# 7 GROUNDBORNE NOISE IMPACT

## Introduction

7.1 Potential ground-borne noise impacts likely arising from the Project during both the construction and operation phases have been evaluated and the results are presented in this section.

## Environmental Legislation, Standards and Guidelines

### *Construction Phase*

7.2 Construction ground-borne noise is under the control of the Noise Control Ordinance (NCO), the Environmental Impact Assessment Ordinance (EIAO), and their subsidiary Technical Memorandum.

7.3 Noise arising from general construction works of the Project during normal daytime (0700-1900 except general holidays and Sunday) is governed by the EIAO-TM. With reference to the Technical Memorandum for the Assessment of Noise from Places Other Than Domestic Premises, Public Places or Construction Sites (IND-TM) under the NCO, the criteria for noise transmitted primarily through the structural elements of the building or buildings should be 10dB(A) less than the relevant acceptable noise level (ANL). These criteria apply to all residential buildings, schools, clinics, hospitals, temples and churches.

7.4 In restricted hours (i.e. between 1900 and 0700 on a normal working day or at any time on a general holiday and Sunday), the construction noise is controlled by the Technical Memorandum on Noise from Construction Work other than Percussive Piling (GW-TM). Similarly, the ground-borne noise criteria shall be limited to 10dB(A) below the respective ANL. Application for Construction Noise Permit (CNP) is required for construction activities involving the use of powered mechanical equipment (PME) carried out in restricted hours unless a CNP has been obtained.

7.5 The construction ground-borne noise criteria for the representative ground-borne NSR of the Project are tabulated in **Table 7.1** below.

**Table 7.1 Construction Ground-borne Noise Criteria**

| Type of NSR / Assessment Point | Ground-borne Noise Criteria, ($L_{eq\ 30\ min}$, dB(A)) [a] | | |
|---|---|---|---|
| | Daytime (0700-1900 hrs) (except General Holidays & Sunday) | Daytime during general holidays and Sundays and all days during Evening (1900 to 2300 hrs) | Night (2300 to 0700 hrs) |
| Domestic premises, hotels and service apartments | 65 | 55 | 40 |
| Schools | 60/55 [c] | 55 | [b] |

Note:
[a] Ground-borne noise would not be affected by any Influencing Factors. Thus, Area Sensitivity Rating of B will be considered for identifying criteria during restricted hours.
[b] No sensitive use/activity during this period.
[c] A 5dB(A) reduction to the ground-borne noise criteria is recommended for school during examination period.

### *Operation Phase*

7.6 With reference to the IND-TM, the criteria for noise transmitted primarily through the structural elements of the building or buildings should be 10dB(A) less than the relevant acceptable ANL. The same criteria are applied to all residential buildings, schools, clinics, hospitals, temples and churches. The criteria applied for ground-borne rail noise assessment are summarised in **Table 7.2**.

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**Table 7.2 Operational Ground-borne Noise Criteria**

| Type of NSR / Assessment Point | Ground-borne Noise Criteria, ($L_{eq\ 30\ min}$, dB(A)) | |
|---|---|---|
| | Day & Evening (0700 to 2300 hrs) | Night (2300 to 0700 hrs) |
| Domestic premises, hotels and service apartments | 55 | 45 |
| Schools | 55 | [a] |

Note:
[a] No sensitive use/activity during this period.

**Identification of Ground-borne Noise Sensitive Receivers**

7.7 In order to evaluate the ground-borne noise impacts from the Project during construction and operational phases, representative existing and planned/committed noise sensitive receivers within 300m from the Project (i.e. Study Area), were identified in accordance with Section 3 of Annex 13 of the EIAO-TM, observations from site visits and relevant land use plans such as Outline Zoning Plans.

***Construction Phase***

7.8 Under the assumption of worst-case scenario, one representative NSR was identified for the assessment of construction ground-borne noise impact due to the use of PME for excavation works and rock chiselling works for diaphragm wall construction. The identified NSR is presented in **Table 7.3** and shown in **Figure No.NEX2213/C/361/ENS/M52/501**.

