MTR Corporation Limited

South Island Line (East)

Operational Ground-borne Noise Review Plan

July 2014

Verified by:

Thomas Chan

Independent Environmental Checker

Date:

2 July 2014

MTR Corporation Limited

South Island Line (East)

Operational Ground-borne Noise Review Plan

July 2014

Certified by:

R Kwan

Richard Kwan

Environmental Team Leader

Date:

02 JUL 2014

REPORT

MTR Corporation Limited

South Island Line (East): *Ground-borne Noise Review Plan*

June 2014

Environmental Resources Management
16/F DCH Commercial Centre
25 Westlands Road
Quarry Bay
Hong Kong
Telephone: (852) 2271 3000
Facsimile: (852) 2723 5660
E-mail: post.hk@erm.com
http://www.erm.com

REPORT

MTR Corporation Limited

South Island Line (East): *Ground-borne Noise Review Plan*

June 2014

Reference 0132172

For and on behalf of
ERM-Hong Kong, Limited

Approved by: Frank Wan

Signed:

Position: Partner

Date: 26 June 2014

This report has been prepared by ERM-Hong Kong, Limited with all reasonable skill, care and diligence within the terms of the Contract with the client, incorporating our General Terms and Conditions of Business and taking account of the resources devoted to it by agreement with the client.

We disclaim any responsibility to the client and others in respect of any matters outside the scope of the above.

This report is confidential to the client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such party relies on the report at their own risk.

CONTENTS

LIST OF FIGURES

LIST OF ANNEXES

1 INTRODUCTION

1.1 BACKGROUND

Following the approval of the South Island Line (East) (SIL(E)) Environmental Impact Assessment (EIA) Report [1] on 26 October 2010, an Environmental Permit (EP-407/2010) was granted for the SIL(E) on 8 December 2010 and further amendments to the EP were approved in December 2011, December 2012, April 2013 and November 2013. The construction of SIL(E) (hereafter referred to as the Project) is now progressing under various works contracts led by the MTR Corporation Limited (MTRCL).

In accordance with Condition 2.25 of the EP-407/2010/D (EP), the Permit Holder shall prepare an Operational Ground-borne Noise (GBN) Review Plan to justify the adequacy of the proposed operational GBN mitigation measures recommended for in the approved EIA Report. The Operational GBN Review Plan shall include:

- The verification of the assumptions adopted in the approved SIL(E) EIA Report, such as Line Source Response (LSR) and ground vibration conditions; and
- Justifications and recommendations for any additional noise mitigation measures.

ERM-Hong Kong, Limited (ERM) was commissioned by MTRCL to prepare the Operational GBN Review Plan. ERM was supported by Wilson Acoustics Limited who acts as the GBN specialist.

1.2 PURPOSE OF THIS REPORT

According to the submitted *Methodology Paper for the Review of the Proposed Mitigation Measures for Operation Ground-borne Noise for SIL(E)* (dated May 2012) (see *Annex C*), hammer impact test is proposed to be conducted in downtrack tunnel near Dover Court (SOH8) to verify the LSR and ground vibration condition, and review the effectiveness of the operational GBN mitigation measures proposed in the approved SIL(E) EIA Report. This *Operational GBN Review Plan* presents the verification measurement results and updated GBN assessment.

[1] South Island Line (East) Environmental Impact Assessment Report (Register No.: AEIAR-155/2010) (SIL(E) EIA Report)

This page is deliberately left blank

2 GBN ASSESSMENT METHODOLOGY

According to the approved SIL(E) EIA Report, the methodology for railway GBN impact assessment is based on the procedures outlined in "The Transit Noise and Vibration Impact Assessment" published by US Department of Transportation Federal Transit Administration (FTA Manual). The GBN level at the identified NSRs was calculated as follows:

L = FDL + TIL + TOC + TCF + LSR + BCF + BSA + BSR + CTN + SAF

where:

L = GBN level, in dB re 20µPa

FDL = Force density level, in dB re lbf/$\sqrt{ft}$

TIL = Trackform attenuation or insertion loss, relative level

TOC = Turnout and crossover factor

TCF = Vibration coupling between the tunnel and the ground for soil based tunnels, relative level

LSR = Line source transfer mobility, in dB re (µin/s)/(lbf/$\sqrt{ft}$)

BCF = Adjustment to account for building coupling loss, in dB

BSA = Building Structure Attenuation, in dB

BSR = Building Structure Resonance, in dB

CTN = Conversion from vibration to noise within the building, in dB

SAF = 10dB safety factor to account for wheel/rail condition and uncertainties in ground conditions, in dB

During the EIA stage, *in situ* LSR for SIL(E) has not been measured. According to the approved SIL(E) EIA Report, most of the underground tunnel areas for SIL(E) have similar geology as the West Island Line project. Therefore, the LSR data collected from the borehole impact test during the EIA stage of West Island Line were adopted in the GBN assessment for the SIL(E).

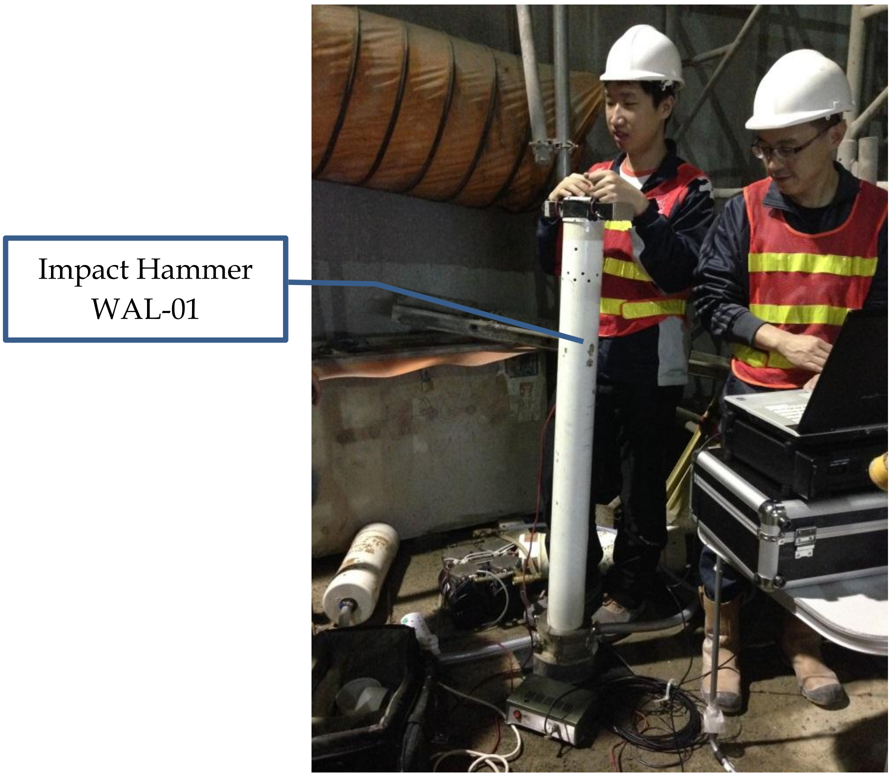
This page is deliberately left blank

3 INSTRUMENTATION

The instruments used in the hammer impact test are listed in *Table 3.1* below.

Table 3.1 Instruments used in the Hammer Impact Test

Instrument	Model No.	Number
7-Channel Spectrum Analyzer	B&K Pulse 3560C	1
4-Channel Sound & Vibration Analyzer	SVAN 958	1
1-Channel Sound & Vibration Analyzer	SVAN 959	1
Piezoelectric Accelerometers	Endevco 86	1
Piezoelectric Accelerometers	PCB 393A03	4
Handheld Vibration Calibrator	IMI 699A02	1
Pneumatic Impact Hammer	WAL-01 (tailor made)	1
Force Transducer for Impact Hammer	FUTEK LCM 550	1



This page is deliberately left blank

4 MEASUREMENT AND ANALYSIS PROCEDURES

The hammer impact test was conducted inside the tunnel. A force transducer was located at the base of the impact hammer to measure the force applied to the tunnel invert. Accelerometers were placed at various setbacks on the ground level to pick up the vibration signals.

The Point Source Response (PSR) is calculated from dividing the vibration signal by the force signal at each individual 1/3 octave band. The LSR is calculated from numerical integration of the PSR at each impact point along the alignment according to the equation below:

$$LSR(s, d, f) = 10\log\left[\int_{-l/2}^{l/2} 10^{PSR\left(\sqrt{s^2+d^2+y^2},\, f\right)/10} dy\right]$$

where
s = perpendicular setback
l = train length
d= tunnel depth

By invoking the assumption that the ground is transversely isotropic along the alignment over the length of the train, LSR can be determined from a single hammer impact point. For this verification test, hammer impact was conducted at 4 points along the alignment, so as to taken into account possible geological variations along the alignment.

Considering the site constraints and accessibility, the 4 impact points are selected as shown in the *Figures 4.1* and *4.2*. These impact points cover both soil and rock geology over the length of the train. Photos showing the locations of vibration sensors on ground are provided in *Figures 4.3, 4.4 and 4.5*. Photos showing the hammer impact test at four selected locations are provided in *Figures 4.6 to 4.9*.

Referring to *Figure 4.5*, although the sensors were placed on ground in open space, there are columns on the ground to support upper floors of the building. Therefore it is considered that the sensors are placed within the building foundation.

