be assumed to be the same as that of the rock and no correction factor is required (i.e. TCF of 0dB).

For the station and soil founded track structure such as SOH station, the following adjustment (**Table 2**) based on Saurenman (1982)[3] is used for this project.

Table.2: Insertion Loss for Tunnel Coupling Factor (TCF)

1/3 Octave Band Centre Frequency (Hz)	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Concrete Tunnel in Rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Station	0	-0.3	-0.7	-1.0	-1.7	-2.3	-3.0	-3.3	-3.7	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0

Spreading and Soil Propagation Loss / Line Source Response (LSR)

The vibration of the transit structure causes vibration waves in the soil that propagate away from the transit structure. Vibration energy can propagate through the soil or rock in a variety of wave forms, including shear wave, compression waves, Rayleigh waves (surface) etc. Attenuation occurs due to internal damping loss as well as spreading loss.

For rock base transmission between the tunnel and the foundation of the nearby buildings, attenuation due to internal damping loss is small compare to spreading loss.

Propagation loss could be estimated using the theoretical model developed by Ungar and Bender or experimentally determined using the WIA/LTI approach (Nelson 1987). For the latter approach, the spreading and soil propagation loss is represented by the experimentally determined transfer mobility (point source response (PSR) and line source response (LSR)) between the vibration source and the receiver building.

For SIL(E), the transfer mobility was selected based on comparing geological condition of the ground with those from other HKSAR based projects. A geological map showing the ground formations for Hong Kong Island and Ap Lei Chau Area is presented in **Figure 1a** and the geological profile along the SIL(E) is shown in **Figure 1b-1h**.

It can be shown that most of the underground tunnel areas for SIL(E), except the area near the Admiralty station, belong to the Repulse Bay Volcanic group formation. The Repulse Bay Volcanic Group consists of both Ap Lei Chau formation and Mount Davis formation. The later is found near the Kennedy Station for MTR West Island Line project. Based on this observation, the point source mobility data obtained for the West Island Line project was selected for estimating the transfer mobility for the SIL(E) study. The PSR data selection criteria are based on the same approach submitted for other underground EIA study in Hong Kong. The selection criteria are based on:

[3] Saurenman, H., Nelson, J., Wilson, G. 1982, Handbook of urban Rail Noise and Vibration Control, US Department of Transportation Urban Mass Transportation Administration (Table 8-8).

a. Similar ground and rock formation type – "Kowloon Granite" (Lion Rock Suite) for Admiralty Section (e.g, Shangri-La Hotel and Paget House) and "Ap Lei Chau Formation" (Repulse Bay Volcanic Group) for the other NSRs

b. Similar distance between rockhead and track/borehole

In order to compensate for the uncertainly arise due to the use of non-site specific WIL borehole impact test for SIL(E) assessment, a conservative safety factor of 10dB(A) is applied to the ground borne noise prediction.

Based on the above criterion, the details of the West Island Line (WIL) boreholes selected for SIL(E) ground borne noise assessment are listed in **Table 3** below. The adaptation of these West Island Line boreholes for the NSRs along SIL(E) are summarised in **Table 4.**

Table.3: Details of the WIL Impact Test Boreholes used in the SIL(E) assessment

West Island Line Bore Hole ID	Rock Type	Rock Head Depth mPD	Bore Hole Depth (mPD)	Distance btw Rock head & Bore Hole (m)
D012 #1	Kowloon Granite	-24	3.0	27.0
D095 #2	Ap Lei Chau Formation	-17	0.3	-17.3
D095 #1	Ap Lei Chau Formation	-17	-10.4	-6.6
D103 #1	Ap Lei Chau Formation	15	-3.1	18.1
D086 #1	Ap Lei Chau Formation	24	0.5	23.5
D103 #2	Ap Lei Chau Formation	15	-11.2	26.2
D086 #2	Ap Lei Chau Formation	24	-17.5	41.5

Table.4: WIL Borehole selection for NSRs along SIL(E).

NSR ID	Description	Ground Surface mPD	Rock Head mPD	Track Depth mPD		Distance btw Rock head & Track (m)		WIL Bore Hole
				ADM to SOH	SOH to ADM	ADM to SOH	SOH to ADM	
SOH 5	South Horizons Phase III - Mei Cheung Court (Block 20)	13.5	-23	0	0	-23.0	-23.0	D095#2
SOH 7	South Horizons Phase IV - Cambridge Court (Block 33A)	13.5	-23	0	0	-23.0	-23.0	
HTL 1	Hotel Project (A/H15/206)	16.6	-20	0	0	-20.0	-20.0	
PBPS	Precious Blood Primary School (South Horizons)	10.7	-20	0	0	-20.0	-20.0	
SOH 6	South Horizons Phase III - Mei Ka Court (Block 23A)	13.5	-10	0	0	-10.0	-10.0	D095#1
SOH 8	South Horizons Phase IV - Dover Court (Block 25)	13.5	-10	0	0	-10.0	-10.0	
SWT 2	Sham Wan Towers - Tower 3	31.7	14	18.6	18.5	-4.6	-4.5	
YOC 4	Yue On Court - Shan On House (Block F)	32.9	24	9.1	9.1	14.9	14.9	D103#1

