Comprehensive Information of Environmental Assessment for the Phase 1 Macau Light Rapid Transit System

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Content

1. INTRODUCTION

1.1 Background

1.1.1 Along with the completion of large-scale entertainment projects in Macau in recent years, Macau has gained the rapid growth in local tourism and hotel industry. The resulted increases in number of visitors, residents and vehicles have demonstrated the urgent need of an upgraded public passenger transportation network with a larger scale and a higher diversity than the existing one. In view of the above, the Macau Special Administrative Region Government (MSARG) announced in 2007 the project "Macau Phase 1 Light Rapid Transit (LRT) system". On 1st January 2007, the Office for the Transportation Infrastructures (GIT/ 運輸基建辦公室) was also set-up. GIT is responsible for the overall coordination throughout design and construction of the LRT system, planning for the future operation, as well as to promote the modernisation and improvement of road transportation system.

1.1.2 The Council of Environment (環境委員會) (the former organisation of Environmental Protection Bureau (環境保護局)) provided technical advice on the development of LRT system in various aspects, including construction noise, vibration, control of black smoke and pollutant emission, as well as control of operational noise. The Council of Environment also recommended to conduct detailed Environmental Impact Assessment, and implementation of related mitigation measures for the project, in order to take into account the concerns on environmental impact with the project development.

1.1.3 In 2008, GIT commissioned Scott Wilson Limited (SW) to conduct an comprehensive Environmental Impact Assessment (the EIA) for the Phase 1 LRT preliminary finalised alignment and operation system. Subsequently, in response to the continuous social developments, GIT also commissioned SW to conduct supplementary environmental studies for the LRT Depot Development at East Cotai, and for the Tunnel Alignment Option on Nam Van Lake and Sai Van Lake, in order to identify appropriate environmental criteria to be adopted in the various stages of LRT development.

1.1.4 On the other hand, Mitsubishi Heavy Industries, Ltd. (MHI /三菱重工業株式會社) commissioned SW in 2011 to conduct railway noise and visual impact review based on the MHI rolling stock system to be adopted in Macau LRT system. Relevant data have been submitted to GIT and would be incorporated into detailed design considerations.

1.1.5 Since there are currently no statutory environmental assessment procedures and corresponding regulations in Macau, abovementioned studies have also referred to the corresponding guidelines and criteria stipulated in the environmental ordinance and regulations in the Mainland and Hong Kong.

1.1.6 This document summarises the study information on potential environmental impacts arising from both the construction and operation phases of Macau Phase 1 LRT System, LRT Depot and other associated projects. Environmental mitigation measures have been recommended for the compliance of related

regulations and guidelines in Macau, the referred environment assessment criteria in Hong Kong and the Mainland, and therefore to minimise potential environmental impact on residents of Macau.

1.2 Project Objectives

The LRT Project has the following objectives:

- to provide Macau residents and visitors a comfortable, efficient and reliable public transportation facility, and to lead Macau to a more modernised society;
- to provide fundamental transportation in Macau in order to alleviate the traffic congestion due to the growth of the number of visitors, local population and activities of the on-road traffic;
- to use electricity driven LRT vehicles and thus improving air quality

2. ENVIRONMENTAL IMPACT ASSESSMENT OF LIGHT RAPID TRANSIT SYSTEM

2.1 Laws and Assessment Criteria

2.1.1 Due to the lack of legislative regulated laws and procedures of EIA in Macau, in addition to the existing Decree Law and guidelines related to the civil development project in Macau, environmental impact assessment conducted for the LRT system also referred to the guidelines and standards that applied in China and Hong Kong, including:

- Macau, Decree Law No. 2/91/M 《環境綱要法》
- Macau, Decree Law No. 56/84/M《建築、景色及文化財產的保護》
- Macau, Decree Law No. 83/92/M《有關文物修訂名單》
- Macau, Decree Law No. 54/94/M《規範若干環境噪音之預防及控制》
- Macau, Decree Law 46/96/M《澳門供排水規章》
- Macau, Decree Law 35/97/M《規範在海事管轄範圍內禁止投擲或傾倒有害物質》
- Macau, Chief Executive's Notice No. 32/2002, "Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal"《控制危險廢物越境轉移及其處置的巴塞爾公約》
- Macau, Appendix of Decree Law 241/94/M「聲學規定」

- Macau "Guidelines for Black Smoke and Noise Control in Construction and Piling Works"《工程及樁基礎工程黑煙及噪音控制指引》
- Macau "Guidelines for Pollution Control in Construction Site" 《地盤污染控制指引》
- Macau "Guidelines for Pollution Control of Demolition" 《拆卸工程污染控制指引》
- Macau "Guidelines for Light Pollution from Advertising Signs, Decorative Lightings on Building and Outdoor Electronic Display"《廣告招牌、建築物裝飾燈和戶外電子顯示屏光污染控制指引》
- Macau "Guidelines for Environmental Impact Assessment Report"《編寫環境影響評估報告書指引》
- Hong Kong "Technical Memorandum on Environmental Impact Assessment Process" in "Environmental Impact Assessment Ordinance" (Cap.499)
- Hong Kong "Air Pollution Control Ordinance" and "Hong Kong Air Quality Objectives"
- Hong Kong "Land (Miscellaneous Provisions) Ordinance" (Cap.28)
- Hong Kong "Antiquities and Monuments Ordinance" (Cap.53)
- Hong Kong "Waste Disposal Ordinance" (Cap.354)
- Hong Kong "Waste Disposal (Chemical Waste) (General) Regulation (Cap.354C)
- Hong Kong "Water Pollution Control Ordinance" (Cap.358)
- Hong Kong "Hong Kong Planning Standards and Guidelines (HKPSG) Chapter 9 – Environment, Section 5 Water Quality
- Relvant Professional Persons Environmental Consultative Committee Practice Note (ProPECC), especially PN 1/94 "*Construction Site Drainage"*
- Hong Kong "Guidelines for Cultural Heritage Impact Assessment"
- Development Bureau Technical Circular (Works) (DVEB TC(W)) No.11/2007 – "Heritage Impact Assessment Mechanism for Capital Works Projects"
- Public Health and Municipal Services Ordinance (Cap. 132) – Public Cleansing and Prevention of Nuisances (Urban Council) and Regional Council) By-laws

