






Land Transport Authority

Environmental Impact Assessment on Central Catchment Nature Reserve for the Proposed Cross Island Line

FINAL CONSTRUCTION & OPERATION ENVIRONMENTAL IMPACT ASSESSMENT REPORT – *VOLUME III*

2 September 2019

The world's leading sustainability consultancy

ERM

Environmental Impact Assessment on Central Catchment Nature Reserve for the Proposed Cross Island Line

Final Construction & Operation EIA – *Volume III*

Environmental Resources Management (S) Pte Ltd

120 Robinson Road #10-01,
Singapore 068913
Telephone (65) 6324 9636
Facsimile (65) 6226 1636
Email ermsg@erm.com
Website: www.erm.com

Client	Project No
Land Transport Authority Singapore	0256660

Project Summary

The Land Transport Authority commissioned ERM to undertake environmental impact assessment studies relating to the construction and operation of the Cross Island Line (CRL) at or in close proximity to the Central Catchment Nature Reserve (CCNR), in Singapore. The phased studies are:

- *Phase 1a*: Environmental Baseline
- *Phase 1b*: EIA of the Soil Investigation (SI) Works
- *Phase 2*: EIA of the construction and operation of the CRL for the two route options.

This document presents ***Volume III*** of the Construction & Operation (C&O) EIA (*Phase 2*) for the Project.

Date

2 September 2019

Approved by

Alastair Scott

Managing Partner, ERM (S) Pte Ltd

Revision	Description	By	Checked	Approved	Date
008	Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	02.09.19
007	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	22.08.19
006	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	02.08.19
006	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	26.07.19
005	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	18.07.19
005	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	4.07.19
005	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	28.05.19
004	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	23.04.19
003	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	18.12.18
002	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY / OSY / MO	WG / BB / TF / RRD	AS	23.03.18
001	Pre-Final C&O Environmental Impact Assessment Report - Vol III	JS / EY/ SMC / TWT / GK	RF / TF / IC / MF / RRD	AS	23.12.16

Distribution

☐ Internal

☒ Public

☐ Confidential

TABLE OF CONTENTS

1 INTRODUCTION

This Volume of the C&O EIA report presents the IA and EMMP for the proposed construction and operation of Alignment Option 1. The objective of the IA is to:

- To identify, quantify and assess potential impacts and determine the significance of impacts on sensitive receivers and potential affected uses;
- To propose mitigation measures to minimize significant impacts during Project construction and operation;
- To identify, predict and evaluate the residual environmental impacts (after practicable mitigation) and the cumulative effects expected to arise during construction and operation in relation to the sensitive receivers and potential affected uses; and
- To identify, assess and specify methods, measures and standards to be included during the construction and operation, i.e. develop an EMMP.

The remainder of this volume (III) is structured as follows:

- *Chapter 2* presents the IA of construction and operation activities on the water environment receptors and resources within the Study Area;
- *Chapter 3* presents the IA of noise and vibration generated during the construction works on human receptors;
- *Chapter 4* presents the IA on emissions from the construction and operation on air quality;
- *Chapter 5* presents the IA on ecology and biodiversity from the construction and operation activities;
- *Chapter 6* presents the IA on other resources such as cultural heritage, landscape and visual amenity and on tourism and recreation land use from the construction and operation activities; and
- *Chapter 7* outlines the EMMP for Alignment Option 1 construction and operation.

2 WATER ENVIRONMENT

2.1 INTRODUCTION

This chapter presents an assessment of the impacts of activities associated with the construction and operation phase of Alignment Option 1 in terms of water resources within and in adjacent to the Project.

This chapter is structured as follows:

- *Section 2.2* defines the scope of the assessment*;*
- *Section 2.3* presents a summary of the baseline water environment within the Project Study Area*;*
- *Section 2.4* provides an overview of the methodology used to assess the impacts to water resources;
- *Section 2.5* provides an assessment of the potential impacts during the construction phase of the Project; and
- *Section 2.6* provides an assessment of the potential impacts during the operation phase of the Project.

2.2 SCOPE OF THE ASSESSMENT

The scoping exercise identified several construction and operational activities that may have significant interactions with the water environment (surface and groundwater) in the Study Area. These activities were reviewed in detail against the construction information outlined in Volume I Chapter 2 and took into consideration the baseline water environment. The types of impact considered are presented in Section 2.5. Where necessary, additional mitigation measures will be implemented to ensure that impacts are mitigated to levels indicated in this report.

A number of types of impact/activities were considered but have been screened out from further assessment as they are not expected to result in any impacts to the nearby surface water receptors. These include:

General

- Where the quality of surface water and groundwater is affected by the Project, this may have secondary impacts to other receptor, in particular ecological resources. There may also be unplanned events, such as accidents resulting in wastewater generation and discharge, which need to be considered. While this chapter focuses on the impacts to the water environment of such events, the resulting impacts to ecological receptors are addressed in Chapter 5.
- The committed development in closest proximity to the Project consists of the PUB's proposed water pipeline installation from Bukit Kalang to Upper Thomson Road. Consultation between the PUB and the LTA has been undertaken during the course of this study to ensure that works will not occur at the same time as the Project. Cumulative surface water impacts have therefore not been assessed in this EIA. PUB and LTA are working together to reduce the combined

footprint of PUB and LTA's possible worksites to minimize overall environmental impact. In the event that new committed developments areidentified, the LTA has committed to undertake a cumulative impact assessment at the Advanced Engineering Study (AES) stage of the Project.

Construction Stage

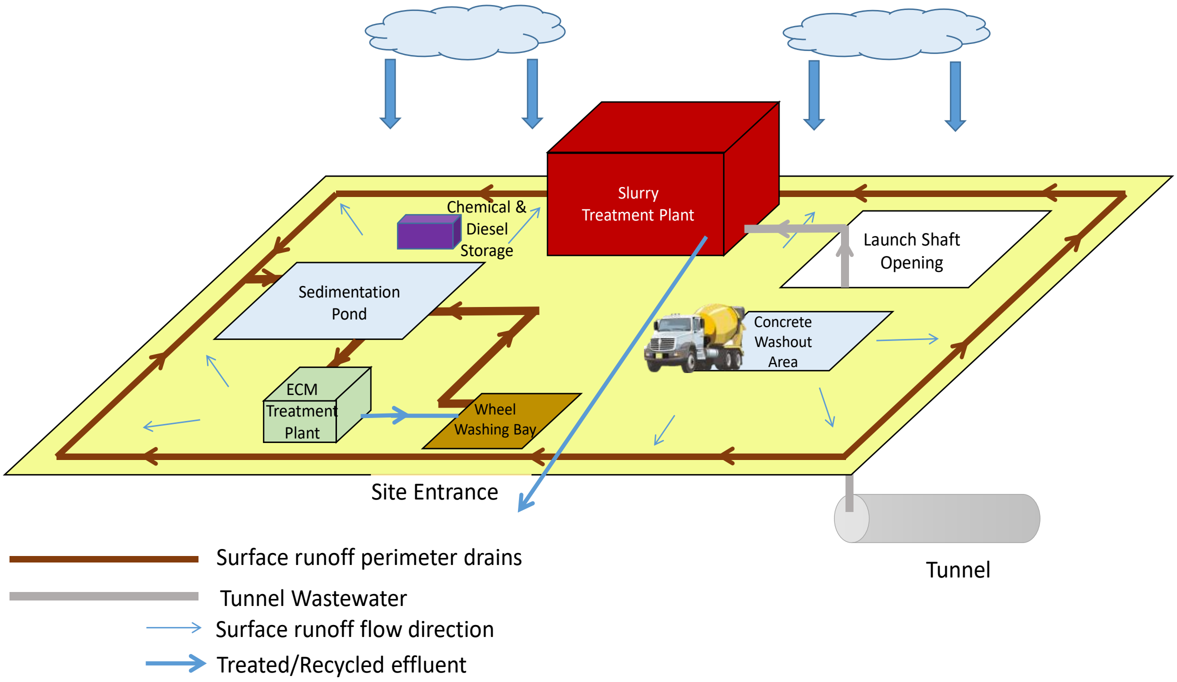
- While there will be no concrete batching plant on site, the nature of the construction works will involve handling quantities of cement in the form of raw cement, wet concrete and grout. Cement is made up of a number of compounds that when mixed with water undergoes a process known as hydration. The process of hydration results in the hardening of cement. For the purpose of this discussion it is sufficient to consider the two principle strength giving components which are tricalcium silicate (Ca_3SiO_5) and dicalcium silicate (Ca_2SiO_4) because their hydration process results in the production of calcium hydroxide ($Ca(OH)_2$) which is of environmental concern. Although $Ca(OH)_2$ is relatively insoluble (1.7 g/L at 20 °C), excessive water in a concrete mix will result in failure of the $Ca(OH)_2$ crystalizing and leading to the forming of a solution known as limewater which is highly alkaline. The alkalinity is associated with the presence of Ca^{2+} and $2OH^-$ ions. [38]

  At the worksites, there is a possibility of limewater formation when wet concrete and grout are in contact with water during a rain event as well as when cements trucks are rinsed at the washing bay before exiting the site. However, as the construction site will be designed with appropriate ECM controls, surface runoff containing limewater will be collected via the perimeter drains leading to ECM treatment plant. In addition, a neutralization system will be provided at the ECM treatment plant such that the water quality at the discharge point of the ECM plant is meeting the pH limit of 6 – 9 stipulated within the *Environmental Protection and Management (Trade Effluent) Regulations* for controlled watercourse. Moreover, a real-time and continuous pH meter will be installed at discharge points of the ECM plant. Alongside this, an automated system will be provided to halt the discharge if any exceedance of the pH limit of 6 to 9 is detected. The water quality will be neutralized until the limit of 6 to 9 is met, before the discharge can be resumed.

  The only potential pathway of limewater entering a surface waterbody directly is due to the unplanned event of overflow. The assessment of this unplanned event is further discussed in *Table 2.6*.

- Wastewater generated the from the slurry treatment plant and water ingress encountered at A1-W1 will not be further assessed as they will not be handled following the typical way shown in *Figure 2.1*.

Figure 2.1: Generic water management systems within a LTA site



The TBM operation will require the use of bentonite slurry as drilling fluid and this will result in the generation of slurry waste. As shown in *Figure 2.1*, typically, used slurry comprising water, mud, adjustment agents and crushed rock (ie muck) will be channelled to the slurry treatment plant located at the above ground worksite and discharged offsite to either a surface drain or public sewer. However, considering that A1-W1 is located in close proximity to stream Ma, wastewater generated from the slurry treatment system will not be treated on site. Instead, the slurry wastewater will be contained within a slurry water pit to be designed with the appropriate engineering control (eg lining and proper sizing etc.) and disposed-off via a licensed third party collector.

Water ingress could be encountered during excavation or TBM operation, although the amount is not expected to be significant considering the shallow level of groundwater and the engineering controls. Similar to the slurry wastewater, water ingress will not be treatment onsite at A1-W1, it will be collected and stored within dedicated tanks prior to being removed by a licensed third party collector.

Based on this, as there will be no surface waterbody receiving the slurry wastewater and water ingress, this has been screened out from further assessment.

For worksite A1-W2, the handling of wastewater from the slurry treatment plant and water ingress will be as per *Figure 2.1* where the treated effluent will be discharged to either a surface drain or public sewer. The impact associated with this will be assessed in *Table 2.6*.

- Sanitary waste will be generated from the temporary sanitary facilities within the worksites. The handling and management of domestic refuse and sewerage will be in accordance with the dedicated regulations such as the *Environmental Public Health (General Waste Collection) Regulations, 2000* and *Sewerage and Drainage (Trade Effluent) Regulations, 2007*. Sanitary waste will either be disposed by a licensed third party collector or the public sewer, whichever is more suitable depending on the site condition. As there will be no surface waterbody receiving the sanitary waste, this has been screened out from further assessment.

- Based on site investigation data and field observations by the LTA, there are no significant fault zones or interconnected fractures within the rock layer under the CCNR. There was reported no observation of artesian water pressure conditions during the drilling of vertical and horizontal boreholes. Data therefore does not indicate any hydraulic link of groundwater to deeper layers of soil or rock. It is therefore unlikely that there is any intercepting of groundwater under the CCNR to the geothermal strata observed under the Sembawang Hot Spring, located 8 km north of the CCNR. It is therefore anticipated that there will be no impact to hydrogeology at the Sembawang Hot Spring due to tunnelling works within the CCNR bedrock, and this has been screened out from further assessment.

Operation Stage

- During the tunnel's operation, various types of water/wastewater will be generated from sources such as water ingress into the tunnel, tunnel washing, testing and emptying of fire mains, condensate from train air-conditioning and environmental control system associated plants etc. In general, the water/wastewater, based on their source and location, will be contained within their dedicated drainage and collection systems for collection by third party contractors for offsite disposal. The design of the different drainage and collection systems is specified in multiple guidebooks (2) and is a topic that will be studied closely by the engineering designer to ensure no impacts/minimal impacts to any nearby surface watercourses. Given this, impacts associated with water/wastewater generated during operations have been screened out from further assessment.

2.3 SUMMARY OF RELEVANT BASELINE CONDITIONS

2.3.1 *Surface Water*

The baseline conditions of surface water receptors in the Study Area were established primarily through baseline surveys conducted as part of the SI EIA in 2014 to 2015 (1). For the purpose of the C&O EIA, additional data pertaining to the rainfall and drainage conditions of the Study Area have been reviewed.

2.3.1.1 *Summary of SI EIA Volume II*

Key elements of the environmental baseline pertinent to the surface water in the Study Area include:

- Given Singapore's equatorial monsoon tropical climate, rainfall is prevalent throughout the year with an average of 2,348 mm/yr. Rainfall is typically highest during the northeast monsoon season, especially in December.

- The tropical climate contributes to daylight of 12 hours, of which 46% (ie 5.7 hours) of the time is sunshine with the highest UVI measured at between 11 am and 3 pm.

- Total rainfall received within the Study Area in 2013 was more than 2,900 mm, 10 % to 30% above the national average.

- MacRitchie Reservoir and the streams within its catchment area form the main surface water receptors identified within the Study Area.

- Water in the reservoir was generally clear. Aquatic plants were observed on the reservoir water surface adjacent to the Bukit Golf Course.

- There are numerous small streams feeding into MacRitchie Reservoir (see *Figure 2.3*) with lengths varying from 6 m to 1,350 m and widths of up to 6 m. These streams are perennial with measured water levels ranging from 0.02 m to 1 m during the surveys conducted in October and November 2014.

- During rainfall events, the public trails within the CCNR become stormwater drainage channels and numerous stormwater gullies traverse the Study Area, in particular in some areas along Sime Track (see photo).

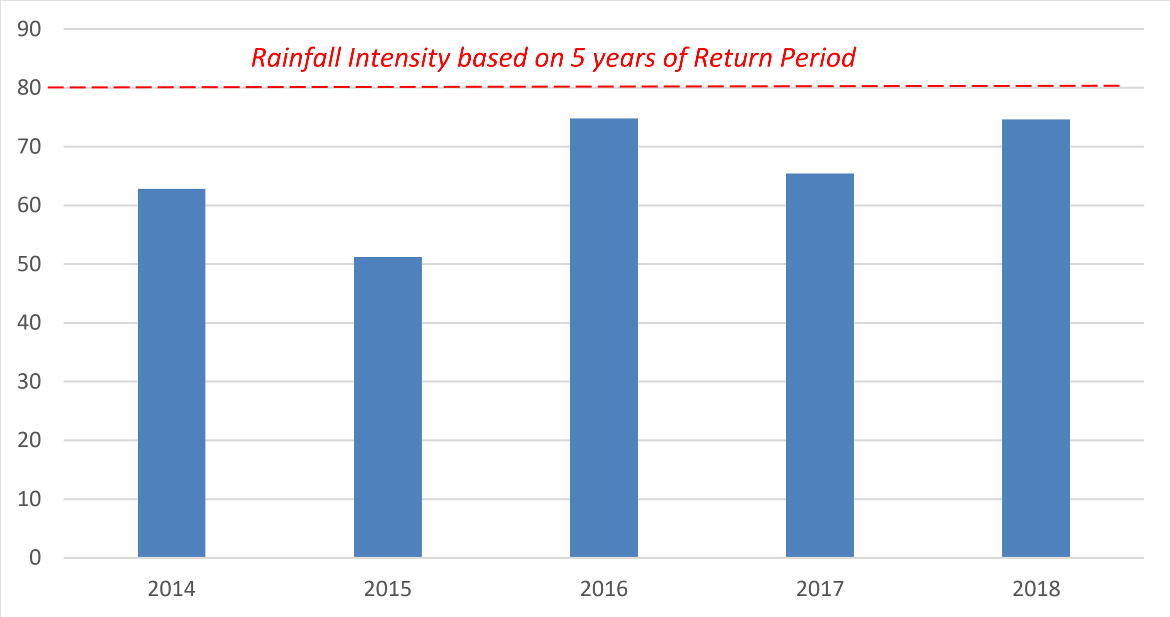
- Concentrations of surface water quality indicators taken at nine locations during the baseline surveys indicated physical and chemical parameters to be well within the raw water quality standards, the *Environmental Protection and Management (EPM) (Trade Effluent) Regulations*, limits for discharge into a controlled watercourse and the *World Health Organization (WHO) Guidelines for Safe Recreational Water Environment*.

2.3.1.1 Site Specific Baseline Conditions

Rainfall

Daily rainfall records for years 2014 and 2018 from the Lower Pierce Reservoir and MacRitchie Stations were reviewed. The highest 60-minute rainfall records, which show the highest rainfall occurred on a particular day for any 1 hour period, were compared against the rainfall intensity level obtained from the PUB published Intensity-Duration-Frequency (IDF) Curves as shown in *Figure 2.2*. The IDF Curves chart is used to estimate the return period of a rainfall event or rainfall amount and the return period of 5 years has been chosen based on the minimum Earth Control Measure (ECM) design stipulated under the *Code of Practice on Surface Water Drainage*.

Figure 2.2: Maximum of the Highest 60-minute Rainfall (mm) for years 2014 to 2018

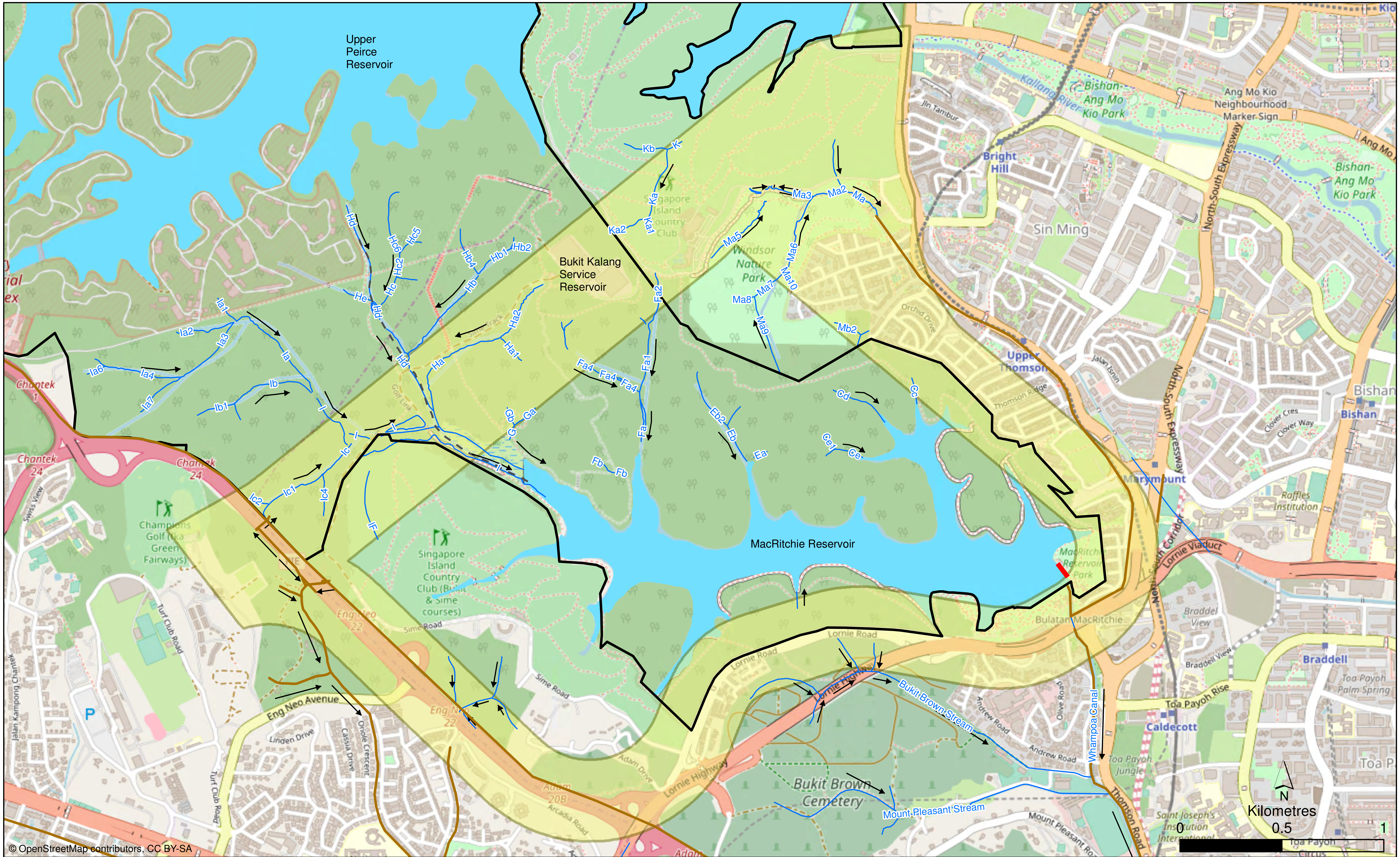


As observed from *Figure 2.2*, there were 2 events that were slightly below a rainfall intensity of 80 mm/hr for the 1 in 5 years rainfall that occurred in the years of 2016 and 2018. The highest 60-minute rainfall events were 74.8 m and 74.6 mm, and were recorded in December 2016 and April 2018 respectively.

Surface Water Receptors

Figure 2.3 to Figure 2.6 presents the surface water receptors identified at each worksite. Specific description of each surface water receptor is provided below.

Figure 2.3: Surface Water Features within Study Area

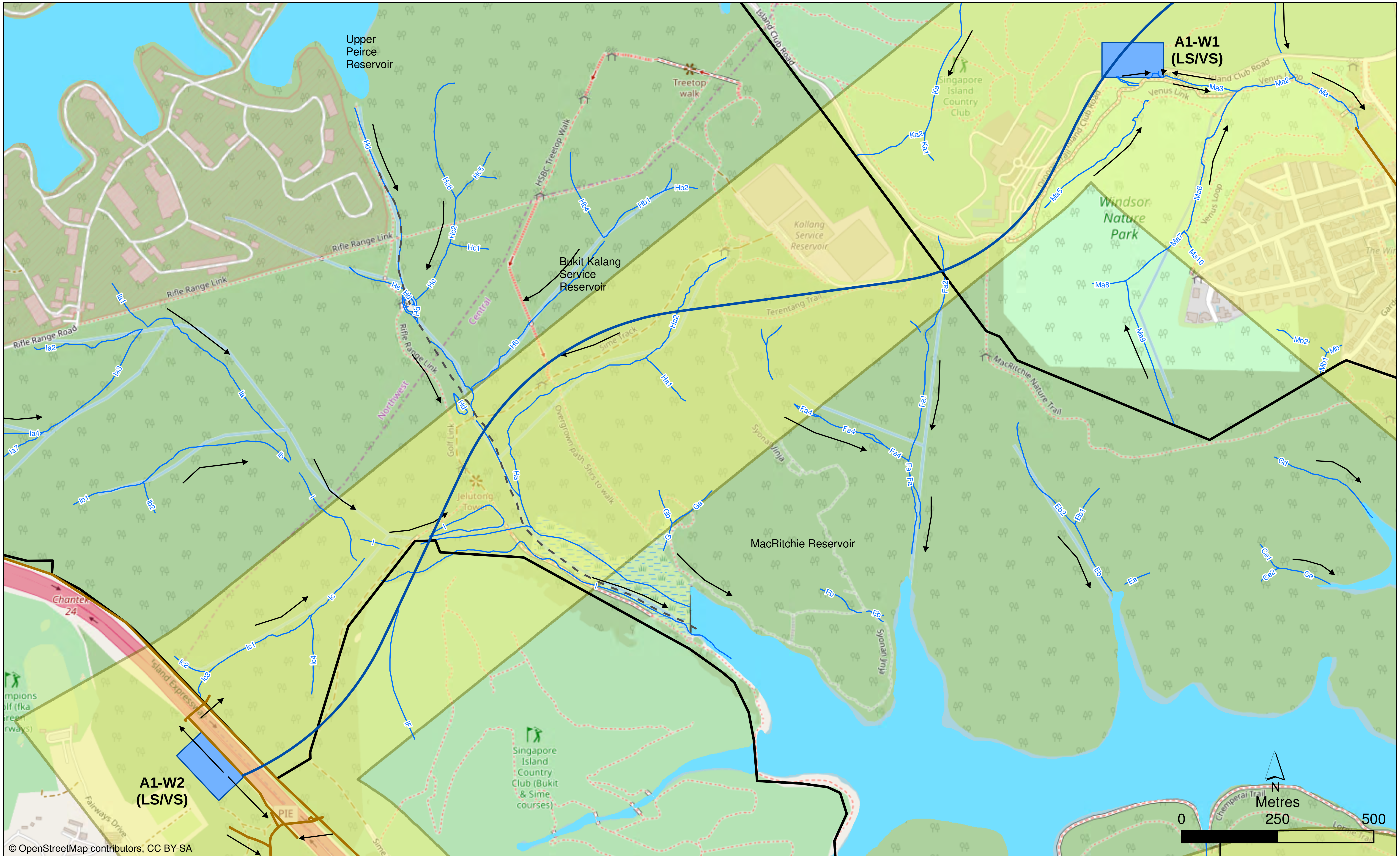


Environmental Resources Management

ERM

File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_II_Surface_Water_Features_v1.mxd
Date: 21/8/2019

Figure 2.4: Overview of Surface Water Receptors for Alignment Option 1



Key

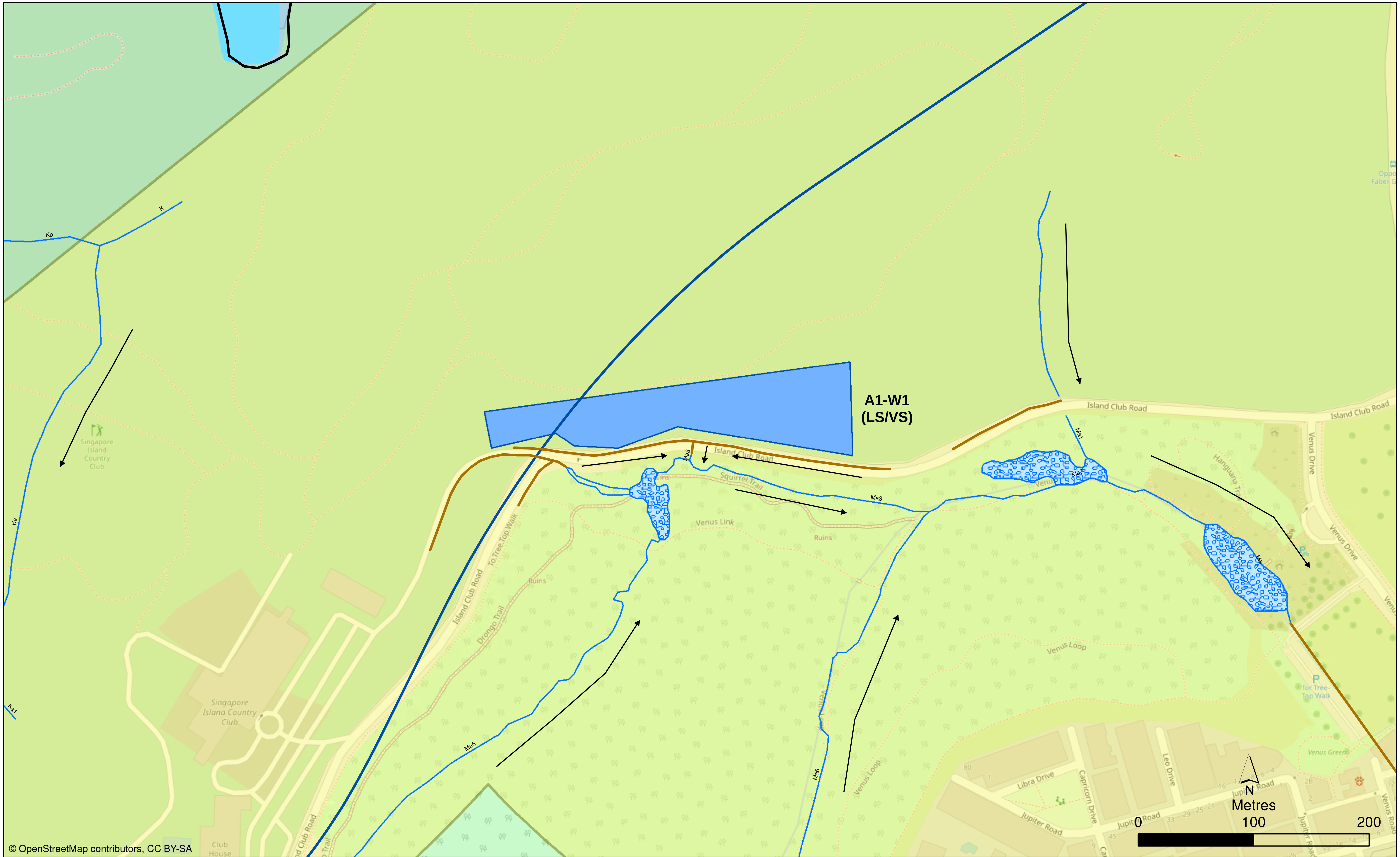
- CCNR Boundary
- Broad Study Area
- Single Bored Tunnel Alignment Option 1
- Indicative Worksite Boundary
- Flow Direction
- Inter Reservoir Water Transfer Route
- Inferred Canal / Drain Route
- Streams

Environmental Resources Management

ERM

File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_III_Surface_Water_Features_Alignment1_v1.mxd
Date: 21/8/2019

Figure 2.5: Surface Water Receptors for A1-W1



Key

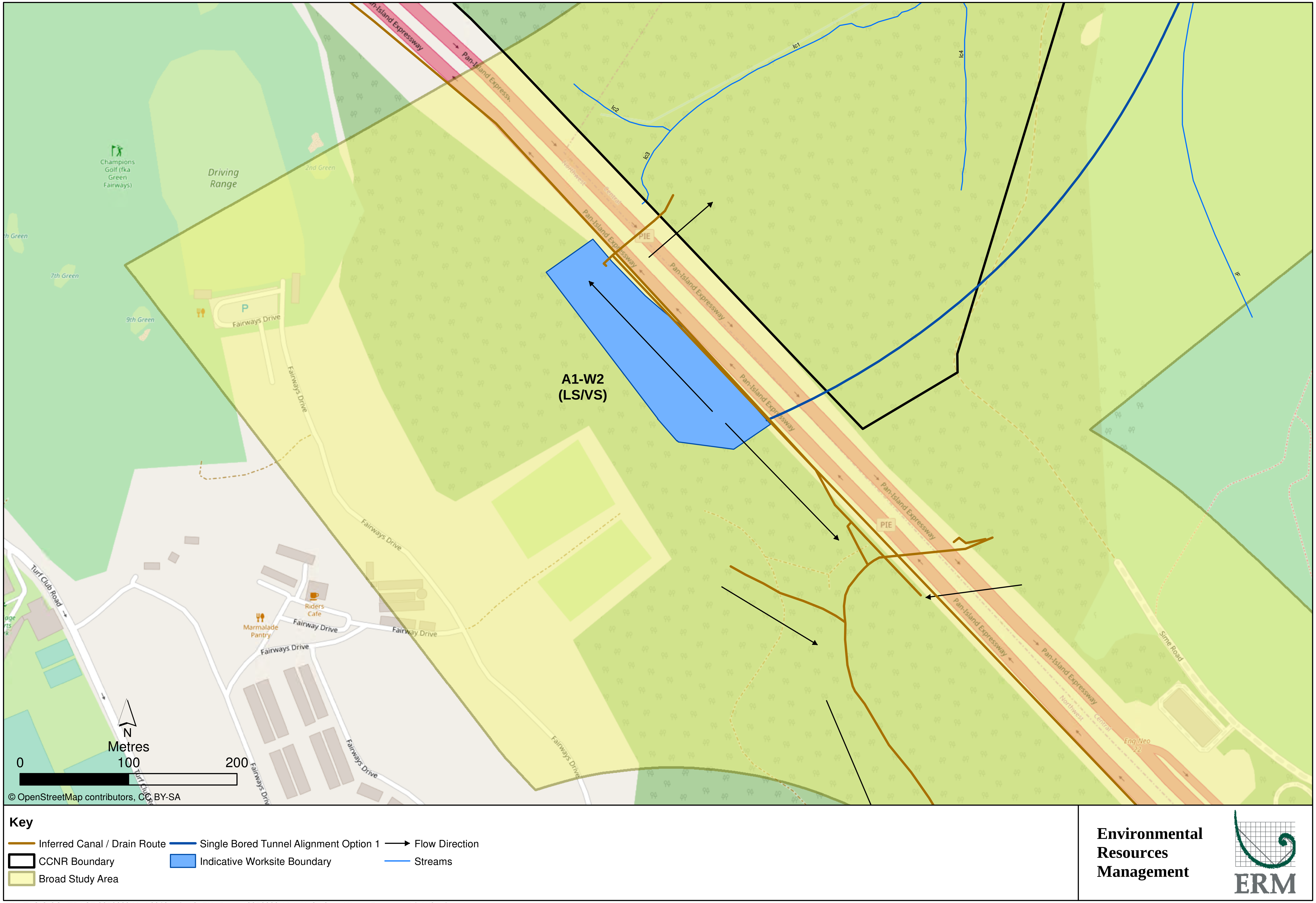
- Inferred Canal / Drain Route
- Single Bored Tunnel Alignment Option 1
- Flow Direction
- Broad Study Area
- Indicative Worksite Boundary
- Streams
- CCNR Boundary
- Wetland

Environmental Resources Management

ERM

File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_III_Surface_Water_Features_A1_W1_v1.mxd
Date: 24/4/2019

Figure 2.6: Surface Water Receptors for A1-W2



File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_III_Surface_Water_Features_A1_W2_v1.mxd
Date: 30/7/2019

Worksite A1-W1

As shown in *Figure 2.4*, the proposed location of A1-W1 is surrounded by a series of roadside drains along Island Club Road which are connected to Stream Ma within the Windsor Nature Park. The roadside drains are generally dry when there is no rain.

Upstream from the roadside, drains collect water from catchment areas further to the west and southwest of the worksite.

Inlet connecting roadside drains and Steam Ma

Roadside drain viewing west from inlet
Photo credit: O'Dempsey A, 12 March 2019

Roadside drain viewing east from inlet
Photo credit: O'Dempsey A, 12 March 2019

Downstream the roadside drains discharge into Stream Ma. From the outlet of the roadside drains, Stream Ma flows around 500 m before it transitions into to a concrete canal running along Upper Thomson Road which ultimately leads to the Marina Reservoir.

Stream Ma is naturally slow flowing during dry conditions with flow rates measured from 3 m^3/hr to 42 m^3/hr [38] along the stream. However as Stream Ma receives water from multiple catchment areas, water flow increases significantly during rainfalls. A collection of photos showing Stream Ma during dry and rainfall are provided below.

Two rounds of water quality monitoring were conducted for Stream Ma in 2014 as outlined in *Vol II, Table 4.5*. Based on this, the results for TSS were below 5 mg/l and for pH were at 6.7.

Stream Ma during dry conditions

Stream Ma After Rain
Photo credit: O'Dempsey A, 12 March 2019

<u>Worksite A1-W2</u>

The surface water receptors at A1-W2 include a network of drains that fall within the catchments of the MacRitchie Reservoir as well as the Marina Reservoir.

As observed from *Figure 2.3*, *Figure 2.4* and *Figure 2.6*, the immediate surface water receptor is the drain located to the east of the worksite, parallel to the PIE. Surface runoff collected within this drain flows either in a northerly direction and eventually towards Stream IC within the CCNR through an underground drain across the PIE, or in a southerly direction towards a series of drains at Eng Neo Avenue that eventually lead to the Marina Reservoir.

Stream IC is a natural stream within the CCNR and is located within the catchment of the MacRitchie Reservoir. Water quality at Stream IC is assumed to be similar to Stream Ma.

Stream IC

<u>Tunnel Alignment</u>

The tunnel will pass beneath a number of natural streams located within the CCNR. As shown in *Figure 2.4* and *Figure 2.5*, these streams include Streams Ha, I and IC. These streams, particularly streams Ha and I, are water sources feeding into the MacRitchie Reservoir.

Stream I

Stream Ha

2.3.2 Ground Water

- Groundwater is not currently abstracted for use in Singapore.

- The majority of the Study Area is underlain by the Bukit Timah Granite. From a hydrostratigraphy perspective the weathering grades of the Bukit Timah Granite can be described according to the summary provided in *Table 2.1*.

Table 2.1 Description of Various Weathering Grades

Grade	Degree of Weathering	Description
G(V) and G(VI)	Completely Weathered Rock to Residual Soil	Porous Media
G(IV)	Highly Weathered Rock	Fractured Porous Media
G(I) to G(III)	Fresh Rock to Moderately Weathered Rock	Predominantly fractured media

Groundwater storage and transport is expected to be highest at the interface between the weathered rock and the overlying soil within the highly weathered zone where the mass permeability is expected to be highest[(3)].

- Packer testing undertaken as part of the site investigations works indicate that hydraulic conductivities are lowest within the moderately weathered rock and highest in fresh rock to slightly weathered rock. *Table 2.2* summarises the hydraulic conductivities of the different weathering grades and is arranged according to increasing hydraulic conductivities.

Table 2.2 Hydraulic Conductivities of Various Weathering Grades (Packer Tests)

Grade	Degree of Weathering	Hydraulic Conductivity (m/s)
G(III)	Moderately Weathered Rock	$<10^{-8}$
G(II) to G(III)	Slightly to Moderately Weathered Rock	10^{-8} to 10^{-6}
G(III) to G(IV)	Moderately to Highly Weathered Rock	10^{-7} to 10^{-6}
G(IV)	Highly Weathered Rock	1.3×10^{-6}
G(I) to G(II)	Fresh Rock to Slightly Weathered Rock	3.7×10^{-6} to 4.3×10^{-6}

Generally the hydraulic conductivity of the unweathered bedrock would be expected to be low. Hydraulic conductivities can be higher in areas of highly fractured rock with potential for higher flow rates and the packer testing results indicate that where the fresh to slightly weathered rock of the Bukit Timah Granite was tested (in the southwest section of Alignment Option 1), fracture derived permeability is significant.

- The Hydrogeological Map of Singapore published by Pfeiffer (1975)[(48)] showed that the Central Catchment Nature Reserve, which is founded on the granite rocks, has extremely small groundwater capacity locally of about 1m^3 per hour. He recognized that the central part of Singapore must be regarded as rather short of groundwater as the Bukit Timah granite material is virtually impermeable with permeability coefficient (k-value) in the range of 1.10^{-8} m/s and 1.10^{-10} m/s. Besides, Pfeiffer (1975) reported that only sandstones of the Mesozoic sequence could be considered as possible aquifers and this was not found to be present in the boreholes carried out in CCNR. In addition, there were no fault zones or artesian condition observed during the drilling of boreholes in the CCNR as there were only few localized fractures observed from the HDC rock cores and vertical borehole rock cores. Furthermore, there was no artesian water pressures encountered during the drilling of HDC works, which indicates no hydraulic connection of these localized fracture zones to the MacRitchie Reservoir or nearby water sources. From the site investigation data, it may be concluded that there are no major fault lines or fracture zones that are hydraulically connected to surface reservoirs and water bodies in and around CCNR. The packer test results support the literature review.

- The field investigation data do not show that there is link of ground water to deeper layers of soil where the intercepting of ground water to geothermal strata could cause hot water to flow to the surface under artesian conditions as in the Sembawang hot springs[(49)].

- It is further noted that anecdotal observations were made by the LTA during the site investigation works in 2017. There were reportedly no observation of artesian water pressure conditions during the drilling of vertical and horizontal boreholes. LTA reported that examinations of the HDC rock core samples undertaken along Alignment Option 1 did not yield any observation of interconnected fractures, which is indicative that no significant fault zones were encountered.

- According to literature sources, groundwater levels in the Study Area generally ranges between 0.5 m below ground level (bgl) to 10 m bgl, with groundwater levels in the 3 to 5 m bgl range being more common[(3)].

- Reported water level data available for bores in close proximity to Alignment Option 1 was collected during the drilling of the geotechnical bores (during which time water level data were collected from 61 bores drilled along Alignment Option 1). As outlined in the baseline section, these water levels were collected from bores while drilling was in progress. The water level depths were recorded with a water level probe and the drilling was undertaken through mud rotary means (with the use of drilling mud as the drilling fluid likely affecting water level measurements within the bore). Water level measurements taken while drilling with mud rotary would have an impact on how reflective the reported values are of aquifer conditions. When considering the reported drilling related water levels for bores along Alignment Option 1, the average, minimum and maximum reported depths were predominantly within the shallow residual soil horizon. Average depths for the water level measurements varied between 3.0 m bgl and 4.0 m bgl along Alignment Option 1. The lowest minimum depth to water was recorded as 0.48 m bgl and the highest maximum depth to the water level was 8.2 m bgl.

- As no boreholes were kept in the CCNR along Alignment Option 1 after drilling, no standpipe piezometers were installed along Alignment Option 1 for the measurements of groundwater levels from targeted depths following completion of drilling groundwater monitoring. Thus, groundwater measurement were only done through the use of 13 standpipe piezometers along Alignment Option 2. Depth of piezometer installation varied between 5 and 25 m bgl (with the Bukit Timah Granite weathering profiles screened by these piezometers varying from completely weathered rock, G(V), to residual soil, G(VI). Average water levels for piezometer screening the G(V) weathering profile (all installed to a depth of 25 m bgl) varied from 6.14 to 9.26 m bgl (with gauging undertaken during different periods in 2014 and 2015). Average water levels for piezometer screening the G(VI) weathering profile (with installation depths varying between 5 and 25 m bgl) varied from 2.33 to 12.08 m bgl (with gauging undertaken at different times between 2012 and 2015). Piezometers installed in differing weathering profiles were not located in close enough proximity (or gauged across the same time periods) to facilitate an assessment of hydraulic gradients between the G(V) and G(VI) weathering profiles.

- An examination of maps and images of the CCNR, as well as field observations, indicated the presence of water saturated soil conditions at the surface in low lying wetland areas and adjacent to waterways. Consequently, it is expected that shallow groundwater levels (0 m bgl to 1.0 m bgl) would occur in low lying wetland areas and adjacent to the streams and MacRitchie reservoir. The aforementioned surface waterbodies in the Study Area would be expected to be in hydraulic connection with groundwater in the shallow residual soil horizon of the Bukit Timah Granite.

2.4 ADMINISTRATIVE FRAMEWORK

In Singapore, the discharge of trade effluent can be either to watercourses (i.e. controlled watercourse and watercourse) or public sewer and such discharges are regulated by the *Environmental Protection and Management (Trade Effluent) Regulations 2008* or *Sewerage and Drainage (Trade Effluent) Regulations 2008* respectively. The permissible discharge limits detailed in these two key regulations are outlined in *Table 2.3.* Approval must be obtained from the PUB prior to discharge of trade effluent to public sewers and watercourses.

Table 2.3: Permissible Limits for Discharge to Public Sewer & Watercourses

Parameter	Limits for Discharge into Public Sewer (Units in mg/l or otherwise stated)	Limits for Discharge into Watercourse (1) (Units in mg/l or otherwise stated)	Limits for Discharge into Controlled Watercourse (2) (Units in mg/l or otherwise stated)
Temperature of discharge	45 ºC	45 ºC	45 ºC

Parameter	Limits for Discharge into Public Sewer (Units in mg/l or otherwise stated)	Limits for Discharge into Watercourse (1) (Units in mg/l or otherwise stated)	Limits for Discharge into Controlled Watercourse (2) (Units in mg/l or otherwise stated)
Colour	-	7 Lovibond Units	7 Lovibond Units
pH	6 – 9	6 – 9	6 – 9
BOD5	400	50	20
COD	600	100	60
Total Suspended Solids (TSS)	400	50	30
Total Dissolved Solids (TDS)	3,000	-	1,000
Chloride (as chloride ion)	1,000	-	250
Sulphate (as SO_4)	1,000	-	200
Sulphide (as sulphur)	1	0.2	0.2
Cyanide (as CN)	2	0.1	0.1
Detergents (linear alkylate sulphonate as MBAS)	30	15	5
Grease and Oil (Total)	-	10	1
Grease and Oil (Hydrocarbon)	60	10	-
Grease and Oil (Non-hydrocarbon)	100	-	-
Arsenic	5	0.1	0.01
Barium	10	2	1
Tin	10	-	5
Iron (as Fe)	50	10	1
Beryllium	5	-	0.5
Boron	5	5	0.5
Manganese	10	5	0.5
Phenolic compounds (expressed as phenol)	0.5	0.2	-
*Cadmium	1	0.1	0.003
*Chromium (trivalent and hexavalent)	5	1	0.05
*Copper	5	0.1	0.1
*Lead	5	0.1	0.1
*Mercury	0.5	0.05	0.001
*Nickel	10	1	0.1
*Selenium	10	0.5	0.01
*Silver	5	0.1	0.1

Parameter	Limits for Discharge into Public Sewer (Units in mg/l or otherwise stated)	Limits for Discharge into Watercourse (1) (Units in mg/l or otherwise stated)	Limits for Discharge into Controlled Watercourse (2) (Units in mg/l or otherwise stated)
*Zinc	10	1	0.5
*Metals in total	10	1	0.5
Chlorine (Free)	-	1	1
Phosphate (as PO_4)	-	5	2
Calcium (as Ca)	-	-	150
Magnesium (as Mg)	-	-	150
Nitrate (NO_3)	-	-	20
Fluoride (F)	15	-	-
Caustic Alkalinity ($CaCO_3$)	2,000	2,000	2,000

Notes:
The concentration of Toxic Metal shall not exceed the limits as shown, individually or in total.
Coastal waters are categorised as watercourses, as defined by the *Environmental Protection and Management Act 2002*.
Controlled watercourse means a watercourse from which water supplied by Public Utilities Board (PUB) under the Public Utilities Act (Cap. 261) is obtained but does not include a watercourse from which water is pumped into a main of PUB, as defined by the *Environmental Protection and Management (Trade Effluent) Regulations 2008*.

The trade effluent discharged must not include:
(1) Calcium carbide;
(2) Petroleum spirit or other inflammable solvents;
(3) Materials that may give rise to fire or explosion hazards;
(4) Materials that may be a hazard to human life, a public nuisance, injurious to health or otherwise objectionable;
(5) Refuse, garbage, sawdust, timber, or any solid matter;
(6) Pesticides, fungicides, insecticides, herbicide, rodenticide or fumigants; or
(7) Radioactive material.
The trade effluent shall be analysed in accordance with the latest edition of *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association, the American Water Works Association and the Water Environment Federation of the United States).

2.5 ASSESSMENT METHODOLOGY

The sensitivity and magnitude criteria outlined in *Table 2.4* and *Table 2.5* have been used for assessment of the water environment. ERM applied the standard matrix based approach as presented in *Figure 2.7* and outlined in *Volume I, Chapter 4* in combination with the sensitivity and magnitude criteria.

Table 2.4: Sensitivity or Value Assessment Criteria for Water Resources

Value Criteria	Contributing Criteria
	The extent to which the water resource provides a use (drinking water, washing and other domestic or industrial uses) to the local communities and businesses, or is important in terms of national resource protection objectives, targets and legislation.
Low	The surface water resource has little or no role in terms of provisioning (Note 1) or services for the local community. The groundwater resource is not currently abstracted and used in the vicinity of the Project, but is of sufficient quality and yield to be used for that purpose in the future (and there is a reasonable potential for future use).
Medium	The surface water resource has local importance in terms of provisioning services (Note 1) but there is ample capacity and/ or adequate opportunity for alternative sources of comparable quality. The groundwater resource is an important water supply, and is currently used, but there is capacity and / or adequate opportunity for alternative sources of comparable quality.
High	The surface water or groundwater resource is wholly relied upon locally, with no suitable technically or economically feasible alternatives, or is important at a regional or transboundary watershed level for provisioning services(Note 1) or contribution to groundwater dependent ecosystems (eg transboundary rivers).

Note 1: Provisioning services are the material/energy products of ecosystems such as food and water.

Table 2.5: Criteria for Impact Magnitude

Magnitude Criteria	Definitions
Negligible	***Surface Water Related*** • Discharges are expected to be well within ambient levels or allowable criteria eg statutory limits. • Potential short-term localised effects on surface water quality but likely to be highly transitory (eg lasting a matter of hours) and well within natural fluctuations. • No alterations to existing drainage regimes and characteristics and thus negligible or no impact on upstream or downstream flood flows. ***Groundwater Related*** • Discharges are expected to be well within ambient levels or allowable criteria eg statutory limits. • Potential short-term localised effects on groundwater quality but likely to be highly transitory (eg lasting a matter of hours) and well within natural fluctuations. • There is likely to be negligible or no impact on groundwater recharge/discharge regimes by the Project at any time.

Magnitude Criteria	Definitions
Small	***Surface Water Related*** • Discharges are likely to be within ambient levels or allowable criteria eg statutory limits. • Potential short-term localised effects on surface water quality but which are likely to return to equilibrium conditions within a short timeframe (eg hours or days at most). • There is likely to be some alteration to existing drainage regimes and characteristics, although the frequency and magnitude of flooding upstream or downstream of the Project is not expected to be materially affected. • There are no known/ expected physical (property, agricultural fields, infrastructure etc) or sensitive ecological receptors upstream or downstream within the catchment that could be affected by the changed drainage regime. ***Groundwater Related*** • Discharges are likely to be within ambient levels or allowable criteria eg statutory limits. • Abstraction or discharge to aquifer(s) may cause localised changes in water quality in the aquifer system. These can be considered potential short-term localised effects on groundwater quality which is likely to return to equilibrium conditions within a short (months) timeframe. • There is likely to be some alteration to existing groundwater recharge/discharge regimes, although these changes are unlikely to result in any significant long term changes to groundwater levels, quality or flows. • There are no known/expected groundwater receptors (which include groundwater abstraction bores and sensitive groundwater dependent ecosystems) that could be affected by changes in groundwater flow and/or quality.
Medium	***Surface Water Related*** • Discharges are likely to result in occasional exceedances of ambient levels or allowable criteria. • Potential localised effects on water quality which are likely to be fairly long lasting (eg weeks or months) and/or give rise to indirect ecological and/or socio- economic impacts. • The Project is likely to involve significant alterations to existing drainage regimes and patterns (eg floodplain embankments, cross drainage structures, canalisation etc). • There are known/ expected physical (property, agricultural fields, infrastructure etc) or sensitive ecological receptors upstream or downstream within the catchment that could experience an increase in flood frequency (above baseline condition) or decrease in low flow conditions as a result of the Project. ***Groundwater Related*** • Discharges are likely to result in occasional exceedances of ambient levels or allowable criteria. • Abstraction or discharge to aquifer(s) are expected to cause potential localised effects on groundwater quality which are likely to be fairly long lasting and/or give rise to indirect ecological and/or social-economic impacts. • The Project is likely to involve significant changes to existing groundwater recharge/discharge regimes which result in long term changes to groundwater flows (vertical and/or horizontal) and/or quality. There are known/expected groundwater receptors (which include groundwater abstraction bores and sensitive groundwater dependent ecosystems) that could be affected by changes in groundwater flow and/or quality.

Magnitude Criteria	Definitions
Large	***Surface Water Related*** • Discharges are likely to routinely exceed ambient criteria levels or allowable criteria. • Potentially severe effects on water quality which are likely to be long-lasting (eg months or more) or permanent and/or give rise to indirect ecological and/or socio-economic impacts. • The Project is likely to involve significant alterations to existing drainage regimes and patterns (eg floodplain embankments, cross drainage structures, canalisation etc). • There are known/ expected physical (property, agricultural fields, infrastructure etc) or sensitive ecological receptors upstream or downstream within the catchment that could experience a "significant" increase in flood frequency (above baseline condition) or decrease in low flow conditions as a result of the Project. ***Groundwater Related*** • Discharges are likely to routinely exceed ambient criteria levels or allowable criteria. Groundwater quality impact is likely to occur over a large lateral and/or vertical extent. • Abstractions or discharge to aquifer(s) are expected to cause potentially severe effects on groundwater quality which are likely to be long-lasting (eg years or permanent) and/or give rise to indirect ecological and/or socio-economic impacts. • The Project is likely to involve significant changes to groundwater flows (vertical and/or horizontal) and/or quality. • There are known/expected groundwater receptors (which include groundwater abstraction bores and sensitive groundwater dependent ecosystems) that could be significantly affected by changes in groundwater flow and/or quality.

Figure 2.7: Impact Significance for Water Resources

		Sensitivity/Vulnerability/Importance of Resource		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

2.6 ASSESSMENT OF IMPACTS DURING PROJECT CONSTRUCTION PHASE

The Project construction will operate within the administrative framework for Singapore. Measures to reduce potential environmental impacts in line with regulatory requirements will therefore be implemented as part of the Project design and are known as “embedded controls” (refer to *Volume I, Chapter 4* for further details). The built in embedded controls that have been taken into consideration during the assessment of impacts on water resources during construction are summarised in *Volume I, Annex 2.0, Table A2.1.*

2.6.1 Impacts to Surface Water due to Construction Phase

2.6.1.1 Sources of Impact

Sources of impacts to water resources during Project Construction consist of:

- Potential impact on water quality from ground-exposing activities that could result in increased erosion and sedimentation. The activities include:
    - Land clearance and grading for preparation of construction work areas; and
    - Creation of temporary access roads to worksites.
- Potential impact on water quality from surface runoff containing limewater.
- Potential impact on water quality due to generation of liquid waste from:
    - Wash water from truck washing bay;
    - Wastewater from slurry treatment plant;
    - Water ingress encountered during excavation and TBM operation and
    - Use of sanitary facilities onsite.
- Potential impacts on water quality due to unplanned events such as the following:
    - Use and disposal of water to extinguish fires in the Project area;
    - Leakage and spillage from temporary storage of hazardous chemicals such as fuel, lubricants, drilling muds, etc. at worksites;
    - Extreme rainfall events, vehicle collision or failure of surface runoff and wastewater treatment systems, leading to uncontrolled discharge of untreated runoff or hazardous chemicals;
    - Slope failure near Sime Stream (i.e. stream Ha) leading to displacement of stream or impact on water quality; and
    - Potential effects on surface water due to excessive ground settlement.

Excessive ground settlement may occur as a result of groundwater ingress into the tunnel during tunnelling works. The downstream impact to surface waterbodies due to excessive ground settlement has therefore been assessed in the groundwater section (see *Section 2.5.2.4, Table 2.11*).

2.6.1.2 Receptors

Surface water bodies located in close proximity to and downgradient of worksites and above the tunnel alignment itself may be impacted by construction activities. Surface water receptors identified for each worksite are presented in *Table 2.6* along with the receptor sensitivity.

Table 2.6*: *Surface Water Receptors

Receptor ID	Receptor(s)	Description	Nearest Worksite	Receptor Sensitivity
SWR1	Roadside drains along Island Club Road that discharges to Stream Ma	The roadside drain is at the perimeter of worksite A1-W1 and was observed to be connected with 'Ma' streams within Windsor Nature Park. Stream Ma discharges to the canal parallel to Upper Thomson Road and ultimately feed into the Marina Reservoir where water is used for potable and domestic supply. However, water accumulated from this drain forms only a minor part of the drainage network leading to the Marina Reservoir.	A1-W1	Medium
SWR2	Drain parallel to PIE that discharges in a northerly direction to Stream IC leading towards MacRitchie Reservoir	Water collected within the drain located to the east of the worksite could flow in either a northerly or southerly direction. If towards the north, the water will be discharged to Stream IC across the PIE via an underground drain, which feeds into the MacRitchie Reservoir.	A1-W2	Medium
SWR3	Drain parallel to PIE that discharges in a southerly direction towards Marina Reservoir	Water collected within the drain located to the east of the worksite could flow in either a northerly or southerly direction. If towards the south, the water will be discharge to the drainage network at Eng Neo Avenue that ultimately leads to the Marina Reservoir.	A1-W2	Medium
SWR4	Streams Ha, I, IC	These streams fall within the catchment area of the MacRitchie Reservoir. There are other sources feeding into the MacRitchie Reservoir.	Tunnel Alignment	Medium

2.6.1.3 Impact Magnitude & Significance

A summary of the magnitude and significance of impacts to surface water during Project construction is provided in *Table 2.7*.

Table 2.7: Impact Magnitude & Significance for Surface Water during Project Construction

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W1 (LS/VS)				
Water quality due to erosion and sedimentation	Land clearance will be undertaken as part of the worksite preparation, which could lead to soil erosion and sedimentation and subsequent changes to water quality. Based on *Table 2.4 in Vol I*, the estimated area of land clearance required is approximately 15,000 m^2 for worksite A1-W1. The study area experiences high rainfall (average 2,348 mm) and the exposed ground would become more susceptible to erosion in the event of rain. This will lead to sediment loading of the downstream waterbody due to surface runoff from the worksite. Impacts of erosion and sedimentation will be managed by embedded controls outlined in *Volume I, Annex 2.0.* In summary, an Earth Control Measures (ECM) designed and endorsed by a Qualified Erosion Control Professional (QECP) with approval from PUB will be prepared prior to the commencement of any construction works. The ECM plan will specify earth control measures and sediment control measures required for each construction phase and the ECM plan will be designed such that it meets the requirements of LTA and PUB. The QECP will carry out monthly monitoring to verify ECM implementation and its effectiveness. The construction site will also have an Environmental Control Officer (ECO) and Earth Control Measure Officer (ECMO) on site to ensure the implementation, maintenance and inspection of the ECM plan at all times during the construction period. Other measures include real time monitoring of Total Suspended Solids (TSS) through CCTV and TSS meter positioned at the discharge outlets. Should there be an exceedance, instantaneous SMS alerts will be sent to the contractor for swift response. Some ground clearance activities will need to commence before the full ECM plant is fully set up and in operation. During this period, which is typically the first month of the construction phase, a phased clearance approach with temporary ECM plant mainly comprising of a holding tank and bund wall will be made available to contain surface runoff. The configuration of the temporary ECM plant will be designed	Large (for the 1st month of the construction phase) Large (for the rest of the construction phase)	SWR1: Medium	Major (for the 1st month of the construction phase) Major (for the rest of the construction phase)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Water quality due to erosion and sedimentation	based on the site conditions and the planned clearance work. Notwithstanding this, there is a possibility that the temporary ECM plant could be inadequate depending on the amount of the surface runoff. Stockpiles of excavated material from shaft construction and tunnelling works could also result in sedimentation if being washed off by rain. However, this will be managed by the aforementioned ECM. In addition, stockpiles will be stored within proper containment and covered by canvas sheet to prevent erosion due to the contact with rain. A dedicated wheel washing bay will be developed within the worksites for cleaning of vehicles leaving the sites. The truck washing bay and other washing facilities will be designed to meet the requirements of the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018* and with approval from the PUB. As illustrated in the figure above, wash water from the wheel washing bay will be discharged for treatment at the ECM Plant. The design and discharge requirements of the ECM plant have been described above within the impact assessment for erosion and sedimentation. In summary, surface runoff containing sediments at A1-W1 will be collected within a site-constructed perimeter drain and treated onsite to meet the discharge limit of 30 mg/l for TSS before being discharged into the roadside drain (SWR1). However, it is noted that the roadside drain is in connection with stream Ma where the level of TSS was found to be lower than 5 mg/l. Therefore, although the runoff from A1-W1 will be within the statutory limits with the implementation of the ECM, ambient levels (or baseline levels) at stream Ma are expected to be exceeded throughout the construction period (**Large** magnitude). However, for the 1st month of the construction phase, there is likely to be occasional exceedances of the ambient levels (or baseline levels) at Stream Ma (i.e. SWR1) due to the temporary ECM plant being inadequate (**Large** magnitude).			

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Event - Spills/leaks of hazardous materials	The construction activities will require the use of fuel and other hazardous chemicals such as oils, paints, lubricants, etc. Due to the nature of the construction, large volume of hazardous chemical will be stored onsite. All hazardous materials will be stored and handled following the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018*. All chemicals will be stored in designated storage containers within bunded areas, with drip tray provided to prevent any spillage. Other embedded control measures that will be in-place include emergency response plans and emergency spillage training. Spillage or leakage contained within the bunded areas will be collected and removed by a licensed third party collector. Additional control measures based on the local regulations can be found within *Vol I, Annex II*. Therefore, impact to water quality due to spills/leaks of hazardous materials will be localised within the worksite and the magnitude is assessed to be **Small**. Localised spills of chemicals, fuel or liquid construction waste have been observed to occur at some construction worksites in Singapore. The likelihood of this occurring at the worksites is therefore evaluated to be *Possible*. The impact significance of surface water contamination, taking into consideration the possible occurrence of leakage or spillage, is evaluated to be **Minor**.	Small	SWR1: Medium	Minor
Unplanned Event – firewater	The TBM operation and improper storage of flammable materials could cause outbreak of fires, resulting in disposal of water used for firefighting purposes to the ground. Firewater within the worksite will be channeled via the perimeter drains to the sedimentation pond for holding until collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to surface water quality in the event of a fire emergency is **Small**. The likelihood of a fire occurrence during the construction phase is considered to be *Unlikely* as discussed in *Annex 1.0*. Therefore, the impact significance is assessed to be **Minor**.	Small	SWR1: Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Event Failure of water management system leading to uncontrolled discharge	Acknowledging the scale of the worksite and the fact that a large number of construction activities will be carried out concurrently, a number of different unplanned events could occur, due to human errors (e.g. collision of vehicles) or extreme rainfall. This could result in damage to and/or overflow of water management systems such as the ECM plant, slurry water pit etc., and ultimately surface water contamination. As such a number of controls will be in place to avoid these events from occurring. For example, the ECM plant with a minimum capacity to cater for a 1 in 5 years rainfall event will be installed , and traffic controls and road safety requirements will be implemented as specified under the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018*. Based on the above, the expected impact magnitude to surface water quality is **Small**. The likelihood of ECM failure during the construction phase is considered to be *Possible* as discussed in *Annex 1.0*. Similarly, it is *Possible* that road accidents could occur during the construction phase. Therefore, the impact significance is assessed as **Minor.**	Small	SWR1: Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W2 (LS/VS)				
Water quality due to erosion and sedimentation	Land clearance will be undertaken as part of the worksite preparation, this could lead to soil erosion and sedimentation, and subsequent changes to water quality. Based on *Table 2.4 in Vol I*, the estimated area of land clearance required for worksite A1-W2 is approximately 15,000 m^2. The study area experiences high rainfall (average 2,348 mm) and the exposed ground would become more susceptible to erosion in the event of rain. This will lead to sediment loading of the downstream waterbody due to surface runoff from the worksite. Impacts of erosion and sedimentation will be managed by embedded controls outlined in *Volume I, Annex 2.0.* In summary, an ECM plan designed and endorsed by a QECP with approval from PUB will be prepared prior to the commencement of any construction works. The ECM plan will specify earth control measures and sediment control measures required for each construction phase and the ECM plan will be designed such that it meets the requirements of LTA and PUB. During construction, the QECP will carry out monthly monitoring to verify ECM implementation and its effectiveness. The construction site will also have an ECO and ECMO on site to ensure the implementation, maintenance and inspection of the ECM plan at all times during the construction period. Other measures include real time monitoring of TSS through CCTV and TSS meter positioned at the discharge outlets. Should there be an exceedance, instantaneous SMS alerts will be sent to the contractor for swift response. Some ground clearance activities will need to commence before the full ECM plant is fully set up and in operation. During this period, which is typically the first month of the construction phase, a phased clearance approach with temporary ECM plant mainly comprising of a holding tank and bund wall will be made available to contain surface runoff. The configuration of the temporary ECM plant will be designed based on the site condition and the planned clearance work. Notwithstanding this, there is a possibility that the temporary ECM plant could be inadequate depending on the amount of the surface runoff. On a worst case basis, it is assumed that during the first month of the land clearance and site set up phase, the temporary ECM plant will not be sufficient. Stockpiles of excavated material from shaft construction and tunnelling works could also result in sedimentation if being washed off by rain. However, this will be managed by the aforementioned ECM	Large (for the 1st month of the construction phase) Large (for the rest of the construction phase)	SWR2: Medium	Major (for the 1st month of the construction phase) Major (for the rest of the construction phase)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Water quality due to erosion and sedimentation	plan. In addition, stockpiles will be stored within proper containment and covered by canvas sheet to prevent erosion due to the contact with rain. A dedicated wheel washing bay will be developed within the worksites for cleaning of vehicles leaving the sites. The truck washing bay and other washing facilities will be designed to meet the requirements of the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018* and with approval from the PUB. Wash water from truck washing bay will be managed and treated under the ECM plan before being discharged to a nearby public drain. Wash water from the wheel washing bay will be discharged for treatment at the ECM Plant. The design and discharge requirements of the ECM plant have been described above within the impact assessment for erosion and sedimentation. In summary, surface runoff containing sediments at A1-W2 will be collected within a site-constructed perimeter drain and treated onsite to meet the discharge limit of 30 mg/l for TSS before being discharged into the nearby drain. The drain could flow in either a northerly or southerly direction. In the event that the treated surface runoff is discharged to the portion of drain that flows in a northerly direction towards stream IC (i.e. SWR 2), the discharge limit of 30 mg/l for TSS may not be sufficient to protect the stream. Therefore, although the runoff from A1-W2 will be within the statutory limits with the implementation of the ECM, ambient levels (or baseline levels) at stream IC may be exceeded throughout the construction period (**Large** magnitude). If the treated surface runoff is discharged to the portion of drain that flows in southerly direction towards Eng Neo Avenue and eventually to the Marina Reservoir (i.e. SWR 3), meeting the discharge limit of 30 mg/l will be adequate to protect the water quality of the drain (i.e. **Small** magnitude). However, for the 1st month of the construction phase, there is likely to be occasional exceedances of the ambient levels (or baseline levels) at stream IC (i.e. SWR2) and occasional exceedances of the discharge limit of 30 mg/l at the drain that flows in the southerly direction towards Eng Neo Avenue (i.e. SWR 3) due to the temporary ECM plant being inadequate (**Large** (SWR 2) and **Medium** (SWR 3) magnitude).	Medium (for the 1st month of the construction phase) Small (for the rest of the construction phase)	SWR 3: Medium	Moderate Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Water quality from storage and handling of liquid waste	The following types of liquid waste will be generated during the construction activities: • Wastewater from slurry treatment plant; and • Water ingress from the tunnel face. The TBM operation will require the use of bentonite slurry as drilling fluid and this will result in the generation of slurry waste. With reference to *Figure 2.1*, used slurry comprising water, mud, adjustment agents and crushed rock (ie muck) will be channelled to the slurry treatment plant located at the above ground worksite. Wastewater generated from the slurry treatment process will be further treated to meet the relevant limits of depending on the final discharge point (e.g. *Environmental Protection and Management (Trade Effluent) Regulations* for discharge to controlled water course or *Sewerage and Drainage (Trade Effluent) for discharge* to the sewer). Water ingress could be encountered during excavation or TBM operation, although the amount is not expected to be significant considering the engineering embedded controls and response plans in place to manage this. Similar to slurry water, water ingress will be channelled to the slurry treatment plant located at the above ground worksite for treatment against the relevant limits of depending on the final discharge point (e.g. *Environmental Protection and Management (Trade Effluent) Regulations* for discharge to controlled water course or *Sewerage and Drainage (Trade Effluent) for discharge* to the sewer). Like the impact to water quality due to erosion and sedimentation, while the liquid waste will be treated to meet the relevant discharge limits, it may not be sufficient to protect Stream IC if the liquid waste is discharged to the portion that flows to the north (i.e. SWR 2). Therefore, it is believed that ambient levels (or baseline levels) at stream IC may be exceeded (**Large** magnitude). In the event if the treated liquid waste is discharged to the portion of drain that flows in southerly direction towards Eng Neo Avenue and eventually to the Marina Reservoir (i.e. SWR 3), meeting the relevant discharge limits is believed to be adequate (**Small** magnitude).	Large Small	SWR2: Medium SWR3: Medium	Major Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Event - Spills/leaks of hazardous materials	The construction activities will require the use of fuel and other hazardous chemicals such as oils, paints, lubricants etc. Due to the nature of the construction, large volume of hazardous chemical will be stored onsite. All hazardous materials will be stored and handled following the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018*. All chemicals will be stored in designated storage containers within bunded areas, with drip trays provided to prevent any spillage. Other embedded control measures that will be in-place include emergency response plan and emergency spillage training. Spillage or leakage contained within the bunded areas will be removed by a licensed third party collector. Additional control measures based on the local regulations can be found within *Vol I, Annex II*. Therefore, impact to water quality due to spills/leaks of hazardous materials will be localised within the worksite and the magnitude is assessed to be **Small**. Localised spills of chemicals, fuel or liquid construction waste have been observed to occur at some construction worksites in Singapore. The likelihood of this occurring at the worksites is therefore evaluated to be *Possible*. The impact significance of surface water contamination, taking into consideration the possible occurrence of leakage or spillage, is evaluated to be **Minor**.	Small	SWR2: Medium SWR3: Medium	Minor Minor
Unplanned Event – firewater	The TBM operation and improper storage of flammable materials could cause outbreak of fires, resulting in disposal of water used for firefighting purpose to the ground. Firewater within the worksite will be channeled via the perimeter drains to the sedimentation pond for holding for collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to surface water quality in the event of a fire emergency is **Small**. The likelihood of a fire occurrence during the construction phase is considered to be *Unlikely* as discussed in *Annex 1.0*. Therefore, the impact significance is assessed to be **Minor**.	Small	SWR2: Medium SWR3: Medium	Minor Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Event – Failure of water management system leading to uncontrolled discharge	Acknowledging the scale of the worksite and the fact that a large number of construction activities will be carried out concurrently, a number of different unplanned events could occur, due to human errors (e.g. collision of vehicles) or extreme rainfall. This could result in damage to and/or overflow of water management systems such as the ECM plant, slurry water pit etc., and ultimately surface water contamination. As such a number of controls will be in place to avoid these events from occurring. For example, the ECM plant with a minimum capacity to cater for a 1 in 5 years rainfall event will be installed, and traffic controls and road safety requirements will be implemented as specified under the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018*. Based on the above, the expected impact magnitude to surface water quality is **Small**. The likelihood of ECM failure during the construction phase is considered to be *Possible* as discussed in *Annex 1.0*. Similarly, it is *Possible* that road accidents could occur during the construction phase. Therefore, the impact significance is assessed as **Minor.**	Small	SWR2: Medium SWR3: Medium	Minor Minor
Tunnel Alignment				
Water quality due to installation of piezometer wells and settlement markers	The installation of piezometer wells and settlement markers will involve activities similar to borehole drilling works during the soil investigation phase. With reference to the SI EIA, impacts to surface waterbodies could arise from the generation of wastewater slurry as well as stormwater runoff leading to erosion and sedimentation which are considered relevant and applicable to the installation of piezometer wells and settlement markers. This assessment has therefore adopted the same impact magnitude from the SI EIA, which is Small.	Small	SWR4: Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Events – risk of slope failure and excessive ground settlement	Consideration has been given to whether waterbodies could be impacted by excessive ground settlement during tunnelling should ground settlement occur near any surface waterbodies. Embedded controls for the management of risk of excessive ground settlement include the design of the tunnel to be excavated below the Bukit Timah Granite rock head, and measures such as advance probing, close monitoring of slurry KPI parameters to maintain positive pressure at the TBM cutter head during tunnel boring, grouting of any highly fractured zones or mixed face conditions identified ahead of the TBM. In addition, the formation of voids at the tunnel face will be closely monitored during the operation of the TBM. As part of the response plan, at the onset of any void formation, remedial grouting will be promptly undertaken at the tunnel face to minimise the propagation of void formation to the ground surface. The prompt undertaking of response measures will enable the extent of ground settlement to be minimised so that impacts to surface waterbodies are localised. In the event of excessive ground settlement, the magnitude of impact is likely to be **Large**. A key embedded control for the management of risk of slope failure include the existing surface drainage within the subcatchment area of the Sime Stream Valley slope. As best practice, visual inspections of the slope brow will also be undertaken during tunnelling to detect any onset of slope failure, especially during works undertaken in heavy rainfall conditions. In the event of slope failure, the magnitude of impact on surface water is likely to be **Large**. The likelihood of excessive ground settlement or slope failure occurring is considered *Unlikely* (see *Annex 1.0*) due to embedded controls such as tunnelling within the Bukit Timah Granite rock and the existing surface drainage within the Sime Stream Valley. The impact significance considering the unlikely risk of excessive ground settlement or slope failure occurring is therefore reduced from Major to **Moderate**.	Large	SWR4: Medium	Major (in the event of excessive ground settlement or slope failure) Moderate (considering that excessive ground settlement is *Unlikely* to occur)

2.6.1.4 Mitigation Measures

In addition to embedded controls, measures to avoid, minimise, and limit the magnitude of surface water impacts caused by the Project's construction phase are outlined in *Table 2.8*. Mitigation includes construction best practices, management plans, monitoring, and general housekeeping activities.