**Table 7.3 Representative Noise Sensitive Receivers for Construction Ground-borne Noise Assessment**

| NSR No. | Description | Uses | Horizontal Distance to the Work Site (m) | Nearest Site |
|---|---|---|---|---|
| HH7 | The Metropolis Residence | Service Apartment | 90 | Construction of HUH |

***Operation Phase***

7.9 Locations of representative NSRs for operational ground-borne noise are presented in **Figure No. NEX2213/C/361/ENS/M52/601** and summarized in **Table 7.4**.

**Table 7.4 Representative Noise Sensitive Receivers for Operational Ground-borne Noise Assessment**

| NSR No. | Description | Land Use | Area Sensitive Rating |
|---|---|---|---|
| HH2 | Wing Fung Building | Residential Premises | B [a] |
| HH3 | The Hong Kong Polytechnic University (PolyU) Cheung On Tak Lecture Theatre | Educational Institutional | B [a] |
| HH5 | Planned PolyU Phase 8 | Educational Institutional | B [a] |
| HH7 | The Metropolis Residence | Service Apartment | B [a] |

Note:
[a] Ground-borne noise would not be affected by any Influencing Factors. According the IND - TM, Area Sensitivity Rating of B will be considered for urban areas.

### Ground-borne Noise Sources

***Construction Phase***

7.10 Potential construction ground-borne noise impacts would arise from modified rigs during rock chiselling for diaphragm wall construction. The modified rigs would be used for soil excavation with grab bucket. Minor rock chiselling would be required in order to toe in the diaphragm wall into the rock. In this case, grab bucket would be replaced by a chisel.

***Operation Phase***

7.11 When trains operate in tunnels that are located in close proximity to occupied structures, there is a possibility that vibrations associated with train passbys will be transmitted through the ground and structure, and be radiated as noise in the occupied spaces within the structure. The transmitted noise through the structure may have impact to the NSRs.

### Ground-borne Noise Prediction Methodology

***Construction Phase***

7.12 The prediction methodology is recommended by the U.S. Department of Transportation and Federal Transit Administration[1] . This projection methodology has been previously used for Ground-Borne Noise & Vibration Assessment for approved Kowloon Southern Link (KSL) EIA[2] (EIA Register No. EIA-098/2004).

7.13 The main components of the proposed prediction model for ground-borne noise are:

- Vibration source level from operation of modified rig during rock chiselling works;
- Vibration propagation through the ground to the structure foundation;
- Vibration reduction due to the soil/structure interface;
- Vibration propagation through the building and into occupied areas; and
- Conversion from floor and wall vibration to noise.

7.14 The vibration level $L_{v,rms}$ at a distance $R$ from the source is related to the vibration source level at a reference distance $R_o$. The conversion from vibration levels to ground-borne noise levels is determined by the following factors:

| | |
|---|---|
| $C_{dist}$: | Distance attenuation |
| $C_{damping}$: | Soil damping loss across the geological media |
| $C_{building}$: | Coupling loss into building foundation |
| $C_{floor}$: | Coupling loss per floor |
| $C_{noise}$: | Conversion factor from floor vibration levels to noise levels |
| $C_{multi}$: | Noise level increase due to multiple sources |
| $C_{cum}$: | Cumulative effect due to neighbouring sites |

7.15 The predicted ground-borne noise level $L_p$ inside the noise sensitive rooms is given by the following equation.

$$L_p = L_{v,rms} + C_{dist} + C_{damping} + C_{building} + C_{floor} + C_{noise} + C_{multi} + C_{cum}$$

<u>Reference Vibration Source ($L_{v,rms}$)</u>

7.16 In view of similar nature of rock chiselling by modified rig and rock breaking by hydraulic breaker, the source term of the modified rig is assumed same as that of hydraulic breaker adopted in the approved EIA study for the Kowloon Southern Link project (EIA-098/2004) as shown in **Table 7.5**. The assumptions adopted in the present assessment are provided in **Appendix 7.1**.