NSR ID	Description	Ground Surface mPD	Rock Head mPD	Track Depth mPD		Distance btw Rock head & Track (m)		WIL Bore Hole
				ADM to SOH	SOH to ADM	ADM to SOH	SOH to ADM	
YOC 1	Yue On Court - Pik On House (Block C)	42.5	38	7.9	7.9	30.1	30.1	D103#2
YOC 2	Yue On Court - Tse On House (Block D)	42.5	43	7.0	7.0	36.0	36.0	
LTE 5	Lei Tung Estate - Tung Sing House	55.0	49	6.2	6.2	42.8	42.8	D086#2
NEC	Lei Tung Neighbour Elderly Centre (G/F of Tung Shing House)	55.0	49	6.2	6.2	42.8	42.8	
LMCC	Aberdeen Baptist Lui Ming Choi College	60.0	57	6	6	51.0	51.0	
NLH	Jockey Club New Life Hostel	79.8	16	-38.2	-38.2	54.2	54.2	
LTE 4	Lei Tung Estate - Tung Mau House	62.5	62	5.8	5.8	56.2	56.2	
LDN	Lei Tung Lutheran Day Nursery (G/F of Tung Mau House)	62.5	62	5.8	5.8	56.2	56.2	
SPC	St Peter's Catholic Primary School	54.0	62	5.8	5.8	56.2	56.2	
AKPS	Apleichau Kaifong Primary School	64.1	58	0.0	-0.0	58.0	58.0	
LTCH	Lei Tung Community Hall	65.0	68	3.3	3.3	64.7	64.7	
LTE 2	Lei Tung Estate - Tung Hing House	68.4	68	3.3	3.3	64.7	64.7	
CMA	CMA Lei Tung Child Care Centre (G/F of Tung Hing House)	68.4	68	3.3	3.3	64.7	64.7	
LTE 1	Lei Tung Estate - Tung Yip House	67.5	68	2.4	2.4	65.6	65.6	
CPHH	Cheng Pon Hing Hostel for the Elderly at G/F of Tung Yip House	67.5	68	2.4	2.4	65.6	65.6	
RP	Regent on the Park	63.4	54	-38.4	-38.4	92.4	92.4	
CIS	Carmel School	134.4	118	-38.4	-38.4	156.4	156.4	
ILS	Island School	146.0	139	-37.3	-37.3	176.3	176.3	
GOV	Non Departmental Quarters	167.6	151	-33.9	-33.9	184.9	184.9	
PH	Paget House	26.1	-4	-33.8	-33.8	29.8	29.8	D012#1
SLH	Island Shangri-la Hotel	45.5	4	-35.6	-35.6	39.6	39.6	

The Line Source Responses (LSR) are determined from the Point Source Response (PSR) data by numerical integration using **Equation 1** below:

$$LSR = 10 \log \{h \times [0.5*10^{(PSR1/10)} + 10^{(PSR2/10)} + 10^{(PSR3/10)} + \ldots\ldots + 10^{(PSRn-i/10)} + 0.5*10^{(PSRn/10)}]\}$$

Equation 1

Where

h = distance between discrete incoherence point source

n = no. of point sources

$PSR_i \ldots PSR_n$ = Point source response at source positions 1….n

LSR = Line source response

MTR Corporation will further review the LSR values during the construction stage after the tunnel boring.

Adjustment for NSR Building Structure

Building Coupling Loss (BCF)

Interaction between the building foundation and the soil will cause some reduction in the vibration level. The correction factors shown in **Table 5** are based on Saurenman (1982)[4]. These building coupling loss adjustment factors are the lower limits recommended for each building types and are adopted for used as conservative prediction.

Table.5: Adjustment Factor for Building Coupling Loss (BCF)

Building Type	Building Coupling Loss (dB)															
	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Large Masonry Building on Pile	-6	-6.7	-7.3	-8	-9	-10	-11	-11.7	-12.3	-13	-13.3	-13.7	-14	-13.3	-12.7	-12
Large Masonry Building on Spread Footings	-12	-12.7	-13.3	-14	-14	-14	-14	-13.7	-13.3	-13	-12.3	-11.7	-11	-10.2	-9.3	-8.5
1 to 2 Storey Residential	-4	-4.2	-4.3	-4.5	-4.5	-4.5	-4.5	-4.2	-3.8	-3.5	-3.3	-3.2	-3	-2.3	-1.7	-1
Building Foundation on Rock Layer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Building Vibration Response (BVR)

Building Vibration Response (BVR) consists of two factors, namely Building Structure Attenuation (BSA)

[4] Saurenman, H., Nelson, J., Wilson, G. 1982, Handbook of urban Rail Noise and Vibration Control, US Department of Transportation Urban Mass Transportation Administration (Figure 8.12).

and Building Structure Resonance (BSR). Vibration generally reduces in level as it propagates through a building. On the other hand, amplification in vibration level occurs due to resonance in building elements. **Table 6** below shows the Building Structure Attenuation factors based on Saurenman (1982)[5]. Since ground-borne vibration level will be the highest on the lower level of a building, a conservative building structure attenuation factor of 2dB per 1/3 octave band is applied for the SIL(E) study (**Table 7**).