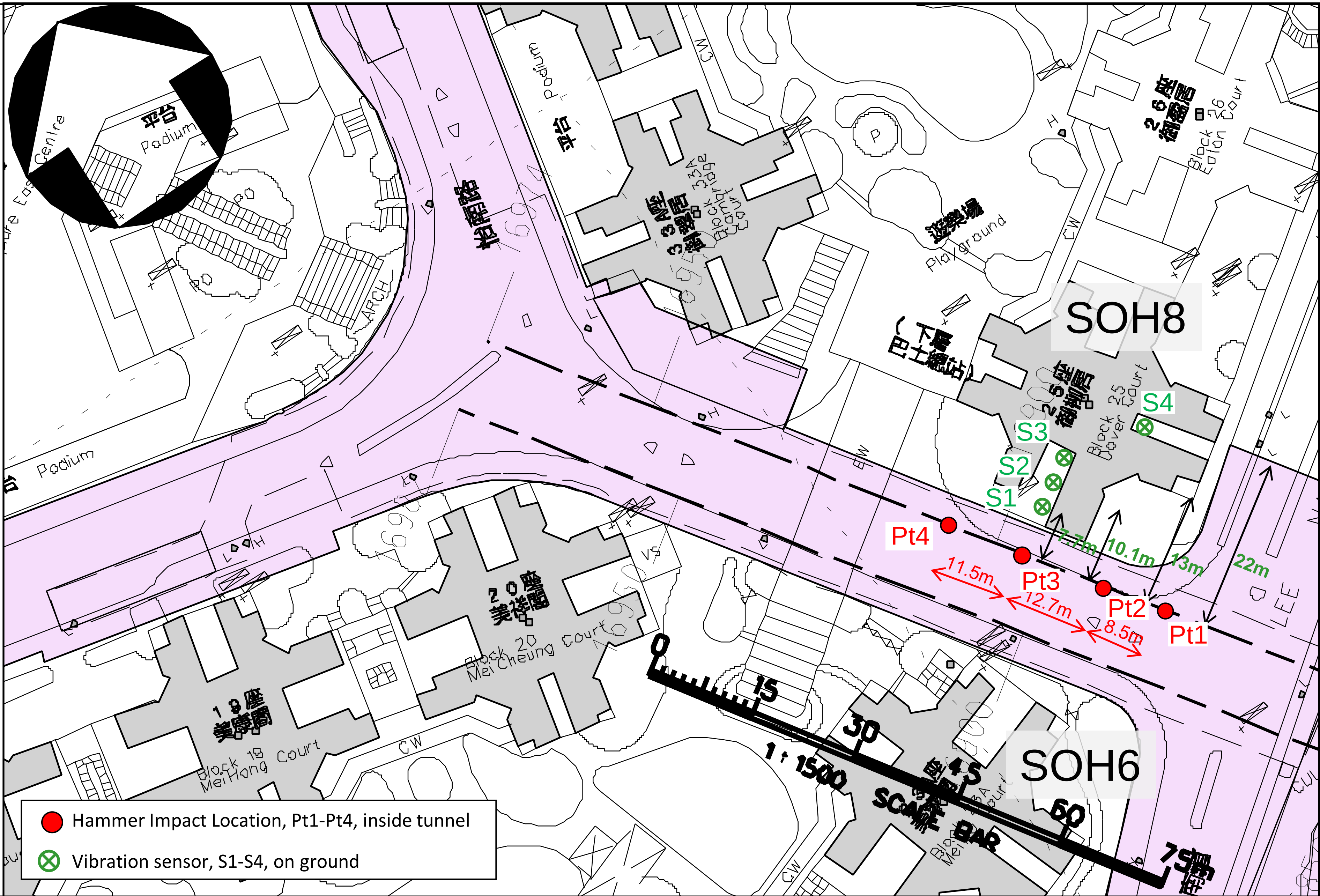


Figure 4.1

Plan View showing Measurement Locations at SOH8

Date 25 Jun 2014

Environmental Resources Management

ERM

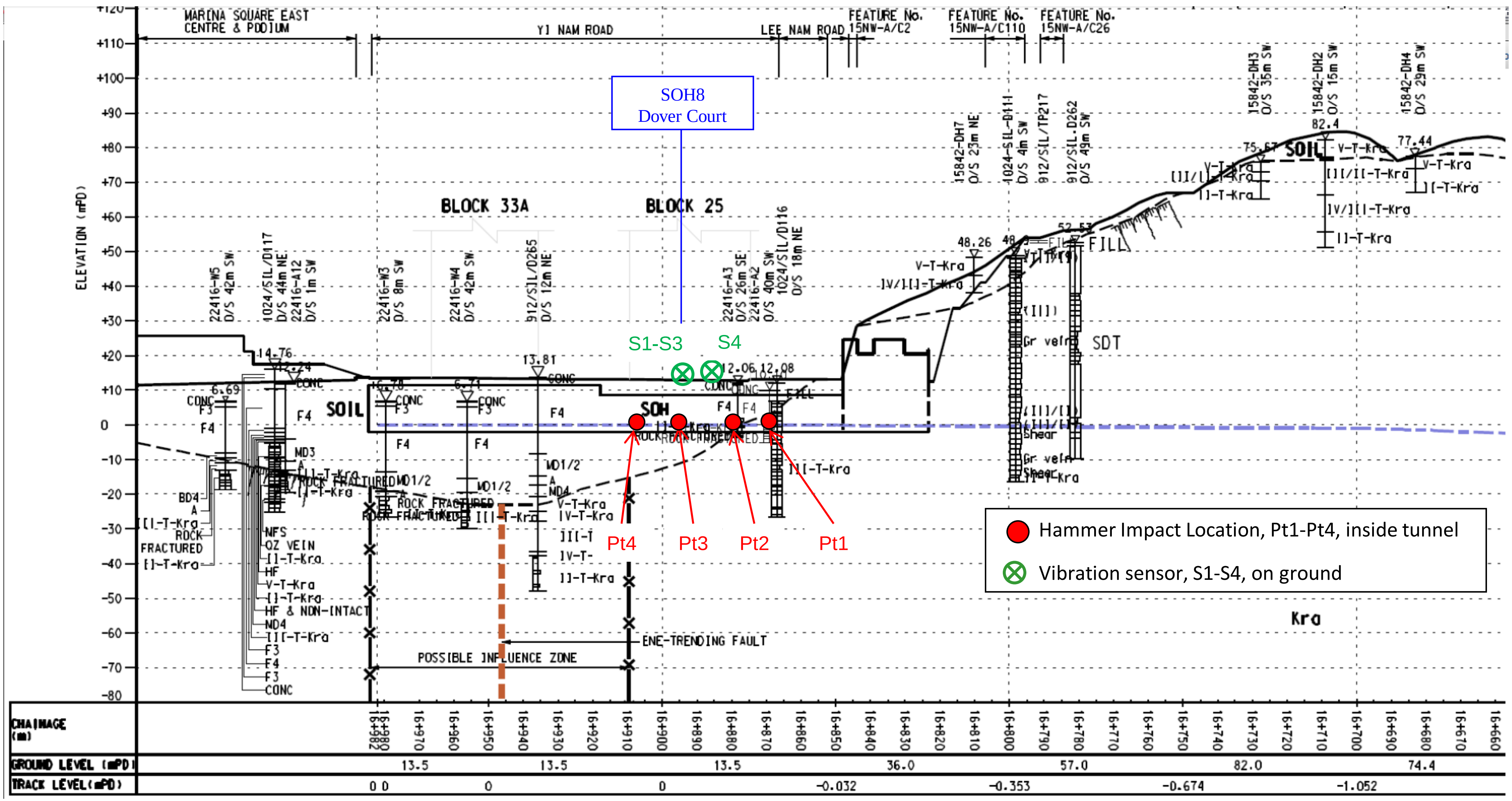


Figure 4.2

Vertical Alignment Showing Measurement Locations at SOH8 and Geological Profile

Date 25 Jun 2014

Environmental Resources Management

ERM

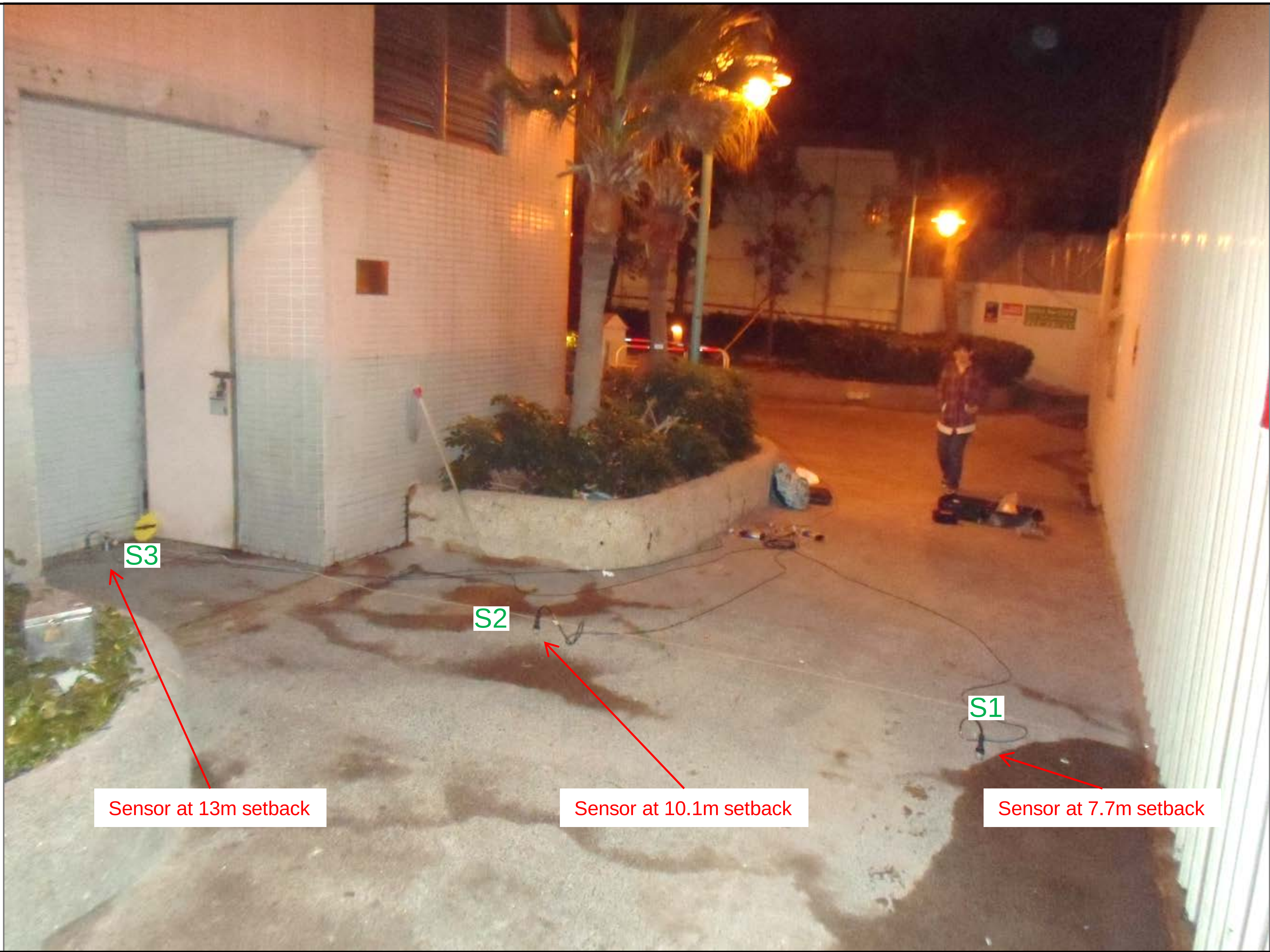


Figure 4.3

Measurement Photos Showing Locations of Vibration Sensors (S1-S3)

Date 25 Jun 2014

Environmental Resources Management

ERM

Figure 4.4

Measurement Photos Showing Locations of Vibration Sensors

Date 25 Jun 2014

Environmental Resources Management

ERM

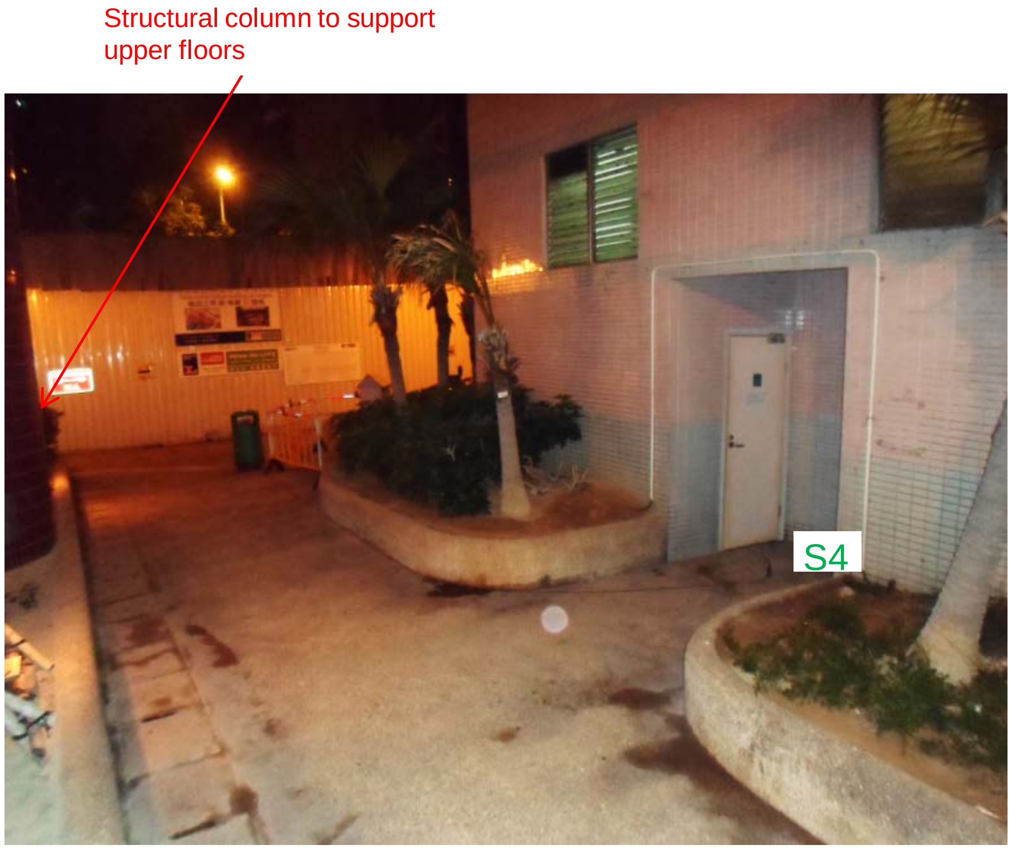


Figure 4.5

Photos Showing Locations of Vibration Sensors (S1-S4) are Within Building Structure

Date 25 Jun 2014

Environmental
Resources
Management

ERM

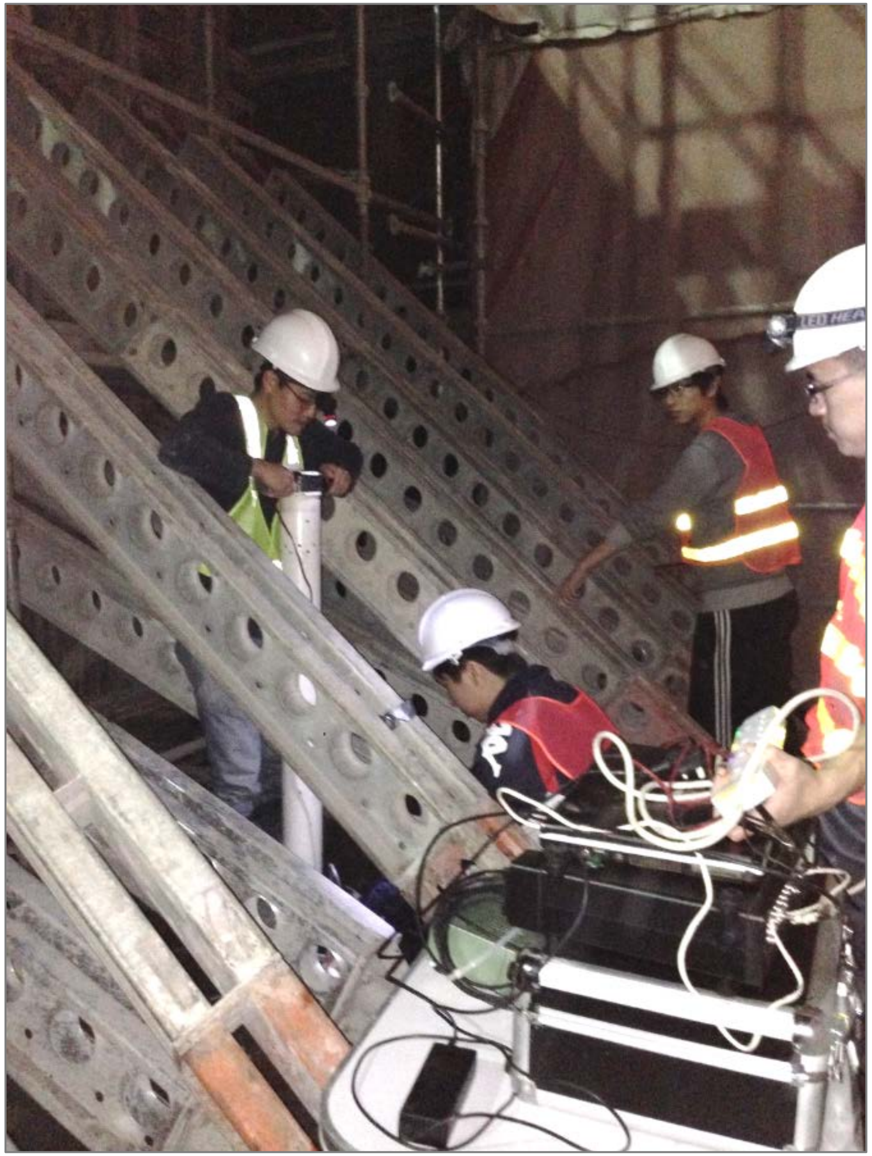


Figure 4.6 Hammer Impact Test at Pt1

Figure 4.7 Hammer Impact Test at Pt2

Figure 4.6 to 4.7

Hammer Impact Test at Pt1 and Pt2

Date 25 Jun 2014

Environmental Resources Management

ERM

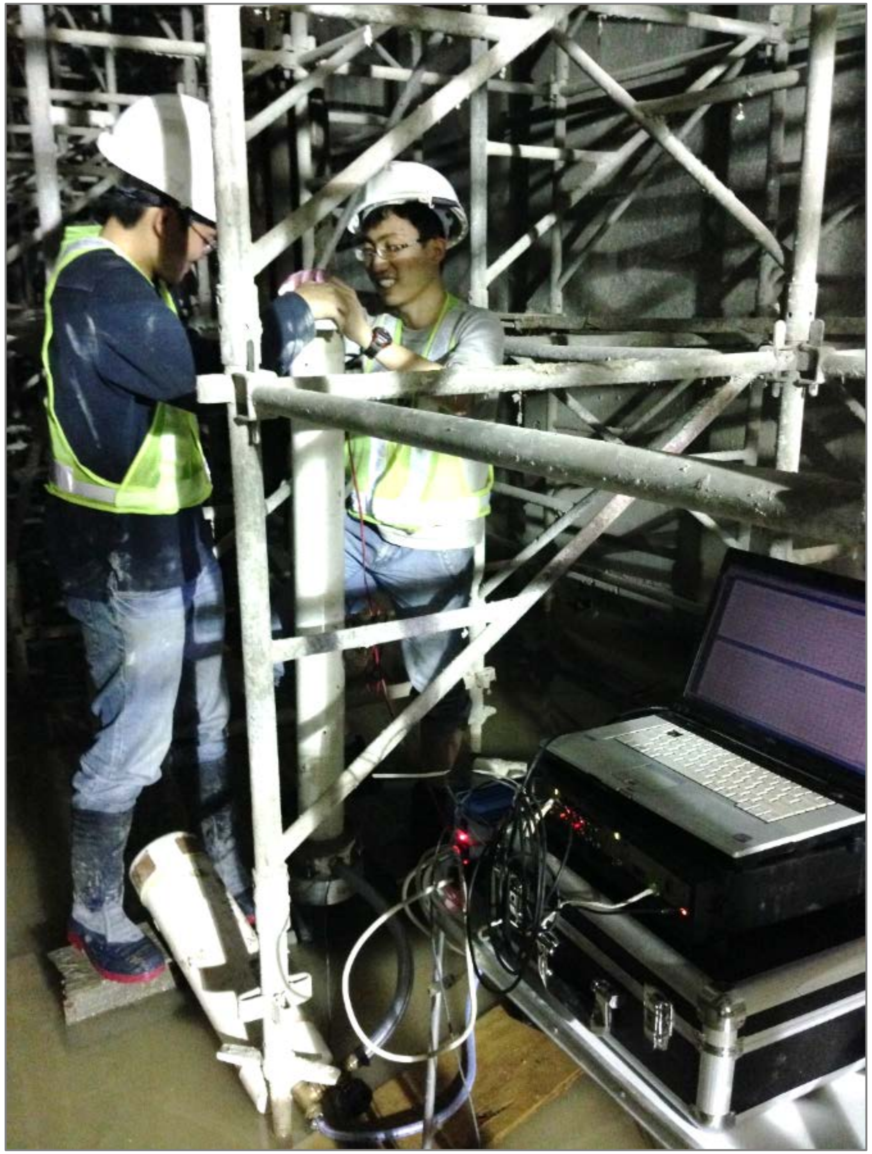


Figure 4.7 Hammer Impact Test at Pt3

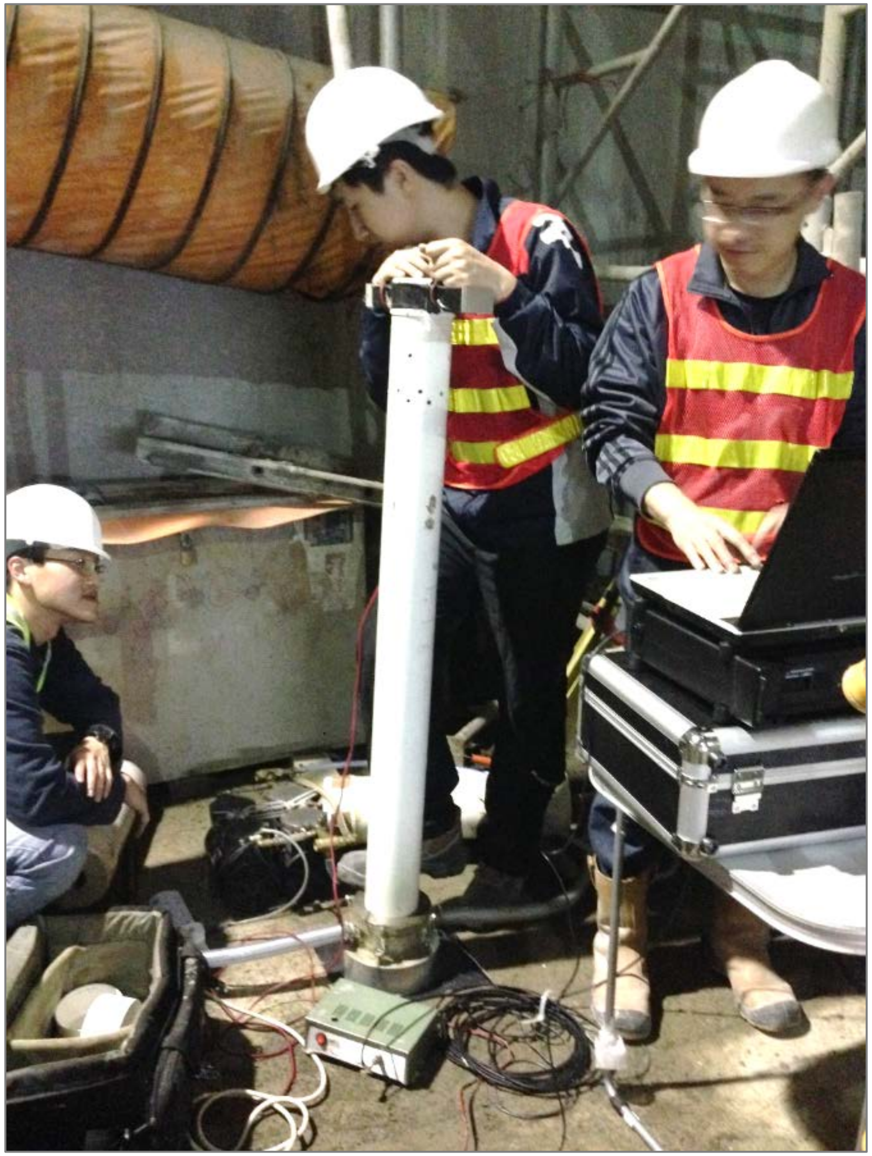


Figure 4.8 Hammer Impact Test at Pt4

Figure 4.8 to 4.9

Hammer Impact Test at Pt3 and Pt4

Date 25 Jun 2014

Environmental Resources Management

ERM

This page is deliberately left blank

5 MEASUREMENT RESULTS

The measured PSRs at the 4 hammer impact points are shown in Figures 5.1 to 5.4. Each PSR is the average of around 10 hammer impacts.