[1] U.S. Department of Transportation “High-Speed Ground Transportation Noise and Vibration Impact Assessment”, 1998

[2] KCRC, KSL GSA 5100 Environmental Impact Assessment & Associated Services Environmental Impact Assessment Report. 2005. (EIA Register No. EIA-098/2004)

**Table 7.5 Reference Vibration Level**

| Plant | Vibration (rms) at reference distance of 5.5m from source [a] |
|---|---|
| Hydraulic Breaker | 0.298 mm/s |

Note:
[a] Extracted from KSL GSA 5100 Environmental Impact Assessment & Associated Services - Environmental Impact Assessment Report, Register No.: EIA-098/2004

Soil Damping Factor ($C_{damping}$)

7.17 Internal losses of soil would cause the vibration amplitude to decay against the propagation distance and the decay relationship is based on the equation set out in the Transportation Noise Reference Book[3].

$$V(R) = V(R_o) \times e^{-2\pi f \eta R/2c}.$$

7.18 The velocity amplitude V is dependent on the frequency f in Hz, the soil loss factor, η, the wave speed c in m/s, the distance R from the source to the NSR. The properties of soil materials are shown in **Table 7.6**.

**Table 7.6 Wave Propagation Properties of Soil**

| Soil Type | Longitudinal Wave Speed c, m/s | Loss Factor, η | Density, $g/cm^3$ |
|---|---|---|---|
| Soil | 1500 | 0.5 | 1.7 |
| Rock | 3500 | 0.01 | 2.65 |

7.19 No damping attenuation was applied for propagation in rocks. All NSRs were assumed to have a piling foundation on rockhead.

Coupling Loss into Building Structures ($C_{building}$)

7.20 The coupling loss into building structures represents the change in the incident ground-surface vibration due to the presence of the piled building foundation. The empirical values with reference to the "Transportation Noise Reference Book", 1987 are given in **Table 7.7**. In addition, a coupling loss correction of -18 dB from bedrock to pile should be adopted. However, the correction from bedrock to pile depends on actual site condition and correction of zero dB is assumed for conservative approach.

**Table 7.7 Loss factor for Coupling into Building Foundation**

| Frequency | Octave Band Frequencies, Hz | | | | | |
|---|---|---|---|---|---|---|
| | 16 | 31.5 | 63 | 125 | 250 | 500 |
| Loss factor for coupling into building foundation, dB | -7 | -7 | -10 | -13 | -14 | -14 |

Coupling Loss per Floor ($C_{floor}$)

7.21 The coupling loss per floor represents the floor-to-floor vibration transmission attenuation. For multi-storey buildings, a coupling loss of 2 dB reduction per floor was assumed in this report for a conservative assessment to account for any possible amplification due to resonance effects.

[3] P. M. Nelson. Transportation Noise Reference Book. 1987.

Conversion from Floor Vibration to Noise Levels ($C_{noise}$)

7.22 Based on FTA Manual, a -27 dB correction for conversion of vibration (re: $10^{-9}$ m/s) in room walls, floors and ceiling to noise (re: 20 micro Pa) was assumed in this study.

Multiply Source Factor ($C_{multi}$)

7.23 This represents the increase in noise level due to multiple noise sources. The ground-borne noise levels from construction plant are summed logarithmically in accordance with standard acoustic principles to obtain the total ground-borne noise level at the area of interest.

Cumulative Effect ($C_{cum}$)

7.24 The cumulative contribution from other nearby concurrent sources, such as (SCL (TAW - HUH)) and KTE at Hung Hom have been added.