Table.6: Adjustment Factor for Building Structure Attenuation (BSA)

Floor level above Grade	**Floor Attenuation Factor (dB)**															
	16	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4
2	1	1	1	2	2	2	2	2	3	3	3	3	3	3	4	4
3	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3
4 to5	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
6 to 7	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3
8 to 9	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3
10 and above	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3

Table.7: Building Structure Attenuation (BSA) for SIL(E) Study

1/3 Octave Band Centre Frequency (Hz)	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
Floor Attenuation Factor (dB)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Ground vibration level will increase within the building due to building element resonance. The amount of amplification will depend on building construction method. For typical concrete based buildings, a 6dB per 1/3 octave band increase in the vibration level was adopted for the SIL(E) study in accordance with the FTA Handbook recommendation (**Table 8**).

Table.8: Building Structure Resonance (BSR) for SIL(E) Study

1/3 Octave Band Centre Frequency (Hz)	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
Floor and Wall Resonance (dB)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

[5] Saurenman, H., Nelson, J., Wilson, G. 1982, Handbook of urban Rail Noise and Vibration Control, US Department of Transportation Urban Mass Transportation Administration (Table 8-7).

Conversion from Vibration to Noise (CTN)

The level of radiated noise level inside a room depends on the spatial averaged vibration levels for room surfaces, the radiation efficiency of the surfaces and the amount of absorption inside the room.

Based on the conservation of power principle, the reverberant sound field inside the room can be approximated by the following equations:

Reverberant Sound Pressure Level L_A (dBA) = Lv (VdB ref 1 μ in/s) + CTN

Equation 2

CTN = K_{rad} + A-weighting Correction

Equation 3

Where

K_{rad} Adjustment to account for conversion from vibration to sound pressure level including accounting for the amount of acoustical absorption inside the room

The room correction factors listed in **Table 9**, which were also adopted in approved previous EIA study, are used in the SIL(E) ground borne noise study:

Table.9: Room Correction Factors

1/3 Octave Band Centre Frequency (Hz)	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
Krad (dB)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A-weighting	-56.7	-50.5	-44.7	-39.4	-34.6	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2
CTN	-56.7	-50.5	-44.7	-39.4	-34.6	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2
For Lv vibration level reference to 1 μ in/s																

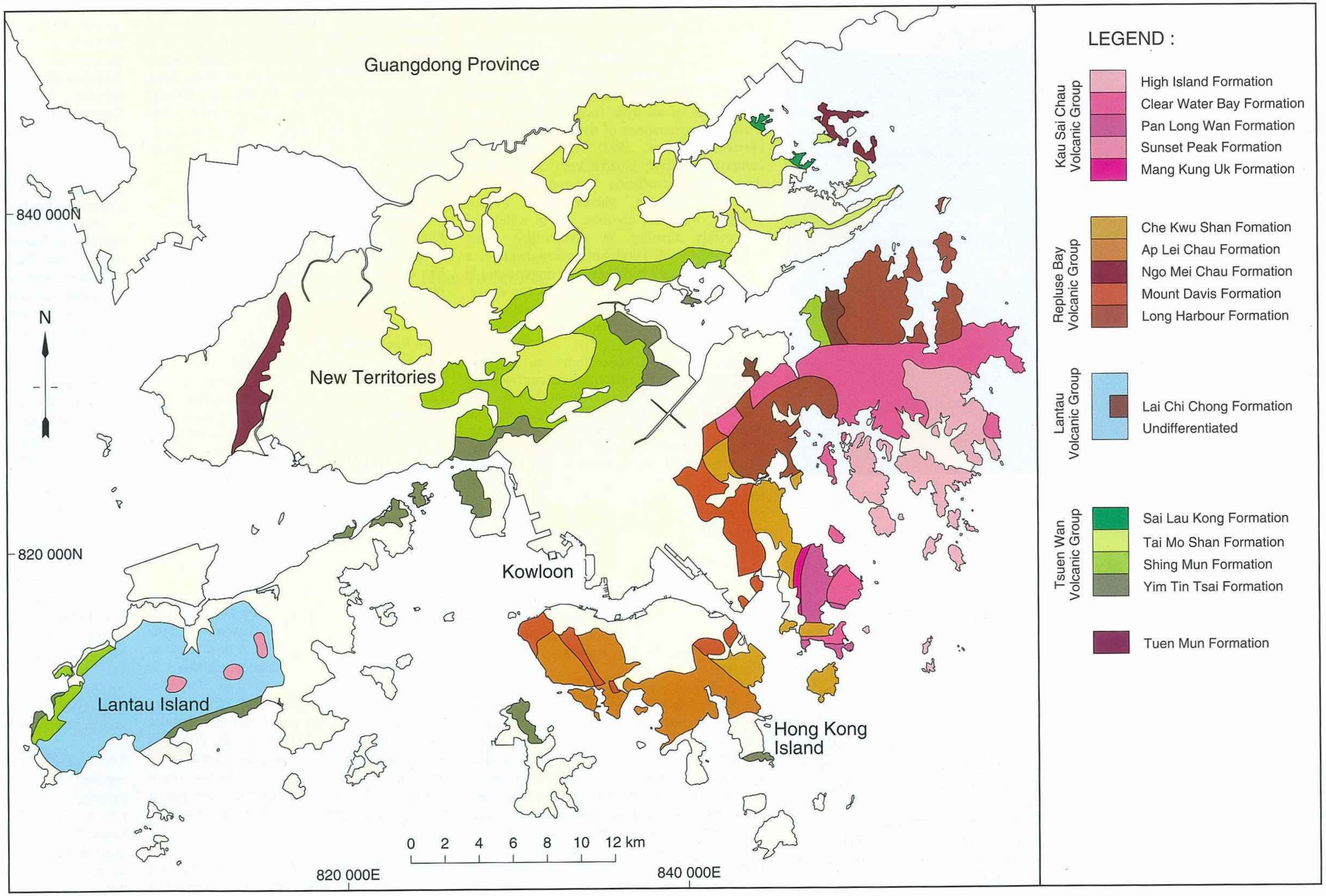

Figure 7 Geological map showing the distribution of Mesozoic volcanic formations in Hong Kong.