To determine the LSR, the PSRs that measured at S1, S2, S3 and S4 are subject to numerical integration. The detailed calculation methodology is presented in Annex D. The LSRs for SOH8 and SOH6 are determined as shown in Figure 5.5 and Figure 5.6 respectively. Since the hammer impact was conducted inside station structure, the determined LSR includes the coupling effect from station structure to soil, which is the Tunnel Coupling Loss (TCF). Also, the vibration sensors were placed on building foundation, the determined LSR includes the coupling effect from soil to building, which is the Building Foundation Coupling Loss (BCF). For direct comparison with the LSR adopted in the approved SIL(E) EIA Report, BCF and TCF are included in the LSR, which is the LSR+TCF+BCF, in order to project the result from outside to inside buildings.

It is found that the overall in situ measured LSR for SOH8 and SOH6 are lower than the LSR values adopted in the approved SIL(E) EIA Report, though the in situ measured LSRs are higher at some 1/3 octave bands.

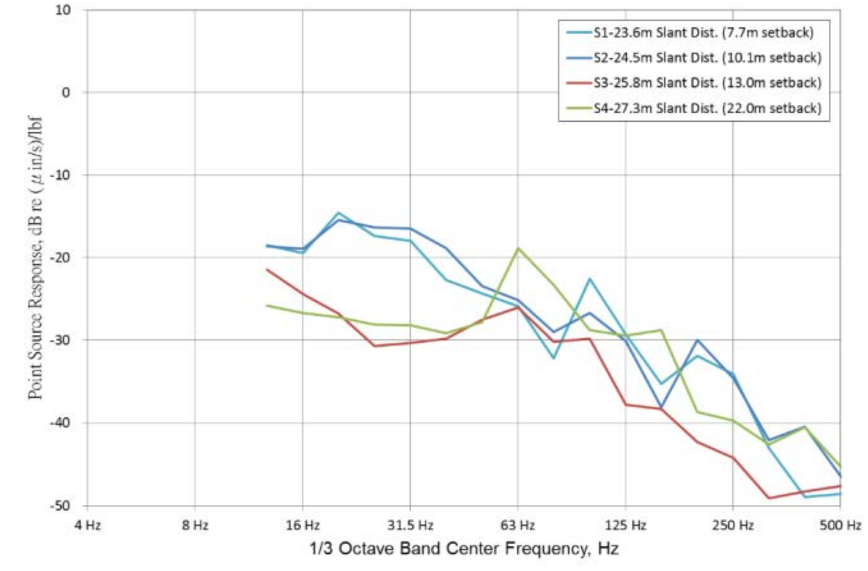


Figure 5.1 PSR at Hammer Impact Point Pt1

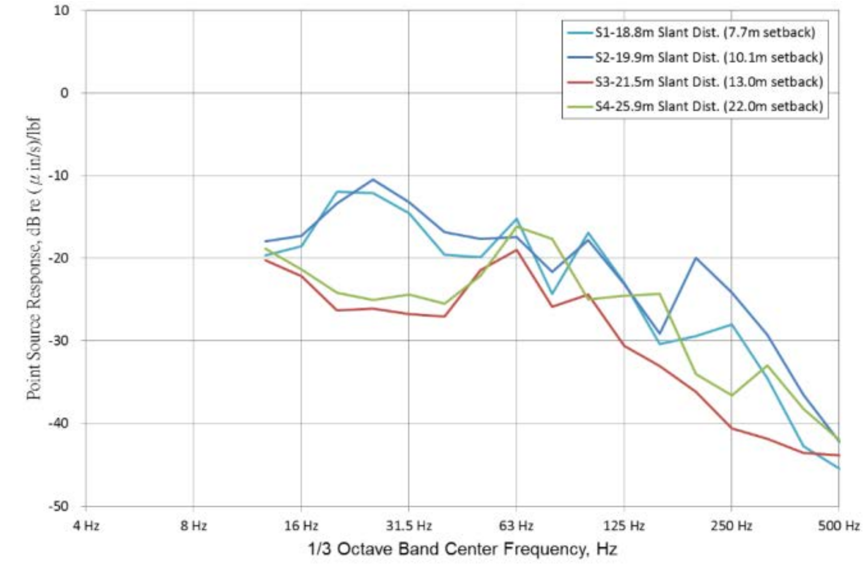


Figure 5.2 PSR at Hammer Impact Point Pt2

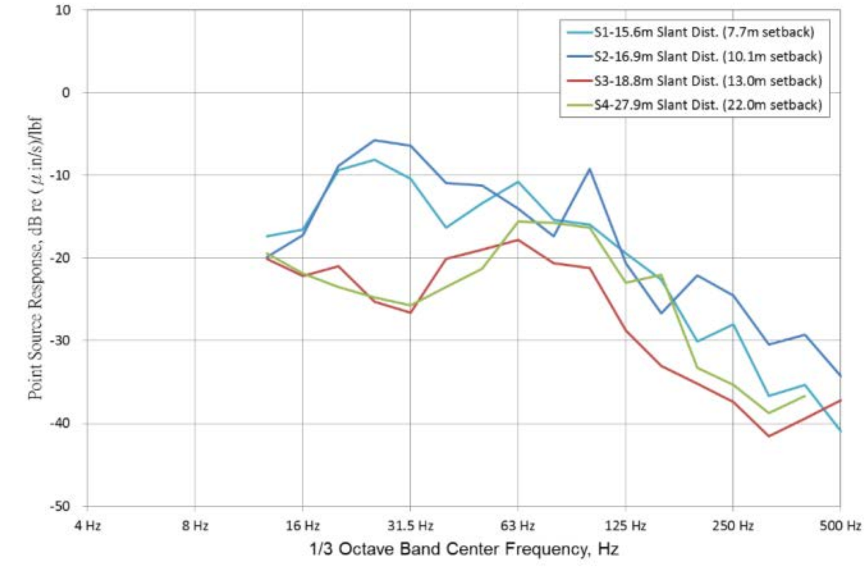


Figure 5.3 PSR at Hammer Impact Point Pt3

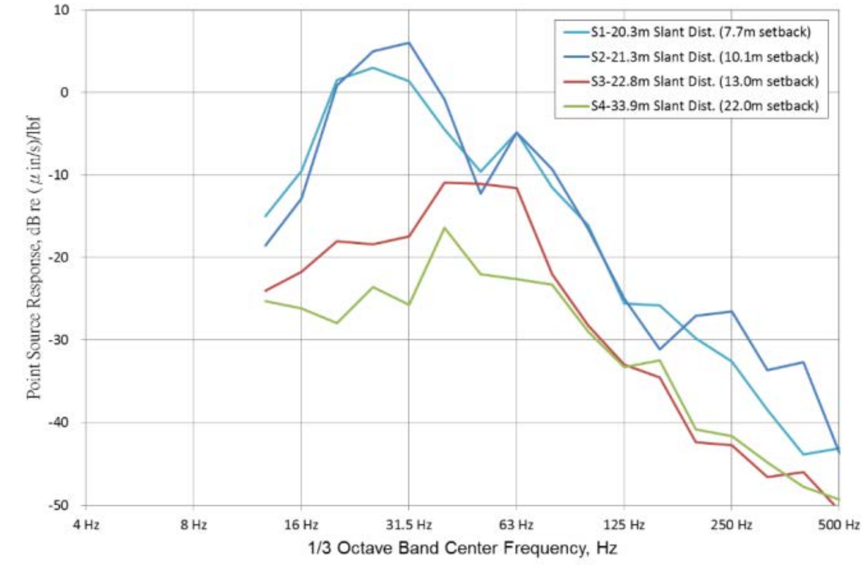


Figure 5.4 PSR at Hammer Impact Point Pt4

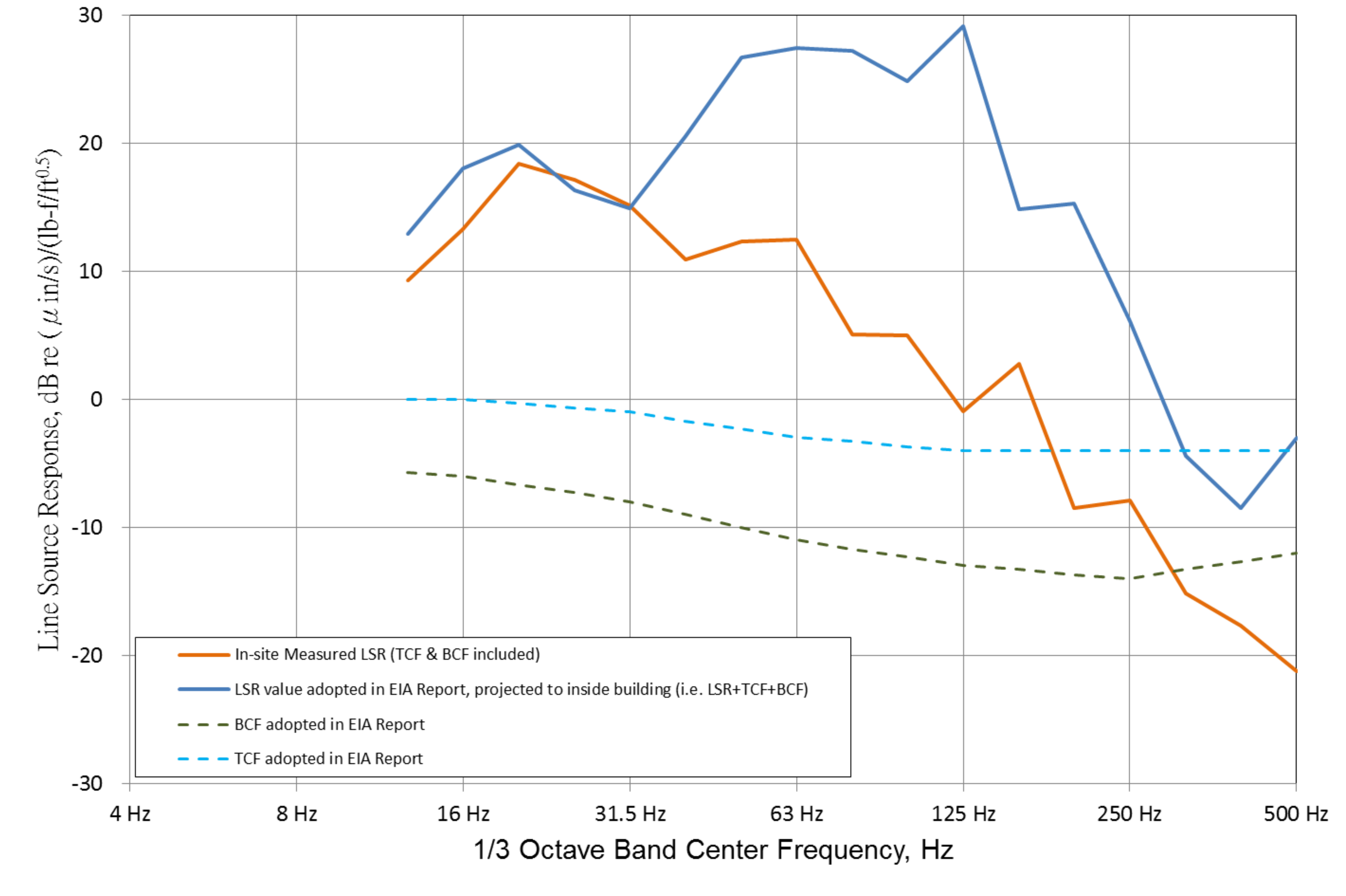
Figures 5.1 to 5.4

Point Source Response at different impact points
(Location of these impact points can be referred to Figure 4.1 and 4.2)

Date 25 Jun 2014

Environmental Resources Management

ERM



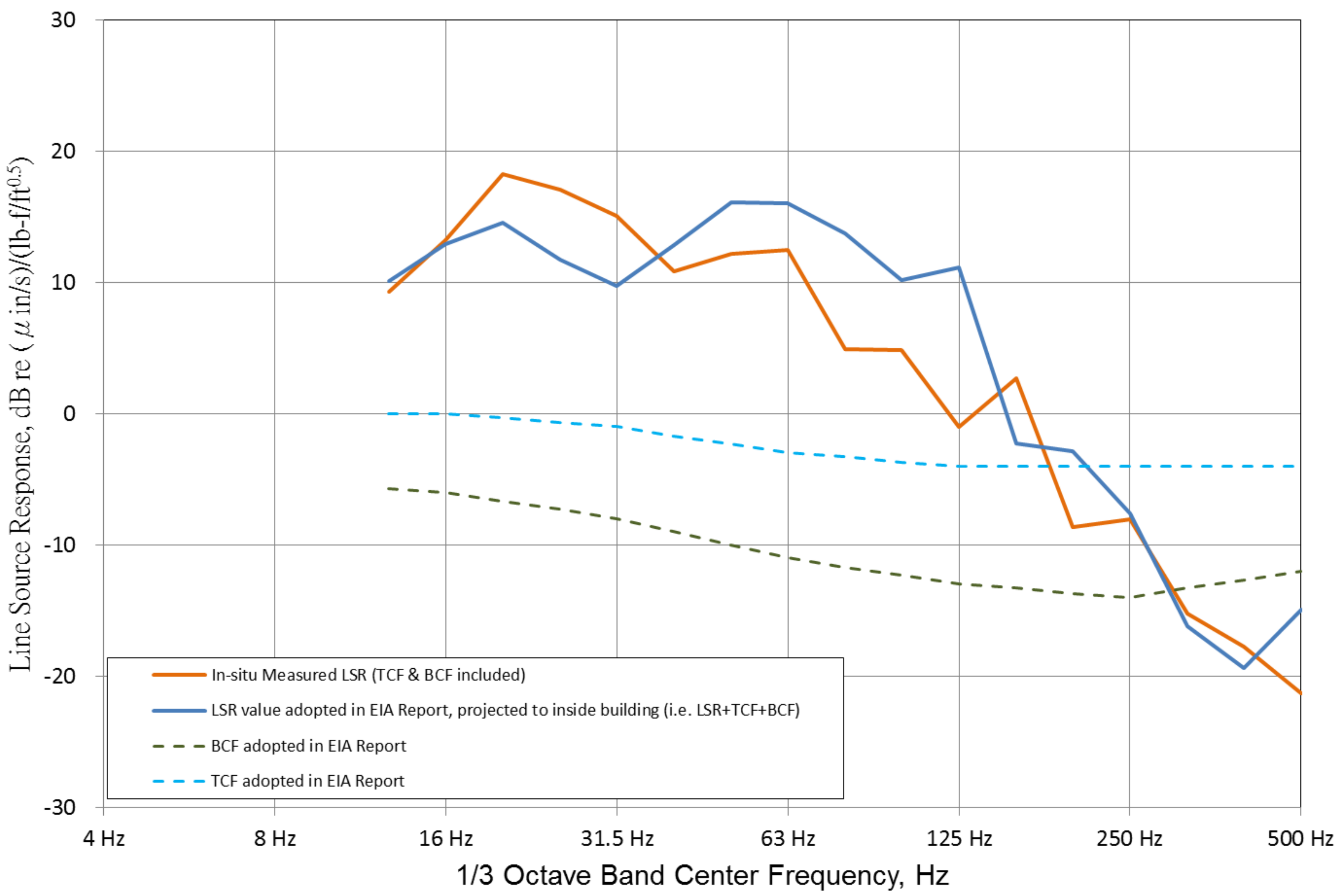
Figures 5.5

Line Source Response at SOH8

Date 25 Jun 2014

Environmental Resources Management

ERM



Figures 5.6

Line Source Response at SOH6

Date 25 Jun 2014

Environmental Resources Management

ERM

This page is deliberately left blank

6 GROUNDBORNE NOISE ASSESSMENT RESULTS

The GBN prediction has been updated following the calculation methodology adopted in the approved SIL(E) EIA Report.

The hammer impact point was inside the station structure, and the sensors were deployed on the building foundation, which indicates that TCF and BCF have been included in the LSR. The comparison of updated LSRs and that adopted in EIA are shown in *Figure 5.5* and *Figure 5.6*. For direct comparison, the LSR adopted in the Approved EIA Report presented in *Figure 5.5* and *Figure 5.6* also include the BCF and TCF.