Table 2.8: Mitigation Measures for Surface Water Receptors during Project Construction

Category	Mitigation
General Mitigation Measures	Mitigation Measures for Normal Operation: • Consult PUB about any site-specific requirements including discharge limits, monitoring regime (eg parameters, frequency etc.) during the AES stage. • Phase activities such as land clearance, demolition works, earthworks, and building construction to minimise the area of ground exposed and the volume of soil and construction material handled at any one time. • Phase activities to limit the extent of land clearance prior to the set-up and operation of the ECM plant. • Inspection and cleaning of perimeter drain, silt sump, sedimentation and holding tanks at least once a week and after every rainfall event, or as and when required. • Provision of silt fence, erosion control blankets and lean concrete of the worksite access to reduce erosion, and sediments from entering streams and surface waterbodies. • Provide concrete-lined cut-off drains along the perimeter of the worksite. • Provide adequate number and size of silt sumps, sedimentation and holding tanks. The sumps and tanks will be designed to handle the volume of water from a rain based on a minimum design return period of 1 in 5 years storm, unless a site specific requirement is stated below. A consultation with PUB will be carried out during the AES stage on any site specific design criteria to be considered and complied with. • Re-vegetate exposed ground as soon as possible to stabilise surfaces once there are no further construction activities to be carried out at the affected area. • Control water used for dust suppression during excavation and earth handling to minimise excess water and sediment disposal into surface water. • Locate temporary stockpiles of spoil as far as possible from any surface drainages or streams. • Position slurry mixing and slurry treatment plant away from any surface drainage and surface waterbodies, as far as possible. • Contain slurry operations within bunded areas to control spillage into waterbodies. • Protect surface water sources during construction by ensuring portable sanitary facilities provided for workers are located away from surface waterbodies and managed by a licensed third party waste contractor. Regular in-house cleanings to be carried out to ensure the cleanliness of the sanitary facilities. • Implement a regular maintenance program and provide drip trays to all equipment and machinery to prevent fuel spillage or leakage during construction activities.

Category	Mitigation
General Mitigation Measures	• Strategically locate and isolate areas for temporary storage of hazardous materials away from surface water resources. Drip trays to be provided to contain any accidental spillages. • In addition to the quarterly monitoring (as discussed within the table above for impact assessment due to liquid waste) specified under the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018*, at the start-up of the construction phase, carry out water quality monitoring at all discharge outlets against the relevant regulations. At a minimum once during initial operations or until full compliance to the relevant limits can be demonstrated and accepted by LTA for all water / wastewater treatment units. For example, discharge to surface drain is to be evaluated against the *Environmental Protection and Management (Trade Effluent) Regulations*, discharge to sewer is to be evaluated against the *Sewerage and Drainage (Trade Effluent) Regulations.* Full lists of parameters listed under these regulations are to be monitored.
Specific Measures for Worksite A1-W1	Mitigation Measures for Construction: • Maintain a buffer distance of 30 m between the construction worksite and stream Ma. • Phase land clearance activities to ensure that perimeter drains for the worksite are constructed and silt fences installed prior to clearance of the whole worksite, and prior to any excavation work. • Strictly no discharge to stream Ma at all time. • ECM discharges are proposed to be conveyed via a double containment pipeline to be discharged to a suitable surface water drain. PUB will be consulted on the alignment of the pipe and discharge point. The piping system including the piping route will be carefully studied so as to minimize the need for any clearance, as much as possible the pipeline will be parallel to the existing drainage reserve along Island Club Road. The design will include suitably sized redundancy for ancillary equipment such as pumping system to allow smooth operation all the time. • Conduct weekly visual monitoring of the portion of Stream Ma3 located immediately downstream of the worksite, from Island Club Road. Should there be visual signs of contamination (oily sheen, colouring of sediments etc), LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation. • Conduct sampling of physical, chemical and biological parameters at Stream Ma3 prior to the commencement of the construction activities to establish baseline level of Stream Ma3. Subsequently, conduct monthly sampling of physical, chemical and biological parameters at Stream Ma3 to verify if stream Ma3 is affected by the construction activities. To minimise human intrusion into the stream habitat, samples should be collected from the Venus Link trail, at the stream intersection with Ma6 and Ma2, and preferably during high volume flow after a rainfall event. No off trail access to Stream Ma3 should be attempted during the sampling. Should there be an exceedance of baseline results for

Category	Mitigation
Specific Measures for Worksite A1-W1	SW108, LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation. <u>Mitigation Measures for Unplanned Events:</u> Acknowledging the topography of the site as well as Stream Ma being ecologically sensitive (see *Chapter 5* for further information), the following measures will be implemented to cope with the unplanned event of overflow of untreated effluent from potential sources including the ECM treatment Plant and slurry storage pits: • The capacity of the ECM will be overdesigned and the design will be subject to consultation with PUB prior to finalization and PUB approval. • Provide sufficient amount of slurry holding tanks with capacity ranging from 150 m^3 to 450 m^3 cater for the volume of slurry water that will be generated. • Place the slurry holding tanks within bund wall for containment of possible spillage and leakage. • In the event of spillage or overflow of effluents into downstream surface waterbodies, contaminating material will be removed using absorbent pad and equivalent options. Following this, regular visual inspections and monitoring of the relevant chemical parameters will be undertaken for the affected stream until stream conditions return to normal. • Carry out routine monitoring and maintenance of the ECM treatment plant-related equipment, especially the pipeline discharging treated effluent to Venus Drive or Thomson Road, to eliminate the possibility of leaks and spills.
Specific Measures for Worksite A1-W2	<u>Mitigation Measures for Construction</u> • The configuration of the worksite to be further studied during the AES stage, taking into account the existing topography, to avoid any discharge that could lead to the IC stream. • Prohibit discharge to the portion of drain that will lead to Stream IC. Discharge of treated surface runoff and/or liquid waste can only be to the part of drain that flows in a southerly direction towards Eng Neo Avenue. • Conduct weekly visual monitoring of the portion of drain that flows towards Stream IC. Should there be visual signs of contamination (oily sheen, colouring of sediments etc), LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation. • Conduct sampling of physical, chemical and biological parameters at Stream IC prior to the commencement of the construction activities to establish baseline level of Stream IC. Subsequently, carry out monthly sampling during the construction phase to verify if stream IC is affected by the construction activities. The sampling should be carried out in a manner that minimises human intrusion into the stream habitat, and preferably during high volume flow after a rainfall event. Should there be an exceedance of baseline results, LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation. <u>Mitigation Measures for Unplanned Events</u> • In the event of spillage or overflow of effluents into downstream surface waterbodies, contaminating material will be removed using absorbent pad and equivalent options. Following this, regular visual inspections and monitoring of the relevant chemical parameters will be undertaken for the affected stream until stream conditions return to normal.

Category	Mitigation
Specific Measures for Tunnel Alignment	• Note that there has been a change in the assessment of receptor sensitivity for water quality from the SI EIA as sensitivity due to presence of ecological receptor is now considered in Chapter 6. As a result, the receptor sensitivity for SWR3 has been adjusted from *High* to *Medium* and thus the overall significance from *Moderate* to *Minor* while the magnitude remains unchanged as *Small*. Mitigation measures recommended in the SI EIA, under the Water Quality Chapter were in view of the ecological sensitivity of the waterbodies. These will be implemented for the installation of piezometer wells and settlement markers and are described in Chapter 6 of this volume.
Implementation management applicable to all worksites	• Contractor Environmental, Health and Safety team to undertake daily inspection of construction area. • Maintain a procedure to log and track response to feedbacks received from stakeholders. • Maintain records of surface water measurement and checklist of the EMMP actions on a daily basis during construction.

2.6.1.5 *Residual Impacts*

Surface water impacts from construction activities can be managed by implementation of the mitigation measures listed in *Table 2.8*. The magnitudes of residual impacts following implementation of mitigation measures are found to be Negligible to Small. A summary of the impact assessment criteria including the implementation of mitigation measures are presented below for each worksite in *Table 2.9*

It is to be highlighted that Stream Ma will not be receiving the treated effluent from the ECM plant during the normal construction, as a pipeline will be installed to divert surface runoff to the drains at Venus Drive or Thomson Road. The residual impact magnitude to Stream Ma is therefore assessed to be Negligible.

In terms of the drains at Venus Drive or Thomson Road, as they fall under the catchment area of Marina Reservoir, their sensitivity is assessed to be Medium. In view that the effluent from the ECM plant will be treated to meet the limits for controlled watercourse under the *Environmental Protection and Management (Trade Effluent) Regulations*, the impact magnitude is considered to be Small. The impact significance due to discharge of treated effluent to the roadsides drains at Venus Drive or Thomson Road is therefore evaluated to be Minor.

Table 2.9: Impact Assessment Summary for Surface Water Impact

<table>
<tr><th>Criterion</th><th>Rating</th><th>Comment</th><th>Criterion</th><th>Rating</th><th>Comment</th></tr>
<tr><td colspan="6">Impacts to surface water quality and hydrology due to construction activities</td></tr>
<tr><td>Nature</td><td>Negative</td><td colspan="4">Negative impacts to surface water quality due to erosion and sedimentation, surface runoff containing limewater, generation of liquid waste, and unplanned events.</td></tr>
<tr><td>Type</td><td>Direct</td><td colspan="4">Construction activities directly affect the surface waterbodies, quantity and hydrology.</td></tr>
<tr><td>Duration</td><td>Long-term</td><td colspan="4">The construction will last 5.5 years.</td></tr>
<tr><td>Extent</td><td>Local</td><td colspan="4">Surface waterbodies down gradient or adjacent to worksites A1-W1 and A1-W2 and tunnel alignment.</td></tr>
<tr><td>Scale</td><td>-</td><td colspan="4">Worksites A1-W1 and A1-W2 are in close proximity to surface waterbodies. Scale potentially significant if not managed well.</td></tr>
<tr><td>Frequency</td><td>Frequent</td><td colspan="4">Impacts will arise throughout the construction period of 5.5 years.</td></tr>
<tr><td rowspan="4">Receptor Sensitivity</td><td><u>A1-W1 (LS/VS)</u>
SWR1: Medium</td><td colspan="4">Roadside drains along Island Club Road that discharges to streams Ma4, Ma3, Ma2, Ma</td></tr>
<tr><td><u>A1-W2 (LS/VS)</u>
SWR2: Medium</td><td colspan="4">Drain in parallel to PIE that discharges in the northerly direction to Stream IC leading towards MacRitchie Reservoir</td></tr>
<tr><td>SWR3: Medium</td><td colspan="4">Drain in parallel to PIE that discharges in a southerly direction towards Marina Reservoir</td></tr>
<tr><td><u>Tunnel Alignment</u>
SWR4: Medium</td><td colspan="4">Streams Ha, I, IC</td></tr>
<tr><td rowspan="2"><u>Pre-Mitigation</u> Magnitude</td><td><u>A1-W1 (LS/VS)</u>
Large</td><td>Impact to water quality due to erosion and sedimentation was assessed to be of Large magnitude for throughout the construction period.</td><td rowspan="2"><u>Residual</u> Impact Magnitude</td><td><u>A1-W1 (LS/VS)</u>
Large</td><td>Residual impact to water quality due to sedimentation and erosion was assessed to be Large for the 1st month of the construction before the ECM is fully set up.</td></tr>
<tr><td>Small</td><td>Impacts to water quality due to unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent or hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire were assessed to be Small magnitude.</td><td>Small</td><td>Residual impacts to water quality due to unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent or hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire, were assessed to be of Small magnitude.</td></tr>
</table>

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality and hydrology due to construction activities					
Pre-Mitigation Magnitude			**Residual** Impact Magnitude	**A1-W1 (LS/VS)** Negligible	Residual impact to water quality in Stream Ma3 due to sedimentation and erosion throughout the construction phase with the exception of the 1st month of the clearance was assessed to be of Negligible magnitude.
	A1-W2 (LS/VS) Large	Impacts to water quality due to erosion and sedimentation and generation of liquid waste were assessed to be of Large magnitude if they are discharged to stream IC (i.e. SWR 2).		**A1-W2 (LS/VS)** Large	Even though discharge to Stream IC will be strictly restricted, residual impact to water quality due to sedimentation and erosion was assessed to be Large for the 1st month of the construction before the ECM is fully set up for SWR 2.
	Medium	Impacts to water quality due to erosion and sedimentation was assessed to be Medium for SWR 3 for the 1st month of the construction before the ECM is fully set up.		Medium	Impact to water quality due to erosion and sedimentation was assessed to be Medium for the 1st month of the construction before the ECM is fully set up for SWR 3.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality and hydrology due to construction activities					
Pre-Mitigation Magnitude	Small	Impacts to water quality due to unplanned events such as spills/leaks of hazardous materials, uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire were assessed to be Small magnitude for both SWR 2 Impacts to water quality due to erosion and sedimentation (with the exception of the 1st month of the clearance); generation of liquid waste; and unplanned events such as spills/leaks of hazardous materials, uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire were assessed to be Small for SWR 3.	**Pre-Mitigation** Magnitude	Small	Residual impacts to water quality due to unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire were assessed to be of Small magnitude for both SWR 2. Residual impacts to water quality due to sedimentation and erosion (with the exception of the 1st month of the clearance); generation of liquid waste; and unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire were assessed to be Small for SWR 3.
				Negligible	Residual impacts to water quality in Stream IC due to sedimentation and erosion throughout the construction phase with the exception of the 1st month of the clearance; and generation of liquid waste were assessed to be of Negligible magnitude for SWR 2.
	Tunnel Alignment Large	Impacts to water quality due to unplanned events including slope failure and excessive ground settlement were assessed to be of Large magnitude.		**Tunnel Alignment** Large	Residual impacts to water quality due to unplanned events including slope failure and excessive ground settlement were assessed to be of Large magnitude.
	Small	Impacts to water quality due to installation of piezometer wells and settlement markers		Small	Residual impacts to water quality due to installation of piezometer wells and settlement markers was assessed to be of Small magnitude.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality and hydrology due to construction activities					
Pre-Mitigation Impact Significance	**A1-W1 (LS/VS)** Major	Impact magnitude of Large for impact to water quality due to erosion and sedimentation, combining with a receptor sensitivity of Medium for SWR 1.	**Residual** Impact Significance	**A1-W1 (LS/VS)** Major	Residual impact to water quality due to sedimentation and erosion was assessed to be Large for the 1st month of the construction. This is a conservative assessment to account for potential sedimentation of stream Ma before the ECM is fully set up and before the discharges from A1-W1 are fully diverted away from the stream. It is noted that the effects would be short-term (not more than 1 month), and that the stream is flowing out of the CCNR into open canals linked to the Marina Reservoir i.e. a receptor sensitivity of Medium for SWR 1.
	Minor	Impact magnitude of Small for impact to water quality due to generation of liquid waste and unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM, slurry water plant or vehicular collisions and used firewater during a fire. This is combined with a receptor sensitivity of Medium for SWR 1.		Minor	Residual impact magnitude of Small for impacts to water quality due to unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM, slurry water plant or vehicular collisions, and used firewater during a fire. This is combined with a receptor sensitivity of Medium for SWR 1.
				Negligible	Residual impact to water quality to Stream Ma3 due to sedimentation and erosion throughout the construction phase with the exception of the 1st month of the clearance was assessed to be of Negligible magnitude, combining with a receptor sensitivity of Medium for SWR 1.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality and hydrology due to construction activities					
Pre-Mitigation Impact Significance	**A1-W2 (LS/VS)** Major	Impacts to water quality due to sedimentation and erosion and generation of liquid waste were assessed to be Large, combining with a receptor sensitivity of Medium for SWR 2.	**Residual** Impact Significance	**A1-W2 (LS/VS)** Major	Residual impact magnitude of Large for impact to water quality due to sedimentation and erosion was assessed for the 1st month of the construction. This is a conservative assessment to account for potential sedimentation of stream IC before the ECM is fully set up and before the discharges from A1-W2 are fully diverted away from the MacRitchie catchment area. This is combined with a receptor sensitivity of Medium for SWR 2.
	Moderate	Impacts to water quality due to erosion and sedimentation was assessed to be Medium for the 1st month of the construction before the ECM is fully set up, combining with a receptor sensitivity of Medium for SWR 3.		Moderate	Residual impact magnitude of Medium for impact to water quality due to erosion and sedimentation for the 1st month of the construction before the ECM is fully set up. This is combined with a receptor sensitivity of Medium for SWR 3.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality and hydrology due to construction activities					
Pre-Mitigation Impact Significance	Minor	Impact magnitude of Small for impacts to water quality due to unplanned events such as spills/leaks of hazardous materials, uncontrolled discharged of untreated effluent or hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions and used firewater during a fire. This is combined with a receptor sensitivity of Medium for SWR 2. Impacts magnitude of Small for impacts to water quality due to erosion and sedimentation (with the exception of the 1st month of the clearance); generation of liquid waste; and unplanned events such as spills/leaks of hazardous materials, uncontrolled discharged of untreated effluent, hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire. This is combined with a receptor sensitivity of Medium for SWR 3.	**Residual** Impact Significance	Minor	Residual impact magnitude of Small for impacts to water quality due to unplanned events such as spills/leaks of hazardous materials, uncontrolled discharged of untreated effluent or hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions and used firewater during a fire. This is combined with a receptor sensitivity of Medium for SWR 2. Residual impact magnitude of Small for impacts to water quality due to sedimentation and erosion (with the exception of the 1st month of the clearance); generation of liquid waste; and unplanned events such as spills/leaks of hazardous materials and uncontrolled discharged of untreated effluent or hazardous materials due to overflow of ECM or slurry water plant or vehicular collisions, and used firewater during a fire. This is combined with a receptor sensitivity of Medium for SWR 3.
				Negligible	Residual impact magnitude of Negligible for impacts to water quality in Stream IC due to sedimentation and erosion throughout the construction phase with the exception of the 1st month of the clearance and generation of liquid waste. This is combined with a receptor sensitivity of Medium for SWR 2.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality and hydrology due to construction activities					
Pre-Mitigation Impact Significance	**Tunnel Alignment** Moderate	Impact magnitude of Large for impact to water quality/hydrology however considering the unlikely occurrence of unplanned events including slope failure and excessive ground settlement. This is combined with a receptor sensitivity of Medium for SWR 4.	**Residual** Impact Significance	**Tunnel Alignment** Moderate	Residual impact magnitude of Large for impact to water quality/hydrology however considering the unlikely occurrence of unplanned events including slope failure and excessive ground settlement. This is combined with a receptor sensitivity of Medium for SWR 4.
	Minor	Impact magnitude of Small for impact to water quality due to installation of piezometer wells and settlement markers, combining with a receptor sensitivity of Medium for SWR 4.		Minor	Residual impact magnitude of Small for impact to water quality due to installation of piezometer wells and settlement markers, combining with a receptor sensitivity of Medium for SWR 4.

2.6.2 Impacts to Groundwater due to Construction Phase

2.6.2.1 Sources of Impact

Activities and sources of impacts to groundwater during the Project construction phase are listed below. The anticipated, typical activities include:

- Activities such as site clearance, the construction of temporary access roads, the establishment of equipment laydown areas, and road and utility diversions works;
- Construction of underground structures such as ventilation shafts cum TBM launch/retrieval shafts and the tunnel; and
- Injection of slurry from the TBM cutterhead to the open tunnel face.

The unplanned events considered in this assessment include:

- Accidental leakage and spillage from temporary storage of hazardous chemicals such as fuel, drilling muds, grout and lubricants (hydraulic and gear oil, grease etc) at worksites above and below ground, or from improper storage and handling of construction waste (ie solid and liquid) generated from tunnel boring activity, above and below ground;
- Disposal of water used to combat fires at or near the Project site, where the water could enter the ground through seepage or overflow of open pits ie sedimentation pond within the worksites;
- Excessive water ingress during tunnelling; and
- Risk of excessive ground settlement due to loss of tunnel pressure during operation of TBM, or the occurrence of slope failure at Sime Stream Valley, leading to formation of voids or slumps and settlement at the surface and therefore resulting in potential loss of hydraulic connectivity between surface water and groundwater resources.

This groundwater assessment relies on the Project description, the groundwater baseline, and related disciplines such as hydrology, hydrogeology, and geology, and geomorphology associated with the Project.

2.6.2.2 Receptors

Surface and groundwater receptors located near, downgradient, and above the tunnel alignments may be impacted by construction activities. Groundwater receptors identified are presented in *Table 2.10* along with the receptor sensitivity.

As groundwater is not directly abstracted and used in the vicinity of the Study Area, the groundwater receptors were identified based on the potential interactions between surficial groundwater and surface water and the sensitivity/value of the potentially groundwater linked surface water receptors.

Table 2.10**: **Groundwater Receptors

Location	Receptor(s)	Description	Receptor Sensitivity
A1-W1 (LS/VS) Worksite	Stream Ma4, Ma3, Ma2	Small surface streams that may or may not be hydraulically connected to groundwater. These are within Windsor Nature Park and CCNR, and eventually connect to controlled surface drains feeding into Marina Reservoir to the south of Singapore. Marina Reservoir is one of a few sources of drinking water in Singapore. Groundwater levels in boreholes close to these worksites ranged from 1 – 7 m bgl while the surface stream depth for Ma was 0.55 m at the time field measurements were taken in October 2014 (Note 1).	Medium
A1-W2 (LS/VS) Worksite	Stream IC	Small surface stream that may or may not be hydraulically connected to groundwater. This is within the CCNR and eventually feeds into the MacRitchie Reservoir. MacRitchie Reservoir is one of a few sources of drinking water in Singapore. Groundwater le vels in boreholes close to these worksites ranged from 1 – 7 m bgl while the surface stream depth for IC was 0.04 m at the time field measurements were taken in October 2014 (Note 1	
Tunnel Alignment	Streams Ha, I, IC and Sime Stream	Small streams that may or may not be hydraulically connected to groundwater. These are located above the proposed tunnel alignment and are within the CCNR, feeding the MacRitchie Reservoir. Water levels of these streams are generally shallow with depths ranging from 0.1 m to 0.5 m. These streams supply water to the MacRitchie Reservoir, which is one of a few sources of drinking water in Singapore. Groundwater level in boreholes along the tunnel alignments ranged from 1 – 10m.	Medium
Worksites and Tunnel	Surficial aquifer (Note 2)	Surficial aquifer which may have some hydraulic connectivity to MacRitchie Reservoir, a drinking water supply, and/or its tributaries. Surficial aquifer directly beneath urbanised area (utilities and building foundations).	Medium

Note 1: Field parameter measurements and observations sourced from ERM October 2014 field sampling *(See ERM (1 February 2016) Environmental Impact Assessment on Central Catchment Nature Reserve for the Proposed Cross Island Line. Site Investigation Environmental Impact Assessment Report – Volume II Environmental Baseline Report Annex 3.0. Revision 005. Retrieved from https://www.lta.gov.sg/content/dam/ltaweb/corp/PublicTransport/files/Final%20SI%20EIA%20Volume%20II.pdf).*

Note 2: As mentioned previously *in Section 2.3,* the aquifer system within the Bukit Timah Granite is conceptualised as consisting of two aquifers, a shallow aquifer within the highly weathered granite and overlying completely weathered material and soil, and a deeper lying fractured aquifer in the fresh to slightly weathered granite with the moderately weathered granite potentially presenting an aquitard between these two aquifers (see *Figure 2.8* below).

2.6.2.3 Conceptual Site Model

Given the available data and general description of the alignments, ERM developed a steady state conceptual site model (CSM) in order to assess potential impacts on groundwater resources. The CSM is based on information sourced from available literature sources and data collected during site investigation works undertaken within the Study Area.

While a standard CSM would describe sources, potential pathways and receptors, the focus of this CSM falls on describing the hydrogeological conditions at the Study Area in the context of the proposed development, while taking into consideration the potential sources of impact described in *Section 2.5.2.1* and the receptors identified in *Section 2.5.2.2*. The conceptual model is a necessary simplification of reality for the purposes of the impact assessment, and outlines the current understanding of the groundwater conditions at the Study Area.

The components of the CSM are illustrated in *Figure 2.8.* Groundwater recharge occurs through precipitation at the surface, which infiltrates to the water table and surficial aquifer below. In areas where surface waterbodies are in direct hydraulic contact with the surficial aquifer, groundwater recharge could occur directly from the surface waterbodies (and depending on relative water levels, baseflow from groundwater to the surface waterbodies could occur). The vertical and horizontal transport of water and the resulting water table elevation are functions of the ability of the aquifer to transmit and retain water as well as the magnitude of recharge.

Taking into consideration the weathering profile within the Bukit Timah Granite (as illustrated in *Figure 2.9*) and the packer testing undertaken as part of the site investigation works, the aquifer system within the Bukit Timah Granite is conceptualised as consisting of two low yielding aquifers. A shallow aquifer within the highly weathered rock, G(IV), and overlying completely weathered rock, G(V), and residual soil, G(VI), (as well as water saturated fill material and sediments of the Kallang Formation where present), and a deeper lying fractured aquifer in the fresh rock, G(I) to slightly weathered rock, G(II). In general, groundwater storage and transport is expected to be highest in the surficial aquifer at the interface between the weathered rock and the overlying soil within the highly weathered zone where the mass permeability is expected to be highest. Generally the hydraulic conductivity of the unweathered bedrock would be expected to be low, however, hydraulic conductivities and the potential for higher flow rates would be higher in sections of bedrock that shows a high degree of fracturing.

Boreholes drilled along Alignment Option 1 has revealed an undulating rock head elevation that generally follows the topography. On average, the depth to the rock head encountered during drilling was approximately 30 m bgl. Drilling period water levels similarly follows this undulating surface, with the minimum depth to water level reported as 0.48 m bgl and the maximum depth to water level reported as 8.2 m bgl. The average depth to drilling period water levels for bores drilled along Alignment Option 1 fell between 3 – 4 m bgl.

Figure 2.8: CSM Processes Contributing to Groundwater Flow

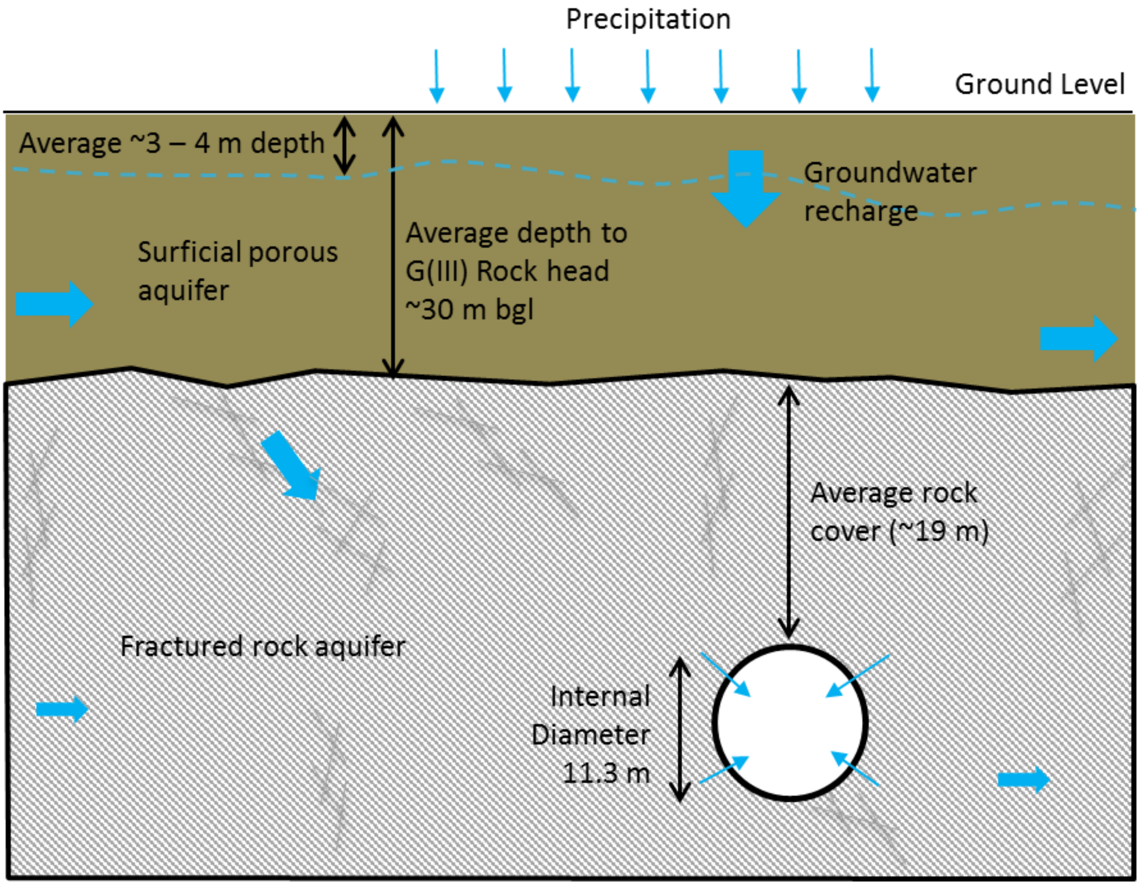


Figure 2.9: Geology of Singapore and weathering profile of Bukit Timah Granite (BTG) (Forsythe and Hawkins, 2014).

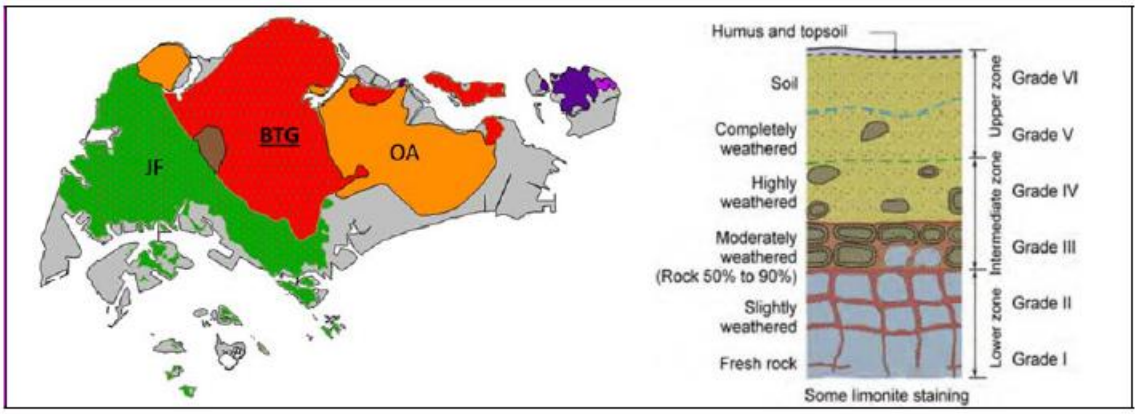


Figure 1. Simplified Solid Geology of Singapore. BTG – Bukit Timah Granite; JF – Jurong Formation; OA – Old Alluvium. Superficial Geology not detailed.

Figure 2. Simplified weathering profile of tropically weathered igneous rocks. After Little, 1969.

To contextualise the potential magnitude of impact on the hydrogeological regime from groundwater seepage into the tunnel during construction and operation, the magnitude of seepage into the tunnels in comparison to groundwater recharge was evaluated. This was done by comparing allowable seepage into the tunnel per unit of tunnel length with expected groundwater recharge to the groundwater system.

As cited earlier, the tunnels will be constructed with a high level of waterproofing with an allowable leakage rate of 2 ml / m^2 / hour (which equates to approximately 17.5 L / m^2 / year). When factoring in the 11.3 m inner diameter of the single tunnel (with the assumption that the leakage rate applies to the inner section of the tunnel lining), a 1 m long section of tunnel would have a surface area of approximately 35.5 m^2 (with area = length [1 m] X (2 X π X radius [5.65 m]). A 1 m long section of tunnel would therefore have a maximum allowable flow rate of approximately 621 L / year (17.5 L / m^2 / year X 35.5 m^2).

Typically, only a certain percentage of rainfall penetrates through the soil to become groundwater recharge. Most rainfall evaporates, or is taken up by vegetation, or flows along the ground surface as runoff. With groundwater recharge conservatively estimated to be 25% of annual precipitation, groundwater recharge would be expected to be 725 mm / year (based on annual rainfall of 2,900 mm / year within Study Area) which equates to 725 L / m^2 / year. When considering a section 11.3 m broad (that covers the width of the tunnel) recharge across that section for 1 m length of tunnel would be approximately 8,200 L / year. The allowable inflow rate per 1 m length of tunnel would therefore be less than 10% of the expected recharge rate for the surface area directly above the tunnel. If an area ten times as broad as the width of the tunnel were considered for groundwater recharge (which would extend 57 m each side of the mid-point of the tunnel width), the allowable inflow rate would be less than 1% of the recharge rate. This ratio of expected groundwater recharge to allowable inflow rates will increase the larger the area considered for groundwater recharge is. The area contributing to groundwater recharge depends on factors such as topography, permeability of the soil etc. There are no empirical studies establishing these factors for the Study Area.

It is further noted that the packer tests during SI works indicate the presence of an aquitard within G(III) rock, located between the surficial aquifer in G(IV) rock and the deeper aquifer in G(I) and G(II) rock. The permeability coefficients established for these grades of Bukit Timah Granite indicate that these aquifers are low yielding. LTA have further provided anecdotal evidence that an examination of rock core samples from vertical and horizontal boreholes was undertaken and that no significant fractures indicating a fault zone was encountered. The combination of these empirical data, site observations by the LTA and the conceptual site model indicates that the hydraulic connectivity between the surficial aquifer and the deeper aquifer is likely to be limited.

2.6.2.4 Impact Magnitude & Significance

The following general impacts to groundwater across all worksites and tunnel alignments due to planned and unplanned construction activities are described and assessed based on the project description, baseline, and scoping efforts.

A summary of the magnitude and significance of impacts to groundwater during Project construction is provided in *Table 2.11*.

Table 2.11: Impact Magnitude & Significance for Groundwater during Project Construction

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W1 (LS/VS)				
Changes in ground surface leading to changes in groundwater recharge rates	Activities such as site clearance, the construction of temporary access roads and establishment of equipment laydown areas, and road and utility diversion works would result in a reduction of vegetated ground surface by up to 15,000 m^2. This would result in an increased rate of site runoff from the worksite, which could lead to a decrease in groundwater recharge rates. The typical groundwater recharge rate within the Study Area is unknown although it is anticipated that existing groundwater recharge rates would be low given that the aquifer within the Bukit Timah Granite formation is low yielding due to the low permeability of the granite rock. The downstream impacts of lower groundwater recharge rates to surface waterbodies are unknown as there are limited monitoring data establishing the hydraulic connectivity of surface streams, such as stream Ma, and the surficial aquifer (see *Vol II, Section 4.8.5*). It is noted that the existing catchment area where the A1-W1(LS/VS) worksite is located feeds the downstream portions of stream Ma. The effect of decreased groundwater recharge rates on stream Ma is therefore anticipated to be limited. The effect of the construction works on groundwater recharge rates will be temporary ie during the construction period of 5.5 years. Replanting will be undertaken over up to 12,200 m^2 of the worksite. The impact magnitude is therefore expected to be **Small**.	Small	Medium	Minor
Excavation for the construction of underground structures	Construction of underground structures such as ventilation shafts cum TBM launch/retrieval shafts, and tunnel, will require deep excavation that will interface with groundwater aquifers, which could alter natural groundwater flow paths, elevations, and groundwater quality. Prior to excavation, ERSS will be installed at the perimeter of each shaft to serve as retaining walls. Retaining walls will serve to provide stability for the retained soil,	Small	Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Excavation for the construction of underground structures	prevent or minimise groundwater intrusion into the shaft. Concrete ring segments will be installed to construct the tunnel as the tunnel is excavated by the TBM. The ERSS and tunnel ring segments will also be waterproofed in accordance with standards for underground structures, as detailed in *LTA's Materials & Workmanship Specification for Civil & Structural Works, Jun 2010 Edition*, to ensure minimal groundwater ingress to the shaft and tunnel. Given these control measures, the impact magnitude to the groundwater aquifers and surface waterbodies is expected to be **Small**.			
Unplanned event - Accidental spills/leaks of hazardous materials	Accidental leakage and spillage of hazardous chemicals such as fuel, drilling muds, and lubricants (hydraulic and gear oil, grease etc), and construction waste could occur at the A1-W1(LS/VS) worksite, ultimately seeping into the ground and potentially leading to contamination of groundwater. The A1-W1(LS/VS) worksite will largely be concreted. Spill control and prevention measures include the provision of bunding of 110% of the largest tank and secondary containment such as drip trays, for chemical and fuel storage areas within the worksite. These embedded controls will limit the extent of seepage into the ground in the event of an accidental leakage or spillage at the worksite. In the event that an accidental leak or spill occurs, spill containment materials will be available on site so that the extent of the spill can be promptly controlled and mitigated. The impact magnitude to groundwater quality is therefore assessed as **Small** in the event of an accidental leak or spill. Localised spills of chemicals, fuel or liquid construction waste have been observed to occur at some construction worksites in Singapore. The likelihood of this occurring at the worksites is therefore evaluated to be *Possible*. The impact significance of groundwater contamination taking into consideration the possible occurrence of leakage or spillage, is evaluated to remain as **Minor**.	Small	Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Firewater	Water used to combat fires at the A1-W1(LS/VS) worksite may contain contaminants, which may infiltrate the ground. Most of the ground surface of the A1-W1(LS/VS) worksite will be concreted. Firewater within the worksite will be channeled via the perimeter drains to the sedimentation pond for holding until collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to groundwater quality in the event of a fire emergency is **Small**. The likelihood of a fire occurrence is deemed *Unlikely* (see *Annex 1.0*). The impact significance on groundwater considering the unlikely risk of a fire occurrence is reduced from Minor to **Negligible**.	Small (in the event of fire)	Medium	Minor (in the event of fire) Negligible (considering that a fire is *Unlikely* to occur)
A1-W2 (LS/VS)				
Changes in ground surface leading to changes in groundwater recharge rates	Activities such as site clearance, the construction of temporary access roads and establishment of equipment laydown areas, and road and utility diversion works would result in a reduction of vegetated ground surface by up to 15,000 m^2. This would result in an increase rate of site runoff from the worksite, which could affect groundwater recharge rates. The typical groundwater recharge rate within the Study Area is unknown although it is anticipated that any aquifer within the Bukit Timah Granite formation would be low yielding. The effect of the construction works on groundwater recharge rates will be temporary ie during the construction period of 5.5 years. Replanting will be undertaken over up to 12,200 m^2 of the worksite. The impact magnitude to hydrogeology within the surficial aquifer is therefore expected to be **Small**.	Small	Medium	Minor
Excavation for the construction of underground structures	Construction of underground structures such as ventilation shafts cum TBM launch/retrieval shafts, and tunnel, will require deep excavation that will interface with groundwater aquifers, which could alter natural groundwater flow paths, elevations, and groundwater quality.	Small	Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Excavation for the construction of underground structures	Prior to excavation, ERSS will be installed at the perimeter of each shaft to serve as retaining walls. Retaining walls will serve to provide stability for the retained soil, preventing or minimise groundwater intrusion into the shaft. Concrete ring segments will be installed to construct the tunnel as the tunnel is excavated by the TBM. The ERSS and tunnel ring segments will also be waterproofed in accordance with standards for underground structures, as detailed in *LTA's Materials & Workmanship Specification for Civil & Structural Works, Jun 2010 Edition*, to ensure minimal groundwater ingress to the shaft and tunnel. Given these control measures, the impact magnitude to groundwater aquifers and surface waterbodies is expected to be **Small**.			
Unplanned event - Accidental spills/leaks of hazardous materials	Accidental leakage and spillage of hazardous chemicals such as fuel, drilling muds, and lubricants (hydraulic and gear oil, grease etc), and construction waste could occur at the A1-W2(LS/VS) worksite, ultimately seeping into the ground and potentially leading to contamination of groundwater. The A1-W2(LS/VS) worksite will largely be concreted. Spill control and prevention measures include the provision of bunding of 110% of the largest tank and secondary containment such as drip trays, for chemical and fuel storage areas within the worksite. These embedded controls will limit the extent of seepage into the ground in the event of an accidental leakage or spillage at the worksite. In the event that an accidental leak or spill occurs, spill containment materials will be available on site so that the extent of the spill can be promptly controlled and mitigated. The impact magnitude to groundwater quality is therefore assessed as **Small** in the event of an accidental leak or spill. Localised spills of chemicals, fuel or liquid construction waste have been observed to occur at some construction worksites in Singapore. The likelihood of this occurring at the worksites is therefore evaluated to be *Possible*. The impact significance of groundwater contamination taking into consideration the possible occurrence of leakage or spillage, is evaluated to remain as **Minor**.	Small	Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Firewater	Water used to combat fires at the A1-W2(LS/VS) worksite may contain contaminants, which may infiltrate the ground. Most of the ground surface of the A1-W2(LS/VS) worksite will be concreted. Firewater within the worksite will be channeled via the perimeter drains to the sedimentation pond for holding until collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to groundwater quality in the event of a fire emergency is **Small**. The likelihood of a fire occurrence is deemed *Unlikely* (see *Annex 1.0*). The impact significance on groundwater considering the unlikely risk of a fire occurrence is reduced from Minor to **Negligible**.	Small (in the event of fire)	Medium	Minor (in the event of fire) Negligible (considering that a fire is *Unlikely* to occur)
Tunnel Alignment				
Injection of slurry into tunnel face	TBM drilling mud slurry will consist of approved non-toxic water based muds which will be designed with limited viscosity in order to seal the fissures or soil pores encountered at the tunnel face, and thereby maintain hydrostatic pressure at the TBM cutterhead. It is therefore likely that any spread of the slurry will be largely localised at the tunnel face located within the deeper aquifer. It is noted that the hydraulic connectivity between the deeper aquifer within the rock head, and the surficial aquifer located within weathered granite is likely to be limited due to the presence of an aquitard. Any impact to the groundwater quality within the surficial aquifer and associated impact to surface waterbodies is therefore assessed to be **Negligible**.	Negligible	Medium	Negligible
Unplanned event - Accidental spills/leaks of hazardous materials	Accidental leakage and spillage of hazardous chemicals such as fuel, drilling muds, and lubricants (hydraulic and gear oil, grease etc), and construction waste could occur in the tunnel worksite, ultimately seeping into the ground and potentially leading to contamination of groundwater. The tunnel worksite will largely be concreted. In the event that an accidental leak or spill occurs, spill containment materials will be available on site so that the extent of the spill can be promptly controlled. It is noted that the hydraulic connectivity between the deeper aquifer within the rock head, and the surficial	Negligible	Medium	Negligible

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Accidental spills/leaks of hazardous materials	aquifer located within weathered granite is likely to be limited due to the presence of an aquitard. Any impact to the groundwater quality within the surficial aquifer and associated impact to surface waterbodies is therefore assessed to be **Negligible**. Localised spills of chemicals, fuel or liquid construction waste have been observed to occur at some construction worksites in Singapore. The likelihood of this occurring at the worksites is therefore evaluated to be *Possible*. Therefore, given the limited hydraulic connectivity of the deeper aquifer to the surficial aquifer and surface waterbodies, the impact significance of groundwater contamination taking into consideration the possible occurrence of leakage or spillage, is evaluated to remain as **Negligible**.			
Unplanned event - Firewater	Water used to combat fires within the tunnel, and which may contain contaminants, may infiltrate the deeper aquifer. The tunnel will be concreted. Firewater within the tunnel will be pumped up into the lined sedimentation pond which forms part of the worksite's ECM system. Firewater will be held within the sedimentation pond until collection by a third party contractor for offsite disposal. It is noted that the hydraulic connectivity between the deeper aquifer within the rock head, and the surficial aquifer located within weathered granite is likely to be limited due to the presence of an aquitard. Any impact to the groundwater quality within the surficial aquifer and associated impact to surface waterbodies in the event of a fire within the tunnel is therefore assessed to be **Negligible**. The likelihood of a fire occurrence is deemed *Unlikely* (see *Annex 1.0*). The impact significance on groundwater considering the unlikely risk of a fire occurrence is evaluated to remain as **Negligible**.	Negligible	Medium	Negligible
Unplanned event – Excessive water ingress during tunnelling	Excessive water ingress during tunneling may occur when the TBM encounters fractures or mixed face conditions within the Bukit Timah Granite. These geological conditions serve as preferential pathways for groundwater, and this may	Negligible	Medium	Negligible

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event – Excessive water ingress during tunnelling	lead to a sudden increase in hydrostatic pressure at the cutterhead so that groundwater leaks into the TBM cutterhead. Excessive water ingress into the tunnel worksite could result in changes to the natural groundwater flow within the deeper aquifer. The TBM will be stopped periodically for advance probing ahead of the TBM cutterhead. In the event that probing results confirm the presence of a highly fractured zone or mixed face condition, grouting can be undertaken prior to advancement of the TBM to minimize the risk of water ingress. In the event that water ingress occurs, the TBM operation will be stopped and remedial grouting will be undertaken to plug any fractures within the tunnel face. Grouting will continue to be undertaken of the geological column ahead of the TBM prior to advancement of the TBM, until the TBM has moved out of the fracture zone. The conceptual site model was applied to contextualise the potential magnitude of impact on the hydrogeological regime due to groundwater seepage into the tunnel during tunnelling works (see *Section 2.5.2.3*). While other factors will contribute to water level variations (such as lateral groundwater inflow and outflow rates), the comparison of allowable inflow rates into the tunnel compared to expected groundwater recharge puts the inflow rates into the tunnels into context, indicating that the magnitude of impact on the hydrodynamics of the hydrogeological regime is likely to be limited. In addition, packer tests during site investigation have identified the presence of an aquitard between the deeper and surficial aquifers. Taking the above into consideration in addition to the embedded controls and the contingency measures in place, the impact magnitude to hydrogeology in the surficial aquifer and surface waterbodies is assessed to be **Negligible** in the event that water ingress occurs during tunneling. The likelihood of water ingress occurring during tunnelling within great depths in Bukit Timah Granite is considered *Possible* (see *Annex 1.0*). Taking into consideration the presence of an aquitard between the deeper aquifer and surficial aquifer, the impact significance of water ingress to the tunnel on the surficial aquifer and surface waterbodies is assessed to remain as **Negligible**.			

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Excessive ground settlement or slope failure during tunnelling	Excessive ground settlement could occur due to loss of tunnel pressure at the TBM cutterhead. Loss of tunnel pressure could occur when the TBM encounters mixed face conditions leading to over-excavation. Excessive ground settlement during tunnelling may also occur as a result of water ingress into the tunnel, leading to consolidation of the rock and soil in the geological column at the tunnel face. In addition, slope failure at the Sime Stream Valley could occur due to the introduction of groundborne vibration during tunneling works along with other factors such as heavy rainfall and natural erosion at the slope base. The formation of voids or slumps and settlement at the ground surface may lead to a change in hydraulic connectivity between surface water and groundwater resources. This may in turn result in a permanent change in natural groundwater flow paths, which may result in downstream impacts to surface waterbodies. Embedded controls for the management of risk of excessive ground settlement include the design of the tunnel to be excavated below the granite rock head, and measures to limit the potential for excessive leakage of groundwater from the deep aquifer. These measures include advance probing, close monitoring of slurry KPI parameters to maintain positive pressure at the TBM cutter head during tunnel boring, grouting of any highly fractured zones or mixed face conditions identified ahead of the TBM. In addition, the formation of voids at the tunnel face will be closely monitored during the operation of the TBM. As a contingency measure, at the onset of void formation, remedial grouting will be promptly undertaken at the tunnel face to minimise the propagation of void formation to the ground surface. The prompt undertaking of contingency measures will enable the extent of ground settlement to be minimised so that impacts to surface waterbodies are localised. A key embedded control for the management of risk of slope failure include the existing installation of surface drainage within the subcatchment area of the Sime	Large (in the event of excessive ground settlement or slope failure)	Medium	Major (in the event of excessive ground settlement or slope failure) Moderate (considering that excessive ground settlement is *Unlikely* to occur)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Excessive ground settlement or slope failure during tunnelling	Stream Valley slope. As best practice, visual inspections of the slope brow will also be undertaken during tunnelling to detect any onset of slope failure, especially during works undertaken in heavy rainfall conditions. It is noted that the hydraulic connectivity of streams Ha, I, IC and the Sime Stream along the tunnel alignment to groundwater resources has not been established. In accordance with the precautionary principle, it is assumed that there is a degree of hydraulic connectivity. Excessive ground settlement may therefore result in significant changes to groundwater flows, resulting in significant downstream impacts to the hydrology of surface streams. The magnitude of impact on the hydrodynamics of the hydrogeological regime is conservatively evaluated to be **Large** in the event of excessive ground settlement or slope failure. The likelihood of excessive ground settlement or slope failure occurring is considered *Unlikely* (see *Annex 1.0*) due to embedded controls such as tunnelling within great depths in Bukit Timah Granite rock and the installation of surface drainage within the Sime Stream Valley. The impact significance on groundwater considering the unlikely risk of excessive ground settlement or slope failure occurring is therefore reduced from Major to **Moderate**.			

2.6.2.5 Mitigation Measures

No additional mitigation measures have been recommended for the Project in view of the embedded engineering controls in place to manage potential impacts to groundwater receptors. It is recommended that the measures presented in *Table 2.12* be undertaken as best practice.

Table 2.12: Best Practice Measures for Groundwater Receptors during Project Construction

Category	Recommendation
Design and Pre Construction	• To capture monitoring (parameters monitored and frequency of monitoring) and reporting requirements, the development of a construction phase groundwater monitoring plan is recommended which can be incorporated in the environmental management and monitoring plans.
Environmental Management and Monitoring Plans	• Contractor to develop and implement stringent environmental management and monitoring plans to ensure safe tunnelling works with minimal impacts to groundwater. Monitoring plans should include development of the construction phase groundwater monitoring plan specifying monitoring and reporting requirements. The plans should further include frequent inspection of the tunnel face and shafts; and monitoring of settlement of nearby buildings (ie SICC Island Clubhouse).

2.6.2.6 Residual Impacts

Groundwater impacts from construction activities can be managed by implementation of the embedded controls referenced in *Volume I, Annex 2.0* and the best practice measures identified in *Table 2.12*. The protection of groundwater is important given its connection surface waterbodies such as streams in the CCNR (in consideration of potential groundwater and surface water interactions), in the unlikely event that excessive ground settlement occurs.

Given the expected limited scale of impact (with effective embedded controls in place) recommendations are focused on verification of impacts being limited through monitoring as outlined in the recommended best practice measures. The implementation of best practice measures will manage potential impacts to groundwater resources to as low as reasonably practicable. A summary of the impact assessment criteria including the best practice measures are presented in *Table 2.13.*

Table 2.13: Impact Assessment Summary for Groundwater Impact during Construction Phase

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to Worksites and Tunnelling					
Nature	Negative	Potential changes in groundwater table elevations, flow paths, and groundwater quality due to ground water seepage, improper storage of materials, and other unplanned events.			
Type	Direct and indirect	Activities directly affecting quantity and quality of groundwater resources, which may then indirectly affect quantity and quality of surface water resources considering potential groundwater-surface water interaction.			
Duration	Long term	Throughout construction duration of the Project			
Extent	Local	With embedded controls in place, the extent of impact to the hydrogeological regime would be expected to be limited and localised.			
Scale	Limited	As with the extent of the impact, with embedded controls in place, the scale of impact would be expected to be limited. For quantification of the scale of impact, numerical modelling would be required. Given the expected limited scale of impact (with effective embedded controls in place) recommendations are focussed on verification of impacts being limited through monitoring as outlined in the mitigation measures.			
Frequency	Continuous	Continuous during several years of construction.			
Receptor Sensitivity	Medium	Surface waterbodies such as streams Ma, Ha, I, and IC which may be hydraulically connected to the surficial aquifer, are tributaries to reservoirs used as drinking water sources in Singapore.			

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to Worksites and Tunnelling					
Pre-Mitigation Magnitude	Small	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Changes in groundwater recharge rates due to increase in impermeable ground surfaces at the worksites; changes in hydrodynamics due to construction of underground structures; and impact to groundwater quality due to accidental spills or leaks of hazardous chemicals. **Tunnel alignment:** Changes to hydrogeology and downstream alteration of surface water drainage regimes or flows due to the unlikely occurrence of excessive ground settlement.	**Residual** Impact Magnitude	Small	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Changes in groundwater recharge rates due to increase in impermeable ground surfaces at the worksites; changes in hydrodynamics due to construction of underground structures; and impact to groundwater quality due to accidental spills or leaks of hazardous chemicals. **Tunnel alignment:** Changes to hydrogeology and downstream alteration of surface water drainage regimes or flows due to the unlikely occurrence of excessive ground settlement.
	Negligible	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact to groundwater quality due to seepage of potentially contaminated firewater from the aboveground worksites. **Tunnel alignment:** Impact to groundwater and surface water quality due to the injection of slurry into the tunnel face during tunnelling works or accidental spills or leaks of hazardous chemicals at the tunnel worksite; and changes in hydrodynamics due to excessive water ingress at the tunnel face during tunnelling works.		Negligible	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Residual impact to groundwater quality due to seepage of potentially contaminated firewater from the aboveground worksites. **Tunnel alignment:** Residual impact to groundwater and surface water quality due to the injection of slurry into the tunnel face during tunnelling works or accidental spills or leaks of hazardous chemicals at the tunnel worksite; and changes in hydrodynamics due to excessive water ingress at the tunnel face during tunnelling works.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to Worksites and Tunnelling					
Pre-Mitigation Impact Significance	Moderate	**Tunnel alignment:** Impact significance to hydrogeology and downstream alteration of surface water drainage regimes or flows due to the unlikely occurrence of excessive ground settlement.	**Residual** Impact Significance	Moderate	**Tunnel alignment:** Residual impact significance to hydrogeology and downstream alteration of surface water drainage regimes or flows due to the unlikely occurrence of excessive ground settlement.
	Minor	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact significance to hydrogeology due to increase in impermeable ground surfaces at the worksites and construction of underground structures; and impact significance to groundwater quality due to accidental spills or leaks of hazardous chemicals.		Minor	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact significance to hydrogeology due to increase in impermeable ground surfaces at the worksites and construction of underground structures; and impact significance to groundwater quality due to accidental spills or leaks of hazardous chemicals.
	Negligible	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact to groundwater quality due to seepage of potentially contaminated firewater from the aboveground worksites. **Tunnel alignment:** Impact to groundwater and surface water quality due to the injection of slurry into the tunnel face during tunnelling works or accidental spills or leaks of hazardous chemicals at the tunnel worksite; impact to groundwater quality due to seepage of potentially contaminated firewater from the tunnel; and changes in hydrodynamics due to excessive water ingress at the tunnel face during tunnelling works.		Negligible	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Residual impact to groundwater quality due to seepage of potentially contaminated firewater from the aboveground worksites. **Tunnel alignment:** Residual impact to groundwater and surface water quality due to the injection of slurry into the tunnel face during tunnelling works or accidental spills or leaks of hazardous chemicals at the tunnel worksite; impact to groundwater quality due to seepage of potentially contaminated firewater from the tunnel; and changes in hydrodynamics due to excessive water ingress at the tunnel face during tunnelling works.

2.7 ASSESSMENT OF IMPACTS DURING PROJECT OPERATION PHASE

2.7.1 *Impacts to Surface Water due to Operation Phase*

2.7.1.1 Sources of Impact

Potential source of impacts to water resources during Project Operation will consist of the following:

- Potential impact on hydrology due to increased surface runoff from impermeable surface at the facility building; and
- Potential impact on water quality due to unplanned events relating to the use and disposal of water to extinguish fires.

Used firewater collected within a tunnel will be managed by a dedicated drainage system as discussed in *Section 2.2* and will not cause any impacts to surface water receptors. Therefore, this assessment focuses on fire incidents at facility buildings.

2.7.1.2 Receptors

Surface water bodies located in close proximity to facility buildings may be impacted by operation activities. Surface water receptors identified for each facility building are presented in *Table 2.14* along with the receptor sensitivity.

Table 2.14: ***Surface Water Receptors***

Receptor ID	Receptor(s)	Description	Nearest Facility Building	Receptor Sensitivity
SWR1	Roadside drains along Island Club Road that discharges to streams Ma4, Ma3, Ma2, Ma	The roadside drain is at the perimeter of worksite A1-W1 and was observed to be connected with 'Ma' streams within Windsor Nature Park. Stream Ma discharges to the canal parallel to Upper Thomson Road and ultimately feed into the Marina Reservoir where water is used for potable and domestic supply. However, water accumulated from this drain forms only a minor part of the drainage network leading to the Marina Reservoir.	A1-W1	Medium
SWR2	Drain parallel to PIE, that discharges in the northerly direction to Stream IC leading towards MacRitchie Reservoir, or in a southerly direction towards Marina Reservoir	Water collected within the drain located to the east of the worksite could flow in either a northerly or southerly direction. If towards the north, the water will be discharge to Stream IC across the PIE via an underground drain, which feeds into the MacRitchie Reservoir. If towards the south, the water will be discharged to the drainage network at Eng Neo Avenue that ultimately leads to the Marina Reservoir.	A1-W2	Medium

2.7.1.3 Impact Magnitude & Significance

A summary of the magnitude and significance of impacts to surface water during Project operation is provided in *Table 2.15*.

Table 2.15: Impact Magnitude & Significance for Surface Water during Project Operation

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W1				
Increased runoff from impermeable surface	An area of approximately 2,800 m^2 will be used for the construction of the facility building and this area will become impermeable. The transformation of the surface type will lead to an increased surface runoff. Due to a lack of design information, an additional 10% has been assumed for access road, making the total impermeable surface close to 3,000 m^2. Presently, surface runoff at A1-W1 is collected and discharged to the roadside drain which drains to stream Ma. Depending on the stormwater event, the increased runoff from the Project facility could lead to flooding of Stream Ma. According to the *Code of Practice (COP) on Surface Water Drainage*, "*Industrial, commercial, institutional and residential developments greater than or equal to 0.2 hectares (ha) in size are required to control the peak runoff discharged from their sites. The maximum allowable peak runoff to be discharged to the public drains will be calculated based on a runoff coefficient of 0.55, for design storms with a return period of 10 years and for various storm durations of up to 4 hours (inclusive).*" Based on this and the estimated size of the facility building, a detention tank will be constructed to cope with the increased runoff due to the impermeable surface. Therefore, impact magnitude due to downstream flooding at Stream Ma is assessed to be Small.	Small	SWR1: Medium	Minor
Unplanned Event – firewater	In the event of a fire incident, water used for firefighting within the facility building site will be channeled via the perimeter drains to the detention tank for holding until collection by a third party contractor for offsite disposal. Considering this, the impact magnitude is assessed to be **Small**. As discussed in *Annex 1.0*, the likelihood of a fire occurrence during the operation phase is considered as *Possible* based on a review of the historical events. Therefore, the impact significance is considered as **Minor.**	Small	SWR1: Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W2				
Increased runoff from impermeable surface	An area of approximately 2,800 m^2 will be used for the construction of the facility building and this area will become impermeable. The transformation of the surface type will lead to an increased surface runoff. Due to a lack of design information, an additional 10% has been assumed for access road, making the total impermeable surface close to 3,000 m^2. Presently, the proposed location of the A1-W2 facility building sits within the catchment area for Marina Reservoir. Surface runoff at A1-W2 will therefore be collected and discharged to the drain, which drains in a southerly direction to the Marina Reservoir. According to the *Code of Practice (COP) on Surface Water Drainage*, "*Industrial, commercial, institutional and residential developments greater than or equal to 0.2 hectares (ha) in size are required to control the peak runoff discharged from their sites. The maximum allowable peak runoff to be discharged to the public drains will be calculated based on a runoff coefficient of 0.55, for design storms with a return period of 10 years and for various storm durations of up to 4 hours (inclusive).*" Based on this and the estimated size of the facility building, a detention tank will be constructed to cope with the increased runoff due to the impermeable surface. Therefore, impact magnitude due to downstream flooding at Marina Reservoir is assessed to be Small. As there is no discharge in the northerly direction to Stream IC, which leads to MacRitchie Reservoir, the impact magnitude to these receptors due to downstream flooding is assessed to be Negligible.	Small	SWR2: Medium	Minor
Unplanned Event – firewater	In the event of a fire incident, the water used for firefighting within the facility building site will be channeled via the perimeter drains to the detention tank for holding until collection by a third party contractor for offsite disposal. Considering this, the impact magnitude is assessed to be **Small**. As discussed in *Annex 1.0*, the likelihood of a fire occurrence during the operation phase is considered as *Possible* based on a review of the historical events. Therefore, the impact significance is assessed as **Minor.**	Small	SWR2: Medium	Minor

A summary of the impact assessment criteria including the implementation of mitigation measures are presented below for each worksite in *Table 2.17*.

Table 2.17: Impact Assessment Summary for Surface Water Impact

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality due to operation activities					
Nature	Negative	Negative impacts to surface water quality due to increased surface runoff and disposal of used firewater during fire.			
Type	Direct	Disposal of used firewater directly affect the surface waterbodies			
Duration	Temporary	During a fire occurrence			
Extent	Local	Surface waterbodies adjacent to facility buildings			
Scale	-	Surface runoff amount depending on the size of the facility building; and the amount of firewater depending on scale of fire.			
Frequency	-	Rainfall event is frequent in Singapore therefore discharge of runoff is often; and the likelihood of fire is *Possible*.			
Receptor Sensitivity	**A1-W1** SWR1: Medium	Roadside drains along Island Club Road that discharges to streams Ma4, Ma3, Ma2, Ma			
	A1-W2 SWR2: Medium	Roadside drain parallel to PIE			
Pre-Mitigation Magnitude	**A1-W1** Small Small	Impact to hydrology due to increased surface runoff was assessed to be of Small magnitude. Impact to water quality due to disposal of used firewater was assessed to be of Small magnitude.	**Residual** Magnitude	**A1-W1** Small Small	Impact to hydrology due to increased surface runoff was assessed to be of Small magnitude. Impact to water quality due to disposal of used firewater was assessed to be of Small magnitude.
	A1-W2 Small Small	Impact to hydrology due to increased surface runoff was assessed to be of Small magnitude. Impact to water quality due to disposal of used firewater was assessed to be of Small magnitude.		**A1-W2** Small Small	Impact to hydrology due to increased surface runoff was assessed to be of Small magnitude. Impact to water quality due to disposal of used firewater was assessed to be of Small magnitude.
Pre-Mitigation Impact Significance	**A1-W1** Minor	Impact magnitude of small for impact to hydrology due to increased surface runoff and for impact to water quality due to disposal of used firewater, combining with a receptor sensitivity of Medium for SWR 1.	**Residual** Impact Significance	**A1-W1** Minor	Impact magnitude of small for impact to hydrology due to increased surface runoff and for impact to water quality due to disposal of used firewater, combining with a receptor sensitivity of Medium for SWR 1.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to surface water quality due to operation activities					
Pre-Mitigation Impact Significance	**A1-W2** Minor	Impact magnitude of small for impact to hydrology due to increased surface runoff for impact to water quality due to disposal of used firewater, combining with a receptor sensitivity of Medium for SWR 2.	**Residual** Impact Significance	**A1-W2** Minor	Impact magnitude of small for impact to hydrology due to increased surface runoff for impact to water quality due to disposal of used firewater, combining with a receptor sensitivity of Medium for SWR 2.

2.7.2 *Impacts to Groundwater due to Operation Phase*

2.7.2.1 *Sources of Impact*

Activities and sources of impacts to groundwater during the Project operation phase are listed below. The anticipated, typical activities include:

- Permanent changes in ground surface permeability due to the presence of permanent facility buildings maintenance roads, and utility access areas, resulting in increased site runoff and reduced groundwater recharge rates; and
- Excessive groundwater seepage into the constructed tunnel.

The unplanned events considered in this assessment include:

- Accidental leakage and spillage from temporary storage of hazardous chemicals such as sanitary waste, lubricants, and fuel, at operational facilities above and below ground; and
- Disposal of water used to combat fires at or near the Project site, where the water could enter the ground around the facility building, or through the tunnel or other access shafts.

2.7.2.2 *Receptors*

Surface and groundwater receptors located near, downgradient, and above the tunnel alignments may be impacted by operation activities. Groundwater receptors identified are presented below in *Table 2.18* along with the receptor sensitivity. Note that surface waterbodies have been included as groundwater receptors where the likelihood of groundwater-surface water interactions is considered to be high.

Table 2.18 Groundwater Receptors

Location	Receptor(s)	Description	Receptor Sensitivity
Facility Buildings and Vent Shafts	Stream Ma4, Ma3, Ma2	Small surface streams that may or may not be hydraulically connected to the groundwater. These are within Windsor Interim Green and CCNR, and eventually connect to controlled surface drains feeding into Marina Reservoir to the south of Singapore. Marina Reservoir is one of a few sources of drinking water supply for Singapore.	Medium
Tunnel Alignment	Streams Ha, I, IC	Small streams that may or may not be hydraulically connected to the groundwater. These are located above the proposed tunnel alignment and are within the CCNR, feeding the MacRitchie Reservoir. Water levels of these streams are generally shallow with depths ranging from 0.1 m to 0.5 m. These streams supply water to the MacRitchie Reservoir, which is one of a few sources of drinking water supply for Singapore.	Medium
Buildings and Tunnel	Surficial aquifer	Surficial aquifer may be directly connected to overlying streams within the CCNR and MacRitchie Reservoir, which is one of a	Medium

Location	Receptor(s)	Description	Receptor Sensitivity
		few sources of drinking water supply for Singapore and beneath urbanised area (utilities and building foundations).	

2.7.2.3 Conceptual Site Model

Given the available data and general description of the alignments, ERM developed a steady state CSM in order to assess potential impacts on groundwater resources. The CSM is described in detail in *Section 2.5.2.3* and outlines the hydrogeological conditions at the Study Area in the context of the proposed development. Based on available data and information, the aquifer system is conceptualised as consisting of two low yielding aquifers - a surficial aquifer within the highly weathered rock to residual soil (including water saturated fill material and sediments of the Kallang Formation where present) and a deeper lying aquifer within fresh and slightly weathered rock of the Bukit Timah Granite. Groundwater storage and transport is expected to be highest in the surficial aquifer at the interface between the weathered rock and the overlying soil within the highly weathered zone where the mass permeability is expected to be highest. The hydraulic conductivity of the unweathered bedrock, fresh rock, would generally be expected to be low, however, hydraulic conductivities and the potential for higher flow rates would be higher in sections of bedrock that shows a high degree of fracturing.

The CSM described in *Section 2.5.2.3* took into consideration embedded controls. A key control relevant for the consideration of potential impacts during the operational phase is the requirement for a high level of waterproofing of the tunnel lining that will limit groundwater seepage into the tunnels. This waterproofing would then also limit the hydraulic connectivity of any spills within the tunnel and groundwater. During the operational phase, all construction activities would have been completed and direct connectivity between spills within existing buildings and groundwater would also be expected to be negligible.

2.7.2.4 Impact Magnitude & Significance

A summary of the magnitude and significance of impacts to groundwater during Project operation is provided in *Table 2.19*.

Table 2.19: Impact Magnitude & Significance for Groundwater during Project Operation

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W1 (LS/VS)				
Changes in ground surface leading to changes in groundwater recharge rates	The effects of changes to ground surface permeability on groundwater recharge rates have been assessed during construction (see *Section 2.5.2.4, Table 2.11*). During the construction period of 5.5 years, 15,000 m^2 of land would be changed from vegetated to concreted ground cover. Following completion of the facility building construction, replanting will be undertaken over up to 12,200 m^2 of the worksite during reinstatement works. A remaining 2,800 m^2 will remain impermeable due to the permanent presence of the facility building, maintenance and access roads. Given that the A1-W1 (LS/VS) facility building is located at the downstream portion of stream Ma, the impact of reduced groundwater recharge rates to the surface water flow is likely to be limited. The impact magnitude is therefore expected to be **Small**.	Small	Medium	Minor
Unplanned event – Accidental leakage or spillage of hazardous chemicals	Maintenance works will be carried out within the facility building during operation, which will involve the storage and handling of chemicals such as lubricants (grease, hydraulic and gear oil). Accidental leakage or spillage will occur within the ventilation shaft or facility building complex, where the ground or shaft is concreted. Any leaks or spills will be collected via onsite drainage to be collected by third party contractors for offsite disposal. There will therefore be no pathway to uncovered ground. The impact to groundwater and surface water quality is therefore assessed to be **Negligible**.	Negligible	Medium	Negligible
Unplanned event - Firewater	Water used to combat fires at the A1-W1(LS/VS) facility building may contain contaminants which may infiltrate the ground. Most of the ground surface of the A1-W1(LS/VS) facility building will be concreted. Firewater within the facility building site will be channeled via the perimeter drains to the detention tank for holding until collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to groundwater quality in the event of a fire emergency is **Small**. The likelihood of a fire occurrence is deemed *Possible* (see *Annex 1.0*). The impact significance on groundwater considering the possible risk of a fire occurrence remains at **Minor**.	Small	Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W2 (LS/VS)				
Changes in ground surface leading to changes in groundwater recharge rates	The effects of changes to ground surface permeability on groundwater recharge rates have been assessed during construction (see *Section 2.5.2.4, Table 2.11*). During the construction period of 5.5 years, 15,000 m^2 of land would be changed from vegetated to concreted ground cover. Following completion of the facility building construction, replanting will be undertaken over up to 12,200 m^2 of the worksite during reinstatement works. A remaining 2,800 m^2 will remain impermeable due to the permanent presence of the facility building, maintenance and access roads. The impact of reduced groundwater recharge rates to the surficial aquifer is likely to be limited. The impact magnitude is therefore expected to be **Small**.	Small	Medium	Minor
Unplanned event – Accidental leakage or spillage of hazardous chemicals	Maintenance works will be carried out within the facility building during operation, which will involve the storage and handling of chemicals such as lubricants (grease, hydraulic and gear oil). Accidental leakage or spillage will occur within the ventilation shaft or facility building complex, where the ground or shaft is concreted. Any leaks or spills will be collected via onsite drainage to be collected by third party contractors for offsite disposal. There will therefore be no pathway to uncovered ground. The impact to groundwater and surface water quality is therefore assessed to be **Negligible**.	Negligible	Medium	Negligible
Unplanned event - Firewater	Water used to combat fires at the A1-W2 (LS/VS) facility building may contain contaminants which may infiltrate the ground. Most of the ground surface of the A1-W2 (LS/VS) facility building will be concreted. Firewater within the facility building site will be channeled via the perimeter drains to the detention tank for holding until collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to groundwater quality in the event of a fire emergency is **Small**. The likelihood of a fire occurrence is deemed *Possible* (see *Annex 1.0*). The impact significance on groundwater considering the possible risk of a fire occurrence remains at **Minor**.	Small	Medium	Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Tunnel Alignment				
Excessive groundwater seepage into tunnel	Due to the high hydrostatic pressure at the tunnel depth, groundwater seepage into the tunnel may occur during the lifespan of the operational tunnel. Embedded controls include regular visual inspections of the tunnels. In the event that significant seepage is detected, grouting will be undertaken to repair the breach of the tunnel wall and/or lining. Due to the design of the tunnel to include waterproof lining and gaskets to ensure the water-tightness of the tunnel, it is expected that any groundwater seepage will be limited to not more than 2 ml / m^2 / hour. A conceptual site model has been undertaken to provide some context to this groundwater inflow rate relative to existing groundwater recharge rates (see *Section 2.6.2.3*). It is established that hydraulic connectivity of the deeper aquifer to the tunnel is likely to be limited. It is further noted from packer tests that the presence of an aquitard indicates limited hydraulic connectivity between the deeper and surficial aquifers. Impacts to hydrodynamics within the surficial aquifer and surface waterbodies are therefore expected to be **Negligible**.	Negligible	Medium	Negligible
Unplanned event – Accidental spills/leaks of hazardous materials	Accidental leakage and spillage of hazardous chemicals, sanitary waste, fuel, and lubricants could occur in the tunnel. Hydraulic connectivity between spills within the enclosed tunnel and groundwater is however expected to be limited. Given this limited connectivity, planning for spill control and prevention plans, and availability of clean up materials (if a spill does occur), the impact magnitude has been classified as **Negligible.**	Negligible	Medium	Negligible
Unplanned event – Firewater	There will be limited pathways for water used to combat fires within the tunnel, to seep into the ground. The concreted tunnel will be constructed to maintain integrity under exposure to fire and explosion. Firewater accumulated within the tunnel will be channelled via designated drainage to the detention tank for holding, until collection by a third party contractor for offsite disposal. Given the embedded controls, the expected impact magnitude to groundwater quality in the event of a fire emergency is **Negligible**. While the likelihood of a fire occurrence during the operation stage is deemed *Possible* (see *Annex 1.0*), given the aforementioned embedded controls, the impact to groundwater from firewater will be limited. Therefore, the impact significance is assessed to remain **Negligible**.	Negligible	Medium	Negligible

2.7.2.5 Mitigation Measures

Embedded controls to avoid, minimise, and limit the magnitude of groundwater impacts caused by the Project's construction phase are described in *LTA Engineering Group Materials & Workmanship Specification for Civil & Structural Works, June 2010*. These measures such as selection of construction material, shaft construction and tunnelling methodology, and required waterproofing specifications for the tunnel lining during the Project construction phase will serve to minimise groundwater seepage during the Project operation phase. Inspections to ensure compliance with the waterproofing specifications should include measurement and documentation of the volumes of tunnel leakage water. In the event of an unplanned event (ie fire), LTA manages fire water via a sump collection within the tunnels. The fire water is then collected by third party contractors for offsite treatment and disposal. It is recommended that the appropriate planning and controls for the fire water management are incorporated within the emergency planning procedures, if not already covered by LTA operation procedures.