***Operation Phase***

7.25 The methodology for the operational ground-borne noise impact assessment has been conducted in accordance with the procedures outlined in FTA Guidance Manual for detailed vibration analysis. This methodology has been adopted for approved West Island Line EIA Study (EIA Register No. EIA-153/2008). The ground-borne noise levels in NSRs have been calculated as follows:

$$L = FDL + TIL + TOC + TCF + LSR + BCF + BVR + CTN + SAF$$

where

| | |
|---|---|
| L | Train passby noise level, in dB |
| FDL | force density level, in dB re 1 lb/in$^{1/2}$ |
| 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 1 (uin/s)/(lb/ft^0.5) |
| BCF | adjustment to account for building coupling loss, in dB |
| BVR | building vibration amplification within the structure, in dB |
| CTN | conversion from vibration to noise within the building, in dB |
| SAF | safety factor to account for wheel/rail condition and uncertainties in ground conditions, in dB |

Force Density Levels (FDL)

7.26 The vibration source levels (force density levels, FDL) for the existing SP1900 EMU were obtained from passby measurements on the up track through Pat Heung Depot in previous rail project. The deterioration in rail and rolling stock condition has already been taken into account in FDL obtained by measurements under rough rail condition. In accordance with the previous KSL approved EIA report, comparisons of FDL obtained from the SP1900 EMU to other Hong Kong transit trains, including old East Rail EMU, as well as several other heavy rail EMUs in operation in the United States, indicated that the SP1900 FDL was 5 dB to 10 dB higher than the maximum FDL levels for the other trains. The level adopted is based on previous approved EIA as shown in **Appendix 7.2**. Speed correction is applied to the FDL using an empirical relationship,

$$\Delta FDL = 20 \times \log\left(\frac{V}{V_{ref}}\right)$$

Trackform Alternatives or Insertion Loss (TIL)

7.27 Trackform attenuation has two components: the magnitude of the attenuation and the frequency above which attenuation occurs (resonance frequency of the trackform). Generally, more compliant trackform support and more massive elements in the trackform would result in a greater magnitude of attenuation occurring at lower frequencies. Thus, floating slab trackform (FST) would produce significantly more attenuation at lower frequencies than a resilient baseplate. However, greater compliance in the trackform support results in greater mobility of the rail, which would require careful examination of changes in rail geometry under loading, and consideration of associated fatigue and component life expectancy. In addition, more massive trackform elements would take up more space in tunnels and may cause spatial incompatibilities that are difficult to be overcome in the design. The TIL for existing MTR trackforms in previous approved EIA has been adopted where appropriate.

7.28 The ground-borne noise levels at NSRs have been calculated initially with direct fixation track without trackform insertion loss. If noise exceedances would be predicted, low noise trackforms including low stiffness fasteners, floating slab track, etc would be considered. The attenuations provided by different low noise trackforms would be included in the calculation to determine the appropriate trackforms for meeting the criteria. The type of vibration mitigating trackform has often been grouped into three categories listed below:

- Type 1: A medium attenuation baseplate or booted dual sleepers based on a bonded or non-bonded compression style baseplate with a resilient elastomeric element having static stiffness of about 25 kN/mm, to be fitted atop the concrete sleepers or atop the invert;
- Type 2: A high attenuation baseplate or booted dual sleepers includes
  - i. a bonded "Egg" style baseplate with a resilient elastomeric element having static stiffness in the range of 7 kN/mm to 14 kN/mm, to be fitted atop concrete sleepers or on the invert;
  - ii. the Pandrol Vanguard baseplate having static stiffness on the order of 3kN/mm to 5kN/mm; or
  - iii. resiliently supported sleepers whose resilient support pad is manufactured from natural rubber and has a static stiffness in the order of 8kN/mm to 12 kN/mm - an alternative for tangent, or near-tangent track only.
- Type 3: A floating mini slab trackform (FST) with loaded resonance frequency of about 16Hz

Tunnel Coupling Factor (TCF)

7.29 Generally heavier transit structures lower the vibration levels. With reference to FTA Manual, vibrations induced by train in Cut and Cover (CC) tunnels and Stations are 3dB and 5dB less than that in bored tunnel in soil. For bored tunnel in soil, the TCF depends on the soil properties. Due to lack of comprehensive data on different soil strata, TCF has been conservatively assumed to be 0dB. Thus, the TCF used is 0dB, -3dB and -5dB for bored tunnel, CC tunnel and stations respectively.