The prediction results include a safety factor of 10dB(A). The operational GBN prediction results for SOH8 and SOH6 without mitigation, which are based on direct fixation trackform, are summarised in *Table 6.1*. In the approved SIL(E) EIA Report, operational GBN mitigation measure of type 1a resilient baseplate and inclined turnout are proposed within SOH station. The mitigated GBN levels, with the use of the same set of operational GBN mitigation measure, are summarised in *Table 6.2*. Detailed calculations are shown in *Annex A*. The calculations and assumptions follow that in the approved SIL(E) EIA Report.

Table 6.1 GBN Prediction Result - Unmitigated Scenario (direct fixation trackform)

NSR	GBN Parameter dB(A)	Prediction Results in the approved SIL(E) EIA Report	Updated Prediction in this Operational GBN Review Plan	Noise Criteria
SOH8	L_{max}	72	50	85
	L_{eq}, 30min (daytime and evening)	62	40	55
	L_{eq}, 30min (night-time)	60	38	45
SOH6	L_{max}	57	52	85
	L_{eq}, 30min (day-time and evening)	48	42	55
	L_{eq}, 30min (night-time)	45	40	45

Table 6.2 GBN Prediction Result - Mitigated Scenario (with type 1a resilient baseplate and inclined turnout within SOH station)

NSR	GBN Parameter dB(A)	Prediction Results in the approved SIL(E) EIA Report	Updated Prediction in this Operational GBN Review Plan	Noise Criteria
SHO8	L_{max}	55	35	85
	L_{eq}, 30min (daytime and evening)	46	26	55
	L_{eq}, 30min (night-time)	43	23	45
SOH6	L_{max}	42	37	85
	L_{eq}, 30min (day-time and evening)	32	27	55

NSR	GBN Parameter dB(A)	Prediction Results in the approved SIL(E) EIA Report	Updated Prediction in this Operational GBN Review Plan	Noise Criteria
	L_{eq}, 30min (night-time)	30	25	45

The updated prediction of operational GBN levels with the same operational GBN mitigation measures are lower than that predicted in the approved SIL(E) EIA Report. This is because the actual ground condition is found to be less favourable for vibration transmission than that assumed in the approved SIL(E) EIA Report.

7 GROUNDBORNE NOISE MITIGATION MEASURES

In accordance with the approved SIL(E) EIA Report, Type 1a trackform was proposed along the SIL(E) alignment. With reference to Section 3.5.2.3 of the approved SIL(E) EIA report, full compliance with the ground-borne Acceptable Noise Level (ANL) could be achieved by the use of incline turnout and Type 1a resilient baseplated trackform within the SOH station between chainage 16730 and 16980. The LSR and ground vibration conditions have been verified with details given in *Sections 2* to *6*.

With a more conservative approach for better performance and service to the community, an upgrade of trackform would be employed in SIL(E). A review of the upgraded trackform provision and the trackform proposed in the approved SIL(E) EIA Report is summarized in the *Table 7.1* below:

Table 7.1 Review of Trackform for SIL(E)

Chainage (Approx.)	Trackform proposed in the approved SIL(E) EIA Report	Upgraded Trackform for SIL(E)
DN 9915—10130 UP 9915—10130	Type 1a Resilient Baseplate Trackform [1]	Type 1 BCT Trackform Delkor Alt 1 Baseplate [2]
DN 10130—10250 UP 10130—10250		Turnout Trackform [3]
DN 10250—13310 UP 10250—13310		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 13310—13530 UP 13310—13530		Type 1 FST Trackform Delkor Alt 1 Baseplate [4]
DN 13530—14055 UP 13530—14075		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 14055—14080		Turnout Trackform
DN 14080—14310		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 14310—14335 UP 14075—14100		Turnout Trackform
DN 14335—14445 UP 14100—14525		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 14445—14470 UP 14525—14550		Turnout Trackform
DN 14470—15800 UP 14550—15800		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 15800—15900 UP 15800—15900		Type 2 Trackform WEB Supported Baseplate (i.e. Vanguard Baseplate) [5]
DN 15900—16715 UP 15900—16720		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 16715—16840 UP 16720—16830	Incline turnout and Type 1a Resilient Baseplate Trackform between Chainage 16730—16980	Turnout Trackform
DN 16840—16850 UP 16830—16850		Type 1 BCT Trackform Delkor Alt 1 Baseplate
DN 16850—16925 UP 16850—16930		Type 1 FST Trackform Delkor Alt 1 Baseplate
DN 16925—16970 UP 16930—16980		Type 1 BCT Trackform Delkor Alt 1 Baseplate

Chainage (Approx.)	Trackform proposed in the approved SIL(E) EIA Report	Upgraded Trackform for SIL(E)

Notes:

1. Type 1a Trackform is the resilient baseplated trackform with stiffness of 25 kN/mm
2. Type 1 BCT (Baseplated Concrete Tie) Trackform is the resilient baseplated trackform with track slab casted in-situ with sleepers. The trackform assembly is the same as Type 1a and using Delkor Alt 1 Baseplate with track stiffness of 20-25 kN/mm
3. Turnout Trackform is trackform at turnout location with resilient baseplate pad with overall stiffness of 25 kN/mm and inclined at 1 in 20
4. Type 1 FST (Floating Slab Track) Trackform is the resilient baseplated trackform with precast slab supported by rubber bearings underneath. The trackform assembly is the same as Type 1a and using Delkor Alt 1 Baseplate with track stiffness of 20-25 kN/mm
5. Type 2 Trackform with Web Supported Baseplate is the resilient baseplated trackform with track slab casted in-situ with sleepers. The baseplate is Vanguard Baseplate and track stiffness of 3-5 kN/mm

As shown in the *Table 7.1* above, the type of trackform proposed in the approved SIL(E) EIA Report would be upgraded to BCT Trackform, Turnout Trackform, FST Trackform with Delkor Alt 1 baseplate or Type 2 Trackform with Vanguard baseplate.

The upgraded trackform is more resilience than that proposed in the approved SIL(E) EIA Report, and hence would have better vibration attenuation. With the upgrade of trackform, the ground-borne noise impact from the operation of SIL(E) on the community will be less than it is predicted in the approved SIL(E) EIA Report.

8 *CONCLUSIONS*

Hammer impact test was conducted inside the tunnel near Dover Court (SOH8), which is the most critical NSR with respect to operational ground-borne noise impact identified in the approved SIL(E) EIA Report. The LSR of are determined and the operational GBN prediction for SOH8 and SOH6 have been updated using the determined LSR.

The updated GBN levels at SOH8 and SOH6 are lower than that predicted in the approved SIL(E) EIA Report. The predicted GBN levels, including 10dB safety factor, are well within the statutory requirements and therefore the GBN mitigation measures proposed in the approved SIL(E) EIA Report are considered to be adequate.

With a more conservative approach for better performance and service to the community, an upgrade of trackform would be employed in SIL(E). The upgraded trackform is more resilience than that proposed in the approved SIL(E) EIA Report, and hence would have better vibration attenuation. With the upgrade of trackform, the ground-borne noise impact from the operation of SIL(E) on the community will be less than it is predicted in the approved SIL(E) EIA Report.

Annex A

Updated Ground-borne Noise Prediction at SOH6 and SOH8

Project:	**SIL Operational Rail Noise Assessment**		Slant Dist, m	Train Speed, km/hr	Daytime Passby (both tracks) / 30min	Nightime Passby (both tracks) / 30min
NSR No.:	SOH8					
NSR Name:	South Horizons Phase IV - Dover Court Block 25	**Near Track**	14	35	30	16
Train Length	68 m					
No. of Basement Floors:	0					
NSR Floor:	5					

Descriptions	Unit	1/3 Octave Band Center Frequency																
		12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Near Track Vibration Calculation																		
FDL	dB re 1lbf/ft$^{0.5}$	47.6	40.8	41.8	47.5	44.6	47.6	42.7	40.6	44.7	47.7	48.5	48.0	44.1	46.3	42.1	39.0	38.1
Speed Correction (+20log(35kph/80kph))	dB	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
TOC	dB	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
TIL (no special treatment)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TCF (structure: station, included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Source Vibration Level	dB re 1μ-in/s	50.4	43.6	44.6	50.3	47.4	50.4	45.5	43.4	47.5	50.5	51.3	50.8	46.9	49.1	44.9	41.8	40.9
LSR (obtained inside building)	dB re 1(μ-in/s)/(lbf/ft$^{0.5}$)	9.3	13.3	18.4	17.1	15.1	10.9	12.3	12.5	5.0	5.0	-0.9	2.8	-8.5	-7.9	-15.2	-17.6	-21.2
BCF (included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BSA - Floor to Floor Attenuation	dB	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
BSR - Building Strcuture Resonance	dB	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Predicted Groundborne Vibration Level	dB re 1μ-in/s	55.7	52.9	59.0	63.4	58.5	57.3	53.8	51.9	48.5	51.5	46.4	49.6	34.4	37.2	25.7	20.2	15.7
A-weighting	dB	-63.4	-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	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAF (Design Factor)	dB	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Predicted Lmax	dB(A)	2.3	6.2	18.5	28.7	29.1	32.7	33.6	35.7	36.0	42.4	40.3	46.2	33.5	38.6	29.1	25.4	22.5
Predicted Lmax	dB(A)	50																
Correction for Passby Duration(10 log(7s))	dB	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Correction for Tailing Effect	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predicted SEL	dB	10.7	14.7	26.9	37.2	37.6	41.1	42.0	44.1	44.5	50.8	48.7	54.6	41.9	47.0	37.6	33.8	30.9
Predicted SEL	dB(A)	58																
Correction for no. of Train Passby, Daytime	dB	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
Correction for no. of Train Passby, Nightime	dB	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Correction for Duration Effect (-10 log(1800s))	dB	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6
Predicted Leq (30min, Daytime)	dB	-7.1	-3.1	9.1	19.4	19.8	23.4	24.3	26.3	26.7	33.0	30.9	36.8	24.2	29.2	19.8	16.0	13.1
Predicted Leq (30min, Daytime)	dB(A)	40																
Predicted Leq (30min, Nightime)	dB	-9.8	-5.9	6.4	16.7	17.1	20.6	21.5	23.6	24.0	30.3	28.2	34.1	21.4	26.5	17.1	13.3	10.4
Predicted Leq (30min, Nightime)	dB(A)	38																

Updated GBN Prediction at SOH8 (Unmitigated Scenario)

Date 25 Jun 2014

Environmental Resources Management

ERM

Project:	**SIL Operational Rail Noise Assessment**
NSR No.:	SOH8
NSR Name:	South Horizons Phase IV - Dover Court Block 25
Train Length	68 m
No. of Basement Floors:	0
NSR Floor:	5

	Slant Dist, m	Train Speed, km/hr	Daytime Passby (both tracks) / 30min	Nightime Passby (both tracks) / 30min
Near Track	14	35	30	16

Descriptions	Unit	1/3 Octave Band Center Frequency																
		12.5	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
Near Track Vibration Calculation																		
FDL	dB re 1lbf/ft$^{0.5}$	47.6	40.8	41.8	47.5	44.6	47.6	42.7	40.6	44.7	47.7	48.5	48.0	44.1	46.3	42.1	39.0	38.1
Speed Correction (+20log(35kph/80kph))	dB	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
TOC	dB	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
TIL (MTR Type 1a)	dB	0	-1	-4	-5	-3	-3	0	-9	-13	-10	-12	-12	-13	-12	-10	-5	-5
TCF (structure: station, included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Source Vibration Level	dB re 1μ-in/s	45.4	37.6	35.6	40.3	39.4	42.4	40.5	29.4	29.5	35.5	34.3	33.8	28.9	32.1	29.9	31.8	30.9
LSR (obtained inside building)	dB re 1(μ-in/s)/(lbf/ft$^{0.5}$)	9.3	13.3	18.4	17.1	15.1	10.9	12.3	12.5	5.0	5.0	-0.9	2.8	-8.5	-7.9	-15.2	-17.6	-21.2
BCF (included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BSA - Floor to Floor Attenuation	dB	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
BSR - Building Strcuture Resonance	dB	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Predicted Groundborne Vibration Level	dB re 1μ-in/s	50.7	46.9	50.0	53.4	50.5	49.3	48.8	37.9	30.5	36.5	29.4	32.6	16.4	20.2	10.7	10.2	5.7
A-w eighting	dB	-63.4	-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	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAF (Design Factor)	dB	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Predicted Lmax	dB(A)	-2.7	0.2	9.5	18.7	21.1	24.7	28.6	21.7	18.0	27.4	23.3	29.2	15.5	21.6	14.1	15.4	12.5
Predicted Lmax	dB(A)	35																
Correction for Passby Duration(10 log(7s))	dB	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Correction for Tailing Effect	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predicted SEL	dB	5.7	8.7	17.9	27.2	29.6	33.1	37.0	30.1	26.5	35.8	31.7	37.6	23.9	30.0	22.6	23.8	20.9
Predicted SEL	dB(A)	44																
Correction for no. of Train Passby, Daytime	dB	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
Correction for no. of Train Passby, Nightime	dB	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Correction for Duration Effect (-10 log(1800s))	dB	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6
Predicted Leq (30min, Daytime)	dB	-12.1	-9.1	0.1	9.4	11.8	15.4	19.3	12.3	8.7	18.0	13.9	19.8	6.2	12.2	4.8	6.0	3.1
Predicted Leq (30min, Daytime)	dB(A)	26																
Predicted Leq (30min, Nightime)	dB	-14.8	-11.9	-2.6	6.7	9.1	12.6	16.5	9.6	6.0	15.3	11.2	17.1	3.4	9.5	2.1	3.3	0.4
Predicted Leq (30min, Nightime)	dB(A)	23																

Updated GBN Prediction at SOH8 (Mitigated Scenario with Type 1a Baseplate and Inclined Turnout)

Date 25 Jun 2014

Environmental Resources Management

ERM

Project: SIL Operational Rail Noise Assessment
NSR No.: SOH6
NSR Name: South Horizons Phase III - Mei Ka Court Block 23A
Train Length 68 m
No. of Basement Floors: 0
NSR Floor: 4

	Slant Dist, m	Train Speed, km/hr	Daytime Passby (both tracks) / 30min	Nightime Passby (both tracks) / 30min
Near Track	16	35	30	16

Descriptions	Unit	1/3 Octave Band Center Frequency																
		12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Near Track Vibration Calculation																		
FDL	dB re 1lbf/ft$^{0.5}$	47.6	40.8	41.8	47.5	44.6	47.6	42.7	40.6	44.7	47.7	48.5	48.0	44.1	46.3	42.1	39.0	38.1
Speed Correction (+20log(35kph/80kph))	dB	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
TOC	dB	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
TIL (no special treatment)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TCF (structure: station, included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Source Vibration Level	dB re 1μ-in/s	50.4	43.6	44.6	50.3	47.4	50.4	45.5	43.4	47.5	50.5	51.3	50.8	46.9	49.1	44.9	41.8	40.9
LSR (obtained inside building)	dB re 1(μ-in/s)/(lbf/ft$^{0.5}$)	9.3	13.2	18.3	17.0	15.0	10.8	12.2	12.4	4.9	4.9	-1.0	2.7	-8.6	-8.0	-15.3	-17.7	-21.3
BCF (included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BSA - Floor to Floor Attenuation	dB	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
BSR - Building Strcuture Resonance	dB	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Predicted Groundborne Vibration Level	dB re 1μ-in/s	57.7	54.8	60.9	65.3	60.4	59.2	55.7	53.8	50.4	53.4	48.3	51.5	36.3	39.1	27.6	22.1	17.6
A-weighting	dB	-63.4	-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	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAF (Design Factor)	dB	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Predicted Lmax	dB(A)	4.3	8.1	20.4	30.6	31.0	34.6	35.5	37.6	37.9	44.3	42.2	48.1	35.4	40.5	31.0	27.3	24.4
Predicted Lmax	dB(A)	52																
Correction for Passby Duration(10 log(7s))	dB	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Correction for Tailing Effect	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predicted SEL	dB	12.7	16.6	28.8	39.1	39.5	43.0	43.9	46.1	46.4	52.7	50.6	56.5	43.8	48.9	39.5	35.7	32.8
Predicted SEL	dB(A)	60																
Correction for no. of Train Passby, Daytime	dB	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
Correction for no. of Train Passby, Nightime	dB	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Correction for Duration Effect (-10 log(1800s))	dB	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6
Predicted Leq (30min, Daytime)	dB	-5.1	-1.2	11.0	21.3	21.7	25.3	26.2	28.3	28.6	34.9	32.8	38.7	26.1	31.1	21.7	17.9	15.0
Predicted Leq (30min, Daytime)	dB(A)	42																
Predicted Leq (30min, Nightime)	dB	-7.8	-4.0	8.3	18.6	19.0	22.5	23.4	25.6	25.9	32.2	30.1	36.0	23.3	28.4	19.0	15.2	12.3
Predicted Leq (30min, Nightime)	dB(A)	40																

Updated GBN Prediction at SOH6 (Unmitigated Scenario)