In the event that groundwater monitoring bores are installed as part of the construction phase, it is further recommended that these be periodically monitored to verify that impacts on groundwater levels are limited (and to allow for contingency actions being triggered if unexpected observations are made). During the first year of operation, monthly monitoring of groundwater levels would be recommended. Depending on the trends observed during the first year of monitoring during the operational phase, monitoring frequency can be decreased (for instance to quarterly monitoring if water level trends are stable, with potential further decrease in monitoring frequency in subsequent years depending on the trends in groundwater levels). Observations of tunnel leakage water volumes should further be taken into account when evaluating timing of groundwater level monitoring events, with sudden increases in tunnel leakage water triggering the need for a groundwater level monitoring event. To capture monitoring requirements, trigger levels, associated actions and reporting requirements, the development of an operational phase groundwater monitoring plan is recommended. The plan can be set in place for an initial two year period, with revisions to the plan (which may include changing the frequency of monitoring) being considered following the initial two year period.

2.7.2.6 Residual Impacts

Groundwater impacts from operation activities can be managed by implementation of the embedded controls referenced in *Volume I, Annex 2.0* and the mitigation measures listed above. The magnitudes of residual impacts following implementation of mitigation measures are conservatively assessed to remain Negligible or Small. A summary of the impact assessment criteria including the mitigation measures are presented in *Table 2.20.*

Table 2.20: Impact Assessment Summary for Groundwater Impact during Operational Phase

Criterion	Rating	Comment	Criterion	Rating	Comment
Nature	Negative	Potential changes in groundwater table elevations, flow paths, and groundwater quality due to groundwater seepages, improper storage of materials, and other unplanned events.			
Type	Direct and Indirect	Activities directly affecting quantity and quality of groundwater resources, which may then indirectly affect quantity and quality of surface water resources considering potential groundwater-surface water interaction.			
Duration	Long term	Throughout operational life of the Project			
Extent	Local	With embedded controls in place, the extent of impact to the hydrogeological regime would be expected to be limited and localised.			
Scale	Limited	As with the extent of the impact, with embedded controls in place, the scale of impact would be expected to be limited. For quantification of the scale of impact numerical modelling would be required. Given the expected limited scale of impact (with effective embedded controls in place), recommendations are focussed on verification of impacts being limited through monitoring as outlined in the mitigation measures.			
Frequency	Continuous	Continuous during several decades of operation			
Receptor Sensitivity	Medium	Surface waterbodies such as streams Ma, Ha, I, and IC which may be hydraulically connected to the surficial aquifer, are tributaries to reservoirs used as drinking water sources in Singapore.			
Pre-Mitigation Impact Magnitude / Scale	Small	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Changes in groundwater recharge rates due to increase in impermeable ground surface at the facility buildings; and impact to groundwater quality due to seepage of potentially contaminated firewater from the aboveground facility buildings.	**Residual** Impact Magnitude / Scale	Small	No change as the implementation of embedded controls will enable the management of groundwater impacts to as low as reasonably practicable.
	Negligible	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact to groundwater and surface water quality due to accidental spills or leaks of hazardous chemicals at the facility buildings. **Tunnel alignment:** Changes in hydrodynamics due to groundwater seepage through the tunnel walls; impact to groundwater and surface water quality due to accidental spills or leaks of hazardous chemicals within the tunnel; and impact to groundwater quality due to seepage of potentially contaminated firewater from the tunnel.		Negligible	No change as the implementation of embedded controls will enable the management of groundwater impacts to as low as reasonably practicable.

Criterion	Rating	Comment	Criterion	Rating	Comment
Pre-Mitigation Impact Significance	Minor	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact significance to changes in groundwater recharge rates due to increase in impermeable ground surface at the facility buildings; and impact to groundwater quality due to seepage of potentially contaminated firewater from the aboveground facility buildings.	**Residual** Impact Significance	Minor	No change as the implementation of embedded controls will enable the management of groundwater impacts to as low as reasonably practicable.
	Negligible	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact significance to groundwater and surface water quality due to accidental spills or leaks of hazardous chemicals at the facility buildings. **Tunnel alignment:** Impact significance to changes in hydrodynamics due to groundwater seepage through the tunnel walls; impact to groundwater and surface water quality due to accidental spills or leaks of hazardous chemicals within the tunnel; and impact to groundwater quality due to seepage of potentially contaminated firewater from the tunnel.		Negligible	No change as the implementation of embedded controls will enable the management of groundwater impacts to as low as reasonably practicable.

3 NOISE & VIBRATION

3.1 INTRODUCTION

This chapter presents an assessment of the impacts of activities associated with the construction phase of Alignment Option 1 due to noise and vibration generated from the worksites.

This chapter is structured as follows:

- *Section 3.2* defines the scope of the assessment*;*
- *Section 3.3* presents a summary of the baseline noise and vibration environment within the Project Study Area*;*
- *Section 3.4* provides an overview of the methodology used to assess the impacts to noise and vibration on sensitive receptors; and
- *Section 3.5* provides an assessment of the potential impacts during the construction phase of the Project.

3.2 SCOPE OF THE ASSESSMENT

Where the ambient noise and vibration levels generated from the construction works are significantly higher than the baseline and/or relevant limits, this may have impacts on both human and ecological receptors. This chapter focuses on the impacts on human receptors. The resulting impacts on noise and vibration on ecological receptors and ecosystems are addressed in *Chapter 5*.

This study took into account noise and vibration sensitive receptors located within a radius of 200 m of the aboveground worksite and alignment. For ambient noise, noise from a typical construction plant only attenuates to acceptable night time levels of 55 dB(A) at distances of approximately 630 m. However, this distance assumes free field propagation of noise, and does not take into account attenuation factors such as screening effect from surrounding buildings and terrain, existing baseline noise levels, absorption due to ground cover etc. For the densely built up area within the Project Study corridor, a scoping distance of 200 m on either side of the alignment and from the worksite was considered reasonable for this study. Based on experience, Hiller[(4)] indicates in his 2011 study on the vibration impacts of tunnelling works that a scoping distance of 200 m from the alignment is considered appropriate to account for vibration impacts within an urban environment.

> It is noted that the vibration assessment was focused on nuisance impacts on human receptors. The assessment of vibration impact on structures due to the construction scheme has been assessed as part of a separate engineering feasibility study conducted by LTA and is not within the scope of this study.

The committed development in closest proximity to the Project consists of the PUB's proposed water pipeline installation from Bukit Kalang to Upper Thomson Road. Consultation between the PUB and the LTA has been undertaken during the course of this study to ensure that works will not occur at the same time as the Project. Cumulative noise and vibration impacts have therefore not been undertaken in this EIA. PUB and LTA are working together to reduce the combined footprint of PUB and LTA's possible worksites to minimize overall environmental impact. In the event that new committed developments are identified, the LTA has committed to undertake a cumulative impact assessment at the AES of the Project.

Ground improvement works may be undertaken where the TBM may encounter mixed face conditions, and in particular where built infrastructure are located overlying the tunnel alignment (see *Volume I, Section 2.5.2.3*). The impacts associated with ground improvement works will only be assessed in detail at the advanced engineering stage of the Project.

3.2.1 Construction Phase

The scoping exercise identified construction activities that have the potential to have significant noise and/or vibration emissions. These were reviewed against the Project description presented in *Volume I, Chapter 2*. The sources of noise and vibration within the Study Area are summarised in *Table 3.1*.

Table 3.1: Sources of Noise & Vibration Impacts

Source(s) of Impact	Impact(s)	Associated Worksite
Construction equipment such as generators, pumps etc	Nuisance (Note 1) impacts from noise	All worksites
Construction activities at aboveground worksites such as installation of secant bored piles, etc.	• Nuisance impacts from noise; and • Nuisance impacts due to vibration.	All worksites
Construction of tunnels	Nuisance impacts from vibration	Tunnel alignment
Note 1: 'Nuisance' being defined in this study as known disturbance effects based on available guidance such as the code of practice for noise and vibration control on construction and open sites (BS 5228).		

The following subsections describe the construction activities that have been scoped out from the EIA due to low ambient noise or vibration levels emitted.

3.2.1.1 Rock Excavation

There are many methods available for rock excavation. For the purpose of this study, a reasonable worst case assumption has been made to assess the potential impacts due to vibration generated from the use of blasting as a means for excavating the launch shaft below the rockhead level. Rock excavation will be required for the construction of the launch shaft at the A1-W1 (LS/VS) worksite, as the launch shaft is within Rock. As the launch shaft at A1-W2 (LS/VS) is within Soil, no rock excavation is assumed to be required at this worksite. For the worst case scenario where blasting method is assumed to be used, the detonation of charges is assumed to commence at depths greater than 20 m, and will likely be undertaken on a daily basis until the assumed launch shaft depth of 35 m bgl is reached. It is noted that impulsive noise generated from rock excavation activities would be instantaneous; the exposure for receptors will therefore be temporary in duration (i.e. a few seconds). In addition, embedded controls, such as the establishment of a blast protective zone where access to the public will be restricted, and placement of protection mats will be implemented. Air overpressure and noise levels generated during rock excavation are therefore expected to be below the WHO guideline limits of $L_{peak,lin}$ 140 dB for adults and 120 dB for children i.e. levels are not expected to result in health impacts such as hearing impairment, to human receptors. It is noted that even with controls in place, noise levels generated during rock excavation may still be audible at nearby receptors. It is conservatively estimated that instantaneous noise levels would be clearly noticeable at distances of up to 300 m from the shaft location. However, in view of the temporary duration of exposure of nearby receptors i.e. a few seconds, nuisance impacts due to ambient noise from rock excavation using blasting method is not deemed to be significant and has been scoped out from further assessment.

3.2.1.2 *Earthworks*

Vibration generated by construction activities such as soil excavation using diggers and excavators, are generally not expected to be significant in magnitude or duration. Construction activities that would generate more significant vibration levels comprise rock excavation using mechanised (e.g. TBM) or other methods and driven piling. These vibratory activities were the subject of a study undertaken by Hiller for the Transport Research Laboratory (2011)[(4)]. It is noted that a key output of the study were empirical vibration predicting equations, and the study generally found these equations to be valid *'at distances of up to about 100 m from the vibration source'*. Extrapolation beyond this distance would generally provide a conservative estimate of vibration levels. It is therefore reasonable to assume that even at distances of tens of metres from the worksite, vibration levels experienced by receptors from activities generating vibration at much lower magnitudes e.g. soil excavation, will not be significant. Vibration levels from soil excavation using diggers and excavators are therefore scoped out from further assessment in this study.

3.2.1.3 *Installation of Monitoring Instrumentation*

Instrumentation for the monitoring of construction activities comprise piezometers and settlement markers, which will be installed at the 16 locations within the CCNR where SI boreholes were drilled as part of Phase I of the Project (see *Volume I, Section 2.5.1.4*).

The installation of settlement markers will involve the hammering of a nail-shaped rod less than 20 cm in length into the ground. The vibration generated from this activity is not expected to be significant in terms of magnitude, duration or extent, and have therefore been scoped out from further assessment in this study.

An A-frame rig will be used to drill the column to tunnel depth, for the installation of the piezometer casing and instrumentation. These rigs were previously used for the drilling of SI boreholes as part of Phase I of the Project. Vibration measurements were collected from the operation of an A-frame rig, to inform the Phase I study, and are summarised in *Table 3.2*. The detailed measurement report is appended in *Annex 2.0*.

Table 3.2: Vibration Measurements at Operational Rotary Borehole Rig

ID	Distance from Rotary Borehole Rig	Ground Type	PPV (mm/s)		
			X-axis	Y-axis	Z-axis
A	2 m	Grass	2.000	2.030	0.825
B	3 m	Grass	1.170	1.420	0.825
C	5 m	Grass	1.150	1.140	1.070
D	15 m	Bitumen	0.597	0.824	0.660
E	11 m	Grass (Note 1)	0.621	0.911	0.529
F	20 m	Grass (Note 1)	0.515	0.896	0.820
G (Note 2)	5 m	Grass	0.555	0.740	0.698

Notes:

(1) Grass verge was not in continuity with the grassy area on which the rotary borehole rig was operating.

(2) Measurements were undertaken when the rig was not operating, to establish baseline vibration levels due to extraneous sources.

As observed at measurement location G, baseline vibration levels due to extraneous sources were not insignificant, in comparison with measurements undertaken at a similar distance during rig operation, ie Measurement Location C. In consideration of the contribution of baseline vibration levels, PPV due to the rotary borehole rig would likely be less than 1.0 mm/s, from distances at and greater than 3 m from the rotary borehole rig. Given the footprint of the rig and temporary worksite, it is unlikely that sensitive receptors such as recreational users of the CCNR trails, would come within a distance of less than 2 m from the rig. Disturbance impacts to human receptors due to vibration from the installation of piezometers is therefore assessed to be not significant, and has been scoped out from further assessment in this study. The disturbance impacts due to noise generated from this activity has been assessed in detail in SI EIA (Footnote 1), and summarised in *Section 3.6.1* of this report.

3.2.1.4 Tunneling (Advance Probing)

Advance probing is the drilling of horizontal boreholes from the TBM cutter head to inspect the material that will be encountered during the next phase of TBM excavation (see *Volume I, Section 2.5.2.2*). This will be undertaken during periodic and temporary pauses in the TBM operation. The size of the drill head for the advance probing depends on the length of the borehole required and can range from

50 mm to 200 mm in diameter. Preliminary modelling using FINDWAVE™ was undertaken assuming drilling within fresh Bukit Timah granite at a depth of 30 m bgl, as a worst case scenario. The results are presented in *Table 3.3*.

(Footnote 1) ERM (2016) **Environmental Impact Assessment on Central Catchment Nature Reserve for the Proposed Cross Island Line: Site Investigation Environmental Impact Assessment Report – Volume III, Alignment Option 1**. Chapter 4. Retrieved from https://www.lta.gov.sg/content/dam/ltaweb/corp/PublicTransport/files/Final%20SI%20EIA%20Volume%20III.pdf

Table 3.3: Summary of Advance Probe Drilling Vibration Predictions

Horizontal Distance from TBM at Ground Level (m)	Highest Predicted PPV (mm s^{-1})
0	0.007 – 0.014
1	0.007 – 0.014
5	0.007 – 0.013
10	0.006 – 0.012
20	0.004 – 0.008
30	0.002 – 0.005
40	0.001 – 0.003
50	0.001 – 0.002

The model predicted that highest PPV anticipated from this activity would reach levels of 0.014 mm/s directly above the drill head. It is noted that this predicted level is likely to be conservative as tunnel depths for Alignment Option 1 are typically 50 m bgl or deeper. Vibration levels from this activity are therefore scoped out from further assessment in this study as they are expected to be well below existing minimum baseline PPV levels of 0.254 mm/s (see *Section 3.3.2* below).

3.2.2 Operation Phase

The following subsections describe the operation activities that have been scoped out from the EIA due to low ambient noise or vibration levels emitted.

3.2.2.1 Facility Building Operation

During Project operation, noise sources would comprise electrical facilities housed within the aboveground facility buildings. Based on observations of existing facility buildings, noise generated from these facility buildings can be effectively contained through building design. It is therefore assumed that noise mitigation measures will be considered at the detailed design stage.

3.2.2.2 Railway Tunnel Operation

Modern rail technology is available to ensure the design of modern railways that produce far less noise and vibration than older systems. Projects, such as the Singapore mass rapid transit lines and the Jubilee Line Extension and HS1 tunnels under London, have shown that modern railways can operate beneath large residential areas with minimal noise and vibration. It is therefore assumed that vibration mitigation options will be considered during the detailed design stage to appropriately mitigate vibration and groundborne noise from the operational railway.

In addition, ERM has carried out a screening study on vibration levels during operation, assuming design parameters such as a maximum train speed of 90 km/h. It is noted that the tunnel depth along Alignment Option 1 will range between 23 to 90 m bgl, with the deepest section underlying the CCNR. Calculations, based on empirical measurements undertaken by the US Department of

Transportation, show that the predicted vibration level at the surface during train operation could reach approximately 0.037 mm/s at the shallowest tunnel depth of 23 m, and less than 0.02 mm/s at the deepest point. Measured maximum vibration during the operation of existing underground railway tunnels such as the Downtown Line, the Circle Line and the North-East Line, indicate that vibration due to train operations will be at or below 0.14 mm/s ie *Small* magnitude[(5)]. This falls significantly below baseline vibration levels of 0.254 – 0.508 mm/s within the CCNR (*see Section 3.3.2*). Vibration levels during train operation will therefore be much lower than baseline vibration levels. Noise and vibration impacts during Project operation are therefore not expected to be significant and are scoped out from further assessment.

3.3 SUMMARY OF RELEVANT BASELINE CONDITIONS

Key elements of the environmental baseline pertinent to the noise and vibration levels within the Study Area are summarised in the following sections. Detailed noise and vibration baseline findings are presented in *Volume II* of the SI EIA Report for the Project [(Footnote 2)]. The locations of the monitoring locations and sensitive receptors identified for ambient noise and vibration are shown in *Figure 3.1*, *Figure 3.2* and *Figure 3.3*.

3.3.1 Ambient Noise

Long-term, short-term and supplementary short-term noise measurements were undertaken over one week from 24 November to 26 December 2014 (ie Round 1, representative of the tail end of the inter-monsoon/ start of the Northeast monsoon), and over one week from 16 January to 9 February 2015 (ie Round 2, representative of the Northeast monsoon). As there has not been significant changes in land use within the Study Area, the 2014 noise measurements are deemed relevant for this study. Monitoring locations were selected to obtain representative baseline noise levels at potential noise sensitive receptors identified within the Study Area (see *Table 5.2*, SI EIA *Volume II Chapter 5* [(Footnote 2)]). These monitoring locations are shown in *Figure 3.1*. General trends observed from measurements undertaken at these locations include:

[(Footnote 2)] **Environmental Impact Assessment on Central Catchment Nature Reserve for the Proposed Cross Island Line: Site Investigation Environmental Impact Assessment Report – Volume II**. Retrieved from https://www.lta.gov.sg/content/dam/ltaweb/corp/PublicTransport/files/Final%20SI%20EIA%20Volume%20II.pdf

Figure 3.1 Location of Project Worksites and Tunnel Alignment (Noise & Vibration Study)

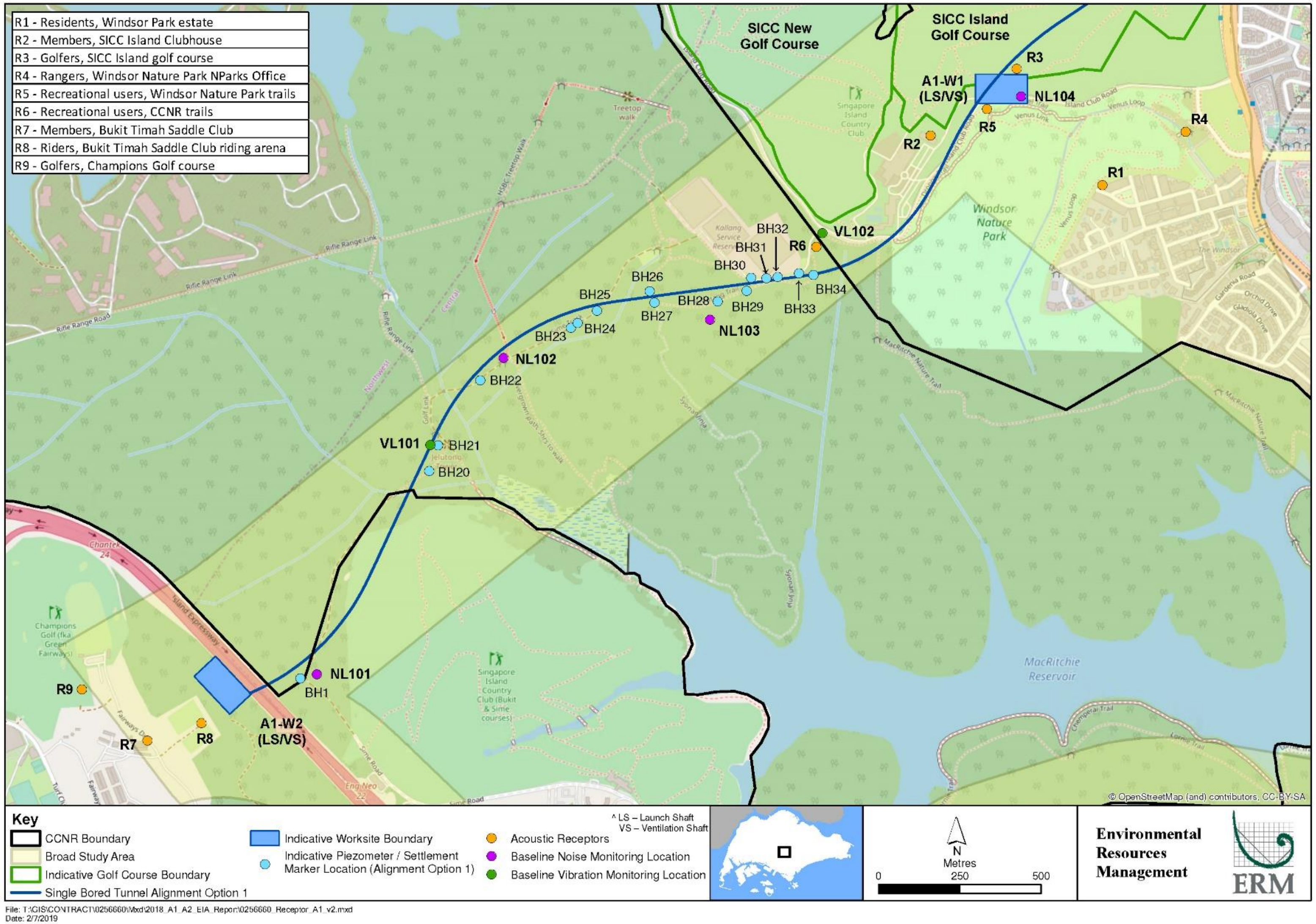


Figure 3.2 A1-W1 (LS/VS) Worksite (Noise & Vibration Study)

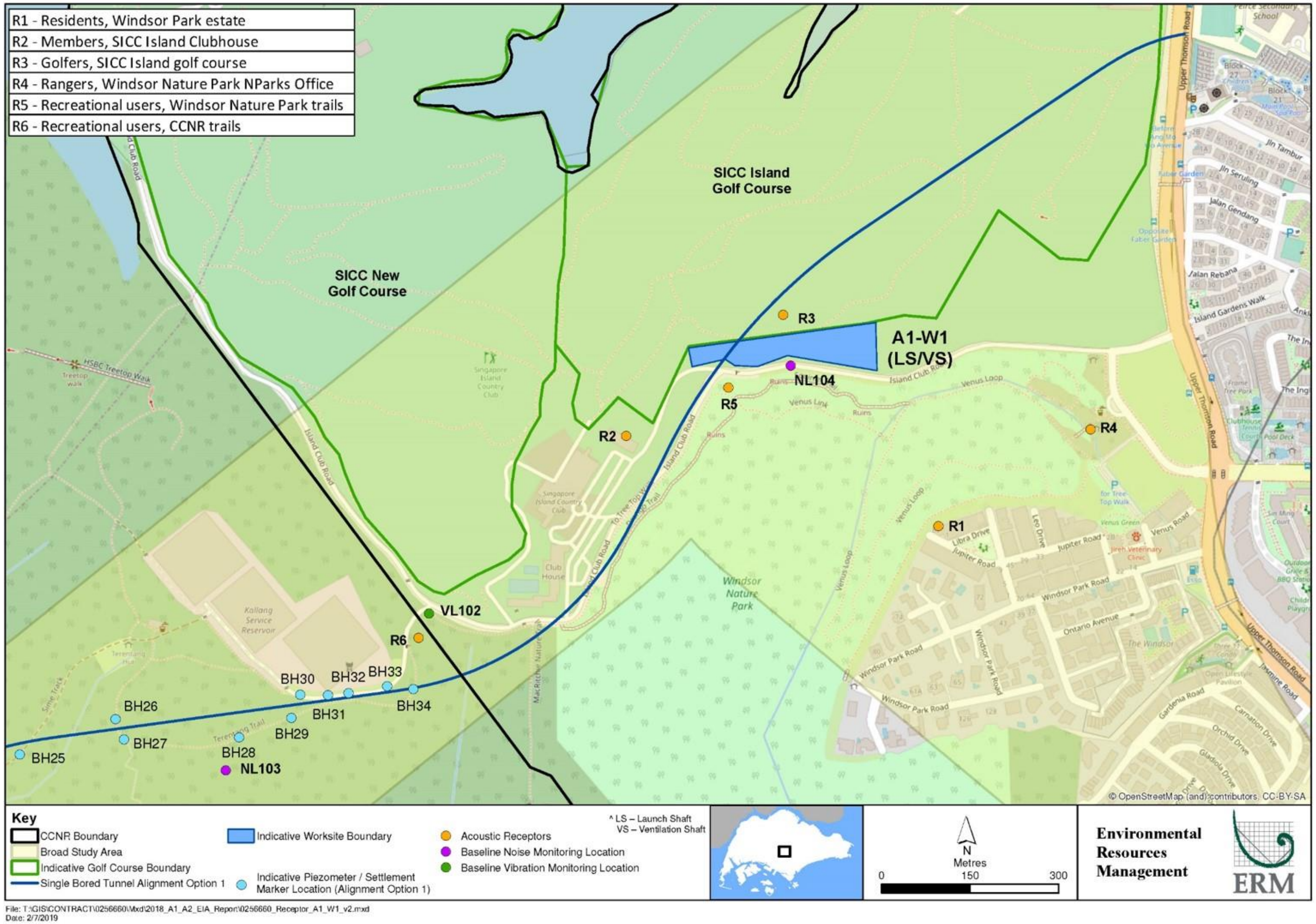
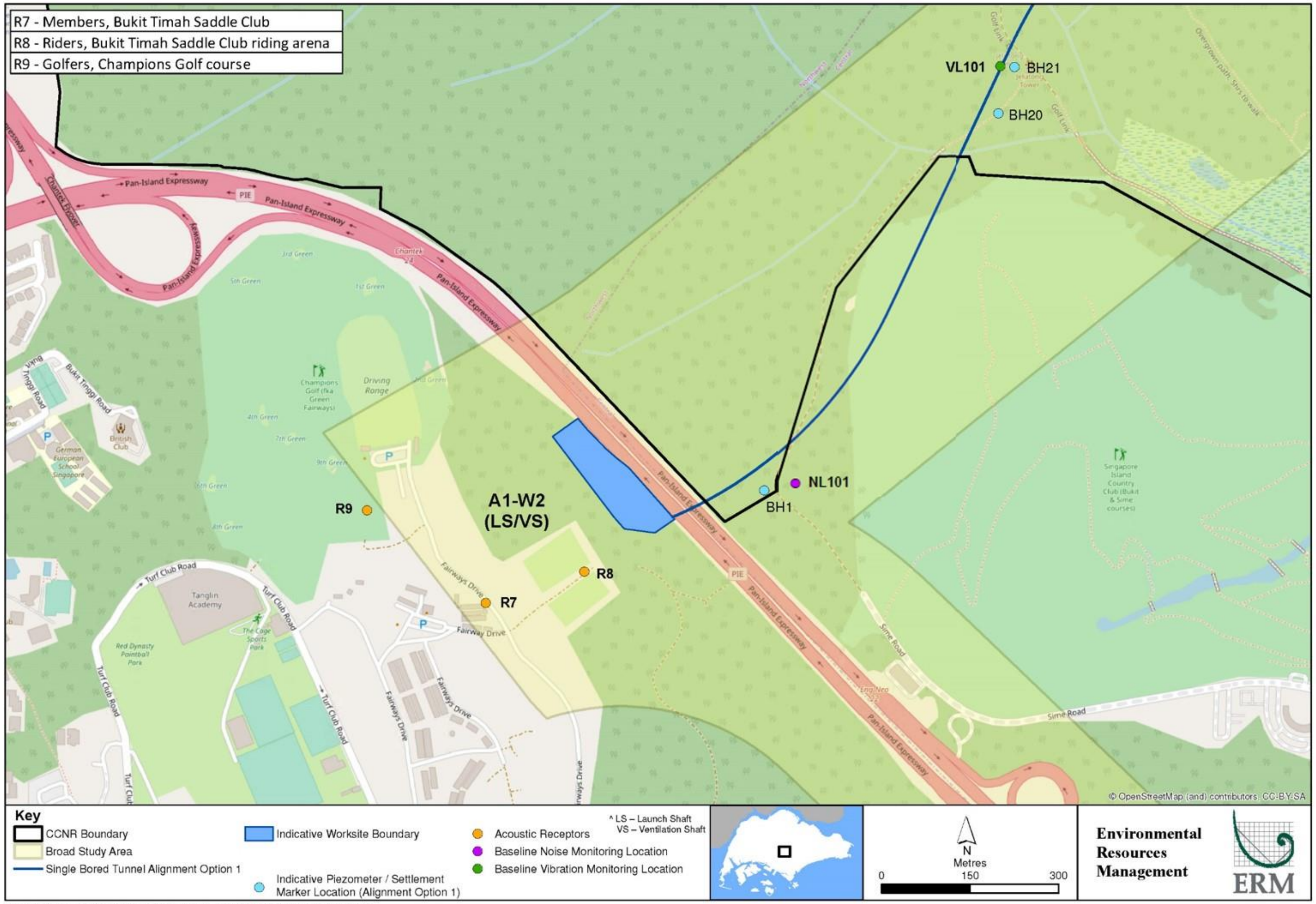


Figure 3.3 A1-W2 (LS/VS) Worksite (Noise & Vibration Study)



File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Receptor_A1_W2_v2.mxd
Date: 2/7/2019

- **NL101, along western perimeter of CCNR and SICC Bukit golf course:** Vehicular traffic using the PIE (approximately 100 m from the measurement location), as well as wildlife vocalisations and wind-blown vegetation, comprise the predominant background noise levels. Hourly measurements indicated that peak traffic conditions occur between 10 am and 5 pm (extending up to 8 pm on some days) when noise levels range between 60 – 63 dB(A), whereas low traffic conditions typically occur between 11 pm to 6 am on weekdays when noise levels drop to 55 dB(A). Similarly, low hourly measurements were observed during the same period on weekends. Peak noise levels were observed from 4 to 5 pm, and between 7 and 8 pm during weekends in December in Round 1 of monitoring, and ranged between 70 – 80 dB(A). These peaks were not observable in measurements taken during January in Round 2 of monitoring. These peak levels in Round 1 could be attributed to the increased movement of public and other trail users and over the weekends during the December holidays.

- **NL102, along Sime Track within the CCNR:** Members of the public using the CCNR for recreational purposes and other personnel using the Sime track, contribute to infrequent peaks in measured baseline noise levels at this location. Hourly measurements averaging 45 – 50 dB(A) indicated that low activity along this track occurs between 4 and 8 am. Peak activity occurs between 9 and 11 am; 12 and 2 pm; and 4 and 5 pm during the weekends, when noise levels range between 60 – 70 dB(A). During the weekday, peak periods along the Sime track were slightly different during Round 1 and Round 2 periods of monitoring. In general, peaks occurred from 9 am to 12 pm, and 2 to 6 pm during Round 1; and between 9 and 10 am, and from 2 to 4 pm during Round 2 of monitoring. Another peak in noise levels was observed at 7 pm on both weekdays and weekends throughout the year, indicating possible contribution from vocalisations of nocturnal species.

- **NL103, 50 m off Terentang trail (within the CCNR forest):** Natural noises, eg wildlife vocalisations and rustling of leaves, were the main contributors to the baseline noise levels measured at this off-trail location. A comparison of significant peaks occurring between 3 and 4 pm on 26 November 2014, at both NL102 and NL103, indicates that anthropogenic noise (observed west of the CCNR), may have contributed to the increased noise levels at NL103. A review of hourly measurements indicated that noise levels typically peak between 60 – 70 dB(A) in the late morning or early afternoon, ie between 10 am and 1 pm; mid-afternoon from 3 to 6 pm; and between 7 and 8 pm.

- **NL104, along Island Club Road:** The predominant source of noise observed at this location was vehicular traffic along Island Club Road. Hourly measurements across the weekdays and weekends for both Round 1 and Round 2 of monitoring remained fairly constant between 60 to 65 dB(A) from \6 am to 7 pm, after which noise levels dropped and fluctuated between 45 – 50 dB(A). This corresponds to the opening hours of the SICC Island course, ie 6.30 am to 7 pm, and indicates that most vehicular traffic along Island Country Club Road are accessing the club facilities. Other intermittent sources of noise include the operation of lawn mowers within the golf course, and noise from members of the public using the Island Club Road.

In general, daytime noise levels measured in Round 1 of monitoring were observed to be 7 – 10 dB(A) higher than those measured during the corresponding periods in Round 2. On the other hand, noise levels measured in the evening and night times were generally similar in both seasons. In most instances, this trend is attributable to the occurrence of thunderstorms in the day during Round 1 of the survey, as observed through a review of hourly rainfall data from NEA's recording station located within the SICC (Island location). Other peaks in noise levels may be attributable to localised events within the CCNR during Round 1 of the survey, and potential movement and vocalisation of animals in close proximity to the noise meters.

The measurements and nearest representative worksite from each baseline noise survey location are summarised in *Table 3.4*.

Table 3.4: Free-field Baseline Noise Levels within the CCNR

Monitoring Point ID	Location	Nearest Representative Worksite		Round 1, Inter-Monsoon Period (Note 1) Baseline Measurements (dB(A)) (Note 2)					Round 2, Monsoon Period (Note 1) Baseline Measurements (dB(A)) (Note 2)				
				Day $L_{Aeq, 12hr}$	Night $L_{Aeq, 12hr}$	Day $L_{Aeq, 5min}$	Eve $L_{Aeq, 5min}$	Night $L_{Aeq, 5min}$	Day $L_{Aeq, 12hr}$	Night $L_{Aeq, 12hr}$	Day $L_{Aeq, 5min}$	Eve $L_{Aeq, 5min}$	Night $L_{Aeq, 5min}$
NL101	End of Sime Road, 100 m east of the PIE	A1-W2 (LS/VS)	**Min**	61	58	57	59	58	59	57	54	55	56
			Ave	63	59	63	61	58	61	58	61	61	57
			Max	65	60	78	69	59	64	60	77	75	58
NL102	Petaling Hut, < 5m from the Sime Track within CCNR	-	**Min**	55	50	40	47	48	47	49	38	39	48
			Ave	61	54	61	57	52	51	50	51	53	48
			Max	72	58	88	75	57	55	51	74	68	49
NL103	Off-trail, approximately 50 m from the Terentang Trail within CCNR	-	**Min**	54	46	34	44	44	46	45	36	38	44
			Ave	59	50	59	53	48	49	49	49	52	46
			Max	64	57	79	70	53	53	51	68	68	48
NL104	Along Island Club Road, approximately 10 m from Windsor Nature Park	A1-W1 (LS/VS)	**Min**	61	56	53	52	54	62	56	54	48	54
			Ave	62	57	62	61	55	63	58	63	61	57
			Max	66	58	74	68	56	65	62	77	70	60

Note 1: Measurements were undertaken over two weeks at each location, once (Round 1) in November/December 2014 and Round 2 in January/February 2015.
Note 2: The minimum and maximum noise levels as measured over 7 continuous days, over the periods where construction works will be undertaken.

3.3.2 Vibration

Vibration measurements were undertaken over a period of one day at two locations listed below in March 2015. Monitoring locations were selected to obtain representative baseline values at potential vibration sensitive receptors identified within the Study Area (see *Table 5.1*, SI EIA *Volume II Chapter 5* (Footnote 2)). General trends observed from measurements undertaken at these locations include:

- **VL101, off trail location near Jelutong Tower within the CCNR:** Horizontal component of vibration (as PPV) ranged between 0.254 and 0.508 mm/s, while vertical vibration was recorded at 0.508 mm/s. PPV levels could be attributed to users, eg joggers, trekkers, soldiers utilizing the nearby trail around Jelutong Tower, as well as potential vibration from fauna or humans, or due to falling branches.

- **VL102, grass verge along PUB service road:** Horizontal PPV ranged between 0.762 and 0.889 mm/s, while vertical PPV was recorded at 0.254 mm/s. Vibration sources observed included joggers and trekkers using the Venus Link and PUB service road, as well as vehicular traffic along the adjacent PUB service road and the nearby Island Club Road.

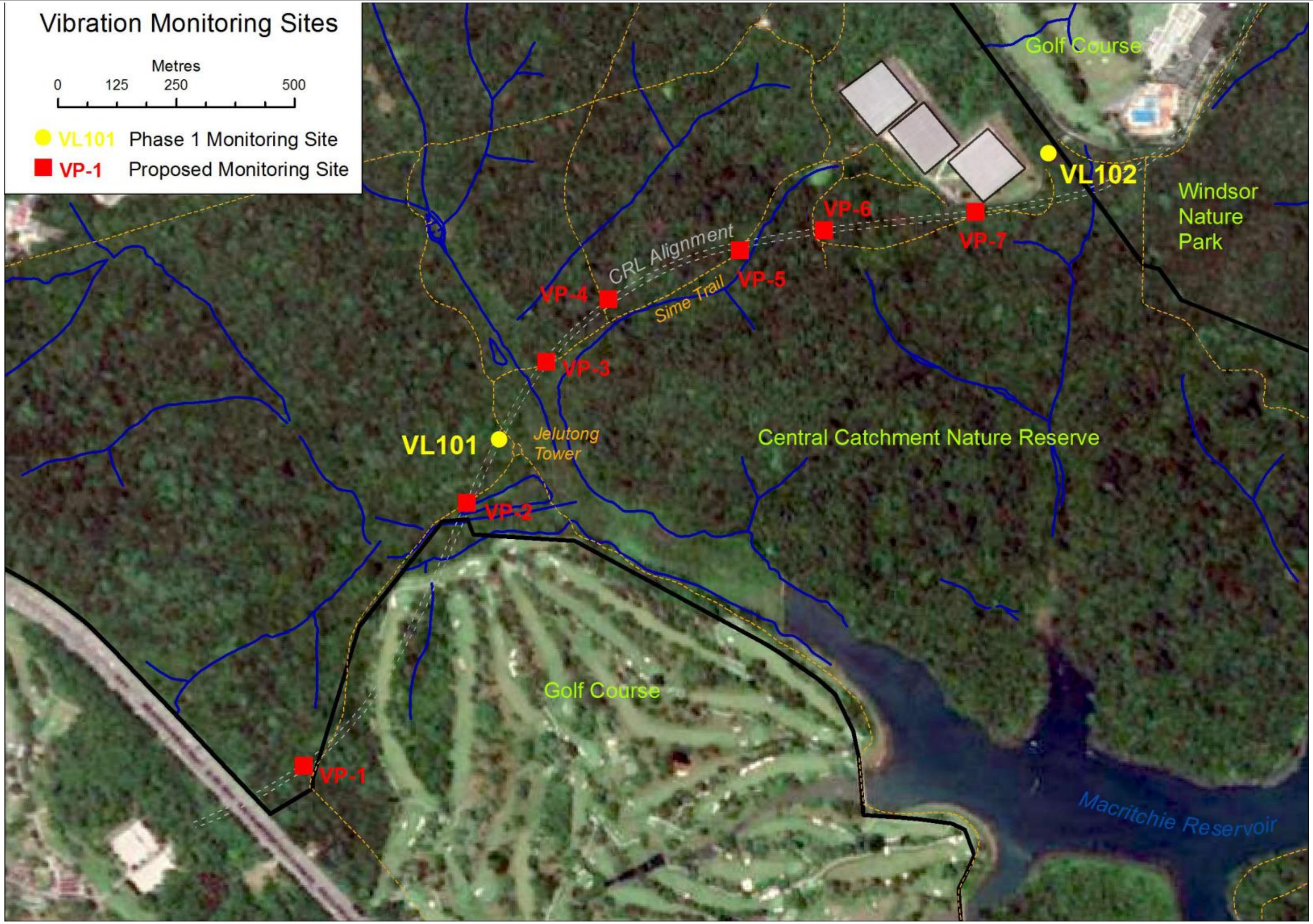
Further baseline vibration measurements were undertaken using a meter with a greater measurement resolution of 0.127 mm/s, for the frequency range of 2 – 250 Hz. These measurements were undertaken for a period of one week between June and July 2019 at the abovementioned locations, as well as seven additional locations within the CCNR. These nine monitoring locations are shown in *Figure 3.4*. The PPV measurements are summarised in *Table 3.5*. Possible vibration sources observed during the measurement comprise distant and constant vehicular traffic along the PIE and Thomson Road, users of the trails, and rainfall events.

Table 3.5: Maximum Permissible Noise Levels for Construction Sites

Monitoring Location	VP-1	VP-2	VL101	VP-3	VP-4	VP-5	VP-6	VP-7	VL102
Maximum PPV (mm/s)	0.38	0.29	0.53	0.48	0.70	0.93	0.80	0.48	0.63

Source: Tritech, 2019

Figure 3.4 Vibration Monitoring Locations



Source: O'Dempsey T, 2019

3.4 ADMINISTRATIVE FRAMEWORK

Noise limits in Singapore are specified under the *Environmental Protection and Management (Control of Noise At Construction Sites) Regulations 2008*, for a range of land uses. These limits are summarised in *Table 3.6*, and are noted to comprise outdoor limits i.e. as measured 1 m from façade of affected building. These outdoor limits are set to manage indoor noise levels for building occupants. Where baseline measurements are available, the regulations stipulate correction factors (see *Table 3.7*) for the determination of applicable limits to the Project.

Table 3.6: Maximum Permissible Noise Levels for Construction Sites

<table>
<tr><th rowspan="3">Types of Affected Buildings</th><th colspan="8">Maximum Permissible Noise Levels for Construction Sites in Decibels (A) (Note 1, Note 2)</th></tr>
<tr><th colspan="2">Over 12 hours</th><th colspan="3">Over 1 hour</th><th colspan="3">Over 5 minutes</th></tr>
<tr><th>7am-7pm (Day)</th><th>7pm-7am (Night)</th><th>7am-7pm (Day)</th><th>7pm-10pm (Eve)</th><th>10pm-7am (Night)</th><th>7am-7pm (Day)</th><th>7pm-10pm (Eve)</th><th>10pm-7am (Night)</th></tr>
<tr><td>Hospitals, schools, institutions of higher learning, homes for the aged sick, etc.</td><td>60</td><td>50</td><td>-</td><td>-</td><td>-</td><td>75</td><td>55</td><td>55</td></tr>
<tr><td rowspan="4">Residential buildings located less than 150 m from the construction site where the noise is being emitted</td><td rowspan="4">75</td><td rowspan="4">-</td><td rowspan="4">-</td><td rowspan="4">65</td><td rowspan="4">55</td><td colspan="3">Mondays - Saturdays</td></tr>
<tr><td>90</td><td>70</td><td>55</td></tr>
<tr><td colspan="3">Sundays and Public Holidays</td></tr>
<tr><td>75</td><td>55</td><td>55</td></tr>
<tr><td>Buildings apart from those listed above</td><td>75</td><td>65</td><td>-</td><td>-</td><td>-</td><td>90</td><td>70</td><td>70</td></tr>
</table>

Note 1: For construction work commenced on or after 1 October 2007

Note 2: The Fourth Schedule states that all works are prohibited from 10 pm every Saturday to 7 am the following Monday, and from 10 pm on the eve of a public holiday to 7 am the following day.

Source: Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008

Table 3.7: Noise Correction Factors

Difference in decibels (A)(Note 1)	Correction Factor in decibels (A)(Note 2)
Below 2	3
2 to less than 4	2
4 to less than 10	1
10 and above	0

Note 1: Denotes the difference between the background noise level and the applicable maximum permissible noise levels listed in *Table A3.3*.

Note 2: The addition of the correction factor to the higher of the two noise levels, ie the background noise level or the relevant maximum permissible noise level will constitute the new maximum permissible noise level applicable to the Project.

Source: Third Schedule of the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008

3.5 ASSESSMENT METHODOLOGY

3.5.1 Assessment Criteria

The evaluation of impact significance for noise and vibration impacts involves an assessment of the magnitude of the noise and vibration levels generated, against the relevant limits. These limits have been established through empirical studies and implicitly take into account the sensitivity of receptors to noise and vibration.

3.5.1.1 Noise

The noise limits for indoor human receptors as stipulated in the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations*, and as presented in *Table 3.6*, have been adopted as criteria for this assessment. Where baseline measurements are available and representative of the noise sensitive receptor, correction factors have been applied to determine the applicable limit for the Project.

For human receptors located in outdoor recreational and ecological areas, the *Environmental Protection and Management Act* defines such areas as falling under the most sensitive premises. The limits for hospitals, schools, institutions of higher learning, homes for the aged sick, etc have therefore been adopted as criteria for human receptors in outdoor recreational and ecological areas. In addition, the short-term duration of exposure of recreational users means that the only relevant criteria to be used are those associated with $L_{eq,5min}$ criteria.

The applicable criteria for identified receptors within the Study Area are summarised in *Table 3.8*.

Table 3.8: Assessment Criteria for Identified Receptors

ID	Receptors	$L_{eq,5min}$ Criteria, dB(A) (Note 1)			$L_{eq,1hr}$ Criteria, dB(A)			$L_{eq,12hr}$ Criteria, dB(A)	
		Day	Eve	Night	Day	Eve	Night	Day	Night
R1	Residents, Windsor Park estate	**90** (Note 2)	**70**	**55**	**-**	**65**	**55**	**75**	-
R2	Members, SICC Island Clubhouse	**90**	**70**	- (Note 3)	-	-	-	**75**	- (Note 3)
R3	Golfers, SICC Island course	**75**	- (Note 4)	-	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)
R4	Rangers, Windsor Nature Park NParks Office	**90**	- (Note 4)	-	-	-	-	**75**	- (Note 5)
R5	Trail users, Windsor Nature Park	**75**	- (Note 4)	-	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)
R6	Trail users, CCNR	**75**	- (Note 4)	-	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)
R7	Members, Bukit Timah Saddle Club	**90**	- (Note 4)	-	-	-	-	**75**	- (Note 5)
R8	Riders, Bukit Timah Saddle Club riding arena	**75**	- (Note 4)	-	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)
R9	Golfers, Champions Golf course	**75**	- (Note 4)	-	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)	- (Note 5)

ID	Receptors	$L_{eq,5min}$ Criteria, dB(A) (Note 1)			$L_{eq,1hr}$ Criteria, dB(A)			$L_{eq,12hr}$ Criteria, dB(A)	
		Day	Eve	Night	Day	Eve	Night	Day	Night

Note 1: Day defined as 7 am – 7 pm; Evening defined as 7 pm – 10 pm; and Night defined as 10 pm – 7 am. In the case of $L_{eq,12hr}$ criteria, Night is defined as 7 pm – 7 am.

Note 2: Bold criteria were derived from maximum permissible limits stipulated in the *Environmental Protection and Management (Control of Noise At Construction Sites) Regulations 2008.*

Note 3: Night criteria are not applicable as operational hours at receptor end at or before 10 pm.

Note 4: Evening and night criteria are not applicable as operational hours at receptor end at or before 7 pm.

Note 5: $L_{eq,1hr}$ and $L_{eq,12hr}$ criteria are not applicable as receptor exposure duration will be much shorter than 12 hours, in view of type of activity being undertaken by receptor and proximity to worksite.

The criteria for assessment of the magnitude of noise impact due to Project construction works are presented in *Table 3.9*.

Table 3.9: Impact Magnitude Criteria for Ambient Noise Impacts

Impact Magnitude	Definitions (Note 1)
Negligible	• Predicted noise levels are at or below the relevant criteria.
Small	• Predicted noise levels are less than 5 dB(A) above the relevant criteria.
Medium	• Predicted noise levels are between 5 and 10 dB(A) above the relevant criteria.
Large	• Predicted noise levels are more than 10 dB(A) above the relevant criteria.

Note 1: See relevant criteria summarised in *Table 3.6*.

According to the *Fundamentals of Acoustics* published by the WHO[(6)], an increase in sound pressure levels of 3 dB represents a doubling of sound power and is just perceptible to the human ear, while a difference of 5 dB is clearly noticeable. Based on this, it is assumed that noise levels up to 5 dB but not more than 10 dB above the criteria will be clearly noticeable to receptors and are classified as being of ***Medium*** impact magnitude, while any levels more than 10 dB(A) above the standards can cause impacts of ***Large*** magnitude to receptors.

As the noise criteria specified in *Table 3.9* take into account the sensitivity of the receptor, separate criteria for receptor sensitivity are not applicable and are therefore not presented. The other significance factor that is taken into account while determining the impact magnitude in this assessment is the duration of impact. For the purposes of this study, the durations of impact exposure are defined in *Table 3.10.*

Table 3.10: Duration of Impact Exposure

Duration	Operating Period
Temporary exposure	< 1 day
Short term exposure	< 1 month
Medium term exposure	1 to 6 months
Long term exposure	> 6 months

Based on the above, the impact significance criteria for the construction works are defined as shown in *Table 3.11*.

Table 3.11: Impact Significance Criteria for Noise Impacts from Project Construction [Note 1]

Impact Magnitude / Increase above criteria, dB(A)	Duration			
	Temporary, < 1 day	Short term, < 1 month	Medium term, 1 to 6 months	Long term, > 6 months
Negligible, ≤ 0 dB(A)	Negligible	Negligible	Negligible	Negligible
Small, < 5 dB(A)	Negligible	Minor	Minor	Moderate
Medium, 5 - 10 dB(A)	Minor	Minor	Moderate	Moderate
Large, > 10 dB(A)	Minor	Moderate	Major	Major

Note 1: The above criteria was developed on the basis that noise levels generated by site activities are deemed to be potentially significant i.e. Moderate and above, if the total noise exceeds the pre-construction ambient noise by 5 dB or more and a duration of one month or more(7).

3.5.1.2 Vibration

There is no legislation or guideline in Singapore that stipulates vibration limits for construction works for the avoidance of disturbance to human or ecological receptors. International standards such as BS 5228-2:2009+A1:2014(7) and those referenced therein, have therefore been reviewed to identify the vibration limits applicable for this study. The criteria for assessment of vibration impacts, are presented in *Table 3.12*.

Table 3.12: Impact Magnitude Criteria for Vibration Impacts on Humans

Impact Magnitude	Vibration Magnitude [PPV(Note 1, Note 2, Note 3)]	Effect
Negligible	Less than 0.14 mm/s	Vibration is barely perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
Small	Greater than or equal to 0.14 mm/s and less than 1 mm/s	Vibration might be just perceptible in residential environments but complaints may not occur.
Medium	Greater than or equal to 1 mm/s and less than 10 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
Large	Greater than or equal to 10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level in most building environments (Note 4).

Impact Magnitude	Vibration Magnitude [PPV(Note 1, Note 2, Note 3)]	Effect

Note 1: The guidance values are applicable in the context of human response to vibration within buildings. There is a lack of guidance on levels triggering a response from human receptors located outdoors. These guidance values will therefore be adopted for such receptors in line with this study's precautionary approach.

Note 2: The magnitudes of the values presented apply to a measurement position that is representative of the point of entry into the receptor.

Note 3: A transfer function (which relates an external level to an internal level) needs to be applied if only external measurements are available.

Note 4: Single or infrequent occurrences of these levels do not necessarily correspond to the stated effect in every case. The values are provided to give an initial indication of potential effects, and where these values are routinely measured or expected then an assessment in accordance with BS 6472-1 or -2, and/or other available guidance might be appropriate to determine whether the time varying exposure is likely to give rise to any degree of adverse comment.

As the vibration criteria specified in *Table 3.12* take into account the sensitivity of the receptor, separate criteria for receptor sensitivity are not applicable and are therefore not presented. The corresponding impact significance rating is outlined in *Table 3.13*, which also accounts for the duration of exposure (defined with reference to *Table 3.10*).

Table 3.13: Impact Significance Criteria for Vibration Impacts on Humans [Note 1]

Impact Magnitude	Duration			
	< 1 day	< 1 month	1 to 6 months	> 6 months
Negligible	Negligible	Negligible	Negligible	Negligible
Small	Negligible	Minor	Minor	Moderate
Medium	Minor	Minor	Moderate	Moderate
Large	Minor	Moderate	Major	Major

Note 1: Minor impact significance can be retained for activities with duration < 1 month for an impact magnitude up to Medium, to take into consideration that the 1 mm/s threshold 'can be tolerated if prior warning and explanation has been given to residents'(7). In addition, construction activities that may give rise to significant vibration are generally short-term in duration in terms of exposure to receptors, e.g. < 1 mth for exposure to demolition, or piling works. It is considered reasonable to upgrade the significance to Moderate for activities that might be longer in duration, i.e. 1 month or more, and which give rise to vibration levels > 1 mm/s i.e. Medium magnitude.

3.6 *Assessment of Impacts during Project Construction Phase*

The Project construction will operate within the administrative framework for Singapore. Measures to reduce potential environmental impacts in line with regulatory requirements will therefore be implemented as part of the Project design and are known as "embedded controls" (refer to *Volume I, Chapter 2* for further details). Key embedded controls that have been considered in the impact assessment are as follows:

<u>Management Planning</u>

- Develop a **Noise Management Plan** which will include:
- Protocol for sourcing quieter construction equipment;

- Procedure for periodic checking of operating equipment against noise specifications, either provided by the vendor or ascertained through measurements prior to commencement of construction and/or after equipment maintenance;
- Protocol for identification of and clearance of danger zones around the launch shaft prior to rock excavation activities;
- Training and competency requirements for personnel involved in rock excavation activities; and
- Stakeholder engagement plan defining protocol for liaising, coordinating and notifying stakeholders, in particular during high noise activities such as rock excavation.

General Controls

- Portable acoustic screens to be erected between receptor and mobile construction equipment during short-term, noise generating activities such as road works.
- Noise barriers tested to have a minimum of Sound Transmission Class 20 to be designed and erected between the worksite and the nearest affected receptors.
- High noise and vibration generating activities such as rock excavation shall be restricted to continuous blocks not exceeding 3 hours each, with a minimum respite period of one hour between each block.
- No piling works shall be done between 10 pm and 7 am unless both machinery and method are of a quiet nature.

Implementation Management

- Noise monitoring records and logged feedbacks to be communicated to the LTA promptly, and recorded in monthly progress reports.
- Mining key performance indicators such as vibration PPV levels at identified receptor buildings, will be closely monitored during the operation of the TBM during construction of the tunnel.

3.6.1 Noise Impacts During the Construction Phase

3.6.1.1 Sources of Impact

Sources of impacts to noise during Project construction comprise of construction equipment operating during aboveground activities such as roadworks, site clearance, installation of secant bored piles, rock excavation for shaft construction, installation of piezometers, tunnel works (operation of TBM), construction of facility building, and reinstatement works. Details on the type, quantity and operational sequence of construction equipment associated with each activity will be defined by the Project Contractor. For the purposes of this study however, assumptions were made in consultation with the Project engineers, to develop an indicative inventory of construction equipment. The inventory of equipment, along with the indicative duration of operation over the course of the construction phase, percentage (%) on time and typical noise specifications are presented in *Volume I, Annex 1.0*.

3.6.1.2 Receptors

Receptors identified within the Study Area are summarised in *Table 3.14*, and shown in *Figure 3.3*.

Table 3.14 Receptors & Nearest Alignment Option 1 Worksites

Receptor ID	Receptor	Nearest Worksite
R1	Residents at Windsor Park estate	A1-W1 (LS/VS)
R2	Members and workers at SICC Island Clubhouse	A1-W1 (LS/VS)
R3	Golfers at the SICC Island golf course	A1-W1 (LS/VS)
R4	Rangers at the Windsor Nature Park NParks Office	A1-W1 (LS/VS)
R5	Recreational users of Windsor Nature Park trails	A1-W1 (LS/VS)
R6	Recreational users of CCNR trails	A1-W1 (LS/VS), piezometer locations
R7	Members of the Bukit Timah Saddle Club	A1-W2 (LS/VS)
R8	Riders at the Bukit Timah Saddle Club riding arena	A1-W2 (LS/VS)
R9	Golfers at the Champions Golf course	A1-W2 (LS/VS)

3.6.1.3 Impact Magnitude & Significance

Noise generated from construction activities is dependent on the type of equipment and plant in operation, and the type of activity or construction methodology employed. In general however, the characteristics of noise generated from a construction worksite is distinct from that generated from other noise sources such as vehicular traffic, outdoor compressor units etc. This gives rise to potential nuisance impacts to human receptors, despite the temporal duration and/or intermittent frequency of noise generated from specific construction activities. Depending on the land use of the nearby receptors, nuisance impacts could comprise:

- Annoyance to users due to disturbance of the perceived amenity of outdoor recreational areas;
- Interference of speech communication for users of outdoor spaces and indoor building occupants;
- Sleep disturbance for residents at Windsor Park estate (R1), during construction works undertaken in the night; and
- Health and safety risks to equestrian riders due to potential spooking of the horses during training courses held at the Bukit Timah Saddle Club riding arena (R9).

As most of the recreational amenities are closed to users at or before 7 pm, noise impacts to recreational users during the evening and night construction works will not occur and is therefore not assessed in this study. This is with the exception of SICC Island Clubhouse, which closes at 10 pm. The impacts to SICC Island Clubhouse during the evening period i.e. 7 pm – 10 pm, have therefore been assessed.

Due to the nature of outdoor activities being undertaken by receptors in close proximity of the worksites, the exposure of these receptors to noise generated during construction is anticipated to be temporal in duration. Recreational users of the Windsor Nature Park (R5) and CCNR trails (R6) would be exposed for the time taken to bypass and walk out of range of the worksite, ie less than a few hours. Similarly, golfers at the SICC Island golf course (R3) and equestrian riders at the Bukit Timah Saddle club riding arena (R9) would be exposed during engagement in outdoor activities, but the duration of these activities would likely be less than a few hours in a single day. It is noted that the assessment criteria have been derived from average baseline measurements in order to represent the majority of outdoor receptors in the Study Area. It is possible that there may be outdoor receptors who are more accustomed to lower baseline levels experienced during less busy periods of the day.

For residents at Windsor Park estate (R1), exposure to noise generated in the night will be over the duration of night-time construction activities ie > 6 months, which may lead to sleep disturbance.

To assess nuisance impacts arising from long-term exposure, activities undertaken over a long-term duration were considered (see *Volume I, Annex 1.0*). The operation of plant and vehicles at the aboveground worksite during tunnelling works was identified as generating the highest sound levels. Tunnelling works will also be carried out continuously at the worksites over a period of 3 years. Considering that Alignment Option 1 is estimated to be completed in 5.5 years, tunnelling works will be the dominant construction activity being undertaken. Due to safety and engineering factors, it is preferable that pressure is maintained against the tunnel face by the TBM cutterhead. Tunnelling will therefore be undertaken continuously i.e. 24 hours a day, with the exception of periodic stoppage for maintenance and advance probing activities. Works will therefore be ongoing at the aboveground worksite to support the operations of the TBM within the tunnel. The day and night sound levels during tunnelling works were predicted at the identified receptors, and are presented in *Table 3.15.* It is noted that calculations did not take into account noise attenuation due to ground cover, topography or shielding effect from structures or thick vegetation, and are therefore conservative.

A summary of the magnitude and significance of noise impacts during Project construction is provided in *Table 3.16*.

Table 3.15: Predicted Noise Levels at Receptors (Tunnelling Works)

ID	Receptors	Nearest Worksite	Applicable Criteria, dB(A) (Note 1, Note 2)								Cumulative Noise Levels, dB(A) (Note 3)								Exceedance of Criteria Before Mitigation, dB(A)							
			$L_{eq,5min}$			$L_{eq,1hr}$			$L_{eq,12hr}$		$L_{eq,5min}$			$L_{eq,1hr}$			$L_{eq,12hr}$		$L_{eq,5min}$			$L_{eq,1hr}$			$L_{eq,12hr}$	
			D	E	N	D	E	N	D	N	D	E	N	D	E	N	D	N	D	E	N	D	E	N	D	N
R1	Residents, Windsor Park	A1-W1 (LS/VS)	**90**	**75**	**55**	-	**65**	**55**	**75**	-	62	62	60	-	62	60	59	-	-28	-13	5	-	-3	5	-16	-
R2	Members, SICC Island Clubhouse	A1-W1 (LS/VS)	**90**	**70**	-	-	-	-	**75**	-	68	66	-	-	-	-	65	-	-22	-4	-	-	-	-	-10	-
R3	Golfers, SICC Island course	A1-W1 (LS/VS)	**75**	-	-	-	-	-	-	-	81	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-
R4	Rangers, Windsor Nature Park NParks Office	A1-W1 (LS/VS)	**90**	-	-	-	-	-	**75**	-	64	-	-	-	-	-	63	-	-26	-	-	-	-	-	-12	-
R5	Trail users, Windsor Nature Park	A1-W1 (LS/VS)	**75**	-	-	-	-	-	-	-	79	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
R6	Trail users, CCNR	A1-W1 (LS/VS)	**75**	-	-	-	-	-	-	-	63	-	-	-	-	-	-	-	-12	-	-	-	-	-	-	-
R7	Members, Bukit Timah Saddle Club	A1-W2 (LS/VS)	**90**	-	-	-	-	-	**75**	-	64	-	-	-	-	-	63	-	-26	-	-	-	-	-	-12	-
R8	Riders, Bukit Timah Saddle Club riding arena	A1-W2 (LS/VS)	**75**	-	-	-	-	-	-	-	73	-	-	-	-	-	-	-	-2	-	-	-	-	-	-	-
R9	Golfers, Champions Golf course	A1-W2 (LS/VS)	**75**	-	-	-	-	-	-	-	61	-	-	-	-	-	-	-	-14	-	-	-	-	-	-	-

Impact Magnitude Definition:

Negligible, at or below criteria	Small, < 5 dB(A) over criteria
Medium, 5 - 10 dB(A) over criteria	Large, ≥ 10 dB(A) over criteria

Note 1: Day defined as 7 am – 7 pm; Evening defined as 7 pm – 10 pm; and Night defined as 10 pm – 7 am. In the case of $L_{eq,12hr}$ criteria, Night is defined as 7 pm – 7 am.
Note 2: Criteria as defined in *Table 3.4*.
Note 3: Cumulative noise levels being defined as the logathrimic sum of the representative baseline measurements and predicted noise levels from the worksite.

Table 3.16: Impact Magnitude & Significance for Noise during Project Construction

Impact	Impact Summary	Impact Magnitude	Duration of Exposure	Impact Significance
Noise from stationary construction equipment at worksites due to aboveground activities such as site clearance, concrete breaking, shaft excavation, secant bored piling, construction of facility building etc.	**A1-W1 (LS/VS)** • Noise levels are predicted to exceed $L_{eq,5min}$ night time regulatory limits by 5 dB(A) at Windsor Park estate (R1). Residents may be exposed to a noticeable increase in noise levels due to tunnelling works undertaken over 3 years, ie long-term duration.	Medium	Long term (> 6 months)	Moderate
	• Golfers at SICC's Island golf course (R3) may be exposed for less than a few hours to noise levels which exceed applicable daytime $L_{eq,5min}$ criteria by 6 dB(A). It is noted that the magnitude of impact will attenuate to levels less than 5 dB(A) above the criteria ie *Small* within 35 m of the worksite. It is therefore anticipated that only golfers at the 17^{th} hole might experience levels of *Medium* magnitude.	Medium	Temporary (< 1 day)	Minor
	• Noise levels for users of trails within the Windsor Nature Park (R5) are predicted to exceed applicable day time $L_{eq,5min}$ criteria by 4 dB(A). Recreational users may be exposed to barely perceptible increase in noise levels for a temporary duration (< 1 hour) during usage of the trail sections connecting Venus Link within the Windsor Nature Park to trails within the CCNR.	Small	Temporary (< 1 day)	Negligible
	• Noise levels at nearby buildings such as the Windsor Nature Park NParks office (R4) and the SICC Island Clubhouse (R2), and noise levels for users of trails within the CCNR (R6) are predicted to be well within the applicable day and evening regulatory limits. Members at the clubhouse and users of the CCNR trails will be exposed over a temporary duration, whereas workers at both buildings will be exposed throughout the Project construction phase ie long term duration.	Negligible	Temporary (< 1 day) / Long term (> 6 months)	Negligible

Impact	Impact Summary	Impact Magnitude	Duration of Exposure	Impact Significance
Noise from stationary construction equipment at worksites due to aboveground activities such as site clearance, concrete breaking, shaft excavation, secant bored piling, construction of facility building etc.	**A1-W2 (LS/VS)** • Noise levels at the Bukit Timah Saddle Club riding arena (R8) are predicted to be well below the applicable daytime criteria of 75 dB(A). It is noted however that this predicted level might be more than 10 dB(A) above the current baseline $L_{eq,5min}$ level of 61 dB(A). Noise levels generated from the A1-W2 (LS/VS) worksite may therefore be noticeable to riders at the arena. There are no studies establishing noise levels at which behavioural effects in horses may occur and therefore no certainty of this occurring. It is further observed that there would be a degree of habituation to existing noise sources such as moving vehicles within the Bukit Timah Saddle Club premises. This study however adopts a precautionary approach to highlight the health and safety impacts that may arise due to potential spooking of horses from intermittent noise generated from the site and potential intermittent interference of speech communication during riding lessons.	Negligible	Temporary (< 1 day)	Negligible
	• Noise levels are predicted to be well below the applicable daytime criteria for receptors such as recreational users of the Bukit Timah Saddle Club facilities (R7) and golfers at the Champions Golf course (R9).	Negligible	Temporary (< 1 day)	Negligible
Noise from stationary rotary borehole rigs during piezometer installation within the CCNR	**Tunnel Alignment** • Daytime noise levels are expected to exceed the 75 dB(A) limits for up to a distance of 15 m from each A-frame rig worksite, during installation of piezometers at 16 locations within the CCNR. It is noted that baseline measurements averaged between 51 and 61 dB(A) in the daytime. Noise levels from the A-frame rig will exceed these baseline levels at distances between 65 m and 140 m from the rig. Recreational users may be exposed to a significant increase in noise levels for a temporary duration (< 1 hour) during usage of the nearest open trail e.g. Golf Link users during installations at Sime Track west of Jelutong Tower, and Sime Track users during installations along Terentang Trail.	Large	Temporary (< 1 day)	Minor

3.6.1.4 Mitigation Measures

In addition to embedded controls, measures to avoid, minimise, and limit the magnitude of noise impacts caused by the Project construction phase are outlined in *Table 3.17*. Mitigation includes construction best practices, management plans and monitoring, and are in addition to the embedded controls (refer to *Volume I, Chapter 2* for further details) that will be implemented in compliance with noise regulations.

Table 3.17: Mitigation Measures for Noise Receptors during Project Construction

Category	Mitigation
General Mitigation Measures	• Acoustic enclosures designed with appropriate ventilation and access to be installed for stationary equipment such as generators, compressors etc. • The feasibility of using mains power in place of diesel generators to be studied at the AES stage. • A detailed noise study to be undertaken by an acoustic consultant prior to construction to determine the configuration and specifications for equipment enclosures, screens and noise barriers required for the worksites to mitigate impacts.
Specific Measures for Piezometer Locations within the CCNR	• Coordination with NParks on the temporary closure of trail sections, due to safety considerations for trail users during installation works. • Schedule works to avoid peak visitation periods, i.e. weekends. • Where there are no space constraints, erect portable acoustic screens between worksite and nearby receptors, e.g. at BH30 - BH33. • A notice describing the proposed piezometer installation works and their duration within the CCNR shall be posted on signboards at the MacRitchie Visitor Centre and Ranger Station for the duration of the installation works.

Category	Mitigation
Specific Measures for Worksite A1-W1 (LS/VS)	• Site layout to be planned to maximise placement of structures along the north and south worksite boundary to act as natural barriers between receptors eg golfers at SICC Island golf club and users of Windsor Nature Park trails, and noise generating activities. • Planning to ensure that noisy works such as site clearance, construction of launch shaft and facility buildings are undertaken in the daytime as far as possible. • Planning to ensure vehicular movements to and from the site, in particular delivery of tunnel segments by trailer, are undertaken mostly in the daytime so as to minimise noise generated from the worksite during tunnelling works in the night. For activities carried out at night, especially for tunnel segments delivery and disposal of spoils, proper traffic controller to be provided to control the vehicular movement to ensure no excessive noise from the trucks. Truck / trailer drivers shall also be briefed to prevent horning / reversing of trucks which will create unnecessary noise. • Provide NParks and SICC Island Club management with the programme of construction activities and promptly notify them of any schedule changes, to facilitate dissemination of information to the public users of the trails and SICC Island club members and enable management of any activities in proximity to the worksite, in particular during noisy activities such as installation of ERSS and rock excavation at the launch shafts.
Specific Measures for Worksite A1-W2 (LS/VS)	• Site layout to be planned to maximise placement of structures along the west worksite boundary to act as natural barriers between receptors and noise generating activities. • Provide Bukit Timah Saddle Club management with the programme of construction activities and promptly notify them of any schedule changes, to facilitate dissemination of information to members and enable management of equestrian activities in proximity to the worksite, in particular during noisy activities such as installation of ERSS at the launch shafts.
Implementation Management	• Regular refresher training to be organised to ensure that all workers are constantly reminded of the need to employ quieter work techniques. • Site inspections, including noise monitoring to be undertaken on a weekly basis. • Trained personnel to maintain a grievance mechanism to log complaints and ensure the adequate and timely response to complainants. • A communications plan to be developed, including protocol for the escalation of complaints to the site supervisor, to enable prompt corrective actions to be taken in response to complaints or detected exceedances of noise limits.

Category	Mitigation
Environmental Monitoring (Note 1)	• Ambient noise monitoring ($L_{eq,5min}$ and $L_{eq,12hr}$) to be undertaken prior to commencement of construction activities in accordance with the guidance in SS 602:2014, at the following receptors: **A1-W1 (LS/VS)** • SICC Island clubhouse • Windsor Nature Park NParks Office • Windsor Park residential estate (Jupiter Road / Libra Drive) **A1-W2 (LS/VS)** • Bukit Timah Saddle Club riding arena • Bukit Timah Saddle Club • Baseline noise monitoring to be undertaken at the abovementioned receptors to determine applicable permissible noise limits. • Real-time noise monitoring to be undertaken at A1-W1 (LS/VS) to ensure that night-time $L_{eq,5min}$ levels are below threshold levels. Threshold levels to be established by applying distance correction to account for regulatory limits at the nearest residence at Windsor Park estate. Investigation into the source(s) of noise should be undertaken promptly, and corrective actions implemented where feasible eg erection of portable acoustic screens, repositioning of equipment away from receptors etc.

Note 1: The monitoring guidelines were recommended taking into consideration impacts to human receptors only. Further monitoring to manage potential impacts to ecological receptors due to the construction of Alignment Option 1, has been captured in *Volume III, Chapter 5.*

3.6.1.5 Residual Impacts

Noise impacts from construction activities can be reduced to ALARP by implementation of the mitigation measures listed in *Table 3.17*. The noise levels were predicted after implementation of the mitigation measures presented in *Table 3.18*.

Table 3.18 Mitigated Construction Equipment Inventory

Construction Activities	Type of Equipment	Quantity (typical on site at any one time)	% ON Time	Assumed Sound Power Level, dB(A) (Note 1)	Mitigation Measure(s)	Possible Attenuation, dB(A)
Tunnel works (Day/Evening)	TBM (Note 2)	2	100%	NA		
	Generator	6	100%	94	Ventilated acoustic enclosure	-20
	Sub Station (temp power supply)	1	100%	93	Acoustic enclosure	-20
	Dump Truck (on site and inside muck pit)	3	20%	107	Barrier	-5
	Dump Truck (transit)	3	20%	115		
	Gantry Crane	2	50%	92		
	Compressed air plants (medical lock, air receivers)	1	100%	100		
	Excavator (soil disposal at muck pit)	5	80%	99	Barrier / acoustic screen	-10
	Trailers (for segment transportation into site)	4 in day/eve	20%	116		
	Crane (50 ton)	1	100%	98	Barrier / acoustic screen	-10
	Cooling tower & ventilation system	2	100%	85	Barrier / acoustic screen	-10
	Muck loader (Note 2)	1	50%	NA		
	Slurry treatment plant	1	100%	110	Barrier / acoustic screen	-10
Tunnel works (Night)	TBM (Note 2)	2	100%	NA		
	Generator	6	100%	94	Ventilated acoustic enclosure	-20
	Sub Station (temp power supply)	1	100%	93	Acoustic enclosure	-20
	Dump Truck (on site and inside muck pit)	3	20%	107	Barrier	-5
	Dump Truck (transit)	3	20%	115		
	Gantry Crane	2	50%	92		
	Compressed air plants (medical lock, air receivers)	1	100%	100		
	Excavator (soil disposal at muck pit)	5	80%	99	Barrier / acoustic screen	-10
	Trailers (for segment transportation into site)	1 at night	20%	116		
	Crane (50 ton)	1	100%	98	Barrier / acoustic screen	-10
	Cooling tower & ventilation system	2	100%	85	Barrier / acoustic screen	-10
	Muck loader(Note 2)	1	50%	NA		
	Slurry treatment plant	1	100%	110	Barrier / acoustic screen	-10

Note 1: Reference made to noise databases in British Standards Institution's Code of Practice for Noise and Vibration Control on Construction and Open Sites – Part 1: Noise. BS 5228-1:2014, and US Department of Transportation Federal Highway Administration Construction Noise Handbook.
Note 2: Noise contribution not significant as equipment will mainly be operating within underground shaft or tunnel.

Mitigated noise levels at identified receptors for each worksite are presented in *Table 3.19.* As shown in *Table 3.19,* it is possible for noise levels at most human receptors to be mitigated to well within applicable criteria, with the exception of golfers at the SICC Island golf course, recreational users of Windsor Nature Park trails and riders at the Bukit Timah Saddle Club riding arena.