- Hong Kong Environmental Protection Department (1994) "Practice Note for Professional Persons on Contaminated Land Assessment and Remediation"

- Hong Kong Environmental Protection Department (1999) "Guidance Note for Investigation and Remediation of Contaminated Sites of Petrol Filling Stations, Boatyards and Car repair/ Dismantling Workshops"

- Hong Kong Environmental Protection Department "Guidance Manual for Use of Risk–based Remediation Goals for Contaminated Land Management"

- Hong Kong Technical Circular (Works) No. 34/2002 Management of Dredged/Excavated Sediment

- EIAO Guidance Note No. 7/2002 "Ecological Baseline Survey for Ecological Assessment" and No. 10/2004 "Methodologies for Terrestrial and Freshwater Ecological Baseline Surveys"

- Mainland, Standards of Inland Water Quality

- "Guidance Notes for the Reduction of Obstructive Light GN01", issued by Institution of Lighting Engineers, UK

2.1.2 Uncertainties in the assessment of impacts were considered when drawing conclusions from the assessment. In carrying out the assessment, realistic worst case assumptions based on the latest available information were made in order to provide a conservative assessment of environmental impact.

2.2 Noise

Construction Phase

2.2.1 Assessment conducted based on the Noise Control Ordinance (NCO) and the related Technical Memorandum in Hong Kong. Acceptable Noise Levels (ANLs) stipulated in the Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM) was adopted for the locations of Noise Sensitive Receivers (NSRs).

2.2.2 With the implementation of the recommended standard noise mitigation measures such as use of quiet plants Powered Mechanical Equipment, temporary noise barrier, noise jacket, mufflers, noise enclosures and limiting number of plants operated concurrently, construction noise impact is expected to be generally controlled to an acceptable level.

2.2.3 However, as some of the NSRs situate close to the site boundary of the LRT system, slight exceedance the ANLs may still occur with the implementation of recommended standard noise mitigation measures. The average of exceedance would be around 5 to 6 dB(A). Further mitigation measures including good site practices, as well as proper scheduling to avoid noisy

construction during school examinations can be adopted to further minimise the construction noise impact.

2.2.4 As the operation frequency of the PMEs is generally lower compared with the actual site condition, the actual construction noise levels would be lower than that of concluded in the EIA assessment. Also, the contractor is strictly required to implement the recommended noise mitigation measures. By conducting the Environmental Monitoring and Audit (EM&A) measures during construction phase and establishment of effective complaint handling procedures so that the construction noise impact could be minimised.

Operation Phase

2.2.5 Environmental Impact Assessment was conducted, with reference to the NCO and the EIAO-TM in Hong Kong. The NCO criteria for the control of rail noise are dependent on the locations of NSRs and their corresponding surrounding environment.

2.2.6 In order to verify the practicability of applying Hong Kong guidelines in Macau, night-time background noise measurements at the NSRs along the proposed LRT alignment were also conducted for the identification of noise criteria.

2.2.7 The predicted railway noise levels and the recommended noise mitigation measures from EIA Report in 2008, and the follow-up supplementary studies are presented below.

Macau Peninsula

2.2.8 According to the proposed operation conditions of the LRT system in 2008, the predicted rail noise levels shall comply with the daytime and evening time ANL stipulated in EIAO-TM at all of the identified NSRs. However, predicted rail noise levels at minor group of NSRs would exceed the nighttime (2300-0700) ANL and 85dB(A)L_{max} stipulated in EIAO-TM. **Table 2-1** shows the measured background noise levels, recommended ANL (i.e. assessment criteria) and the predicted rail noise levels in different regions of Macau Peninsula during different periods under unmitigated scenario. **Figure 2-1** shows the LRT alignment and the night-time background noise levels, based on the preliminary design of Phase 1 LRT alignment in 2008 updated with tunnel alignment option.

Table 2-1 Measured Background Noise Levels, Recommended ANLs and Predicted Rail Noise Levels in Different Regions of Macau Peninsula under Unmitigated Scenario

Region ID	Region Name	Night-time Background Noise Levels, L_{eq} dB(A)	Daytime & Evening-time ANL $L_{eq,30min}$, dB(A)	Daytime & Evening-time Predicted Maximum Rail Noise Levels $L_{eq,30min}$ dB(A) **	Nighttime L_{max} Noise Limit dB(A)	Predicted Nighttime L_{max} Noise Levels dB(A) **
M1	Barrier Gate (關閘)	67.5	70 / 60*	63	85	50 – 96
M2	Areia Preta (黑沙環)	68.2	70 / 60*	69		68 – 103
M3	Outer Harbour (外港)	69.1	70 / 60*	60		70 – 94
M4	NAPE (Novos Aterros do Porto Exterior) (外港填海區)	68.3	70 / 60*	60		69 – 93
M5	Nam Van Lake (1) (南灣湖（一）)	55.5	65 / 55*	60		76 – 82
	Nam Van Lake (2) (南灣湖（二）)	63.7	70 / 60*	51		51 – 72
M6	Sai Van Lake & Barra (西灣湖及媽閣)	57.1	65 / 55*	N/A[1]		N/A[1]

Remarks:
*Recommended Night-time ANLs are lower than the measured background noise levels.
** The calculated ANL and L_{max} levels were solely contributed by the operation of the LRT system. Background noise level is excluded.
[1]As LRT will be operated inside underground tunnel in the region of Sai Van Lake and Barra, operation rail noise impact at the NSRs in this region is anticipated to be insignificant.