Turnout and Crossover Factor (TOC)

7.30 At points and crossings, where the wheel transitions from one rail to another, the sudden loading/unloading of the leading and trailing rails results in increased broad band vibration levels over that of plain line continuous rail. While it is not possible to grind the rails through either the points or crossings, surface deterioration would often be evident. For standard level turnouts and crossings receiving average maintenance, the FTA Manual has recommended a correction of 10dB. For modern inclined turnouts in good condition, where impact loads are lessened, a correction of 5dB would be appropriate. These corrections would be adopted in this study.

Line Source Response (LSR)

7.31 The LSR determines the vibration levels or attenuation in the ground as a function of distance caused by an incoherent line source of unit force point impacts, with line source (train) orientated along the alignment. Thus, the basic quantity required for the determination of the LSR would be the vibration response caused by a unit point source impact, which has been defined as the Point Source Response (PSR). Given that the PSR would be along the alignment, the LSR would follow directly by incoherent integration of the PSR values over the train length. However, the determination of the LSR from force point impacts in numerous boreholes along the alignment over the length of the alignment is neither practical nor affordable. Thus, idealised assumptions of transverse isotropy and layer-wise homogeneity are invoked, which allow PSR obtained from a single borehole to be taken as representative along the alignment near a building receiver and used in the calculation of LSR.

7.32 Soil mobility has already been measured in Hong Kong at a number of locations, including KSL and WIL. The selection of borehole data is based on tunnel depth and rockhead level (i.e. whether the tunnel is borned in rock or soil strata). The geological profiles are illustrated in **Appendix 3.2**. Relevant borehole information is listed in **Table 7.8**. In the ground-borne noise assessment, these soil mobility data would be referenced. The most relevant measured results (taking into account the ground type) have been used for the calculations. It has been noted that the nearest NSR is located more than 75m horizontally from the SCL rail track. With such a large setback distance, the distance attenuation effect was the dominant factor while the selection of any particular borehole LSR data would become far less important. Typical PSRs for various geologies have been identified and presented in **Appendix 7.3**.

**Table 7.8 Typical PSR to be adopted for the Representative NSR**

| Selected NSR | | | | Selected Borehole | | |
|---|---|---|---|---|---|---|
| **NSR No.** | **Rock(R) / Soil-borne(S)** | **Approx. Track Depth [m]** | **Approx. Rockhead Depth [m]** | **Borehole No.** | **Borehole Depth [m]** | **Rockhead Depth [m]** |
| HH2 – Wing Fung Court | S | 11 | 30-40 | WIL D095 | 10.4 | 23 |
| HH3 - Cheung On Tak Lecture Theatre | S | 13 | 40-50 | WIL D095 | 10.4 | 23 |
| HH5 - Planned Poly U Phase 8 | S | 15 | 35-40 | WIL D095 | 10.4 | 23 |
| HH7 - The Metropolis Residence | S | 11 | 21-31 | WIL D095 | 10.4 | 23 |

7.33 PSR is numerically interpolated between setbacks to create contour surface in frequency and distances. The Line Source Response (LSR) is then determined by numerical incoherent integration of the PSR along the length of the train centred on the receiver for each individual 1/3 octave bands.

$$LSR(s,d,f) = 10\log\left[\int_{-l/2}^{l/2}\left[10^{PSR\left[\sqrt{d^2+s^2+y^2},\,f\right]/20}\right]^2 dy\right]$$

where s = perpendicular setback
d = depth to top of rail
l = train length

Building Coupling Factor (BCF)

7.34 In general, larger and heavier structures have greater vibration attenuation than smaller and lighter structures. The recommended BCF established within FTA Manual would be followed. Receivers in this study would be divided into 5 types according to its structures and would have different BCF attenuation as below:

- Type 0 – Large Masonry with spread footings
- Type 1 – 2-4 storeys medium sized structures
- Type 2 – 1-2 storeys complexes
- Type 3 – Single family detached residences
- Type 4 – Large Masonry Building On Piles

7.35 The BCF for different types of structure is shown in **Appendix 7.4** which indicates that larger and heavier structures have greater vibration attenuation than smaller and lighter structures. In fact, the extent of the attenuation is governed by the difference in mechanical impedance between the soil and the foundation, with impedance being determined by differences in mass and stiffness within the soil and foundation. For structures founded on rock, there would be no impedance contrast between the soil and the foundation and therefore the BCF has been considered to be zero.