Table 3.19: Predicted Noise Levels at Receptors (Tunnelling Works) After Mitigation

ID	Receptors	Nearest Worksite	Applicable Criteria, dB(A) (Note 1, Note 2)								Cumulative Noise Levels, dB(A) (Note 3)								Exceedance of Criteria After Mitigation, dB(A)							
			$L_{eq,5min}$			$L_{eq,1hr}$			$L_{eq,12hr}$		$L_{eq,5min}$			$L_{eq,1hr}$			$L_{eq,12hr}$		$L_{eq,5min}$			$L_{eq,1hr}$			$L_{eq,12hr}$	
			D	E	N	D	E	N	D	N	D	E	N	D	E	N	D	N	D	E	N	D	E	N	D	N
R1	Residents, Windsor Park	A1-W1 (LS/VS)	**90**	**75**	**55**	-	**65**	**55**	**75**	-	56	56	55	-	56	55	53	-	-32	-17	0	-	-7	0	-19	-
R2	Members, SICC Island Clubhouse	A1-W1 (LS/VS)	**90**	**70**	-	-	-	-	**75**	-	64	61	-	-	-	-	63	-	-25	-7	-	-	-	-	-12	-
R3	Golfers, SICC Island course	A1-W1 (LS/VS)	**75**	-	-	-	-	-	-	-	76	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
R4	Rangers, Windsor Nature Park NParks Office	A1-W1 (LS/VS)	**90**	-	-	-	-	-	**75**	-	63	-	-	-	-	-	62	-	-27	-	-	-	-	-	-13	-
R5	Trail users, Windsor Nature Park	A1-W1 (LS/VS)	**75**	-	-	-	-	-	-	-	73	-	-	-	-	-	-	-	-2	-	-	-	-	-	-	-
R6	Trail users, CCNR	A1-W1 (LS/VS)	**75**	-	-	-	-	-	-	-	62	-	-	-	-	-	-	-	-13	-	-	-	-	-	-	-
R7	Bukit Timah Saddle Club	A1-W2 (LS/VS)	**90**	-	-	-	-	-	**75**	-	59	-	-	-	-	-	61	-	-29	-	-	-	-	-	-13	-
R8	Riders, Bukit Timah Saddle Club riding arena	A1-W2 (LS/VS)	**75**	-	-	-	-	-	-	-	68	-	-	-	-	-	-	-	-7	-	-	-	-	-	-	-
R9	Golfers, Champions Golf course	A1-W2 (LS/VS)	**75**	-	-	-	-	-	-	-	57	-	-	-	-	-	-	-	-18	-	-	-	-	-	-	-

Impact Magnitude Definition:		
	Negligible, at or below criteria	Small, < 5 dB(A) over criteria
	Medium, 5 - 10 dB(A) over criteria	Large, ≥ 10 dB(A) over criteria

Note 1: Day defined as 7 am – 7 pm; Evening defined as 7 pm – 10 pm; and Night defined as 10 pm – 7 am. In the case of $L_{eq,12hr}$ criteria, Night is defined as 7 pm – 7 am.
Note 2: Criteria as defined in *Table 3.4*.
Note 3: Cumulative noise levels being defined as the logathrimic sum of the representative baseline measurements and predicted noise levels from the worksite.

A summary of the residual impact magnitude and significance for each worksite is presented in *Table 3.20*.

Table 3.20: Residual Impact Magnitude & Significance for Noise during Project Construction

Impact	Impact Summary	Residual Impact Magnitude	Duration of Exposure	Residual Impact Significance
Noise from stationary construction equipment at worksites and aboveground activities such as site clearance, concrete breaking, shaft excavation, secant bored piling, construction of facility building etc.	**<u>A1-W1 (LS/VS)</u>** • Golfers at the 17th hole of the SICC Island golf course (R3), will be exposed temporarily to noise levels up to 1 dB(A) above criteria.	Small	Temporary (< 1 day)	Negligible
	• Residual noise levels at the nearest trails within Windsor Nature Park (R5) and the CCNR (R6) will be well below the applicable daytime limit.	Negligible	Temporary (< 1 day)	Negligible
	• Residual noise levels at other outdoor recreational areas and nearby buildings (R2 & R4) will be well within applicable noise limits in the day and night. Most notably, night-time levels at residences within Windsor Park estate (R1) will be mitigated to levels at or below the applicable daytime and night-time regulatory limits.	Negligible	Long term (> 6 months)	Negligible
	<u>A1-W2 (LS/VS)</u> • Residual noise levels at the Bukit Timah Saddle Club riding arena (R8) are predicted to be well below the applicable daytime criteria of 75 dB(A). Riders at the Bukit Timah Saddle Club riding arena (R8) may still be exposed to residual noise levels which exceed existing baseline $L_{eq,5min}$ levels of 61 dB(A) by 7 dB(A). Implementation of mitigation measures to enable the management of equestrian activities in proximity to the worksite and the design of barriers at the detailed engineering stage will result in attenuation of residual noise to levels to Negligible impact magnitude.	Negligible	Temporary (< 1 day)	Negligible
	• Residual noise levels at the grounds within Bukit Timah Saddle Club (R7) and at the Champions Golf course (R9) will be well within applicable criteria.	Negligible	Temporary (< 1 day)	Negligible
Noise from stationary rotary borehole rigs during piezometer installation within the CCNR	**<u>Tunnel Alignment</u>** • It is assessed that the implementation of the mitigation measures listed above will reduce the impact magnitude to ALARP, although noise levels are still expected to exceed current baseline levels by more than 10 dB(A). The advance notification of recreational users, in addition to the temporary closure of trails, is expected to reduce exposure by enabling potential receptors to take alternative routes to avoid locations where installation works will be ongoing.	Large	Temporary (< 1 day)	Minor

A summary of the impact assessment including the assessment of residual impacts after implementation of mitigation measures, is presented in *Table 3.21*.

Table 3.21: Impact Assessment Summary for Noise

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to noise generated during Project construction phase					
Nature	Negative	The Project will result in incremental ambient noise levels, which will exceed current baseline levels at outdoor recreational areas, and exceed night-time limits at nearby residential areas.			
Type	Direct	Users of outdoor recreational areas and nearby buildings, and Windsor Park estate residents will be directly exposed to elevated noise levels generated from the A1-W1 (LS/VS) and A1-W2 (LS/VS) worksites.			
Duration	Temporary	Exposure duration of recreational users will be temporary, eg less than a day for members of SICC Island clubhouse (R2) and Bukit Timah Saddle Club (R7); and less than a few hours for golfers and users of Windsor Nature Park and CCNR trails.			
	Long term	Residents at Windsor Park estate (R1), and rangers at the Windsor Nature Park NParks Office (R4) will be exposed to noise generated throughout the Project construction phase, which is estimated to last approximately 5.5 years.			
Extent	Local	Effects will be on recreational users and residents within 500 m from the worksites.			
Frequency	Continuous and impulsive	Continuous noise will be generated throughout the Project construction phase at both worksites, and impulsive noise will be generated during rock excavation at the A1-W1 (LS/VS) worksite.			
Receptor Sensitivity	N/A	Receptor sensitivity is accounted for in the impact magnitude criteria.			
Pre-Mitigation Impact Magnitude / Scale	Large	**Tunnel Alignment:** Recreational users of the CCNR trails may be exposed to noise levels more than 10 dB(A) above the construction noise limits for sensitive receptors and the baseline levels, during the installation of piezometers within the CCNR.	**Residual Impact** Impact Magnitude / Scale	Large	**Tunnel Alignment:** Recreational users of the CCNR trails may be exposed to noise levels more than 10 dB(A) above the construction noise limits for sensitive receptors and the baseline levels, during the installation of piezometers within the CCNR.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to noise generated during Project construction phase					
Pre-Mitigation Impact Magnitude / Scale	Medium	**A1-W1 (LS/VS):** Residents at Windsor Park estate (R1) may be exposed to noise levels which exceed applicable day and night time $L_{eq,5min}$ limits by 5 dB(A). Golfers at SICC's Island golf course (R3) may be exposed to noise levels which exceed applicable day time $L_{eq,5min}$ limits by 6 dB(A).	**Residual Impact** Impact Magnitude / Scale	Small	**A1-W1 (LS/VS):** Golfers at the SICC Island golf course (R3) may be exposed to residual noise levels which exceed applicable daytime $L_{eq,5min}$ limits by 1 dB(A) respectively, even after implementation of mitigation measures.
	Small	**A1-W1 (LS/VS):** Recreational users of the Windsor Nature Park trails (R5) may be exposed to noise levels which exceed applicable day $L_{eq,5min}$ limits by 4 dB(A).		Small	**A1-W2 (LS/VS):** Implementation of mitigation measures to manage equestrian activities and worksite activities will likely reduce the level of exposure of riders at the Bukit Timah Saddle Club riding arena (R8).
	Negligible	**A1-W1 (LS/VS):** Noise levels at indoor receptors such as SICC Island clubhouse (R2) and Windsor Nature Park NParks Office (R4) are predicted to be well within the daytime and evening criteria. Noise levels are predicted to be at the applicable day $L_{eq,5min}$ limits for recreational users of the CCNR trails (R6). **A1-W2 (LS/VS):** Noise levels at the Bukit Timah Saddle Club (R7), Bukit Timah Saddle Club riding arena (R8) and Champions Golf course (R9) are predicted to be well within the applicable criteria.		Negligible	**A1-W1 (LS/VS):** Implementation of mitigation measures will effectively attenuate noise levels to at or below applicable noise criteria for members and workers at the SICC Island Clubhouse (R2), rangers at the Windsor Nature Park NParks office (R4) and recreational users of Windsor Nature Park (R5) and CCNR trails (R6). Notably, daytime and night-time levels at Windsor Park residential estate (R1) will be attenuated to below applicable criteria.
Pre-Mitigation Significance	Moderate	**A1-W1 (LS/VS):** Moderate sleep disturbance to residents at Windsor Park estate may occur due to long term exposure to levels in exceedance of $L_{eq,5min}$ and $L_{eq,1hr}$ night limits by up to 5 dB(A).	**Residual Impact** Significance	Minor	**Tunnel Alignment:** Minor nuisance impacts to recreational users of CCNR trails due to temporary exposure to elevated ambient noise levels in exceedance of baseline and limits by more than 10 dB(A), during piezometer installation works along temporarily closed CCNR trails.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to noise generated during Project construction phase					
Pre-Mitigation Significance	Minor	**A1-W1 (LS/VS):** Minor nuisance impacts to golfers at SICC's Island golf course (R3) can be expected due to temporary exposure to elevated ambient noise levels in exceedance of existing baseline $L_{eq,5min}$ levels by up to 6 dB(A). **Tunnel Alignment:** Minor nuisance impacts to recreational users of CCNR trails due to temporary exposure to elevated ambient noise levels in exceedance of baseline and limits by more than 10 dB(A), during piezometer installation works.	**Residual Impact** Significance	Negligible	Negligible nuisance impacts to all human receptors can be expected due to temporary or long term exposure to residual ambient noise levels at up to 1 dB(A) above or below applicable criteria.
	Negligible	**A1-W1 (LS/VS):** Negligible nuisance impacts to receptors at the SICC Island clubhouse (R2), Windsor Nature Park NParks Office (R4), as noise levels are predicted to be well below the applicable criteria. Negligible impacts to users of trails within the Windsor Nature Park (R5) due to temporary exposure to levels up to 4 dB(A) above daytime criteria. **A1-W2 (LS/VS):** Negligible nuisance impacts to receptors at Bukit Timah Saddle Club (R7), Bukit Timah Saddle Club riding arena (R8) and Champions Golf course (R9) as noise levels are predicted to be well below the applicable criteria.			

3.6.2 *Vibration Impacts During the Construction Phase*

3.6.2.1 Sources of Impact

Sources of vibration during Project Construction will comprise of rock excavation and piling (assumed secant bored piles and rock bolting) for the construction of launch shafts; and the operation of TBM for the excavation and construction of the single bored tunnel along the direct alignment.

3.6.2.2 Impact Magnitude & Significance

Construction of Launch Shaft

At shaft worksites, the main vibration source will be the rock excavation activities. This study will assess the use of blasting method as a worst case scenario. Rock excavation events are impulsive and can result in significant magnitudes of vibration dependent upon charge weights and delays. LTA has provided recorded vibration levels at receptors at different distances from rock excavation activities, which were undertaken during the construction of a TBM shaft for tunnelling works associated with Contract T213 of the Thomson-East Coast Line located within an area with similar geological characteristics as the Project. *Table 3.22* presents the recorded vibration magnitude due to rock excavation using timed detonation of explosive charges at two different shaft locations at tunnels associated with Caldecott Station. The recorded vibration magnitudes vary, which is typical in such datasets.

Table 3.22: Recorded Vibration Magnitude at Contract T213, Thomson-East Coast Line

Receptor Number	Rock excavation location	Horizontal Distance (metres)	Recorded Vibration Magnitude, PPV (mm/s)
1	1	105	0.13
2		65	0.12
3		15	0.16
4		20	0.11
5	2	32	0.16
6		22	0.14
7		80	0.19

Source: LTA

The nearest residential receptor to the worksites along Alignment Option 1 is located at more than 200 m from the nearest worksite ie the launch shaft at the A1-W1 (LS/VS) worksite. Assuming that the same methodology will be used for the construction of the shafts for CRL, the vibration magnitude due to rock excavation activities are predicted to be similar to, or lower than, the highest recorded value of 0.19 mm/s. The highest recorded value of 0.19 mm/s was recorded at a distance of 80 m from the source, and the nearest receptor to the Project worksite is approximately 80 m. It is noted based on general guidance on human response to vibration that residents or building occupants would be able to just perceive vibration at or greater than 0.14 mm/s, and that the likelihood of disturbance giving rise to complaints would increase significantly at the 1 mm/s threshold. Vibration from rock excavation works would be just perceptible to human receptors near the A1-W1 (LS/VS) worksite i.e. user of SICC clubhouse facilities, as well as outdoor receptors such as recreational users of SICC golf course and nearby walking trails. In addition, the frequency of rock excavation will likely be once a day at most, and the duration of each episode of rock excavation is estimated to last for a few seconds each time. It is conservatively assumed that each round of rock excavation will result in the excavation of 1 m depth of rock, ie rock excavation works to be undertaken over approximately 3 weeks for the excavation of 15 m depth of rock. The impact magnitude and significance of vibration from rock excavation works is summarised in *Table 3.24.*

Piling

Vibration at receptors is anticipated during piling activities for the ERSS associated with the launch shaft construction at both the A1-W1 (LS/VS) and A1-W2 (LS/VS) worksites. The vibration magnitude at nearby receptors was predicted using empirical equations developed for vibratory piling, as presented in the BS 5228-2:2009+A1:2014(7). This was to simulate potential vibration impacts associated with the extraction of secant bored pile casings. The empirical equation used is presented below and is widely accepted by the international scientific community as being adequately robust for vibration predictions within 100 m from construction sources. The equation was empirically derived from a study commissioned by the Transport Research Laboratory from vibration measurements taken during a wide range of construction activities(47).

Equation 1 Empirical Predictor for Groundborne Vibration Arising from Vibratory Piling

$$v_{res} = \frac{k_v}{x^\delta}$$

Where

- v_{res} is the resultant PPV, mm/s
- k_v is a scaling factor, ie 60 at 50%; 126 at 33.3%; and 266 at 5% probability of predicted value being exceeded
- x is the distance between the receptor and source, measured along the ground surface
- δ is a modal factor, ie 1.3 during all operations; 1.2 during start up and run down; and 1.4 during steady state operation of the rig

The geological conditions at the A1-W1 (LS/VS) launch shaft have been extrapolated from actual SI data recorded at boreholes RC/4052 and RC/4053 (see *Volume II, Figure 3.3*). Piling will be undertaken up to the rockhead level, which SI data indicates will be encountered at depths of 25 – 30 m bgl. It is noted that for secant bored piling, casings will typically be installed using a rotary bored piling rig, which involves the use of an auger to excavate the soil ahead of the installation of the pile casing. This means that there is no need to force the casing into soil, so significant vibration levels are not anticipated. This assessment therefore only considers the potential vibration generated during the extraction of piling casings using vibro-driving, which is a typical method. Ground vibration is generated during this activity due to the need to transmit vibrational energy to the pile casings, in order to overcome the friction from the soil surrounding the pile.

Taking the above factors in consideration, a reasonably conservative approach has been undertaken for the vibration prediction. A scaling factor (k_v) equal to 126 was used, and a modal factor (δ) of 1.4 assuming steady state operation of the vibro-driving rig. The calculated vibration magnitude (PPV) is presented in *Table 3.23.*

Table 3.23: Summary of Calculated Vibration Levels during Piling (Extraction of Casings)

Receptor ID	Receptor	Nearest Worksite	Horizontal Distance from Nearest Launch Shaft, m	Calculated PPV, mm/s
R1	Residents, Windsor Park estate	A1-W1 (LS/VS)	460	0.02
R2	Workers, SICC Island clubhouse	A1-W1 (LS/VS)	230	0.06
R3	Golfers, SICC Island golf course	A1-W1 (LS/VS)	35	0.87
R5	Recreational users, Windsor Nature Park trails	A1-W1 (LS/VS)	35	0.87
R7	Members, Bukit Timah Saddle Club	A1-W2 (LS/VS)	260	0.05
R8	Equestrian riders, Bukit Timah Saddle Club riding arena	A1-W2 (LS/VS)	100	0.20

Vibration levels are predicted to be less than 0.14 mm/s at most receptors with the exception of golfers at SICC Island golf course (R3) and recreational users of Windsor Nature Park trails (R5) where levels are approximately 0.9 mm/s; and for riders at Bukit Timah Saddle Club riding arena (R8) where levels are approximately 0.2 mm/s. The construction of the shafts will last for approximately 1.5 years; however, the piling activities are anticipated to take place for a period of less than 6 months ie medium term exposure. The impact magnitude and significance of vibration from extraction of casings during piling is summarised in *Table 3.24.*

Construction of Tunnel

The main vibration source during the tunneling works will be the operation of the TBM. Vibration from tunnelling is typically generated when the TBM's cutting shield rotates whilst being under a constant pressure from hydraulic cylinders that push the TBM forward. The TBM machine is active for approximately 15 to 20 minutes per hour. The generation of vibration will therefore be intermittent.

The vibration magnitude at receptors overlying the tunnel during pass by of a TBM, was estimated from a review of results using two empirical prediction methods:

- An empirical equation developed from measurements of small and medium sized TBM (1.2 – 6.5 m diameter) operating in a range of ground conditions in America and the United Kingdom[(8)] (see *Equation 2*). These TBMs were operating at depths ranging from 4 to 17 m bgl.

- The vibration propagation equation as per US Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual[(45)] (see *Equation 3*), and vibration source levels obtained by Wilkinson Murray[(46)] during construction of the Epping to Chatswood Rail Line in Sydney, which involved tunnelling through sandstone and shale using a 7.2 m diameter Main Beam TBM. These source measurements were validated during the tunnelling of the Kowloon Southern Link, which involved tunnelling through hard rock using a 8.05 m slurry TBM.

It is noted that there are multiple vibration prediction methods which may yield a range of vibration levels. The abovementioned empirical equations were therefore validated against measured data from tunnelling projects undertaken in rock conditions. In addition, vibration levels predicted using the abovementioned empirical approaches were reported to be upper bound values, which is in line with the precautionary approach adopted for this EIA. The empirical equations reviewed are presented below.

Equation 2 Empirical Predictor for Groundborne Vibration Arising from Tunnelling[8]

$$v_{res} = 10 \times \beta \times D \times r^{n}$$

Where

- v_{res} is the resultant PPV, mm/s
- β is the factor for ground condition, ie 0.25 for soft ground with cone resistivity < 5 MPa; 1.00 for hard ground with cone resistivity > 15 MPa; and a linear interpolation between 0.25 and 1.00 for ground with cone resistivity between 5 and
15 MPa
- D is the TBM diameter, m
- r is the slant distance of the receptor from the TBM cutterhead, m
- n is a factor to account for damping effect of the ground.

Equation 3 Generic Empirical Predictor for Groundborne Vibration Propagation from Construction Source[45]

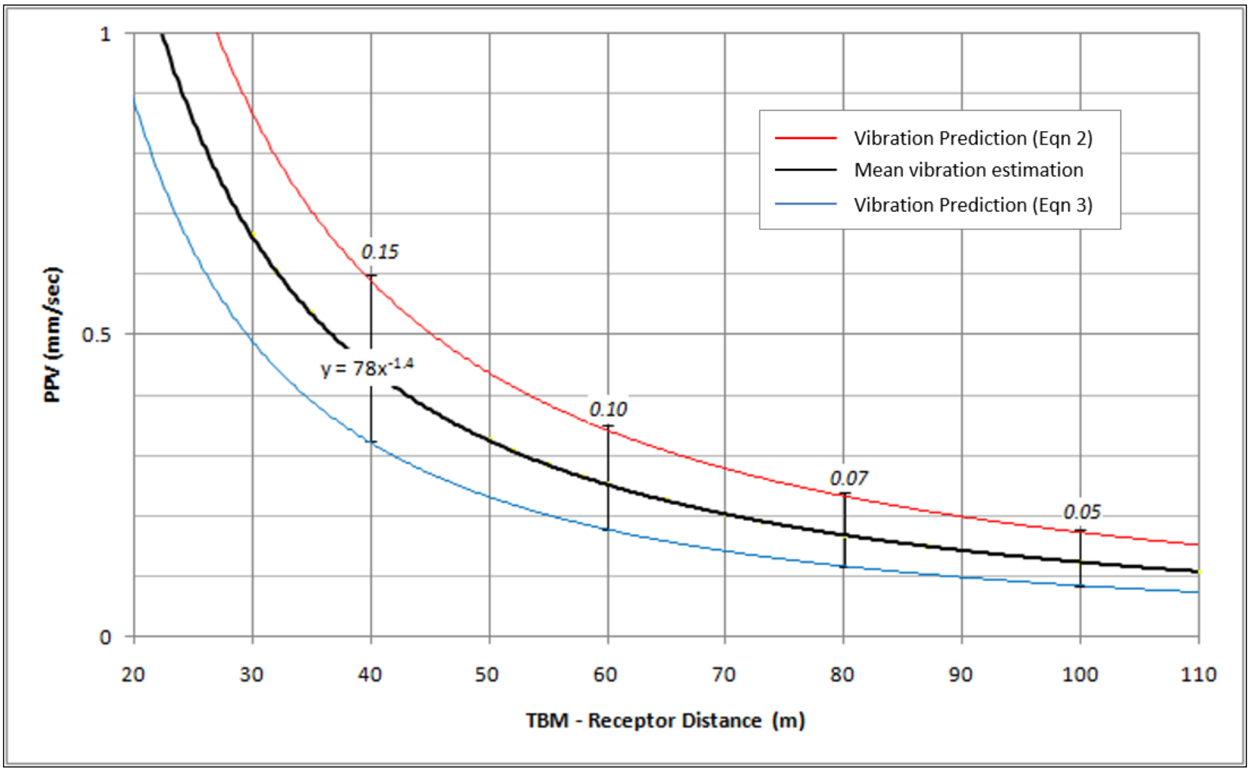
$$PPV_{TBM} = PPV_{ref} \times \left(\frac{25}{r}\right)^{1.5}$$

Where

- PPV_{TBM} is the resultant PPV at ground surface level, in/sec
- PPV_{ref} is the reference vibration level at 25 feet, in/sec as measured by Wilkinson Murray[46]
- r is the slant distance of the receptor from the TBM cutterhead, m

The predictions using Equation 2 and Equation 3 are presented in *Figure 3.5*. As both empirical methods were validated, both predictions were adopted to serve as lower and upper bound values for the assessment.

Figure 3.5: Comparison of Empirical Vibration Predictions



Source: O'Dempsey A, 15 July 2019

Based on the average empirical equation shown in *Figure 3.5*, most receptors are predicted to be exposed to vibration levels of 0.01 to 0.67 mm/s, which correspond to a Negligible to Small impact magnitude. Due to the distance of receptors from the tunnel alignment, vibration levels are predicted to drop below 0.14 mm/s for receptors such as residences within the Windsor Park estate (R1), receptors at the SICC Island Clubhouse (R2) and rangers at the Windsor Nature Park NParks Office (R4) i.e. Negligible impact magnitude.

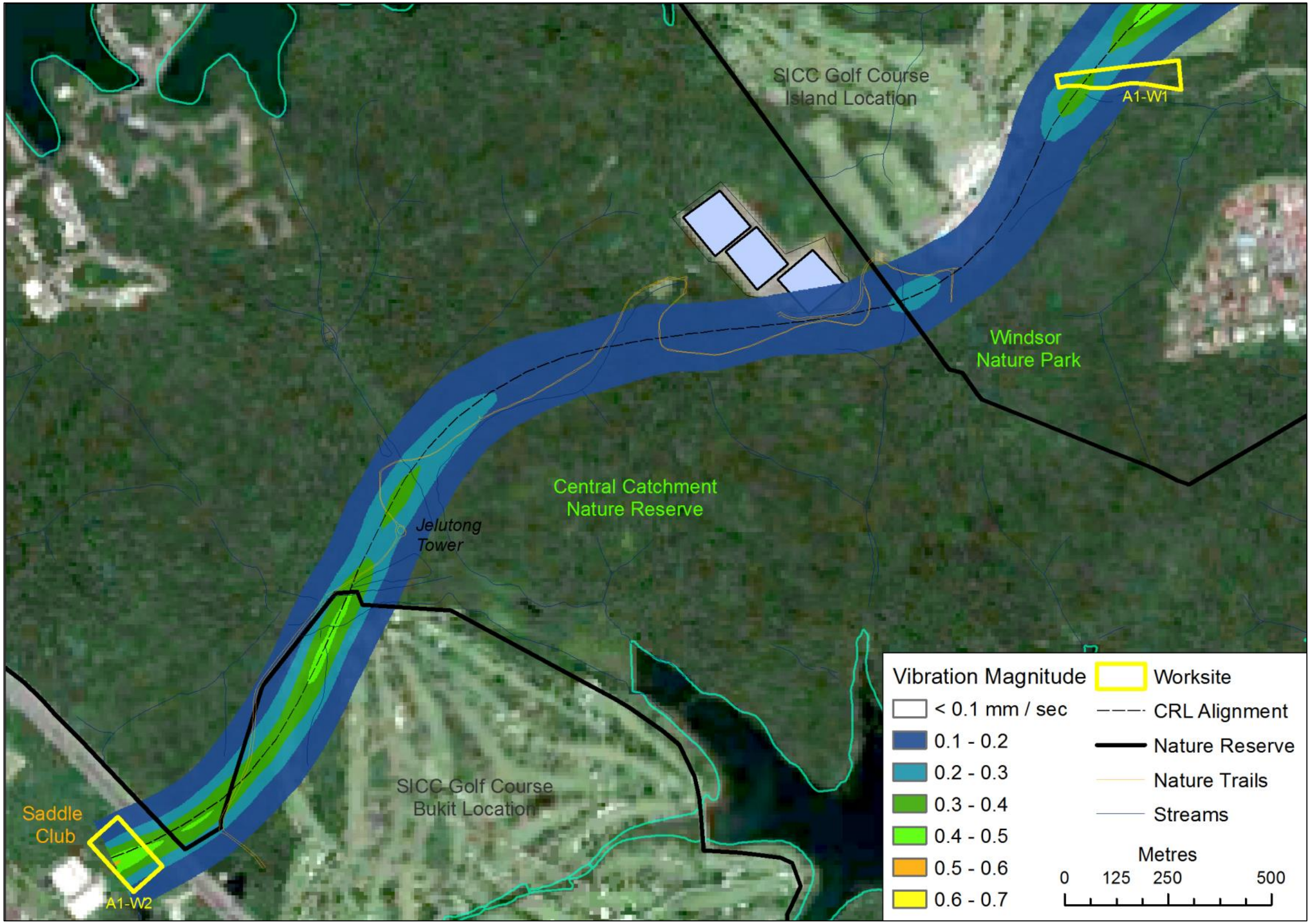
Based on the empirical equation, depending on the underlying geological conditions in the area, vibration levels above 0.14 mm/s may be encountered by receptors located at up to approximately 90 m from the TBM cutterhead. Golfers at the SICC Island golf course (R3), recreational users of the Windsor Nature Park and CCNR trails (R5 & R6) users of the Bukit Timah Saddle Club facilities (R7) and riding arena (R8) may therefore be exposed to levels above 0.14 mm/s but less than 1 mm/s i.e. Small impact magnitude. Due to the nature of the recreational activities being undertaken, the duration of exposure of recreational receptors is expected to be less than one day ie temporary.

The full contour of the predicted vibration levels along the tunnel alignment route is presented in *Figure 3.6*. It is noted that actual contours will be localized around the TBM, and will move along the tunnel alignment as the TBM advances at a rate of 3 to 7 m per day.

It is noted that the above vibration predictions are calculated using PPV (mm/s), which is a vector sum value of vibration components along three perpendicular axes(47). This means that there is a directional aspect to vibration in addition to amplitude of displacement. Where there are two or more vibration sources within the same location, an additive effect only happens if the resultant PPV from each source occurs along the same vector or axis. In an uncontrolled environment i.e. outside a laboratory, such an occurrence is highly unlikely to happen. It is therefore unlikely that there will be an additive effect of the predicted vibration levels from construction activities, with baseline vibration levels.

A summary of the magnitude and significance of vibration impacts during Project construction is provided in *Table 3.24*.

Figure 3.6   Predicted Vibration Contours along Alignment Option 1 during Tunnelling



Source: O'Dempsey T, 2019

Table 3.24: Impact Magnitude & Significance for Vibration during Project Construction

Source of Impact	Impact Summary	Impact Magnitude	Duration of Exposure	Impact Significance
Construction of A1-W1 (LS/VS) launch shaft	Vibration monitoring results for rock excavation activities undertaken in similar geological conditions indicate that vibration will be at or less than 0.19 mm/s. Vibration levels will be just perceptible at SICC Island clubhouse. The frequency of charge detonation will be one cycle per day over an estimated duration of three weeks. However, it is noted that vibration from rock excavation will be instantaneous ie temporary duration.	Small	Temporary (< 1 day)	Negligible
Piling (extraction of casings)	**<u>A1-W1 (LS/VS)</u>** • Vibration levels are calculated to be 0.9 mm/s at the nearest outdoor receptor locations ie Windsor Nature Park trail (R5) and SICC Island golf course (R3) during piling activities ie perceptible but not likely to generate adverse feedback. Due to the nature of the recreational activity undertaken by the receptors, the duration of exposure will be less than 1 day ie temporary duration.	Small	Temporary (< 1 day)	Negligible
	• Vibration levels are calculated to be less than 0.14 mm/s at the SICC Island clubhouse (R2) and at the nearest residence in Windsor Park estate (R1). These levels are below the guidance value for human perceptibility of low frequency vibration.	Negligible	Medium term (1 – 6 months)	Negligible
	<u>A1-W2 (LS/VS)</u> Vibration levels due to piling activities are calculated to be 0.2 mm/s for riders at the Bukit Timah Saddle Club riding arena. It is noted that this is within the range of the recorded baseline vibration levels of 0.254 – 0.889 mm/s recorded for locations by the side of a road, and more than 100 m from the PIE. While these levels are above the guidance threshold of human perceptibility, it is unlikely that these levels will cause particular alarm to riders. Due to the lack of studies establishing threshold levels for horses, the health and safety impacts to riders due to startle reaction of horses will be conservatively assessed. Due to the nature of the recreational activity undertaken by the receptors, the duration of exposure will be less than 1 day ie temporary duration.	Small	Temporary (< 1 day)	Negligible
	• Vibration levels for members using the facilities within the Bukit Timah Saddle Club (R7) are predicted to be less than 0.14 mm/s. Due to the nature of the	Negligible	Temporary (< 1 day)	Negligible

Source of Impact	Impact Summary	Impact Magnitude	Duration of Exposure	Impact Significance
Piling (extraction of casings)	recreational activity undertaken by the receptors, the duration of exposure will be less than 1 day ie temporary duration.			
Construction of Tunnel	**Tunnel Alignment** • Vibration due to tunnelling is predicted to be less than 0.14 mm/s for residences at Windsor Park estate (R1), workers at the SICC Island Clubhouse (R2) and rangers at the Windsor Nature Park NParks office (R4). Vibration levels will likely be intermittent throughout the day and may last from two weeks to one month until the TBM passes by ie short term exposure duration.	Negligible	Short term (< 1 month)	Negligible
	• Vibration due to tunnelling is predicted to be between 0.2 and 0.7 mm/s for golfers at SICC Island golf course (R3), users of trails within Windsor Nature Park (R5) and CCNR (R6) and users of the Bukit Timah Saddle Club facilities (R7) and riding arena (R8). Due to the nature of recreational activities being undertaken, the duration of exposure is expected to be less 1 day ie temporary.	Small	Temporary (< 1 day)	Negligible
	• Vibration due to tunnelling is predicted to be less than 0.14 mm/s for golfers at Champions Golf course (R9). Due to the nature of recreational activities being undertaken, the duration of exposure is expected to be less 1 day ie temporary.	Negligible	Temporary (< 1 day)	Negligible

3.6.2.3 Mitigation Measures

The findings of the assessment indicate that vibratory piling and tunnelling for Alignment Option 1 will result in Negligible vibration impacts at human receptors near the aboveground worksites and the tunnel alignment. In view of the embedded controls that will be in place to manage the vibration impacts and taking into consideration the temporary to short term exposure of most human receptors, no additional mitigation measures have been recommended. It is noted that measures to reduce vibration levels from tunnelling works for ecological receptors have been identified and are presented in *Chapter 5* of this report.

For best practice however, it is recommended that stakeholder engagement be undertaken with the Bukit Timah Saddle Club management prior to and during vibration generating activities at A1-W2 (LS/VS). Advance notice should be provided for such activities to allow measures to be undertaken to minimise potential health and safety risks to equestrian riders at the riding arena (R8).

A summary of the vibration impact assessment for Alignment Option 1 is presented in *Table 3.25*.

Table 3.25: Impact Assessment Summary for Vibration

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to vibration generated during Project construction phase					
Nature	Negative	The Project will result in vibration levels which may exceed current baseline levels.			
Type	Direct	Recreational users and nearby residents will be directly exposed to vibration levels generated from worksites during rock excavation of launch shaft at A1-W1 (LS/VS) worksite, piling of ERSS at launch shafts at A1-W1 (LS/VS) and A1-W2 (LS/VS) worksites, and construction of tunnel.			
Duration	Temporary	Due to the nature of recreational activities being undertaken by receptors around the A1-W1 (LS/VS) and A1-W2 (LS/VS) worksites, the duration of their exposure will be less than 1 day.			
	Short term	Due to the nature of the vibration generating works, exposure duration of receptors to vibration from rock excavation works during construction of launch shaft at A1-W1 (LS/VS) and operation of TBM is estimated to be short term (< 1 month) at most.			
	Medium term	Residents located within close proximity to the worksites A1-W1 (LS/VS) and A1-W2 (LS/VS) may be exposed to vibration from piling works over a period of up to 6 months.			
Extent	Local	Effects may be experienced by residents near the worksites, workers and recreational users of the SICC Island Clubhouse and recreational users of CCNR trails and Bukit Timah Saddle Club facilities/riding arena.			
Frequency	Continuous	Vibration will be generated continuously during vibratory extraction of casings during installation of secant bored piles as ERSS for the launch shafts, which will be a short term activity.			
	Intermittent	Vibration will be generated intermittently during the operation of a TBM.			
	Transient	Instantaneous and transient vibration will be generated during rock excavation works assumed to take place on a daily basis during construction of the A1-W1 (LS/VS) launch shaft.			
Receptor Sensitivity	N/A	Receptor sensitivity is accounted for in the impact magnitude criteria.			

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to vibration generated during Project construction phase					
Pre-Mitigation Impact Magnitude / Scale	Small	**Tunnel Alignment:** Receptors at the SICC Island golf course (R3), users of trails within Windsor Nature Park (R5) and CCNR (R6) and users of the Bukit Timah Saddle Club facilities (R7) and riding arena (R8) may experience levels between 0.2 and 0.7 mm/s during construction of the tunnel. **A1-W1 (LS/VS):** Receptors at SICC Island Clubhouse (R2) may experience levels between 0.14 and 1 mm/s during rock excavation at the A1-W1 launch shaft; and recreational users of Windsor Nature Park trail (R5) and SICC Island golf course (R3) during extraction of piling casings at A1-W1 launch shaft. **A1-W2 (LS/VS):** Equestrian riders at the Bukit Timah Saddle Club (R8) may experience levels between 0.14 and 1 mm/s during extraction of piling casings at the A1-W2 (LS/VS) launch shaft.	**Residual Impact** Impact Magnitude / Scale	Small	**Tunnel Alignment:** Receptors at the SICC Island golf course (R3), users of trails within Windsor Nature Park (R5) and CCNR (R6) and users of the Bukit Timah Saddle Club facilities (R7) and riding arena (R8) may experience levels between 0.2 and 0.7 mm/s during construction of the tunnel. **A1-W1 (LS/VS):):** Receptors at SICC Island Clubhouse (R2) may experience levels between 0.14 and 1 mm/s during rock excavation at the A1-W1 launch shaft; and recreational users of Windsor Nature Park trail (R5) and SICC Island golf course (R3) during extraction of piling casings at A1-W1 launch shaft. **A1-W2 (LS/VS):** Equestrian riders at the Bukit Timah Saddle Club (R8) may experience levels between 0.14 and 1 mm/s during extraction of piling casings at the A1-W2 (LS/VS) launch shaft.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts due to vibration generated during Project construction phase					
Pre-Mitigation Impact Magnitude / Scale	Negligible	**Tunnel Alignment:** Residences at the Windsor Park Estate (R1), workers at the SICC Island Clubhouse (R2), rangers at the Windsor Nature Park NParks office (R4), and golfers at Champions Golf course (R9) may experience levels less than 0.14 mm/s during construction of the tunnel. **A1-W1 (LS/VS):** Receptors at SICC Island Clubhouse (R2) and at the nearest residence in Windsor Park estate (R1) may experience levels less than the threshold of human perceptibility i.e. 0.14 mm/s during extraction of piling casings at A1-W1 (LS/VS) launch shaft. **A1-W2 (LS/VS):** Users of facilities within the Bukit Timah Saddle Club premises (R7) may experience levels less than the threshold of human perceptibility i.e. 0.14 mm/s during piling at A1-W2 (LS/VS) launch shaft.	**Residual Impact** Impact Magnitude / Scale	Negligible	**Tunnel Alignment:** Residences at the Windsor Park Estate (R1), workers at the SICC Island Clubhouse (R2), rangers at the Windsor Nature Park NParks office (R4), and golfers at Champions Golf course (R9) may experience levels less than 0.14 mm/s during construction of the tunnel. **A1-W1 (LS/VS):** Receptors at SICC Island Clubhouse (R2) and at the nearest residence in Windsor Park estate (R1) may experience levels less than the threshold of human perceptibility i.e. 0.14 mm/s during extraction of piling casings at A1-W1 (LS/VS) launch shaft. **A1-W2 (LS/VS):** Users of facilities within the Bukit Timah Saddle Club premises (R7) may experience levels less than the threshold of human perceptibility i.e. 0.14 mm/s during piling at A1-W2 (LS/VS) launch shaft.
Pre-Mitigation Significance	Negligible	Negligible impacts due to vibration are likely to be experienced by receptors during rock excavation at the A1-W1 (LS/VS) launch shaft, during piling works at A1-W1 (LS/VS) and A1-W2 (LS/VS) launch shafts and during the construction of the tunnel.	**Residual Impact** Significance	Negligible	Negligible impacts due to vibration are likely to be experienced by receptors during rock excavation at the A1-W1 (LS/VS) launch shaft, during piling works at A1-W1 (LS/VS) and A1-W2 (LS/VS) launch shafts and during the construction of the tunnel.

4 AIR QUALITY

4.1 INTRODUCTION

This chapter presents an assessment of the impacts to ambient air quality as a result of activities associated with the construction and operation phase of Alignment Option 1.

This chapter is structured as follows:

- *Section 4.2* defines the scope of the assessment*;*
- *Section 4.3* presents a summary of the baseline air quality within the Project Study Area*;*
- *Section 4.4* provides an overview of the methodology used to assess the impacts to air quality; and
- *Section 4.5* provides an assessment of the potential impacts during the construction phase of the Project.

4.2 SCOPE OF THE ASSESSMENT

The pre-construction and construction activities will give rise to dust emissions that have potential to result in impact to human health. In considering ambient air quality, dust is usually categorised into three particulate size classifications or fractions:

- Total Suspended Particulate (TSP) – Particles of less than 50 µm in aerodynamic diameter;
- PM_{10} - Particles of less than 10 µm in aerodynamic diameter; and
- $PM_{2.5}$ - Particles of less than 2.5 µm in aerodynamic diameter.

The size fractions are cumulative, so that PM_{10} also includes $PM_{2.5}$ and TSP includes both PM_{10} and $PM_{2.5}$. Of these size fractions, only PM_{10} and $PM_{2.5}$ have the potential to enter the human respiratory system (ie they are inspirable). Of the inspirable size fractions, studies indicate that 85 – 90% of dust generated from construction activities typically comprises particle in the size range between 2.5 and 10 µm [(9)]. For the purposes of this assessment, dust will therefore be assessed in terms of PM_{10}.

A number of types of impact/activities were considered but either have been screened out from further assessment, as they are not expected to result in any impacts to the nearby air quality receptors, or covered elsewhere in the report. These include:

<u>General</u>

- The scope of the assessment in this chapter is focused on impacts to human health from dust emissions associated with construction activities. Assessment of impacts to specific habitat, flora and fauna is discussed in further detail in *Volume III, Chapter 5: Ecology and Biodiversity*.
- The committed development in closest proximity to the Project consists of the PUB's proposed water pipeline installation from Bukit Kalang to Upper Thomson Road. Consultation between the PUB and the LTA has been undertaken during the course of this study to ensure that works will

not occur at the same time as the Project. Cumulative air quality impacts have therefore not been undertaken in this EIA. PUB and LTA are working together to reduce the combined footprint of PUB and LTA's possible worksites to minimize overall environmental impact. In the event that new committed developments are identified, the LTA has committed to undertake a cumulative impact assessment at the AES of the Project.

Construction

- As information pertaining to the number of construction vehicles and equipment was not available at the stage of writing, a set of 'typical' construction vehicles and equipment used for similar scale and nature of projects have been obtained from the project engineers (see *Volume I, Annex 1.0*). Upon review of this, it is anticipated that the number of diesel engines that will be operated during the construction will unlikely be more than 30 at any one point of time within a worksite. Furthermore, only off-road diesel engines meeting the emission standards stipulated within the *Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations 2012* will be used. Therefore, the emissions associated with the use of diesel engines are not expected to be significant and these emissions have been screened out from further assessment. However, the project is still at the preliminary stage and the number of construction vehicles and equipment is subject to change. Based on the criteria established by the United Kingdom (UK) Institute of Air Quality Management (IAQM), should the construction require more than 500 diesel engines (or heavy duty vehicles)[10] on a daily basis and averaged over a year, an impact assessment on the vehicular emissions from the diesel engines should be conducted.

- Fire incidents could occur during the construction and operation phases. Depending on the causes, the fire could occur aboveground at the worksites or shafts, or underground within the tunnel. With reference to *Annex 1.0*, the likelihoods of a fire occurrence for a number of scenarios have been identified based on a review of historical events and are summarized as follows:

Table 4.1: Summary of Likelihood Designations for Fire Scenarios Studied

Phase	Scenario	Likelihood
Construction	Fire within tunnelling worksites	*Unlikely*
	Fire within aboveground worksites	*Unlikely*
Operation	Fire within tunnel	*Possible*
	Fire within aboveground ventilation shafts/facility buildings	*Possible*

During a fire incident, smoke and dust will be released to the atmosphere, leading to an impact on local air quality. However, a number of local regulatory frameworks as well as LTA's internal protocols specify comprehensive requirements on fire protection systems and emergency response procedures. Moreover, in the event of a fire, the nature of response is to combat it as soon as possible. As such, the durations of a fire and its secondary impact of smoke emissions to the atmosphere are expected to be transient. Considering this, the impacts to air quality due to a fire occurrence during the construction and operation stages have been screened out from further assessment.

- The installation of piezometer wells and settlement markers will involve activities similar to borehole drilling works during the soil investigation phase. With reference to the SI EIA, impacts to air quality could arise from the generation of dust. Noting that the scale of ground disturbance works would be small and control measures will be in place, the impact magnitude was considered as *Negligible*. As it is believed that potential impact to air quality due to piezometer wells and settlement markers will be largely similar to the borehole drilling works, this has been screened out from further assessment.

4.3 ADMINISTRATIVE FRAMEWORK

Singapore has adopted ambient air quality targets which are largely based on the World Health Organization Air Quality Guidelines (WHO AQGs). The air quality targets for PM_{10} are specified for short-term averaging period as well as long-term averaging period and are 50 μg/m^3 for 24-hour mean 20 μg/m^3 for annual mean.

4.4 SUMMARY OF RELEVANT BASELINE CONDITIONS

Key findings of baseline ambient air quality conditions are summarised as follows:

- The main existing sources of emissions to air in the Study Area are vehicular emissions along the roads on the boundary of the CCNR; namely Upper Thomson Road, Lornie Road and the PIE.
- Other sources of vehicular emissions include trucks, occasional emergency vehicles and NParks' maintenance vehicles operated on an ad-hoc basis within the CCNR, as well as lawn mowers operated within the golf courses bounding the CCNR.
- A review of historical measurements of PM_{10} by the NEA for the years between 2011 and 2013 indicates that over the long-term, the ambient concentrations of particulate matter in the vicinity of the study area were generally above the Singapore 2020 and long-term ambient air quality targets.
- Short-term measurements recorded at select locations along Alignment Option 1 from November 2014 to January 2015 (*Table 6.3* of *Volume II, Chapter 6* of the SI EIA Report for the Project*)* (1) indicate that ambient concentrations of PM_{10} and $PM_{2.5}$ in the Study Area were generally within the Singapore ambient air quality targets, though levels in excess of the targets were recorded on some days of Round 1 of the survey.

4.5 ASSESSMENT METHODOLOGY

The approach to air quality assessment combines impact magnitude with sensitivity to determine impact significance. Dust from construction activities is typically re-deposited within 350 m(9) of the source, thus the scale of impacts predicted from each worksite are within this range. Considering the type of construction activities that will be undertaken at the proposed worksites along Alignment Option 1, criteria for 'earthworks' and 'construction' published in the Guidance on the Assessment of Dust from Demolition and Construction by the UK Institute of Air Quality Management (IAQM)(9) have been adopted and are outlined in *Table 4.2*.

Table 4.2: Magnitude Criteria for Assessment of Dust Impacts

Magnitude of Impacts	Definitions

Negligible	• No demolition or building construction works; or
	• Earthworks:
	    • Total site area < 500 m^2;
	    • Soil type with large grain size (eg sand); and/or
	    • Total material moved < 5,000 tonnes.

Small	• Demolition:
	    • Total building volume < 20,000 m^3;
	    • Construction material with low potential for dust release (eg metal cladding, timber); and/or
	    • Demolition activities undertaken < 10 m above ground level; and/or
	    • Demolition during wetter months
	• Construction:
	    • Total building volume < 25,000 m^3; and/or
	    • Construction material with low potential for dust release, eg metal cladding, timber.
	• Earthworks:
	    • Total site area 500 m^2 to 2,500 m^2;
	    • Soil type with large grain size (eg sand);
	    • <5 heavy earth moving vehicles active at any one time; and/or
	    • Total material moved 5,000 to 20,000 tonnes.
	• Trackout:
	    • <10 HDV (>3.5t) outward movements[Note 1] in any one day[Note 2];
	    • Surface material with low potential for dust release; and/or
	    • Unpaved road length <50 m.

Medium	• Demolition:
	    • Total building volume 20,000 – 50,000 m^3;
	    • Construction material with potential for dust release; and/or
	    • Demolition activities undertaken 10 - 20 m above ground level.
	• Construction:
	    • Total building volume 25,000 – 100,000 m^3;
	    • Potentially dusty construction material eg concrete; and/or
	    • On site concrete batching.
	• Earthworks:
	    • Total site area 2,500 m^2 to 10,000 m^2;
	    • Moderately dusty soil type (eg silt);
	    • 5 – 10 heavy earth moving vehicles active at any one time; and/or
	    • Total material moved 20,000 tonnes to 100,000 tonnes.
	• Trackout:
	    • 10 – 50 HDV (>3.5t) outward movements[Note 1] in any one day[Note 2];
	    • Moderately dusty surface material (eg high in clay content); and/or
	    • Unpaved road length 50 m – 100 m.

Magnitude of Impacts	Definitions

Large	• Demolition:
	  • Total building volume > 50,000 m^3;
	  • Potentially dusty construction material eg concrete;
	  • On site crushing and screening; and/or
	  • Demolition activities undertaken > 20 m above ground level.
	• Construction:
	  • Total building volume > 100,000 m^3;
	  • Potentially dusty construction material eg concrete; and/or
	  • On site concrete batching and sandblasting.
	• Earthworks:
	  • Total site area > 10,000 m^2;
	  • Potentially dusty soil type (eg clay, which will be prone to suspension when dry due to small particle size);
	  • >10 heavy earth moving vehicles active at any one time; and/or
	  • Total material moved > 100,000 tonnes.
	• Trackout:
	  • >50 HDV (>3.5t) outward movements (Note 1) in any one day (Note 2);
	  • Potentially dusty surface material (eg high in clay content); and/or
	  • Unpaved road length > 100 m.

Note 1: A vehicle movement is a one-way journey ie from A to B, and excludes the return journey
Note 2: HDV movements during a construction project vary over its lifetime, and the number of movements is the maximum not the average.

The sensitivity of human receptors to the health effects of dust follows the IAQM criteria for PM_{10} as presented in *Table 4.3*.

Table 4.3: Determination of Receptor Sensitivity

Sensitivity	Description
Low	• Human Receptors: • Locations where human exposure is transient (Note 1)
Medium	• Human Receptors: • Locations where the people exposed are workers (Note 2), and exposure is over a time period relevant to the air quality objective for PM_{10} (in the case of the 24-hour objectives, a relevant location would be one where individuals may be exposed for eight hours or more in a day) (Note 3).
High	• Human Receptors: • Locations where members of the public are exposed over a time period relevant to the air quality objective for PM_{10} (in the case of the 24-hour objectives, a relevant location would be one where individuals may be exposed for eight hours or more in a day). Indicative examples include residential properties, hospitals, schools and residential care homes.

Sensitivity	Description
Note 1: In accordance with the IAQM guidance, there are no standards that apply to short-term exposure, eg one or two hours, but there is still a risk of health impacts, albeit less certain.	
Note 2: Notwithstanding the fact that the air quality objectives and limit values do not apply to people in the workplace, such people can be affected to exposure of PM_{10}. However, they are considered to be less sensitive than the general public as a whole because those most sensitive to the effects of air pollution, such as young children are not normally workers. For this reason workers are included in the medium sensitivity category.	
Note 3: This follows Department for Environment Food and Rural Affairs (DEFRA) guidance as set out in Local Air Quality Management –Technical Guidance published in 2009.	

The impact significance has been designated taking into consideration the impact magnitude and receptor sensitivity, using the matrix shown in *Figure 4.1*.

Figure 4.1: Impact Significance for Air Quality

		Sensitivity/Vulnerability/Importance of Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

4.6 ASSESSMENT OF IMPACTS DURING PROJECT CONSTRUCTION PHASE

The Project construction will operate within the administrative framework for Singapore. Measures to reduce potential environmental impacts in line with regulatory requirements will therefore be implemented as part of the Project design and are known as “embedded controls” (refer to *Volume I, Chapter 4* for further details). The built in embedded controls that have been taken into consideration during the assessment of impacts on air quality during construction are summarised in in *Volume I, Annex 2.0, Table A2.3.*

4.6.1 Impacts to Air Quality due to Construction Phase

4.6.1.1 Sources of Impact

Sources of impacts to Air Quality during Project Construction comprise of:

- Earthworks including:
    - Land clearance for the preparation of worksites and temporary lay down areas;
    - Excavation and rock excavation for launch shaft construction; and
    - Stockpiling of spoil within worksites.
- Construction of aboveground structures such as the facility building;
- Movement of construction vehicles and equipment on unpaved surfaces within the worksite; and
- Soil and/or construction material being tracked out by vehicles leaving the worksites.

4.6.1.2 Receptors

Human receptors located within 350 m from the worksites have the potential to be impacted by dust generated from construction activities. Sensitive receptors identified based on each worksite are presented in *Table 4.4,* along with the receptor sensitivity, and *Figures 4.2 to Figure 4.4*.

Table 4.4*: *Air Quality Sensitive Receptors

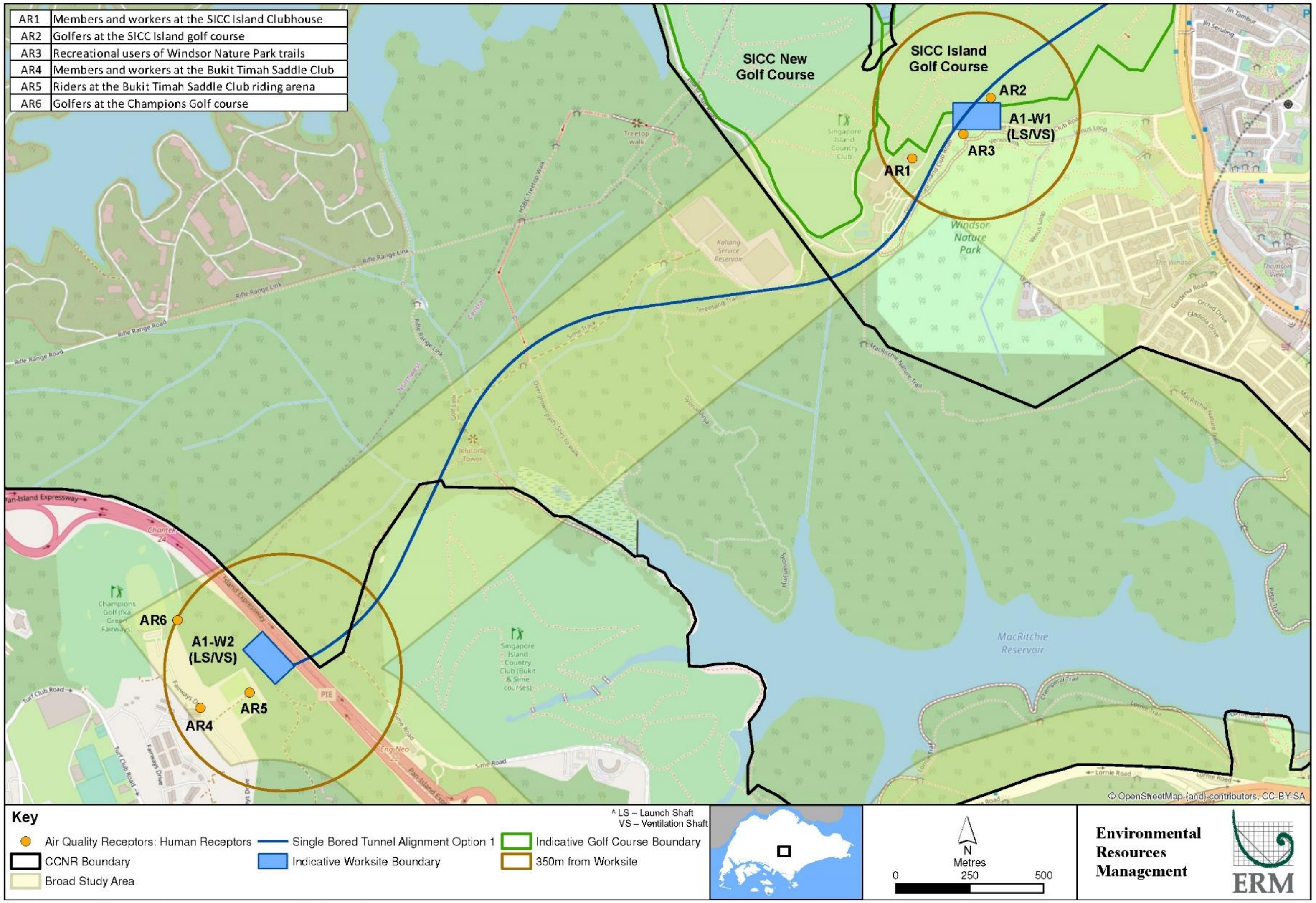
Receptor ID	Receptor	Nearest Worksite	Receptor Sensitivity
AR1	Members and workers at the SICC Island Clubhouse	A1-W1 (LS/VS)	Medium
AR2	Golfers at the SICC Island golf course	A1-W1 (LS/VS)	Low
AR3	Recreational users of Windsor Nature Park trails	A1-W1 (LS/VS)	Low
AR4	Members and workers at the Bukit Timah Saddle Club	A1-W2 (LS/VS)	Medium
AR5	Riders at the Bukit Timah Saddle Club riding arena	A1-W2 (LS/VS)	Low
AR6	Golfers at the Champions Golf course	A1-W2 (LS/VS)	Low

4.6.1.3 Impact Magnitude & Significance

A summary of the magnitude and significance of impacts to air quality during Project construction is provided in *Table 4.5*.

Figure 4.2: Overview of Air Quality Sensitive Receptors for Alignment Option 1

AR1	Members and workers at the SICC Island Clubhouse
AR2	Golfers at the SICC Island golf course
AR3	Recreational users of Windsor Nature Park trails
AR4	Members and workers at the Bukit Timah Saddle Club
AR5	Riders at the Bukit Timah Saddle Club riding arena
AR6	Golfers at the Champions Golf course



File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_III_AQ_Receptors_A1_v2.mxd
Date: 27/8/2019

Figure 4.3: Air Quality Sensitive Receptors for A1-W1

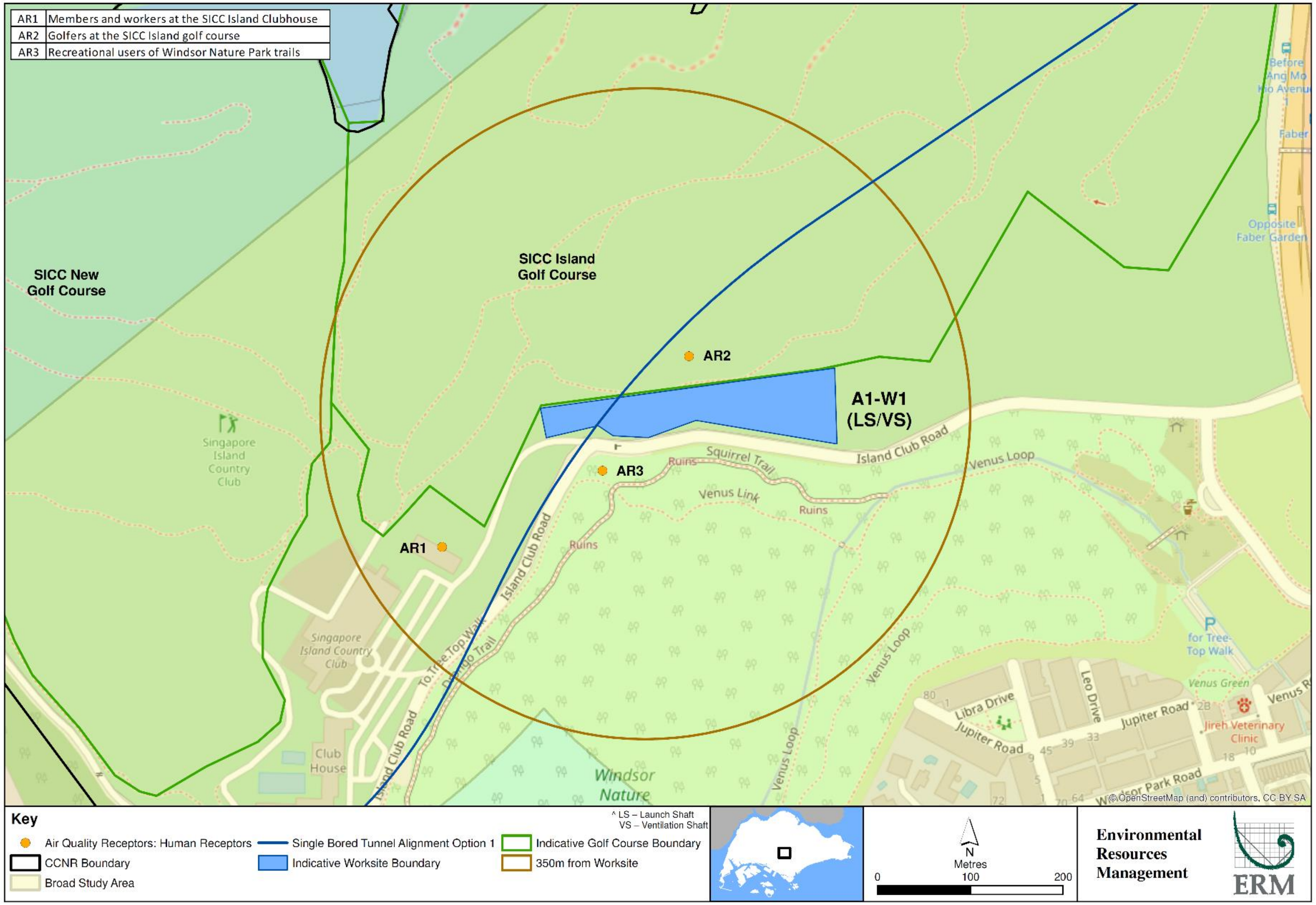


Figure 4.4: Air Quality Sensitive Receptors for A1-W2

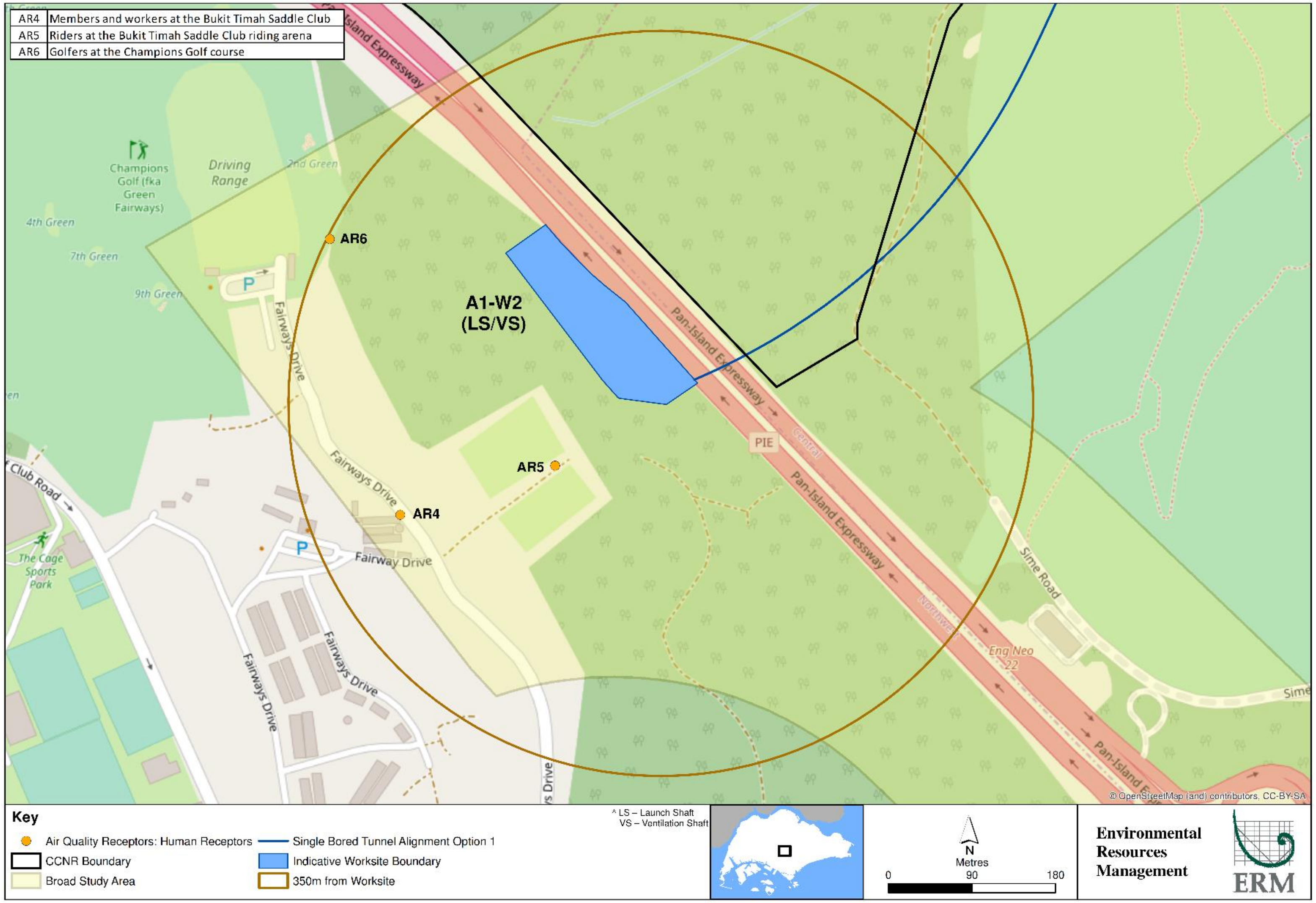


Table 4.5*: *Impact Magnitude & Significance for Air Quality during Project Construction

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W1 (LS/VS)				
Elevated dust level	Land clearance will be required prior to the commencement of the construction activities. The main activities undertaken will involve vegetation clearance and land levelling. As estimated in *Volume I, Chapter 2, Table 2.4*, the area of land to be cleared is approximately 15,000 m^2 for A1-W1. Based on a review of borehole data at A1-W1, the surface soil type comprises very thin Fill layer (<1m) followed by residual soil (ie slightly gravelly, sandy silt) to the depth of over 20 m below ground level. The pre-construction activities will not require demolition of any existing structures. There will be no concrete batching plant on site. Prior to tunnelling work, excavation and rock excavation will be conducted for shaft construction at worksite A1-W1. In addition, spoil and crushed rock will also be generated from the tunnelling work. With reference to *Volume I, Chapter 2, Section 2.5.3.7*, the total volume of spoil and crushed rock for alignment option *1* is expected to be 980,000 m^3. At the point of writing, the volume that will be handled by each of the worksites is unknown. To provide a context, it is assumed that the volume will be equally split between the worksites and thus the volume that will be handled at A1-W1 is 490,000 m^3. The amount of excavated material generated for construction of launch shaft could be up to 1,292,000 tonnes in weight based on a density of 2,636 kg/m^3 for G(II) to G(III) Bukit Timah Granite[(11)]. Trackout may occur when heavy duty vehicles leave the construction site with dusty material, which may then spill onto the road, and/or when heavy duty vehicles transfer dust and dirt onto the road having travelled over muddy ground on site. Based on a typical dump truck capacity of 5 to 8 m^3, it is estimated that up to 24 heavy duty vehicles could be required for the removal of 150 m^3 of spoil per day. Consequently, the number of outward movements in any one day will be 24 trips.	Medium	AR1: Medium AR2: Low AR3: Low	AR1: Moderate AR2: Minor AR3: Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Elevated dust level	Worksite A1-W1 will be transformed into a facility building upon completion of tunnelling works. The facility building will be two-storey of approximately 10 m with a footprint of 70 m x 40 m (ie volume 28,000 m^3). The air quality impacts associated with the pre-construction and construction activities will be managed through the implementation of control measures as discussed in *Section 4.5* above. Notably, the *LTA's General Specification for Safety, Health and Environment, October 2018* specifies the submission of an air pollution control plan within 3 months of contract award. The air pollution control plan should include air pollution control details of identified air sensitive receptors, air pollution sources and controls etc. In addition to this, the *LTA's General Specification for Safety, Health and Environment, October 2018* also enforces use of canvas sheets or erosion control blankets to cover temporary stockpiles; removal of stockpiles for disposal at an authorized staging/disposal ground at the end of every workday; wheel washing of vehicles at dedicated washing bay prior leaving the worksites; implementation of dust control measures such as dust netting etc. In consideration of the above and the magnitude of criteria defined in *Table 4.2*, the magnitude of impact of elevated dust level at worksite A1-W1 is evaluated to be **Medium**.			
A1-W2 (LS/VS)				
Elevated dust level	Land clearance will be required prior to the commencement of the construction activities. The main activities undertaken will involve vegetation clearance and land levelling. As estimated in *Volume I, Table 2.4*, the area of land to be cleared is approximately 15,000 m^2 for A1-W2. Based on a review of borehole data at A1-W1*,* the surface soil type comprises Fill layer followed by slightly gravelly sandy silt. The pre-construction activities will not involve demolition of any existing structures. There will be no concrete batching plant on site. Prior to tunnelling work, excavation will be conducted for shaft construction at worksite A1-W2. In addition, spoil and crushed rock will also be generated from the tunnelling work. With reference to *Volume I, Chapter 2, Section 2.5.3.7*, the total volume of spoil and crushed rock for alignment option	Medium	AR4: Medium AR5: Low AR6: Low	AR4: Moderate AR5: Minor AR6: Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Elevated dust level	*1* is expected to be 980,000 m^3. At the point of writing, the volume that will be handled by each of the worksites is unknown. To provide a context, it is assumed that the volume will be equally split between the worksites and thus the volume that will be handled at A1-W2 is 490,000 m^2. The amount of excavated material generated for construction of launch shaft could be up to 1,292,000 tonnes in weight based on a density of 2,636 kg/m^3 for for G(II) to G(III) Bukit Timah Granite[(11)]. Trackout may occur when heavy duty vehicles leave the construction site with dusty material, which may then spill onto the road, and/or when heavy duty vehicles transfer dust and dirt onto the road having travelled over muddy ground on site. Based on a typical dump truck capacity of 5 to 8 m^3, it is estimated that up to 24 heavy duty vehicles could be required for the removal of 150 m^3 of spoil per day. Consequently, the number of outward movements in any one day will be 24 trips. Worksite A1-W2 will be transformed into a facility building upon completion of tunnelling works. Each facility building will be two-storey of approximately 10 m with a footprint of 70 m x 40 m (ie total volume 28,000 m^3). The air quality impacts associated with the pre-construction and construction activities will be managed through the implementation of control measures as discussed in *Section 4.5* above. Notably, the *LTA's General Specification for Safety, Health and Environment, September 2016* specifies the submission of an air pollution control plan within 3 months of contract award. The air pollution control plan should include air pollution control details of identified air sensitive receptors, air pollution sources and controls etc. In addition to this, the *LTA's General Specification for Safety, Health and Environment, October 2018* also enforces use of canvas sheets or erosion control blankets to cover temporary stockpiles; removal of stockpiles for disposal at an authorized staging/disposal ground at the end of every workday; wheel washing of vehicles at dedicated washing bay prior leaving the worksites; implementation of dust control measures such as dust netting etc. In consideration of the above and the magnitude of criteria defined in *Table 4.2*, the magnitude of impact of elevated dust level at worksite A1-W2 is evaluated to be **Medium**.			

4.6.1.4 *Mitigation Measures*

In addition to embedded controls, measures to avoid, minimise, and limit the magnitude of air quality impacts caused by the Project's construction phase are outlined in *Table 4.6*.

Table 4.6*: *Mitigation Measures for Air Sensitive Receptors during Project Construction

Category	Mitigation
General Mitigation Measures to be applied to all Worksites	• Phase potential dust generating activities such as land clearance, earthworks and building construction to minimise the area of ground exposed and the volume of soil and construction material handled at any one time. • Review construction plan and ensure availability of water for dust suppression on site. • Use water suppression during excavation and earth handling at exposed areas under dry weather. • Follow the approved Environmental Management and Monitoring Plan throughout the pre-construction and construction activities. • Re-vegetate exposed ground as soon as possible to stabilize surfaces once there are no further construction activities to be carried out at the affected areas. • Apply water to roads at a rate 2 litres/m^2/hour prior to and during truck use in dry conditions ie during non-raining day and during dry spells such as in the late Northeast monsoon period between late January and early March. • Ensure trucks undergo wheel washing at the washing bay prior to exit from site to prevent staining on public roads.
Specific Measures for Worksite A1-W1 (LS/VS)	• Strictly prohibit the use of water from stream Ma for water suppression. • Water suppression is to be controlled to the minimum necessary to reduce excess water runoff that may enter stream Ma. Close inspection to ensure that surface runoff is not entering stream Ma. • Undertake twice daily checks of Island Club Road, Thomson Road and other roads that will be used as the haul route for accidental spillage of spoil/earth being tracked out of the Project area. • Clean up any spoil/earth spillage onto the haulage routes immediately.
Specific Measures for Worksite A1-W2 (LS/VS)	• Undertake twice daily checks of the PIE and other roads that will be used as the haul route for accidental spillage of spoil/earth being tracked out of the Project area. • Clean up any spoil/earth spillage onto the haulage routes immediately.

Implementation management applicable to all worksites	• Continuously monitor PM_{10} levels at one location upwind and one location downwind of worksites. Should measurements indicate exceedances of 250 µg/m^3 averaged over a 15-minute period [(12)], mitigation measures shall be undertaken including but not limited to:
	    • Employ or increase water suppression to dust generating activity.
	    • Reduce the number of dust generating activities being undertaken.
	
	Note: Dust generation from the work area is indicated by low measurements upwind and high measurements downwind of the Project site boundary. If both upwind and downwind measurements are high, it is likely that ambient dust levels are due to contributing sources outside the Project Study Area, eg transboundary haze.