2.2.9 **Table 2-1** shows that the predicted rail noise levels exceed the night-time ANL and L_{max} limit at some identified NSRs under unmitigated scenario. Therefore, noise mitigation measures are recommended, including reduction of train speed and frequency during nighttime, installation of vertical noise barrier, full-enclosure and semi-enclosure. By applying the recommended noise mitigation measures, the predicted rail noise levels at the identified NSRs are evaluated to be complied with the noise limits stipulated in EIAO-TM. **Table 2-2** shows that the predicted rail noise levels at the identified NSRs in different regions would comply with the ANL during night-time under mitigated scenario. Details of the predicted rail noise levels at the identified NSRs are attached in **Appendix A**. As the LRT alignment in different regions in Macau Peninsula is now under detailed design, recommended noise mitigation measures would be slightly adjusted associated with the amendment of LRT alignment. Therefore, recommended noise mitigation measures would not be presented in this report for the time being.

Table 2-2 Measured Background Noise Levels, Recommended ANLs and Predicted Rail Noise Levels in Different Regions of Macau Peninsula under Mitigated Scenario

Region ID	Region Name	Night-time Background Noise Levels, L_{eq} dB(A)	Daytime & Evening-time ANL $L_{eq,30min}$, dB(A)	Daytime & Evening-time Predicted Maximum Rail Noise Levels $L_{eq,30min}$ dB(A) **	Nighttime L_{max} Noise Limit dB(A)	Predicted Nighttime L_{max} Noise Levels dB(A) **
M1	Barrier Gate (關閘)	67.5	70 / 60*	62 / 57	85	49 – 85
M2	Areia Preta (黑沙環)	68.2	70 / 60*	62 / 57		51 – 85
M3	Outer Harbour (外港)	69.1	70 / 60*	56 / 53		71 - 83
M4	NAPE (Novos Aterros do Porto Exterior) (外港填海區)	68.3	70 / 60*	61 / 57		70 – 85
M5	Nam Van Lake (1) (南灣湖（一）)	55.5	65 / 55*	57 / 54		76 – 79

	Nam Van Lake (2) (南灣湖（二）)	63.7	70 / 60*	51 / 48		51 - 72
M6	Sai Van Lake & Barra (西灣湖及媽閣)	57.1	65 / 55*	N/A[1]		N/A[1]

Remarks:
*Recommended Night-time ANLs are lower than the measured background noise levels.
** The calculated ANL and Lmax levels were solely contributed by the operation of the LRT system. Background noise level is excluded.
[1] As LRT will be operated inside underground tunnel in the region of Sai Van, operation rail noise impact at the NSRs in this region is anticipated to be insignificant.

2.2.10 In order to verify the effectiveness of the recommended noise mitigation measures, it is recommended that noise monitoring should be conducted by and independent authority during the first year of operation.

2.2.11 On the other hand, vibration impact at the Macau Cultural Centre due to the passing-by LRT system has been assessed. The vibration force is expected to be insignificant with the elevated viaduct, concrete guideway and rubber-tyred wheel system.

Taipa

2.2.12 As the detailed design in Taipa has been commenced in an early stage, the environmental impact assessment on Taipa could be conducted based on the latest information of rolling stock and proposed LRT alignment provided by MHI.

2.2.13 The predicted rail noise levels at all of the identified NSRs on Taipa could comply with the L_{max} criterion stipulated in the EIAO-TM. However, predicted rail noise levels at minor group of NSRs would exceed the daytime/evening time and nighttime (0700-2300 hours & 2300-0700 hours) ANL stipulated in the EIAO-TM. **Table 2-3** shows the measured background noise levels, recommended ANL (i.e. assessment criteria) and the predicted rail noise levels in different regions of Taipa at different periods of a day under unmitigated scenario.

Table 2-3 Measured Background Noise Levels, Recommended ANLs and Predicted Rail Noise Levels in Different Regions of Taipa under Unmitigated Scenario

Region ID	Region Name	Night-time Background Noise Levels, L_{eq} dB(A)	Daytime & Evening-time ANL $L_{eq,30min}$, dB(A) **	Daytime & Evening-time Predicted Maximum Rail Noise Levels $L_{eq,30min}$ dB(A)	Nighttime L_{max} Noise Limit dB(A) Nighttime L_{max} Noise Limit dB(A) **	Predicted Nighttime L_{max} Noise Levels dB(A)
T1	Ocean Gardens (海洋花園)	63.3	70 / 60*	68	85	62 – 78
T2	Macau Jockey Club (澳門賽馬會)	64.0	70 / 60*	74		62 – 83
T3	Co-Tai (路氹填海區)	62.4	70 / 60*	57		67 – 73
T4	Wetland & Macau East Asian Games Dome (路氹生態保護區及澳門東亞運動會體育館)	58.4	65 / 55*	56		68
T5	Macau University of Science & Technology (澳門科技大學)	59.5	65 / 55*	60		60 – 76
T6	Avenida Vai Long & Macau International Airport (偉龍馬路及澳門國際機場)	72.7	70 / 60*	73		64 – 83

Remarks:

* Recommended Night-time ANLs are lower than the measured background noise levels.
** The calculated ANL and Lmax levels were solely contributed by the operation of the LRT system. Background noise level is excluded.

2.2.14 Noise mitigation measures are recommended for the LRT alignment on Taipa Island, including reduction of train speed and frequency during nighttime, installation of vertical noise barrier and track-side acoustic treatment. By applying the recommended noise mitigation measures, the predicted rail noise levels at the identified NSRs could comply with the noise limits stipulated in the EIAO-TM. **Figure 2-2** shows the locations of recommended vertical noise barrier, track-side acoustic treatment and reduction of train speed. **Table 2-4** shows that the predicted rail noise levels at the identified NSRs in different regions, while the predicted operation noise created by the LRT system would comply with the ANL during night-time under mitigated scenario.