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Title: General Geological Plan

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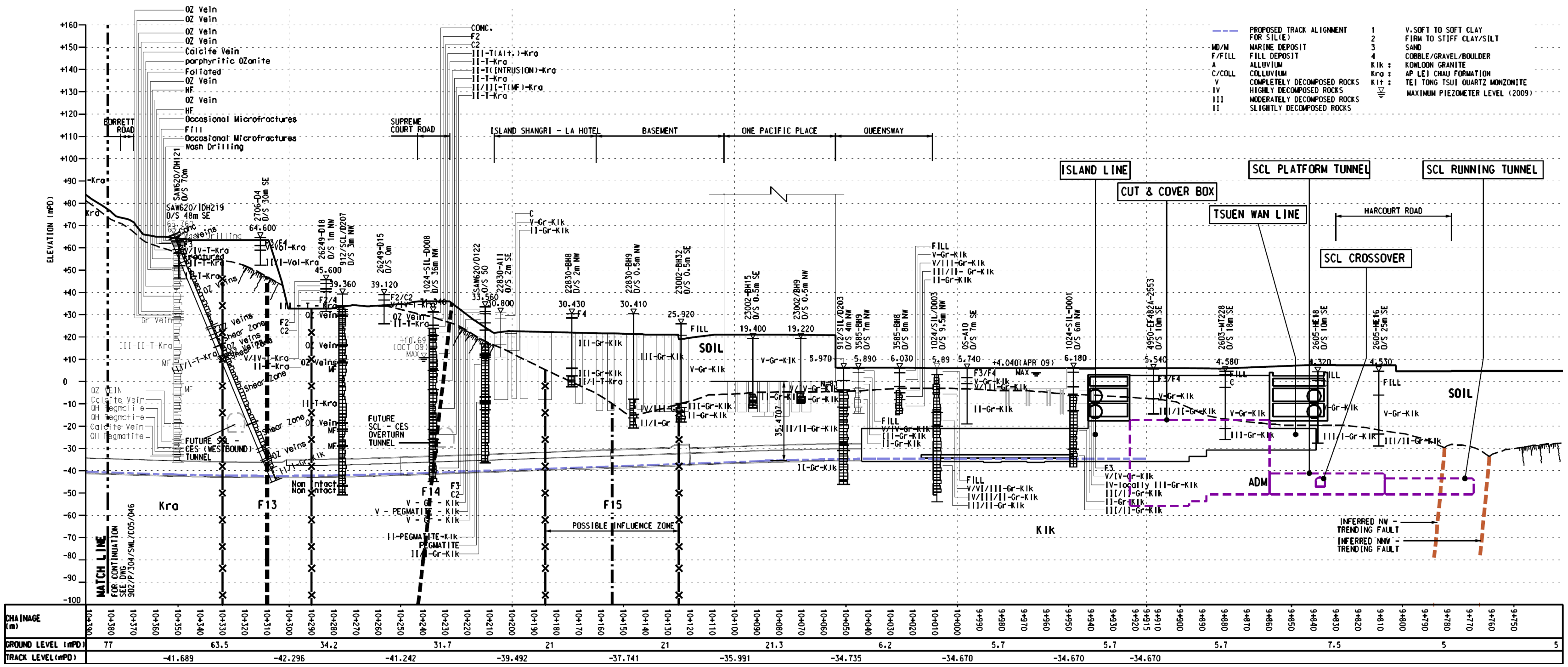
Dwg.Chk.		Approved	
Scale		Project	Status
		CAD File	
Drawing No.	Appendix 3.13		Rev