Category	Mitigation
Environmental Monitoring	• Contractor EHS team to undertake daily inspection of construction area. • Maintain a feedback log to track response to feedback received from stakeholders. • Maintain records of ambient dust measurement and checklist of the EMMP actions used across the Project area on a daily basis during construction.

4.6.1.5 Residual Impacts

Air quality impacts due to dust emission from construction activities can be managed by implementation of the mitigation measures listed in *Table 4.6*. A summary of the impact assessment criteria including the implementation of mitigation measures is in *Table 4.7*.

Table 4.7: ***Impact Assessment Summary for Elevated Dust Level***

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Air Quality Due to Elevated Dust Levels from Construction Activities					
Nature	Negative	Generation of dust			
Type	Direct	Human receivers directly exposed to dust			
Duration	Long-term	The construction will last for 5.5 years.			
Extent	Local	PM_{10} generated by construction activities will generally be deposited within 350 m of the worksite boundary.			
Scale	-	Significant increase in concentrations of PM_{10}.			
Frequency	Frequent	Daily throughout the construction period of 5.5 years.			
Receptor Sensitivity	**A1-W1 (LS/VS)** AR1: Medium	Members and workers at the SICC Island Clubhouse will likely be exposed to dust emission for eight hours or more in a day.			
	AR2: Low	Golfers at the SICC Island golf course will unlikely spend 8 hours at the areas within 350 m from the worksites.			
	AR3: Low	Recreational users of Windsor Nature Park trails will unlikely spend 8 hours at the areas within 350 m from the worksites.			
	A1-W2 (LS/VS) AR4: Medium	Members and workers at the Bukit Timah Saddle Club will likely be exposed to dust emission for eight hours or more in a day			
	AR5: Low	Riders at the Bukit Timah Saddle Club riding arena will unlikely spend 8 hours at the areas within 350 m from the worksites.			
	AR6: Low	Golfers at the Champions Golf course will unlikely spend 8 hours at the areas within 350 m from the worksites.			

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Air Quality Due to Elevated Dust Levels from Construction Activities					
Pre-Mitigation Impact Magnitude	**A1-W1 (LS/VS)** Medium	The area of land clearance for worksites A1-W1 is 15,000 m^2. The amount of spoil materials from the construction of launch shaft and tunnel is estimated to be 1,292,000 tonnes. An aboveground facility building will be constructed with a volume of approximately 8,400 m^3. Total outward movements are estimated to be 24 trips in any one day. There will be no demolition and concrete batching plant onsite. Dust emission will be managed through the implementation of embedded controls, as outlined in *Volume II, Annex 2*.	**Residual Impact Magnitude**	**A1-W1 (LS/VS)** Small	Mitigation measures will minimise the amount of dust that will be generated from construction activities, as well as the extent of the dust dispersion.
	A1-W2 (LS/VS) Medium	The area of land clearance for worksites A1-W2 is 15,000 m^2. The amount of spoil materials from the construction of launch shaft and tunnel is estimated to be 1,292,000 tonnes. An aboveground facility building will be constructed with a volume of approximately 8,400 m^3. There will be no demolition and concrete batching plant onsite. Dust emission will be managed through the implementation of embedded controls, as outlined in *Volume II, Annex 2*.		**A1-W2 (LS/VS)** Small	Mitigation measures will minimise the amount of dust that will be generated from construction activities, as well as the extent of the dust dispersion.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Air Quality Due to Elevated Dust Levels from Construction Activities					
Pre-Mitigation Impact Significance	Moderate	Impact magnitude of Medium combined with receptor sensitivity of Medium: **A1-W1 (LS/VS)** AR1: Members and workers at the SICC Island Clubhouse **A1-W2 (LS/VS)** AR4: Members and workers at the Bukit Timah Saddle Club	**Residual Impact Significance**	Minor	Residual impact magnitude of Small combined with receptor sensitivity of Medium: **A1-W1 (LS/VS)** AR1: Members and workers at the SICC Island Clubhouse **A1-W2 (LS/VS)** AR4: Members and workers at the Bukit Timah Saddle Club
	Minor	Impact magnitude of Medium combined with receptor sensitivity of Low: **A1-W1 (LS/VS)** AR2: Golfers at the SICC Island golf course AR3: Recreational users of Windsor Nature Park trails **A1-W2 (LS/VS)** AR5: Riders at the Bukit Timah Saddle Club riding arena AR6: Golfers at the Champions Golf course		Negligible	Residual impact magnitude of Small combined with receptor sensitivity of Low: **A1-W1 (LS/VS)** AR2: Golfers at the SICC Island golf course AR3: Recreational users of Windsor Nature Park trails **A1-W2 (LS/VS)** AR5: Riders at the Bukit Timah Saddle Club riding arena AR6: Golfers at the Champions Golf course

5 ECOLOGY & BIODIVERSITY

5.1 INTRODUCTION

This chapter presents an assessment of the impacts of activities associated with the construction and operation phase of Alignment Option 1 on ecology and biodiversity.

This chapter is structured as follows:

- *Section 5.2* defines the scope of the assessment*;*
- *Section 5.3* presents a summary of the baseline ecological environment and biodiversity within the Project Study Area*;*
- *Section 5.4* provides an overview of the methodology used to assess the impacts to ecology and biodiversity receptors; and
- *Section 5.5* provides an assessment of the potential impacts during the construction and operation phase of the Project.

5.2 SCOPE OF THE ASSESSMENT

The construction and operation activities associated with the tunnelling strategy for Alignment Option 1 were reviewed to identify those that were likely to impact ecology and biodiversity receptors in the Study Area (ie sources of impact). These activities were then further assessed to understand their magnitude and significance of impact on biodiversity values in the Project Area and Area of Influence.

The sources of impacts to ecological receptors are summarised in *Section 5.5.1.1*. Impacts to ecological receptors due to vibration during operation of the underground line were scoped out of this EIA as a result of a screening study summarised as follows. Based on empirical data and methods as per the US Federal Transport Authority for calculation of vibration during train operations, vibration levels are estimated to be at most 0.037 mm/s at the shallowest depth of 23 m bgl (see *Volume III, Chapter 3 Noise and Vibration*). This does not take into account best available technology such as floating slab-deck design for the railway track, which would further isolate vibration within the tunnel. In addition, measurements of the existing trainlines indicate PPV levels being below 0.14 mm/s. This is well within or at the lower ranges of the baseline vibration levels 0.254 - 0.508 mm/s measured within the CCNR at Jelutong Tower. On this basis, vibration from operation was scoped out for this Project.

The committed development in closest proximity to the Project consists of the PUB's proposed water pipeline installation from Bukit Kalang to Upper Thomson Road. Consultation between the PUB and the LTA has been undertaken during the course of this study to ensure that works will not occur at the same time as the Project. Cumulative impacts have therefore not been undertaken in this EIA. PUB and LTA are working together to reduce the combined footprint of PUB and LTA's possible worksites to minimize overall environmental impact. In the event that new committed developments are identified, the LTA has committed to undertake a cumulative impact assessment at the AES of the Project.

5.3 SUMMARY OF RELEVANT BASELINE CONDITIONS

Baseline ecological conditions and biodiversity richness of the Study Area are described in the *Site Investigation (SI) EIA, Volume II, Chapter 7* (Footnote 1) [1]. Additional baseline data has been obtained from NParks and LTA's Independent Reviewer to supplement the existing baseline data. Key findings are summarised below.

5.3.1 Key Baseline Conditions at Worksite Options

The specific baseline conditions at each project component are summarised in *Table 5.1*. The locations of the alignment corridor, and the worksites for Alignment Option 1 are presented in *Figure 5.1*, *Figure 5.2* and *Figure 5.3* against the habitat map developed as part of the baseline phase.

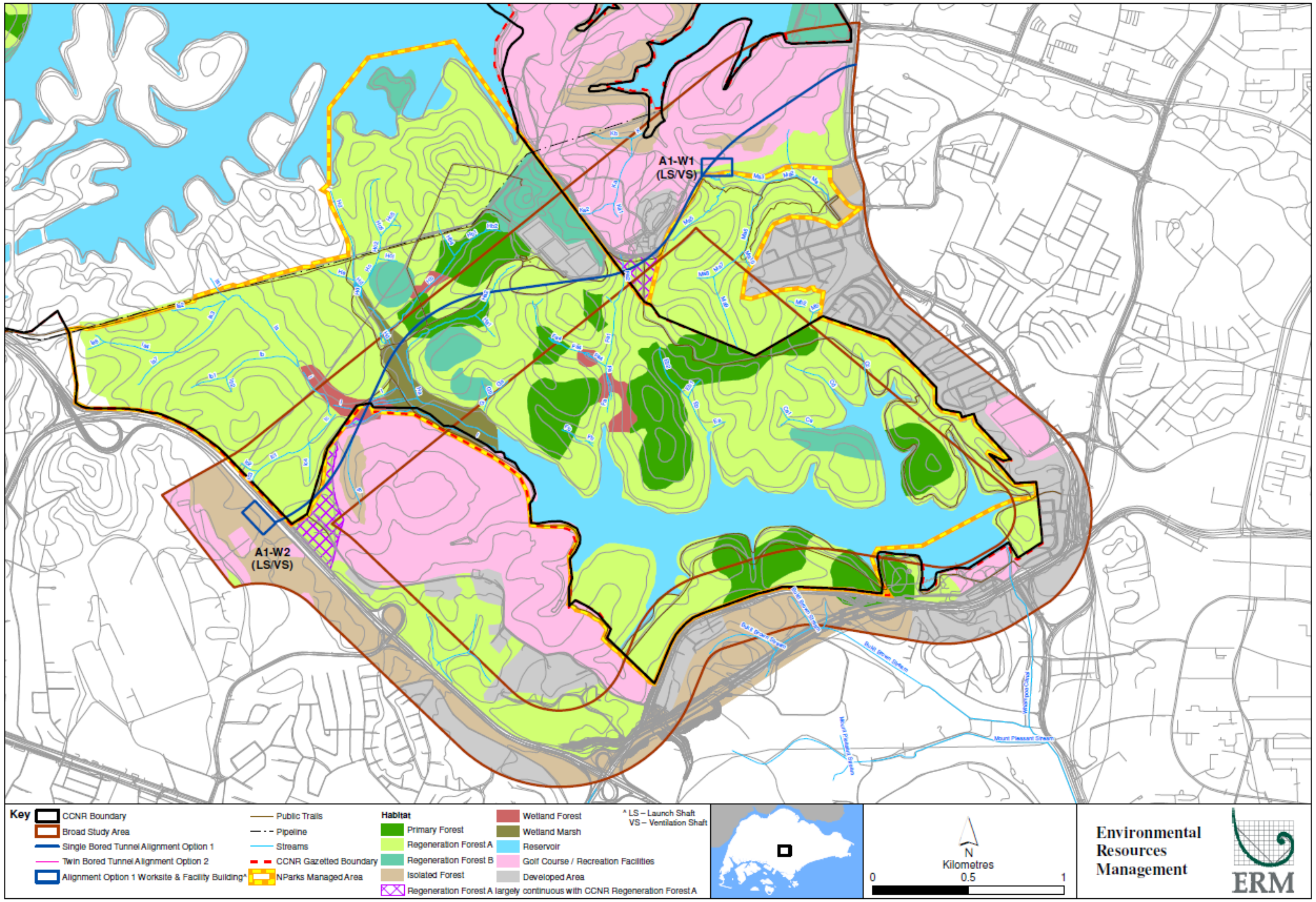
Table 5.1: Relevant Baseline Conditions for Worksites at Alignment Option 1

Component	Baseline Conditions
Tunnel Alignment	The tunnel alignment passes under the CCNR containing Primary Forest, Regeneration Forest A, Wetland Marsh, Wetland Forest, Regeneration Forest B, Golf course and Isolated Forest habitats as shown on *Figure 5.1*. The CCNR is the largest of the nature reserves in Singapore, situated at the centre of the country and occupying over 2,000 ha of forest cover. Although the CCNR experiences several internal stressors from human use, developmental and environmental pressures, it is home to diverse fauna and flora. Rich biodiversity inhabit these habitats, including the Keruing (*Dipterocarpus spp.*), Meranti (*Shorea spp.*), Sunda Slow Loris (*Nycticebus coucang*) (CR) and the Sunda Pangolin (*Manis javanica*) (CR). Over 413 vascular plant species, 218 bird species, 30 mammal species, 56 reptile species, 17 amphibian species, 178 butterfly species, 82 odonate species and 24 freshwater fish species of conservation interest have been recorded from the Study Area, the majority of them recorded within the CCNR. A number of stream networks also fall within the corridor for Alignment Option 1.

(Footnote 1) https://www.lta.gov.sg/content/dam/ltaweb/corp/PublicTransport/files/Final%20SI%20EIA%20Volume%20II.pdf

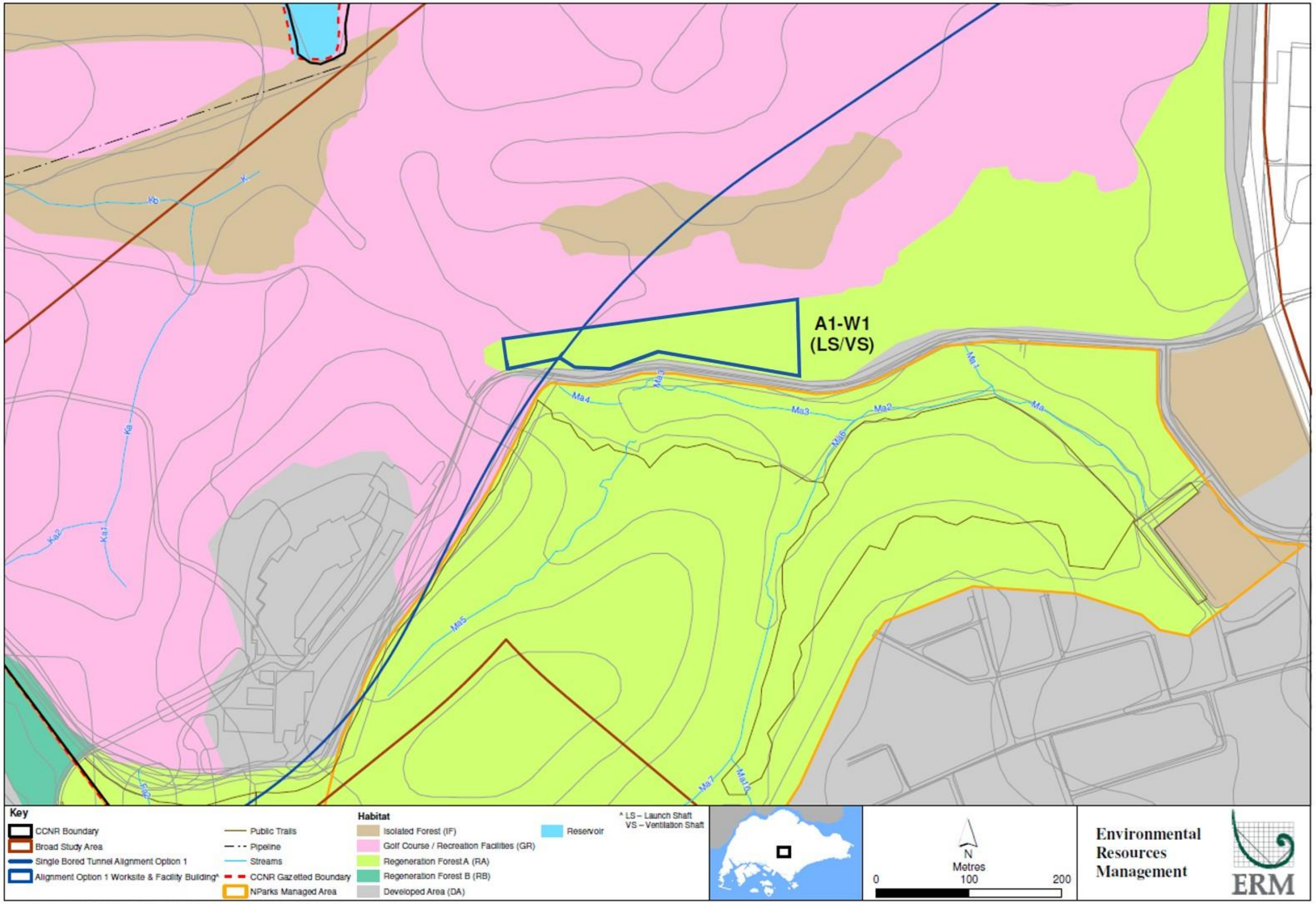
Component	Baseline Conditions
A1-W1 (Launch Shaft/ Ventilation Shaft)	The habitat within A1-W1 has been classified as Regeneration Forest (A). The worksite is located within an approximately 100,000 m^2 forest patch fringing the Island Golf Course, bordered to the south by Island Club Road which is a two-lane road. Despite being separated from the CCNR and Windsor Nature Park by Island Club Road, fauna can still traverse between the forest fragments through gliding, flying or crossing over to the habitat on either side of Island Club Road. Flora observed in the area include the Marsh Pulai *(Alstonia spatulata*), Rambutan (*Nephelium lappaceum*), African Oil Palm (*Elaeis guineensis*), Wild Cinammon (*Cinnamomum iners*), African Tulip (*Spathodea campanulata*) and Corn Palm (*Dracaena fragrans)*. No streams were observed within A1-W1, but it is located beside a stormwater drain that channels stormwater into stream Ma3 in Windsor Nature Park via a deep culvert that runs under Island Club Road. Approximately 100 m east of the boundary of A1-W1 along Island Club Road lies a second culvert linking storm water flow from within the forest patch to stream Ma1. Based on observations, this could be a possible passageway for wildlife to cross between Windsor Nature Park and the forest patch due to the drain's gentle gradient and ephemeral flow. The Raffles' Banded Langur (*Presbytis femoralis femoralis*) (CR), Sunda Pangolin (*Manis javanica*) (CR), Common Palm Civet (*Paradoxurus hermaphroditus*), Lesser Mousedeer (*Tragulus kanchil*) (CR), Horsfield's Flying Squirrel (*Iomys horsfieldii*) (EN), Malayan Colugo (*Galeopterus variegatus*), Long-tailed Macaque (*Macaca fascicularis*) and Wild Boar (*Sus scrofa*) have been observed in the habitat. The striped-kukri snake (*Oligodon octolineatus*) is often observed as roadkill on Island Club Road.
A1-W2 (Launch Shaft/ Ventilation Shaft)	The habitat within A1-W2 has been classified as Isolated Forest (IF), which is disconnected from the CCNR by the Pan-Island Expressway (PIE). A1-W2 is located within an approximately 200,000 m^2 Isolated Forest patch containing scrub vegetation and mature trees bounded by the PIE and Fairways Drive. This forest patch is separated from the CCNR by the PIE. Due to its size and separation from the core CCNR forests, it is expected to have lower species richness and diversity for both flora and fauna. There are a number of wooded patches in the landscape to the south of this forest patch. The forest patch is at an elevation to the PIE and held back by concrete retaining walls that run parallel to the expressway. There are storm water drains at the foot of the concrete wall. On the Fairways Drive side, there is a small ditch at the base of the forest patch that runs along its margins. A field used for horse riding activities as part of Bukit Timah Saddle Club is located approximately 65 m south-west of A1-W2. Wildlife such as the Sunda Pangolin (*Manis javanica*) (CR), Malayan Colugo (*Galeopterus variegatus*), Straw-headed Bulbul (*Pycnonotus zeylanicus*) (EN), Changeable Hawk-Eagle (*Spizaetus cirrhatus*) (EN), Rhinoceros Hornbill (*Buceros rhinoceros*) (VU), White-throated Kingfisher (*Halcyon smyrnensis*), Pink-necked Green Pigeon (*Treron vernans*) and Javan Myna (*Acridotheres javanicus*) were observed in the area.

Figure 5.1: Alignment Option 1 Corridor



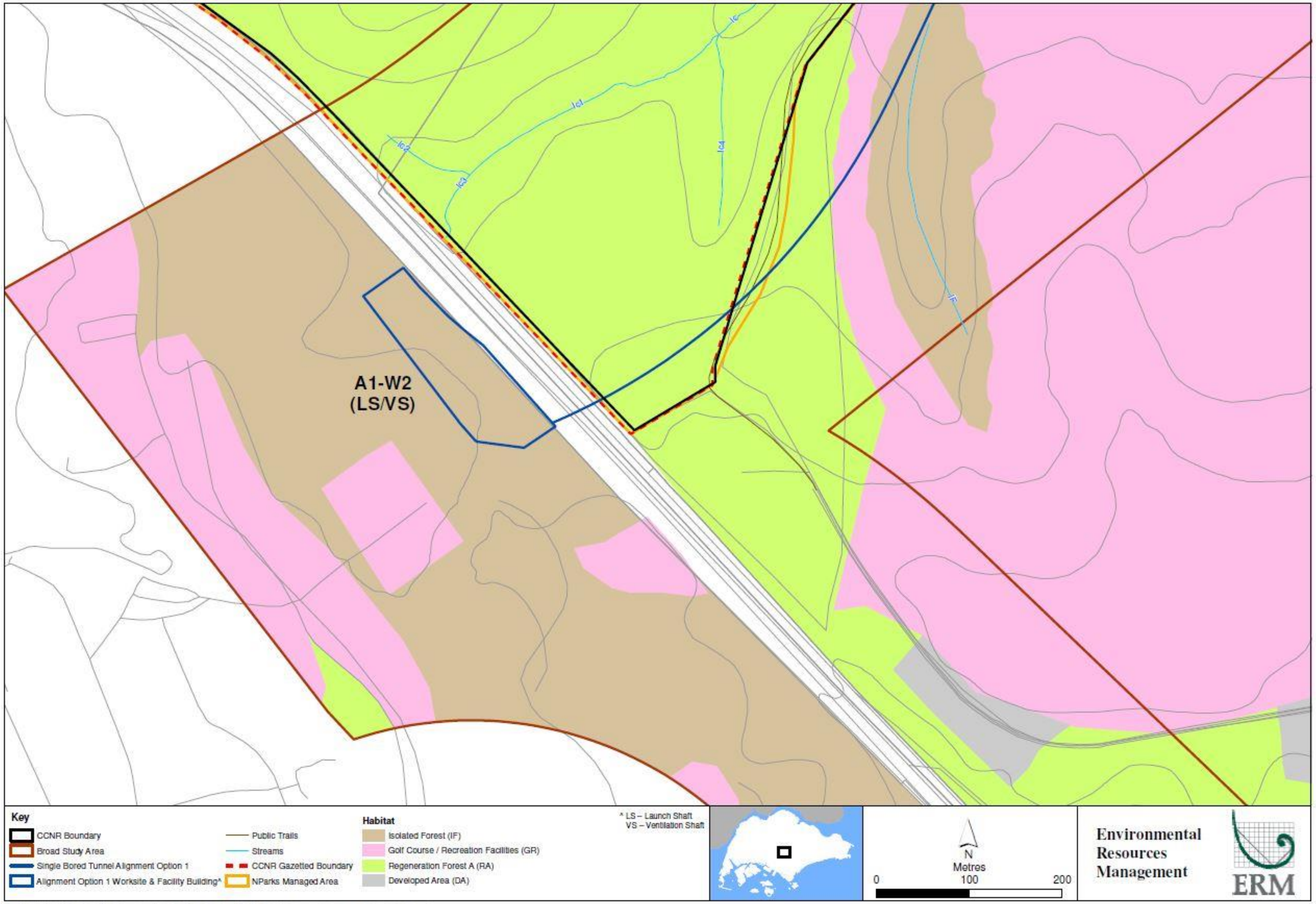
File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_III_Habitat_Alignment_A1_v5.mxd
Date: 22/8/2019

Figure 5.2: Alignment Option 1, A1-W1 (LS/VS) Worksite



File: T:\GIS\CONTRACT\0256660\Mxd\2018_A1_A2_EIA_Report\0256660_Vol_III_Habitat_Alignment_A1_W1_v1.mxd
Date: 19/6/2019

Figure 5.3: Alignment Option 1, A1-W2 (LS/VS) Worksite



5.4 ASSESSMENT METHODOLOGY

The sensitivity of habitats and species were evaluated against criteria set out in *Table 5.2* and *Table 5.3* respectively.

Table 5.2: Summary of the Habitat Sensitivity Value Definitions

Sensitivity Value of Different Habitats within NParks' Managed Areas		
Habitat	**Description**	**Sensitivity Value**
Primary Forest	These habitats were found important/ significant for various species of flora and fauna, in particular globally Critically Endangered (CR) or Endangered (EN) on the IUCN Red List or the Singapore RDB. All of the habitats identified within NPark's Managed Area are ecologically linked, and therefore their sensitivities are considered together as a whole with High Sensitivity Value.	High
Regeneration Forest A		High
Regeneration Forest B		High
Wetland Forest		High
Wetland Marsh		High
Streams		High
Reservoir		High
Sensitivity Value of Different Habitats outside of NParks' Managed Areas		
Habitat	**Description**	**Sensitivity Value**
Regeneration Forest A	Some patches of this habitat type are located outside NPark's Managed Area. Most of these patches are influenced by edge effects due to the highway or moderate traffic on roads or high usage of the adjacent golf courses. Some wildlife and species of conservation interest were found utilizing these areas. It should be noted that these areas were still considered as part of the habitats of significant importance for nationally restricted range species, with mostly avifauna flying over.	Medium
Regeneration Forest A – largely continuous with CCNR Regeneration Forest A	One particular patches of this habitat type which is outside NPark's Managed Area, is only separated by trail from the managed area and is therefore still ecologically linked to the large continuous forest within the NPark's Managed area (demarcated by black dotted boundary in Figure 5.2). In addition there is anecdotal evidence of Sunda Pangolins (*Manis javanica*) (CR/RDB; CR/IUCN; CITES-II) using the nearby Bukit Golf course to forage in the evenings, suggesting that this area of Regeneration Forest A may be part of their daytime range. There are also reliable sightings of Slow Lorises (*Nycticebus coucang*) and Malayan Colugos (*Galeopterus variegatus*) from this area.	High
Isolated Forest	Fragmented habitat of medium quality and used by common species. Some located within nationally designated or recognized areas such as the Tree Conservation Area in Bukit Brown Cemetery.	Medium
Golf Course/ Recreational Facilities	Low value habitats of significant importance for nationally restricted range species. This habitat type mainly acts as a green buffer/ corridor connecting forests.	Medium
Developed Area	Disturbed habitats with minimal interest for biodiversity overall.	Low

Table 5.3: Summary of Species' Sensitivity Value Definitions

Value	Definition Summary (Note 1)
Negligible	Species with no specific value or importance attached to them.
Low	Species: • of LC on the IUCN Red List; • of DD in the *Singapore Red Data Book 2008* (SRDB 2008); or • not meeting criteria for medium or high value.
Medium (Note 2)	Species on IUCN Red List as VU, NT, or DD; • protected under national legislation; • on SRDB 2008 as VU; • nationally restricted range species, nationally important numbers of migratory or congregatory species; • not meeting criteria for high value; or • species vital to the survival of a medium value species.
High (Note 2)	Species on IUCN Red list as CR or EN; • on SRDB 2008 as NE, CR or EN; • having a globally restricted range (ie plants endemic to a site, or found globally at fewer than 10 sites, fauna having a distribution range (or globally breeding range for bird species) less than 50,000 km^2); • internationally important numbers of migratory, or congregatory species; • key evolutionary species; or • vital to the survival of a high value species.

Note 1: Value Definitions follow the ERM IA Standard, Annex B-9 ERM Biodiversity Standard and take into account IFC PS6 and guidance such as the BBOP Standard and accompanying materials

Note 2: Species that have value rankings of Medium and High are considered species of conservation concern.

The impact magnitude is a function of a range of considerations including extent (eg local, regional or national), impact duration (eg temporary, short-term, long-term or permanent), scale (ie size of the impact), frequency (ie constancy or periodicity of the impact), and likelihood (for unplanned events only, eg unlikely, possible, or likely). By considering all of the above characteristics, the uniqueness of the CCNR and in consultation of stakeholders, magnitudes of impacts to ecology and biodiversity for this EIA were defined for this EIA as five qualitative scales outlined in *Table 5.4* for habitats and species.

Table 5.4: Magnitude Criteria for Effect on Baseline Habitats and Species

Magnitude	Definitions
Positive	The effect brings beneficial outcomes to ecology or biodiversity and flora or fauna taxa. No magnitude will be assigned to a positive impact.
Negligible	Effect is within the normal range of natural variation and variation for the population of the species.
Small	Affects only a small area of habitat, such that there is no loss of viability/function of the habitat. Effect does not cause a substantial change in the population of the species, or other species dependent on it.
Medium	Affects part of the habitat, but does not threaten the long-term viability/function of the habitat. Effect causes a substantial change in abundance and/or reduction in distribution of a population over one, or more generations, but does not threaten the long term viability/function of that population, or any population dependent on it.
Large	Affects the entire habitat, or a significant proportion of it, and the long-term viability/function of the habitat is threatened. Affects entire population, or a significant part of it causing a substantial decline in abundance and/or change in and recovery of the population (or another dependent on it) is not possible either at all, or within several generations due to natural recruitment (reproduction, immigration from unaffected areas).

Once the sensitivities of ecology and biodiversity resources/ receptors and impact magnitude have been determined according to the definitions above, a Significance Matrix was used to determine the significance of the impact. The matrix used with respect to ecology and biodiversity is shown in *Figure 5.4*.

Figure 5.4: Impact Significance for Ecology & Biodiversity

		Sensitivity/Vulnerability/Importance of Resource/Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Critical

5.5 ASSESSMENT OF IMPACTS DURING PROJECT CONSTRUCTION AND OPERATION PHASE

The Project will operate within the administrative framework for Singapore. Measures in line with regulatory requirements will therefore be implemented as part of the Project design. The assessment of impacts to ecology and biodiversity has taken into account the stipulations of these regulations, a summary of which are presented in *Table 5.5*. Embedded controls that follow these stipulations strictly will be adopted by the Project.

Table 5.5: Embedded Controls for Ecology and Biodiversity

Reference	Control Measures
Parks and Trees Act 2005	The Project will control strictly any: • Activities that will damage flora, the land or cause injury to fauna within the Nature Reserves; • Cutting or damaging trees with girth of more than 1 m within a Tree Conservation Area; • Cutting or damaging trees or plants within the heritage road green buffers; The Project will also: • Provide temporary sanitary facilities and waste management areas to be provided to avoid fouling of surface water resources; and • Seek approval from NParks before carrying out restricted activities.
Wild Animals and Birds Act 2000	Workers to be trained to avoid undertaking prohibited activities within the CCNR and Windsor Nature Park such as: • The killing, taking or keeping of any wildlife; and • Placing contraptions that are likely to cause injury to humans.
Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations 2006	The Project will: • Undertake measures to manage impacts to surface water quality; and • Ensure its activities will not lead to the damage of flora or fauna in the CCNR and the forested fringes of the CCNR
LTA's General Specification, Appendix A, Safety, Health and Environment (for Rail Project), October 2018	The Project will: • Ensure lighting at aboveground worksites will be directed downwards to minimize glare effects on surrounding habitats; and • Ensure site utilisation plans consider preservation and protection of native trees as far as possible. Trees or shrubs that can be preserved and

Reference	Control Measures
	protected shall be identified with methods to prevent harm to them with reference to NParks' Conservation of Trees and Plants Guidelines; • Ensure an arborist is engaged prior to the commencement of any site clearance, tree felling and transplanting activities; • Adopt best noise management practices; • Adopt measures to suppress dust; • Conduct an Environmental Impact Workshop within the first 2 months upon signing of the Contract to establish site specific environmental management; • Managed and implement an Environmental Impact Register; • Submit site-specific environmental plans; • Ensure Environmental Control Officers and team are adequately trained; • Ensure all litter is cleared from site on a daily basis; and • Develop a series of Environmental Plans which take into consideration the relevant regulations, Codes of Practice, LTA environmental guidebooks, guidance and recommendations stated in the EIA Report. With respect to water and land pollution, the Project will: • Carry out repair, servicing, engine overhaul works etc on an area that is contained and all waste be appropriately disposed of; • Store diesel drums and chemicals under shelter and within localised containment with spill trays provided to prevent rain from washing out any pollutive substances; • Ensure emergency spill kits are provided; • Prevent silt from being washed into public drains, with discharge not containing Total Suspended Solids in concentration greater than 50 mg/l; • Sequence and schedule earthworks/demolition works in stages and progressively with subsequent construction activities and building works; • Ensure site clearance works are kept to a minimum by retaining as much of the existing vegetation as possible; • Pave up bare surfaces and all construction access; • Protect bare slopes and earth stockpiles; • Restore ground cover over disturbed areas as soon as possible; • Carry out trench excavation work in sequence with progress of permanent works to minimise impact on the environment; • Implement sediment control and monitoring measures; and • Install turbidity curtains in water bodies that are raw water sources for potable water and/or needed for recreational purposes.
Environmental Protection and Management Act 2002	The Project will: • Implement Earth Control Measures (ECM); • Take adequate measures to prevent sedimentation to drainage systems; • Not discharge or cause discharge of toxic substance or hazardous substance into any inland water; • Contain toxic waste adequately on site and dispose it via a licensed toxic waste collector; • Provide spill containment and leak prevention facilities; and • Ensure ambient noise levels do not exceed maximum permissible levels.

Reference	Control Measures
Sewerage and Drainage (Surface Water Drainage) Regulations 2007	The Project will: • Ensure worksite is planned such that runoff within, upstream of and adjacent to the worksite will be drained away without causing flooding within or in the vicinity of the worksite; • Ensure land adjacent to any drain will be closely turfed during reinstatement works; and • Take adequate measures to prevent sedimentation to drainage systems.
Code of Practice on Surface Water Drainage	• The facility building will be designed with a detention tank that is sized to cope with the increased runoff due to the introduction of impermeable ground surface at the site.

5.5.1 Impacts to Ecology and Biodiversity due to Construction Phase

5.5.1.1 Sources of Impact

The sources of impacts associated with the construction phase, and their associated impacts are as follows in *Table 5.6*.

Table 5.6: Sources of Impact and Potential Impact Types (Construction Phase)

Source of Impact	Potential Impact
Vegetation Clearance	
Vegetation clearance for establishment of worksite, access roads and road diversion	• Loss of vegetation and habitat resource • Habitat fragmentation • Exacerbation of edge effects • Pollution to aquatic habitats from erosion and sedimentation • Disturbance to wildlife during clearance, including potential injury and mortality
Construction Activities	
Construction activities such as: • Installation of perimeter walls (Earth Retaining Stabilising Structures) for launch/retrieval shafts; • Installation of monitoring instruments (piezometers and settlement markers) • Excavation of launch/retrieval/standalone ventilation shafts; • Backfilling of shafts and construction of ventilation shafts; • Facility building construction; and • Illumination from worksites.	• Disturbance to wildlife from increased human presence, working activities, dust settlement, illumination, and noise and vibration

Source of Impact	Potential Impact
Increased vehicular traffic along access roads and roads adjacent to worksites	• Increased wildlife injury and mortality risk from vehicle strike along: - Access roads; and - Roads adjacent to worksites as wildlife are moving into neighbouring areas as a result of construction disturbance
Waste generation: • Toxic and hazardous waste; • Effluent, slurry, and wastewater; • General waste; • Concrete wash; and • Sanitary waste.	• Pollution of aquatic habitats
Tunneling	• Disturbance to wildlife from vibration
Unplanned Events	
Unplanned events such as: • Excessive ground settlement; • Slope failure; and • Fire occurrence.	• Pollution of soil and surface waterbodies • Wildlife injury and mortality • Vegetation and habitat resource loss

5.5.1.2 Receptors

Impacts arising from Project activities are likely to impact both habitats and species within the Study Area.

Habitats

The worksite footprints will fall on a combination of habitat types within and outside of sensitive biodiversity areas; the area of each habitat type covered by the worksite footprint has been calculated and their sensitivity values listed in *Table 5.7*. At the end of the construction phase, some areas that have been cleared will be regained through replanting activities, with the advice from relevant agencies and experts, and potentially converted to other use. However, there will be a permanent loss of habitat due to the establishment of the facility building (each takes up 2,800 m^2). The net habitat loss per worksite, where applicable, is presented in *Table 5.7*.

Table 5.7: Habitat Types Impacted during Construction and Sensitivity Evaluation

Worksite/Area	Habitat Type	Habitat Sensitivity	Temporary Habitat Loss (m^2)	Permanent Habitat Loss (m^2)	Approximate Area Regained as Non-forest Habitat (m^2)
Tunnel Alignment	Regeneration Forest A (RA), Isolated Forest (IF), Primary Forest (PF), Wetland Marsh (WM), Wetland Forest (WF) and Golf Course/ Recreation Facilities (GC/RF)	High	-	-	-
	Streams Ha, I, IC within the CCNR	High	-	-	-
A1-W1 (LS/VS)	Regeneration Forest A (RA)	Medium	15,000	2,800	12,200
	+ Regeneration Forest A (RA) (Windsor Nature Park)	High	-	-	-
	Roadside drains along Island Club that eventually discharges to Stream Ma, located within Windsor Nature Park, downstream of the CCNR	High			
A1-W2 (LS/VS)	Isolated Forest (IF)	Medium	15,000	2,800	12,200
	+ Regeneration Forest A (RA) (CCNR)	High	-	-	-

+These refer to additional adjacent habitats with ecological receptors that experience edge effects

Species

Species sensitivity at each worksite has been evaluated based on criteria listed in *Table 5.3*. The sensitivity ratings and rationale are provided in *Table 5.8*.

Table 5.8: Species Sensitivity Evaluation

Worksite/Area	Rationale	Sensitivity
Tunnel Alignment	The tunnel alignment will be constructed within rock, beneath habitat types classified as Regeneration Forest A (RA), Isolated Forest (IF), Primary Forest (PF), Wetland Marsh (WM), Wetland Forest (WF) and Golf Course/ Recreation Facilities (GC/RF) within the CCNR. These high value habitats provide for various flora and fauna species of conservation significance, including CR and EN species.	High

Worksite/Area	Rationale	Sensitivity
Tunnel Alignment	Streams Ha, I, IC within the CCNR and the alignment corridor are likely to contain at least seven SRDB listed CR or EN freshwater species. The Harlequin Rasbora (*Trigonostigma heteromorpha*) was observed within the shaded forest streams found within the Study Area.	High
A1-W1 (LS/VS)	The RA patch where the worksite is located contains SRDB-listed CR or EN species. The Sunda Pangolin (*Manis javanica*) (CR), Raffles' Banded Langur (*Presbytis femoralis femoralis*) (CR), Malayan Colugo (*Galeopterus variegatus*), Lesser Mousedeer (*Tragulus kanchil*) (CR) and Horsfield's Flying Squirrel (*Iomys horsfieldii*) (EN) have been recorded in this area.	High
	The northern forest fringes of Windsor Nature Park to the south of worksite A1-W1, comprising RA habitat, are the potential receptors impacted by edge effects from construction works. The area contains SRDB-listed CR or EN flora [16] and fauna species, a notable species being the Raffles' Banded Langur (*Presbytis femoralis femoralis*) (CR) that is known to utilise the area [17].	High
	Stream Ma located downslope of worksite A1-W1 runs from CCNR to downstream portions within Windsor Nature Park. It is likely to contain at least seven SRDB listed CR or EN freshwater species. The Harlequin Rasbora (*Trigonostigma heteromorpha*) was observed within the shaded forest streams found within the Study Area.	High
A1-W2 (LS/VS)	The IF patch where the worksite is located contains SRDB-listed CR or EN species. The Sunda Pangolin (*Manis javanica*) (CR), Malayan Colugo (*Galeopterus variegatus*), Straw-headed Bulbul *(Pycnonotus zeylanicus*) (EN) and Changeable Hawk-Eagle (*Spizaetus cirrhatus*) (EN) were observed at the site.	High
	The forest fringes of the CCNR to the east of worksite A1-W2, comprising RA habitat, are the potential receptors impacted by edge effects from construction works. These high value habitats provide for various flora and fauna species of conservation significance, including CR and EN species.	High

5.5.1.3 Impact Magnitude & Significance

Embedded controls listed in *Table 5.5* and assessments conducted in the preceding chapters on impacts from Noise and Vibration, to Surface Water and Air Quality (ie *Chapters 2, 3* and *4*) have been considered in the evaluation of impacts in this chapter. A summary of the magnitude and significance of impacts to habitat and species receptors during Project construction is provided in *Table 5.9*. The impacts on different species groups have been considered in the assessment, limited to the existing baseline information. This will be further developed and updated during the AES Stage.

Table 5.9: Magnitude of Impacts Associated with Construction Phase

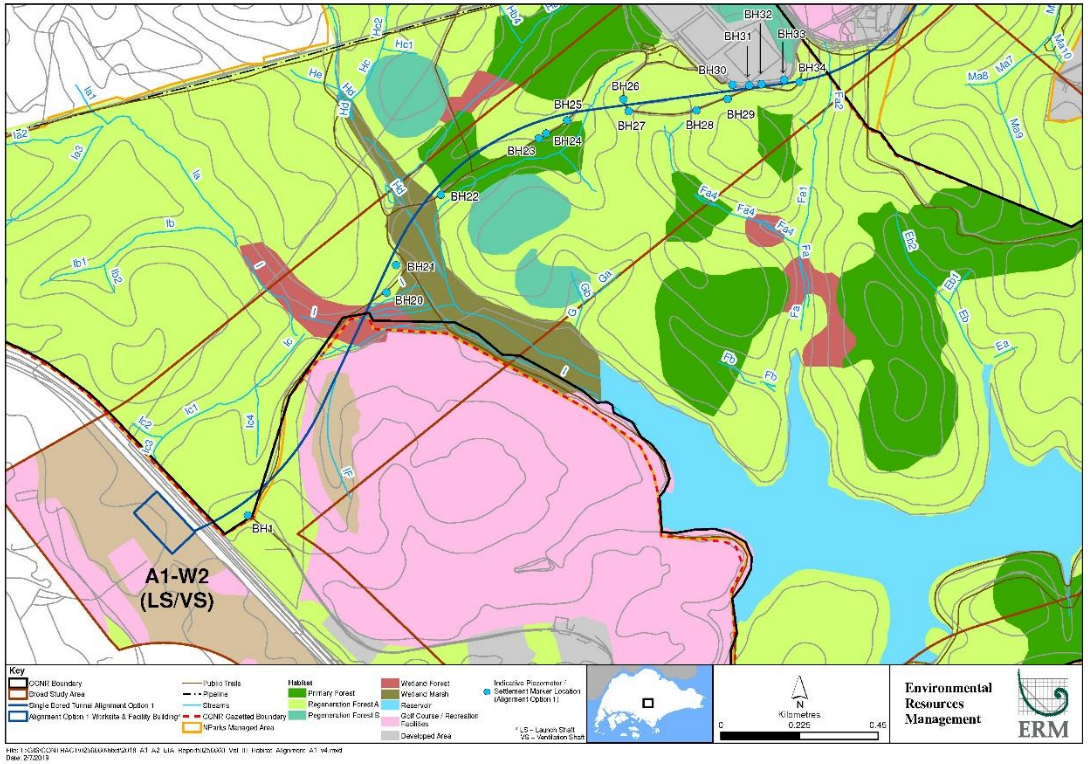
Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Tunnel Alignment				
Disturbance to wildlife from vibration from the operation of TBM during tunnel construction	<u>Impacts on Species</u> The TBM will be operated beneath habitat types classified as Regeneration Forest A (RA), Isolated Forest (IF), Primary Forest (PF), Wetland Marsh (WM), Wetland Forest (WF) and Golf Course/ Recreation Facilities (GC/RF) within the CCNR. The majority of the tunnel alignment runs underneath RA habitat type ie High sensitivity. Vibration levels ie Peak Particle Velocity (PPV) levels are estimated to range between 0.13 to 0.33 mm/s within the CCNR, where the tunnel will be 50 to 95 m bgl. The average tunnel depth for the alignment within the CCNR is 70 m bgl. Baseline vibration levels ranged between 0.254 and 0.508 mm/s measured at Jelutong Tower within the CCNR. This means that predicted vibration levels from TBM operation are below or within the baseline vibration range, within a radius of approximately 50 to 95 m and an average of 70 m from the TBM. Vibration from TBM operation may occasionally be above the lowest recorded baseline vibration value. The TBM is estimated to advance at a speed between 3 and 7 m a day. In addition, the TBM will periodically cease operations to allow for maintenance and advance probing works ie vibrations generated will be intermittent. A stationary ecological receptor may therefore be exposed to intermittent vibration above the lowest baseline vibration level of 0.254 mm/s for approximately 24 days. Vibration impacts to wildlife within the abovementioned habitats include disrupting sensory communication between animals, and interfering with mating, hunting and predator-evasion success [22]. These impacts may lead to further deleterious impacts on downstream ecological functions. The anticipated vibration levels from tunnelling have been evaluated in *Vol III Chapter 3 Noise & Vibration* based on human receptor thresholds. The scales and units of measure used in *Vol III Chapter 3 Noise & Vibration* are those used to assess impacts on humans and may not be directly applicable to fauna [22]. This is because some fauna species are understood to have sensory receptors	Species: Small	Species: High	Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to wildlife from vibration from the operation of TBM during tunnel construction	which have perception ranges and sensitivities that are above and/or below the ranges of human perception and sensitivity [22] [(Footnote 2)]. During the course of the EIA, further assessments were undertaken to assess the potential vibration impact to wildlife, and the potential wildlife vibration thresholds based on research and literature review. A summary of the assessments provided in *Annex 3.0* further discusses the impacts of vibration on wildlife. The effect of vibration from construction works will differ for different fauna types. Fauna that are ground-dwelling, nesting and/or utilise vibration for environmental sensing and communication are more susceptible to vibration impacts, compared to other fauna types such as those in flight that are less exposed to vibration from TBM operation [22]. The tunnel alignment will run below the CCNR and is likely to pass through habitats supporting ground-dwelling species along the alignment corridor. In conclusion, there are no available studies establishing thresholds for wildlife tolerance to vibration from the operation of a TBM during tunnelling works. However, it is noted that vibration exposure will be intermittent and transient due to the mobile nature of the tunnelling works. In addition, the predicted vibration levels introduced by tunnelling works are within the baseline vibration range that is currently occurring within the CCNR, and may be occasionally marginally above the lowest recorded baseline value. It is therefore anticipated that the impact magnitude of vibration generated during tunnelling will range from Negligible to Small. <u>Embedded Controls</u> The tunnel alignment has been lowered so as to attain depths of between 50 to 95 m bgl within the CCNR. The average depth of the tunnel within the CCNR is 70 m. This reduces the magnitude of vibrations experienced by ecological receptors at the ground surface, as vibration levels decrease over distance of wave propagation.			

[(Footnote 2)] The suitability of using different frequencies for the assessment has been evaluated for these disturbances, such as the appropriateness of using dB(A) and dB(G) for noise evaluations due to the disparity of human and fauna perception ranges. Infrasound sound and vibration ie sound and vibration waves occurring at < 20 Hz (below the audibility range for a typical healthy human), has implications for ecological taxa such as leaf-litter invertebrates, spiders and aquatic crustaceans, and fossorial snakes. The standardised G-weighting function is the most appropriate for infrasound but there are few established dB(G) thresholds by which to inform a quantitative impact assessment for the identified taxa groups which utilise or are particularly sensitive to vibration/infrasound due to function. The assessment was therefore undertaken using the A-weighted decibel, which is the measurement most representative of the human ear response to sound.

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to wildlife from vibration from the operation of TBM during tunnel construction	Due to the depth of the tunnel under the CCNR, it is anticipated that short-term exposure of ground-dwelling or vibration-utilising fauna species will be localised within a horizontal distance of tens of metres of the TBM. The impact is not anticipated to cause a substantial change in populations and/or threaten the long-term viability of species populations in the CCNR ie Negligible to Small impact magnitude (Footnote 3).			
Disturbance to wildlife from the installation of monitoring instrumentation (piezometers and settlement marker)	Impacts on Species The necessity for the locations of piezometers will be studied at the AES of the Project. Should piezometers be required for the monitoring of groundwater during tunnelling, these will be drilled and installed at the same locations and using the same equipment and embedded controls utilised in the drilling of the SI boreholes completed within the CCNR in 2017. There was a total of 16 locations within the CCNR, 10 of which were located on the exiting Sime and Terentang trails within the CCNR; 2 of which were located slightly of trail but within existing clearings in the CCNR; and 4 of which were located on the Kalang Service Reservoir Road off Island Club Road. These locations are presented below.	Species: Small	Species: High	Species: Moderate

(Footnote 3) Due to the paucity of the understanding of wildlife tolerance thresholds to vibration from construction, this assessment is conservative with an emphasis on the Precautionary Principle (23). The Precautionary Principle is an environmental approach that recommends for anticipatory action to be taken, when an activity possesses potential to cause harm and there is uncertainty about the impact magnitude of the activity (23). The application of the Precautionary Principle has also taken into account that species of high conservation status inhabit other habitats in Singapore. Therefore, it is anticipated that the impact will not threaten the long-term viability of the species populations (Medium impact magnitude), as the national species populations can persist despite potential disturbance to species within the Project Area.

<table>
<tr><th>Impact</th><th>Impact Summary</th><th>Impact Magnitude</th><th>Receptor Sensitivity</th><th>Impact Significance</th></tr>
<tr><td>Disturbance to wildlife from the installation of monitoring instrumentation (piezometers and settlement marker)</td><td>

Species may be disturbed by the presence of humans, illumination, noise and vibration. Fauna may temporarily avoid the area. As the works will be intermittent, the impact is not anticipated to cause a substantial change in the population of the species.</td><td></td><td></td><td></td></tr>
</table>

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Excessive ground settlement and/or slope failure, leading to: • Pollution of surface waterbodies • Wildlife injury and mortality • Loss of habitat resources	<u>Impacts on Habitat</u> The operation of TBM may lead to excessive ground settlement and/or slope failure. These unplanned event scenarios may occur due to: • Loss of pressure at TBM face; and • Propagation of vibration from TBM passing under a steep slope weakened by heavy rainfall. Excessive ground settlement and/or slope failure within the Sime Stream Valley could increase turbidity levels in waterbodies due to sedimentation. A failure of the slope within the Sime Stream Valley could also alter the course of the Sime Stream or stop its flow. Slope failure and/or excessive ground settlement can also cause the collapse of trees and vegetation, therefore leading to a loss of habitat resources. The impact of excessive ground settlement can be severe if it occurs at key areas such as Primary Forest (PF), Wetland Marsh (WM) and Wetland Forest (WF) habitats at MacRitchie, disrupting stream connectivity. <u>Impacts on Species</u> Species dependent on aquatic habitats could be impacted when sediment loading occurs due to excessive ground settlement and/or slope failure near Sime Stream. These aquatic species could also be seriously impacted when the flow of streams is heavily altered. Species that happen to be present at the site of a slope failure or excessive ground settlement could also suffer injury or mortality. There are known species of conservation concern present along the tunnel alignment and at the worksites, that are dependent on aquatic and forest habitats where there may be slope failures or excessive ground settlement. <u>Embedded Controls</u> As discussed in *Volume I, Chapter 2, Section 2.5.4.1* and *Section 2.5.4.2*, the Project will incorporate the following construction methodologies and key embedded controls to prevent unplanned events: • Design of the tunnel alignment to be undertaken at depth to ensure that the TBM is operating within rock while tunnelling beneath the CCNR;	Habitat: Large (in the event that slope failure or excessive ground settlement occurs)	Habitat: High	Habitat: Critical (in the event that slope failure or excessive ground settlement occurs) Habitat: Moderate (considering that it is *Unlikely* for slope failure or excessive ground settlement to occur)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event - Excessive ground settlement and/or slope failure, leading to: • Pollution of surface waterbodies • Wildlife injury and mortality • Loss of habitat resources	• Use of slurry type, close shield TBM with close monitoring of mining KPIs to mitigate the risk of excessive ground settlement in the event that the TBM encounters mixed face tunnelling conditions; • Conduct advance probing at regular intervals during tunnelling works, to identify fracture zones ahead of the TBM cutterhead, and allow for further operational measures to be undertaken eg grouting from within the tunnel to prevent the loss of tunnel pressure at the TBM cutterhead; and • Presence of surface water drainage at the brow of the Sime Stream Valley slope, which will ensure stability of the slope even during prolonged periods of heavy rainfall. <u>Likelihood Evaluation</u> In view of the abovementioned embedded controls, the likelihood of excessive ground settlement is therefore considered *Unlikely* (see *Volume III, Annex 1.0*, *Section A1.2.1*). The presence of a surface drainage system at the brow of the Sime Stream valley slope, and the shallow undercut erosion observed at the stream bank at the base of the slope overlying the proposed tunnel alignment, indicates that the slope is stable. The likelihood of a slope failure is therefore assessed to be *Unlikely* (see *Volume III, Annex 1.0, Section A1.2.2*). In the event that an excessive ground settlement or slope failure occurs, the magnitude of impact to habitats and species is conservatively assessed to be Large. Taking into consideration the embedded controls that will be in place to prevent the occurrence of these unplanned events ie these events are *Unlikely* to occur, the significance of impact to habitats and species is assessed to be reduced from Critical to Moderate.	Species: Large (in the event that slope failure or excessive ground settlement occurs)	Species: High	Species: Critical (in the event that slope failure or excessive ground settlement occurs) Species: Moderate (considering that it is *Unlikely* for slope failure or excessive ground settlement to occur)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W1 (LS/VS)				
Loss of vegetation and habitat resources	Impacts on Habitat Site clearance for the temporary worksite of 5.5 years will lead to the loss of ~15,000 m^2 of Regeneration Forest A (RA) habitat. It is anticipated that the impact is of a Medium impact magnitude as it will affect part of the habitat but does not threaten the long-term viability of the habitat.	Habitat: Medium	Habitat: Medium	Habitat: Moderate
	Impacts on Species Site clearance will require removal of vegetation, including flora of conservation concern and habitat resources. This will lead to species-related impacts elaborated below, based on categories of species that have been found to utilise the habitats at these areas.			
	• **Ground-dwelling mammals** Mammals such as the Sunda Pangolin (*Manis javanica*) (CR) and Lesser Mousedeer (*Tragulus kanchil*) (CR) will be displaced or extirpated during construction. Less agile fauna such as the Sunda Pangolin may not be able to avoid the area during construction. It is likely that this area contains suitable resting and foraging sites for these species. Once displaced, ground dwelling fauna will no longer be able to access the Project site over the construction period of 5.5 years. Displaced individuals will seek refuge in suitable nearby habitats. There may be conflict over resources as the refuge areas may contain existing species populations.	Species: Medium	Species: High	Species: Major

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Loss of vegetation and habitat resources	• **Arboreal mammals** Notable arboreal mammals observed in this area were the Malayan Colugo (*Galeopterus variegatus*), Long-tailed Macaque (*Macaca fascicularis*), Horsfield's Flying Squirrel (*Iomys horsfieldii*) (EN) and Raffles' Banded Langur (*Presbytis femoralis femoralis)* (CR). Malayan Colugos and Horsfield's Flying Squirrels may be displaced or extirpated if they inhabit the trees due for clearance, or do not escape in time from the trees they may be resting on that are scheduled for felling. Four Raffles' Banded Langur (*Presbytis femoralis femoralis*) (CR) individuals have been observed in the vicinity [17], specifically at the SICC guardhouse area located at Island Club Road which is south of A1-W1 (NParks, pers. comm., 8 October, 2018). The individuals observed in the area are understood to be bachelor males that have a larger territory compared to the family units (Andie Ang, pers. comm., 10 October 2018). It is speculated that the forest habitats in the area may provide feeding and/or sleeping sites suitable for the Raffles' Banded Langur. They have also been observed to enter Windsor Nature Park by traversing through the tree canopy along Island Club Road [17] where the worksite is situated. Habitat clearance at A1-W1 will reduce forest connectivity and prevent the species from utilising this habitat, thereby limiting their movement. A species-specific study is being undertaken independently to better understand the usage of the site by the Raffles' Banded Langurs.	Species: Medium	Species: High	Species: Major
	• **Birds** The birds observed in the area were the Olive-winged Bulbul (*Pycnonotus plumosus*), Striped Tit-Babbler (*Macronous gularis*), Greater Racket-tailed Drongo (*Dicrurus paradiseus*), Changeable Hawk Eagle (*Nisaetus cirrhatus*) (EN) and Glossy Swiftlet (*Collocalia esculenta)*. These species are mobile and have home ranges dependent on forest distributions. They utilise trees for nesting and roosting. Clearing activities will likely affect the availability of habitats and resources for these species during construction, such as food sources and suitable nesting sites.	Species: Medium	Species: High	Species: Major

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Loss of vegetation and habitat resources	• **Herpetofauna** The herpetofauna species observed include the Oriental Whip Snake (*Ahaetulla prasina*), Paradise Tree Snake (*Chrysopelea paradisi*), Reticulated Python (*Malayopython reticulatus*), Wagler's Pit Viper (*Tropidolaemus wagleri*) (EN) and Green Crested Lizard (*Bronchocela cristatella*). These species are mobile and adaptable, but may be impacted by clearance activities if they are burrowed in resting places.	Species: Medium	Species: High	Species: Major
	• **Invertebrates** Invertebrate species that reside within the habitat will be impacted through changes in available resources from construction activities. Invertebrate species observed at the worksite were dragonfly and butterfly species, including the Common Birdwing (*Troides helena cerberus*) (VU). Impacts include the loss of suitable breeding habitats, foraging habitats, food sources and the direct loss of individuals at both the pupal and adult stages.	Species: Medium	Species: Medium	Species: Moderate
	<u>Embedded Controls</u> The impacts to flora species of conservation concern will be managed by embedded controls listed under LTA's *General Specification, Appendix A, Safety, Health and Environment (for Rail Project), October 2018*. It is stated that site utilisation plans shall consider preservation and protection of native trees as far as possible. Tree or shrubs that can be preserved and protected shall be identified with methods to prevent harm to the tree, branches and roots. Through these measures, plants of conservation concern are likely to be salvaged or protected on site as far as practicable. However, it is a reality that not all individual plants can be salvaged, and those that are unsuitable for transplantation will need to be removed. Hence, embedded controls are unlikely to reduce impacts on species from vegetation and habitat resource removal.			

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Exacerbation of edge effects	Impacts on Habitat Edge effects will be experienced by the remaining habitats after vegetation clearance, particularly the exacerbation of edge effects at the forest fringes of Windsor Nature Park to the south of worksite A1-W1, comprising RA habitat. There may be direct effects to vegetation such as altering the physical conditions of habitat close to the edge [19]. This can be in the form of desiccation of vegetation, or windthrow, which refers to the uprooting or breaking of trees by wind. The forest patch experiences existing edge effects as evidenced by tree fall and its open structure, possibly from exposure to the existing Island Club Road. Impacts on Species Species diversity and composition can be impacted from edge effects, leading to changes in community dynamics and ecosystem functioning. However, the species residing in the habitat experience existing edge effects from activities and road traffic along the adjacent Island Club Road. Species at the forest edge may have already adapted to the surroundings, while forest-dependent species may have already moved towards the forest core from the existing disturbance.	Habitat: Medium Species: Small	Habitat: High Species: High	Habitat: Major Species: Moderate
Habitat Fragmentation	Impacts on Habitat The forest patch where A1-W1 will be located is currently fragmented by the two-lane Island Club Road from the larger forest habitats at Windsor Nature Park and the CCNR. As the A1-W1 will occupy the west-end of the forest patch, it is unlikely to be a significant contributor to the existing level of fragmentation experienced at this RA Patch, and will not threaten the long-term viability of the habitat.	Habitat: Small	Habitat: Medium	Habitat: Minor

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Habitat Fragmentation	Impacts on Species • **Ground-dwelling mammals** The linear configuration of the worksite will pose as a greater barrier to fauna movement, by enhancing the barrier that is Island Club Road, during the construction period of 5.5 years. Despite this, mammals such as the Sunda Pangolin (*Manis javanica*) (CR) and Lesser Mousedeer (*Tragulus kanchil*) (CR) are anticipated to be able to traverse across Island Club Road between the forest fragments using the eastern portion of the forest habitat. As the worksite is also established at the edge of instead of within the habitat, the worksite is unlikely to cause significant fragmentation in addition to the current degree of fragmentation. In addition, the worksite will not encroach upon the culvert that offers a safer crossing option between both areas that ground-dwelling mammals such as the Sunda Pangolin (*Manis javanica*) (CR) are likely to utilise.	Species: Small	Species: High	Species: Moderate
	• **Arboreal mammals** The presence of the worksite will lead to the absence of interconnecting canopy and trees that currently allow arboreal mammals to move between the forest fragments. This may especially affect species with habitual routes such as the Malayan Colugo (*Galeopterus variegatus*) and Raffles' Banded Langur (*Presbytis femoralis femoralis)* (CR). Fragmentation can lead to the restriction of gene flow for these species, which can cause a change in abundance and/or reduction in distribution of the populations.	Species: Medium	Species: High	Species: Major
	• **Birds** As some birds can cover a greater landscape and are able to move across forest patches, habitat fragmentation in this area is unlikely to affect the species observed on site such as the Olive-winged Bulbul (Pycnonotus plumosus), Striped Tit-Babbler (*Macronous gularis*), Greater Racket-tailed Drongo (*Dicrurus paradiseus*), Changeable Hawk Eagle (*Nisaetus cirrhatus*) (EN) and Glossy Swiftlet (*Collocalia esculenta).* However, fragmentation can affect other bird species that forage and nest on the forest floor by increasing the distance between adjacent forest fragments. It is anticipated that the presence of the worksite will not cause a substantial change to bird species populations.	Species: Small	Species: High	Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Habitat Fragmentation	• **Herpetofauna** The herpetofauna species observed include the Oriental Whip Snake (*Ahaetulla prasina*), Paradise Tree Snake (*Chrysopelea paradisi*), Reticulated Python (*Malayopython reticulatus*), Wagler's Pit Viper (*Tropidolaemus wagleri*) (EN) and Green Crested Lizard (*Bronchocela cristatella*). The linear configuration of the worksite will pose as a greater barrier to fauna movement, by enhancing the barrier that is Island Club Road, during the construction period of 5.5 years. Despite this, herpetofauna species may still be able to move across the barrier using the remaining habitats and the impact will not cause a substantial change to herpetofauna populations.	Species: Small	Species: High	Species: Moderate
	• **Invertebrates** Invertebrate species observed on site were the dragonfly and butterfly species, including the Common Birdwing (*Troides helena cerberus)* (VU). Habitat fragmentation will lead to the increased distance between forest fragments for the species to move, and can impact the availability of remaining habitat. It is anticipated that the impact will not cause a substantial change to invertebrate species populations.	Species: Small	Species: Medium	Species: Minor
Disturbance to wildlife from: • Increased human presence; • Dust settlement; • Increased noise and vibration; and • Illumination	Impacts on Species Construction activities will result in disturbance to wildlife from increased noise, vibration, dust settlement, illumination and human presence at the worksite. These potentially stressful disturbances for wildlife are anticipated to be generated over the construction period of 5.5 years. Illumination from the worksite will result in avoidance from light-intolerant species, or attraction of light-tolerant species or insects. This may alter natural competition dynamics and divert food sources for insect-dependent species. Illumination can also disrupt circadian rhythms of wildlife by extending diurnal or crepuscular behaviours in the vicinity of the worksite, as well as disorient and disrupt orientation in nocturnal animals eg Sunda Pangolin [20]. Other impacts to wildlife from artificial lighting include disruption of reproductive behaviours and communication patterns which have downstream impacts on ecosystem functions [20]. Dust generated from construction activities may also deposit onto vegetation and smother leaves, leading to a reduction in vegetative growth [21]. This can affect the larger ecosystem that these vegetation provides for. The impact of changes in air quality to human receptors has been evaluated	Species: Medium	Species: High	Species: Major

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to wildlife from: • Increased human presence; • Dust settlement; • Increased noise and vibration; and • Illumination	in *Vol III Chapter 4 Air Quality*. Noise and vibration is anticipated to be generated intermittently from construction activities over the construction period (5.5 years). The anticipated noise and vibration levels from construction activities have been evaluated in *Vol III Chapter 3 Noise & Vibration* based on human receptor thresholds. The calculated vibration levels during piling (extraction of casings) at worksites ranged from 0.02 mm/s – 0.87 mm/s at identified human receptors in close proximity to the worksite. The scales and units of measure used in *Vol III Chapter 3 Noise & Vibration* [Footnote 4] and *Vol III Chapter 4 Air Quality* are those used to assess impacts on humans and may not be directly applicable to fauna [22]. This is because some fauna species are understood to have sensory receptors which have perception ranges and sensitivities that are above and/or below the ranges of human perception and sensitivity [22]. Excessive noise and vibration is known to disrupt sensory communication between animals and potentially interfere with mating, hunting and predator-evasion success [22]. Wildlife typically flee from the source to cope with the environmental disturbances, resulting in wildlife displacement and			

[Footnote 4] The suitability of using different frequencies for the assessment has been evaluated for these disturbances, such as the appropriateness of using dB(A) and dB(G) for noise evaluations due to the disparity of human and fauna perception ranges. Infrasound sound and vibration ie sound and vibration waves occurring at < 20 Hz (below the audibility range for a typical healthy human), has implications for ecological taxa such as leaf-litter invertebrates, spiders and aquatic crustaceans, and fossorial snakes. The standardised G-weighting function is the most appropriate for infrasound but there are few established dB(G) thresholds by which to inform a quantitative impact assessment for the identified taxa groups which utilise or are particularly sensitive to vibration/infrasound due to function. The assessment was therefore undertaken using the A-weighted decibel, which is the measurement most representative of the human ear response to sound.

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to wildlife from: • Increased human presence; • Dust settlement; • Increased noise and vibration; and • Illumination	exclusion of habitat. This can lead to increased competition for resources, and bring territorial species into conflict with each other. While such disturbance may impact individual species populations, it is not anticipated to threaten the long-term viability of any species populations due to the localised areas of impact [(Footnote 5)]. <u>Embedded Controls</u> Impacts from noise, vibration and illumination will be managed by embedded controls listed in *Table 5.5*. For example, light will be directed downwards to minimise glare on surrounding habitats and noise management measures will be implemented at the worksite. The development of a noise management plan will include measures that ensure quieter construction equipment are sourced, periodic checking of operating equipment against noise specifications are conducted, and training and competency requirements for personnel involved are met. Based on LTA's *General Specification Appendix A (Safety, Health and Environment) October 2018*, worksites are required to install lighting in a wildlife-friendly manner. However, additional mitigations are required to further reduce disturbance from light, noise and vibration to wildlife.			

[(Footnote 5)] Due to the paucity of the understanding of wildlife tolerance thresholds to these disturbances, this assessment is conservative with an emphasis on the Precautionary Principle [(23)]. The Precautionary Principle is an environmental approach that recommends for anticipatory action to be taken, when an activity possesses potential to cause harm and there is uncertainty about the impact magnitude of the activity [(23)]. As the wildlife tolerance thresholds to these disturbances are uncertain, the Precautionary Principle has been adopted in this assessment. The application of the Precautionary Principle has also taken into account that species of high conservation status inhabit other habitats in Singapore. Therefore, it is anticipated that the impact will not threaten the long-term viability of the species populations (Medium impact magnitude), as the national species populations can persist despite potential disturbance to species within the Project Area.

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Increased wildlife injury and mortality risk from vehicle strike along: • Access roads; and • Roads adjacent to worksites as wildlife are moving into neighbouring areas as a result of construction disturbance	<u>Impacts on Species</u> • **Ground-dwelling mammals** Increased traffic volume during the construction period of 5.5 years can lead to an increased risk of traffic strike on ground-dwelling mammals attempting to cross Island Club Road to reach the habitat across the road. Individuals moving across the habitat may suffer injury and mortality as a result, affecting species such the Sunda Pangolin (*Manis javanica*) which may not be so quick to avoid incoming traffic. As observed in development works close to natural habitat [24], the clearance of forest habitats may drive wildlife out from the area, causing them to be pushed to the edge of habitats close to roads where they become more susceptible to vehicle strike. With construction works at A1-W1, increased wildlife-vehicle collisions are anticipated to occur along Island Club Road. This is predicted to occur throughout the 5.5 years of construction works.	Species: Medium	Species: High	Species: Major
	• **Arboreal mammals** Arboreal mammals will also impacted by increased traffic volume during the construction period of 5.5 years. As the Malayan Colugo (*Galeopterus variegatus*) and Raffles' Banded Langur (*Presbytis femoralis femoralis)* (CR) are species that utilise habitual routes, the individuals may end up on the ground in the absence of a tree that was once present in the area and used as a connection to the adjacent forest fragment. The Long-tailed macaques (*Macaca fascicularis*) are edge species and will utilise habitats by Island Club Road, increasing their risk to vehicle strike as a result of increased traffic volume during the construction period. Roadkill records and observations indicate that these species are capable of crossing roads on the ground, despite it being not their preferred or usual way of movement especially for gliding mammals and the Raffles' Banded Langur. This may result in them suffering from injury and mortality from vehicle strike, which can cause a change in abundance and/or reduction in distribution of the populations.	Species: Medium	Species: High	Species: Major
	• **Birds** Birds are less likely to suffer injury and mortality from vehicle strike due to their mobility and mode of movement. Despite this, roadkill records indicate it is still plausible. Some bird species may also be struck by heavy vehicles moving along Island Club Road if the flight paths and vehicle paths coincide. However, it is anticipated that the presence of the worksite will not cause a substantial change to bird species populations.	Species: Small	Species: High	Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Increased wildlife injury and mortality risk from vehicle strike along: • Access roads; and • Roads adjacent to worksites as wildlife are moving into neighbouring areas as a result of construction disturbance	• **Herpetofauna** Increased traffic volume during the construction period of 5.5 years can lead to an increased risk of traffic strike on herpetofauna attempting to cross Island Club Road to reach the habitat across the road, or those that happen to bask in the path of incoming vehicles. These individuals may suffer injury and mortality as a result, affecting species such the species that may not be so quick to avoid the vehicles. The impact is not anticipated to cause a substantial change to herpetofauna populations.	Species: Small	Species: High	Species: Moderate
	• **Invertebrates** Butterflies and dragonflies can also suffer injury and mortality from vehicle strike with increased traffic volume throughout the construction period of 5.5 years, with species such as the Common Birdwing (*Troides helena cerberus)* (VU) present in the area. These are normally observed as collisions with the windscreens of incoming vehicles. It is anticipated that the impact will not cause a substantial change to invertebrate species populations.	Species: Small	Species: Medium	Species: Minor
Pollution of aquatic habitats from: • Sedimentation; • Hazardous runoff; and • Disposal of wastewater.	<u>Impacts on Habitat</u> The proposed location of A1-W1 is parallel to a series of roadside drains along Island Club Road, which are connected to stream Ma3 within Windsor Nature Park. Based on the assessment presented in *Chapter 2*, soil erosion and sedimentation could arise from the land clearance and grading works during the establishment of A1-W1. In addition, cement present on site may enter stream Ma3 via these roadside drains if cement gets into contact with surface runoff collected and discharged from the worksite. Sedimentation and hazardous runoff into the streams will cause increase in turbidity, and alkalinity decreasing water quality. As Stream Ma3 is connected to streams Ma2 and Ma1, there is a potential for these downstream sections to be affected.	Habitat: Large (for the 1st month of the construction phase and the rest of the construction phase)	Habitat: High	Habitat: Critical (for the 1st month of the construction phase and the rest of the construction phase)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Pollution of aquatic habitats from: • Sedimentation; • Hazardous runoff; and • Disposal of wastewater.	<u>Impacts on Species</u> *Volume III Chapter 2 Water Environment* has assessed that water quality impacts from sedimentation at A1-W1 could result in routine exceedances of ambient levels of total suspended solids (TSS) which was measured to be lower than 5 mg/l in these roadside drains. This effect is expected to be localised and until land cover is adequately restored. There are several organisms living within Ma3, Ma2 and Ma1 that can be affected by a decrease in water quality even if only for a few hours through the interference with breathing apparatus and poisoning. This could lead to potential mortality. While more mobile organisms such as fish can seek refuge in unaffected parts of the stream, smaller organisms could find the distance challenging to cover or are restricted to microhabitats within the stream. Stream-dependent fauna such as some bird species can also be affected by polluted habitats, affecting their food source. A stream section of 600 m will also be potentially affected thereby reducing the amount of refugia available overall to displaced wildlife. <u>Embedded Controls</u> Sedimentation and hazardous runoff will be managed by embedded controls to reduce the likelihood of discharge of water with sediment content over the statutory limit of 30 mg/L. While the Project is legally allowed to discharge water with sediment level up to 30 mg/L into the roadside drain, it is noted that the streams at Windsor Nature Park possess a baseline a TSS of less than 5 mg/L (*Volume II Table 4.5, SW108*); a TSS level approaching 30 mg/L is still a considerably large deviation from baseline conditions. The ECM treatment plant within the A1-W1 worksite will also include a neutralization system, to ensure that the water quality at the discharge point of the ECM plant falls within the range of pH 6 – 9 as required by regulations. This discharge limit is consistent with baseline pH level of 6.9 measured for stream Ma.	Species: Large (for the 1st month of the construction phase and the rest of the construction phase)	Species: High	Species: Critical (for the 1st month of the construction phase and the rest of the construction phase)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Pollution of aquatic habitats from: • Sedimentation; • Hazardous runoff; and • Disposal of wastewater.	In addition, LTA has committed to only allowing the discharge of runoff water into roadside drains, while requirements for offsite treatment and disposal of wastewater, ie slurry and dewatering water, from the construction site will be imposed on contractors. This reduces the potential for impact from hazardous runoff on aquatic habitats and species. Notwithstanding this, there is a possibility that the temporary ECM plant could be inadequate depending on the amount of the surface runoff. On a worst case basis, it is assumed that during the first month of the land clearance and site set up phase, the temporary ECM plant will not be sufficient.			