Table 2-4 Measured Background Noise Levels, Recommended ANLs and Predicted Rail Noise Levels in Different Regions of Macau Peninsula under Mitigated Scenario

Region ID	Region Name	Night-time Background Noise Levels, L_{eq} dB(A)	Daytime & Evening-time ANL $L_{eq,30min,}$ dB(A) **	Daytime & Evening-time Predicted Maximum Rail Noise Levels $L_{eq,30min}$ dB(A)	Nighttime L_{max} Noise Limit dB(A) Nighttime L_{max} Noise Limit dB(A) **	Predicted Nighttime L_{max} Noise Levels dB(A)
T1	Ocean Gardens (海洋花園)	63.3	70 / 60*	65 60	85	51 – 68
T2	Macau Jockey Club (澳門賽馬會)	64.0	70 / 60*	65 / 60		54 – 77
T3	Co-Tai (路氹填海區)	62.4	70 / 60*	57 / 53		57 – 73
T4	Wetland & Macau East Asian Games Dome (路氹生態保護區及澳門東亞運動會體育館)	58.4	65 / 55*	56 / 52**		68

T5	Macau University of Science & Technology (澳門科技大學)	59.5	65 / 55*	60 / 55		62 – 76
T6	Avenida Vai Long & Macau International Airport (偉龍馬路及澳門國際機場)	72.7	70 / 60*	65 / 60		56 – 73

Remarks:
* Recommended Night-time ANLs are lower than the measured background noise levels.
** The calculated ANL and Lmax levels were solely contributed by the operation of the LRT system. Background noise level is excluded.

2.2.15 In order to verify the effectiveness of the recommended noise mitigation measures, it is recommended that noise monitoring should be conducted by and independent authority during the first year of operation.

2.3 Air Quality

2.3.1 Potential air quality impact generated by typical construction works and major dust generating activities have been identified and reviewed at the representative Air Sensitive Receivers (ASRs). Good site practices recommended in this EIA Report should be conveyed to site staff to ensure effective implementation of dust control measures during the construction phase. Provided that these recommendations are strictly followed by the future Contractor, control on fugitive dust emissions is considered to be adequate and the maximum estimated 1-hr average and 24-hr average Total Suspended Particulate (TSP) concentrations are predicted to comply with the TSP criteria (500 $\mu g/m^3$ for 1-hr TSP and 260 $\mu g/m^3$ for 24-hr TSP) at all representative ASRs. The predicted maximum TSP concentrations (1-hr TSP and 24-hr TSP averaged) under mitigated scenario is attached in **Appendix B**.

2.3.2 Dust monitoring is recommended at the potentially most affected ASRs during construction. Although “dark smoke” emission from construction plant is unlikely to occur with proper maintenance of equipment, it is recommended that this should be audited during the site environmental audit. Should “dark smoke” emissions be observed, the future Contractor should provide proper maintenance for the equipment, and to prepare abatement report as needed.

2.4 Water Quality

2.4.1 There are 7 Potential Water Sensitive Receivers (WSRs) identified along the proposed LRT alignment, including the Reservoir along Avenida de Amizade in Macau Peninsula, Nam Van Lake, Sai Van Lake, Zhujiang Kou, Wetland along Estrada da Baía de Nossa Senhora da Esperança in Taipa, Pond along Istmo Causeway Taipa-Coloane in Coloane (Remarks: Pond along Istmo Causeway Taipa-Coloane in Coloane no longer available) as well as Wetland along Estrada Flor de Lótus. Because of the underground tunnel construction between Station 9 and Station 12 across Nam Van Lake and Sai Van Lake and the Station 11 construction by the Sai Van Lake, attentions have been paid to these 2 WSRs and a quantitative water quality assessment has been carried out. Figure 2-3 reveals the locations of WSRs.

Baseline Investigation at Nam Van Lake and Sai Van Lake

2.4.2 A preliminary site investigation was conducted before any of the study to gather baseline information of water and sediment quality in both Nam Van Lake and Sai Van Lake respectively for the purpose of facilitating the detailed EIA study.

2.4.3 Results of the site investigation indicated the presence of a certain level of sediment contamination. It was therefore recommended to dredge and transport those contaminated sediment with care and effectively isolated from the surrounding environment. The sediment that identified as Category L (contaminant concentration below Lower Chemical Exceedance Level- LCEL) could be considered for open sea disposal. Majority of the sediment samples are classified with contamination concentration of Category M and H, which is recommended to adopt confined marine disposal, referring to deposit sediments in the bottom of a natural depression or a hole dug in the bottom and placing the sediment in by hydraulic pipeline with or without a submerged diffuser, direct placement with a clamshell, or release from bottom-dump scow. The State Oceanic Administration People's Republic of China (國家海洋局) shall be liaised with for the detailed arrangements of disposal permit and suitable disposal site for any marine disposal.

2.4.4 Particular care should be taken during the ongoing site construction works to ensure that any material excavated from this area is not redeposited elsewhere within the site. Site workers delivering dredged sediment should be equipped with suitable personal protective equipment (such as gloves and overalls) and should follow good hygiene practices (i.e. washing of hands and avoiding smoking and eating) during handling of excavated/dredged sediment, in order to prevent the exposure to the contaminated sediment and lake water through ingestion, inhalation and dermal contact.

2.4.5 The East Cotai Landfill is the current disposal site for excavated sediment in Macau. The future Contractor should clearly laid down and rigidly adhered to precautions with respect to any:

- trench and excavation;

- creation of confined spaces, near to or below ground level, that might be associated with dumping activities in East Cotai Landfill

2.4.6 Moreover, all safety procedures of East Cotai Landfill shall be strictly followed by future Contractor. No worker should be allowed to work alone at any time in or near any excavation of the landfill. At least one other worker should be available to assist with a rescue if needed. Smoking, naked flames and all other sources of ignition should be prohibited within 15m of any excavation or ground-level confined space. All electrical equipment to be employed by the future Contractor, such as motors and extension cords should be intrinsically safe.

Construction Phase

2.4.7 Nam Van Lake and Sai Van Lake are isolated with Pearl River by metal water gate. Such metal water gate will not be opened during construction in order to avoid releasing potential pollutant in both lakes into Pearl River. On the other hand, since the Water Quality Sensitive Receivers (WSRs) outside both lakes will not to be affected by the tunnel construction, they would not be further evaluation conducted in the study for other WSRs.