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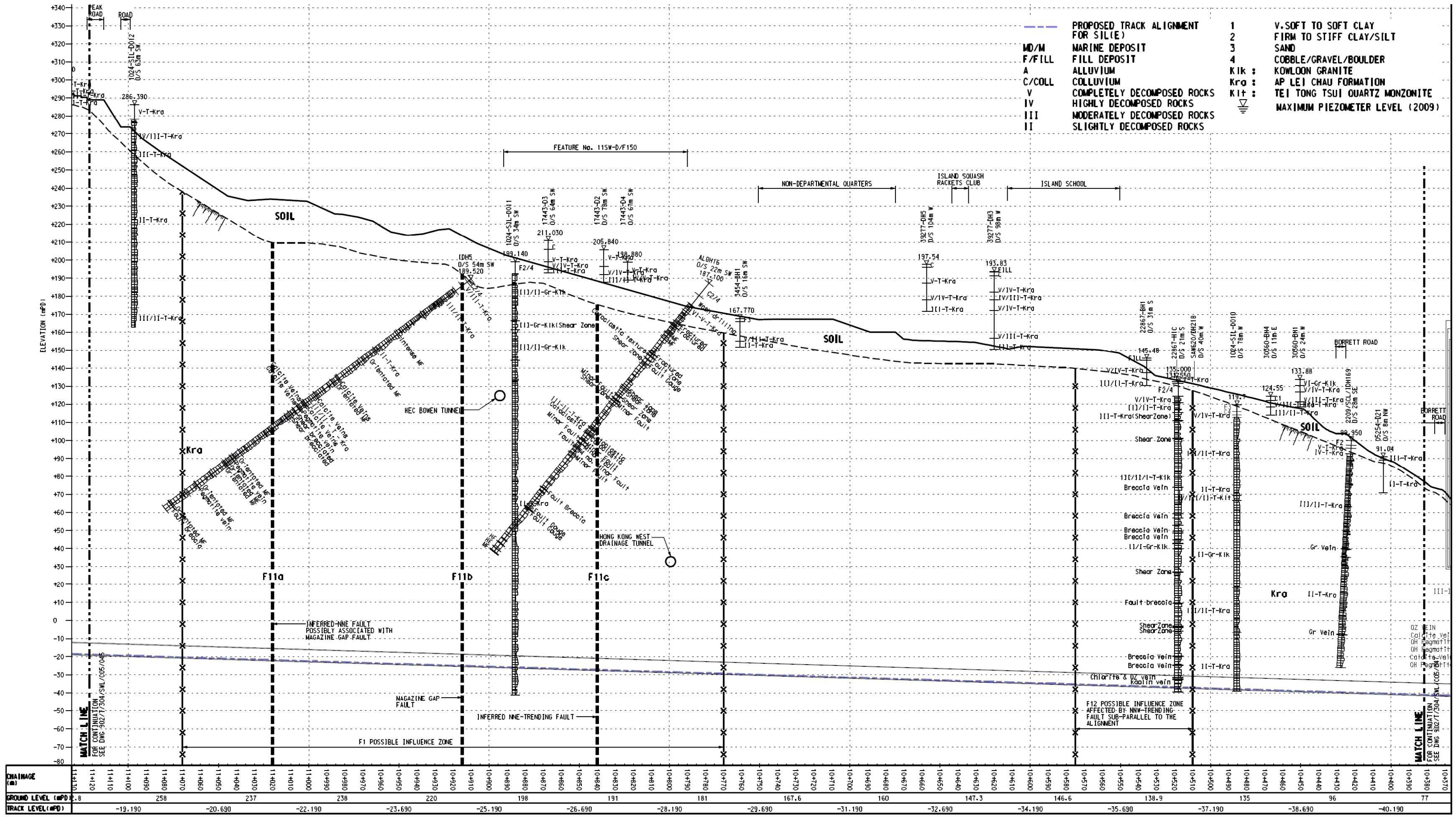
Scale		Project	Status
		CAD File	
Drawing No.	Appendix 3.13		Rev



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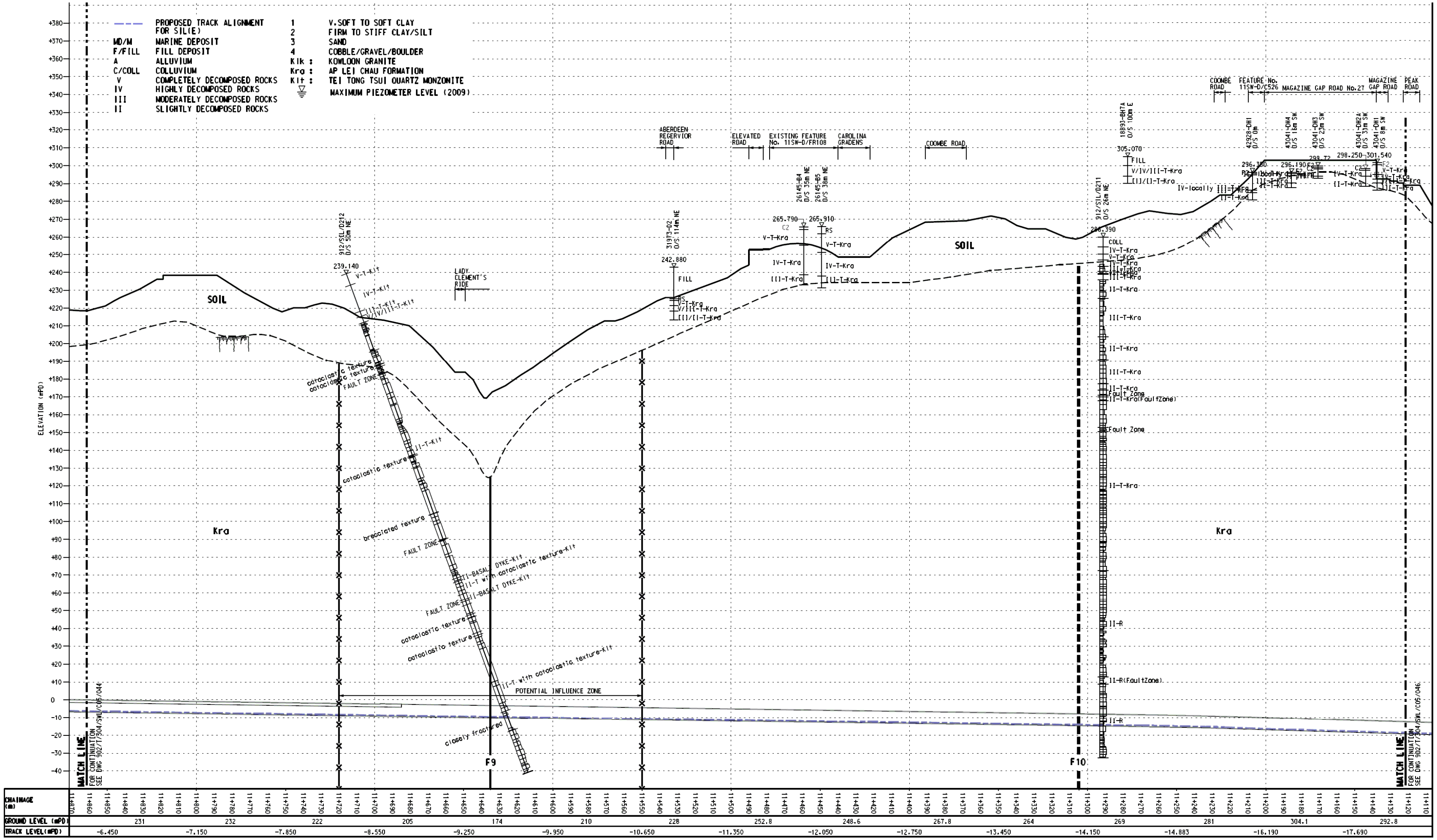