Date 25 Jun 2014

Environmental Resources Management

ERM

Project: SIL Operational Rail Noise Assessment

NSR No.: SOH6

NSR Name: South Horizons Phase III - Mei Ka Court Block 23A

Train Length 68 m

No. of Basement Floors: 0

NSR Floor: 4

	Slant Dist, m	Train Speed, km/hr	Daytime Passby (both tracks) / 30min	Nightime Passby (both tracks) / 30min
Near Track	16	35	30	16

Descriptions	Unit	1/3 Octave Band Center Frequency																
		12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Near Track Vibration Calculation																		
FDL	dB re 1lbf/ft$^{0.5}$	47.6	40.8	41.8	47.5	44.6	47.6	42.7	40.6	44.7	47.7	48.5	48.0	44.1	46.3	42.1	39.0	38.1
Speed Correction (+20log(35kph/80kph))	dB	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
TOC	dB	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
TIL (MTR Type 1a)	dB	0	-1	-4	-5	-3	-3	0	-9	-13	-10	-12	-12	-13	-12	-10	-5	-5
TCF (structure: station, included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Source Vibration Level	dB re 1μ-in/s	45.4	37.6	35.6	40.3	39.4	42.4	40.5	29.4	29.5	35.5	34.3	33.8	28.9	32.1	29.9	31.8	30.9
LSR (obtained inside building)	dB re 1(μ-in/s)/(lbf/ft$^{0.5}$)	9.3	13.2	18.3	17.0	15.0	10.8	12.2	12.4	4.9	4.9	-1.0	2.7	-8.6	-8.0	-15.3	-17.7	-21.3
BCF (included in LSR)	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BSA - Floor to Floor Attenuation	dB	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
BSR - Building Strcuture Resonance	dB	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Predicted Groundborne Vibration Level	dB re 1μ-in/s	52.7	48.8	51.9	55.3	52.4	51.2	50.7	39.8	32.4	38.4	31.3	34.5	18.3	22.1	12.6	12.1	7.6
A-weighting	dB	-63.4	-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	dB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAF (Design Factor)	dB	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Predicted Lmax	dB(A)	-0.7	2.1	11.4	20.6	23.0	26.6	30.5	23.6	19.9	29.3	25.2	31.1	17.4	23.5	16.0	17.3	14.4
Predicted Lmax	dB(A)	37																
Correction for Passby Duration(10 log(7s))	dB	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Correction for Tailing Effect	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predicted SEL	dB	7.7	10.6	19.8	29.1	31.5	35.0	38.9	32.1	28.4	37.7	33.6	39.5	25.8	31.9	24.5	25.7	22.8
Predicted SEL	dB(A)	46																
Correction for no. of Train Passby, Daytime	dB	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
Correction for no. of Train Passby, Nightime	dB	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Correction for Duration Effect (-10 log(1800s))	dB	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6	-32.6
Predicted Leq (30min, Daytime)	dB	-10.1	-7.2	2.0	11.3	13.7	17.3	21.2	14.3	10.6	19.9	15.8	21.7	8.1	14.1	6.7	7.9	5.0
Predicted Leq (30min, Daytime)	dB(A)	28																
Predicted Leq (30min, Nightime)	dB	-12.8	-10.0	-0.7	8.6	11.0	14.5	18.4	11.6	7.9	17.2	13.1	19.0	5.3	11.4	4.0	5.2	2.3
Predicted Leq (30min, Nightime)	dB(A)	25																

Updated GBN Prediction at SOH6 (Mitigated Scenario with Type 1a Baseplate and Inclined Turnout)

Date 25 Jun 2014

Environmental Resources Management

ERM

Annex B

Equipment Calibration Certificates

SVANTEK

ISO9001 certified

FACTORY CALIBRATION DATA OF THE SVAN 958 *No. 23412*

SOUND LEVEL METER

1. CALIBRATION (electrical)

LEVEL METER; Filter: LIN; Input signal =114.0dB, f_{sin}=1kHz

	Range 105dB		Range 130dB	
	Indication [dB]	**Error** [dB]	**Indication** [dB]	**Error** [dB]
Channel 1	113.99	-0.01	114.04	0.04
Channel 2	113.99	-0.01	114.04	0.04
Channel 3	113.99	-0.01	114.04	0.04
Channel 4	113.99	-0.01	114.04	0.04

2. CALIBRATION* (acoustical)

LEVEL METER; Range: 130 dB; Reference frequency: 1000Hz;

Filter	LIN		A		C	
	Indication [dB]	**Error** [dB]	**Indication** [dB]	**Error** [dB]	**Indication** [dB]	**Error** [dB]
Channel 1	113.9	0.1	113.9	0.1	113.9	0.1
Channel 2	113.9	0.1	113.9	0.1	113.9	0.1
Channel 3	113.9	0.1	113.9	0.1	113.9	0.1
Channel 4	113.9	0.1	113.9	0.1	113.9	0.1

Calibration measured with the microphone SVANTEK type SV22 No. 4010479. Calibration factor: 0.2dB

3. LINEARITY TEST* (electrical)

LEVEL METER; Range: 105 dB; Filter: A; f_{sin}= 1000 Hz

	Input [dB]	24.0	30.0	40.0	60.0	80.0	100.0	114.0
Channel 1	**Error** [dB]	0.20	0.08	0.00	-0.02	0.00	0.01	0.01
Channel 2	**Error** [dB]	0.17	0.07	0.00	-0.02	0.00	0.01	0.01
Channel 3	**Error** [dB]	0.03	0.02	0.00	-0.02	0.00	0.01	0.00
Channel 4	**Error** [dB]	0.13	0.05	-0.01	-0.02	0.00	0.01	0.01

LEVEL METER; Range: 130 dB; Filter: A; f_{sin}= 1000 Hz

	Input [dB]	45.0	50.0	60.0	80.0	100.0	120.0	135.0
Channel 1	**Error** [dB]	0.00	0.08	0.04	0.01	0.01	0.00	0.01
Channel 2	**Error** [dB]	0.03	0.09	0.04	0.00	0.00	0.00	0.01
Channel 3	**Error** [dB]	0.00	0.00	0.01	0.01	0.01	0.00	0.01
Channel 4	**Error** [dB]	0.00	-0.01	0.00	0.00	0.00	0.00	0.03

1/3 OCTAVE (1kHz); Range: 130 dB; Filter: A; f_{sin}= 1000 Hz

	Input [dB]	35.0	40.0	60.0	80.0	100.0	120.0	135.0
Channel 1	**Error** [dB]	0.32	0.08	0.01	0.01	0.01	0.00	0.02
Channel 2	**Error** [dB]	0.37	0.04	0.01	0.01	0.01	0.00	0.02
Channel 3	**Error** [dB]	0.26	-0.12	-0.01	0.01	0.01	0.00	0.02
Channel 4	**Error** [dB]	0.25	-0.06	-0.02	0.01	0.01	0.00	0.03

4. TONEBURST RESPONSE* (electrical)

LEVEL METER: Characteristic: A; f_{sin}= 4000 Hz; Burst duration: 2s;

Range: **105dB**; Equivalent input steady level = 112dB

Result	Detector	Ch.	Duration [ms]	1000	500	200	100	50	20	10	5	2	1	0.5	0.25
MAX	Fast	1	**Indication** [dB]	112.0	111.9	111.0	109.4	107.2	103.7	100.9	97.9	94.0	91.0	87.9	84.9
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	-0.0	-0.0	-0.1	-0.1
		2	**Indication** [dB]	111.9	111.8	110.9	109.3	107.1	103.6	100.8	97.8	93.9	90.9	87.8	84.8
			Error [dB]	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.0	-0.1	-0.1
		3	**Indication** [dB]	112.1	112.0	111.1	109.5	107.2	103.8	100.9	98.0	94.0	91.0	88.0	84.9
			Error [dB]	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.1	-0.1	-0.1
		4	**Indication** [dB]	112.0	111.9	111.0	109.4	107.1	103.7	100.8	97.9	93.9	90.9	87.9	84.8
			Error [dB]	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.1	-0.1	-0.1
	Slow	1	**Indication** [dB]	110.0	108.0	104.6	101.8	98.9	95.0	92.0	89.0	85.0	-	-	-
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
		2	**Indication** [dB]	109.9	107.9	104.5	101.7	98.8	94.9	91.9	88.9	84.9	-	-	-
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
		3	**Indication** [dB]	110.1	108.0	104.7	101.9	99.0	95.0	92.0	89.0	85.0	-	-	-
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
		4	**Indication** [dB]	110.0	107.9	104.5	101.7	98.8	94.9	91.9	88.9	84.9	-	-	-
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
SEL	-	1	**Indication** [dB]	112.0	109.0	105.0	102.0	99.0	95.0	92.0	89.0	85.0	82.0	78.9	75.9
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1
		2	**Indication** [dB]	111.9	108.9	104.9	101.9	98.9	94.9	91.9	88.9	84.9	81.9	78.8	75.8
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.1
		3	**Indication** [dB]	112.1	109.1	105.1	102.1	99.1	95.1	92.1	89.0	85.0	82.0	79.0	75.9
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1
		4	**Indication** [dB]	112.0	109.0	105.0	102.0	99.0	95.0	92.0	88.9	84.9	81.9	78.9	75.8
			Error [dB]	-0.0	-0.0	0.0	-0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1

Range: **105dB**; Equivalent input steady level = 52dB

Result	Detector	Ch.	Duration [ms]	1000	500	200	100	50	20	10	5
MAX	Fast	1	**Indication** [dB]	52.0	51.9	51.0	49.4	47.2	43.7	40.9	38.0
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.1
		2	**Indication** [dB]	51.9	51.8	50.9	49.3	47.1	43.6	40.8	37.8
			Error [dB]	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	0.0
		3	**Indication** [dB]	52.1	52.0	51.1	49.5	47.2	43.8	40.9	38.0
			Error [dB]	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	0.0
		4	**Indication** [dB]	52.0	51.9	51.0	49.4	47.1	43.7	40.8	37.9
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	0.0	-0.0	0.0
	Slow	1	**Indication** [dB]	50.0	48.0	44.6	41.8	38.9	35.0	32.0	29.1
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	0.0	0.1
		2	**Indication** [dB]	49.9	47.9	44.5	41.7	38.8	34.9	31.9	28.9
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0
		3	**Indication** [dB]	50.1	48.0	44.7	41.9	39.0	35.1	32.1	29.1
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	0.0	0.0
		4	**Indication** [dB]	50.0	47.9	44.6	41.8	38.9	35.0	32.0	29.0
			Error [dB]	0.0	0.1	0.0	-0.0	-0.0	0.0	0.0	0.1
SEL	-	1	**Indication** [dB]	52.0	49.0	45.0	42.0	39.0	35.1	32.1	29.2
			Error [dB]	0.0	-0.0	0.0	0.0	0.0	0.1	0.1	0.2
		2	**Indication** [dB]	51.9	48.9	44.9	41.9	38.9	35.0	32.0	29.1
			Error [dB]	-0.0	-0.0	0.0	0.0	0.0	0.1	0.1	0.2
		3	**Indication** [dB]	52.1	49.1	45.1	42.1	39.1	35.1	32.2	29.3
			Error [dB]	0.0	-0.0	0.0	0.0	0.0	0.1	0.1	0.2
		4	**Indication** [dB]	52.0	49.0	45.0	42.0	39.0	35.1	32.1	29.2
			Error [dB]	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3

Range: **105dB**; Equivalent input steady level = 34dB

Result	Detector	Ch.	Duration [ms]	1000	500
MAX	Fast	1	**Indication** [dB]	34.0	33.9
			Error [dB]	-0.0	-0.0
		2	**Indication** [dB]	33.9	33.8
			Error [dB]	0.0	-0.0
		3	**Indication** [dB]	34.0	33.9
			Error [dB]	0.0	-0.0
		4	**Indication** [dB]	34.0	33.9
			Error [dB]	0.0	0.0
	Slow	1	**Indication** [dB]	32.0	29.9
			Error [dB]	-0.0	0.0
		2	**Indication** [dB]	31.9	29.9
			Error [dB]	0.0	0.1
		3	**Indication** [dB]	32.0	30.0
			Error [dB]	0.0	0.1
		4	**Indication** [dB]	31.9	29.9
			Error [dB]	0.0	0.1
SEL	-	1	**Indication** [dB]	34.0	31.1
			Error [dB]	0.0	0.1
		2	**Indication** [dB]	33.9	31.0
			Error [dB]	0.0	0.1
		3	**Indication** [dB]	34.0	31.1
			Error [dB]	0.0	0.1
		4	**Indication** [dB]	34.0	31.0
			Error [dB]	0.1	0.1

Range: **130dB**; Equivalent input steady level = 134dB

Result	Detector	Ch.	Duration [ms]	1000	500	200	100	50	20	10	5	2	1	0.5	0.25
MAX	Fast	1	**Indication** [dB]	134.0	133.9	133.0	131.4	129.2	125.7	122.8	119.9	116.0	113.0	109.9	106.9
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.0	-0.1	-0.1
		2	**Indication** [dB]	133.9	133.8	132.9	131.3	129.1	125.6	122.7	119.8	115.9	112.8	109.8	106.8
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.1	-0.1	-0.1
		3	**Indication** [dB]	134.1	134.0	133.1	131.5	129.2	125.8	122.9	120.0	116.0	113.0	110.0	106.9
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.1	-0.1	-0.1
		4	**Indication** [dB]	134.0	133.9	133.0	131.4	129.1	125.7	122.8	119.9	115.9	112.9	109.9	106.9
			Error [dB]	0.0	0.0	0.0	0.0	129.1	-0.0	-0.1	0.0	-0.0	-0.1	-0.1	-0.1
	Slow	1	**Indication** [dB]	132.0	129.9	126.6	123.8	120.9	117.0	114.0	111.0	107.0	-	-	-
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
		2	**Indication** [dB]	131.9	129.8	126.5	123.7	120.8	116.9	113.9	110.9	106.9	-	-	-
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
		3	**Indication** [dB]	132.1	130.0	126.7	123.9	121.0	117.0	114.0	111.0	107.0	-	-	-
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
		4	**Indication** [dB]	132.0	129.9	126.5	123.8	120.9	116.9	113.9	110.9	107.0	-	-	-
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-	-	-
SEL	-	1	**Indication** [dB]	134.0	131.0	127.0	124.0	121.0	117.0	114.0	111.0	107.0	104.0	100.9	97.9
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.1
		2	**Indication** [dB]	133.9	130.9	126.9	123.9	120.9	116.9	113.9	110.9	106.9	103.9	100.8	97.8
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.1
		3	**Indication** [dB]	134.1	131.1	127.1	124.1	121.0	117.1	114.1	111.0	107.0	104.0	101.0	97.9
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1
		4	**Indication** [dB]	134.0	131.0	127.0	124.0	121.0	117.0	114.0	111.0	107.0	103.9	100.9	97.8
			Error [dB]	0.0	-0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1

Range: **130dB**: Equivalent input steady level = 74dB

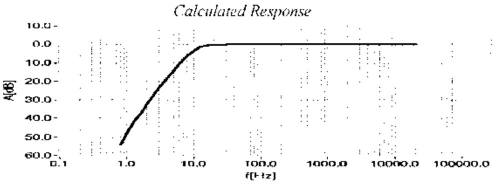
Result	Detector	Ch.	Duration [ms]	1000	500	200	100	50	20	10	5
MAX	Fast	1	**Indication [dB]**	74.0	73.9	73.0	71.4	69.2	65.7	62.9	59.9
			Error [dB]	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
		2	**Indication [dB]**	73.9	73.8	72.9	71.3	69.1	65.6	62.7	59.8
			Error [dB]	0.0	0.0	72.9	0.0	-0.0	-0.0	-0.1	0.0
		3	**Indication [dB]**	74.1	74.0	73.1	71.5	69.2	65.8	62.9	60.0
			Error [dB]	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.0
		4	**Indication [dB]**	74.0	73.9	73.0	71.4	69.1	65.7	62.8	59.9
			Error [dB]	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.1	0.0
	Slow	1	**Indication [dB]**	72.0	70.0	66.6	63.8	60.9	57.0	54.0	51.0
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	0.0	-0.0
		2	**Indication [dB]**	71.9	69.9	66.5	63.7	60.8	56.9	53.9	50.9
			Error [dB]	0.0	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
		3	**Indication [dB]**	72.1	70.0	66.7	63.9	61.0	57.0	54.1	51.0
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
		4	**Indication [dB]**	72.0	69.9	66.5	63.7	60.8	56.9	54.0	51.0
			Error [dB]	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
SEL	-	1	**Indication [dB]**	74.0	71.0	67.0	64.0	61.0	57.0	54.1	51.1
			Error [dB]	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
		2	**Indication [dB]**	73.9	70.9	66.9	63.9	60.9	57.0	53.9	51.0
			Error [dB]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		3	**Indication [dB]**	74.1	71.1	67.1	64.1	61.1	57.1	54.1	51.1
			Error [dB]	-0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	0.1
		4	**Indication [dB]**	74.0	71.0	67.0	64.0	61.0	57.0	54.0	51.1
			Error [dB]	0.0	-0.0	0.0	-0.0	-0.0	0.0	0.1	0.1