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event – Fire occurrence leading to: • Wildlife injury and mortality • Loss of habitat resources	Impacts on Habitat As stated in *Volume I, Section 2.5.4.5*, improper storage of flammable materials could result in the outbreak of fire at worksites. This will lead to the direct loss of habitat resources. Impacts on Species Direct injury and mortality from fire is expected from such an event. Some terrestrial and arboreal species, especially those that are nesting and resting, would not be able to flee from a sudden fire outbreak. Embedded Controls As per *Volume I, Section 2.5.4.5*, the worksite will adopt measures to ensure the proper handling of flammable materials so as to reduce the risk of fire. In addition, the volume of petroleum and flammable materials stored at the worksite will be restricted, and the regular checking and certification of use of all electrical installations, equipment and tools by a full-time licensed electrical worker will be enforced. Likelihood Evaluation As discussed in *Annex 1*, the likelihood of fire occurrence during construction is considered to be *Unlikely* (ie unlikely but may occur at some time during normal operating conditions). A response plan to the fire emergency would be the use of firefighting equipment stored on site by trained first responders, and the prompt mobilisation of the SCDF to the site to contain a larger fire. In the event that a fire occurs, the impact magnitude to wildlife and terrestrial habitats is conservatively assessed to be Large. Taking into consideration the embedded controls in place to minimise the likelihood of a fire occurring to *Unlikely*, the impact significance is evaluated to be reduced from Critical to Moderate.	Habitat: Large (in the event of a fire) Species: Large (in the event of a fire)	Habitat: Medium Species: High	Habitat: Major (in the event of a fire) Habitat: Moderate (considering the *Unlikely* occurrence of a fire) Species: Critical (in the event of a fire) Species: Moderate (considering the *Unlikely* occurrence of a fire)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Event – Spillage/overflow of effluent into surface waterbodies leading to pollution of aquatic habitats	<u>Impacts on Habitats</u> As stated in *Volume I, Section 2.5.4.4*, a number of unplanned events could result in uncontrolled discharge of untreated effluent potentially contaminated with concrete, chemicals, fuel, chemicals used for firefighting. Due to the topography of the area, this would mean that effluents might directly enter waterbodies such as stream Ma3, which is located downslope from the A1-W1 worksite. As these streams are connected to the Windsor Nature Park streams, disposal of untreated effluents into these channels could decrease the water quality of an entire stream network. <u>Impacts on Species</u> Several threatened species dwell within the Windsor Nature Park streams and there are many others dependent on the streams as a water source. Some aquatic species would not be able to avoid any disturbance within the streams as they could be restricted to certain sections of the stream.	Habitat: Large (in the event of spillage/ overflow)	Habitat: High	Habitat: Critical (in the event of spillage/ overflow) Habitat: Moderate (in the *Unlikely* event of spillage/ overflow)
	<u>Embedded Controls</u> Embedded measures include the sizing of an ECM system with adequate capacity to cater for exceptional rainfall events such as a once in 5 year storm, and the provision of perimeter drains and a sedimentation pond for containment and holding of firewater within the worksite until collection by a third party contractor for offsite disposal. <u>Likelihood Evaluation</u> As discussed in *Annex 1*, the likelihood of fire occurrence during construction is considered to be *Unlikely* (ie unlikely but may occur at some time during normal operating conditions). A response plan to fire emergency will include the holding of firewater within the worksite's ECM system (ie perimeter drain and sedimentation pond) for collection by a third party contractor for offsite disposal (see *Volume I, Section 2.5.4.5*). The likelihood of an ECM failure due to heavy rainfall is assessed to be *Possible*. In the event that a fire occurs, the impact magnitude to the aquatic habitat and species within stream Ma is conservatively assessed to be Large. Taking into consideration the embedded controls in place to minimise the likelihood of a fire or ECM failure occurring, the impact significance is evaluated to be reduced from Critical to Moderate.	Species: Large (in the event of spillage/ overflow)	Species: High	Species: Critical (in the event of spillage/ overflow) Species: Moderate (in the *Unlikely* event of spillage/ overflow)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
A1-W2 (LS/VS)				
Loss of vegetation and habitat resources	Impacts on Habitat Site clearance will lead to the loss of habitat, including the removal of 15,000 m^2 of Isolated Forest (IF) habitat for the construction of the worksite. The total area of available habitat within the forest patch is approximately 200,000 m^2. The loss of habitat due to the construction as a proportion of available habitat is 7.5% of the IF vegetation patch. This is anticipated to affect a part of the habitat but there is no loss of viability or function of the habitat.	Habitat: Medium	Habitat: Medium	Habitat: Moderate
	Impacts on Species • **Ground-dwelling mammals** Mammals such as the Sunda Pangolin (*Manis javanica*) (CR) will be displaced or extirpated during construction. They are less agile when threatened and will not be able to avoid the area during construction. It is likely that this area contains suitable resting and foraging sites for this species. Once displaced, ground dwelling fauna will no longer be able to access the Project site over the construction period of 5.5 years. Displaced individuals will seek refuge in suitable nearby habitats. There may be conflict over resources as the refuge areas may contain existing species populations.	Species: Medium	Species: High	Species: Major
	• **Flying mammals** The Narrow-winged Pipistrelle (*Pipistrellus stenopterus*) was observed in the area. Clearance will remove foraging and roosting sites for bats in the area, likely displacing the individuals. Once displaced, ground dwelling fauna will no longer be able to access the Project site over the construction period of 5.5 years. Displaced individuals will seek refuge in suitable nearby habitats. There may be conflict over resources as the refuge areas may contain existing species populations.	Species: Medium	Species: Low	Species: Minor
	• **Arboreal mammals** Malayan Colugos (*Galeopterus variegatus*) may be displaced or extirpated if they inhabit the trees due for clearance, or do not escape in time from the trees they may be resting on that are scheduled for felling. The displaced individuals will seek refuge in nearby habitats and may lead to conflict over resources. This can affect the population but will not threaten the long-term viability of the species population.	Species: Medium	Species: High	Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Loss of vegetation and habitat resources	• **Birds** Bird species observed at this site were the Straw-headed Bulbul (*Pycnonotus zeylanicus*) (EN) and the Changeable Hawk-eagle (*Spizaetus cirrhatus*) (EN). These species are mobile and have home ranges dependent on forest distributions. They utilise trees for nesting and roosting. Clearing activities will likely affect the availability of habitats and resources for these species during construction, such as food sources and suitable nesting sites.	Species: Medium	Species: High	Species: Major
	• **Invertebrates** Invertebrate species that reside within the habitat will be impacted through changes in available resources from construction activities. The dragonflies observed at this site were the Sapphire Flutterer (*Rhyothemis triangularis*) and Banded Skimmer (*Pseudothemis jorina*). Impacts include the loss of suitable breeding habitats, foraging habitats, food sources and the direct loss of individuals at both the pupal and adult stages.	Species: Medium	Species: Low	Species: Minor
	<u>Embedded Controls</u> The impacts to flora species of conservation concern will be managed by embedded controls listed under LTA's General Specification, Appendix A, Safety, Health and Environment (for Rail Project), October 2018. Through these measures, plants of conservation concern are likely to be salvaged or protected on site as far as practicable. Additional mitigation measures are required to survey for raptor roosts and confirm the presence of nest inhabitants. If roosts are determined to be inhabited, measures must be undertaken to ensure the safety of these birds, fledglings and eggs, if any. Works should wait until the fledgling has left the nest before progressing. Where this is not feasible, measures should be taken to ensure careful translocation of nest inhabitants with the guidance of fauna specialists.			

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Exacerbation of edge effects	Impacts on Habitat Edge effects such as vegetation desiccation will be experienced by the remaining habitats after vegetation clearance. This includes the exacerbation of edge effects at the forest fringes of the CCNR to the east of worksite A1-W2, comprising RA habitat. As dust from construction activities is typically deposited within 350 m of the source [(10)], dust emitted from worksite A1-W2 can be deposited on vegetation in this localised area of the CCNR. Dust deposition on leaves can affect the photosynthetic capacity of flora. Dust can affect respiration, transpiration and allow gaseous pollutants to penetrate, inducing mechanical stress on plants. It is anticipated that there could be a reduction in flowering and fruiting rates due to dust pollution from reduced photosynthesis [(21)]. This can affect the larger ecosystem that the habitat provides for. As rainfall is likely to wash away dust that has deposited, the impacts are likely to be an issue only during extended periods of low rainfall. The impact is anticipated to be localised and temporary. Impacts on Species Species diversity and composition can be impacted from edge effects, leading to changes in community dynamics and ecosystem functioning. However, the species residing in the habitat experience existing edge effects from activities and road traffic along the adjacent PIE. Species at the forest edge may have already adapted to the surroundings, while forest-dependent species may have already moved towards the forest core from the existing disturbance.	Habitat: Small Species: Small	Habitat: High Species: High	Habitat: Moderate Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Habitat Fragmentation	Impacts on Habitat The presence of the worksite will reduce the connectivity within the IF forest to a small extent but the entire habitat remains connected. Hence, this effect will affect a small part of the habitat and no loss of viability of the habitat is anticipated. The existing habitat is already separated from the CCNR by an 11-lane section of the PIE. The establishment of A1-W2 would not contribute significantly to existing fragmentation experienced by the habitat from the CCNR. In addition, the IF habitat remains a continuous forest patch as the worksite has been placed on the edge of the habitat.	Habitat: Small	Habitat: Medium	Habitat: Minor
	Impacts on Species • **Ground-dwelling mammals** As the habitat is presently separated from the CCNR by the PIE, the worksite is not likely to create significant additional fragmentation effects to this. The worksite is also placed at the edge of the habitat to prevent fragmentation within the forest patch. Roadkill records indicate that species still attempt to cross this barrier and the impact is not anticipated to cause a substantial change in the species population.	Species: Small	Species: High	Species: Moderate
	• **Flying mammals** As the habitat is presently separated from the CCNR by the PIE, the worksite is not likely to create significant additional fragmentation effects to this. Bats can also cover a greater landscape and can move across the forest batches through flight. It is anticipated that the presence of the worksite will not cause a substantial change to bat populations, given the existing fragmentation effects.	Species: Small	Species: Low	Species: Negligible
	• **Arboreal mammals** Malayan colugos (*Galeopterus variegatus*) will not be significantly affected by fragmentation due to the presence of the worksite, given the existing levels of fragmentation between the habitat and the CCNR. Crossing the PIE may not be a common occurrence due to this. Hence, the presence of the worksite will not cause a substantial change in the species populations from habitat fragmentation.	Species: Small	Species: High	Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Habitat Fragmentation	• **Birds** As some birds can cover a greater landscape and are able to move across forest patches, habitat fragmentation in this area is unlikely to affect the species observed on site such as the Straw-headed Bulbul (*Pycnonotus zeylanicus*) (EN) and the Changeable Hawk-eagle (*Spizaetus cirrhatus*) (EN). However, fragmentation can affect other bird species that forage and nest on the forest floor by increasing the distance between adjacent forest fragments. It is anticipated that the presence of the worksite will not cause a substantial change to bird species populations.	Species: Small	Species: High	Species: Moderate
	• **Invertebrates** Invertebrate species observed on site were dragonfly species, namely the Sapphire Flutterer (*Rhyothemis triangularis*) and Banded Skimmer (*Pseudothemis jorina*). Habitat fragmentation will lead to the increased distance between forest fragments for the species to move, and can impact the availability of remaining habitat. It is anticipated that the impact will not cause a substantial change to invertebrate species populations.	Species: Small	Species: Low	Species: Negligible
Disturbance to wildlife from: • Increased human presence; • Dust settlement; • Increased noise and vibration; and • Illumination.	Impacts on Species Construction activities will result in disturbance to wildlife from increased noise, vibration, dust settlement, illumination and human presence at the worksite. These potentially stressful disturbances for wildlife are anticipated to be generated over the construction period of 5.5 years. Illumination from the worksite will result in avoidance from light -intolerant species, or attraction of light- tolerant species or insects. This may alter natural competition dynamics and divert food sources for insect-dependent species. Illumination can also disrupt circadian rhythms of wildlife by extending diurnal or crepuscular behaviours in the vicinity of the worksite, as well as disorient and disrupt orientation in nocturnal animals possibly present at the worksite [20]. Other impacts to wildlife from artificial lighting include disruption of reproductive behaviours and communication patterns which have downstream impacts on ecosystem functions [20]. Dust generated from construction activities may also deposit onto vegetation and smother leaves, leading to a reduction in vegetative growth [21]. This can affect the larger ecosystem that this vegetation provides for. The impact of changes in air quality to human receptors has been evaluated	Species: Medium	Species: High	Species: Major

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to wildlife from: • Increased human presence; • Dust settlement; • Increased noise and vibration; and • Illumination.	in *Vol III Chapter 4 Air Quality*. Noise and vibration is anticipated to be generated intermittently from construction activities over the construction period (5.5 years). The anticipated noise and vibration levels from construction activities have been evaluated in *Vol III Chapter 3 Noise & Vibration* based on human receptor thresholds. The calculated vibration levels during piling (extraction of casings) at worksites ranged from 0.05 mm/s – 0.20 mm/s at identified human receptors in close proximity to the worksite. The scales and units of measure used in *Vol III Chapter 3 Noise & Vibration* [Footnote 6] *and Vol III Chapter 4 Air Quality* are those used to assess impacts on humans and may not be directly applicable to fauna [22]. This is because some fauna species are understood to have sensory receptors which have perception ranges and sensitivities that are above and/or below the ranges of human perception and sensitivity [22]. Excessive noise and vibration is known to disrupt sensory communication between animals and potentially interfere with mating, hunting and predator-evasion success [22]. Wildlife typically flee from the source to cope with the environmental disturbances, resulting in wildlife displacement and exclusion of habitat. This can lead to increased competition for resources, and bring territorial species into conflict with each other.			

[Footnote 6] The suitability of using different frequencies for the assessment has been evaluated for these disturbances, such as the appropriateness of using dB(A) and dB(G) for noise evaluations due to the disparity of human and fauna perception ranges. Infrasound sound and vibration ie sound and vibration waves occurring at < 20 Hz (below the audibility range for a typical healthy human), has implications for ecological taxa such as leaf-litter invertebrates, spiders and aquatic crustaceans, and fossorial snakes. The standardised G-weighting function is the most appropriate for infrasound but there are few established dB(G) thresholds by which to inform a quantitative impact assessment for the identified taxa groups which utilise or are particularly sensitive to vibration/infrasound due to function. The assessment was therefore undertaken using the A-weighted decibel, which is the measurement most representative of the human ear response to sound.

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to wildlife from: • Increased human presence; • Dust settlement; • Increased noise and vibration; and • Illumination.	The abovementioned impacts can result in displacement of wildlife from the vicinity of the worksite into adjacent refugia, but the disturbance is not anticipated to threaten the long-term viability of species populations in the area (Footnote 7). <u>Embedded Controls</u> Impacts from noise, vibration and illumination will be managed by embedded controls listed in *Table 5.5*. For example, light will be directed downwards to minimise glare on surrounding habitats and noise management measures will be implemented at the worksite. The development of a noise management plan will include measures that ensure quieter construction equipment are sourced, periodic checking of operating equipment against noise specifications are conducted, and training and competency requirements for personnel involved are met.			

(Footnote 7) Due to the paucity of the understanding of wildlife tolerance thresholds to these disturbances, this assessment is conservative with an emphasis on the Precautionary Principle (23). The Precautionary Principle is an environmental approach that recommends for anticipatory action to be taken, when an activity possesses potential to cause harm and there is uncertainty about the impact magnitude of the activity (23). As the disturbances have the potential to cause harm and wildlife tolerance thresholds to these disturbances are uncertain, the Precautionary Principle has been adopted in this assessment. The application of the Precautionary Principle has also taken into account that species of high conservation status inhabit other habitats in Singapore. Therefore, it is anticipated that the impact will not threaten the long-term viability of the species populations (Medium impact magnitude), as the national species populations can persist despite potential disturbance to species within the Project Area.

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Increased wildlife injury and mortality risk from vehicle strike along: • Access roads; and • Roads adjacent to worksites as wildlife are moving into neighbouring areas as a result of construction disturbance	<u>Impacts on Species</u> • **Ground-dwelling mammals** Increased traffic volume during the construction period of 5.5 years can lead to an increased risk of traffic strike on ground-dwelling mammals attempting to cross the PIE to reach the CCNR habitats across the road. Individuals moving across the habitat may suffer injury and mortality as a result, affecting species such the Sunda Pangolin (*Manis javanica*) which may not be so quick to avoid incoming traffic. As observed in development works close to natural habitat (24), the clearance of forest habitats may drive wildlife out from the area, causing them to be pushed to the edge of habitats close to roads where they become more susceptible to vehicle strike. With construction works at A1-W2, increased wildlife-vehicle collisions are anticipated to occur along the PIE. This is predicted to occur throughout the 5.5 years of construction works.	Species: Medium	Species: High	Species: Major
	• **Flying mammals** Bats are less likely to suffer injury and mortality from vehicle strike due to their mobility and mode of movement. Some individuals may also be struck by heavy vehicles moving along the PIE if their flight paths and vehicle paths coincide. However, it is anticipated that the presence of the worksite will not cause a substantial change to bat species populations.	Species: Small	Species: Low	Species: Negligible
	• **Arboreal mammals** As Malayan Colugos (*Galeopterus variegatus)* may still glide across the PIE, this poses the risk of vehicle strike when their gliding paths and vehicle paths of heavy vehicles collide. Crossing the PIE may not be a common occurrence due to the length of the PIE. However, it is anticipated that the presence of the worksite will not cause a substantial change to bat species populations.	Species: Small	Species: High	Species: Moderate
	• **Birds** Similar to bats, birds are less likely to suffer injury and mortality from vehicle strike due to their mobility and mode of movement. Some individuals may also be struck by heavy vehicles moving along the PIE if their flight paths and vehicle paths coincide. However, it is anticipated that the presence of the worksite will not cause a substantial change to bird species populations.	Species: Small	Species: High	Species: Moderate

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Increased wildlife injury and mortality risk from vehicle strike	• **Invertebrates** Increased traffic volume during the construction period of 5.5 years can lead to an increased risk of traffic strike on herpetofauna attempting to cross the PIE reach the CCNR, or those that happen to bask at the roadside in the path of incoming vehicles. These individuals may suffer injury and mortality as a result, affecting species such the species that may not be so quick to avoid the vehicles. The impact is not anticipated to cause a substantial change to herpetofauna populations.	Species: Small	Species: Low	Species: Negligible
Pollution of aquatic habitats from: • Sedimentation; • Hazardous runoff; and • Disposal of wastewater.	<u>Impacts on Habitat</u> The proposed location of A1-W2 is adjacent to roadside drains parallel to the PIE, flows either in a northerly direction and eventually towards Stream IC within the CCNR through an underground drain across the PIE, or in a southerly direction towards a series of drains at Eng Neo Avenue that eventually lead to the Marina Reservoir. Based on the assessment presented in *Chapter 2*, soil erosion and sedimentation could arise from the land clearance and grading works during the establishment of A1-W2. In addition, cement present on site may enter stream IC via these roadside drains if cement gets into contact with surface runoff collected and discharged from the worksite. Sedimentation and hazardous runoff into the streams will cause increase in turbidity, and alkalinity decreasing water quality. As the roadside drains flow towards stream IC within the CCNR, there is a potential for the connected aquatic habitats within the CCNR to be affected.	Habitat: Large (for the 1st month of the construction phase and the rest of the construction phase)	Habitat: High	Habitat: Critical (for the 1st month of the construction phase and the rest of the construction phase)
	<u>Impacts on Species</u> Given that stream IC is a forest stream within the CCNR, it is likely that there are organisms of conservation significance inhabiting the aquatic habitat. Species may be affected from the decrease in water quality from sedimentation at A1-W2, through the interference with breathing apparatus and poisoning. This could lead to potential mortality. While more mobile organisms such as fish can seek refuge in unaffected parts of the stream, smaller organisms could find the distance challenging to cover or are restricted to microhabitats within the stream. Stream-dependent fauna such as some bird species can also be affected by polluted habitats, affecting their food source.	Species: Large (for the 1st month of the construction phase and the rest of the construction phase)	Species: High	Species: Critical (for the 1st month of the construction phase and the rest of the construction phase)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Pollution of aquatic habitats from: • Sedimentation; • Hazardous runoff; and • Disposal of wastewater.	Embedded Controls Sedimentation and hazardous runoff will be managed by embedded controls to reduce the likelihood of discharge of water with sediment content over the statutory limit of 30 mg/L. While the Project is legally allowed to discharge water with sediment level up to 30 mg/L into the roadside drain, it is noted that Stream IC is a natural stream within the CCNR and is located within the catchment of the MacRitchie Reservoir. Water quality at Stream IC is assumed to be similar to Stream Ma. The ECM treatment plant within the A1-W2 worksite will also include a neutralization system, to ensure that the water quality at the discharge point of the ECM plant falls within the range of pH 6 – 9 as required by regulations. Notwithstanding this, there is a possibility that the temporary ECM plant could be inadequate depending on the amount of the surface runoff. On a worst case basis, it is assumed that during the first month of the land clearance and site set up phase, the temporary ECM plant will not be sufficient			
Unplanned event – Fire occurrence leading to: • Wildlife injury and mortality • Loss of habitat resources	Impacts on Habitat As stated in *Volume III, Chapter 2 Table 2.5*, improper storage of flammable materials could result in the outbreak of fire at worksites. This will lead to the direct loss of habitat resources. Embedded measures such as proper handling and management of flammable materials will be implemented. Impacts on Species Direct injury and mortality from fire is expected from such an event. Some terrestrial and arboreal species, especially those that are nesting and resting, would not be able to flee from a sudden fire outbreak. Embedded Controls As per *Volume I, Section 2.5.3* and *Section 2.5.4.5*, the worksite will adopt measures to ensure the proper handling of flammable materials so as to reduce the risk of fire. Likelihood Evaluation	Habitat: Large (in the event of a fire)	Habitat: Medium	Habitat: Major (in the event of a fire) Habitat: Moderate (in the *Unlikely* event of a fire)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned event – Fire occurrence leading to: • Wildlife injury and mortality • Loss of habitat resources	As discussed in *Annex 1*, the likelihood of fire occurrence during construction is considered to be *Unlikely* (ie unlikely but may occur at some time during normal operating conditions). A response plan for fire emergencies will include the holding of firewater within the worksite's ECM system (ie perimeter drain and sedimentation pond) for collection by a third party contractor for offsite disposal (see *Volume I, Section 2.5.4.5*). In the event that a fire occurs, the impact magnitude to wildlife and terrestrial/aquatic habitats is conservatively assessed to be Large. Taking into consideration the embedded controls in place to minimise the likelihood of a fire occurring to *Unlikely*, the impact significance is evaluated to be reduced from Critical to Moderate.	Species: Large (in the event of a fire)	Species: High	Species: Critical (in the event of a fire) Species: Moderate (in the *Unlikely* event of a fire)
Unplanned Event – Spillage/overflow of effluent into surface waterbodies leading to pollution of aquatic habitats	Impacts on Habitats As stated in *Volume I, Section 2.5.4.4*, a number of unplanned events could result in uncontrolled discharge of untreated effluent potentially contaminated with concrete, chemicals, fuel, chemicals used for firefighting. Effluents might flow to stream IC from the roadside drains adjacent to the worksite A1-W2. As these streams are within the CCNR and likely connected to the CCNR streams, disposal of untreated effluents into these channels could decrease the water quality of an entire stream network. Impacts on Species Pollution of the habitats can affect sensitive species within Stream IC and the connected streams within the CCNR. Some aquatic species would not be able to avoid any disturbance within the streams as they could be restricted to certain sections of the stream. Stream-dependent fauna will also be affected by the downstream impacts of pollution. Embedded Controls Embedded measures include the sizing of an ECM system with adequate capacity to cater for exceptional rainfall events such as a once in 5 year storm, and the provision of perimeter drains and a sedimentation pond for containment and holding of firewater within the worksite until collection by a third party contractor for offsite disposal.	Habitat: Large (in the event of spillage/ overflow) Species: Large (in the event of spillage/ overflow)	Habitat: High Species: High	Habitat: Critical (in the event of spillage/ overflow) Habitat: Moderate (in the *Unlikely* event of spillage/ overflow) Species: Critical (in the event of spillage/ overflow)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Unplanned Event – Spillage/overflow of effluent into surface waterbodies leading to pollution of aquatic habitats	<u>Likelihood Evaluation</u> As discussed in *Annex 1*, the likelihood of fire occurrence during construction is considered to be *Unlikely* (ie unlikely but may occur at some time during normal operating conditions). A response plan to fire emergency will include the holding of firewater within the worksite's ECM system (ie perimeter drain and sedimentation pond) for collection by a third party contractor for offsite disposal (see *Volume I, Section 2.5.4.5*). The likelihood of an ECM failure due to heavy rainfall is assessed to be *Possible*. In the event that a fire occurs, the impact magnitude to the aquatic habitat and species within Stream IC is conservatively assessed to be Large. Taking into consideration the embedded controls in place to minimise the likelihood of a fire or ECM failure occurring, the impact significance is evaluated to be reduced from Critical to Moderate.			Species: Moderate (in the *Unlikely* event of spillage/ overflow)

5.5.1.4 Mitigation Measures

In addition to embedded controls, measures to avoid, minimise, and limit the magnitude of impacts to ecology and biodiversity caused by the Project's construction phase are outlined in *Table 5.10*. Mitigation includes construction best practices, management plans, monitoring, and general housekeeping activities.

Table 5.10: ***Mitigation Measures for Ecology and Biodiversity Receptors during Project Construction***

Category	Mitigation
Governance and Administration	
Establishing key contact points	LTA and other relevant agencies to assign within their agencies dedicated individuals to manage and oversee all environmental aspects of the construction. These individuals are responsible for the review of documentation such as enhancements of the Biodiversity Monitoring and Management Plan, camera trap data and field survey findings. These individuals are to be copied in all key correspondence and also be involved in inspection spot checks. A monthly working meeting should be set up between both teams to discuss key findings, proposed adaptive management measures and address pressing issues relating to the environmental management of the worksites.
Contractor selection and evaluation	LTA should seek to engage contractors with experience and competence in undertaking development in environmentally sensitive areas, demonstrable sustainable construction policies and robust environmental management plans. LTA should ensure the incorporation of mitigation measures in the contractual provisions aimed at minimising deleterious impacts to ecology and biodiversity.
Biodiversity Monitoring	
Monitoring of construction impact on flora and fauna	Biodiversity monitoring should be undertaken to study the impacts of construction works on biodiversity in habitats adjacent to the construction worksites. This can inform the actions and next steps to be taken based on the monitoring results, as well as assist in decision-making processes for projects near sensitive habitats in the future. Biodiversity monitoring throughout the construction phase should be included in the **Biodiversity Monitoring and Management Plan** (as required by LTA's General Specifications). Ecological monitoring methods should include camera trap studies, transect surveys and vegetation surveys, all of which are to be conducted by expert personnel. These surveys are to include roadkill surveys on construction access roads and roads adjacent to the worksites. Wildlife specialists and/or NParks should advise on the study design, timing, frequency, scope, details of camera trap deployment and set-up which includes but is not limited to camera height, camera angle, camera placement, distribution of camera traps in the field, duration of the study, target species and capacities eg manpower and equipment. LTA should hire and appoint an environmental management consultant to propose a detailed environmental monitoring plan to include the specifics of the ecological monitoring plan. The plan, including the fauna and flora study designs, will be endorsed by the relevant technical agencies.

Category	Mitigation
Pre-construction	

Minimising harm to flora and fauna	Vegetation and land clearance will need to be undertaken prior to construction in preparation for the worksites. In order to minimise impacts on species that are found in habitats at the worksites and in close proximity, clearance must be undertaken with sensitivity and caution. Each worksite must be assessed for presence of species and key habitats of conservation concern and an evaluation undertaken on how these elements can be best conserved. This may be achieved through the enhancement of mitigation measures in the **Biodiversity Monitoring and Management Plan** (outlined below and as required by LTA's General Specifications) that will specify key actions to be undertaken before, during and after vegetation clearance. The plan will seek to minimise the loss of biodiversity due to vegetation and land clearance as far as practicable and compensate in kind, through the implementation of mitigation measures prior to construction activities.
	
	Biodiversity Monitoring and Management Plan
	The identification of species and habitat resources within and around the worksites are to be carried out by qualified wildlife specialists, vegetation specialists and arborists, with close supervision by and engagement with NParks.
	
	(i) Surveys within worksites to confirm the presence of flora species of conservation interest for salvage, transplantation and/or relocation:
	• Engage specialists to undertake vegetation surveys to identify flora species of interest to be salvaged and recorded in a database for reference.
	• Identified flora species of interest are to be tagged in the field and locations marked with a GPS to be recorded in the database.
	• Develop transplantation/salvage plan for saplings of conservation interest (if any) through engagement with NParks and consult NParks on the fate of the saplings within the worksite.
	• Upon arborist advice, salvaged saplings may be transplanted into a nursery to be maintained as a native stock before being planted back at the worksite post-construction.
	• Removal of any trees, especially those with girth > 1 m and/or listed as CR, EN and VU on the Singapore Red Data Book, must be approved by NParks.
	• Establish Tree Protection Zones (TPZ) around trees in close proximity to the worksites. These distances should be adhered to according to tree girth:
	    • Minimum protection zone of 2.0 m around a tree with girth ≤1.0 m.
	    • Minimum protection zone of 3.0 m around a tree with girth ≥1.0 m but ≤1.5 m.
	    • Minimum protection zone of 4.0 m around a tree with girth ≥1.5 m but ≤2.0 m.
	    • Minimum protection zone of 5.0 m around a tree with girth ≥2.0 m.
	
	(ii) Wildlife shepherding, hoarding and tree felling strategy:
	• The wildlife shepherding process should be coupled with the hoarding and tree felling strategy, and should only be scheduled during daylight hours.
	• The hoarding for the worksite will be erected prior to the shepherding and tree felling process. The installed hoarding will function as a drift fence to guide large fauna in the intended direction of movement into the adjacent forested areas and away from the roads. A section of the hoarding will be opened to face the area where wildlife will be shepherded towards in a systematic fashion out of the work areas into refuge sites (adjacent forested

Category	Mitigation
Minimising harm to flora and fauna	areas). The worksite area should be sectioned into parcels such that the process is conducted systematically for effective fauna management. The hoarding and shepherding plan is described below for both worksites: • A1-W1: The hoarding is to open to face the eastern portion of the forest patch, while guiding fauna to the culvert and restricting movement towards Island Club Road. • A1-W2: The hoarding is to open to face the habitat towards the west, while restricting fauna movement towards the PIE. • This process will be scheduled to avoid the prime breeding season for local avifauna ie mid-March to July annually. • Once the hoarding has been installed, fauna specialists should conduct tree inspections for trees scheduled for tree felling/transplantation. The surrounding area should also be inspected for fauna as part of the shepherding process, including dens and burrows within the worksite. Inspections include looking out for the presence of bird nests, squirrel nests, fauna inhabited in tree hollows eg Sunda Pangolin (*Manis javanica*) (CR) and potential wildlife on the tree eg Malayan Colugo (*Galeopterus variegatus*), Horsfield's Flying Squirrel (*Iomys horsfieldii*) (EN), Red-cheeked Flying Squirrel (*Hylopetes spadiceus*) (CR), Slow Loris (*Nycticebus coucang*) (CR). Snakes and bats are also likely to be encountered during this process. • Trees found to have active hollows or bird nests, ie inhabited with avifauna or their eggs, should not be felled until inhabitants have left on their own accord. Monitoring of active bird nests to be conducted at a frequency advised by NParks. Where this is not feasible due to Project constraints, fauna specialists should be engaged to relocate the fauna to a suitable habitat, upon the approval from relevant technical agencies. • For fauna found in the surrounding area that are unlikely to escape quickly during disturbance, eg Sunda Pangolin, Malayan Colugo and snake species should be handled by wildlife specialists, checked on by veterinarians if necessary and relocated to suitable habitats as advised by the EMMP consultants before tree felling can proceed. • Tree felling should be conducted in a controlled manner by skilled arboriculture workers e.g. directional felling methods. Trees should not be removed by pushing with excavators or heavy machinery to prevent affecting adjacent trees that have yet to undergo fauna inspections or are intended to be retained. With human presence and slight disturbance from controlled tree felling activities, it is expected that large and highly mobile fauna e.g. Wild Boar (*Sus scrofa*) will be naturally shepherded towards the refuge sites while being guided by the installed hoarding. • Notwithstanding the aforementioned measures, specialists should search through the felled tree material for potential injured or trapped fauna that may have gone undetected during tree inspections. Immediate veterinary care should be administered for injured or trapped fauna • A database should be maintained to record the species, GPS locations and actions taken for every encountered fauna individual.

Category	Mitigation

Minimising harm to flora and fauna	(iii) Biodiversity awareness training to workers on site
	• All construction personnel will undertake biodiversity awareness training prior to commencement of construction to raise their awareness of the:
	  • Ecological sensitivity of the CCNR located in close vicinity to the site;
	  • Proper protocols and reporting procedures to be adopted when wildlife is encountered; and
	  • Need to be cautious when operating machinery to avoid injury/mortality to fauna.
	• All workers to be educated to ensure that all work places are kept clean and waste is not left in open areas. Food should only be consumed at designated food and rest areas away from natural habitat where possible, to prevent attracting wildlife to the area as a food source. All workers will be prohibited from feeding animals.
	• Refresher training will be provided every 6 months during the construction phase for all new and old personnel.
	
	(iv) General measures for the installation of piezometers and settlement markers within the CCNR
	• Vegetation clearance, cutting or breaking or damaging branches of trees, shrubs and climbers are strictly prohibited.
	• No works at night (2000 h to 0559 h), dawn (0600 h to 0759 h) or dusk (1800 h to 1959 h).
	• Strictly no littering throughout works. All general waste to be bagged immediately and disposed of at dedicated public waste bins outside CCNR and the golf courses daily.
	• Restrict meal consumption to restricted designated areas as far away as possible from forest habitat to prevent human-wildlife conflict.
	• Use of trail/off trails as sanitary facility strictly prohibited. For work within the CCNR, public facilities within CCNR to be used. Outside CCNR, portable toilets to be provided and used.
	• Operations to be suspended during rain.

Protecting surface waterbodies and aquatic habitats	Land and vegetation clearance activities to be scheduled outside of November to January to avoid periods of higher rainfall in Singapore. This will reduce soil erosion and surface runoff, thereby reducing heavy sedimentation to adjacent habitats including surface waterbodies. Specific to A1-W1 Discharge to the roadside drain at Island Club Road leading to Stream Ma will be strictly prohibited. Treated effluent from the ECM at A1-W1 are proposed to be conveyed via a double containment pipeline to be discharged to a suitable surface water drain. PUB will be consulted on the alignment of the pipe and discharge point. Spare pumps, piping and other ancillary equipment will be stored at the worksite for redundancy to enable prompt replacements/repairs are made to allow for smooth operation of the ECM system at all times. Regular inspections will be made of the pipeline to ensure replacements are made in advance of significant leakage due to wear and tear.

Category	Mitigation
Protecting surface waterbodies and aquatic habitats	Specific to A1-W2 Discharge to the portion of drain that will lead to Stream IC will be strictly prohibited. Discharge of treated surface runoff and/or liquid waste can only be to the part of drain that flows in a southerly direction towards Eng Neo Avenue.
Managing unplanned events	Response plans have been developed to manage the risks of identified unplanned events ie excessive ground settlement and pollution of surface waterbodies from fire at worksites (see *Volume I, Section 2.5.4*). Further review of embedded controls are to be conducted and additional design considerations will be considered during the Advanced Engineering Study (AES) Stage due to the ecological sensitivity of the Study Area.
Construction Activities	
Protecting habitats	There are several measures that the Project will undertake to protect surface waterbodies in close proximity to the worksites. Given the need to completely clear the site of vegetation to establish the worksite, there will be a risk of erosion and sedimentation of nearby streams. Measures must also be taken to minimise the risk of spills and leaks of material, and response measures must be in place to manage these events should they occur. The measures have been grouped into the following categories: Surface Water Drainage • Offsite treatment and disposal of wastewater, ie slurry and dewatering water, to be strictly imposed at A1-W1. • Discharge to the roadside drain at Island Club Road leading to stream Ma is strictly prohibited at all times. Treated effluent from the ECM system at A1-W1 (LS/VS) worksite will be discharged to drains along Venus Drive or Upper Thomson Road, via a double containment pipeline. Waste and Stockpile Management • Locate temporary stockpiles of spoil/excavated earth at areas away from surface waterbodies and excavations (eg carparks), on solid ground and cover with a tarpaulin when not in use and/or during periods of rain. • Ensure control measures will be put in place to prohibit temporarily stockpiled material being washed into surface waterbodies, eg temporary drainage which is connected to Earth Control Measures facilities with collection sumps around stockpiling area; booms; regular removal and disposal of waste spoil etc. • To minimise the volume of spoil stockpiled and potential for dust generation and erosion/runoff, schedule removal of spoil from the Project area or waste material by licensed third party at least once every 5 days. • To minimise the mobilisation of dust during windy conditions, cover all stockpiles with well-maintained tarpaulin when not in use or as soon as practicable. • Illegal disposal of construction waste will be strictly prohibited. Waste bins to be provided in dedicated areas for general waste. • Waste avoidance, recycling, reuse and reduction initiatives to be implemented.

Category	Mitigation

Protecting habitats	• Wildlife-proof bins (bins with proper covers) should be procured and no food waste should be left in the open at all times to prevent attracting fauna into the worksites.
	• All general waste will be cleared daily.
	
	<u>Material Transportation</u>
	• Vehicles used to transport spoil will have proper cover and will not be overloaded.
	• All vehicles and machinery used for construction purposes will be cleaned prior to use on site to remove any seeds, plant and/or contaminating material. If vehicles and machinery leave the site, they will be cleaned/washed down prior to re-entry or departure from the Project area. All construction vehicles to pass through a bunded wheel wash upon entry and exit of the construction work areas.
	
	<u>Spill and Leak Management</u>
	• All equipment and machinery used at the construction or demolition worksites will be maintained and operated in a manner such that it does not give rise to smoke emissions or leakage of fuel/oil to ground, and will comply with the *Environmental Protection and Management (Vehicular Emissions) Regulations.*
	• Maintenance and mechanical repairs will be undertaken at dedicated designed locations, bunded to capture and control oil, grease and other spills.
	• Hazardous materials to be stored in bunded and covered areas in accordance with the manufacturer's safety requirements. Storage of hazardous materials on-site should be limited to the minimum necessary in order to reduce the impact of any spillage or mitigation failure.
	• Spill control measures (leaks from pipework during decommissioning; from machinery and equipment; spills as a result of accidental damage to other underground structures uncovered during excavation works etc.) throughout construction phase, to include but not be limited to the following:
	  ◦ Training protocol for all staff in spill response measures.
	  ◦ Spill management kits will be provided at worksites (composition will depend on the type of hazardous materials to be used, but likely include rags, sands, eyewash, protective gloves etc.) in particular where hazardous materials, equipment and machinery will be stored and used.
	
	<u>Sanitary Waste Management</u>
	• Locate portable sanitary facilities on hardstandings away from surface waterbodies.

Maintaining habitat connectivity	<u>Specific to A1-W1</u> • Suspected wildlife passageway culvert to be maintained to provide passage for wildlife between the IF patch and Windsor Nature Park throughout the construction phase. The EMMP consultant should use camera traps to verify fauna usage of the culvert during the AES Stage, under the advice of fauna specialists. There should be no dumping of waste at the culvert and no sedimentation. Inspections are to be carried out at the culvert daily to verify that it is clear. • Rope bridges with the dimensions and design appropriate for and specific to the Raffles' Banded Langur (*Presbytis femoralis femoralis*) should be implemented, upon advice from specialists and information on the species movement. This is to ensure that there is connectivity for the species to traverse between forest fragments.

Category	Mitigation
Minimising edge effects	Softening worksite edges • Planting of worksite perimeter with dense shrubs and saplings of indigenous stock to reduce the hardness of the worksite to the forest and maintain lower light levels and higher humidity around the edge. Planting is to be carried out in advance with the advice of a qualified arborist/horticulturist and with approval from NParks. The sites where planting is required should be assessed based on the conditions of the adjacent habitats identified from the worksite-specific baseline studies conducted at the AES stage. • For worksite hoarding, a colour palette will be used that has a Light Reflective Value (LRV) of less than 30%. The LRV Value may be varied where built structures are enclosed or do not directly face or reflect onto vegetated areas. All glazed surfaces will be placed at angles that limit direct light reflection into vegetated areas). Screens, louvres or shading may be used to limit direct sunlight penetration and reflection from glazed surfaces. Reducing dust on edge habitats • To minimise the transport of dust beyond the construction worksites, ensure that stockpiles will be maintained below a maximum height of 2 m so that perimeter hoarding or barriers (2.4 m high at least) can serve as an effective shield for surrounding buildings. Maintaining edge vegetation health • In the event where damaged trees and vegetation patches are observed after storm events or strong winds, engage an ISA-certified arborist to inspect the area as soon as practicable after the event. Recommendations (temporary measures or long term solutions) from the arborist are to be considered and implemented with consensus from NParks. • Monthly monitoring of edge vegetation health to be conducted by arborists.
Preventing introduction of exotic species	There are a number of ways Project activities may cause the establishment of exotic and potentially invasive species such as the creation of edge habitat and transportation of materials to and from the site. The following measures will be undertaken to protect the habitat integrity and native species present at high sensitivity areas such as Windsor Nature Park and CCNR. Preventing introduction through transportation pathway • All vehicles and machinery used for construction purposes will be cleaned prior to use on site to remove any seeds, plant, contaminating material. If vehicles and machinery leave the site, they will be cleaned/washed down prior to re-entry or departure from the Project area. • All construction vehicles to pass through a bunded wheel wash upon entry and exit of the construction work areas.

Category	Mitigation
Reducing disturbance to species at worksites	<u>Reducing light impacts</u> • Avoid all night works as far as possible. It is noted that for safety reasons, tunnelling will need to be undertaken round the clock. Night-time activities will be stepped down to as far as reasonably possible, while maintaining support to tunnelling works underground. • Lighting will be directed away from vegetated areas and habitats. Upward lighting will be avoided. Where lighting is required to be installed for safety and security purposes, regulatory requirements will be followed and light will be directed downwards where work is carried out. A lighting management plan will be developed to include measures that reduce illumination from worksites to adjacent habitats. • Avoid using lumination that has a high UV component to reduce impacts on insects. • Avoid using broad spectrum lights. <u>Reducing noise impacts</u> • As much as possible, schedule the changing of shifts during periods dominated by fauna vocalisations ie sunrise and sunset. Stepping down of equipment and activities will reduce noise disturbance to these fauna species. The feasibility of this will be assessed at the AES stage. <u>Fauna management</u> As part of the **Biodiversity Monitoring and Management Plan**, the following measures should be adopted: • Fully biodegradable Erosion Control Blankets should be procured. • No barbed wires and fences are to be used on site to prevent fauna from getting trapped. • Conduct daily checks on the integrity of the hoarding to prevent the entry of fauna into worksite. In the event that any damage to hoarding is detected, repair works should be undertaken immediately. • Upon encounter with dead/injured/live fauna on site, construction staff should stop work in the immediate area and are not permitted to handle or harass any fauna. • Workers should report the presence of fauna encountered on site to a designated wildlife specialist on call, and the wildlife specialist should capture the animal for follow-up actions upon engagement with NParks. Incidents should be investigated to identify possible points of entry from the hoarding which are to be sealed immediately.

Category	Mitigation

Reducing wildlife injury and mortality risk from vehicle strike	Mitigating roadkill at construction access roads
	• Vehicles ferrying workers, equipment and material to and from the worksites are to abide by a speed limit of 40 km/h to provide reaction time for stopping in case an animal is in the path.
	• Establish a register and investigation process to determine the cause of any roadkills during construction and operation. Ensure that all deaths are investigated and that gaps in mitigation measures that may have led to the death/injury are identified, and appropriate changes made to the mitigation strategy.
	• In consultation with NParks, specific roadkill mitigation measures and implementation locations are to be recommended during the Advance Engineering Study (AES), when access road locations have been determined and the ecological interactions throughout the greater landscape have been studied.
	
	Mitigating roadkill at roads adjacent to worksites
	• The feasibility of implementing roadkill mitigation measures should be considered and their effectiveness in the local context should be tested, with consultation with NParks, including but not limited to the following:
	  • Implement structural mitigation measures such as roadside barriers and crossing structures (26), known to be effective in facilitating wildlife movement towards connectivity structures while preventing their access to roads (27). These crossing structures are to include overpasses and underpasses to cater to the ecology of various fauna types i.e. terrestrial and arboreal.
	  • Install virtual fence devices (28) at roads adjacent to worksites that are in close proximity to natural habitats ie A1-W1, A1-W2 to prevent animals from crossing roads when there are approaching vehicles. The devices are triggered by light and sound to detect vehicle headlights and noise from approaching vehicles. When the device is triggered, it emits light and sound that can deter target animals from the roads. The type of light and sound emitted should be adjusted based on the sensory range that the target wildlife can pick up for this measure to be effective.
	  • Implement speed bumps and traffic calming signs at non-expressway roads next to worksites identified to have an increased traffic strike risk for wildlife ie Island Club Road adjacent to A1-W1.
	  • Install wildlife warning signs and animal detection systems to warn drivers of oncoming wildlife, specifically large mammals ie Wild Boars (*Sus scrofa*) and Sambar Deers (*Rusa unicolor*). Animal detection systems utilise infrared technology to detect animals that are approaching the road (29). The signal from the animal detection system activates the wildlife warning signs to warn motorists of approaching wildlife (29).
	
	Monitoring and maintenance of roadkill mitigation measures
	• Maintain all mechanical mitigation measures to ensure their structural and functional integrity. For example, virtual fence devices and animal detection systems, where implemented, should be regularly checked for their functionality and maintained according to manufacturer's recommendations.
	• Implement monitoring techniques of roadkill mitigation measures to provide insight on the effectiveness of the measures, and allow for the analysis of wildlife movements throughout the landscape.
	• Monitoring programmes are to be specified at a later stage when feasible mitigation measures have been identified for implementation.

Category	Mitigation
Reducing vibration impact and occurrence of unplanned events from operation of TBM	Vibration impact during TBM operation can be mitigated to As Low As Reasonably Practicable (ALARP) by: • Maintaining cutter tools in good condition; • Controlling cutterhead rotation speed and advance rate; • Fitting TBM with articulated front section for negotiating curves. Vibration monitoring at selected locations on the ground surface above and in advance of the TBM will be undertaken during construction. Vibration predictions will be forecasted on a monthly basis or as applicable e.g. when the TBM transitions into different geological conditions or depth of rock, based on these measurements. The vibration prediction forecasts will be reported to the TBM operator to enable prompt implementation of the abovementioned mitigation measures when vibration levels are predicted to exceed background levels during TBM operation. Strict engineering controls are also in place in accordance to LTA's standard approach of using a new TBM for the Project, in addition to measures in place to maintain positive cutterhead pressure. The tunnel excavation face will be grouted and stabilised prior to dismantling the TBM after works. For safety reasons, tunnelling will need to be undertaken round the clock. Night-time activities will be stepped down to as far as reasonably possible, while maintaining support to tunnelling works underground.
Post-Construction	
Replanting of native species	At the completion of the construction phase, facility buildings will be constructed within the worksite footprint of A1-W1 and A1-W2. As both worksites occupy 15,000 m^2 of land and the facility building landtake is 2,800 m^2, this presents the potential for 12,200 m^2 of land for replanting of native species and other pioneer species suitable for restoration activities. Upon the advice of arborists, the Project will seek to replant the land with saplings from the native stock salvaged during pre-construction. Planners should take into consideration the advice from NParks after arboriculture studies and fauna inspections to minimise disturbance to flora and fauna. Should there be excessive ground settlement, recovery works shall be carried out to make safe the area, followed by investigation works at the affected area. Habitat resources that could have been lost and wildlife injury to be recorded. If possible and feasible, restoration work to be undertaken after the situation has been deemed safe. NParks to be notified immediately should there be a loss of habitat resources; NParks and restoration specialists are to be consulted before restoration works are undertaken.

5.5.1.5 Residual Impacts

Based on the adoption of the abovementioned mitigation measures, potential impacts to species and habitats are anticipated to be reduced.

With the implementation of the appropriate mitigation measures, the impact magnitude of the described impact are reduced by one magnitude, with the exception of impact to habitat due to loss of vegetation. This is despite compensatory replanting of the worksite area after the completion of the construction phase. It is acknowledged that regeneration of the area with reforestation activities will take time (estimated to be 15 years or more), and even then will not fully restore the habitat to what it was prior to construction. Therefore, even with the implementation of the measure to conduct replanting activities, the impact magnitude for habitat loss remains the same.

A summary of the impact assessment for the construction phase of Alignment Option 1 is presented in *Table 5.11*.

Table 5.11: ***Impact Assessment Summary for Construction Phase of Alignment Option 1***

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Nature	Negative	Habitat loss, habitat fragmentation, disturbance to wildlife, edge effects and potential mortality to wildlife may occur from Project activities associated with establishing worksites A1-W1 and A1-W2.			
Type	Direct	Impacts to habitats and species will arise from Project activities.			
Duration	Long-term	These impacts will be present throughout the construction phase, which is estimated to take approximately 5.5 years.			
	Permanent	There will be permanent habitat loss as IF habitats will be cleared for A1-W1 and A1-W2. Facility buildings of 2,800 m^2 will be established within the worksites.			
Extent	Local	Impacts are localised within Singapore.			
Scale		15,000 m^2 of RA habitat will be cleared at A1-W1. 15,000 m^2 of IF habitat will be cleared at A1-W2.			
Frequency	Once	Vegetation clearance will occur during the construction phase. Ensuing resource loss, habitat fragmentation and edge effects will be experienced throughout the construction phase.			
	Intermittent	Generation of elevated noise and vibration levels, dust settlement, erosion and sedimentation will occur intermittently throughout the construction phase.			
	Daily	Increased human presence, vehicular traffic will be experienced daily and artificial illumination will be required every night. Specific to A1-W1, treated effluent may be discharged to roadside drainage linked to stream Ma within Windsor Nature Park.			

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Receptor Sensitivity	**Tunnel Alignment** Habitat: High Species: High	The tunnel alignment passes beneath habitat types classified as Regeneration Forest A (RA), Isolated Forest (IF), Primary Forest (PF), Wetland Marsh (WM), Wetland Forest (WF) and Golf Course/ Recreation Facilities (GC/RF), as well as streams within the CCNR. The portion of the CCNR has the potential to support CR/EN and endemic species.			
	A1-W1 (LS/VS) Habitat: Medium Species: High	A1-W1 is located on RA habitat, which has been classified as Medium sensitivity. A1-W1 is located in close proximity to the stream Ma within Windsor Nature Park, which is downstream of streams within the CCNR which may contain freshwater species of conservation interest ie High sensitivity. The Raffles' Banded Langur (*Presbytis femoralis femoralis*) (CR), Sunda Pangolin (*Manis javanica*) (CR), Common Palm Civet (*Paradoxurus hermaphroditus*), Lesser Mousedeer (*Tragulus kanchil*) (CR), Horsfield's Flying Squirrel (*Iomys horsfieldii*) (EN), Malayan Colugo (*Galeopterus variegatus*), Long-tailed Macaque (*Macaca fascicularis*) and Wild Boar (*Sus scrofa*) have been observed in the habitat. The striped-kukri snake (*Oligodon octolineatus*) is often observed as roadkill on Island Club Road.			
	A1-W2 (LS/VS) Habitat: Medium Species: High	A1-W2 is located on IF habitat, which has been classified as Medium sensitivity. A1-W2 is located across the PIE from RA habitat within CCNR, which has been classified as High sensitivity. Wildlife such as the Sunda Pangolin (*Manis javanica*) (CR), Malayan Colugo (*Galeopterus variegatus*), Straw-headed Bulbul (*Pycnonotus zeylanicus*) (EN), Changeable Hawk-Eagle (*Spizaetus cirrhatus*) (EN), Rhinoceros Hornbill (*Buceros rhinoceros*) (VU), White-throated Kingfisher (*Halcyon smyrnensis*), Pink-necked Green Pigeon (*Treron vernans*) and Javan Myna (*Acridotheres javanicus*) were observed in the area.			

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Pre-Mitigation Impact Magnitude	Large	**Tunnel Alignment:** Habitat & Species: Large impact from the *Unlikely* occurrence of excessive ground settlement **A1-W1 (LS/VS):** Habitat: Large impact for pollution of aquatic habitats in stream Ma, the *Unlikely* occurrence of a fire and the *Possible* occurrence of spillage/overflow of effluent into stream Ma Species: Large impact for pollution of aquatic habitats in stream Ma, the *Unlikely* occurrence of a fire and the *Possible* occurrence of spillage/overflow of effluent into stream Ma **A1-W2 (LS/VS):** Habitat: Large impact for pollution of aquatic habitats in stream IC, the *Unlikely* occurrence of a fire and the *Possible* occurrence of spillage/overflow of effluent into stream IC Species: Large impact for pollution of aquatic habitats in stream IC, the *Unlikely* occurrence of a fire and the *Possible* occurrence of spillage/overflow of effluent into stream IC	**Residual Impact Magnitude**	Large	**A1-W1 (LS/VS):** Habitat: Large impact for pollution of aquatic habitats in stream Ma during the 1st month of construction before the ECM is fully set up Species: Large impact for pollution of aquatic habitats in stream Ma during the 1st month of construction before the ECM is fully set up_ **A1-W2 (LS/VS):** Habitat: Large impact for pollution of aquatic habitats in stream IC during the 1st month of construction before the ECM is fully set up Species: Large impact for pollution of aquatic habitats in stream IC during the 1st month of construction before the ECM is fully set up

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Pre-Mitigation Impact Magnitude	Medium	**A1-W1 (LS/VS):** Habitat: Medium impact for loss of vegetation and habitat resources and exacerbation of edge effects Species: Medium impact for loss of vegetation and habitat resources, habitat fragmentation, disturbance to wildlife, increased wildlife injury and mortality risk from vehicle strike **A1-W2 (LS/VS):** Habitat: Medium impact for loss of vegetation and habitat resources Species: Medium impact for loss of vegetation and habitat resources, disturbance to wildlife, and increased wildlife injury and mortality risk from vehicle strike	**Residual Impact Magnitude**	Medium	**A1-W1 (LS/VS) & A1-W2 (LS/VS):** Impact magnitude for habitat remains Medium for loss of vegetation despite compensatory replanting of the worksite area after the completion of the construction phase. It is acknowledged that regeneration of the area with reforestation activities will take time (estimated to be 15 years or more), and even then will not fully restore the habitat to what it was prior to construction.
	Small	**Tunnel Alignment:** Species: Small impact for disturbance to wildlife due to vibration from operation of TBM and installation of monitoring instrumentation within the CCNR **A1-W1 (LS/VS):** Habitat: Small impact for habitat fragmentation Species: Small impact for exacerbation of edge effects		Small	**A1-W1 (LS/VS), A1-W2 (LS/VS):** With the implementation of mitigation measures, impact magnitudes on habitat and species from most sources remain Small. Some impacts are reduced but remain Small. Impact magnitudes cannot be considered to be Negligible (ie within the normal range of natural variation and variation for the population for the species).

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Pre-Mitigation Impact Magnitude	Small	**A1-W2 (LS/VS):** Habitat: Small impact for exacerbation of edge effects and habitat fragmentation Species: Small impact for exacerbation of edge effects and habitat fragmentation	**Residual Impact Magnitude**	Negligible	**Tunnel Alignment:** With the implementation of mitigation measures, the disturbance to biodiversity from the operation of the TBM is anticipated to be Negligible as the vibration levels would be below baseline levels. It is noted that excessive ground settlement is considered an unplanned event, and has been assessed separately. **A1-W1 (LS/VS):** The relocation of the A1-W1 ECM discharge from the roadside drain along Island Club Road to Venus Drive or Upper Thomson Road, eliminates the pathway between A1-W1 discharge and stream Ma. This measure will be in place from the 1st month of the construction phase. **A1-W2 (LS/VS):** Discharge to stream IC will be prohibited. ECM discharges from the A1-W2 worksite will be routed to the drain running in the southerly direction towards the Marina Reservoir. This measure will be in place from the 1st month of the construction phase.

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Pre-Mitigation Impact Significance	Critical	**A1-W1 (LS/VS):** Habitat: Critical impact for pollution of aquatic habitat in stream Ma Species: Critical impact to aquatic species in stream Ma **A1-W2 (LS/VS):** Habitat: Critical impact for pollution of aquatic habitat in stream IC Species: Critical impact to aquatic species in stream IC	**Residual Impact Significance**	Critical	**A1-W1 (LS/VS):** Habitat: Critical impact for pollution of aquatic habitat in stream Ma (1st month of the construction) Species: Impact to aquatic species in stream Ma (1st month of the construction) This is a conservative assessment to account for potential sedimentation of stream Ma before the ECM is fully set up and before the discharges from A1-W1 are fully diverted away from the stream. It is noted that the effects would be short-term (not more than 1 month), and that the stream is flowing out of the CCNR into open canals linked to the Marina Reservoir. **A1-W2 (LS/VS):** Habitat: Critical impact for pollution of aquatic habitat in stream IC (1st month of the construction) Species: Impact to aquatic species in stream IC (1st month of the construction) This is a conservative assessment to account for potential sedimentation of stream IC before the ECM is fully set up and before the discharges from A1-W2 are fully diverted away from the MacRitchie catchment area.
	Major	**A1-W1 (LS/VS):** Habitat: Major impact for exacerbation of edge effects Species: Major impact for loss of vegetation and habitat resources, disturbance to wildlife, habitat fragmentation and increased wildlife injury and mortality risk from vehicle strike **A1-W2 (LS/VS):** Species: Major impact for loss of vegetation and habitat resources, disturbance to wildlife, and increased wildlife injury and mortality risk from vehicle strike			

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Pre-Mitigation Impact Significance	Moderate	**Tunnel Alignment:** Habitat: Moderate impact for excessive ground settlement Species: Moderate impact for disturbance to wildlife and excessive ground settlement	**Residual Impact Significance**	Moderate	**Tunnel Alignment:** Habitat: Moderate impact for excessive ground settlement Species: Moderate impact for excessive ground settlement
		A1-W1 (LS/VS): Habitat: Moderate impact for loss of vegetation and habitat resources, fire occurrence and spillage/overflow of effluent into stream Ma Species: Moderate impact for exacerbation of edge effects, fire occurrence and spillage/overflow of effluent into stream Ma			**A1-W1 (LS/VS):** Habitat: Moderate impact for loss of vegetation and habitat resources and exacerbation of edge effects Species: Moderate impact for loss of vegetation and habitat resources, habitat fragmentation, fire occurrence, disturbance to wildlife, increased injury and mortality from vehicle strike, and pollution impacts to aquatic species in stream Ma due to spillage/overflow of effluent into stream Ma
		A1-W2 (LS/VS): Habitat: Moderate impact for loss of vegetation and habitat resources, exacerbation of edge effects, fire occurrence and spillage/overflow of effluent into stream IC Species: Moderate impact for exacerbation of edge effects, habitat fragmentation, fire occurrence and spillage/overflow of effluent into stream IC			**A1-W2 (LS/VS):** Habitat: Moderate impact for loss of vegetation and habitat resources and exacerbation of edge effects Species: Moderate impact for loss of vegetation and habitat resources, habitat fragmentation, fire occurrence, disturbance to wildlife, and increased wildlife injury and mortality from vehicle strike, and pollution impacts to aquatic species in stream IC due to spillage/overflow of effluent into stream IC

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity due to Construction Phase					
Pre-Mitigation Impact Significance	Minor	**A1-W1 (LS/VS):** Habitat: Minor impact for habitat fragmentation **A1-W2 (LS/VS):** Habitat: Minor impact for habitat fragmentation	**Residual Impact Significance**	Minor	**A1-W1 (LS/VS):** Habitat: Minor impact for habitat fragmentation **A1-W2 (LS/VS):** Habitat: Minor impact for habitat fragmentation
				Negligible	**Tunnel Alignment:** Species: Negligible impact for disturbance to wildlife
					A1-W1 (LS/VS): Habitat & Species: Negligible impact to aquatic species in stream Ma3 due to relocation of ECM discharge from roadside drain along Island Club Road to drain along Venus Drive or Upper Thomson Road. **A1-W2 (LS/VS):** Habitat & Species: Negligible impact to aquatic species in stream IC due to rerouting of ECM discharge to drainage running in a southerly direction into the Marina Reservoir catchment area instead of in the northerly direction into Stream IC.

5.5.2 Impacts to Ecology and Biodiversity due to Operation Phase

5.5.2.1 Sources of Impact

The sources of impacts associated with the operation phase are as follows:

- Presence of permanent structures such as facility buildings and access roads; and
- Unplanned events such as explosion or fire.

The impacts that will arise due to these activities are:

- Edge effects from the presence of permanent structures;
- Disturbance to wildlife due to presence of permanent structures;
- Pollution of surface waterbodies and aquatic habitats; and
- Loss of habitat resources and direct injury and/or mortality to fauna from fire due to unplanned events.

5.5.2.2 Receptors

The sensitivity values of the species within each worksite footprint and along Alignment Option 1 have been presented in *Table 5.8*.

5.5.2.3 Impact Magnitude & Significance

A summary of the magnitude and significance of impacts to receptors during Project operation is provided in *Table 5.12*.

Table 5.12: Magnitude of Impacts to Receptors (Operation Phase)

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Edge effects from the presence of permanent structures	With permanent facility buildings during Project operation phase, wind tunnel effects may be observed where the presence of structures causes wind to accelerate at the base and around the corners of buildings [25]. Localised wind issues may result in vegetation desiccation and tree fall due to the newly construction facility building. There may also be drying of surrounding vegetation due to air emissions from the outlets of the ventilation shafts. A separate study will be undertaken to better understand the drying effect of surrounding vegetation from ventilation shafts. This study will verify the zone of influence and the effects to ambient air temperature from ventilation shaft emissions, with which the effects on ecology will be assessed. This information will be provided as an addendum to this EIA report at a later stage.			
Disturbance to species due to presence of the permanent structures	The permanent presence of the facility buildings poses a partial barrier to wildlife movement and may induce behavioural changes in animals that view this structure to be intrusive. For A1-W2, the facility building will permanently reduce the connectivity within the forest patch. Animals such as bats, birds and some invertebrate species (eg wasps) may set up roosts on the facility buildings. If these roosts interfere with maintenance works, they may need to be cleared resulting in disturbance and potential wildlife injury/mortality. It should be noted that these impacts are continued from the construction phase as there is little difference between transitioning from a worksite that has been hoarded for approximately 5.5 years to a permanent structure. It is recognised that facility buildings in operation have the potential to change ambient temperatures due to air and heat movement, possibly having a drying effect on adjacent habitats and contributing to the heat island effect. As noted above a separate study will be undertaken to better understand the drying effect of surrounding vegetation from the buildings.	A1-W1: Medium A1-W2: Medium	A1-W1: High A1-W2: High	A1-W1: Major A1-W2: Major

Impact	Impact Summary	Impact Magnitude	Receptor Sensitivity	Impact Significance
Disturbance to species due to presence of the permanent structures	This study will verify the zone of influence and the effects to ambient air temperature from ventilation shaft emissions, with which the effects on ecology will be assessed. Without mitigation measures guiding the sensitive design of the buildings, protocols for roost removal and habitat reinstatement methods, the impact magnitude of the presence of these permanent structures has been evaluated to be **Medium**.			
Pollution of surface waterbodies and aquatic habitats	The presence of the facility buildings at A1-W1 and A1-W2 will introduce an increase of up to 3,000 m^2 of impermeable ground surface. This will lead to an increase in surface runoff. This may alter surface flow regimes of the stream Ma3 as surface runoff at the A1-W1 location is currently discharged to the roadside drain at Island Club Road, which eventually discharges to stream Ma3. Presently, the proposed location of the A1-W2 facility building sits within the catchment area for Marina Reservoir. Surface runoff at A1-W2 will therefore be collected and discharged to the drain, which drains in a southerly direction to the Marina Reservoir. As there will be no discharge in the northerly direction to Stream IC which leads to MacRitchie Reservoir, the impact magnitude to these receptors is therefore assessed to be **Negligible**. As an embedded control, the facility building will be designed with a detention tank that is sized to cope with the increased runoff due to the introduction of impermeable ground surface at the site. This will reduce the rate of increased surface runoff discharged from the facility building sites. The impact magnitude to streams Ma3 is therefore assessed to be **Small**.	A1-W1: Small A1-W2: Negligible	A1-W1: High A1-W2: High	A1-W1: Moderate A1-W2: Negligible

<table>
<tr><th>Impact</th><th>Impact Summary</th><th>Impact Magnitude</th><th>Receptor Sensitivity</th><th>Impact Significance</th></tr>
<tr><td rowspan="4">Unplanned event –
Fire leading to
• Pollution of aquatic habitat
• Loss of habitat resources
• Direct injury and/or mortality to fauna</td><td rowspan="4">Major fires and explosion in the tunnels or fires at the facility building will lead to the direct loss of habitat resources, and direct injury and/or mortality to fauna from fire. There will also be venting of smoke through the facility buildings during a fire in the tunnel. This will deposit dust and fumes over a potentially large area of the habitat, causing substantial disturbance to populations and may even result in injury/mortality if the event is severe enough. Some terrestrial and arboreal species, especially those that are nesting and resting, would not be able to flee from a sudden fire outbreak beyond the facility building.

Specific to A1-W1, firewater generated from firefighting may be discharged to the roadside drain along Island Club Road, which will eventually discharge to stream Ma3 within Windsor Nature Park. This will lead to a decrease in water quality, leading to impacts to the aquatic habitat and species.

<u>Embedded Controls</u>
Embedded controls will include regular inspections of electrical equipment within the tunnel and facility building, the design of the facility building with a minimum buffer distance of 30 m from the forest edge, and the design of perimeter drains and a detention tank for the containment of firewater within the facility building site (see Volume III, Annex 1.0, Section A1.2.5).

<u>Likelihood Evaluation</u>
As discussed in Annex 1, the likelihood of fire occurrence as an unplanned event during Operation is considered to be Possible (ie the event is likely to occur at some time during normal operating conditions) (see Volume III, Annex 1.0, Section A1.2.5).

In the event that a fire occurs, automatic firefighting systems installed within the tunnel and facility building eg smoke detector alarm, sprinkler system, will be triggered as a first line of response. The SCDF will be deployed to the site to further contain the fire. Firewater will be contained within the site's perimeter drains and detention tank for offsite disposal. In view of the response plan, the impact magnitude to wildlife and terrestrial habitats is assessed to be Small. Taking into consideration the possible likelihood of a fire occurring, the impact significance has been evaluated to remain as Minor for habitat, and Moderate for species.</td><td rowspan="2">A1-W1: Small (in the event of a fire)</td><td>Habitat: Medium</td><td>A1-W1: Minor</td></tr>
<tr><td>Species: High</td><td>A1-W1: Moderate</td></tr>
<tr><td rowspan="2">A1-W2: Small (in the event of a fire)</td><td>Habitat: Medium</td><td>A1-W2: Minor</td></tr>
<tr><td>Species: High</td><td>A1-W2: Moderate</td></tr>
</table>

5.5.2.4 Mitigation Measures

Measures to avoid, minimise, and limit the magnitude of impacts to ecology and biodiversity caused by the Project's operation phase are outlined in *Table 5.15*.

Table 5.15: ***Mitigation Measures for Habitat and Species Receptors during Project Operation***

Category	Mitigation Measures
Minimising disturbance to species	<u>Building Design</u> • Design of permanent aboveground structures, including security fences, to adopt use of natural materials, vertical greening and wildlife friendly design. Natural tones for the building façade or green roofing to be considered to increase visual compatibility with surroundings and non-reflective finishes to be adopted to reduce potential glare effect. • Verge around facility building to be planted up with attractive, native plant species. Plants of a variety of growth habits should be utilized to provide structure to the vegetation and integration with the surrounding forest. • Replanting of native fauna species at the land around the facility building is to be carried out at the worksite. <u>Building Location</u> • Prior to confirmation of facility building locations, planners should take into consideration the advice from NParks after arboriculture studies and fauna inspections, to minimise disturbance to flora and fauna. <u>Managing Roosts at Facility Buildings</u> • Any roosts and nests found to interfere with maintenance works or the ventilation shaft building function to be removed by trained personnel; • LTA to maintain and share with NParks a record of the numbers of roosts/animals removed and the methods undertaken.
Managing unplanned events – fire occurrence	Response plans have been developed to manage the risks of fire occurrence e.g. firefighting system installed within tunnel and facility building, and containment of firewater within the detention tank for holding until collection by third party contractors for offsite disposal (see *Volume I, Section 2.5.4*). Further review of embedded controls are to be conducted and additional design considerations should be considered during the Advanced Engineering Study (AES) Stage due to the ecological sensitivity of the sites.

5.5.2.5 Residual Impacts

Based on the adoption of the abovementioned mitigation measures, potential impacts to habitats and species associated with the operation phase of Alignment Option 1 are anticipated to be largely reduced.

With the implementation of the appropriate mitigation measures, the impact magnitude of the described impacts are reduced by one magnitude.

A summary of the impact assessment for the operation phase of Alignment Option 1 is presented in *Table 5.16*.

Table 5.16: ***Impact Assessment Summary for Operation Phase of Alignment Option 1***

Criterion	Rating	Comment	Criterion	Rating	Comment
Impacts to Ecology and Biodiversity during Operation Phase					
Nature	Negative	Similar to the impacts during construction phase, the permanent presence of the facility building poses a partial barrier to wildlife movement, may result in behavioural changes (continued from construction phase). Roosts or nests on the facility buildings that interfere with maintenance works may need to be removed leading to potential wildlife displacement, mortality or injury. A fire/explosion during operation may vent out copious amounts of dust and smoke which can affect a large area of habitat. It can also lead to the direct loss of habitat resources, and injury and/or mortality of fauna in the affected area.			
Type	Direct	These effects are directly due to the Project.			
Duration	Long-term	These impacts will be present until wildlife become accustomed to these structures. However, risk of mortality from roadkill or removal of roots will still be present.			
Extent	Local	These impacts are localised within Singapore.			
Scale	-	-			
Frequency	Daily	Presence of permanent facility building poses as a potential barrier to wildlife movement.			
Likelihood	Possible	Based on correspondence with LTA, the probability of fire and explosion during Operation is Possible.			
Receptor Sensitivity	**A1-W1 (LS/VS)** Habitat: Medium Species: High	A1-W1 is located on RA habitat, which has been classified as Medium sensitivity. A1-W1 is located in close proximity to the stream Ma within Windsor Nature Park, which is downstream of streams within the CCNR which may contain freshwater species of conservation interest ie High sensitivity. The Raffles' Banded Langur (*Presbytis femoralis femoralis*) (CR), Sunda Pangolin (*Manis javanica*) (CR), Common Palm Civet (*Paradoxurus hermaphroditus*), Lesser Mousedeer (*Tragulus kanchil*) (CR), Horsfield's Flying Squirrel (*Iomys horsfieldii*) (EN), Malayan Colugo (*Galeopterus variegatus*), Long-tailed Macaque (*Macaca fascicularis*) and Wild Boar (*Sus scrofa*) have been observed in the habitat. The striped-kukri snake (*Oligodon octolineatus*) is often observed as roadkill on Island Club Road.			
	A1-W2 (LS/VS) Species: High	A1-W2 is located on IF habitat, which has been classified as Medium sensitivity. A1-W2 is located across the PIE from RA habitat within CCNR, which has been classified as High sensitivity. Wildlife such as the Sunda Pangolin (*Manis javanica*) (CR), Malayan Colugo (*Galeopterus variegatus*), Straw-headed Bulbul (*Pycnonotus zeylanicus*) (EN), Changeable Hawk-Eagle (*Spizaetus cirrhatus*) (EN), Rhinoceros Hornbill (*Buceros rhinoceros*) (VU), White-throated Kingfisher (*Halcyon smyrnensis*), Pink-necked Green Pigeon (*Treron vernans*) and Javan Myna (*Acridotheres javanicus*) were observed in the area.			