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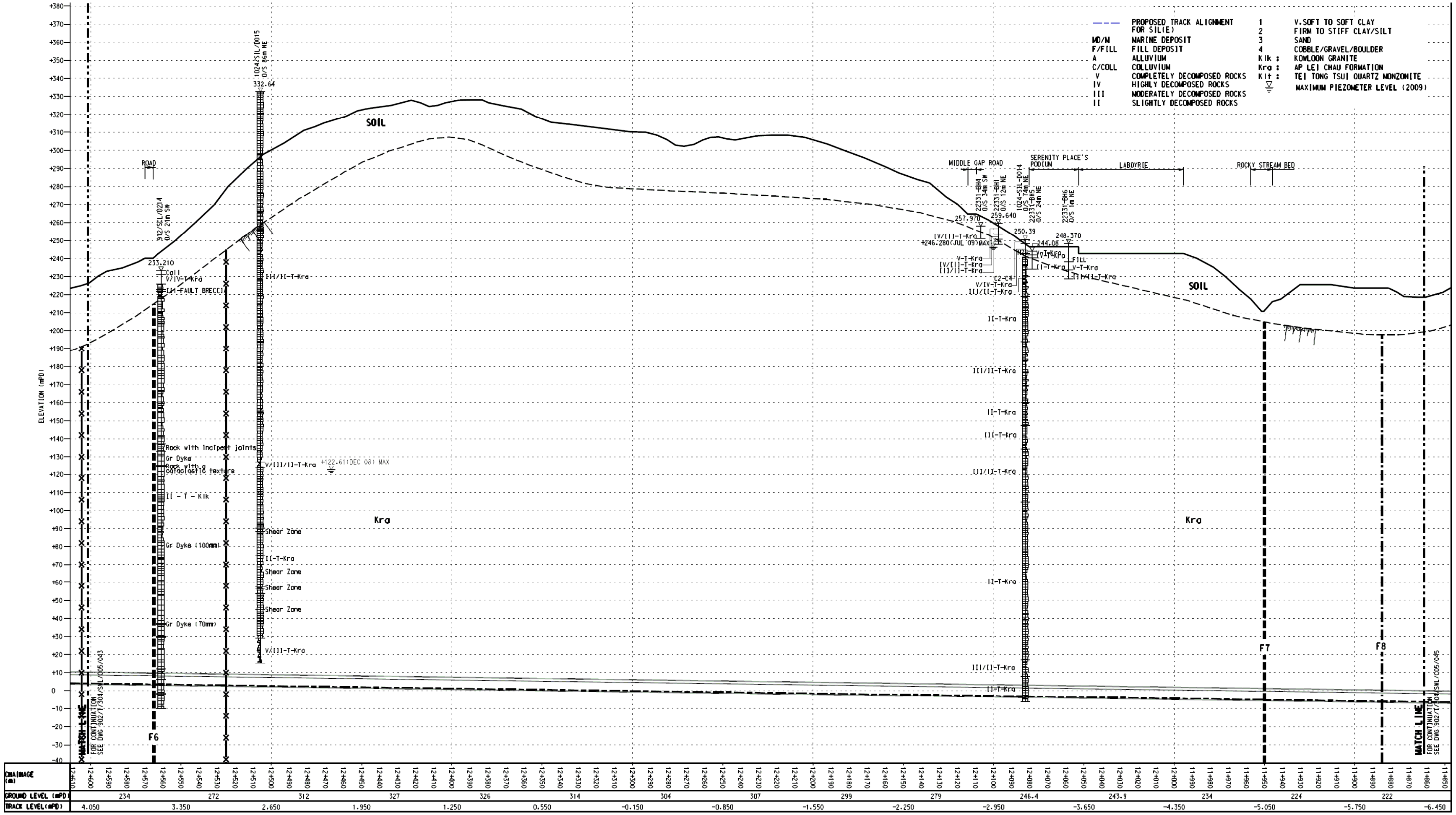