2.4.8 Major source of water quality impact is anticipated to be excavation and fill dumping during construction of seawall, temporary embankment and bored piles construction. Since the tunnel construction will be conducted based on the cut-and-cover method on the already formed temporary embankment, such construction work is not anticipated to disturb the lakebed. Besides, surface runoff from exposed grounds, storage and stockpiles, oil and fuel storage cum maintenance area, and dust suppression mist will potentially increase concentration of suspended solid in the lakes. Site sewage, packaging waste and waste from site activities will also have impact on water quality sensitive receivers.

2.4.9 Quantitative water quality modeling was carried out by using computational hydraulic model Delft3D. Modeling results indicated the exceedance of suspended solid criteria without any mitigation measures. However, the exceedance would only be temporary because the suspended solid in the water will always settle within 48 hours. As referred to the analysis result of in-situ collected sediments, it is noted that organic pollutant is not the major concern for the development. Assuming the worse case that all pollutants in terms of suspended solids are released to the water in both lakes, potential pollutant concentration in the lakes are still limited and should be within acceptable levels. Modeling result of the suspended solid dispersion are provided in **Appendix C**.

2.4.10 According to the modeling result, with the implementation of mitigation measures such as multiple silt curtain system, slight residual impact would still occur in both lakes. It is therefore suggested that water features, such as aerators and cybernetic fountains, should not be in operation during the construction period to further reduce these residual impacts. Water quality simulations have been performed, based on the information provided in June 2010. According to the preliminary finalised construction work programme,

sheet piles would be constructed in advance of other works. In this connection, impermeable silt curtain system and advanced seawall have been included as mitigation measures. The EIA report indicated that maximum length of leading seawall formation shall not exceed 300m/day. Also for water-based works below +2.5mPD, the maximum filling rate shall not exceed 200m^3/day, and dredging rate shall not exceed 100m^3/day. The future Contractor shall carry out on-site pilot test to verify silt-removal efficiency of the adopted silt-curtain system prior to the commencement of major construction works. Environmental monitoring and auditing should be carried out during construction phase, and related monitoring and auditing requirements are detailed in the report.

2.4.11 Besides, other water quality impact to sensitive receivers during construction work would be also due to the surface runoff discharged from site stockpile area, dust suppression mist, cleaning water from wheel washing and waste fuel, oil, solvent and lubricants. The report recommended that mitigation measures stipulated in Macau water supply and discharge regulations (澳門供排水規章), Guideline on Control of Site Pollution and Hong Kong ProPECC 1/94 "Construction Site Drainage" should be followed, where most of them are related to good site management. Future Contractor shall strictly implement these mitigation measures, construction phase of LRT system will not have significant impact to water quality to both of the lakes.

Operation Phase

2.4.12 During operation, water quality impacts will mainly be associated with LRT surface runoff, stations and Depot discharged wastewater. The development should provide appropriate water discharge systems. Track runoff discharge shall be diverted to oil and grease / silt interceptors, or oil and lubricating fluids can be spilt to remove oil, grease and sediment prior to discharge into drainage system. Report indicated that, the LRT operation would not cause additional water quality impact provided that drainage and sewerage are appropriately connected to public storm drains and sewerage networks.

2.5 Landscape and Visual Impacts

2.5.1 A Landscape and Visual Impact Assessment of the LRT has been carried out for both the construction and operational stages. Potential and significant levels of landscape and visual impact due to the LRT alignment and stations have been identified. Mitigation measures have also been recommended.

Landscape Impact

2.5.2 Landscape Character Areas (LCAs) which will be affected during construction include:

1) The road and pedestrian network along the LRT track, in particular at Stations 4 to 9 and Stations 10 to 12, which are located at Avenida Dr. Sun Yat Sen and Avenida da Praia Grande, respectively;

2) the landmark and visual recognition at Station 6 and along the tracks of Stations 14 to 15, where the Macau Art Museum and Four-Faced Buddha are located, respectively; and

3) the open space along the tracks of Stations 4 to 9.

2.5.3 In 2010, there was modification of the originally 2km viaduct to entirely underground (and underwater) tunnels between Station 9 and Station 12 for LRT alignment across Nam Van Lake and Sai Van Lake in Macau Peninsula; modification of Station 11 and Station 12 from viaduct/ at-grade to underground; and cancellation of the original Station 10, fronting Headquarters of the Macau SAR Government. A Landscape and Visual Impact Assessment was also carried out in the same year.

2.5.4 As most of the construction of the proposed tunnel alignment between station 9 and station 12 are mainly carried out inside and under the two lakes, the landscape impact on the Landscape Character Types associated with the proposed alignment is predicted to be negligible.

Visual Impact

2.5.5 During construction and operation phases, the main visual impacts will be felt by residents and tourists/open space users who may experience adverse impacts of substantial significance under unmitigated scenario. Students, industrial/construction site workers, casino visitors and pedestrian/vehicle travelers, who may experience impacts of Slight to Moderate Significance.

2.5.6 With the implementation of the suggested mitigation measures, the residual long term impacts arising from the LCAs at Year 10 after the commencement of service of the LRT system will be abated to Slight to Insubstantial Significance.

2.5.7 The results of visual impact assessment for tunnel alignment between station 9 and station 12 shows that the impact on the Visual Sensitive Receiver (VSR) on the land with planned development would be insignificant. The impact on other VSRs, including views from the sea, buildings and roads, will be acceptable after application of mitigation measures on the relevant sections of the LRT alignment and stations.

Mitigation Measures

2.5.8 In order to reduce the impact on the receivers, it is recommended that greening should be carried for the affected locations during construction such as temporary tree plantation acting as barrier, tree transplantation for avoiding loss of trees due to the project whenever necessary, protection for affected tree, proper control of construction program and work area and control of nighttime lighting.