Pre-Mitigation Impact Magnitude	Medium	The facility buildings at A1-W1 and A1-W2 will create some disturbance to wildlife at the onset but these impacts are continued from the construction phase.	**Residual Impact Magnitude**	Small	**A1-W1 (LS/VS):** With the implementation of mitigation measures, impact magnitudes on species due to presence of facility buildings are reduced from Medium to Small. Impact magnitude on aquatic species due to the presence of the facility building at A1-W1 remains as Small. Impacts cannot be considered to be Negligible (ie within the normal range of natural variation and variation for the population for the species). **A1-W2 (LS/VS):** With the implementation of mitigation measures, impact magnitudes on species due to presence of facility buildings are reduced from Medium to Small.
	Small	Due to the design of a detention tank to control the peak discharge of surface runoff from the facility building, the impact on stream Ma3 due to increased impermeable surface at the A1-W1 facility building during operation is evaluated to be Small. The impact of fire occurrence has been evaluated to be Small due to the ability of personnel to contain the fire within the facility building.			
	Negligible	Due to the proposed location of the A1-W2 facility building within the catchment area for Marina Reservoir, surface runoff collected at the facility building site will be discharged to drain networks the empty to the Marina Reservoir. As there will be no discharge to Stream IC, which leads to MacRitchie Reservoir, the impact of increased surface runoff to these receptors is evaluated to be Negligible.		Negligible	**A1-W2 (LS/VS):** Impact magnitude on aquatic species within Stream IC and MacRitchie Reservoir due to the presence of the facility building at A1-W2 is evaluated to be Negligible as there will be no pathway for surface runoff to be discharged from A1-W2 to these waterbodies.
Pre-Mitigation Impact Significance	Major	**A1-W1 (LS/VS):** Species: Major impact for disturbance to species due to presence of permanent structures	**Residual Impact Significance**	Moderate	**A1-W1 (LS/VS):** Habitat: Moderate impact for pollution of stream Ma due to increased surface runoff Species: Moderate impact for disturbance to species due to presence of permanent structures, impact to aquatic species in stream Ma and fire occurrence
		A1-W2 (LS/VS): Species: Major impact for disturbance to species due to presence of permanent structures			**A1-W2 (LS/VS):** Species: Moderate impact for disturbance to species due to presence of permanent structures and fire occurrence

<table>
<tr><td rowspan="5"><u>Pre-Mitigation</u> Impact Significance</td><td rowspan="2">Moderate</td><td>A1-W1 (LS/VS):
<u>Habitat</u>: Moderate impact for pollution of stream Ma due to increased surface runoff
<u>Species</u>: Moderate impact to aquatic species in stream Ma and fire occurrence</td><td rowspan="5"><u>Residual</u> Impact Significance</td><td rowspan="4">Minor</td><td>A1-W1 (LS/VS):
<u>Habitat:</u> Minor impact for fire occurrence</td></tr>
<tr><td>A1-W2 (LS/VS):
<u>Species</u>: Moderate impact for fire occurrence</td><td rowspan="3">A1-W2 (LS/VS):
<u>Habitat:</u> Minor impact for fire occurrence</td></tr>
<tr><td rowspan="2">Minor</td><td>A1-W1 (LS/VS):
<u>Habitat</u>: Minor impact for fire occurrence</td></tr>
<tr><td>A1-W2 (LS/VS):
<u>Habitat</u>: Minor impact for fire occurrence</td></tr>
<tr><td>Negligible</td><td>A1-W2 (LS/VS):
<u>Habitat & Species</u>: Negligible impact for pollution of stream IC due to increased surface runoff</td><td>Negligible</td><td>A1-W2 (LS/VS):
<u>Habitat & Species</u>: Negligible impact for pollution of stream IC as increased surface runoff from the facility building will be routed away from stream IC, and in a southerly direction towards the Marina Reservoir</td></tr>
</table>

6 VISUAL, CULTURAL HERITAGE, TOURISM & RECREATION

6.1 INTRODUCTION

This chapter presents an assessment of the impacts to landscape and visual receptors, cultural and heritage resources and tourism and recreation from activities associated with the construction and operation phase of Alignment Option 1.

This chapter is structured as follows:

- *Section 6.2* presents the scope, summary of baseline environment, overview of the IA methodology and the assessment of potential visual impacts of the Project; and
- *Section 6.3* the scope, summary of baseline environment, overview of the IA methodology and the assessment of potential impacts to tourism and recreation land uses within the Project Study Area.

No cultural and heritage resources were identified as being potentially affected by Project activities during the construction and operation phase along Alignment Option 1. Therefore, impacts to cultural and heritage resources have been scoped out of this assessment.

6.2 VISUAL

6.2.1 Scope of the Assessment

The construction and operation activities that were identified in the scoping exercise as having potentially significant interactions with visual receptors were reviewed against the Project description presented in *Volume I, Chapter 2*. As the worksites, including the permanent facility buildings, are the only aboveground structures of the Project, the impacts on visual receptors are restricted to Project activities that occur at these locations.

During the construction phase, Project activities that will potentially give rise to impacts on the visual receptors within the Study Area are as follows:

- Site clearance (including tree felling, land grading activities) for worksites, temporary access roads, road diversion works etc;
- Utilities diversion (ie cut and cover works);
- Setting up of temporary worksite office and laydown areas (including sanitary facilities);
- Transportation of manpower, equipment and materials to/from the worksites;
- Backfilling and construction of ventilation shafts;
- Construction of facility buildings (including permanent access road and vehicle parking lots); and
- Unplanned events such as excessive ground settlement due to loss of tunnel pressure to the surface.

Permanent aboveground structures, ie facility buildings, will be established during the construction phase and persist throughout the operation phase. The facility buildings will occupy 2,800 m^2 of land and will be 2 storeys high. A review of their location, associated visual receptors and dimensions indicated that they are unlikely to affect the visual envelope significantly. Therefore, visual impacts from the operation phase were scoped out of this assessment.

The committed development in closest proximity to the Project consists of the PUB's proposed water pipeline installation from Bukit Kalang to Upper Thomson Road. Consultation between the PUB and the LTA has been undertaken during the course of this study to ensure that works will not occur at the same time as the Project. Cumulative impacts have therefore not been undertaken in this EIA. PUB and LTA are working together to reduce the combined footprint of PUB and LTA's possible worksites to minimize overall environmental impact. In the event that new committed developments are identified, the LTA has committed to undertake a cumulative impact assessment at the AES of the Project.

6.2.2 *Summary of Relevant Baseline Conditions*

Each potential worksite location was visited and the baseline visual amenities observed are recorded in *Table 6.1*.

Table 6.1: Visual Amenities Observed at Each Worksite

Worksite/Area	Baseline Conditions
A1-W1 (LS/VS)	A1-W1 is located within a forest patch on the fringes of the Singapore Island Golf Course (SICC), classified as Regeneration Forest A (RA) habitat. Vegetation type at this forest patch is similar to Windsor Nature Park, and include the Marsh Pulai *(Alstonia spatulata*), Rambutan (*Nephelium lappaceum*), African Oil Palm (*Elaeis guineensis*), Wild Cinammon (*Cinnamomum iners*), African Tulip (*Spathodea campanulata*) and Corn Palm (*Dracaena fragrans)*. The forest patch is bounded on the south by Island Club Road, and to the east by Upper Thomson Road.
A1-W2 (LS/VS)	A1-W2 is located within Isolated Forest (IF) habitat comprising scrub vegetation and some mature trees bounded by the PIE and Fairways Drive. The forest patch is at an elevation to the PIE and held back by concrete retaining walls that run parallel to the expressway. A field used for horse riding activities at Bukit Timah Saddle Club is located approximately 106 m south of A1-W2.

6.2.3 *Assessment Methodology*

Visual receptors are defined as people that have viewpoints of the Project worksites. The level of sensitivity of visual receptors varies according to the occupation or activity of people experiencing the view; location and context of the view; and the extent to which their attention of interest may be focused on the view and their visual amenity [(30)]. The criteria used to determine sensitivity of visual receptors is presented in *Table 6.2*.

Table 6.2: Sensitivity of Visual Receptors

Sensitivity	Description
High	• Users of all outdoor recreational facilities, including public rights of way, whose interest may be focused on the landscape; • Communities where the development results in changes in the landscape setting or valued views; and • Occupiers of residential properties with views affected by the development
Medium	• People engaged in outdoor sports or recreation (other than appreciating the landscape) • People travelling through or past the affected landscape in cars or trains along a recognised scenic route; and • People enjoying passive recreation such as urban viewpoints, locations with scenic views and seating facilities.
Low	• People travelling through or past the affected landscape in cars or trains along a recognised commuter route, major road or motorway; and • People at their place of work whose attention is focused on their work or activity.

The impact magnitude criteria adopted for this assessment are presented in *Table 6.3*.

Table 6.3: Visual Magnitude of Effect

Visual Magnitude of Effect	Description
Negligible	A change which is barely or rarely perceptible, at very long distances, or visible for a short duration, perhaps at an oblique angle, or which blends in with the existing view. The change may be short term.
Small	A subtle change in the view, at long distances, or visible for a short distance, perhaps at an oblique angle, or which blends into an extent with the existing view. The change may be short term.
Medium	A noticeable change in the view at an intermediate distance, resulting in either a distinct new element in a prominent part of the view, or a more wide-ranging, less concentrated change across an expansive area. The change may be medium to long term and may not be reversible.
Large	A clearly evident change in the view at a close distance, affecting a substantial part of the view, continuously visible for a long duration, or obstructing important elements of the view. The change may be medium to long term and would not be reversible.

The impact significance was designated taking into consideration the sensitivity of receptors and the impact magnitude, in accordance with the matrix shown in *Figure 6.1*.

Figure 6.1: Impact Significance for Visual Receptors

		Sensitivity/Vulnerability/Importance of Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

6.2.4 Assessment of Visual Impacts during Project Construction Phase

Measures in line with LTA requirements will be implemented as part of the Project design. The assessment took into account the implementation of these embedded controls, a summary of which is presented in *Table 6.4*. It is noted that some embedded controls have been designed primarily for other purposes (eg noise barriers to minimise noise levels, prevent sedimentation to aquatic resources etc). These are recognised to also double up as measures that can help to improve the visual perception of the site. There are also a number of measures that the Project will have to implement on site that may impact its visual compatibility with its surrounding environment.

Table 6.4: Embedded Controls for Management of Visual Impacts

Reference	Control Measures
LTA General Specification for Safety, Health and Environment, Appendix A. October 2018 Edition.	<u>Waste and Spillage Management</u> • A paved truck wash bay for washing vehicles leaving the worksite to be provided; • Washwater from the wash bays to be directed into a water treatment plant for treatment; and • Preventive measures to be taken to limit the incidence of earth droppings from earth moving vehicles. Spillages to be removed by the Contractor and roads and drains washed. <u>Hoarding, Barriers and Enclosures</u> • A 2.4 m high durable metal perimeter hoarding to be provided and regularly maintained around the worksite boundary and of all satellite locations; • Full length perimeter noise barriers with aesthetically pleasing designs will be erected; • All launch shafts, including muck pits, and slurry treatment plants are to be

LTA General Specification for Safety, Health and Environment, Appendix A. October 2018 Edition.

housed within a full acoustic enclosure (where a full enclosure is not possible, an acoustic enclosure with the opened face oriented away from any residential/sensitive premises and covered with retractable acoustic rolling shutters to be considered);

- The openings of all acoustic enclosures to be oriented away from residential/sensitive premises; and
- Contractors encouraged to use 'green' hoardings to beautify the site and reduce impact from traffic carbon emissions (see examples below).

Source: *LTA General Specification for Safety, Health and Environment. Appendix A. October 2018 Edition.*

Housekeeping and Stockpiling

- Temporary stockpiles to be covered; and
- Contractors to practise proper housekeeping so worksites are kept tidy, roadways and pedestrian walkways are well maintained.

Silt fences and perimeter drains will be installed at worksites to prevent discharge of slurry to downstream waterbodies, including natural streams at Windsor Nature Park.

6.2.4.1 Sources of Impact

Construction activities will potentially give rise to impacts to visual receptors within the Study Area due to site clearance works including tree felling and land grading, the establishment of hoardings along the worksite boundaries, and the transportation of workers, equipment and material to and from the worksites. The occurrence of an unplanned event such as excessive ground settlement could also lead to a localised change in the landscape, resulting in impact to visual receptors.

6.2.4.2 Receptors

The types of visual receptors identified at each worksite and their sensitivity values are presented in *Table 6.5*.

Table 6.5: Visual Receptor Characterization and Sensitivity Evaluation

Worksite	Visual Receptors (Type)	Sensitivity
A1-W1 (Note 1)	Motorists along Island Club Road	Low
	Recreational users at the Singapore Island Country Club, and recreational users utilising the MacRitchie trails at the Central Catchment Nature Reserve (CCNR) and the trails at the Windsor Nature Park	Medium
A1-W2	Motorists along the PIE	Low
	Recreational users at Bukit Timah Saddle Club	Medium

Note 1: The worksite will be located approximately 500 m away from Upper Thomson Road and low-lying. Therefore, it is unlikely to form a major component of the visual context of the residents on high rise apartments along Upper Thomson Road.

6.2.4.3 Impact Magnitude & Significance

A summary of the magnitude and significance of impacts to visual receptors during Project construction is provided in *Table 6.6*.

6.2.4.4 Mitigation Measures

In addition to embedded controls, measures to avoid, minimize, and limit the magnitude of landscape and visual impacts caused by the Project's construction phase are outlined in *Table 6.7*.

Table 6.6: Magnitude of Visual Impacts

Impact	Impact Description and Potential Consequences	Magnitude of Impact	Significance of Impact
A1-W1			
Visual	The visual amenity of motorists along Island Club Road, recreational users at the SICC and recreational users utilising the MacRitchie trails at the CCNR and trails in Windsor Nature Park may be changed through the establishment of the worksite. Embedded controls are in place such as hoarding and noise barriers to screen majority of the visually intrusive elements of the worksite (ie stockpiles, excavation sites, earth piles) to the motorists and recreational users. However, the presence of the worksite itself constitutes an adverse change in the view as compared to the forest along both sides of Island Club Road. After construction, the facility building will be established permanently. It is estimated to occupy approximately 2,800 m^2. This is unlikely to form a major component of the visual context of recreational users at the SICC and motorists along Island Club Road are transient viewers. This change will be long term (approximately 5.5 years throughout the construction phase) to permanent (establishment of facility building).	This will be a noticeable change in view at an intermediate distance, but the change will not be continuously visible for a long duration. To motorists along Island Club Road, the worksite will be present on the side of the road and not in their main viewing context; it will not obstruct key elements of their view. The worksite will also not obstruct important elements of the view for recreational users at the SICC and those utilising the MacRitchie trails at the CCNR and trails at Windsor Nature Park. The impact magnitude of the worksite has been evaluated to be ***Medium***.	***Minor*** for motorists along Island Club Road ***Moderate*** for recreational users

Impact	Impact Description and Potential Consequences	Magnitude of Impact	Significance of Impact
A1-W2			
Visual	The visual amenity of motorists along the PIE may be changed due to the establishment of A1-W2. Both sides of the PIE are relatively well vegetated and contain stretches of maintained vegetation to enhance the experience of driving on the expressway. However, the PIE has undergone several road works in the past few years and is likely to accommodate this change. The worksite will also be positioned along the PIE and not form a major component of the viewing context of a motorist, who is also considered a transient visual receptor. The visual amenity of recreational users at Bukit Timah Saddle Club may also be changed due to the establishment of the worksite, although it is unlikely to constitute a major component of their visual context. After construction, the facility building will be established permanently. It is estimated to occupy approximately 2,800 m^2. Similarly, it is not expected to form a major component of the viewing context of a motorist. This change will be long term (approximately 5.5 years throughout the construction phase) to permanent (establishment of facility building).	Although there will be a noticeable change at an intermediate distance to motorists, the change will not be continuously visible for a long duration. Also, it will not obstruct important elements of the view for motorists, who are focused on the view ahead and potential hazards. The worksite will also not obstruct key elements of the view for recreational users at Bukit Timah Saddle Club. The impact magnitude has been evaluated to be ***Medium***.	***Minor*** for motorists along the PIE ***Moderate*** for recreational users at Bukit Timah Saddle Club

Table 6.7: Mitigation Measures for Visual Impacts

Category	Mitigation	Effect of Mitigation	Residual Impact Magnitude

General Mitigation Measures during Construction	• Non-reflective material or paint for hoardings to be used so as to minimize glare on pedestrians, motorists and residents.
	• Worksite boundary to be planted to reduce visual incompatibility. Planted verges and green walls to be implemented with the following guiding principles:
	  • For both worksites, prioritise the use of species native to Singapore and part of the plant community found within the CCNR;
	  • Select attractive plant species; and
	  • For the green verge, utilize a variety of growth habits (eg shrubs and trees) to break up the hardness of the worksite boundary.
	• Worksite lighting to be:
	  • Directed within the worksite to prevent light spillage.
	• The following measures are to be implemented:
	  • Stockpiles are to be placed away from the direct line of sight from the worksite entrance;
	  • Designate a temporary canteen or sheltered resting area for workers within the worksite to minimise large gatherings within public spaces.
	  • Enforcement of no littering policies amongst workers within and around the worksite; and
	• The Project to make information of worksites, their locations and durations available to the public prior to commencement of works. This can be in the form weather-proof notifications mounted beside NParks mapboards. This will allow visual receptors to plan ahead to avoid and minimise exposure to the worksites.
	• Maintain a grievance and feedback mechanism where visual receptors can report on visual intrusions from the worksites (eg improper waste storage, staining of facilities). Public feedback to be investigated and a follow-up conducted to close out the comment.
		These mitigation measures are expected to improve the aesthetics and visual compatibility of the worksite when viewed at an intermediate distance. However, these measures will not be sufficient to detract from the presence of the large worksite within environments that feature few urban elements (ie Windsor Nature Park and Island Golf Course fringing forest).	A1-W1: ***Small***
			A1-W2: ***Small***

Specific Measures for Worksite A1-W1 (LS/VS)	• Noise barriers will be erected at the boundary of the worksite, which will also reduce line of sight between receptors and the A1-W1 (LS/VS) worksite. These barriers will be designed to increase visual compatibility with the surroundings.		

Category	Mitigation	Effect of Mitigation	Residual Impact Magnitude
General Mitigation Measures for the Design of the Facility Buildings	• Architectural design of permanent aboveground structures, including any security fencing/measures, to adopt use of natural materials, vertical greening and wildlife friendly design. Natural tones to be considered for building facade to increase visual compatibility with surroundings and non-reflective finishes to be adopted to reduce potential glare effect. • Verge around facility building to be planted with attractive, native plant species. Plants of a variety of growth habits should be utilised to break up the hardness of the building edge and integrate it better with its surroundings. • Replanting of native species will be conducted on the remaining 12,200 m^2 of land after the establishment of the permanent facility building.	With the adoption of these mitigation measures, the visual compatibility and integration of the facility building with the surrounding environment is expected to be improved. Replanting of native species are also expected to shield the facility building from the dominant viewpoint. Finally, given the smaller footprint of the facility building as compared to the worksite, the facility building is expected to be less visually intrusive than the worksite to the viewer.	

6.2.4.5 Residual Impacts

The residual impact assessment summary for Alignment Option 1 is presented in *Table 6.8*.

Table 6.8: Impact Assessment Summary for Alignment Option 1

Criterion	Rating	Comment	Criterion	Rating	Comment
Visual Impacts from Alignment Option 1					
Nature	Negative	The worksites are visually intrusive and incompatible with the surrounding forested features. However, it is noted that A1-W2 will be located along the PIE, which has seen several major roadworks over the years and is likely to accommodate the change in view.			
Type	Direct	The change in view is directly attributed to the Project.			
Duration	Long-term to Permanent	Worksites will be present for approximately 5.5 years throughout the construction phase. After the construction phase, part of the worksites will be replanted with native species and part will be converted into permanent facility buildings.			
Extent	Local	-			
Scale	-	Each worksite has a footprint of 15,000 m^2 of which 2,800 m^2 will be converted into permanent facility buildings that are 2 storeys high. 12,200 m^2 of land will undergo replanting of native species at each worksite.			
Frequency	-	-			
Receptor Sensitivity	Medium	**A1-W1:** Recreational users to whom the view is not a key element. **A1-W2:** Recreational users at Bukit Timah Saddle Club to whom the view is not a key element.			
	Low	**A1-W1:** Motorists along the Island Club Road to whom the view is transient. **A1-W2:** Motorists along the PIE to whom the view is transient.			
Pre-Mitigation Impact Magnitude	Medium	**A1-W1:** The worksite will be a noticeable change at an intermediate distance for motorists and recreational users, but will not be continuously visible. It will also not obstruct important elements of the motorists' and recreational users' view.	**Residual Impact Magnitude**	Small	**A1-W1:** Mitigation measures are expected to improve the aesthetics and visual compatibility of A1-W1 when viewed at an intermediate distance. However, measures are not sufficient to completely detract from the presence of the large worksite within the forest fringing the SICC which features few urban elements.

Criterion	Rating	Comment	Criterion	Rating	Comment
Visual Impacts from Alignment Option 1					
Pre-Mitigation Impact Magnitude	Medium	**A1-W2:** The worksite will be a noticeable change at an intermediate distance to motorists but the change will not be continuously visible over a long distance along the PIE. It will also not obstruct important elements of the motorists' view. The worksite will also not be a key element of the visual context of recreational users at Bukit Timah Saddle Club.	Residual Impact Magnitude	Small	**A1-W2:** Mitigation measures are expected to improve the aesthetics and visual compatibility of A1-W2 when viewed at an intermediate distance. However, measures are not sufficient to completely detract from the presence of the large worksite within the scrub vegetation which features few urban elements.
Pre-Mitigation Impact Significance	Moderate	**A1-W1:** For recreational users. **A1-W2:** For recreational users at Bukit Timah Saddle Club.	Residual Impact Significance	Minor	**A1-W1:** For recreational users. **A1-W2:** For recreational users at Bukit Timah Saddle Club.
	Minor	**A1-W1:** For motorists along Island Club Road. **A1-W2:** For motorists along the PIE.		Negligible	**A1-W1:** For motorists along Island Club Road. **A1-W2:** For motorists along the PIE.

6.3 TOURISM & RECREATION

6.3.1 Scope of the Assessment

As construction worksite A1-W2 is not located within or near recreational areas, impact to existing tourism and recreational land uses have only been scoped in for A1-W1 worksite which is near the Singapore Island Country Club (SICC). Access restrictions associated with A1-W1 construction may impact visitors to the SICC and recreational users utilising the MacRitchie trails at the CCNR.

Facility building(s) would comprise the only aboveground structures during operation, and access to existing recreational amenities would have been reinstated during construction phase. No impacts to tourism and recreational land uses are therefore anticipated due to the operation of the Project.

6.3.2 Summary of Relevant Baseline Conditions

A1-W1 is located within RA habitat, comprising forest vegetation similar to Windsor Nature Park, such as Marsh Pulai *(Alstonia spatulata*), Rambutan (*Nephelium lappaceum*), African Oil Palm (*Elaeis guineensis*), Wild Cinammon (*Cinnamomum iners*), African Tulip (*Spathodea campanulata*) and Corn Palm (*Dracaena fragrans)*, on the fringes of the SICC. The forest patch is bounded on the south by Island Club Road, and to the east by Upper Thomson Road.

6.3.3 Assessment Methodology

This assessment is primarily focused on identifying the effects of Project construction activities on public access to existing tourism and recreational land uses. No impact magnitude and sensitivity criteria are required to inform this qualitative assessment.

6.3.4 Assessment of Impacts to Tourism & Recreation during Project Construction

During the course of the construction works, activities such as the use of heavy vehicles for transport of workers, equipment and materials, and rock excavation at the ventilation shaft could also require temporary access restrictions at Island Club Road within close proximity of the site due to safety concerns. Visitors to the SICC and recreational users of the CCNR walking trails may be affected by limited access paths and road congestion that can be expected during construction.

6.3.4.1 Mitigation Measures

The following mitigation measures are recommended to minimise impacts to existing tourism and recreational land uses to as low as reasonably practicable:

- Plan the site layout and construction activities at A1-W1 so as to minimise access restrictions and road congestion at Island Club Road due to movement of heavy machinery.
- Provide advance notification to NParks regarding any construction activities that require temporary access closures due to public safety concerns, e.g. rock excavation. Coordinate with NParks and LTA to post such notifications on NParks' and/or LTA's online platforms and/or at NParks' mapboards.

7 MANAGEMENT AND MONITORING

7.1 ENVIRONMENTAL MANAGEMENT REQUIREMENTS

This Environmental Management and Monitoring Plan (EMMP) sets out actions for the Construction and Operation (C&O) Phase of the CRL Project in the vicinity of the CCNR. The EMMP establishes actions that need to be undertaken in order to avoid, alleviate, mitigate and remediate the potential impacts that were systematically identified during the development of the Project's C&O EIA. These actions complement the statutory and LTA requirements which are to be strictly complied with during the C&O Phase of the Project. It is noted that this EMMP will be further refined to include detailed and site-specific measures once the advanced engineering study is undertaken for the Project.

The EMMP also assigns responsibilities for implementing and monitoring the actions required prior to and during the C&O works. In order to ensure adequate handover and interpretation, *Section 7.6.1* includes provisions for training on the requirements of the EMMP.

This EIA was undertaken based on a study of the conceptual design of the Project. As part of the EIA, key engineering design considerations have been identified for incorporation into the advanced engineering design. These design considerations are summarised in *Section 7.7*.

7.2 PURPOSE OF THE EMMP

The objectives of this EMMP include:

- Ensuring compliance with the mitigation measures as identified in the C&O EIA; and
- Determining the project's actual environmental impacts so that, if necessary, corrective actions can be taken and the necessary modifications can be made to the Project.

7.3 DEVELOPMENT OF THE EMMP

The EMMP was developed following the assessment of impacts, which was undertaken in accordance with the approach adopted for the C&O EIA study. The Project activities were reviewed to identify potential impacts across a range of environmental aspects eg ecology and biodiversity, ambient air quality, ambient noise *etc*. Embedded controls(Footnote 1) were taken into account during the impacts assessment and mitigation measures to reduce potential impacts were identified. These embedded controls are presented in *Volume I Annex 2.0*.

Footnote 1 Physical or procedural controls that are already planned as part of the Project design; compliance with statutory requirements; and LTA requirements such as the *General Specifications, Safety, Health and Environment*. The mitigation measures presented herein are over and above the Project "embedded controls". For further details refer to *C&O EIA, Volume I, Chapter 4*.

7.4 STRUCTURE OF THE EMMP

The EMMP planning table is provided in *Table 7.1* and details the following:

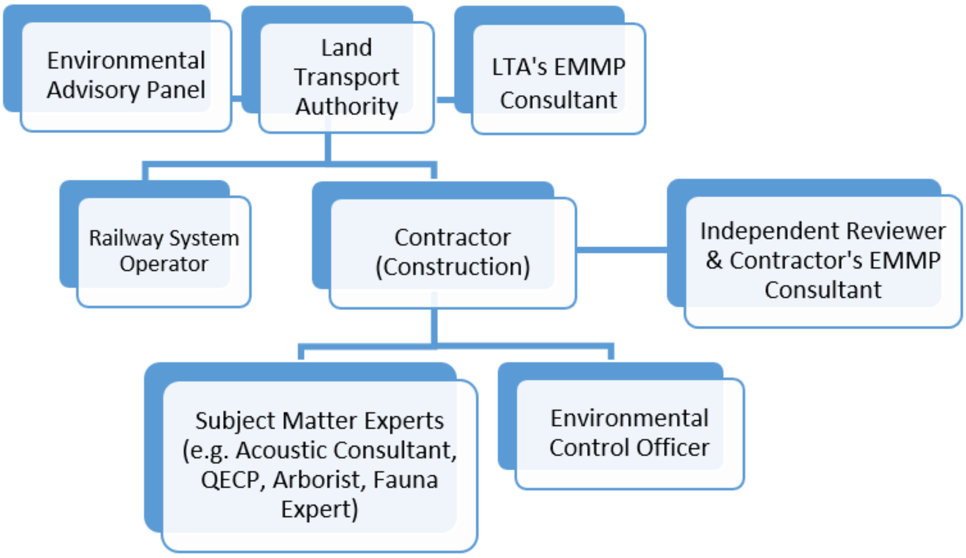
- Environmental **Topic** to which the action pertains, eg ecology and biodiversity, noise, and air quality;
- The **C&O Phase** of the works to which the specific actions apply;
- The **Aspect** of the C&O works and potential environmental impact/issue;
- **Reference** to the relevant statutory requirement, LTA requirement, and Chapter within the C&O EIA;
- **Specific Actions** (ie mitigation) that require implementation. Actions that are detailed from the mitigation measures identified within the Project EIA;
- **Responsible person for ensuring action implementation.** Further details on the roles and responsibilities are provided in the subsequent section;
- **Means of verification that commitment has been met**;
- **Monitoring/verification/inspection** measures, where applicable to the **Action**; and
- Any **Related Management Plans** within which the Action would need to be appropriately captured.

7.5 EMMP ROLES AND RESPONSIBILITIES

7.5.1 LTA

Environmental management of LTA projects is illustrated in the organizational structure outlined in *Figure 7.1*.

Figure 7.1: Organisational Structure for LTA Departments/Divisions Managing Construction & Operation for Rail Projects



In addition, LTA will set up an independent Environmental Advisory Panel (EAP) comprised of external subject matter experts to provide the LTA a forum for discussion and guidance on decision-making in relation to the overall environmental management of the Project. The responsibilities of the EAP will include:

- Support the LTA in periodic audits during the construction and/or operation phase to review the efficacy of the mitigation measures in the EMMP.
- Attend LTA's Management Review meetings and when required, provide oversight and guidance to the EMMP consultant on corrective actions during the construction and/or operation phase. Where the EAP have identified that modifications to the EMMP are required, these will be undertaken as part of the Management of Change subject to consultation with the relevant technical agencies.

7.5.1.1 LTA Environmental Policy

LTA's *Environmental Policy Statement* commits the Project to put in place measures to manage and protect the environment, during implementation of activities. In order to achieve its environmental commitment, LTA aims to:

- Incorporate environmental protection into LTA's strategic decision-making to ensure that both the environmental and economic needs of the communities are met;

- Ensure compliance with all relevant environmental legislation and regulations;

- Ensure good environmental practices are met or exceeded;

- Work with partners, eg other government agencies and contractors, to operate in an environmentally responsible manner; and

- Monitor, evaluate and continually improve their environmental management practices to ensure efficient use of limited resources.


Land Transport Authority

ENVIRONMENTAL POLICY STATEMENT

LTA is committed to nurture its staff to care and protect our environment. We incorporate environmental protection in our strategic decisions and conduct our business in a manner that balances the environmental and economic needs of the communities in which we operate.

We will:

- Comply fully with all relevant environmental legislation and regulations and meet or exceed good environmental practices;
- Work with our partners i.e., transport operators, contractors, suppliers, interest groups and other government agencies in a concerted effort to operate in an environmentally responsible manner;
- Create a cleaner and greener environment by making continuous efforts to be energy-efficient and to practice Reduce, Reuse and Recycle; and
- Monitor, evaluate and continually improve our environmental management practices to ensure efficient use of the limited resources.

Ngien Hoon Ping,
Chief Executive

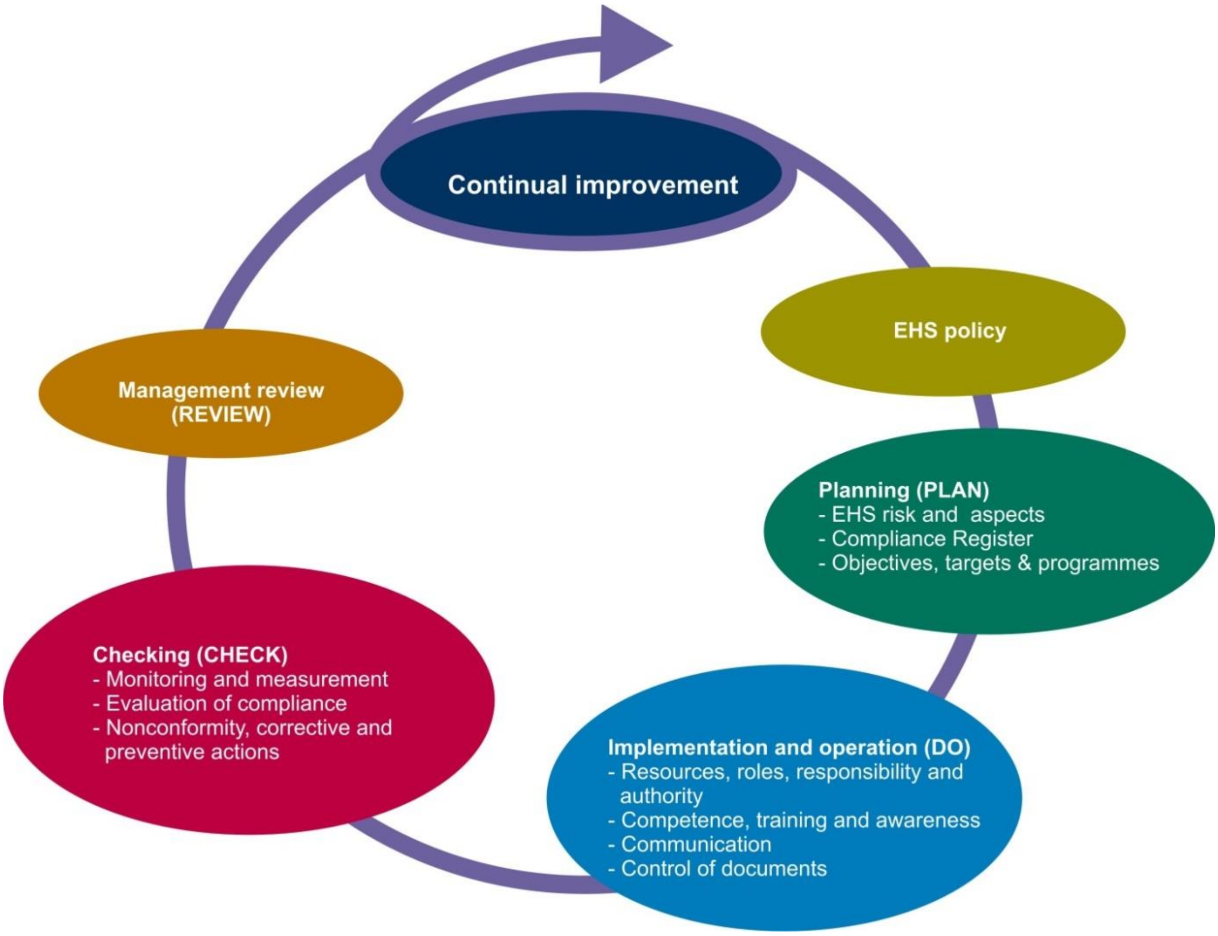
Date : 15 November 2016

In adherence to this *Environmental Policy Statement,* all Project personnel including LTA staff, contractor(s) and subcontractor(s) are expected to be responsible for their own environmental performance and the environmental impact to others due to Project activities.

7.5.1.2 LTA Environmental Management System

An environmental management system (EMS) provides a framework to support the process by which a company puts its general principles into practice. The LTA's EMS is understood to be based around the requirements of ISO 14001, which follows the general principles of the "*Plan, Do, Check, Review*" cycle as illustrated on *Figure 7.2*.

Figure 7.2: Plan, Do, Check, Review Cycle



7.5.1.3 LTA EMMP Role and Responsibility

In accordance with *LTA's Environmental Policy Statement,* the LTA Project Team has overall accountability for environmental performance during the C&O works, and assumes ultimate ownership over the Project's compliance with relevant legislation, guidelines and best practice. The LTA Project Team will be supported by:

- An independent EAP, which will function as described in *Section 7.5.1*; and
- An independent EMMP Consultant, which will undertake routine audits/verification checks of the EMMP implementation by the Contractor.

The LTA will establish and maintain a corrective action/ grievance mechanism and lines of communication within the Project Organization to ensure stakeholders' concerns and public feedback are addressed in a timely manner.

7.5.2 Contractor (Construction)

The Contractor shall be responsible to identify, manage and mitigate all environmental impacts arising from construction works. They are required to comply with the LTA's EMS requirements; take ownership of the EMMP and ensure that the construction works are undertaken in accordance with the mitigation measures outlined within this EMMP along with the LTA's *General Specifications, Appendix A, Safety Health and Environment (for Rail Project) October 2018 Edition* and statutory requirements. The Contractor will be responsible for establishing an Environmental Team (ET) for the construction works, ensuring inclusion of an *Environmental Control Officer (Environmental Public Health, Employment of Environmental Control Offices Order)*. The ET is expected to hold the requisite and relevant experience to carry out various tasks such as monitoring as per the LTA's *General Specifications*, data analysis, compliance checking, site inspections as well as provide advice on corrective actions for environmental issues/mitigation measures arising during the works.

7.5.3 Environmental Control Officer (ECO)

The appointment and qualifications of the ECO should be in compliance with the Environmental Public Health (Registration of Environmental Control Officers) Regulations 2001 and the Code of Practice for Environmental Control Officers.

The role of the ECO is to advise the Contractor on what needs to be done and to look out for conditions/ situations at the construction site which could cause environmental problems. Among other responsibilities, the ECO should also prepare and submit a Site Environmental Control Programme to the Contractor at least three weeks before work commences at the worksite. The ECO is also required to submit a Site Environmental Control Report to the Contractor once every 2 weeks. The report will contain any irregularities or exceedances detected by the ECO and the report on remedial measures to be taken by the Contractor.

7.5.4 Independent Reviewer

In accordance with the LTA's *General Specifications, Appendix A, Safety, Health and Environment, October 2018*, and *Particular Specifications, Appendix B, Safety, Health and Environment, October 2018*, for contracts with contract sum of $30 million and above, the Contractor shall appoint an independent approved audit company to audit the safety, health and environmental management system every six months. Such a role is recommended to ensure full compliance of relevant regulations.

7.5.5 EMMP Consultant

The Contractor will be required to hire an EMMP Consultant to undertake regular inspections of the worksites to ensure full compliance against the requirements in the EMMP.

7.5.6 Subject Matter Expert (SME)

It is specified in the *LTA's General Specifications, Appendix A, Safety, Health and Environment, October 2018*, and *Particular Specifications, Appendix B, Safety, Health and Environment, October 2018*, that, for contracts with contract sum of $20 million and above, the Contractor shall appoint an acoustical consultant to prepare the Noise Management Plan and the Vibration Management Plan on behalf of the Contractor. In addition, the acoustic consultant will propose and conduct regular site inspections on the implementation of the noise and vibration mitigation measures.

Depending on the site condition, other subject matter experts that could be required include Qualified Erosion Control Professional (QECP) for the design of ECM system at the worksite; and arborist and/or fauna expert to undertake or provide guidance around measures within the Biodiversity Management and Monitoring Plan.

7.5.7 *Railway System Operator (Operation)*

The Railway System Operator will be responsible for ensuring that the Project is operated in compliance with regulations and LTA requirements, which will include developing any environmental management plans and implementing any mitigation measures identified as an outcome of the AES stage of the Project.

7.6 COMMUNICATION PLAN

7.6.1 *Training and EMMP Implementation*

The planning table outlined in *Table 7.1* and the project description from the C&O EIA will be incorporated into the Contractor contract for the C&O works. In order to arrange appropriate handover of the EMMP to the C&O Contractor, the LTA will arrange a planning meeting with the Contractor during the construction planning stage to provide training on the EMMP. The training should include:

- Safety procedures and guidelines, including any specific requirements from government authorities such as NParks;
- SHE management plans to be prepared by the Contractor;
- Communication procedures, including tool box talk and reporting requirements;
- Briefing by a Specialist Consultant on the potential environmental impacts, ecological sensitivities and mitigation measures associated with construction worksites which will require vegetation clearance.
- Corrective action procedures (refer to *Section 7.6.3* for further details); and
- Stakeholder grievance process.

All training attendance records will be submitted to LTA immediately following completion of the training to maintain in the Project records.

While the Contractors are responsible for implementation of the EMMP, the whole implementation process will require supervision, checking, documentation and verification so that any potential problems are identified and properly addressed. In order to ensure proper execution of the EMMP, periodic reviews will be conducted by the LTA throughout the C&O works. This will include the preliminary EMMP training; progress calls and corrective action discussions; and spot check site audits.

7.6.2 *Reporting*

Records of training, progress calls, agreements and verification reports throughout the C&O works should be maintained with a unique identifier so that they can be distinguished from any other material and can be easily retrieved. Suitable templates for reports should be developed prior to commencement of the construction and operational phases, for consistency and efficiency. Furthermore, all the templates should be clearly communicated to all potential users during the initial training outlined in *Section 7.6.1*.

In summary, the documentation generated during the C&O works will comprise:

- Training attendance records;
- Management Plans (Contractors);
- Daily/weekly SHE Inspection Report (Contractors) (see EMMP table for reporting frequency);
- Monitoring Records (Contractors);
- Half-yearly SHE audit reports (Contractors);
- Minutes of Meeting of progress calls and management review meetings (LTA) (see *Section 7.6.3* for reporting frequency); and
- EMMP audit reports (LTA).

7.6.3 *Management of Change*

The aim of the EMMP is to be a live document and to allow environmental performance to be monitored – this means there must be scope for things to be acted on and corrective action taken if required. It should be noted that the mitigation measures identified in the C&O EIA that are listed in the current EMMP are based on the feasibility stage of the Project. Should there be more detail in the advance engineering study stage, the EMMP actions should be further reviewed and updated accordingly.

It may be necessary to make modifications to the EMMP over the course of the C&O works when:

- Unanticipated impacts arise that require additional mitigation;
- When mitigation proposed proves ineffective or unable to be implemented; and
- When the project changes in a way that is substantially different to that described in the C&O EIA.

Contractors may propose changes to the EMMP at any time throughout the course of the C&O works. The steps for managing change to the EMMP are as follows:

- Identify and describe unanticipated impacts, ineffective mitigation or changes in the Project description.
- Suggest mitigation to manage the identified issues for existing EMMP Planning Table (*Table 7.1*). Issues should be raised and discussed initially through the progress calls with LTA;
- Record recommended corrective actions into the progress call Minutes of Meeting;
- Circulate proposed modification through the progress call Minutes of Meeting and seek advice on the proposed new mitigation measure, from SHE personnel / Technical Agencies, as appropriate. LTA will confirm or reject suggested modifications normally within one working day of the progress call; and
- Record corrective action/mitigation measure implemented in SHE Inspection report, and modify the EMMP planning table.

Changes will become effective immediately following LTA approval of the suggested modification.

In addition to the steps for managing change outlined above, a Management Review meeting shall be led by the LTA every 1 month during the Construction phase and once a quarter during the Operation phase or whenever there is a major incident of non-compliance[Footnote 1] to which the EMMP relates[Footnote 2]. The following will be reviewed and assessed and a view taken to whether the EMMP needs to be updated to reflect the findings and ensure continued compliance with LTA's objectives and goals:

- Status of performance regarding objectives and targets;
- Internal audit report findings;
- Non-compliances to the EMMP by the Contractor and the status and effectiveness of corrective actions;
- Improvement proposals or suggestions; and
- Review of the effectiveness of mitigation measures and whether they continue to reflect best practice.

[Footnote 1] In the context of this Project we recommend that a major incident of non-compliance be defined as any incident that has resulted, or could potentially result, in - serious damage to flora; any pollution of soil or water bodies; and any injury or death of wildlife.

7.7 KEY AES DESIGN CONSIDERATIONS

The following measures have been identified during the course of the IA, for incorporation into the advanced engineering design of the Project:

- Worksite layouts and configurations will be reviewed in order to optimize the footprint of each proposed worksite.
- Critical infrastructure such as underground utilities, surface drainage etc that may need to be diverted as part of the Project pre-construction works will be further identified.
- The necessity for instrumentation, such as piezometers, settlement markers and vibration meters, to monitor the tunneling works will be reviewed in consultation with relevant agencies.
- The location of potential mixed face conditions and the necessity for ground improvement works will be investigated and assessed.
- A noise study will be undertaken to determine the configuration and specifications for equipment enclosures, screens and noise barriers required for the worksites.
- A detailed biodiversity monitoring program will be developed to be implemented before, during and after the construction phase of the Project.
- A detailed hoarding strategy for each worksite will be developed where wildlife shepherding is required, taking into consideration the different strategies required for species for various taxa groups.
- The feasibility of using mains power in place of diesel generators at each worksite will be reviewed.
- The feasibility of alternative construction methodologies to secant bored piles and rock excavation using blasting for launch shaft construction; and rock excavation using blasting for cross passageway construction will be examined.
- The PUB will be consulted about any site-specific requirements including discharge limits, monitoring regime (eg parameters, frequency etc.), and minimum design capacity of the Earth Control System, during the AES stage of the Project. In particular, consultation with the PUB will be needed to obtain approval for the design of the double containment pipeline with an alternative ECM discharge point at either Venus Drive or Upper Thomson Road from the A1-W1 (LS/VS) worksite; and ECM discharge point from the A1-W2 (LS/VS) worksite.
- Planting of worksite perimeter with shrubs and saplings of indigenous stock to reduce the hardness of the worksite to the forest and maintain lower light levels and higher humidity around the edge. Planting is to be carried out in advance with the advice of a qualified arborist/horticulturist and with approval from NParks. The sites where planting is required should be assessed based on the conditions of the adjacent habitats identified from the worksite-specific baseline studies conducted at the AES stage.

- The feasibility of scheduling the changing of shifts during periods dominated by fauna vocalisations i.e. sunrise and sunset will be assessed. Stepping down of equipment and activities will reduce noise disturbance to these fauna species.

- The detention tank design will be developed to ensure that in the event of a fire, the detention tank within the facility building can double up to store firewater. The Detention tank will be designed with a closing valve that will be automatically tripped along with the fire alarm. There should not be any uncontrolled discharge of firewater to surface water drainage.

- The design and location of the Facility Building for fire containment will be reviewed within the site, e.g. overdesign of fire rating for doors of electrical room.

- The architectural design of permanent aboveground structures will be further developed, including any security fencing / measures, to adopt use of natural materials, vertical greening and wildlife friendly design. Natural tones to be considered for building facade to increase visual compatibility with surroundings and non-reflective finishes to be adopted to reduce potential glare effect.

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
1	General Management	All	Compliance	EIA Vol I, CPT 2.8	Strictly comply with all statutory requirements during the C&O Phase of the CRL Project including the: (i) Arms and Explosives Act and subsidiary regulations (ii) Control of Vectors and Pesticides Act (iii) Environmental Protection and Management Act and subsidiary regulations (iv) Environmental Public Health Act and subsidiary regulations (v) Fire Safety Act and subsidiary regulations (vi) Parks and Trees Act and subsidiary regulations (vii) Public Utilities (Reservoirs and Catchment Areas and Waterway) Regulations (viii) Sewerage and Drainage Act and subsidiary regulations (ix) Wild Animals and Birds Act and subsidiary regulations/orders (x) Workplace Safety and Health Act and subsidiary regulations	Civil Contractor / Railway System Operator	LTA verification of contractor compliance to statutory requirements in management plans and implementation	-	-	A1-W1, A1-W2, tunnel alignment	-	-
2	General Management	All	Management plan development	EIA Vol I, CPT 2.8	Develop environmental management plans as per this EMMP and LTA's requirements of contractors including: (i) LTA's General Specifications, Appendix A, Safety Health and Environment (for Rail Project), October 2018 Edition. (ii) LTA Handbook on Development Building Works in Railway Protection Zone, January 2005 Edition (iii) LTA Civil Design Criteria for Road and Rail, February 2010 Edition (iv) LTA Materials & Workmanship Specification for Civil & Structural Works, June 2010 Edition (v) LTA guidebooks for Contractors (vi) LTA design specifications	Civil Contractor / Railway System Operator	LTA verification of contractor compliance to the EMMP and LTA's requirements	-	-	A1-W1, A1-W2, tunnel alignment	-	-
3	General Management	All	Management plan approval	EIA Vol I, CPT 2.8	Ensure that the required environmental management plans are approved. These management plans are: (i) Air Pollution Control Plan (ii) Vector Control Plan (iii) Waste Management Plan (iv) Noise Management Plan (v) Earth Control Measures Plan (vi) Water Pollution Management Plan (vii) Emergency Preparedness Plan (viii) Fire Safety Plan (ix) Biodiversity Monitoring and Management Plan	Civil Contractor	LTA approval of all required management plans and auditing implementation	-	-	A1-W1, A1-W2, tunnel alignment	-	-
4	General Management	Operation	Management plan approval	EIA Vol III, CPT 7.5.7	As appropriate (to be further defined at the AES stage of the Project), ensure that the required environmental management plans are approved. These management plans are: (i) Vector Control Plan (ii) Waste Management Plan (iii) Water Pollution Management Plan (iv) Emergency Preparedness Plan (v) Fire Safety Plan (vi) Biodiversity Monitoring and Management Plan	Railway System Operator	LTA approval of all required management plans and auditing implementation	-	-	A1-W1, A1-W2, tunnel alignment	-	-
5	General Management	All	Compliance	EIA Vol I, CPT 2.8	Comply with the EMMP actions stated in this document which complement the above statutory requirements and specifications. The embedded controls considered in this Project that are relevant to water resources, ambient noise, ambient air quality, ecology and biodiversity, waste management, health and safety, and geology are summarised in Volume I, Annex 2.0.	Civil Contractor / Railway System Operator	LTA verification of compliance to EMMP actions	-	-	A1-W1, A1-W2, tunnel alignment	-	-
6	General Management	All	Monitoring management	EIA Vol I, CPT 2.8	LTA should consider engaging third parties to verify monitoring data of environmental parameters at worksites and along the tunnel alignment, where accessible. These parties should be external to the Project and engaged to assess that the intended objectives are achieved.	LTA	-	-	-	A1-W1, A1-W2, Tunnel Alignment	-	-
7	Surface Water	Pre-construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Consult PUB about any site-specific requirements including discharge limits, monitoring regime (eg parameters, frequency etc.) during the Advance Engineering Stage (AES)	LTA	LTA verification of site-specific requirements	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
8	Surface Water	Pre-construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Phase activities such as land clearance, demolition works, earthworks, and building construction to minimise the area of ground exposed and the volume of soil and construction material handled at any one time.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	Submit phasing plan to LTA.	Water Pollution Management Plan
9	Surface Water	Pre-construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Phase activities to limit the extent of land clearance prior to the set-up and operation of the ECM plant.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	Submit phasing plan to LTA.	Water Pollution Management Plan
10	Surface Water	Pre-construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Provide adequate number and size of silt sumps, sedimentation pond and holding tanks. The sumps and tanks will be designed to handle the volume of water from a rain based on a minimum design return period of 1 in 5 years storm, unless a site specific requirement is stated separately for the worksite. A consultation with PUB will be carried out during the AES on any site specific design criteria to be considered and complied with (see item 6 above).	Civil Contractor/ QECP	LTA verification	-	-	A1-W1, A1-W2	Submit ECM Plan	ECM Plan
11	Surface Water	Pre-construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Acknowledging the topography of the site as well as Stream Ma being ecologically sensitive (see Chapter 5 for further information), the following measures will be implemented to cope with the unplanned event of overflow of untreated effluent from potential sources including the ECM treatment Plant and slurry storage pits: - The capacity of the ECM will be overdesigned and the design will be subject to consultation with PUB prior to finalization and PUB approval. - Provide sufficient amount of slurry holding tanks with capacity ranging from 150 m3 to 450 m3 cater for the volume of slurry water that will be generated. - Place the slurry holding tanks within bund wall for containment of possible spillage and leakage.	Civil Contractor/ QECP	LTA verification	-	-	A1-W1	Submit ECM Plan	ECM Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
12	Surface Water	Pre-construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	In the event of spillage or overflow of effluents into downstream surface waterbodies, as much of the contaminating material will be removed using absorbent pad and equivalent options. Following this, regular visual inspections and monitoring of the relevant chemical parameters will be undertaken for the affected stream until stream conditions return to normal.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	EIA Report	EMMP
13	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Provide silt fence, erosion control blankets and lean concrete of the worksite access to reduce erosion and sediments from entering streams and surface waterbodies.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
14	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Provide concrete-lined cut-off drains along the perimeter of the worksite.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
15	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Install ECM plant that is designed and sized to filter silt. The treated water will either be recycled for non-potable use onsite or discharge into public drains.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
16	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Clean perimeter drain, silt sump, sedimentation pond and holding tanks at least once a week and after every rainfall event, or as and when required.	Civil Contractor	LTA inspection	At least once a week and after every rainfall event	-	A1-W1, A1-W2	-	Water Pollution Management Plan
17	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Implement a regular maintenance program and provide drip trays to all equipment and machinery to prevent fuel spillage or leakage during construction activities.	Civil Contractor	LTA inspection	Every 3 months	-	A1-W1, A1-W2	Produce inspection records of condition of equipment and machinery after every maintenance.	Water Pollution Management Plan
18	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Ensure portable sanitary facilities provided for workers are located away from surface water courses and managed by a licensed third party waste contractor to protect surface water sources. Regular in-house cleanings to be carried out to ensure the cleanliness of the sanitary facilities.	Civil Contractor	LTA verification	Every change in site configuration and relocation of portable sanitary facilities	-	A1-W1, A1-W2	-	Water Pollution Management Plan
19	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Strategically locate and isolate areas for temporary storage of hazardous materials away from surface water resources. Drip trays to be provided to contain any accidental spillages.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
20	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Position slurry mixing and slurry treatment plant away from any surface drainage and surface waterbodies.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
21	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Locate temporary stockpiles of spoil as far as possible from any surface drainages or streams.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
22	Surface Water	Construction, Operation	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Re-vegetate exposed ground as soon as possible to stabilise surfaces.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan, Earth Control Measures Plan
23	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Control water used for dust suppression during excavation and earth handling to minimise excess water and sediment disposal into surface water.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
24	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	In addition to the quarterly monitoring specified under the *LTA's General Specification (Appendix A) for Safety, Health and Environment (for Rail Project), October 2018*, at the start-up of the construction phase, carry out water quality monitoring at all discharge outlets against the relevant regulations. At a minimum once during initial operations or until full compliance to the relevant limits can be demonstrated and accepted by LTA for all water / wastewater treatment units. For example, discharge to surface drain is to be evaluated against the *Environmental Protection and Management (Trade Effluent) Regulations*, discharge to sewer is to be evaluated against the *Sewerage and Drainage (Trade Effluent) Regulations*. Full lists of parameters listed under these regulations are to be monitored.	Civil Contractor	LTA verification	At the start-up of the construction phase; subsequently ever quarter throughout the construction period	Depending on the final discharge point. Full lists of parameters listed under *Environmental Protection and Management (Trade Effluent) Regulations* and/or *Sewerage and Drainage (Trade Effluent) Regulations*	A1-W1, A1-W2	Produce a monitoring record after every monitoring session.	Water Pollution Management Plan
25	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Contain slurry operations within bunded areas to control spillage into waterbodies.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Water Pollution Management Plan
26	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Maintain a buffer distance of 30 m between the construction worksite and stream Ma.	Civil Contractor	LTA verification	-	-	A1-W1	-	Water Pollution Management Plan
27	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Phase land clearance activities to ensure that perimeter drains for the worksite are constructed and silt fences installed prior to clearance of the whole worksite, and prior to any excavation work.	Civil Contractor	LTA verification	-	-	A1-W1	-	Water Pollution Management Plan
28	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Strictly no discharge to stream Ma at all time.	Civil Contractor	LTA verification	-	-	A1-W1	-	Water Pollution Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
29	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Strictly prohibit discharge of wastewaters to the roadside drain along Island Club Road as well as Stream Ma. Discharge will be to temporary storage tanks for removal by third party licensed wastewater collector. Use of slurry tanks instead of pits for storage of slurry water to prevent the possibility of overflow during rain. Provide sufficient amount of slurry holding tanks with capacity ranging from 150 m^3 to 450 m^3 cater for the volume of slurry water that will be generated.	Civil Contractor	LTA verification	-	-	A1-W1~~, A1-W2~~	-	Water Pollution Management Plan
30	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	ECM discharges are proposed to be conveyed via a double containment pipeline to be discharged to a suitable surface water drain. PUB will be consulted on the alignment of the pipe and discharge point. The piping system including the piping route will be carefully studied so as to minimize the need for any clearance, as much as possible the pipeline will be parallel to the existing drainage reserve along Island Club Road. The design will include suitably sized redundancy for ancillary equipment such as pumping system to allow smooth operation all the time.	Civil Contractor	LTA verification	-	-	A1-W1	-	Water Pollution Management Plan
31	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Conduct weekly visual monitoring of the portion of Stream Ma3 located immediately downstream of the worksite, from Island Club Road. Should there be visual signs of contamination (oily sheen, colouring of sediments etc), LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation.	Civil Contractor	LTA verification	Weekly	-	A1-W1	Produce a monitoring record after every monitoring session. Both LTA and Nparks to be notified and to submit a detailed investigation report, detailing the incident and rectification actions.	Water Pollution Management Plan
32	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Conduct monthly sampling of physical, chemical and biological parameters at Stream Ma3. To minimise human intrusion into the stream habitat, samples should be collected from the Venus Link trail, at the stream intersection with Ma6 and Ma2, and preferably during high volume flow after a rainfall event. No off trail access to Stream Ma3 should be attempted during the sampling. The actual limits that would be applicable for both before and after rain event will be established during the AES stage and this has been updated in the EMMP stage. Should there be an exceedance of baseline results for the limits established, LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation.	Civil Contractor	LTA verficication	Monthly	Monthly sampling at Ma3 to include the following parameters: - Temperature - pH @ 25˚C - TSS - TDS - Turbidity - DO - COD - BOD_5 at 20˚C - Oil & Grease (Total) - Oil & Grease (Hydrocarbon) - *E.Coli*	A1-W1	Produce a monitoring report after every sample. Both LTA and Nparks to be notified and to submit a detailed investigation report detailing the incident and rectification actions.	Water Pollution Management Plan
33	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Carry out routine monitoring and maintenance of the ECM treatment plant-related equipment, especially the pipeline discharging treated effluent to Venus Drive or Thomson Road, to eliminate the possibility of leaks and spills.	Civil Contractor	LTA verficication	Every 3 months		A1-W1	Produce inspection records of condition of equipment and machinery after every maintenance	Water Pollution Management Plan
34	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	The configuration of the worksite to be further studied during the AES stage, taking into account the existing topography, to avoid any discharge that could lead to the IC stream.	Design Engineer (AES)	LTA verificication	-	-	A1-W2	-	-
35	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Prohibit discharge to the portion of drain that will lead to Stream IC. Discharge of treated surface runoff and/or liquid waste can only be to the part of drain that flows in a southerly direction towards Eng Neo Avenue.	Design Engineer (AES)/ Civil Contractor	LTA verificication	-	-	A1-W2	-	-
36	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Conduct weekly visual monitoring of the portion of drain that flows towards Stream IC. Should there be visual signs of contamination (oily sheen, colouring of sediments etc), LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation.	Civil Contractor	LTA verification	Weekly	-	A1-W2	Produce a monitoring record after every monitoring session. Both LTA and Nparks to be notified and to submit a detailed investigation report, detailing the incident and rectification actions.	Water Pollution Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
37	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Conduct sampling of physical, chemical and biological parameters at Stream IC prior to the commencement of the construction activities to establish baseline levels of Stream IC for before and after rain.	Civil Contractor	LTA verficication	Before commencement of construction activities	Monthly sampling at Stream IC to include the following parameters: - Temperature - pH @ 25˚C - TSS - TDS - Turbidity - DO - COD - BOD_5 at 20˚C - Oil & Grease (Total) - Oil & Grease (Hydrocarbon) - *E.Coli*	A1-W2	Produce a monitoring report for verification against the monthly monitoring result during the construction stage.	Water Pollution Management Plan
38	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Carry out monthly sampling during the construction phase to verify if stream IC is affected by the construction activities. The sampling should be carried out in a manner that minimises human intrusion into the stream habitat, and preferably during high volume flow after a rainfall event. Should there be an exceedance of baseline results, LTA/NParks to be notified and undertake an investigation on the potential source of contamination. Corrective actions are to be carried out immediately based on the investigation.	Civil Contractor	LTA verficication	Monthly	Monthly sampling at Stream IC to include the following parameters: - Temperature - pH @ 25˚C - TSS - TDS - Turbidity - DO - COD - BOD_5 at 20˚C - Oil & Grease (Total) - Oil & Grease (Hydrocarbon) - *E.Coli*	A1-W2	Produce a monitoring report after every sample. Both LTA and Nparks to be notified and to submit a detailed investigation report detailing the incident and rectification actions.	Water Pollution Management Plan
39	Surface Water, Air, Noise and Vibration	Construction	Reduce impacts on water, air, noise and vibration, ecology and biodiversity	EIA Vol III, CPT 2.5.1	Develop a daily inspection checklist encompassing mitigation measures that require daily attention at the worksite, and undertake daily inspection of construction area.	Civil Contractor	LTA verification	Daily	Checks to include: - General housekeeping - Equipment quality and performance	A1-W1, A1-W2	Submit daily inspection checklist to LTA.	Air Pollution Control Plan, Noise Management Plan and Water Pollution Management Plan
40	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Maintain a procedure to log and track response to feedback received from stakeholders.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2, tunnel alignment	-	Water Pollution Management Plan
41	Surface Water	Construction	Reduce surface water impacts	EIA Vol III, CPT 2.5.1	Maintain records or surface water measurement and checklist of the EMMP actions on a daily basis during construction.	Civil Contractor	LTA audit	Daily	-	A1-W1, A1-W2	Submit surface water measurements and checklist of EMMP actions to LTA.	Water Pollution Management Plan
42	Groundwater	Construction	Reduce groundwater impacts	EIA Vol III, CPT 2.5.2	Develop and implement stringent EMMPs to ensure safe tunneling works with minimal impacts to groundwater. Monitoring plans should include development of the construction phase groundwater monitoring plan specifying monitoring and reporting requirements. The plans should further include frequent inspection of the tunnel face and shafts; and monitoring of settlement of nearby buildings (ie SICC Island Clubhouse)	QPD (appointed by LTA)	LTA verification	-	-	A1-W1, A1-W2, Tunnel alignment	-	Water Pollution Management Plan
43	Groundwater	Operation	Reduce groundwater impacts	EIA Vol III, CPT 2.6.2	Incorporate appropriate planning and controls for firewater management within the emergency planning procedures, if not already covered by LTA operation procedures. Such controls to include the management of firewater within sumps located in the tunnels, to be collected by third party contractors for offsite treatment and disposal in the event of a fire emergency.	Railway System Operator	LTA verification	In the event of a fire emergency	-	Tunnel alignment	In accordance with LTA requirements	Emergency Response Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
44	Groundwater	Operation	Reduce groundwater impacts	EIA Vol III, CPT 2.6.2	Monitor groundwater monitoring bores to verify that impacts on groundwater levels are limited and to allow for contingency actions to be triggered if unexpected observations are made.	-Instrumentation Contractor (appointed by LTA)	LTA verification	Monthly (first year), monitoring frequency in subsequent years to be advised depending on trends observed in the first year	-	Tunnel alignment	Both LTA and NParks to be notified should there be unexpected observations and to submit a detailed investigation report, detailing the incident and rectification actions.	Operational phase groundwater monitoring plan (recommended for initial two years of operation)
45	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Install acoustic enclosures designed with appropriate ventilation and access for stationary equipment such as generators, compressors etc.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Noise Management Plan
46	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Where possible, use mains power in place of diesel generators.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Noise Management Plan
47	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Undertake a detailed noise study by an acoustic consultant prior to construction to determine the configuration and specifications for equipment enclosures, screens and noise barriers required for the worksites to mitigate impacts.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Noise Management Plan
48	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Plan site layout to maximise placement of structures along the north and south worksite boundary to act as natural barriers between receptors eg golfers at SICC Island golf club and users of Windsor Nature Park trails, and noise generating activities.	Civil Contractor	LTA verification	-	-	A1-W1	Submit site layout plan to LTA.	Noise Management Plan
49	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Plan to carry out noisy works such as site clearance, construction of launch shaft and facility buildings in the daytime as far as possible.	Civil Contractor	LTA verification	-	-	A1-W1	-	Noise Management Plan
50	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Delivery of materials to be carried out in the day time, wherever possible. For activities carried out at night, especially for tunnel segments delivery and disposal of spoils, proper traffic controller to be provided to control the vehicular movement to ensure no excessive noise from the trucks. Truck / trailer drivers shall also be briefed to prevent horning / reversing of trucks which will create unnecessary noise.	Civil Contractor	LTA verification	-	-	A1-W1	-	Noise Management Plan
51	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Provide NParks and SICC Island Club management with the programme of construction activities and promptly notify them of any schedule changes, to facilitate dissemination of information to the public users of the trails and SICC Island club members and enable management of any activities in proximity to the worksite, in particular during noisy activities such as installation of ERSS and rock excavation at the launch shaft.	LTA	NParks and SICC Island Club Management are notified of construction activities	-	-	A1-W1	-	Noise Management Plan
52	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Plan site layout to maximise placement of structures along the west worksite boundary to act as natural barriers between receptors and noise generating activities.	Civil Contractor	LTA verification	-	-	A1-W2	Submit site layout plan to LTA.	Noise Management Plan
53	Noise	Pre-construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Provide Bukit Timah Saddle Club management with the programme of construction activities and promptly notify them of any schedule changes, to facilitate dissemination of information to members and enable management of equestrian activities in proximity to the worksite, particularly for noisy activities such as installation of earth retaining stabilising structures during launch shaft construction.	LTA	Bukit Timah Saddle Club is notified of construction activities	-	-	A1-W2	-	Noise Management Plan
54	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Organise regular refresher training to ensure that all workers are constantly reminded of the need to employ quieter work techniques.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	Maintain attendance logs to ensure all workers attend relevant trainings.	Noise Management Plan
55	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Conduct noise monitoring inspections to ensure compliance to acceptable noise levels.	Civil Contractor	LTA audit	Weekly	-	A1-W1, A1-W2	Maintain noise monitoring records.	Noise Management Plan
56	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Maintain a feedback log and ensure the adequate and timely response to all feedback.	Civil Contractor	Complainants are responded to	-	-	A1-W1, A1-W2	Maintain grievance records.	Noise Management Plan
57	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Develop communications plan, including protocol for the escalation of complaints to the site supervisor, to enable prompt correction actions to be taken in response to complaints or detected exceedances of noise limits.	Civil Contractor	LTA verification and plan approval	-	-	A1-W1, A1-W2	Submit communications plan to LTA.	Noise Management Plan
58	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Undertake ambient and baseline noise monitoring (Leq,5min, Leq,1hr and Leq,12hr) prior to commencement of construction activities in accordance with the guidance in SS 602:2014, at the following receptors: • SICC Island clubhouse • Windsor Nature Park NParks Office • Windsor Park residential estate (Jupiter Road / Libra Drive)	Civil Contractor	LTA audit	-	Leq,5min, Leq,1hr and Leq,12hr	A1-W1	Maintain ambient and background noise monitoring records.	Noise Management Plan
59	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Undertake ambient and baseline noise monitoring (Leq,5min and Leq,12hr) prior to commencement of construction activities in accordance with the guidance in SS 602:2014, at the following receptors: • Bukit Timah Saddle Club riding arena • Bukit Timah Saddle Club	Civil Contractor	LTA audit	-	Leq,5min and Leq,12hr	A1-W2	Maintain ambient and background noise monitoring records.	Noise Management Plan
60	Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 3.5.1	Undertake real-time noise monitoring to ensure that night-time Leq,5min and Leq,1hr levels are below threshold levels. Threshold levels to be established by applying distance correction to account for regulatory limits at the nearest residence at Windsor Park estate. Investigation into the source(s) of noise should be undertaken promptly, and corrective actions implemented where feasible eg erection of portable acoustic screens, repositioning of equipment away from receptors etc.	Civil Contractor	LTA audit	-	Leq,5min and Leq,1hr	A1-W1	Implement corrective actions should levels exceed threshold levels.	Noise Management Plan
61	Ecology and Biodiversity, Noise	Construction	Reduce noise impacts	EIA Vol III, CPT 5.5.1	As much as possible, schedule the changing of shifts during periods dominated by fauna vocalisations ie sunrise and sunset. Stepping down of equipment and activities will reduce noise disturbance to these fauna species. The feasibility of this will be assessed at the Advanced Engineering Stage (AES) stage.	LTA/Civil Contractor	LTA audit	Weekly	-	A1-W1, A1-W2	Maintain noise monitoring records.	Noise Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
62	Vibration	Pre-construction, Construction	Reduce vibration impacts	EIA Vol III, CPT 3.5.2	Undertake stakeholder engagement with the Bukit Timah Saddle Club management prior to and during vibration generating activities. Advance notice should be provided for such activities to allow measures to be undertaken to minimise potential health and safety risks to equestrian riders at the riding arena.	Civil Contractor	Bukit Timah Saddle Club is notified of construction activities	Prior to and during vibration generating activities	-	A1-W2	-	-
63	Air	Pre-construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Phase potential dust generating activities such as land clearance, earthworks and building construction to minimise the area of ground exposed and the volume of soil and construction material handled at any one time.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	Submit phasing plan to LTA.	Air Pollution Control Plan
64	Air	Pre-construction, Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Review construction plan and ensure availability of water for dust suppression on site.	Civil Contractor	LTA verification and plan approval	-	-	A1-W1, A1-W2	Submit construction plan to LTA.	Air Pollution Control Plan
65	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Use water suppression during excavation and earth handling at exposed areas under dry weather.	Civil Contractor	LTA verification	During dry weather	-	A1-W1, A1-W2	-	Air Pollution Control Plan
66	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Re-vegetate exposed ground as soon as possible to stabilize surfaces once there are no further construction activities to be carried out at the affected areas.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Air Pollution Control Plan, Earth Control Measures Plan
67	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Apply water to roads at a rate 2 litres/m2/hour prior to and during truck use in dry conditions ie during non-raining day and during dry spells such as in the late Northeast monsoon period between late January and early March.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Air Pollution Control Plan
68	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Ensure trucks undergo wheel washing at the washing bay prior to exit from site to prevent staining on public roads.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Air Pollution Control Plan
69	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Strictly prohibit the use of water from stream Ma for water suppression.	Civil Contractor	LTA inspection	-	-	A1-W1	-	Air Pollution Control Plan
70	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Control water suppression to the minimum necessary to reduce excess water runoff that may enter stream Ma. Close inspection to ensure that surface runoff is not entering stream Ma.	Civil Contractor	LTA inspection	Daily	-	A1-W1	-	Air Pollution Control Plan
71	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Undertake twice daily checks of Island Club Road, Thomson Road and other roads that will be used as the haul route for accidental spillage of spoil/earth being tracked out of the Project area. Clean up any spoil/earth spillage onto the haulage routes immediately.	Civil Contractor	LTA inspection	Twice daily	-	A1-W1	-	Air Pollution Control Plan
72	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Undertake checks of the PIE and other roads that will be used as the haul route for accidental spillage of spoil/earth being tracked out of the Project area. Clean up any spoil/earth spillage onto the haulage routes immediately.	Civil Contractor	LTA inspection	Twice daily	-	A1-W2	-	Air Pollution Control Plan
73	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Continuously monitor PM10 levels at one location upwind and one location downwind of the Project site boundary. The monitoring should be conducted by a SAC-SINGLAS accredited lab. Should measurements indicate exceedances of 250 µg/m3 averaged over a 15-minute period, mitigation measures shall be undertaken including but not limited to: • Employ or increase water suppression to dust generating activity. • Reduce the number of dust generating activities being undertaken.	Civil Contractor	LTA audit	Continuously	-	A1-W1, A1-W2	-	Air Pollution Control Plan
74	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Maintain a feedback log to track response to feedback received from stakeholders.	LTA	Stakeholders are responded to	-	-	A1-W1, A1-W2	Maintain a complaints log to be shared with LTA.	Air Pollution Control Plan
75	Air	Construction	Reduce air impacts	EIA Vol III, CPT 4.5.1.4	Maintain records of ambient dust measurement and checklist of EMMP actions used across the Project area on a daily basis during construction.	Civil Contractor	LTA audit	-	-	A1-W1, A1-W2	Maintain ambient dust measurement records.	Air Pollution Control Plan
76	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Establish key contact points with NParks to assign within their agencies dedicated individuals to oversee all environmental aspects of the construction. These individuals are responsible for the review of documentation such as enhancements of the Biodiversity Monitoring and Management Plan, camera trap data and field survey findings. These individuals are to be copied in all key correspondence and also be involved in inspection spot checks. A monthly working meeting should be set up between both teams to discuss key findings, proposed adaptive management measures and address pressing issues relating to the environmental management of the worksites.	LTA	Minutes of Meeting from monthly working meetings	-	-	A1-W1, A1-W2, tunnel alignment	Record Minutes of Meeting every meeting.	Biodiversity Monitoring and Management Plan
77	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	During award of contracts, seek to engage contractors with experience and competence in undertaking development in environmentally sensitive areas, demonstrable sustainable construction policies and robust environmental management plans.	LTA	Extensive review of contractor policies and plans during procurement.	-	-	A1-W1, A1-W2, tunnel alignment	-	Biodiversity Monitoring and Management Plan
78	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Ensure the incorporation of mitigation measures in the contractual provisions aimed at minimising deleterious impacts to ecology and biodiversity.	LTA	Verification of contractual provisions	-	-	A1-W1, A1-W2, tunnel alignment	-	Biodiversity Monitoring and Management Plan
79	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Undertake biodiversity monitoring to study the impacts of construction works on biodiversity in habitats adjacent to the construction worksites, to inform on the actions and next steps to be taken based on the monitoring results. Ecological monitoring methods should include camera trap studies, transect surveys and vegetation surveys, all of which are to be conducted by expert personnel. These surveys are to include roadkill surveys on construction access roads and roads adjacent to the worksites. Wildlife specialists and/or NParks should advise on the study design, details of camera trap deployment and set-up which includes but is not limited to camera height, camera angle, camera placement, distribution of camera traps in the field, duration of the study, target species and capacities eg manpower and equipment. LTA should hire and appoint an environmental management consultant to propose a detailed environmental monitoring plan to include the specifics of the ecological monitoring plan. The plan, including the fauna and flora study designs, will be endorsed by the relevant technical agencies.	LTA	Liaison with NParks in the formation of a Biodiversity Monitoring Plan	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
80	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Engage specialists to undertake vegetation surveys to identify flora species of interest to be salvaged and record in a database for reference.	LTA	Specialist vegetation surveys	-	-	A1-W1, A1-W2	Maintain a database of flora species salvaged from worksite with details on locations and species.	Biodiversity Monitoring and Management Plan
81	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Develop transplantation/salvage plan for flora species of interest through engagement with NParks and consult NParks on the fate of the flora species within the worksite.	LTA	Liaison with NParks in the formation of a transplantation/salvage plan	-	-	A1-W1, A1-W2	Maintain a database of flora species salvaged from worksite with details on locations and species.	Biodiversity Monitoring and Management Plan
82	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Transplant salvaged saplings into a nursery to be maintained as a native stock before being planted back at the worksite post-construction.	LTA	Liaison with arborist and NParks on the maintenance of saplings	-	-	A1-W1, A1-W2	Maintain a database of flora species salvaged from worksite with details on locations and species.	Biodiversity Monitoring and Management Plan
83	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Seek approval from NParks prior to removal of any trees, especially those with girth >1m and/or listed as CR, EN, VU on the Singapore Red Data Book.	LTA	Liaison with NParks in the formation of a transplantation/salvage plan	-	-	A1-W1, A1-W2	Maintain a database of trees removed and retained.	Biodiversity Monitoring and Management Plan
84	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Establish Tree Protection Zones (TPZ) around trees in close proximity to the worksites. These distances should be adhered to according to tree girth: • Minimum protection zone of 2.0 m around a tree with girth ≤1.0 m. • Minimum protection zone of 3.0 m around a tree with girth ≥1.0 m but ≤1.5 m. • Minimum protection zone of 4.0 m around a tree with girth ≥1.5 m but ≤2.0 m. • Minimum protection zone of 5.0 m around a tree with girth ≥2.0 m.	LTA	Appointed arborist verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
85	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Develop and conduct wildlife shepherding together with the hoarding strategy, to be scheduled only during daylight hours. The hoarding for the worksite will be erected prior to the shepherding process. A section of the hoarding will be opened to which wildlife will be shepherded towards in a systematic fashion out of the work areas into refuge sites (adjacent forested areas). The worksite area should be sectioned into parcels such that the process is conducted systematically for effective fauna management. The hoarding and shepherding plan is described below for both worksites: • A1-W1: The hoarding is to open to face the eastern portion of the forest patch, while guiding fauna to the culvert and restricting movement towards Island Club Road. • A1-W2: The hoarding is to open to face the habitat towards the west, while restricting fauna movement towards the PIE.	LTA	Appointed wildlife specialist and arborist verification	To be advised by specialists	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
86	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Schedule wildlife shepherding to avoid the prime breeding season for local avifauna ie Mid-March to July annually.	LTA	Appointed wildlife specialist and arborist verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
87	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Engage fauna specialists to conduct wildlife shepherding, and fauna individuals captured on site by the fauna specialists are to be released to suitable habitats advised by NParks. Veterinary care is to be administered if necessary.	LTA	Appointed wildlife specialist and arborist verification	To be advised by specialists	-	A1-W1, A1-W2	Maintain a database of any found fauna with details on locations and species.	Biodiversity Monitoring and Management Plan
88	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Engage fauna specialists to check for the presence of burrows or dens encountered during the shepherding process. Fauna individuals captured on site by the fauna specialists are to be released to suitable habitats advised by NParks. Veterinary care is to be administered if necessary. Inactive dens are to be collapsed to prevent inhabitation by other wildlife.	LTA	Appointed wildlife specialist and arborist verification	In conjunction with wildlife shepherding	-	A1-W1, A1-W2	Maintain a database of any found burrows and dens, with details on locations and encountered fauna where applicable.	Biodiversity Monitoring and Management Plan
89	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Deploy camera traps to monitor the movement of wildlife out of the worksite before and after shepherding, to detect potential fauna still in the worksite after shepherding for further action eg additional shepherding rounds.	LTA	Appointed wildlife specialist and arborist verification	To be advised by specialists	-	A1-W1, A1-W2	Maintain a database of camera trap data to be shared with NParks.	Biodiversity Monitoring and Management Plan
90	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Engage wildlife specialist, alongside arborist, to conduct fauna inspections on inhabitats on trees that require relocation prior to the commencement of tree felling or transplantation activities. This includes but is not limited to looking for the presence of bird nests, squirrel nests, fauna inhabited in tree hollows eg Sunda Pangolin (*Manis javanica*), and wildlife on the tree eg Malayan Colugo (*Galeopterus variegatus*), Horsfield's Flying Squirrel (*Iomys horsfieldii*), Red-cheeked Flying Squirrel (Hylopetes spadiceus). Engage NParks on fate of any found fauna species eg relocation, administer for veterinary care etc.	LTA	Appointed wildlife specialist and arborist verification	-	-	A1-W1, A1-W2	Maintain a database of any found fauna with details on tree locations and species.	Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
91	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Do not fell trees found to have active bird nests, ie inhabited with avifauna or their eggs, until inhabitants have left on their own accord. Monitor active bird nests at a frequency advised by NParks.	LTA	Appointed wildlife specialist and arborist verification	-	-	A1-W1, A1-W2	Maintain a monitoring record of active bird nests and bird activity.	Biodiversity Monitoring and Management Plan
92	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Do not conduct tree felling or transplanting during prime local avifauna breeding season in Singapore ie approximately mid-March to July annually.	LTA	Appointed wildlife specialist and arborist verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
93	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Fauna found to inhabit tree hollows or found on the tree that are unlikely to escape quickly during disturbance, eg Sunda Pangolin and Malayan Colugo, should be handled by wildlife specialists, checked on by veterinarians if necessary and relocated to suitable habitats as advised by NParks before tree felling can proceed.	LTA	Appointed wildlife specialist and arborist verification	-	-	A1-W1, A1-W2	Maintain a monitoring record of any found species and locations.	Biodiversity Monitoring and Management Plan
94	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Engage fauna specialists to to search through the felled tree material for potential injured or trapped fauna that may have gone undetected during tree inspections. Immediate veterinary care should be administered for injured or trapped fauna.	LTA	Appointed wildlife specialist and arborist verification	-	-	A1-W1, A1-W2	Maintain a monitoring record of any found species and locations.	Biodiversity Monitoring and Management Plan
95	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Conduct biodiversity awareness trainings for construction personnel prior to the commencement of construction to raise their awarenesss of the: • Ecological sensitivity of the CCNR located in close vicinity to the site. • Proper protocols and reporting procedures to be adopted when wildlife is encountered. • Need to be cautious when operating machinery to avoid injury/mortality to fauna.	LTA	Approval of biodiversity awareness training content by NParks and maintenance of attendance log	Before commencement of construction activities and to new staff	-	A1-W1, A1-W2, tunnel alignment	Maintain a biodiversity awareness training attendance log to ensure attendance of all construction personnel.	Biodiversity Monitoring and Management Plan
96	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Educate all workers to ensure that all work places are kept clean and waste is not left in open areas. Ensure that food should only be consumed at designated food and rest areas away from natural habitat where possible, to prevent attracting wildlife to the area as a food source. Prohibit all workers from feeding animals.	LTA	-	-	-	A1-W1, A1-W2, tunnel alignment	-	Biodiversity Monitoring and Management Plan
97	Ecology and Biodiversity	Pre-construction, Operation	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1 EIA Vol III, CPT 5.5.2	Further review of embedded controls and response plans are to be conducted and additional design considerations should be considered during the Advanced Engineering Study (AES) Stage due to the ecological sensitivity of the worksites.	LTA	-	-	-	A1-W1, A1-W2, Tunnel alignment	-	Biodiversity Monitoring and Management Plan
98	Ecology and Biodiversity	Pre-Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	In consultation with NParks, recommend specific roadkill mitigation measures and implementation locations during the Advanced Engineering Study (AES) stage, when access road locations have been determined and the ecological interactions throughout the greater landscape have been studied.	LTA	LTA and NParks verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
99	Ecology and Biodiversity	Pre-Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	The feasibility of implementing roadkill mitigation measures should be considered and their effectiveness in the local context should be tested, with consultation with NParks, including but not limited to the following: • Implement structural mitigation measures such as roadside barriers and crossing structures, known to be effective in facilitating wildlife movement towards connectivity structures while preventing their access to roads. There crossing structures are to include overpasses and underpasses to cater to the ecology of various fauna types ie terrestrial and arboreal. • Install virtual fence devices at roads adjacent to worksites that are in close proximity to natural habitats ie A1-W1, A1-W2 to prevent animals from crossing roads when there are approaching vehicles. The devices are triggered by light and sound to detect vehicle headlights and noise from approaching vehicles. When the device is triggered, it emits light and sound that can deter target animals from the roads. The type of light and sound emitted should be adjusted based on the sensory range that the target wildlife can pick up for this measure to be effective. • Implement speed bumps and traffic calming signs at non-expressway roads next to worksites identified to have an increased traffic strike risk for wildlife ie Island Club Road adjacent to A1-W1. • Install wildlife warning signs and animal detection systems to warn drivers of oncoming wildlife, specifically large mammals ie Wild Boars (*Sus scrofa*) and Sambar Deers (*Rusa unicolor*). Animal detection systems utilise infrared technology to detect animals that are approaching the road. The signal from the animal detection system activates the wildlife warning signs to warn motorists of approaching wildlife.	LTA	LTA and NParks verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
100	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Provide biodiversity awareness refresher training to construction personnel every 6 months for all new and old personnel.	LTA	Approval of biodiversity awareness training content by NParks and maintenance of attendance log	Every 6 months	-	A1-W1, A1-W2, tunnel alignment	Maintain a biodiversity awareness training attendance log to ensure attendance of all construction personnel.	Biodiversity Monitoring and Management Plan
101	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Vegetation clearance, cutting or breaking or damaging branches of trees, shrubs and climbers are strictly prohibited.	Civil Contractor	LTA inspection	-	-	Tunnel alignment		Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
102	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	No works at night (2000 h to 0559 h), dawn (0600 h to 0759 h) or dusk (1800 h to 1959 h).	Civil Contractor	LTA inspection	-	-	Tunnel alignment		Biodiversity Monitoring and Management Plan
103	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Strictly no littering throughout works. All general waste to be bagged immediately and disposed of at dedicated public waste bins outside CCNR and the golf courses daily.	Civil Contractor	LTA inspection	-	-	Tunnel alignment		Biodiversity Monitoring and Management Plan
104	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Restrict meal consumption to restricted designated areas as far away as possible from forest habitat to prevent human-wildlife conflict.	Civil Contractor	LTA inspection	-	-	Tunnel alignment		Biodiversity Monitoring and Management Plan
105	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Use of trail/off trails as sanitary facility strictly prohibited. For work within the CCNR, public facilities within CCNR to be used. Outside CCNR, portable toilets to be provided and used.	Civil Contractor	LTA inspection	-	-	Tunnel alignment		Biodiversity Monitoring and Management Plan
106	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Operations to be suspended during rain.	Civil Contractor	LTA inspection	-	-	Tunnel alignment		Biodiversity Monitoring and Management Plan
107	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Schedule land and vegetation clearance activities outside of November to January to avoid periods of higher rainfall, reducing the risk of heavy sedimentation to nearby surface water courses.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
108	Ecology and Biodiversity	Pre-construction, Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Discharge point to the roadside drain at Island Club Road leading to Stream Ma is strictly prohibited. Treated effluent from the ECM at A1-W1 are proposed to be conveyed via a double containment pipeline to be discharged to a suitable surface water drain. PUB will be consulted on the alignment of the pipe and discharge point. Spare pumps, piping and other ancillary equipment will be stored at the worksite for redundancy to enable prompt replacements/repairs are made to allow for smooth operation of the ECM system at all times. Regular inspections will be made of the pipeline to ensure replacements are made in advance of significant leakage due to wear and tear.	Design Engineer (AES) / Civil Contractor	LTA and PUB verification	-	-	A1-W1	-	Water Pollution Management Plan
109	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Strictly impose offsite treatment and disposal of wastewater, ie slurry and dewatering water.	Civil Contractor	LTA inspection	-	-	A1-W1	-	Biodiversity Monitoring and Management Plan
110	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Locate temporary stockpiles of spoil/excavated earth at areas away from surface water courses and excavations (eg carparks), on solid ground and cover with a tarpaulin when not in use and/or during periods of rain.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
111	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Ensure control measures will be put in place to prohibit temporarily stockpiled material being washed into surface water courses, eg temporary drainage which is connected to Earth Control Measures facilities with collection sumps around stockpiling area; booms; regular removal and disposal of waste spoil etc.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
112	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Schedule removal of spoil from the Project area or waste material by licensed third party at least once every 5 days to minimise the volume of spoil stockpiled and potential for dust generation and erosion/runoff,	Civil Contractor	LTA verification	At least once every 5 days	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
113	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Cover all stockpiles with well-maintained tarpaulin when not in use or as soon as practicable to minimise the mobilisation of dust during windy conditions.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
114	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Strictly prohibit the illegal disposal of construction waste. Provide waste bins in dedicated areas for general waste.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
115	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Implement waste avoidance, recycling, reuse and reduction initiatives.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
116	Ecology and Biodiversity	Pre-construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Procure wildlife-proof bins (bins with proper covers) and ensure that no food waste should be left in the open at all times to prevent attracting fauna into the worksites.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
117	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Clear general waste daily.	Civil Contractor	LTA verification	Daily	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
118	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Use a proper cover for vehicles transporting spoil and ensure no overloading of soil on trucks.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
119	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Clean all vehicles and machinery used for construction purposes prior to use on site to remove any seeds, plant and/or contaminating material. If vehicles and machinery leave the site, they will be cleaned/washed down prior to re-entry or departure from the Project area. All construction vehicles to pass through a bunded wheel wash upon entry and exit of the construction work areas.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
120	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Maintain and operate all equipment and machinery used at the construction or demolition worksites in a manner such that it does not give rise to smoke emissions or leakage of fuel/oil to ground, and will comply with the Environmental Protection and Management (Vehicular Emissions) Regulations.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
121	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Undertake maintenance and mechanical repairs at dedicated designed locations, bunded to capture and control oil, grease and other spills.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
122	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Store hazardous materials in bunded and covered areas in accordance with the manufacturer's safety requirements. Storage of hazardous materials on-site should be limited to the minimum necessary in order to reduce the impact of any spillage or mitigation failure.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
123	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Include but not limit spill control measures (leaks from pipework during decommissioning; from machinery and equipment; spills as a result of accidental damage to other underground structures uncovered during excavation works etc.) throughout construction phase to the following: • Training protocol for all staff in spill response measures. • Spill management kits will be provided at worksites (composition will depend on the type of hazardous materials to be used, but likely include rags, sands, eyewash, protective gloves etc.) in particular where hazardous materials, equipment and machinery will be stored and used.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	Maintain attendance logs to ensure all workers attend relevant trainings.	Biodiversity Monitoring and Management Plan
124	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Locate portable sanitary facilities on hardstandings away from surface water courses.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
125	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Maintain suspected wildlife passageway culvert to provide passage for wildlife between the IF patch and Windsor Nature Park throughout the construction phase. There should be no dumping of waste at the culvert and no sedimentation. Inspections are to be carried out at the culvert daily to verify that it is clear.	Civil Contractor	LTA verification	Daily inspection	-	A1-W1	-	Biodiversity Monitoring and Management Plan
126	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Plant worksite perimeter with shrubs and saplings of indigenous stock to reduce the hardness of the worksite to the forest and maintain lower light levels and higher humidity around the edge. Planting is to be carried out with the advice of a qualified arborist/horticulturist and with approval from NParks. The sites where planting is required should be assessed based on the conditions of the adjacent habitats identified from the worksite-specific baseline studies conducted at the AES stage.	Civil Contractor	LTA, appointed arborist and NParks verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
127	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Use a colour palette that has a Light Reflective Value (LRV) of less than 30% worksite hoarding. The LRV Value may be varied where built structures are enclosed or do not directly face or reflect onto vegetated areas. All glazed surfaces will be placed at angles that limit direct light reflection into vegetated areas). Screens, louvres or shading may be used to limit direct sunlight penetration and reflection from glazed surfaces.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
128	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Ensure that stockpiles will be maintained below a maximum height of 2 m so that perimeter hoarding or barriers (2.4 m high at least) can serve as an effective shield for surrounding buildings to minimise the transport of dust beyond the construction worksites.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
129	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Engage an ISA-certified arborist to inspect areas of damaged trees and vegetation patches observed after storm events of strong winds as soon as practicable. Recommendations (temporary measures or long term solutions) from the arborist are to be considered and implemented with consensus from NParks.	Civil Contractor	LTA, appointed arborist and NParks verification	-	-	A1-W1, A1-W2	Maintain tree species records and actions taken.	Biodiversity Monitoring and Management Plan
130	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Conduct monitoring of vegetation health to identify onset of edge effects.	LTA	Appointed arborist verification	Monthly	-	A1-W1, A1-W2	Maintain tree species records and actions taken.	Biodiversity Monitoring and Management Plan
131	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Direct lighting away from vegetated areas and habitats.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
132	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Avoid using broad spectrum lights and lumination that has a high UV component to reduce impacts on insects.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
133	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Procure fully biodegradable Erosion Control Blankets.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
134	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Do not use barbed wires and fences on site to prevent fauna from getting trapped.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
135	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Conduct daily checks on the integrity of the hoarding to prevent the entry of fauna into worksite. In the event that any damage to hoarding is detected, repair works should be undertaken immediately.	Civil Contractor	LTA verification	Daily	-	A1-W1, A1-W2	Maintain records of fauna intrusions into worksites to be shared with LTA and NParks.	Biodiversity Monitoring and Management Plan
136	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Upon encounter with dead/injured/live fauna on site, construction staff should stop work in the immediate area and are not permitted to handle or harass any fauna. Workers should report the presence of fauna encountered on site to a designated wildlife specialist on call, and the wildlife specialist should capture the animal for follow-up actions upon engagement with NParks. Incidents should be investigated to identify possible points of entry from the hoarding which are to be sealed immediately.	Civil Contractor	LTA and NParks verification	-	-	A1-W1, A1-W2	Maintain records of fauna intrusions into worksites to be shared with LTA and NParks.	Biodiversity Monitoring and Management Plan
137	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Vehicles ferrying workers, equipment and material to and from the worksites are to abide by a speed limit of 40 km/h to provide reaction time for stopping in case an animal is in the path.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
138	Ecology and Biodiversity	Construction, Operation	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Establish a register and investigation process to determine the cause of any road kills during construction and operation. Ensure that all deaths are investigated and that gaps in mitigation measures that may have led to the death/injury are identified, and appropriate changes made to the mitigation strategy.	Civil Contractor	LTA and NParks verification	-	-	A1-W1, A1-W2	Maintain a register of road kills to be shared with LTA and NParks.	Biodiversity Monitoring and Management Plan
139	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Maintain all mechanical mitigation measures to ensure their structural and functional integrity. For example, virtual fence devices and animal detection systems, where implemented, should be regularly checked for their functionality and maintained according to manufacturer's recommendations.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
140	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Implement monitoring techniques of roadkill mitigation measures to provide insight on the effectiveness of the measures, and allow for the analysis of wildlife movements throughout the landscape. Monitoring programmes are to be specified at a later stage when feasible mitigation measures have been identified for implementation (see Item 131 above).	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
141	Ecology and Biodiversity	Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	Mitigate vibration impact during TBM operation to As Low As Reasonably Practicable (ALARP) by: • Maintaining cutter tools in good condition; • Controlling cutterhead rotation speed and advance rate; • Fitting TBM with articulated front section for negotiating curves. Vibration monitoring at selected locations on the ground surface above and in advance of the TBM will be undertaken during construction. Vibration predictions will be forecasted on a monthly basis or as applicable e.g. when the TBM transitions into different geological conditions or depth of rock, based on these measurements. The vibration prediction forecasts will be reported to the TBM operator to enable prompt implementation of the abovementioned mitigation measures when vibration levels are predicted to exceed background levels during TBM operation.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2, tunnel alignment	-	Biodiversity Monitoring and Management Plan
142	Ecology and Biodiversity, Visual	Operation	Reduce ecology and biodiversity impacts, reduce visual impacts	EIA Vol III, CPT 5.5.1 EIA Vol III, CPT 6.2.4.4	Replant vegetation of native species at the remaining land available at the worksite after the construction of the facility building.	LTA	LTA and NParks verification	-	-	A1-W1, A1-W2	Maintain a register of native species planted and their locations between LTA and NParks.	Biodiversity Monitoring and Management Plan
143	Ecology and Biodiversity, Visual	Pre-construction, Operation	Reduce ecology and biodiversity impacts, reduce visual impacts	EIA Vol III, CPT 5.5.2 EIA Vol III, CPT 6.2.4.4	Adopt the use of natural materials, vertical greening and wildlife friendly design for the design of permanent aboveground structures, including security fences. Natural tones for the building façade or green roofing to be considered to increase visual compatibility with surroundings and non-reflective finishes to be adopted to reduce potential glare effect.	LTA	LTA and NParks verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
144	Ecology and Biodiversity, Visual	Operation	Reduce ecology and biodiversity impacts, reduce visual impacts	EIA Vol III, CPT 5.5.2 EIA Vol III, CPT 6.2.4.4	Plant verge around facility building with attractive, native plant species. Plants of a variety of growth habits should be utilized to provide structure to the vegetation and integration with the surrounding forest.	LTA	LTA and NParks verification	-	-	A1-W1, A1-W2	Maintain a register of native species planted for reference.	Biodiversity Monitoring and Management Plan
145	Ecology and Biodiversity	Pre-construction, Operation	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.2	Take into consideration advice from NParks after aboriculture studies and fauna inspections prior to the confirmation of facility building locations, to minimise disturbance to flora and fauna.	LTA	LTA and NParks verification	-	-	A1-W1, A1-W2	-	Biodiversity Monitoring and Management Plan
146	Ecology and Biodiversity	Operation	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.2	Engage trained personnel to remove any roosts and nests found to interfere with maintenance works or the ventilation shaft building function.	Railway System Operator	LTA and NParks verification	-	-	A1-W1, A1-W2	Maintain a shared database of roost and nest information with NParks.	Biodiversity Monitoring and Management Plan
147	Ecology and Biodiversity	Post-Construction	Reduce ecology and biodiversity impacts	EIA Vol III, CPT 5.5.1	In the event of excessive ground settlement, carry out recovery works to make safe the area, followed by investigation works at the affected area. Habitat resources that could have been lost and wildlife injury to be recorded. If possible and feasible, restoration work to be undertaken after the situation has been deemed safe. Notify NParks immediately should there be a loss of habitat resources. Consult with NParks and restoration specialists before restoration works are undertaken.	LTA	Restoration specialists and NParks verifications			A1-W1, A1-W2	NParks to be notified and to submit a detailed investigation report, detailing the incident and rectification actions.	Biodiversity Monitoring and Management Plan / Emergency Response Plan
148	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Use non-reflective material or paint for hoardings so as to minimise glare on pedestrians, motorists and residents.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	-
149	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Implement planted verges and/or green walls at the worksite boundary to reduce visual incompatibility by priotising the use of species native to Singapore and part of the plant community found within the CCNR; slsecting attricing plant species; and utilising a variety of growth habits (eg shrubs and trees) to break up the hardness of the worksite boundary.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	-
150	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Direct lighting within the worksite to prevent light spillage.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	-
151	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Place stockpiles away from the direct line of sight from the worksite entrance.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	-
152	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Strictly enforce no littering policies amongst workers within and around the worksite.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	-
153	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Designate a temporary canteen or sheltered resting area for workers within the worksite to minimise large gatherings within public spaces.	Civil Contractor	LTA verification	-	-	A1-W1, A1-W2	-	-
154	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Make information of worksites, their locations and durations available to the public prior to commencement of works. This can be in the form weather-proof notifications mounted beside NParks mapboards. This will allow visual receptors (eg recreational users of the CCNR trails) to plan ahead to avoid and minimise exposure to the worksites.	LTA	Notifications are mounted	-	-	A1-W1, A1-W2	-	-
155	Visual	Construction	Reduce visual impacts	EIA Vol III, CPT 6.2.4.4	Maintain a grievance and feedback mechanism where visual receptors can report on visual intrusions from the worksites (eg improper waste storage, staining of facilities). Public feedback to be investigated and a follow-up conducted to close out the comment.	LTA	Public feedback is addressed	-	-	A1-W1, A1-W2	Maintain a grievance and feedback mechanism for investigation and follow-up actions.	-
156	Tourism and Recreation	Construction	Reduce tourism and recreation impacts	EIA Vol III, CPT 6.3.4.1	Plan the site layout and construction activities so as to minimise access restrictions and road congestion at Island Club Road due to movement of heavy machinery.	Civil Contractor	LTA verification	-	-	A1-W1	-	-