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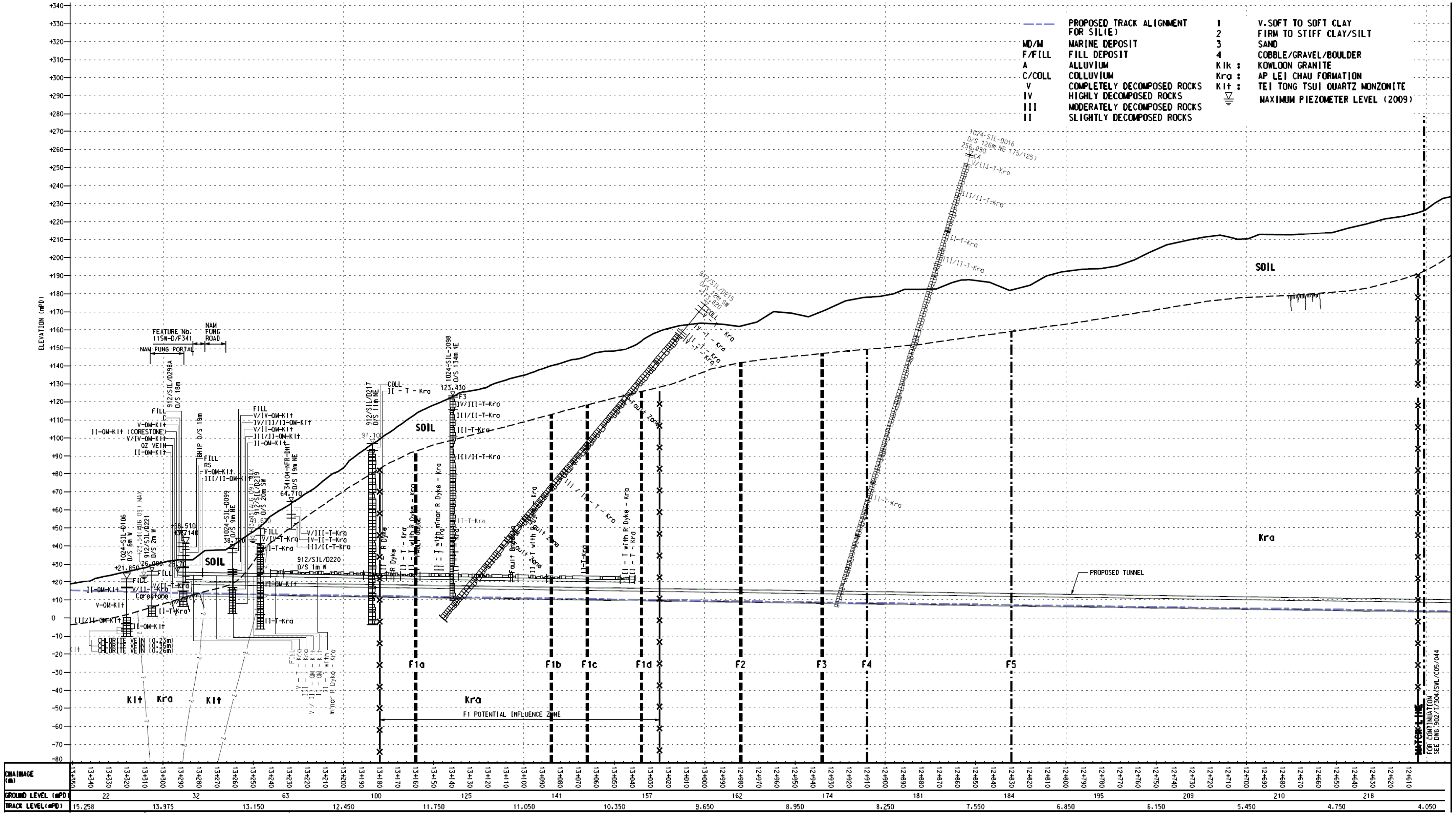