Range: **130dB**; Equivalent input steady level = 54dB

Result	Detector	Ch.	Duration [ms]	1000	500
MAX	Fast	1	**Indication [dB]**	54.0	53.9
			Error [dB]	0.0	0.0
		2	**Indication [dB]**	54.0	53.9
			Error [dB]	0.0	0.0
		3	**Indication [dB]**	54.1	53.9
			Error [dB]	0.0	0.0
		4	**Indication [dB]**	53.9	53.8
			Error [dB]	0.0	-0.0
	Slow	1	**Indication [dB]**	52.0	50.0
			Error [dB]	0.0	0.1
		2	**Indication [dB]**	52.0	50.0
			Error [dB]	0.0	0.1
		3	**Indication [dB]**	52.0	50.0
			Error [dB]	0.0	0.1
		4	**Indication [dB]**	51.9	49.9
			Error [dB]	0.0	0.1
SEL	-	1	**Indication [dB]**	54.1	51.1
			Error [dB]	0.1	0.1
		2	**Indication [dB]**	54.0	51.1
			Error [dB]	0.0	0.1
		3	**Indication [dB]**	54.1	51.1
			Error [dB]	0.0	0.1
		4	**Indication [dB]**	54.0	51.0
			Error [dB]	0.1	0.1

6. FREQUENCY RESPONSE (electrical)

LEVEL METER; Filter: Z; Range: 130 dB; Input signal =135 dB;



Measured Response with Preamplifier SV12 (f-frequency, An-attenuation in channel n)

f [Hz]	A1[dB]	A2[dB]	A3[dB]	A4[dB]	f [Hz]	A1[dB]	A2[dB]	A3[dB]	A4[dB]
10	3.2	3.2	3.2	3.1	250	0.0	-0.0	0.0	-0.0
12.5	1.4	1.4	1.4	1.3	500	0.0	-0.0	0.0	-0.0
16	0.5	0.5	0.5	0.5	1000	0.0	-0.0	0.0	-0.0
20	0.2	0.2	0.1	0.1	2000	0.0	-0.0	0.0	-0.0
25	0.0	-0.0	0.0	-0.0	4000	0.0	-0.0	0.0	-0.0
31.5	0.0	-0.0	-0.1	-0.1	8000	0.1	0.1	0.0	-0.0
63	0.0	-0.0	0.0	-0.0	16000	0.1	0.1	0.0	-0.0
125	0.0	-0.0	0.0	-0.0	20000	0.0	-0.0	0.0	-0.0

All frequencies are nominal center values for the 1/3 octave bands

7. INTERNAL NOISE LEVEL* (electrical)

LEVEL METER; Range: 105 dB; Back-light – off; Calibration factor: 0dB

	Filter	Z	A	C
Channel 1	Level [dB]	13.5	11.8	10.3
Channel 2	Level [dB]	14.6	11.6	10.0
Channel 3	Level [dB]	11.8	11.1	10.0
Channel 4	Level [dB]	15.3	12.2	11.4

---

* measured with preamplifier SVANTEK type SV12 No. 1992.

VIBRATION LEVEL METER

1. CALIBRATION (electrical)

LEVEL METER; Filter: HP10; Input signal =140.0dB (10.0 m/s²), f_{sin}=79.6Hz

	Range 145dB		Range 170dB	
	Indication [dB]	Error [dB]	Indication [dB]	Error [dB]
Channel 1	139.99	-0.01	140.05	0.05
Channel 2	139.99	-0.01	140.05	0.05
Channel 3	140.00	0.00	140.05	0.05
Channel 4	140.00	0.00	140.05	0.05

2. CALIBRATION (vibrational)

LEVEL METER; Range: 145dB; Input signal: 120dB;

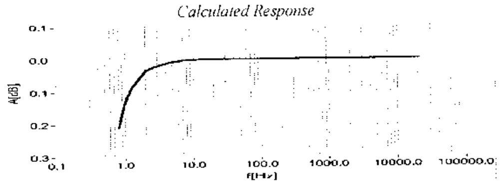
Filter	HP1		HP10		Wd		Wm		Wh	
	Indication [dB]	Error [dB]	Indication [dB]	Error [dB]	Indication [dB]	Error [dB]	Indication [dB]	Error [dB]	Indication [dB]	Error [dB]
Channel 1	119.7	-0.3	119.8	-0.2	105.9	-0.2	107.9	-0.2	115.1	-0.2
Channel 2	119.8	-0.2	119.8	-0.2	106.0	-0.1	107.9	-0.2	115.1	-0.2
Channel 3	119.8	-0.2	119.9	-0.1	105.9	-0.2	108.0	-0.1	115.1	-0.2
Channel 4	119.8	-0.2	119.8	-0.2	105.9	-0.2	107.9	-0.2	115.1	-0.2

Calibration measured with the accelerometer SVANTEK type SV80 No. B5841. Calibration factor: -0.5dB

3. FREQUENCY RESPONSE (electrical)

1/3 OCTAVE: Filter: HP; Range: 170 dB; input=175 dB;

Calculated Response



Measured Response (f-frequency; An-attenuation in channel n)

f [Hz]	A1[dB]	A2[dB]	A3[dB]	A4[dB]	f [Hz]	A1[dB]	A2 [dB]	A3[dB]	A4[dB]	f [Hz]	A1[dB]	A2[dB]	A3[dB]	A4[dB]
0.8	0.21	0.21	0.20	0.20	5	0.02	0.02	0.01	0.02	500	0.00	0.00	-0.01	0.00
1	0.15	0.15	0.14	0.15	6.3	0.01	0.01	0.00	0.01	1000	0.01	0.01	0.00	0.00
1.25	0.08	0.08	0.07	0.08	8	0.01	0.02	0.01	0.01	2000	0.01	0.01	0.00	0.01
1.6	0.05	0.05	0.04	0.04	16	0.01	0.01	0.00	0.01	4000	0.02	0.02	0.01	0.02
2	0.06	0.06	0.05	0.05	31.5	0.01	0.01	0.00	0.00	8000	0.05	0.05	0.04	0.05
2.5	0.04	0.04	0.03	0.03	63	0.00	0.01	0.00	0.00	16000	0.03	0.04	0.02	0.03
3.15	0.02	0.02	0.01	0.02	125	0.00	0.00	-0.01	0.00	20000	0.00	0.03	0.02	0.00
4	0.01	0.01	0.00	0.01	250	0.00	0.00	-0.01	0.00					

All frequencies are nominal center values for the 1/3 octave bands

4. INTERNAL NOISE LEVEL (electrical)

LEVEL METER func.; Range: 145 dB; Back-light – off

	Filter	HP1	HP10	Wd	Wm	Wh
Channel 1	**Indication [dB]**	56.1	53.8	42.6	42.7	37.6
Channel 2	**Indication [dB]**	55.0	52.8	42.3	38.7	36.4
Channel 3	**Indication [dB]**	54.5	52.6	42.0	38.7	35.8
Channel 4	**Indication [dB]**	54.7	52.3	42.4	39.5	36.4

ENVIRONMENTAL CONDITIONS

Temperature	Relative humidity	Ambient pressure
22 °C	26 %	982 hPa

TEST EQUIPMENT

Item	Manufacturer	Model	Serial no.	Description
1.	SVANTEK	SVAN 401	87	Signal generator
2.	SVANTEK	SVAN 912A	6120	Sound & Vibration Analyser
3.	KEITHLEY	2000	0910165	Digital multimeter
4.	SVANTEK	SV30A	5369	Acoustic calibrator
5.	SVANTEK	ST02	-	Microphone equivalent electrical impedance (18pF)
6.	DYTRAN	3233A	436	Reference accelerometer

CONFORMITY & TEST DECLARATION

1. Herewith Svantek company declares that this instrument has been calibrated and tested in compliance with the internal ISO9001 procedures and meets all specification given in the Manual(s) or respectively surpass them.

2. Tracebility of the calibration is guarantied by the above mentioned ISO9001 procedures.

3. The information appearing on this sheet has been compiled specifically for this instrument. This form is produced with advanced equipment & procedures which permit comprehensive quality assurance verification of all data supplied herein.

4. This calibration sheet shall not be reproduced except in full, without written permission of the SVANTEK Ltd.

Calibration specialist: Waclaw Skarżycki .... Test date: 2013-03-19

~ *Calibration Certificate* ~

Per ISO 16063-21

Model Number: 393A03

Serial Number: 36982

Description: ICP® Accelerometer

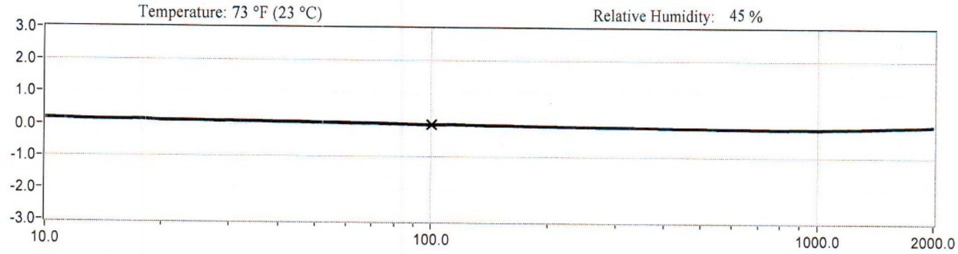
Method: Back-to-Back Comparison (AT401-3)

Manufacturer: PCB

Calibration Data

Sensitivity @ 100.0 Hz	**1008**	**mV/g**	Output Bias	11.0	VDC
	(102.7	**mV/m/s²)**	Transverse Sensitivity	2.7	%
Discharge Time Constant	1.0	seconds	Resonant Frequency	14.3	kHz

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10.0	2.0	300.0	-0.8
15.0	1.5	500.0	-1.2
30.0	1.1	1000.0	-1.5
50.0	0.7	2000.0	-0.4
REF. FREQ.	0.0		

Mounting Surface: Stainless Steel w/Silicone Grease Coating Fastener: Stud Mount Fixture Orientation: Vertical
Acceleration Level (rms)[1]: 1.00 g (9.81 m/s²)[2]

[1]The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude; Acceleration Level (g) = 0.010 x (freq)².

[2]The gravitational constant used for calculations by the calibration system is; 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Scott Skibniewski Date: 01/23/13

ACCREDITED
CALIBRATION CERT #1862.02

PCB PIEZOTRONICS
VIBRATION DIVISION

Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

cal57 - 3441803071.01

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393A03

Serial Number: 36981

Description: ICP® Accelerometer

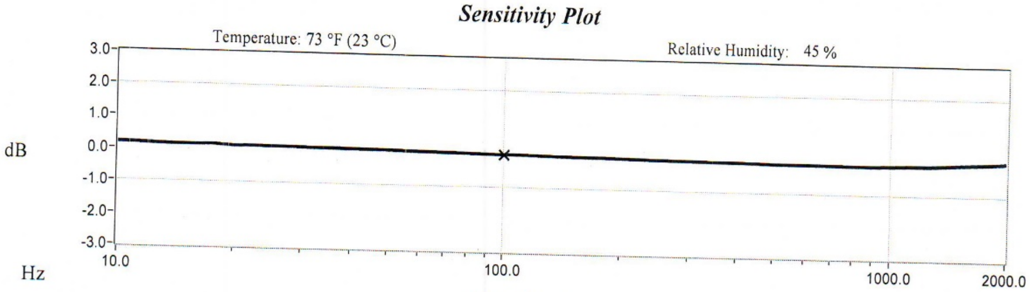
Manufacturer: PCB

Method: Back-to-Back Comparison (AT401-3)

Calibration Data

Sensitivity @ 100.0 Hz	**1004**	**mV/g**	Output Bias	10.8	VDC
	(102.4	**mV/m/s²)**	Transverse Sensitivity	1.5	%
Discharge Time Constant	1.2	seconds	Resonant Frequency	13.1	kHz

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10.0	2.0	300.0	-0.7
15.0	1.5	500.0	-1.1
30.0	1.1	1000.0	-1.2
50.0	0.8	2000.0	0.5
REF. FREQ.	0.0		

Mounting Surface: Stainless Steel w/Silicone Grease Coating Fastener: Stud Mount Fixture Orientation: Vertical
Acceleration Level (rms)[1]: 1.00 g (9.81 m/s²)[2]

[1]The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude; Acceleration Level (g) = 0.010 x (freq)².
[2]The gravitational constant used for calculations by the calibration system is; 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Scott Skibniewski

Date: 01/23/13

ACCREDITED
CALIBRATION CERT #1862.02

PCB PIEZOTRONICS
VIBRATION DIVISION
Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

cal57 - 3441802883.09

~ *Calibration Certificate* ~

Per ISO 16063-21

Model Number: 393A03

Serial Number: 37179

Description: ICP® Accelerometer

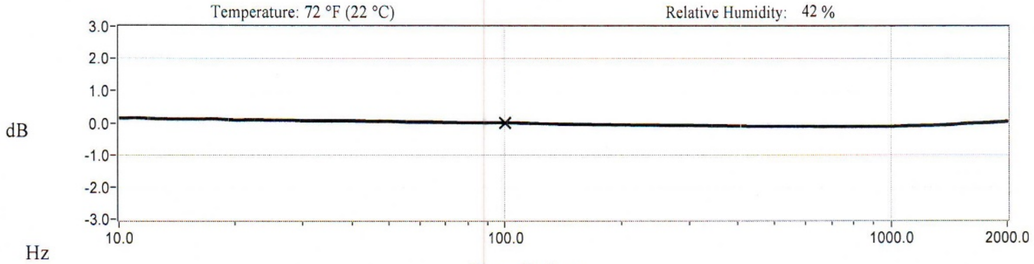
Method: Back-to-Back Comparison (AT401-3)

Manufacturer: PCB

Calibration Data

Sensitivity @ 100.0 Hz	**1009 mV/g**	Output Bias	10.8 VDC
	(102.9 mV/m/s²)	Transverse Sensitivity	2.0 %
Discharge Time Constant	1.1 seconds	Resonant Frequency	12.4 kHz

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10.0	1.7	300.0	-0.9
15.0	1.4	500.0	-1.3
30.0	0.9	1000.0	-1.3
50.0	0.6	2000.0	0.5
REF. FREQ.	0.0		

Mounting Surface: Stainless Steel w/Silicone Grease Coating Fastener: Stud Mount Fixture Orientation: Vertical
Acceleration Level (rms)[1]: 1.00 g (9.81 m/s²)[2]

[1]The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude; Acceleration Level (g) = 0.010 x (freq)². [2]The gravitational constant used for calculations by the calibration system is; 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Scott Skibniewski Date: 01/22/13

ACCREDITED
CALIBRATION CERT #1862.02

PCB PIEZOTRONICS
VIBRATION DIVISION

Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

cal57 - 3441715051.41

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 393A03

Serial Number: 37189

Description: ICP® Accelerometer

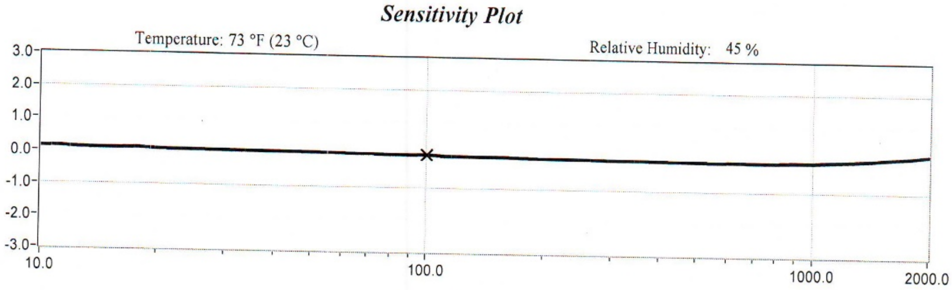
Manufacturer: PCB

Method: Back-to-Back Comparison (AT401-3)

Calibration Data

Sensitivity @ 100.0 Hz	**1010**	**mV/g**	Output Bias	11.0	VDC
	(103.0	**mV/m/s²)**	Transverse Sensitivity	5.0	%
Discharge Time Constant	1.1	seconds	Resonant Frequency	10.4	kHz

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10.0	1.4	300.0	-1.0
15.0	1.0	500.0	-1.2
30.0	0.6	1000.0	-1.1
50.0	0.3	2000.0	1.8
REF. FREQ.	0.0		

Mounting Surface: Stainless Steel w/Silicone Grease Coating Fastener: Stud Mount Fixture Orientation: Vertical

Acceleration Level (rms)[1]: 1.00 g (9.81 m/s²)[2]

[1]The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude; Acceleration Level (g) = 0.010 x (freq)².