Building Vibration Response (BVR)

7.36 The BVR has been determined by two factors as described below:

- Resonance amplification due to floor, wall and ceiling spans: With reference to the FTA Manual, a 6 dB correction would be considered to account for structural resonances of typical reinforced concrete buildings. The spectral correction has been provided in **Appendix 7.5**.
- Floor-to-floor attenuation: A floor-to-floor attenuation of 2 dB reduction per floor would be assumed. Where there is a multi-floor occupancy, only the structure borne noise impact on the lowest occupied floor is considered.

Conversion to Noise (CTN)

7.37 A +2 dB correction for conversion of vibration (re: $10^{-6}$ in/s) in room walls, floors and ceiling to noise (re: 20 micro Pa) would be assumed in this study.

Safety Factor (SAF)

7.38 To tackle the problem of differences in overall predicted and measured A-weighted noise levels, a safety factor would be applied in the model. As a conservative approach, a 10 dB safety factor would be adopted to account for uncertainty and variation in ground characteristics.

**Assessment Results**

***Construction Phase***

7.39 Construction ground-borne noise level associated with operation of the modified rigs, hydraulic breakers and piling rigs were predicted and summarized in **Table 7.9**. For the worst case scenario, it was assumed in the calculation that the PMEs would be operated simultaneously. Detailed calculation and assumptions are provided in **Appendix 7.1**.

**Table 7.9 Predicted Construction Ground-borne Noise Impact**

| NSR No. | Description | Predicted Ground-borne Noise Levels $L_{eq(30mins)}$, dB(A) | Noise Criteria for daytime (0700-1900), $L_{eq(30mins)}$, dB(A) | Criteria Achieved? |
|---|---|---|---|---|
| HH7 | The Metropolis Residence | 48 – 50 | 65 | Yes |

7.40 As shown in **Table 7.9**, construction ground-borne noise levels at The Metropolis Residence (HH7) would comply with the day time (0700-1900) noise criteria of 65 dB(A). Adverse ground-borne construction noise impact due to the use of PME would not be envisaged.

7.41 In case of any construction activities to be conducted during restricted hours (i.e. between 1900 and 0700 on a normal working day or at any time on a general holiday and Sunday), it is the Contractor's responsibility to ensure compliance with the Noise Control Ordinance (NCO) and the relevant technical memoranda. The Contractor will be required to submit CNP application to the Noise Control Authority and abide by any conditions stated in the CNP, should one be issued.

***Operation Phase***

7.42 The ground-borne noise levels at NSRs have been calculated based on direct fixation track. The prediction results are summarized in **Table 7.10**. Sample calculation and assumptions have been provided in **Appendix 7.6**. The predicted noise contribution from the Project at the worst-affected NSR is <20dB(A), which is insignificant and down to the ambient level.

**Table 7.10 Predicted Operational Ground-borne Noise Impact (Unmitigated)**

| NSR No. | Description | Predicted Ground-borne Noise Levels, $L_{eq(30mins)}$ dB(A) | Noise Criteria, $L_{eq(30mins)}$ dB(A) | Criteria Achieved? |
|---|---|---|---|---|
| HH2 | Wing Fung Building | <20 | 45 (with night-time operation) | Yes |
| HH3 | Cheung On Tak Lecture Theatre | <20 | 55 (with day/evening operation only) | Yes |
| HH5 | Planned Poly U Phase 8 | <20 | 55 (with day/evening operation only) | Yes |
| HH7 | The Metropolis Residence | <20 | 45 (with night-time operation) | Yes |

7.43 The potential cumulative ground-borne noise impacts with SCL (TAW - HUH) and KTE have also been assessed. Ground-borne noise impacts assessment results for SCL (TAW - HUH) and KTE have been extracted from both EIA reports for cumulative assessment. The cumulative results are shown in **Table 7.11**.