2.5.9 Possible mitigation measures are suggested in the EIA Report. These include

a) Soft landscaping measures

- new trees planted along roadways and pedestrian walkways for amenity and screening purposes;

- featured shrubs planting and lawns to provide an improved environment and incorporate the LRT system better into the existing environment; and
- **Figure 2-4** shows the Preliminary Tree Planting Proposal which aims to soften the impacts due to the LRT structure, especially at areas adjacent to the stations, to create visual and landscape comfort to the public, and to incorporate the LRT system into the existing environment such that the cityscape can be enhanced.

b) Hard landscaping measures

- colourful planters and green panels at different parts of the LRT alignment, footers, pedestrian footbridges and stations, which aim to soften the artificial concrete structures with a natural organic texture, while alleviating the visual impact on the surroundings; and
- featured hard paving, water features, e.g. water cascade, fountain and ponds and any related landscape features, e.g. sculpture, landmark and lighting features, trellis and pavilion along the LRT alignment and its stations, which aim to further highlight the existing or newly proposed open spaces and the associated facilities of the LRT, and to create an improved environment to the general public.

c) Any possible engineering approaches, such as noise barriers, to be implemented in the LRT systems, should be properly incorporated with either soft or hard landscaping measures.

2.5.10 Two areas in the Study Area including (1) high density building areas and their associated landmark feature; and (2) existing district facilities and parks featured with streetscape. Examples of these areas are Station 1, Station 8. In the EIA Report, these examples have been discussed in detail.

2.5.11 Regarding the supplementary study for the Tunnel Alignment Option, visual impact on the tunnel alignment between Nam Van Lake and Sai Van Lake from station 9 to station 12 was also assessed. A baseline study on landscape and visual character was conducted. 4 Landscape Resources (LRs) including mountains / hills, trees / tree groups, lakes coastal areas, as well as urban areas; 6 Landscape Characters Types (LCTs) including an urban township, coastal area, upland and hillside area, governmental / institutional areas, lakes and planned developments; and 4 Visual Sensitive Receivers (VSRs) including views from the sea, buildings, land with planned development and roads. There VSRs represent 3 VSR categories whose the sensitivity and quality were assessed. **Figure 2-5** shows the sectional drawings of the recommended mitigation measures for station 9

2.5.12 It is reported that the landscape near Tiagoda Barra would be deteriorated by the section of elevated station 12. Station 12 is recommended to locate at-grade level, changed to the south west which is the location of the existing bus terminal at Avenida Panoramica. The extension of the Project would be greatly reduced. Hence, the landscape and visual impacts rising from the alignment before mitigation measures are relieved accordingly. **Figure 2-6**

shows the comparison of Landscape and Visual Impact Areas between the two alignment options.

Conclusion

2.5.13 Within implementation of the above mitigation measures, the Phase 1 LRT project would not cause significant landscape and visual impact.

2.6 Cultural Heritage Impacts

2.6.1 There are 11 Designated Monuments, 12 Buildings of Architectural Interest, 1 Assessed Architectural Group and 7 Assessed Architectural Places on Macau Peninsula and Taipa. The above Monument and Heritage sites are shown in **Figure 2.7**.

2.6.2 All known sites of archaeological interest and built heritage resources in the vicinity of the Project have been identified. The alignment of the LRT system will not be not situated in the vicinity of any known archaeological sites, and will be almost exclusively situated on reclaimed land instead, apart from a very small section of Stations 1 and 23. As such, no adverse impact on archaeological sites is expected to occur as a result of the Project.

Construction Phase

2.6.3 The proposed alignment of the LRT will not infringe on the protected zone as defined in Decree Law No. 56/84/M and 83/92/M, but will run in comparative close proximity to the protected zone along Avenida da Praia Grande and the alignment of Station 13. There are a number of Designated Monuments and Buildings of Architectural Interest in the vicinity of the proposed alignment. This indicates that the Project is not proposed to cause direct adverse impacts to built heritage resources.

2.6.4 Mitigation measures have been proposed to ensure that the adverse impacts are either eliminated or kept within acceptable levels. The proposed measures include the standardisation of the foundation vibration level and reduction of construction vibration. The vibration level of the easily affected area in the vicinity of built heritage should be monitored and the shortest distance between the construction site and built heritage should be set to leave a buffer and safety pedestrian walkway. A full Built Heritage Impact Assessment is recommended at a later stage of the Project, at which detailed construction methods and programme should be confirmed by the future Contractor.

Operation Phase

2.6.5 The viaduct, ground rail and tunnel in the proposed LRT have the potential to cause adverse impacts on the built heritage, cultural heritage and protected zone. Colourful planters and green panels at different parts of the LRT

alignment is proposed to aim to soften the artificial concrete structures with a natural organic texture, while alleviating the visual impact on the surroundings.

2.7 Waste Management Implications

Waste Disposal

2.7.1 The Project has evaluated the potential waste management problems in the construction and operation phases, and the potential environmental impacts of handling, collecting and dealing with the waste. The methods of waste reduction, collection, storage and disposal have been checked and the reduction of environmental impacts when handling and dealing with the waste has been suggested.

2.7.2 The Project is likely to result in the generation of a variety of wastes and require the management of construction materials and chemical waste. Special and dangerous wastes not available for incineration, like old tire, solid and liquid dangerous wastes, animal bodies and oil precipitates, are transported to Pac-On reclaimed industrial area for special waste treatment. Provided that the waste arisings are managed using approved methods, such as reuse on-site as filling material, incineration at the Macau Refuse Incineration Plant (MRIP), and disposal at landfill sites, special and dangerous waste treatment station, no unacceptable adverse environmental impact is envisaged.

2.7.3 Mitigation measures recommended in the EIA Report should be incorporated into a Waste Management Plan (WMP) and applied through the contract documents to avoid environmental impact due to improper waste management.

A detailed estimation of waste amount during the Project detailed design stage is suggested to ensure the effectiveness of the WMP.

Land Contamination

2.7.4 There are a number of land uses adjacent to, or within the site boundary of the LRT system that have the potential to cause land contamination, which may pose a risk to construction workers, LRT staff and users. Further contamination land site investigation and assessment, including groundwater, soil and landfill gas monitoring, are recommended at the identified potentially contaminated land uses.