[2]The gravitational constant used for calculations by the calibration system is; 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Scott Skibniewski Date: 01/23/13

ACCREDITED
CALIBRATION CERT #1862.02

PCB PIEZOTRONICS
VIBRATION DIVISION

Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

cal57 - 3441801779.66

~ Calibration Certificate ~

Model Number: 699A02

Serial Number: 989

Description: Portable Handheld Shaker

Manufacturer: IMI
ICS-12

Customer: ______

P.O. : ______

Method : Back-to-Back Comparison (AT701-1)

Calibration Data

Operating Frequency: 160.6 Hz.

Test Point Voltage: 100.4 mVAC

Acceleration Level: 1.00 g's rms
9.826 m/s^2

Temperature: 69 °F (21 °C)

Relative Humidity: 49 %

Condition of Unit

As Found: Overload Shut Off Feature Malfunctioning
As Left: In Tolerance, After Repair

Notes

1. Calibration is N.I.S.T. Traceable thru Project 822/267400 and PTB Traceable thru Project 1055.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for reference frequency is +/-1.6%.

Equipment Used For Calibration

Manufacturer	Description	Model#	Serial No.	Cal Date	Due Date
National Instruments	Acquistion Brd	PCI-6052E	1125572	2/5/2012	2/5/2013
PCB Piezotronics	Accelerometer	Y353B34	93740	4/16/2012	4/16/2013
PCB Piezotronics	Power Supply	480C02	CA360	2/2/2012	2/2/2013

Technician: Luke Rogers L. R.

Date: 11/22/12

Due Date: ______

ACCREDITED
CALIBRATION CERT #1862.01

IMI SENSORS
A PCB PIEZOTRONICS DIV.
3425 Walden Avenue
Depew, New York 14043
TEL: 888-684-0003 FAX: 716-684-3823
www.imi-sensors.comhh1 2012150606.88

Annex C

Methodology Paper for the Review of the Proposed Mitigation Measures for Operation Ground-borne Noise for SIL(E)

MTR Corporation Limited

Consultancy Agreement No. C10010 – Environmental Term Consultancy for WIL, SIL(E) and KTE:
Methodology Paper for the Review of the Proposed Mitigation Measures for Operation Ground-borne Noise for SIL(E)

May 2012

Environmental Resources Management
21/F Lincoln House
979 King's Road
Taikoo Place
Island East, Hong Kong
Telephone: (852) 2271 3000
Facsimile: (852) 2723 5660
E-mail: post.hk@erm.com
http://www.erm.com

MTR Corporation Limited

Consultancy Agreement No. C10010 – Environmental Term Consultancy for WIL, SIL(E) and KTE:

Methodology Paper for the Review of the Proposed Mitigation Measures for Operation Ground-borne Noise for SIL(E)

May 2012

Reference 0132172

For and on behalf of
ERM-Hong Kong, Limited

Approved by: Frank Wan

Signed:

Position: Partner

Date: 17 May 2012

This report has been prepared by ERM-Hong Kong, Limited with all reasonable skill, care and diligence within the terms of the Contract with the client, incorporating our General Terms and Conditions of Business and taking account of the resources devoted to it by agreement with the client.

We disclaim any responsibility to the client and others in respect of any matters outside the scope of the above.

This report is confidential to the client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such party relies on the report at their own risk.

CONTENTS

LIST OF FIGURES

LIST OF ANNEX

1 INTRODUCTION

1.1 BACKGROUND

South Island Line (East) [hereinafter refer to as SIL(E)] was proposed by MRTCL as an extension to the existing railway network to serve the Southern District of Hong Kong. The proposed SIL(E) comprises a new medium-capacity railway system with an approximate total route length of 7km from Admiralty to South Horizons, via three intermediate stations at Ocean Park, Wong Chuk Hang and Lei Tung.

The Environmental Impact Assessment (EIA) was approved on 26 October 2010, Register No.: AEIAR-155/2010. As per the requirements stated in Clause 5.2.2 item (v) of Part 2 – Scope of Services, a Methodology Paper for the review of proposed mitigation measures for operation ground-borne noise should be prepared and submitted to MTRCL for agreement. The Methodology Paper should include but not limited to:

- detailed methodology on how to review the proposed mitigation measures for operation ground-borne noise and relevant assumptions made in the SIL(E) EIA Report including the Line Source Response (LSR) and ground vibration conditions; and

- detailed description for on-site test(s) to be carried out for verification of the assumptions adopted in the SIL(E) EIA Report, such as LSR and ground vibration conditions.

ERM was commissioned by MTRCL to prepare the Methodology Paper. ERM was supported by Wilson Acoustics Limited who acts as the ground-borne noise specialist.

1.2 PURPOSE OF THIS REPORT

This Methodology Paper presents the proposed methodology for verification of the line source response (LSR) and ground vibration condition during construction phase of the SIL(E), and reviews the effectiveness of the operation ground-borne noise mitigation measures proposed in the approved SIL(E) EIA Report.

This page is deliberately left blank

2 *EIA PREDICTION METHODOLOGY*

According to the approved SIL(E) EIA Report, the methodology for the vibration and ground-borne railway noise impact assessment is based on the procedures outlined in "The Transit Noise and Vibration Impact Assessment" published by US Department of Transportation Federal Transit Administration (FTA Manual). The ground borne noise level at the identified NSRs was calculated as follows:

L = FDL + TIL + TOC + TCF + LSR + BCF + BSA + BSR + CTN + SAF

where:

L = ground-borne noise level, in dB re 20μPa

FDL = Force density level, in dB re lbf/√ft

TIL = Trackform attenuation or insertion loss, relative level

TOC = Turnout and crossover factor

TCF = Vibration coupling between the tunnel and the ground for soil based tunnels, relative level

LSR = Line source transfer mobility, in dB re (μin/s)/(lbf/√ft)

BCF = Adjustment to account for building coupling loss, in dB

BSA = Building Structure Attenuation, in dB

BSR = Building Structure Resonance, in dB

CTN = Conversion from vibration to noise within the building, in dB

SAF = 10dB safety factor to account for wheel/rail condition and uncertainties in ground conditions, in dB

During the EIA stage, in situ LSR has not been measured. According to the SIL(E) EIA Report, most of the underground tunnel areas for SIL(E) have similar geology as the West Island Line project. Therefore, the LSR data collected from borehole impact test during the EIA stage of West Island Line (borehole D103, D086, D012) were adopted.

This Methodology Paper presents the proposed methodology for the review of the ground-borne noise prediction presented in the approved EIA Report. Hammer impact test will be conducted at the tunnel invert to verify the LSR.

This page is deliberately left blank

A total of 28 ground-borne noise sensitive receivers (NSRs) were identified in the approved SIL(E) EIA Report. Their predicted ground-borne noise levels are shown in *Table 3.1*.

Table 3.1 SIL (E) Operational Ground-borne Noise Level at Sensitive Receivers

No.	NSR	Predicted Leq,30min, dB(A) [(d)]		Criteria, Leq,30min, dB(A)		Safety Margin [(b)]
		Day and Evening	Night	Day and Evening	Night	
Admiralty						
1	Island Shangri-La Hotel (SLH)	19	16	55	45	39
2	Regent on the Park (RP)	23	20	55	45	35
3	Jockey Club New Life Hostel (NLH)	5	-	55	- [(c)]	>40
4	Island School (ILS)	6	-	55	-	>40
5	Carmel School (CIS)	7	4	55	45	>40
6	Non Departmental Quarters (GOV)	4	1	55	45	>40
Lei Tung						
7	Sham Wan Tower – Tower 1 (SWT1)	10	7	55	45	>40
8	Sham Wan Tower – Tower 3 (SWT2)	8	5	55	45	>40
9	Pik On House (YOC1)	33	30	55	45	25
10	Tse On House (YOC2)	32	30	55	45	25
11	Shan On House (YOC4)	42	39	55	45	16
12	Tung Yip House (LTE1)	34	31	55	45	24
13	Cheng Pon Hing Hostel for Elderly (CPHH)	36	-	55	-	29
14	Tung Hing House (LTE2)	33	30	55	45	25
15	CMA Lei Tung Child Care Center (CMA)	34	-	55	-	31
16	Lei Tung Community Hall (LTCH)	29	-	55	-	36
17	Tung Mau House (LTE4)	33	31	55	45	24
18	Lei Tung Lutheran Day Nursery (LDN)	35	-	55	-	30
19	Aberdeen Baptist Lui Ming Choi College (LMCC)	34	-	55	-	31
20	Lei Tung Neighbour Elderly Centre (NEC)	33	31	55	45	24

No.	NSR	Predicted Leq,30min, dB(A) (d)		Criteria, Leq,30min, dB(A)		Safety Margin (b)
		Day and Evening	Night	Day and Evening	Night	
21	St Peter's Catholic Primary School (SPC)	38	-	55	-	27
22	Ap Lei Chau Kaifong Primary School (AKPS)	37	-	55	-	28
South Horizons						
23	Mei Cheung Court (SOH5)	3	<0	55	45	>40
24	Mei Ka Court (SOH6)	48	45	55	45	10 (a)
25	Cambridge Court (SOH7)	<0	<0	55	45	>40
26	Dover Court (SOH8) (e)	62	60	55	45	0
27	Precious Blood Primary School (PBPS)	<0	-	55	-	>40
28	Planned Future Hotel (HTL1)	<0	<0	55	45	>40

Notes:

(a) NSRs with relatively small prediction safety factors are highlighted in red.

(b) A 10dB safety factor was included in the predicted ground-borne noise level in the EIA. Therefore a 15dB safety margin means a difference of 5dB between the noise criteria and EIA predicted noise level.

(c) Night time criteria are not applicable to NSRs with no sensitive use for the intended purpose at night.

(d) The EIA predicted ground-borne noise levels are based on plinth track with direct fixation, i.e. unmitigated scenario.

(e) SOH8 is considered to have similar ground condition as SOH6. Only 1 hammer impact test will be conducted for these two NSRs.

4 TESTING LOCATION

4.1 TESTING LOCATION SELECTION CRITERIA

The following considerations have been taken into account in the selection of appropriate testing locations:

- *Relative high ground-borne noise levels predicted* - LSR in different ground conditions could have 10-15dB variation. In-situ hammer impact tests or vibration verification measurement shall be considered for NSRs with relative small safety margin.

- *Ground condition* - The SIL(E) tunnel will pass through mostly Repulse Bay Volcanic group formation while a small portion of the tunnel will be located in soil.

- *Ambient vibration* - Ambient vibration arises from road traffic and existing Island Line. At some locations the vibration signal produced by the hammer impact may be masked by ambient vibration, making it difficult to verify the LSR. Locations with lower ambient vibration are preferred.

- *Accessibility* - The testing locations shall allow fairly easy access into the tunnel for testing, and there are appropriate positions for fixing the vibration transducers on ground. Approval of site access by the land owner would also be sought where necessary.

4.2 HAMMER IMPACT TEST AT SOH8

Based on the above selection criteria, a hammer test location is proposed at South Horizon, in the downtrack tunnel near Dover Court (SOH8). Plan view of the impact test locations are shown in *Figure 4.1*. Geology profiles are shown in *Figure 4.2*.

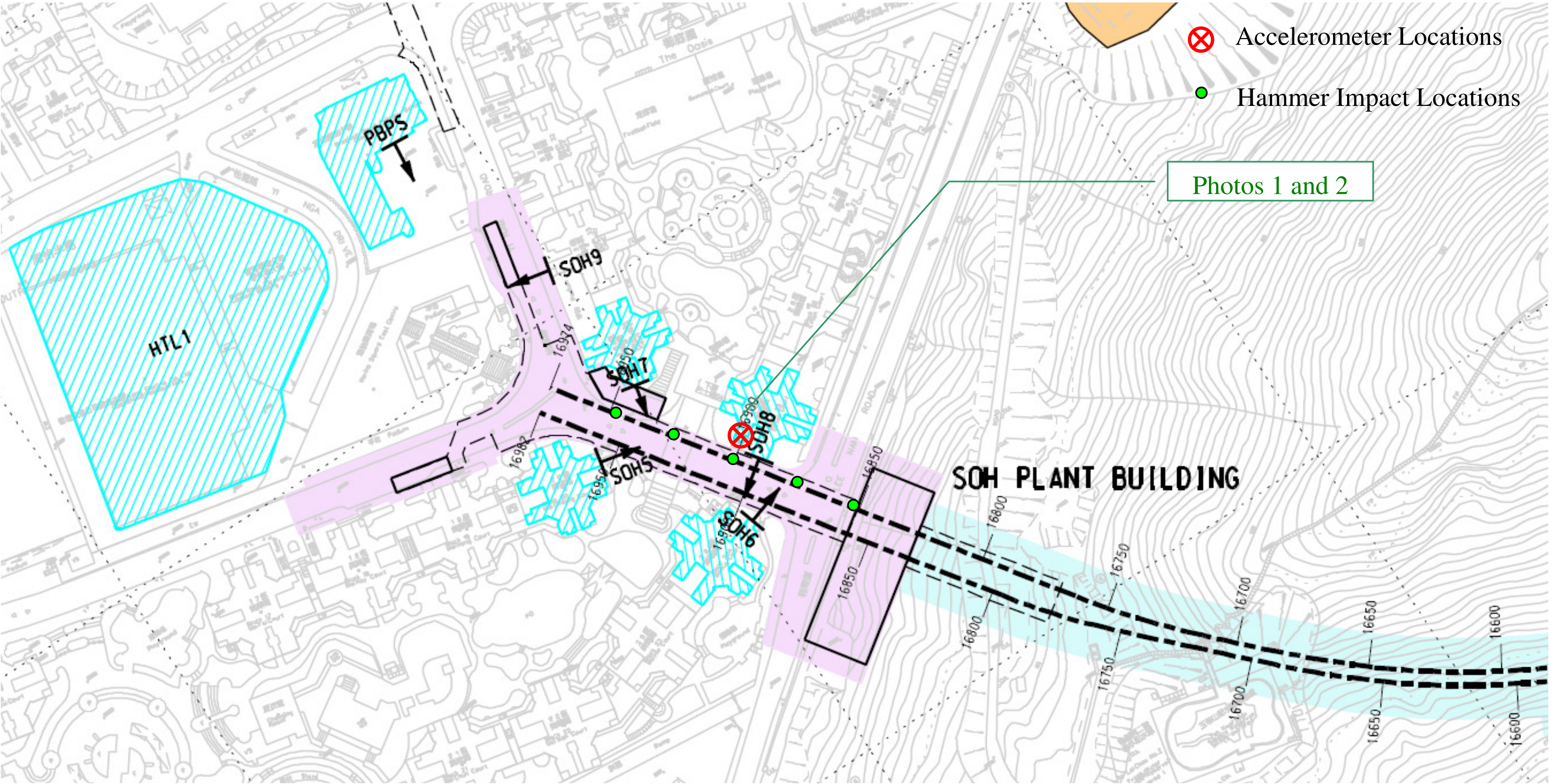


Figure 4.1

Plan View showing Measurement Location at SOH8

Date 8 May 2012

Environmental Resources Management

ERM

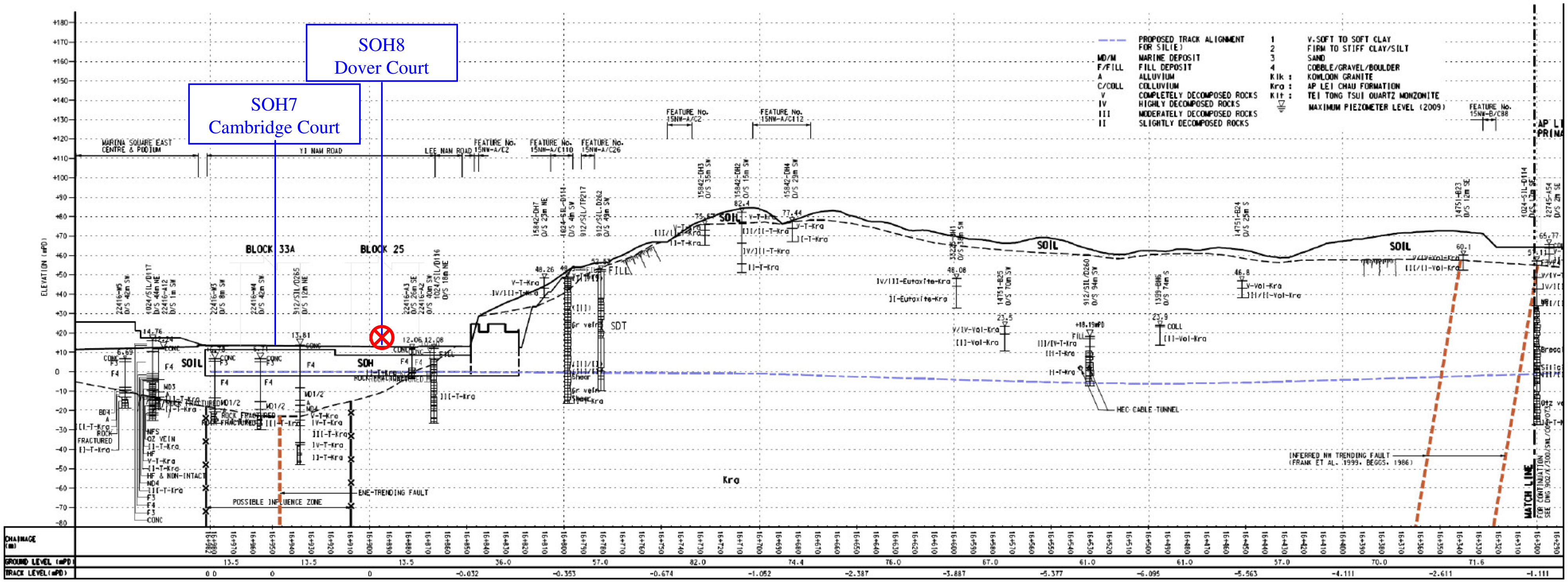


Figure 4.2

Vertical Alignment and Geological Profile at SOH8

Date 8 May 2012

Environmental Resources Management

ERM

5 TESTING PROCEDURES

Schematic sketch of the hammer impact test is shown in *Figure 4.3*. Hammer impacts will be conducted inside the tunnel along the alignment. A force transducer is located at the base of the impact hammer to measure the force applied to the tunnel invert. Accelerometers will be placed at various setbacks on the ground to pick up the vibration signals. Site visit on the test locations has been conducted to identify appropriate location for fixing accelerometers. Site photos showing the accelerometer locations are shown in *Annex A*.