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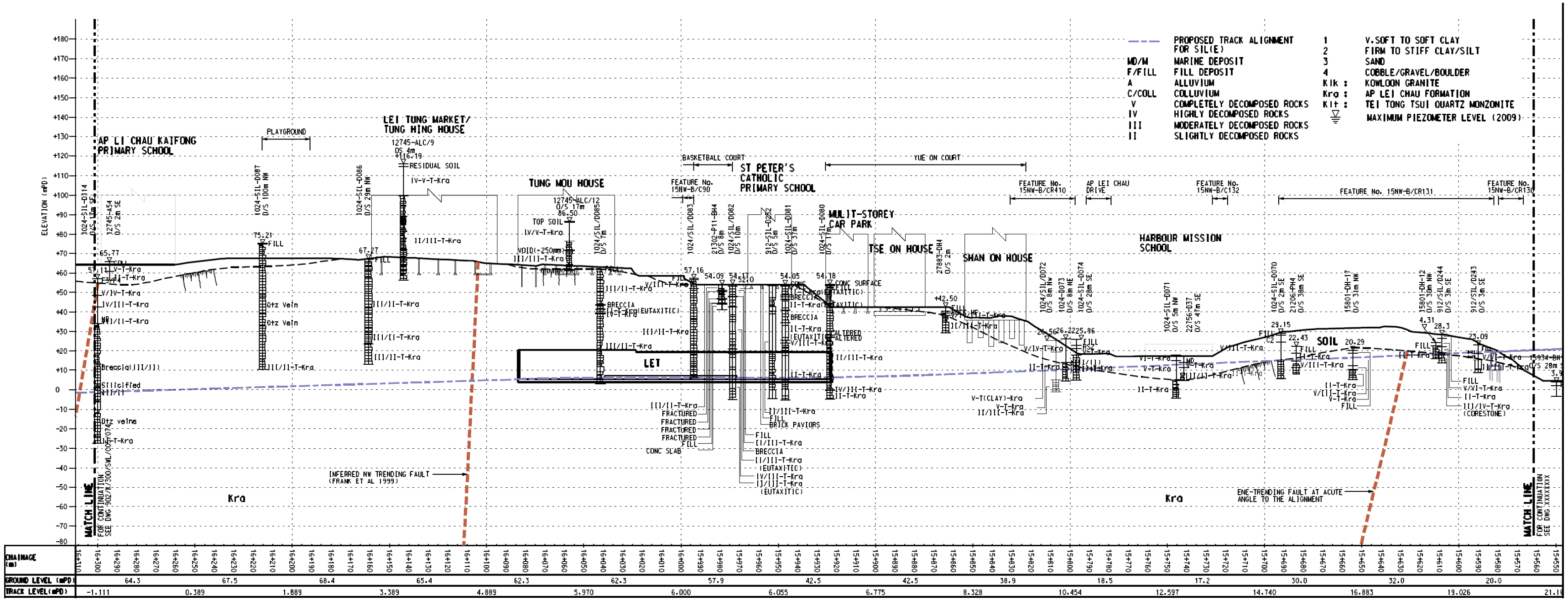

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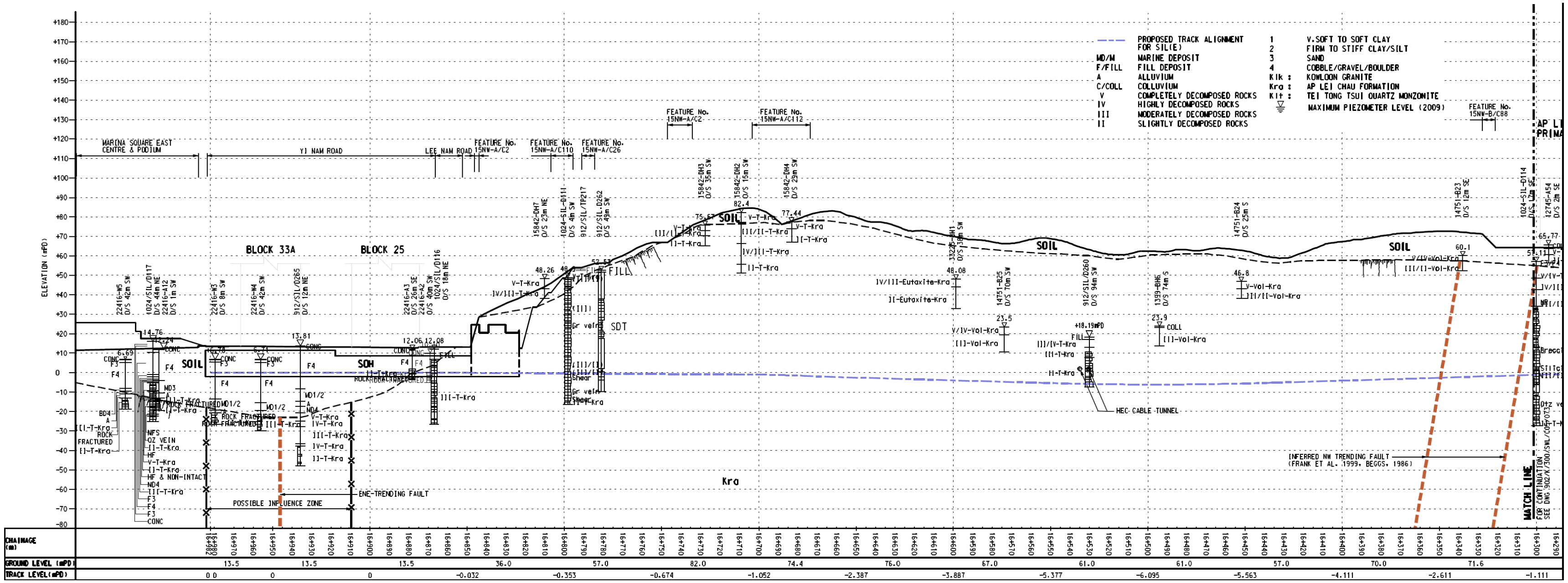

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Project

CONSULTANCY AGREEMENT NO. NEX/2301
SOUTH ISLAND LINE (EAST)
ENVIRONMENTAL IMPACT ASSESSMENT

Title

Geological Longitudinal Section

Designed		Eng.Chk.	
Drawn		Coordination	
Dwg.Chk.		Approved	
Scale		Project	Status

Drawing No. Appendix 3.13 Rev