2.7.5 The LRT factory was originally a landfill site, the precautions of the construction of the Coloane-Taipa East LRT Factory should be referred to Section 3: Coloane-Taipa East LRT Factory Environmental Impact Assessment and Land Surveying.

2.8 Ecology

2.8.1 Three habitats types, namely woodlands, wetlands/lakes and urban green zones were identified. Wetlands/lakes include the Nam Van Lake, Sai Van Lake

and the corresponding intertidal wetlands, and the Coloane-Taipa City Ecology Protection Area near the Leun Fa Bridge. Urban green zones include the streets inside and near the site. The woodlands are mainly distributed in the Barra Hill area and some artificial islands in the Nam Van Lake.

Nam Van Lake and Sai Van Lake

2.8.2 A literature review of baseline ecological information of both Nam Van Lake and Sai Van Lake was conducted. No rare or protected species has been previously recorded. In order to fill in the information gap of existing ecological conditions, detailed ecological baseline field surveys covering both dry and wet seasons were carried out. A total of 130 floral species, 20 birds species, 2 herpetofauna species, 8 insect species, 15 benthic faunal species, and 25 fish and crustacean species were recorded. No rare or protected species were found also in these field surveys. The ecological values of woodland, wetland/lake and urban areas identified were considered as low to medium, medium, and low to medium respectively.

2.8.3 Both direct and indirect potential ecological impacts during the construction phase were identified and evaluated. Major sources of impacts include habitat loss, water quality degradation, surface runoff and human disturbance arising from construction activities. However, none of these impacts is significant. Despite the ecological impact of the construction phase being considered as insignificant, pollution control measures should be implemented to abate ecological nuisance which may be induced by construction activities.

2.8.4 Impacts to the surrounding habitats and associated wildlife are likely to arise from increased human activities or disturbance such as railway operation, visitors, and other commercial activities induced by the operation of the Project. Acceleration of urbanised activities may change the surrounding micro-climate, such as rainfall, temperature, wind and sunlight, etc. which may indirectly affect surrounding flora and fauna, however, this is considered insignificant and therefore mitigation measures are not required.

2.8.5 The project site was generally situated on the artificial lakes which have a low sensitive ecological component. There is no ecologically sensitive species with a high conservation interest recorded in habitats nearby. The ecological impact on the surrounding ecology was considered not significant. With the implementation of pollution control measures, no accumulative and residual impacts are anticipated as a result of the construction and operation of the project.

Coloane-Taipa City Ecology Protection Area

2.8.6 The Coloane-Taipa City Ecology Protection Area near the Leun Fa Bridge locates near the developed zone including the hotel development area. The LRT track system is out of the protected zone. Therefore the LRT system is concluded not to have significant ecological impacts on the existing species and habitats in the protected zone.

2.8.7 Although the LRT system is expected to have insignificant ecological impacts on the conserved species, mitigation measures should be implemented to lower down the possible ecological impact. The mitigation measures include good site management during construction phase, and a section of opaque semi-enclosure along the alignment of the LRT system to minimize the impacts on the habitat during the operational stage. The location of the proposed semi-enclosure is shown in Figure 2-8.

2.9 Glare Impact

2.9.1 As there is no legislation focusing on glare impact in Macau and Hong Kong, this report takes the corresponding requirements of “Advertisement Signboard, Building Decorative Lights and Outdoor Electronic Display Light Pollution Control Guidance” as reference and the “Guidance Notes for the Reduction of Obstructive Light (GN01)” issued by the Institution of Lighting Engineers, HK as the standards of light impact.

2.9.2 In view of situation in Macau, it is considered that the Project is classified as the environmental zone “E4” in relation to external lighting controls, as defined in GN01. Light pollution control on upward light, light trespass, source intensity and building luminance stipulated in GN01 are recommended.

2.9.3 Light pollution to the adjacent sensitive receivers might occur along the LRT alignment, especially during night-time (2300 – 0100) operation. Recommendations are provided in the EIA Report to control light pollution. These include minimization of upward waste light by proper application of suitably directional luminaries and light controlling attachments, and adoption of tinted glass in train cars to minimize light spillage to nearby sensitive receivers.

2.9.4 For the tunnel alignment option, Station 9 is of close proximity to nearby residents in Nam Van Peninsula and Lake View Mansion. Exterior lighting, such as street lighting for the access ramp from Nam Van Peninsula to Station 9 concourse, floodlights for signage of the LRT system, and light spillage from the stations indoor lighting such as concourse illuminance, would impose adverse glare impacts on nearby residents if not carefully controlled.

2.9.5 The greatest potential for achieving satisfactory control of light spill is at the design stage. Detailed architectural and lighting designs should meet the operational requirement of Station 9 as well as provide mitigation measures to avoid obtrusive light impacts. Lighting design objectives, practicable mitigation measures as well as operation and maintenance requirements shall be included in specification for the Station 9 design. An assessment should be conducted during the design stages to demonstrate the established lighting design and environmental objectives can be achieved.

3. ADDITIONAL FOCUS ON LRT DEPOT DEVELOPMENT AT EAST COTAI

3.1 Introduction

3.1.1 The LRT depot at East Cotai is originally a landfill disposal site filled with construction and demolition waste. The Scott Wilson Ltd was appointed by GIT in 2009 to carry out an additional environmental study LRT depot development at East Cotai in order to assure the safety of the construction of depot and to avoid any accident caused by landfill gases. The investigation works, which consisted of sinking of drillholes, soil and groundwater sampling, geotechnical and environmental laboratory testing, and landfill gas measurements, were managed by the Civil Engineering Laboratory of Macau (LECM) associated with on-site supervision by Scott Wilson.

3.1.2 The intrusive environmental investigations were carried out with 50 soil samples in total. These samples were collected from 10 drillholes. 15 groundwater samples were collected from the fill, marine clay and alluvium layers. All the soil and groundwater samples were tested and analysed by ALS Laboratory Group (ALS), a HOKLAS accredited laboratory in Hong Kong. On-site landfill gas measurements were carried out by ENSR Asia (HK) Ltd. (ENSR), which has extensive landfill gas monitoring experience in Hong Kong.