The hammer impact test will be carried as follows:

1. Connect the force transducer to the analyzer in the tunnel.
2. Fix accelerometers at various setbacks and connect them to the analyzer on the ground surface.
3. Activate the pneumatic impact hammer. 3-10 impacts will be conducted at each impact point.
4. Record the impact force and the vibration signals.
5. Conduct narrow band frequency analysis of the force and vibration signals.
6. Correct for ambient vibration or electronic noise where necessary.
7. Average the data and calculate the Point Source Response (PSR) at each 1/3 octave band.
8. Move the impact hammer by ~20 meters along the tunnel and repeat the hammer impact. ~5 impact points will be conducted along the alignment subject to site conditions.
9. Calculate the LSR from PSR. The LSR is calculated from numerical integration of the PSR at each impact point along the alignment according to the equation below:

$$LSR(s,d,f) = 10\log\left[\int_{-l/2}^{l/2} 10^{PSR\left(\sqrt{s^2+d^2+y^2},\,f\right)/10}\,dy\right]$$

   where
   s = perpendicular setback
   l = train length
   d= tunnel depth

10. Verify the LSR and ground vibration condition assumed in the EIA Report to justify the adequacy of the proposed operation ground-borne noise mitigation measure.

11. Recommend necessary measure(s) if required.

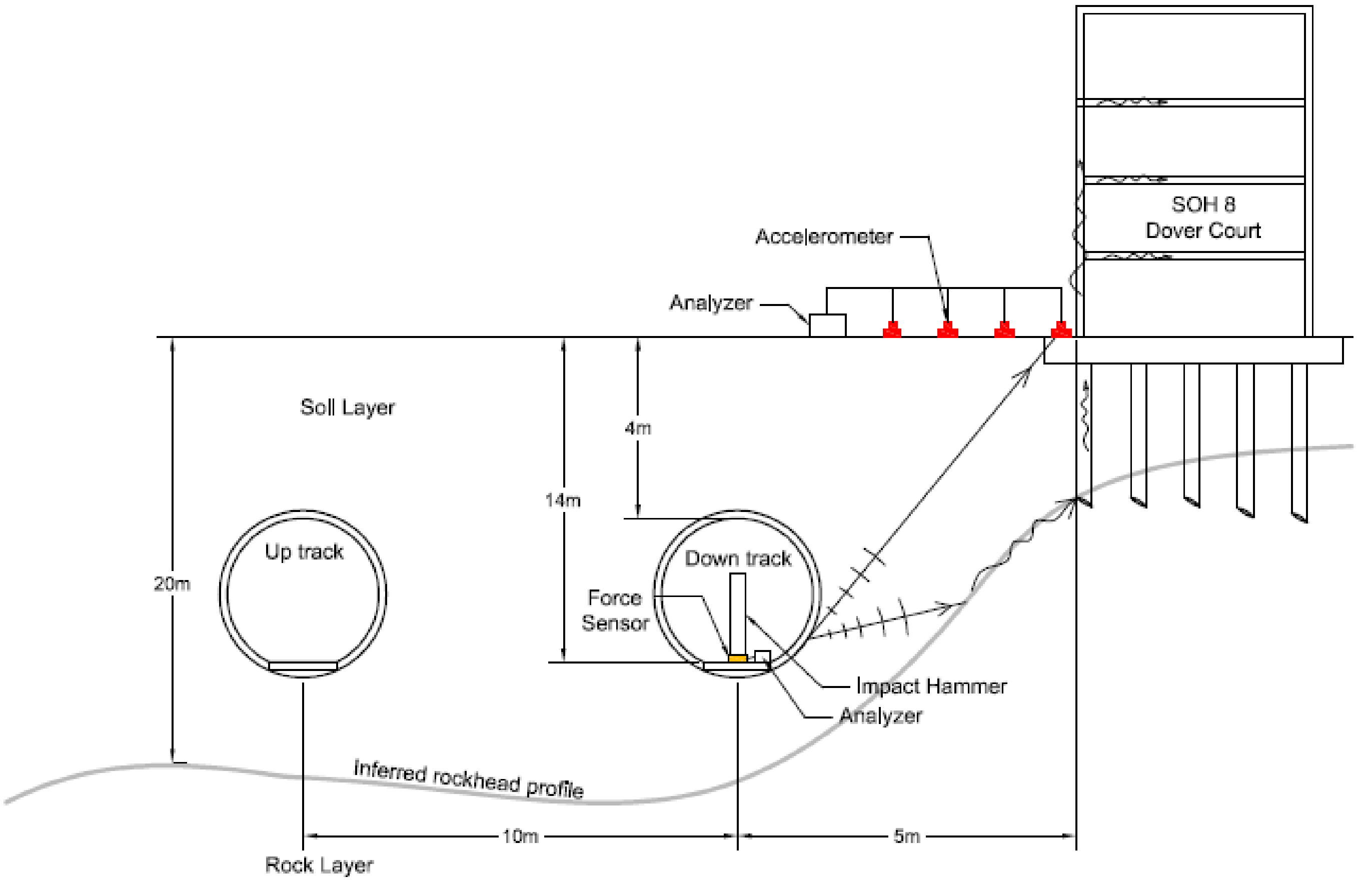


Figure 4.3

Schematic sketch of hammer impact test at SOH8

Date 8 May 2012

Environmental Resources Management

ERM

6 INSTRUMENTATION

The instruments to be used in the impact test are listed in *Table 6.1* below.

Table 6.1 Instruments to be used in the Vibration Impact Test

Instrument	Model No.	Number
7-Channel Spectrum Analyzer	B&K Pulse 3560C	1
4-Channel Sound & Vibration Analyzer	SVAN 958	1
Piezoelectric Accelerometers	Endevco 86	1
Piezoelectric Accelerometers	CTC AC135-1A	4
Vibration Calibrator	IMI 699A02	1
Pneumatic Impact Hammer	WAL-01 (tailor made)	1
Force Transducer for Impact Hammer	FUTEK LCM 550	1

Impact Hammer WAL-01

CTC 135-1A Accelerometer

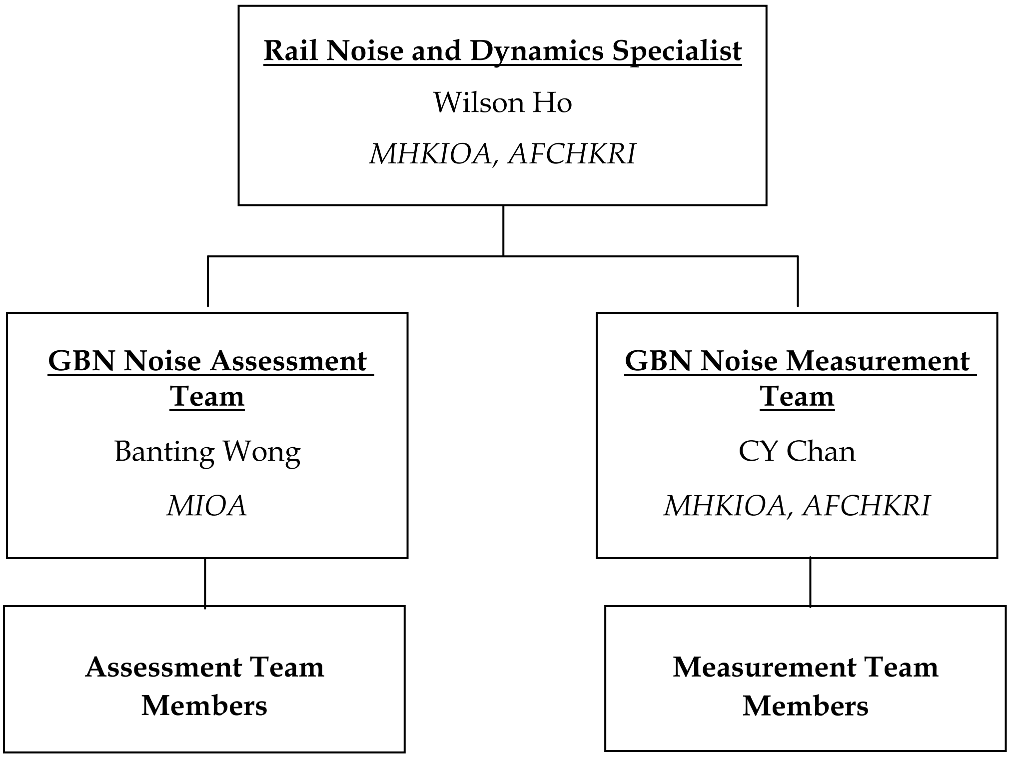
Endevco 86 Accelerometer

WAL-001 was tailor-developed for in railway/TBM ground borne noise and vibration prognosis. It has been used for impact test in Lo Wu, Hung Hom, West Drainage Tunnel and Taiwan. The impact is produced by a 20kg falling mass driven by pneumatic pump, which can provide adjustable 40-220kN impulsive force for soil mobility determination.

This page is deliberately left blank

7 STAFFING

The organisation chart of the project team is shown below.



The Rail Noise and Dynamics Specialist will be responsible for the overall management and review of the rail noise and vibration impact of the KTE.

The GBN Noise Assessment Team will be responsible for the preparation of the Operational Ground-borne Noise Review Plan as per SIL(E) EP Condition 2.19, analysis of the hammer impact test LSR data, verification of adequacy of the proposed mitigation measure and recommending necessary measure(s) if required.

The GBN Noise Measurement Team will be responsible for preparation of instruments and conducting the hammer impact testing.

This page is deliberately left blank

8 PROGRAMME

The schedule of hammer impact test is subjected to the tunnel construction program. No construction works such as tunnel drilling should be carried out within 300m from the testing locations during the test.

Measurements will be conducted during the night-time period (between 01:00 to 05:00 hours) to minimise the background vibration due to road traffic. Another 1~1.5hr will be required for transportation of test equipment into and out of the tunnel.

At least two weeks of advance notice is required for the preparation of measurement equipment.

Annex A

Site Visit Photos Showing the Sensor Locations

Photo 1 Accelerometer Locations at SOH8

Photo 2 Accelerometer Locations 1, 2 and 3 at SOH8

Annex D

Calculation Methodology of LSR

1 CALCULATION METHODOLOGY OF LSR

To determine LSR for SOH8, a tunnel section of 68m (i.e. train length for the project) nearest to this NSR is divided into 3 sections namely Sections E1, E2 and E3 (see Figure D1) and LSR for each section is calculated separately.

To calculate LSR for Section E2, the 4 sets of PSRs measured at S1, which is the most sensitive to impact force among other sensor locations, are adopted. Section E2 is divided into 48 sub-sections. PSR for each sub-section is derived from interpolation of a pair of appropriate measured PSRs and the sub-sections' PSRs are integrated to obtain the LSR.

To calculate LSR for Sections E1 and E3, PSRs measured at S1, S2, S3 and S4 are adopted. Sections E1 and E3 are divided into 32 and 19 sub-sections respectively. PSR for each subsection is derived from interpolation of a pair of appropriate measured PSRs and the sub-sections' PSRs are integrated to obtain the LSR. PSR-S1Pt4(20.3m), PSR-S3Pt4 (22.8m), PSR-S1Pt1(23.6m), PSR-S2Pt1(24.5m), PSR-S3Pt1(25.8m), PSR-S4Pt2(25.9m), PSR-S4Pt1(27.3m), PSR-S4Pt3(27.9m) and PSR-S4Pt4(33.9m), PSR-S4Pt3(27.9m) and PSR-S4Pt4(33.9m) are employed in the calculation.

The LSR for SOH8 is then derived by summing LSRs for E1, E2 and E3.

By invoking the assumption that the ground is transversely isotropic along the alignment, same method is applied to determine the LSR of SOH6 from nearside track.

* PSR-S1Pt4 (20.3m) stands for PSR measured at S1 for hammer impact at Pt4 with slant distance of 20.3m between the impact point and the sensor.

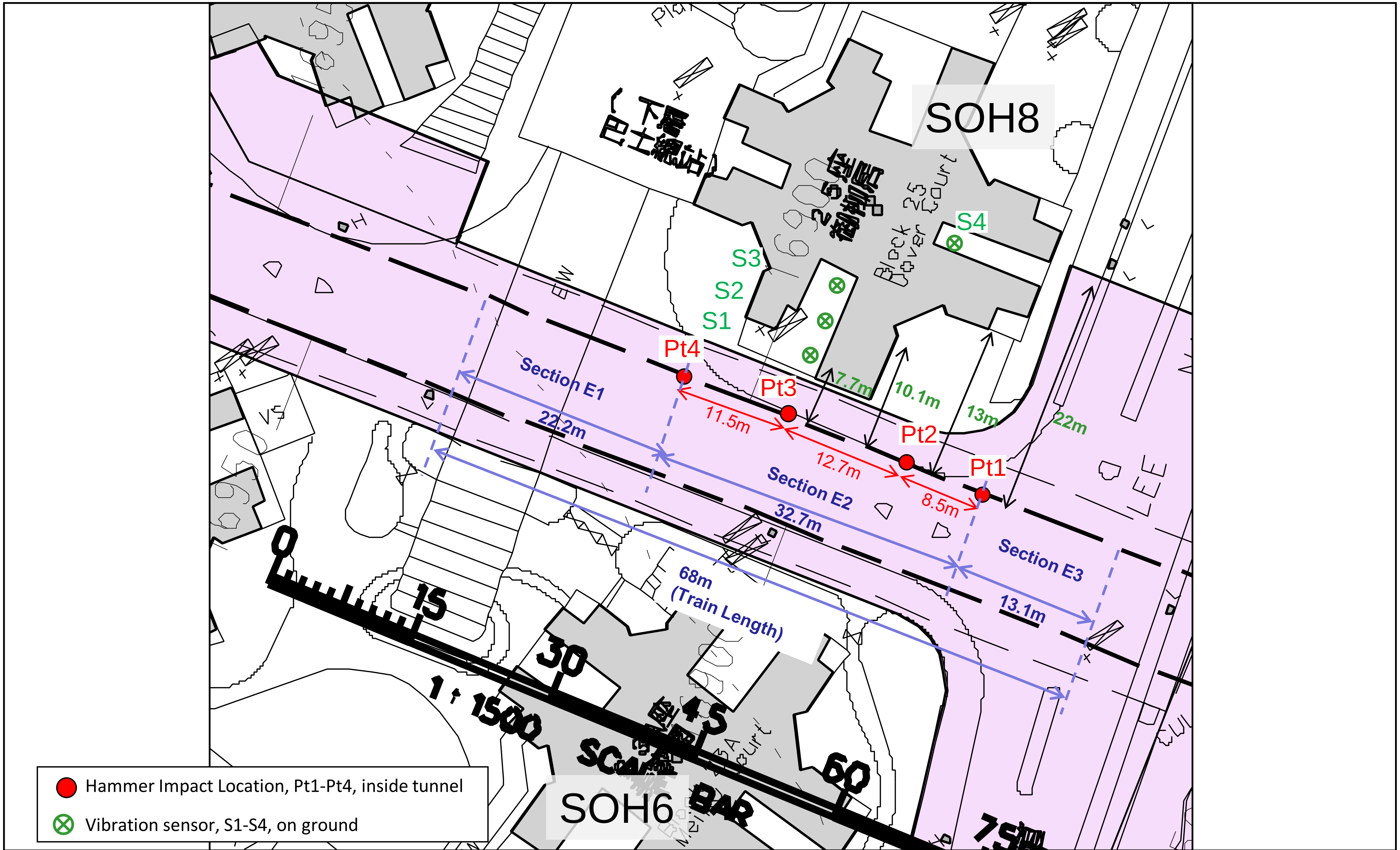


Figure D1

Schematic View of LSR Calculation

Date 25 Jun 2014

Environmental Resources Management

ERM