**Table 7.11 Cumulative Operational Ground-borne Noise Impact**

| NSR No. | Description | Predicted Ground-borne Noise Levels arising from SCL (MKK – HUH), $L_{eq(30mins)}$ dB(A) | Predicted Ground-borne Noise Levels arising from SCL (TAW – HUH), $L_{eq(30mins)}$ dB(A) | Predicted Ground-borne Noise Levels arising from KTE, $L_{eq(30mins)}$ dB(A) | Cumulative Ground-borne Noise Levels, dB(A) | Criteria, $L_{eq(30mins)}$ dB(A ) | Criteria Achieved? |
|---|---|---|---|---|---|---|---|
| HH2 | Wing Fung Building | <20 | 36 | <20 | 36 | 45 (with night-time operation) | Yes |

7.44 Cumulative noise levels due to the Project, SCL (TAW - HUH) and KTE at NSR would be 9 dB(A) below the criteria. Adverse impact from the Project is therefore not anticipated.

7.45 During abnormal and emergency operations of SCL (MKK - HUH), the train service would be interrupted or stopped. Therefore, the train frequency at that period would be lower than the scheduled timetable. Hence, the ground-borne noise impact would not be worse than the above prediction, which has been conducted based on the worst case scenario.

**Recommended Mitigation Measure**

***Construction Phase***

7.46 The predicted construction ground-borne noise at identified NSR would comply with the noise criteria. Mitigation measures are not required.

***Operation Phase***

7.47 The predicted operational ground-borne noise at all identified NSR would comply with the noise criteria. Mitigation measures are not required.

7.48 The prediction was based on a conservative approach. However, provisions have been allowed in the design of the tunnel for installation of any necessary contingency mitigation measures. Based on the size of the tunnel proposed under the Project, these contingency measures may be as follows:

- Medium attenuation baseplates (Type 1) — additional attenuation of about 5 to 10dB(A);
- High attenuation baseplate or booted dual sleepers (Type 2) additional attenuation of about 10 to 15dB(A); or
- Floating mini slab trackform (Type 3) — additional attenuation of about 20 to 30dB(A).

**Environmental Monitoring and Audit Requirements**

***Construction Phase***

7.49 The predicted construction ground-borne noise would comply with the noise criteria. Therefore, environmental monitoring is considered not necessary during construction phase.

***Operational Phase***

7.50 Prior to the operation phase of the Project, a commissioning test should be conducted to ensure compliance of the operational ground-borne rail noise levels with the noise criteria. Details of the test requirements are provided in a stand-alone EM&A Manual.

**Conclusion**

7.51 During construction phase, projections of ground-borne noise at identified NSR/assessment point have been performed, based on a methodology recommended by the US Department of Transportation. It was found that the predicted construction ground-borne noise at representative NSR (Metropolis Residence) would comply with the noise criteria stipulated in the EIAO.

7.52 During operation phase, projections of ground-borne noise at identified NSR have been performed, according to the methodology recommended by the US Department of Transportation. Based on direct fixation track, the predicted operational ground-borne noise at all the identified NSR would comply with the criteria. The predicted noise contribution from the Project at the worst-affected NSR is 19dB(A), which is insignificant and down to the ambient level. Thus, adverse impact from the Project is not anticipated. Cumulative noise levels from the Project, SCL (TAW - HUH) and KTE at the worst-affected NSRs would be 9dB(A) below the noise criteria. Provisions have been allowed in the design of the tunnel for installation of any necessary contingency mitigation measures. Based on the size of the tunnel proposed under the Project, these contingency measures could be medium attenuation baseplates (Type 1), high attenuation baseplate or booted dual sleepers (Type 2) or floating mini slab trackform (Type 3).