3.2 Testing Results of Soil and Groundwater Samples

3.2.1 The environmental laboratory results do not indicate the presence of significant soil or groundwater contamination from metals, TPHs, SVOCs and VOCs. Since it is not intended to extract groundwater for potable use on or around the site, any limited groundwater contamination is not considered to pose a risk to future depot workers.

3.3 Measurement Results of Landfill Gases

3.3.1 According to the landfill gas measurement results some compositions, such as carbon dioxide and methane, were consistently detected above the respective limits specified in Waste Management Paper No. 27: Landfill Gas. Risk mitigation measures recommended as below should be implemented to reduce the risks of health and safety hazards to workers during the construction and operating phases.

- Site workers in the construction stage should be equipped with suitable personal protective equipment (such as gloves and overalls) and should follow good hygiene practices (i.e. washing of hands and avoiding smoking and eating) during the progress of excavation works.

- In addition to normal site safety procedures, gas detection equipment and appropriate breathing apparatus should be available and used when entering confined spaces or trenches deeper than 1 meter.

- A Safety Officer, trained in the use of gas detection equipment and landfill gas-related hazards, should be present on site throughout the groundworks phase so as to ensure the operational safety of the construction work.

- Comprehensive safety measures should be established in the construction site. For instance, adequate fire extinguishing equipment, fire-resistant clothing and breathing apparatus (BA) sets should be made available on site; Welding, flame-cutting or other hot works may only be carried out in trenches or confined spaces when controlled by a "Permit to Work" procedure, properly authorised by the Safety Officer; Ground level construction plant should be fitted with vertical exhausts at least 0.6m above ground level and with spark arrestors.

3.3.2 Based on preliminary considerations, it is estimated that the entire site where the depot is located could be emitting from approximately 20 to 50 cubic metres of landfill gases per hour at its peak rate of generation.

3.4 Geotechnical Assessment

3.4.1 The geotechnical assessment concluded that the proposed depot development will encounter two major construction issues:

- low soil bearing capacity; and
- large overall and differential ground settlement potential (with predicted settlements of up to 2.0m).

3.4.2 The low bearing capacity and settlement characteristics of the site are the consequence of marine deposits, including very soft clays, present below the waste material used to reclaim the site. These very soft clays failed during the placing of the waste and thus have led to a series of mud waves being developed on the seaward side of the reclamation and being trapped beneath the reclamation.

3.4.3 Ground improvement works, such as pre-loading of the site with surcharge, should be considered over the entire depot site to improve the site's bearing capacity and to reduce the potential levels of settlement that will occur. In areas without buildings, structures and concrete slab siding areas, additional ground improvement works, such as vibro-replacement with stone columns could be used to accelerate settlement and reduce long-term corrective measures. Band drains could be combined with surcharging to enhance ground improvement.

3.4.4 Shallow foundations are not recommended because of the potential overall and differential settlement characteristics of the site due to the soft clays and the presence of decomposing materials in the waste layer. All structures should

thus be piled, with the piles founded on rock. Large displacement steel driven tubular piles are the preferred option, in view of their speed of construction and better quality assurance reliability, but other options could be adopted to suit alternative methods of construction. Pile construction is best procured under a design and build contract.

3.4.5 It is recommended that all building structures should be designed with a piled deck to allow a void of say 1m depth to be incorporated under the deck to protect the building and its occupants from the hazards and effects of landfill gas. The void should allow for any such landfill gas to be vented to the atmosphere. Depending on the building size and the likely gas emission rates and gas composition, passive or active control measures should be adopted for the venting of the accumulated gaseous discharge from the void (for example, higher methane concentrations were detected at the northwest and southeast parts of the site, whilst carbon dioxide concentration were higher at the western side of the site).

4. ENVIRONMENTAL MONITORING AND AUDIT

4.1.1 The future Contractor shall strictly follow and implement the recommended environmental mitigation measures in the report during construction. It is recommended that the Contractor shall establish an dedicated Environmental Team (ET) to conduct monthly site inspections. The ET shall regularly submit progress report on appropriate environmental protections to GIT, authorities, relevant government departments and independent environmental monitoring unit.

4.1.2 Environmental Impact Assessment Report has described mitigation measures to minimise potential impacts associated with the Project, with respect to construction dust, noise and water quality, etc. The ET of the Contractor should conduct regular site inspections and should keep detailed site records in order to ensure environmental mitigation measures are strictly carried out, and the environmental nuisance can comply with relevant statutory limits. If necessary, the Contractor shall formulate additional measures, and propose to the GIT and independent environmental monitoring unit for approval.

4.1.3 The Contractor, GIT, authorities, relevant government departments and independent environmental monitoring unit shall establish regular communication to exchange comments, review and follow up.

5. CONCLUSION

5.1.1 In respect of the design and construction of “Phase 1 Light Rapid Transit System”, the Macau Special Administrative Region Government commissioned Scott Wilson Limited to conduct Environmental Impact Assessments for the proposed alignment, proposed depot site and tunnel alignment option from 2008 to 2010. In 2011, the Project rolling stock system contractor, Mitsubishi Heavy Industries Ltd., commissioned Scott Wilson Limited to conduct an environmental review against potential noise and visual impact based on the MHI rolling stock system and the latest alignment.

5.1.2 This executive summary summarised the assessments and evaluations conducted in various EIAs, in terms of potential noise, air quality, water quality, ecology, visual, landscape, cultural heritage, waste management and glare impacts associated with the Project. This executive summary also summarises the proposed corresponding mitigation measures for the compliance with Macau regulations and the corresponding environmental impact criteria referred to Hong Kong and the Mainland. With the implementation of the recommended mitigation measures, the Project can comply with the environmental impact assessment criteria in general.

5.1.3 Detailed design of the Project is now in progress. Scott Wilson Limited will take into account the updated and latest Project information, so as to review the environmental assessment conclusions, to summarise the potential environmental impacts, and to update the required mitigation measures as needed.