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
157	Tourism and Recreation	Construction	Reduce tourism and recreation impacts	EIA Vol III, CPT 6.3.4.1	Provide advance notification to NParks regarding any construction activities that require temporary access closures due to public safety concerns, eg rock excavation. Coordinate with NParks and LTA to post such notifications on NParks' and/or LTA's online platforms and/or at NParks' mapboards.	LTA	Notification to NParks	-	-	A1-W1	-	-
158	Ecology and Biodiversity	Pre-construction (installation of piezometers)	Impact to wild plants	EIA Vol III, CPT 5.5.1.4	For Rotary BH drilling works within the CCNR, vegetation clearance, cutting or breaking or damaging branches of trees, shrubs and climbers are strictly prohibited.	Contractor	SHE Inspections	Daily	Vegetation around the rotary rig worksites	All rotary rig operation locations	SHE Inspection Report (to include Corrective Action)	SHE Inspection Report
159	Ecology and Biodiversity	Pre-construction (installation of piezometers)	Ecological Disturbance	EIA Vol III, CPT 5.5.1.4	For Rotary BH drilling operators undertaking works within the CCNR, meal consumption to be restricted to worksites outside the CCNR.	Contractor	SHE Inspections	Daily	-	All rotary rig operation locations	SHE Inspection Report (to include Corrective Action)	SHE Inspection Report
160	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human and Ecological Disturbance	EIA Vol III, CPT 5.5.1.4 Environmental Protection and Management Act, 2008 Code of Practice for Noise Control on Construction and Demolition Sites, SS602:2014 NParks Specification	All drilling works to be scheduled during daylight hours (09.00 - 17.00) with one hour (17.00 - 18.00) demobilization time from the Project area, Monday to Friday only, unless specified otherwise within. No rotary BH drilling works to be undertaken within the CCNR at night, dawn or dusk.	Contractor	Approval of works schedule prior to commencement of drilling works SHE Inspections and Clock In/Out Procedure	Daily	-	Clock In/Out at NParks Ranger Station when undertaking works within CCNR; SICC when undertaking works outside CCNR	-	-
161	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Impact to wild plants and animals	SI EIA Vol III, CPT 3.5.1 and CPT 6 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition	All survey equipment, rigs and vehicles (Rotary Rigs, Vehicles) involved in the drilling works within the CCNR gazetted boundary and golf courses to undergo maintenance checks and cleaning prior to mobilization into the CCNR and upon exit from the CCNR. Note, no equipment washing to be undertaken within the CCNR.	Contractor	SHE Inspections Maintenance Records and Certification of Equipment	Prior to mobilization into the CCNR	-	Contractor Equipment Storage Yards	SHE Inspection Report; Maintenance Records; and Equipment Certification	Water Pollution Management Plan Emergency Preparedness Plan
162	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Wastewater runoff to ground and/or surface watercourses Potential pollution hazards to aquatic and wildlife communities in the stream and wetland areas	SI EIA Vol III, CPT 3.5.1 Environmental Protection and Management Act, 2008	Fluid Containment Tank (FCT) to be used at all times during operation of rotary rigs to contain slurry. FCT to be positioned on absorbent mat and within secondary containment to contain potential spill / leak to ground.	Contractor	SHE Inspections	Daily	Visual inspection of overflow to ground from FCT	All rotary rig operation locations	SHE Inspection Report (to include Corrective Action)	Water Pollution Management Plan
163	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Wastewater runoff to ground and/or surface watercourses Potential pollution hazards to aquatic and wildlife communities in the stream and wetland areas	SI EIA Vol III, CPT 3.5.1 Environmental Protection and Management Act, 2008	Wastewater from the FCT to be pumped to an enclosed 1,000 liter tote tank and removed offsite by a small vehicle approved by NParks/LTA to a licensed third party waste management facility. Pump hose connecting FCT to wastewater tote tank to be secured so as to avoid any spillage from loose hoses, including being fitted with a valve to prevent drips to ground. All equipment at the worksite to be enclosed with tertiary containment with impermeable surface to prevent accidental leakage to surrounding environment.	Contractor	SHE Inspections	Daily	Visual inspection of overflow to ground from FCT	All rotary rig operation locations	SHE Inspection Report (to include Corrective Action)	Water Pollution Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
164	Water Quality Ecology Biodiversity, Climate and Air Quality	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Potential pollution hazards to aquatic and wildlife communities in the stream and wetland areas Human and ecological disturbance from dust	SI EIA Vol III, CPT 3.5.1 Environmental Protection and Management Act, 2008 Sewerage and Drainage (Surface Water Drainage) Regulations, 2007 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition LTA Guidebook for Best Environmental Practices: Water Resource Management at LTA Sites, 2011	During Preliminary Investigation phase, prior to commencement of the Rotary BH, Erosion Control Blankets (ECB) to be positioned beneath equipment at all unpaved worksite areas. ECBs should be restricted to trails only, ie no disturbance of vegetation. Inspection and maintenance of ECBs to continue during rotary BH drilling works.	Contractor	SHE Inspections (to include inspection schedule, checklist and maintenance schedule to be carried out by Contractor for all proposed erosion and sediment control measures)	Weekly	-	All unpaved areas utilized for rotary rig operations, including mobilization/demobilization routes	SHE Inspection Report(to include Corrective Action)	Earth Control Measures Plan Air Pollution Control Plan Water Pollution Control Plan Biodiversity Monitoring and Management Plan
165	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Contamination of ground and surface watercourses	SI EIA Vol III, CPT 3.5.1	In the event Rotary BH locations within CCNR and golf courses need to be adjusted, boreholes should not be sited within the 30 m surface water buffer zone or at or adjacent to location of steep gradient and be subject to LTA and NParks approval.	Contractor	Approval from LTA and NParks	-	-	-	-	-
166	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Contamination of ground and surface watercourses and impact to aquatic and wildlife communities	SI EIA Vol III, CPT 3.5.1 Environmental Protection and Management Act, 2008 LTA Guidebook for Best Environmental Practices; Water Resource Management at LTA Sites, 2011	The small amounts of hazardous fluids (ie, <5 liter maintenance oil) are required to be stored within a dedicated locked hazardous material storage box at each worksite and during mobilization/demobilization to and from each worksite. Diesel storage within CCNR strictly prohibited. Spill kits such as absorbent pads and drip trays as well as secondary containment with impermeable surface to be provided at each worksite. Storage box and spill kits to be secured at all times to prevent access from wildlife. Note, use of jerry cans is prohibited within the CCNR.	Contractor	SHE Inspections	Daily for Rotary BH's within CCNR	Visual inspection	All rotary rig operation locations	SHE Inspection Report (to include Corrective Action)	Water Pollution Management Plan
167	Noise and Vibration	Pre-construction (installation of piezometers)	Human Disturbance from Noise generated during Rotary BH and HDC operations	LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition Code of Practice for Noise control on construction and demolition sites, SS602:2014	As per LTA General Specification, Noise Management Plan to ensure equipment/rigs are operating within the manufacturers specifications. In addition, rig /equipment selected for use should have sound power specifications: i) Rotary borehole drilling rig (A-frame, crawler mounted): 105 dB(A) before enclosure and 101 dB(A) after use of wood enclosure for rig power source. ii) Water pump (diesel operated): 96 dB(A)	Contractor	Review of vendor specifications against Code of Practice and SI EIA SHE Inspection	During Preliminary Investigation Phase, prior to commencement of Rotary BH	-	-	Method Statement	Noise Management Plan
168	Noise and Vibration	Pre-construction (installation of piezometers)	Human Disturbance from Noise generated during Rotary BH and HDC operations	LTA General Specification, Safety, Health and Environment (for Rail Project) October 2018 Edition	All rigs and equipment used must have both the noise emission levels of: a) engine noise and b) operational noise under normal operating conditions, clearly indicated on a weather-proof sticker pasted at the equipment.	Contractor	SHE Inspection	During Preliminary Investigation Phase, prior to commencement of Rotary BH	-	-	-	Noise Management Plan
169	Noise and Vibration	Pre-construction (installation of piezometers)	Human Disturbance from Noise generated during Rotary BH and HDC operations	LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition LTA's Handbook for Best Environmental Practices: Noise Control at LTA Sites, July 2008	All rigs and vehicles (including ancillary vehicle mobilizing water/wastewater to and from each worksite) in intermittent use to be shut down or throttled down to a minimum in the intervening periods between works.	Contractor	SHE Inspection	Daily for Rotary BH's within CCNR	Visual inspection	All rotary rig operation locations	SHE Inspection Report	Noise Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
170	Noise and Vibration	Pre-construction (installation of piezometers)	Human Disturbance from Noise generated during Rotary BH operations	Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2008 Code of Practice for Noise Control on Construction and Demolition Sites, SS602:2014 LTA's Handbook on Best Environmental Practices: Noise Control at LTA Sites	Should there be an exceedance of the permissible noise limits during continuous noise monitoring at noise sensitive receptors, ie the golf clubhouses, temporarily suspend works and notify the LTA. LTA to then engage SICC and NEA and undertake a review of the schedule of works to avoid impacts to human receptors as well as exceedance of the construction noise limits.	Contractor	Noise Monitoring Records attached to SHE Inspection Report	-	-	-	-	Noise Management Plan
171	Noise and Vibration	Pre-construction (installation of piezometers)	Human Disturbance from Noise generated during Rotary BH operations	SI EIA Vol III, CPT 4.5.1, CPT 4.5.2 & CPT 4.5.3	Schedule works to avoid periods of peak usage in the Study Area, eg golf tournaments or marathons within CCNR. The schedule should be shared in advance with LTA and/or other stakeholders (NParks and SICC at a minimum) to obtain their agreement prior to commencement of works.	Contractor	Approved schedule of works	-	-	-	-	-
172	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human Disturbance from Noise generated during Rotary BH operations	SI EIA Vol III, CPT 4.5.2 Environmental Protection and Management Act, 2008	Low-noise generators and/or engines to be used at all times. (With reference to criteria provided under the NEA's *Guidelines on Quieter Construction Fund* , quieter equipment may be defined as equipment that is at least 5dB quieter than two similar pieces of equipment commonly used for the same type of work in Singapore)	Contractor to provide Silenced / low Noise Generator and/or engine Environmental Advisor (ERM)	SHE Inspection Complete verification monitoring and technical note submission to LTA	- Once during first week of drilling works for Rotary BH Rig	- Laeq,5min	- As per the vendor specifications for the silenced / low noise generators and/or engines	- Technical Note to be submitted to the LTA within one week of verification monitoring.	Noise Management Plan
173	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to Noise from operation of Rotary BH Rigs	SI EIA Vol III, CPT 4.5.3 & CPT 4.5.4 Environmental Protection and Management Act, 2008 Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2008	Acoustic enclosures to be placed on noise generating equipment such as engines, generator set and water pumps throughout operation at HDC sites (unless full enclosures of HDC sites provided). For the construction of machinery enclosures, a sheet material mass of at least 10 kg/m3 shall be used. The sound absorbent inside lining of the enclosure (which may be made of mineral wool, woodwool or absorbent tiles) should be at least 25 mm thick. Panels used in the enclosure should meet a STC rating of 20 or higher, with reference also being made to the performance requirements for enclosures published by NEA under its Guidelines on Quieter Construction Fund	Contractor to provide and ensure enclosures in place	SHE Inspection	-	-	-	-	Noise Management Plan
174	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human and Ecological Disturbance due to Noise from Rotary BH works	SI EIA Vol III, CPT 4.5.1 & CPT 4.5.3 Environmental Protection and Management Act, 2008 Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2008	Where there are no space constraints, erect portable acoustic screens at least 3 m high around the Rotary BH rig motors, e.g. at BH30 - BH33.	Contractor to provide and ensure screens in place.	SHE Inspection	-	-	-	-	Noise Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
175	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to Noise from vehicles used during Rotary BH works Disturbance to wild animals and destruction of vegetation during Rotary BH in CCNR	SI EIA Vol III, CPT 4.5.4 Environmental Protection and Management (Vehicular Emissions) Regulations, 2008	All vehicles used to mobilize/demobilize equipment, water/wastewater to and from worksites to be in compliance with the stipulated (*Environmental Protection and Management (Vehicular Emissions) Regulations, 2008*) noise standards for new and in-use motor vehicles, eg 99 dB(A) and 107 dB(A) respectively for new and in-use goods vehicles with gross vehicle weight exceeding 3.5 tons.	Contractor	SHE Inspection Vehicle Manufacturer's Certificate	-	-	-	-	Noise Management Plan
176	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to Noise from vehicles used during Rotary BH within CCNR Disturbance to wild animals during Rotary BH operations	SI EIA Vol III, CPT 4.5.4 and CPT 6	Investigate if any other lower noise, compact vehicles are available to transport water/wastewater to and from the BH locations within CCNR and deploy if practicable (ie do not require turning circle)	Contractor	Method Statement Approval	-	-	-	-	-
177	Noise, Vibration, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to Noise from vehicles used during Rotary BH within CCNR	SI EIA Vol III, CPT 4.5.5	Plan logistics and resources to limit the number of trips required for haulage of water/wastewater to as low as possible (max 2 trips a day), during drilling works.	Contractor	Approval of Rotary BH Schedule during Preliminary Investigation Phase SHE Inspections	Daily within CCNR	-	Clock In/Out at vehicle entrance to CCNR.	SHE Inspection Report	-
178	Noise, Vibration, Climate and Air Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to Noise from vehicles used during Rotary BH within CCNR Dust generation from mobilization and demobilization Disturbance to wild animals during Rotary BH in CCNR	SI EIA Vol III, CPT 4.5.5 and CPT 6 Public Utilities (Central Water Catchment Area and Catchment Area Parks) Regulations 2003 Best Environmental Practices; Noise Control at LTA Sites, 2008 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition Public Utilities (Reservoirs, Catchment Areas and Waterway) Regulations 2006	All vehicles should be maintained at a constant and low speed of less than 3 km/hour at all off main road locations.	Contractor	SHE Inspection	Weekly spot checks	-	ad hoc off main road locations	SHE Inspection Report	Noise Management Plan
179	Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to wild animals during Rotary BH in CCNR	SI EIA Vol III, CPT 6.5.3	During mobilization/demobilization of rigs, secondary and tertiary vehicles along trail, a contractor to walk at a safe distance in front of rig/vehicle to spot for any wildlife (including that which may be present on vegetation which extends over the trails). If encountered, vehicles to stop movement, contractors to remain still and silent until such time as the wildlife has moved away from the trail. In the instance wildlife does not move from the trail/vegetation, Contractor to notify NParks and await further instruction before continuing to move vehicles. Contractors are strictly prohibited from handling/touching any wildlife encountered, including forcing movement of wildlife away from the work areas.	Contractor	Training records of Contractors attendance of EMMP Planning Meeting SHE Inspection Discussion and notification to LTA Project team during daily progress calls and SHE Toolbox talks Notifications to NParks	Daily during mobilization/ demobilization of rigs/vehicles	-	All trails utilized within CCNR	SHE Inspection Report to include comments on any wildlife encountered/reports to NParks	Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
180	Noise and Vibration, Air Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Human disturbance due to Noise from vehicles used during Rotary BH within CCNR	SI EIA Vol III, CPT 4.5.5	Operators of the crawler rigs and ancillary vehicles to maintain suitable driving qualification, such as a Class 4 driving license for heavy motor cars and motor tractors, the weight of which unladen exceeds 2,500 kg, in accordance with the Road Traffic (Motor Vehicles, Driving Licenses) Rules.	Contractor	Class 4 driving license	-	-	-	-	Noise Management Plan
181	Surface Water Quality, Ecology & Biodiversity	Pre-construction (installation of piezometers)	Human and ecological disturbance from dust	SI EIA Vol III CPT 5.5.1 Environmental Protection and Management Act, 2008	Strictly no stockpiling of spoil material generated during Rotary BH works. Waste material to be bagged and removed daily from each worksite location by licensed third party waste contractor.	Contractor	SHE Inspection Waste Transfer Manifests	-	-	-	-	Air Pollution Control Plan Waste Management Plan
182	Surface Water Quality, Ecology & Biodiversity	Pre-construction (installation of piezometers)	Effects to Water quality, Ecological and Biodiversity post Rotary BH	Environmental Protection and Management Act, 2008	All worksites to be reinstated following completion of Rotary BH to same condition as found and in accordance with NParks approval.	Contractor	NParks Permit to Work in CCNR and approval of reinstatement	-	-	-	Inclusion in detailed Rotary BH method statements	-
183	Climate and Air Quality	Pre-construction (installation of piezometers)	Air Quality compliance, human and ecological disturbance from emissions to air from off road diesel vehicles	Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations 2012. Environmental Protection and Management (Vehicular Emissions) Regulations 2008 Schedule of the Environmental Protection and Management (Air Impurities) Regulations 2008	In addition to ensuring all Rotary BH drilling and associated equipment complies with standard requirement of *Schedules of the Environmental Protection and Management (Vehicular Emissions) Regulations 2008 and the limits stipulated in the Schedule of the Environmental Protection and Management (Air Impurities) Regulations 2008;* all off-road diesel vehicles used in the CCNR and golf courses (ie the crawler mounted drilling rig, secondary and tertiary vehicle used to transport fresh water and wastewater to and from each worksite in the CCNR and associated vehicles) to comply with the exhaust emission limits listed under Schedule of the *Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations 2012* .	Contractor	Vehicle Exhaust Emissions Test Report submission	Prior to commencement of Rotary BH	-	-	Emissions Test Report	Air Pollution Control Plan
184	Stakeholder Engagement	Pre-construction (installation of piezometers)	Human and ecological disturbance from Rotary BH operations within CCNR	SI EIA Vol III	Post a notice providing details on the proposed Rotary BH activities and their duration within the CCNR, on signboards at the MacRitchie Visitor Centre and Ranger Station as well as other appropriate locations (to be confirmed with NParks) for the duration of the Rotary BH drilling Program.	LTA	Confirmation from NParks	-	-	-	-	-
185	Ancillary Facilities	Pre-construction (installation of piezometers)	Waste	SI EIA Vol III CPT 2.4.4 Public Utilities (Reservoirs, Catchment Areas and Waterway) Regulations 2006	Portable lavatories are to be positioned outside the CCNR at Kalang Service Reservoir (in agreement with PUB) and at the end of Sime Road through Bukit Golf Course (in agreement with SICC). For work within the CCNR, public facilities within CCNR to be used. Use of trail / off trails as sanitary facility is strictly prohibited.	Contractor	SHE Inspection	Daily	-	-	SHE Inspection Report	Waste Management Plan
186	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Waste Management throughout Rotary BH Disturbance to wild plants and animals	SI EIA Vol III CPT 2.4.4 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition Environmental Protection and Management Act, 2008	Waste Management Plan to include the following: • Bagging and daily removal of all solid waste from each worksite. • Mobilization and demobilization procedures for the wastewater collection vehicle. • Logging of waste generation and removal from each worksite. • Strictly no use of trails or off-trail areas for sanitary purposes. • Provision of sanitary facilities outside CCNR (eg portable toilets). • Sanitary facility location outside CCNR (eg off Island Club Road, Sime Road or at Kalang Service Reservoir Compound), maintenance and waste removal procedures. • Inspection procedures to ensure waste management implementation. • Disposal protocols and documentation requirements by licensed third party contractors. • Daily SHE inspection of Waste Management Plan and Feedback Management Plan.	Contractor	SHE Inspection	Daily	-	-	SHE Inspection Report	Waste Management Plan Feedback Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
187	Ecology and biodiversity	Pre-construction (installation of piezometers)	Potential pollution hazards to aquatic and wildlife communities in the stream and wetland areas	SI EIA Vol III, CPT 6.5 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition	30 m buffer zone each side of streams and wetland areas (wetland forest and wetland marsh), to be maintained at all times for Rotary BH drilling locations.	Contractor	SHE Inspection	Prior to commencement of Rotary BH	-	-	-	Earth Control Management Plan
188	Ecology and biodiversity Noise	Pre-construction (installation of piezometers)	Disturbance to wild plants and animals during operation of drilling	SI EIA Vol III, CPT 6.5.2 Environmental Protection and Management Act, 2008 Public Utilities (Reservoirs and Catchment Areas) Regulations, 2006 Wild Animals and Birds Act, 2000	All Contractor personnel to attend a two hour training of the ecological sensitivities within CCNR and a toolbox health and safety briefing including a briefing on wildlife encounters on and off trail and noise minimization measures. Health and safety briefing to include NParks requirements for working within CCNR. The training is to be provided at the Preparatory Works stage, prior to the onset of the Rotary BH.	Environmental Advisor (ERM)	Training record of completion	Prior to commencement of Rotary BH	-	-	Training record	-
189	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild plants and animals in high sensitive habitat	SI EIA Vol III, CPT 6.5 Environmental Protection and Management Act, 2008	Restrict the number of workers completing the Rotary BH within the CCNR to 5 personnel per rig for mobilization/demobilization and set up; and 5 personnel for operation.	Contractor	Method Statement NParks Permit to Work in CCNR	Throughout Rotary BH in CCNR	-	Rotary BH's within CCNR	-	-
190	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild plants and animals	SI EIA Vol III, CPT 6.5 Environmental Protection and Management Act, 2008	Strictly no littering throughout Rotary BH. All general waste to be bagged and disposed at dedicated public waste bins outside CCNR and the golf courses daily.	Contractor	SHE Inspection	Daily	-	All worksite areas	-	Waste Management Plan
191	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild animals during equipment	SI EIA Vol III, CPT 6.5 Environmental Protection and Management Act, 2008	Ensure all drilling equipment and geophysical survey equipment is secure at each worksite when being left overnight so as to avoid interference and potential harm to wild animals. Equipment should also be secured on vehicles during mobilization and demobilization.	Contractor	SHE Inspection	Spot checks weekly during operations	-	-	SHE Inspection Report	Emergency Preparedness Plan
192	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild plants and animals during Rotary BH Operations in CCNR	SI EIA Vol III, CPT 6.5 Environmental Protection and Management Act, 2008 Public Utilities (Reservoirs and Catchment Areas) Regulations, 2006	Method Statement and Emergency Preparedness Plan for Rotary Borehole to include vehicle mobilization /demobilization schedule and routes as outlined in the *SI EIA Volume III, Chapter 2* .	Contractor to incorporate within Emergency Preparedness Plan Environmental Advisor (ERM) to Review Emergency Preparedness Plan	Environmental Advisor (ERM) Review NParks verification and approval	During Preliminary Investigations prior to Rotary BH	-	-	Rotary BH Method Statement	Emergency Preparedness Plan
193	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild animals during Rotary BH in CCNR	SI EIA Vol III, CPT 6.5.3	Meet with NParks prior to commencement of the surveys to agree if any additional informaiton to be included within NParks wildlife encounters plan, eg if a snake is on a branch extending into the trail, particularly for geophysical surveys off trail	Contractor	Wildlife Encounter Plan NParks Permit to Work in CCNR	During Rotary BH	-	-	-	-

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
194	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to any flora species of conservation interest, as specified in Annex 9 (e.g. *Aquilaria malaccensis* seedlings) from Rotary BH works	SI EIA Vol III, CPT 6.5	During site reconnaissance, extent of any flora species of conservation interest, as specified in Annex 9 should be verified to avoid impact. For example, in the vicinity of BH28 two *Aquilaria malaccensis* trees (VU/RDB; VU/ IUCN) were observed on the left side of path (facing east) and numerous seedlings also along the left side of the path (facing east) between BH28 and BH29, as well as Dipterocarp trees in close proximity to the trail. These Rotary BH locations should be shifted slightly on the existing trail to avoid the worksite impacting the seedlings. During mobilization and demobilization, to ensure abovementioned plant species and species listed as CR, EN or VU in the Singapore RDB will not be damaged. Environmental Advisor to review method statement and verification by NParks and LTA	Contractor	Method Statement Review by Environmental Advisor (ERM) NParks Permit to Work in CCNR	Prior to commencement of Rotary BH particularly in vicinity of BH28	-	All boreholes (including those outside the CCNR) but in particular Terentang Trail between BH28 and BH29	-	-
195	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild plants and animals during operation of rotary borehole	SI EIA Vol III, CPT 6.5 Environmental Protection and Management Act, 2008 Public Utilities (Reservoirs and Catchment Areas) Regulations, 2006	Restrict the number of Rotary Rigs/ associated daily support vehicle on the trail operating at any one time within CCNR.	Contractor	NParks Permit to Work in CCNR and along nearby trails. LTA spot check & daily progress call	-	-	-	-	-
196	Ecology and Biodiversity	Pre-construction (installation of piezometers)	Disturbance to wild plants and animals	SI EIA Vol IV, CPT 6.5.3	Conduct daily check of work site boundaries to ensure that they are not breached and that damage does not occur to surrounding areas.	Contractor	SHE Inspection	Daily	-	All worksite areas	-	Biodiversity Monitoring and Management Plan
197	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Disturbance to aquatic environment	SI EIA Vol III, CPT 3 and CPT 6 LTA Guidebook for Best Environmental Practices; Water Resource Management at LTA Sites, 2011	As a precautionary measure, Contractor ET to review weather forecast at end of each day and review schedule for mobilization/demobilization of ancillary vehicle and equipment within CCNR to avoid periods of rainfall. Contractor staff outside CCNR to monitor NEA rainfall forecasts and to update Contractor teams on site of any forecast rainfall events. Contractor teams to be equipped with walkie talkies to allow for communication with staff outside the CCNR and to check in prior to any vehicle movements along trail. Contractor ET to share upcoming daily works schedule, including weather forecast projection and schedule during daily progress call with LTA project team; daily toolbox talk with onsite contractors; and document within weekly SHE Inspection report.	Contractor	Review and approval of upcoming weather forecast and works schedule during daily progress call with LTA. Notification of Contractor field team of forecast and schedule during daily toolbox talks. SHE Inspection Reporting	-	-	-	-	Biodiversity Monitoring and Management Plan Water Pollution Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
198	Water Quality, Ecology and biodiversity	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Disturbance to aquatic environment	SI EIA Vol III, CPT 3.5.1 LTA Guidebook for Best Environmental Practices; Water Resource Management at LTA Sites, 2011	Rainfall and Rotary Borehole Drilling Operations Borehole drilling operations at each worksite within CCNR to be suspended during rainfall and all equipment to be covered with tarpaulin; FCT to be fitted with tight lid; closure of wastewater tote tank; storage of hazardous liquids/materials (eg maintenance oil, oily rags etc) within lockable enclosure to prevent generation of contaminated run-off and overflow. Contractor ET to seek NParks advice to recommence borehole drilling operations within CCNR following a rainfall event. As a minimum ET to wait until rain has fully stopped prior to instructing rig operator to remove FCT lid and tarpaulin before starting/recommence drilling. Movement of ancillary equipment along trails between each borehole worksite location to be suspended within the CCNR. All vehicle movement along trails within CCNR and through SICC Golf Course to be suspended.	Contractor	Visual inspection of access routes and worksites for signs of change in the ground conditions as a result of rainfall that would enable sediment runoff from worksite area	Weekly inspection	Changes to pre-work ground conditions, eg creation of surface water pools or channels as a result of the presence of the rotary drilling worksite	Access routes and rotary drilling and HDC worksites	Document within weekly SHE Inspection Report Issues / Corrective actions to be raised during daily progress calls with LTA	-
199	Water Quality, Ecology and biodiversity	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Disturbance to aquatic environment	SI EIA Vol III, CPT 3 and CPT 6 LTA Guidebook for Best Environmental Practices; Water Resource Management at LTA Sites, 2011	Rainfall and Manual Transport of Rotary Borehole Ancillary Equipment Prohibit manual transport of ancillary equipment along trails between each borehole worksite locations during rainfall. In the event of an unforeseen rainfall event while there is manual equipment movement occurring along the trail, transportation should continue to the planned destination and then stop (eg stop at the worksite or access point to the trail) until further notification from the Contractor ET. Contractor ET to wait at least one hour and review of the access route to confirm no signs of flooding, prior to approving further movement along the trails within CCNR. Following rainfall event, manual transport of ancillary equipment to and from each worksite permitted upon seeking advice from NParks after rainfall has completed halted and as instructed by the Contract ET.	Contractor	Review of schedule and rainfall during daily progress call with LTA.	Weekly inspection	Changes to pre-work ground conditions, eg creation of surface water pools or channels as a result of the presence of the rotary drilling worksite	Access routes and rotary drilling and HDC worksites	Document within weekly SHE Inspection Report Issues / Corrective actions to be raised during daily progress calls with LTA	-
200	Water Quality, Ecology and biodiversity	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Disturbance to aquatic environment Unplanned Events	SI EIA Vol III, CPT 3 and CPT 6 LTA Guidebook for Best Environmental Practices; Water Resource Management at LTA Sites, 2011	Rainfall and Vehicle Movement Along Trails and within SICC Golf Course No vehicle movement permitted along trails within CCNR and through SICC Golf Courses during rain. In the event of an unforeseen rainfall event while there is ancillary vehicle moving occurring along the trail, transportation should continue to the planned destination and then stop (eg stop at the worksite or access point to the trail) until further notification from the Contractor ET. Contractor ET to wait at least one hour and review of the access route to confirm no signs of flooding, prior to approving further movement along the trails within CCNR. Contractor ET to instruct, upon seeking advice from NParks, when to commence vehicle movement along trails and within SICC golf course following a rainfall event. As a minimum ET to wait one hour or longer after rain has fully stopped and seek advice from NParks before instructing further vehicle movement.	Contractor	Review of schedule and rainfall during daily progress call with LTA.	Weekly inspection	Changes to pre-work ground conditions, eg creation of surface water pools or channels as a result of the presence of the rotary drilling worksite	Access routes and rotary drilling and HDC worksites	Document within weekly SHE Inspection Report Issues / Corrective actions to be raised during daily progress calls with LTA	-
201	Ecology and biodiversity	Pre-construction (installation of piezometers)	Disturbance to visible roots at BH21	SI EIA Vol III, CPT 6.5	For BH21 select location in area with least exposed roots and as far from neighbouring trees as practical. For access to this location, place tarpaulin along rig access route from trail and lay double bagged sand bags on top of tarpaulin to protect underlying roots. Drive rig over sandbags to worksite location. Rig only to be positioned within clearing while ancillary equipment to remain on the nearby trail. All equipment to be removed following completion of the borehole. For BH01 similar measures to be considered based upon condition of ground at the time of the preliminary survey.	Contractor	SHE Inspections	-	-	-	-	Biodiversity Monitoring and Management Plan

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
202	Ecology and biodiversity	Pre-construction (installation of piezometers)	Leaks to ground or unplanned event	SI EIA Vol III, CPT 6.5 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition	Ensure absorbent mats available on vehicles at all times during mobilization and demobilisation for use in the event of an emergency spillage/leak	Contractor	SHE Inspections	-	-	-	-	Emergency Preparedness Plan Fire Safety Plan
203	Ecology and biodiversity	Pre-construction (installation of piezometers)	Leaks to ground or unplanned event	SI EIA Vol III, CPT 6.5 LTA General Specifications, Safety, Health and Environment (for Rail Projects) October 2018 Edition	All equipment at each borehole worksite to be enclosed within tertiary containment with impermeable surface to prevent accidental leakage to ground.	Contractor	SHE Inspections	-	-	-	-	Emergency Preparedness Plan Fire Safety Plan
204	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Wastewater runoff to ground and/or surface watercourses Potential pollution hazards to aquatic and wildlife communities in the stream and wetland areas	SI EIA Vol III, CPT 6.5	Apply refueling procedure as follow: - Tarpaulin sheets, spill kits and absorbent mats will be placed on the ground to prevent spillage of fuel into ground - Inspect engine oil levels each morning and top-up as necessary - Placing the transported diesel on ground with tarpaulin sheets and using hand pump (with valve to end of hose) to refuel the fuel tank on the rotary boring machine Note, storage of fuel within CCNR strictly prohibited. Note, use of jerry cans is prohibited within the CCNR.	Contractor	Visual Inspection	During Rotary BH	-	Drilling rig boring machines	SHE Inspection Record	Biodiversity Monitoring and Management Plan Water Pollution Management Plan
205	Water Quality	Pre-construction (installation of piezometers)	Wastewater runoff to ground and/or surface watercourses Potential pollution hazards to aquatic and wildlife communities in the stream and wetland areas Unplanned events	SI EIA Vol III, CPT 6.5	Emergency Preparedness Plan and Fire Safety Plan to include: - Use of freshwater (rather than chemical suppressant) where appropriate and ensure compliance with the requirements of emergency authorities in Singapore (eg SCDF) - All SI operational personnel should be provided with training on implementation of the Emergency Preparedness Plan and Fire Safety Plan; - Vehicle mobilization/demobilization schedule and routes, including turning area (if required). Schedule to minimize the volume of vehicle movement on the trail	Contractor	Review of Emergency Preparedness Plan and Fire Safety Plan	Prior to Rotary BH During occurrence of unplanned event	-	-	Training record	Emergency Preparedness Plan Fire Safety Plan
206	Water Quality	Pre-construction (installation of piezometers)	Unplanned events	SI EIA Vol III, CPT 6.5	Minimize the likelihood of a fire through visual observations of generators and engines for signs of overheating, ie turn off engine if looks to be overheating	Contractor	Visual Inspection	During Rotary BH	-	-	SHE Inspection Record	Fire Safety Plan
207	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Leaks to ground or unplanned event	SI EIA Vol III, CPT 6.5	Refueling to be conducted when drilling rigs/generators are not operational.	Contractor	Visual Inspection	During Rotary BH	-	-		Water Pollutino Management Plan
208	General Management	Pre-construction (installation of piezometers)	Enhancing operations	SI EIA Vol III, CPT 6.5	Rotary BH contractor to conduct trial borehole operations off-site prior to commencement of the actual works in CCNR. The trials will include implementation of the mitigation measures as detailed in the EMMP. This provides the opportunity to enhance operations to minimize impacts, while allowing contractors to familiarize themselves with the stringent requirements of working within the CCNR.	LTA Contractor	NParks Verification and approval	Prior to commencement of Rotary BH	-	-	-	-

S/N	Topic	Phase (Pre-construction, Construction, Operation)	Aspect, Potential Impact /Issue	Reference	Specific Actions (Developed from the mitigation measures identified in the Project C&O EIA)	Responsible Person for Ensuring Action Implementation	Means of Verification that Commitment Has Been Met	Monitoring/Verification/Inspection				Related Management Plans
								Timing and Frequency	Parameters	Location	Reporting Requirements	
209	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Sediment loading of stormwater / increased sediment discharge to surface watercourses Disturbance to aquatic environment	SI EIA Vol III, CPT 6.5	Rotary BH contractor ET has to wait till the rain has fully stopped and seek advice from NParks to resume the mobilization/ demobilization works after heavy rain. This is to reduce the possibility of soil being dislodged, flowing off-site and causing siltation in streams.	Contractor	NParks Verification and approval	During Rotary BH	-	-	-	Biodiversity Monitoring and Management Plan Water Pollution Management Plan
210	Water Quality, Ecology and Biodiversity	Pre-construction (installation of piezometers)	Uneven terrain	SI EIA Vol III, CPT 6.5	As access routes to the borehole locations may have undulating and uneven ground, double bagged sand bags are to be deployed at such areas to level the ground to reduce the chances of machinery and/or ancillary equipment from toppling during transportation. This will also reduce the risk of waste and water spillage during transport due to the uneven terrain at the trails.	Contractor	NParks verification and approval	During Rotary Borehole set up During Rotary BH	-	Along all trails that display uneven terrain	-	-

8 REFERENCE LIST

(1) ERM (1 February 2016) **Environmental Impact Assessment on Central Catchment Nature Reserve for the Proposed Cross Island Line. Site Investigation Environmental Impact Assessment Report – Volume II Environmental Baseline Report.** Revision 005. Retrieved from https://www.lta.gov.sg/content/dam/ltaweb/corp/PublicTransport/files/Final%20SI%20EIA%20Volume%20II.pdf

(2) Land Transport Authority Engineering Group (February 2010) **Civil Design Criteria (CDC) for Road and Rail Transit Systems** (E/GD/09/106/A1).

(3) Forsythe, A. & Pearse – Hawkins, N., 2014: **Assessment of Hydraulic Conductivity and Groundwater Flow Models in the Bukit Timah Granite.** Underground Singapore 2014 Conference Paper.

(4) Hiller D (November 2011) **The prediction and mitigation of vibration impacts of tunneling.** Proceedings of ACOUSTICS 2011.

(5) LTA (2018) **Cross Island Line (CRL) Engineering Study on Alignment Options around Central Catchment Nature Reserve (CCNR).**

(6) Hansen CH (nd) **Fundamentals of Acoustics.** Retrieved from http://www.who.int/occupational_health/publications/noise1.pdf

(7) The British Standards Institution (2014) **Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration.** BS 5228-2:2009+A1:2014. ISBN 978 0 580 77750 9.

(8) Flanagan, RF (1993) **Ground vibration from RBMs and shields.** Tunnels and Tunnelling International, 25, pp 30-33.

(9) Institute of Air Quality Management (2014) **Guidance on the Assessment of Dust from Demolition and Construction**. Retrieved from http://iaqm.co.uk/text/guidance/construction-dust-2014.pdf

(10) Institute of Air Quality Management (May 2015) **Land-Use Planning & Development Control: Planning For Air Quality**. Retrieved from: http://www.environmental-protection.org.uk/wp-content/uploads/2013/07/air-quality-planning-guidance_v1.1_May15.pdf

(11) Land Transport Authority**, Contract C1040/006 – Site Investigation Engineering Services – Final Report** (Gravity Survey in Central Catchment Nature Reserve (Zone A1 & A2)). Prepared by Tritech Engineering & Testing (Singapore) Pte Ltd, October 2017

(12) Institute of Air Quality Management (2012) **Guidance on Air Monitoring in the Vicinity of Demolition and Construction Sites**. Retrieved from: http://www.iaqm.co.uk/wp-content/uploads/guidance/monitoring_construction_sites_2012.pdf

(13) Nature Society Singapore (6 January 2014) **Cross Island Line Working Group Report.**

(14) Lim, KK, Leong, TM, & Lim, FL (2011). **The king cobra, *Ophiophagus hannah* (Cantor) in Singapore (Reptilia: Squamata: Elapidae)**. Nature in Singapore, 4, 143-156.

(15) Davison GWH, Ng PKL and Ho HC (2008) **The Singapore Red Data Book: Threatened plants & animals of Singapore.** Nature Society.

(16) Neo L, Yee A T, Chong K Y, Yeoh Y S, & Tan H T (2014). **The vascular plant flora of abandoned plantations in Singapore IV: Windsor Forest.** Nature in Singapore, 7, 93-109. Retrieved from https://lkcnhm.nus.edu.sg/app/uploads/2017/06/2014nis093-109.pdf

(17) Ang A (2019) **Raffles' banded langurs at Windsor Nature Park.** Retrieved from https://lkcnhm.nus.edu.sg/app/uploads/2019/01/sbr2019-032-035.pdf

(18) Lim KS and Yong DL (2011) **Recent Trends of Nationally Threatened Birds in Singapore**. Proceedings of Nature Society, Singapore's Conference on 'Nature Conservation for a Sustainable Singapore'. Retrieved from https://www.nss.org.sg/documents/Pages%2071-92.%20Lim%20&%20Yong,%202013.%20Nationally%20Threatened%20Birds.pdf

(19) Murcia C (1995) **Edge Effects in Fragmented Forests: Implications for Conservation**. Trends in ecology & evolution, 10 (2), 58 – 62.

(20) Longcore T and Rich C (2004) **Ecological light pollution**. Frontiers in Ecology and the Environment, 2(4), 191-198.

(21) Farmer AM (1993) **The effects of dust on vegetation – a review**. Environmental pollution, 79(1), 63 – 75.

(22) Fraser J, Hall S, Mellen J & Shepherdson D (2000) **Response of zoo animals to air blast and ground vibration resulting from Tri-Met light rail tunnel construction**. Oregon Zoo. Tri-Met Light Rail Construction.

(23) Jackson W and Steingraber S (1999) **Protecting public health and the environment: implementing the precautionary principle**. Island Press.

(24) Tan A (2018) **Animals affected by Mandai park works: Wildlife groups**. Retrieved from https://www.straitstimes.com/singapore/environment/animals-affected-by-mandai-park-works-wildlife-groups

(25) RWDI (2017) **Wind Effects and Tall Buildings**. Retrieved from https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/design/Documents/wind-and-tall-buildings-pan.pdf

(26) van der Grift, EA and van der Ree, R (2015) **Guidelines for evaluating use of wildlife crossing structures**. Handbook of road ecology, 119-128.

(27) Glista DJ, DeVault TL, & DeWoody JA (2009) **A review of mitigation measures for reducing wildlife mortality on roadways**. Landscape and urban planning, 91(1), 1-7.

(28) Fox S, Potts JM, Pemberton D and Crosswell D (2018) **Roadkill mitigation: trialing virtual fence devices on the West Coast of Tasmania**. Australian Mammalogy.

(29) Huijser MP, Mosler-Berger C, Olsson M and Strein M (2015) **Wildlife Warning Signs and Animal Detection Systems Aimed at Reducing Wildlife-Vehicle Collisions**. Handbook of road ecology, 198-212.

(30) Adopted from **ERM IA Standard Version 1.1** (2014), Annex B-8, Landscape and Visual

(31) Land Transport Authority**, Contract C1040/005 & 009 – Site Investigation Engineering Services – Final Report** (Electrical Resistivity Survey in the Central Catchment Nature Reserve (Zone A1, A2 & B)). Prepared by by Tritech Engineering & Testing (Singapore) Pte Ltd, 29 September 2017.

(32) Maraš-Dragojević, S. (2012). **Analysis of ground settlement caused by tunnel construction.** *Građevinar*. Vol 64, Issue 07, pp 573 - 581.

(33) Shirlaw JN, Ong JCW, Rosser HB, Tan CG, Osborne NH, Heslop PE (2001). **Local Settlements and Sinkholes due to EPB Tunnelling Proceedings of the Institution of Civil Engineers.** Vol 156, Issue GE4, pp 193 – 211.

(34) The Government of the Hong Kong Special Administrative Region (2009) **Geo Report No. 249 - Ground control for slurry TBM tunneling.** Geotechnical Engineering Office, Civil Engineering and Development Department. Golder Associates (HK) Ltd. Retrieved from https://www.cedd.gov.hk/eng/publications/geo_reports/geo_rpt249.html

(35) Osborne NH, Hassell CK, Tan LC & Wong R (2008) **A review of the performance of the tunneling for Singapore's circle line project.**

(36) Conners R (2017) **The challenges of tunneling with slurry shield machines in mixed ground.** The David Sugden Young Engineers Writing Award. Retrieved from http://www.ats.org.au/wp-content/uploads/2017/11/The-Challenges-of-Tunnelling-with-Slurry-Shield-Machines-in-Mixed-Ground_Russell-Connors.pdf

(37) Land Transport Authority (October 2018) **General Specification, Appendix A, Safety, Health and Environment (for Rail Project)**. Retrieved from https://www.lta.gov.sg/content/ltaweb/en/industry-matters/safety-and-health-and-environment/construction-safety-and-environment/general-specs-for-SHE.html

(38) O'Dempsey A (3 December 2019) **Independent Review of Cross Island Line Phase 2 Vol III Pre-Final EIA.**

(39) Veeresh C, Venkta R, Chen DC & Lim TF (2016) **Construction Challenges in Bukit Timah Granite Formation.** Underground Singapore 2016.

(40) Ma CB, Sahabdeen MM & Lian W (2016) **Challenges in Tunnelling through Bukit Timah Granite Formation in Singapore.** Underground Singapore 2016.

(41) ChannelNewsAsia (11 Feb 2017) **Trains designed for fire safety, rail operators regularly tested: LTA.** Retrieved from https://www.channelnewsasia.com/news/singapore/trains-designed-for-fire-safety-rail-operators-regularly-tested--7598594

(42) Land Transport Authority (8 October 2017) **Preliminary investigations into train service disruption on North-South Line.** Retrieved from https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=f6200493-4639-4631-8561-e607c7599e10

(43) Straits Times (25 November 2015) **Fire breaks out at Ang Mo Kio MRT station on Wednesday morning.** Retrieved from https://www.straitstimes.com/singapore/fire-breaks-out-at-ang-mo-kio-mrt-station-on-wednesday-morning

(44) Public Utilities Board (n.d.) **Water from Local Catchment.** Retrieved from https://www.pub.gov.sg/watersupply/fournationaltaps/localcatchmentwater

(45) US Federal Transit Administration (September 2018) **Transit Noise and Vibration Impact Assessment Manual.** FTA Report No. 0123. Retrieved from https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf

(46) Wilkinson Murray (9 July 2019) **Technical Note – Preliminary Groundborne Noise and Vibration Study for Cross Island Line.** WM Ref: 19711_Technical Note_Ver A.

(47) Transport Research Laboratory (2000) **Groundborne vibration caused by mechanized construction works.** TRL Report 429.

(48) Pfeiffer D (1975) The Hydrogeologic Map of the Islands of Singapore 1:100 000

(49) Zhao J, Chen CN & Cai JG (2001) **A Hydrogeological Study of the Sembawang Hot Spring in Singapore.**

Annex 1.0

Likelihood Qualification for Unplanned Events

ANNEX 1.0 LIKELIHOOD QUALIFICATION FOR UNPLANNED EVENTS

A1.1 INTRODUCTION

Unplanned events or emergencies that might occur during the construction of the Project, may subsequently give rise to direct or indirect impacts to receptors. In accordance with the EIA methodology (see *Vol I, Chapter 4*), the impact magnitude of an unplanned event will take into account the likelihood of such an event occurring[Footnote 1]. While the impact magnitude criteria for most of the environmental topics are quantifiable to a degree, the likelihood criteria is based on a qualitative scale (see *Table A1.1*). A review of case studies associated with tunnelling projects undertaken by the LTA in similar geological conditions has therefore been undertaken with a view to qualify the likelihood of Project unplanned events in an objective manner. The findings and subsequent designation of likelihood for each unplanned event identified is presented herein.

Table A1.1: Definitions for Likelihood Designations

Likelihood	Definition
Unlikely	The event is unlikely but may occur at some time during normal operating conditions.
Possible	The event is likely to occur at some time during normal operating conditions.
Likely	The event will occur during normal operating conditions (ie it is essentially inevitable).

A1.2 UNPLANNED EVENTS

A1.2.1 Excessive Ground Settlement

As described in *Vol I, Section 2.5.4.1*, excessive ground settlement during construction could possibly occur during tunneling works. In general, ground movement that is induced as a result of tunneling depends on a variety of factors, which include:

- geological, hydrogeological and geotechnical conditions;
- tunnel geometry and depth;
- tunnel excavation methods;
- initial state of stress and stress-strain behaviour of ground surrounding the tunnel; and,
- the quality of the planned construction activities, which is dependent on the type of equipment used and management of the type of geology encountered[31].

For the purposes of this study, excessive ground settlement is defined as involving the vertical movement or displacement of rock and/or soil, in such volumes that significant alterations occur to the

[Footnote 1] It is noted that the occurrence of an event does not necessarily indicate that the associated impact(s) are significant.

existing environment. Such alterations may result directly in safety concerns to users of aboveground facilities, or damage to the aboveground natural environment due to:

- Changes in stress condition resulting in excess movement and possible local failures and fracturing of rock surface due to tunneling. This causes fall-outs or rock collapse that will directly interfere with the rock tunneling process[32].
- Subsidence or ground deformation approximate to excavations and tunneling.
- Changes in pore water pressure that is induced by loading and unloading of the ground due to tunneling and excavation activities, or the lowering of the water table associated with tunneling during construction and associated drainage. Water moving through the rock or soil, especially highly fractured rock; may carry loosened particles of material into the excavation openings creating voids and instabilities in the rock mass.

Indirect effects may comprise alterations to hydrogeological and hydrological patterns. These effects are discussed in the respective topical chapters in *Vol III*.

It is generally observed that there is a higher risk of ground settlement occurring during the following tunneling stages or under certain conditions encountered during the operation of a slurry shield type TBM [33, 34]:

- Launching of the TBM ie during break-in of the TBM from the launch shaft to the tunnel;
- Docking of the TBM at the end of the tunneling drive ie during break-out of the TBM from the tunnel to the retrieval shaft;
- At the interface of differing geological strata;
- Mixed face condition, where the TBM cutterhead excavation face is in contact with a mix of rock and soil conditions;
- During a stoppage of the TBM for maintenance, troubleshooting, advanced probing etc; and
- During long tunneling drives in abrasive ground conditions, leading to a high rate of wear and tear of the TBM.

In addition to the above factors, human error in the correct implementation of TBM operation parameters may also contribute to the risk of ground settlement [34]. From a review of case studies where a slurry shield TBM was deployed in similar ground conditions as the Project, the abovementioned conditions were observed to contribute to challenges in fully eliminating the risk of ground settlement. Ground settlement events occurred during the construction of the Circle Line, and were attributed to the mixed face conditions comprising varying grades of Bukit Timah granite, weathered Jurong and Kallang formations[35]. Similarly, mixed face conditions were encountered during the construction of Contract T208 of the Thomson East-Coast Line, where a 6.67 m diameter slurry shield TBM was used for the boring of twin tunnels at depths of 12 to 29 m [35] through varying grades of Bukit Timah Granite and Kallang formation. These were attributed to the encountering of large boulders and the increased wear and tear of the machine during tunneling in mixed ground conditions, which necessitated multiple and extended stoppage of the TBM. It is noted however that in the latter case study, response measures undertaken were largely effective in managing the scale of ground settlement during mixed face tunneling. There was minimal ground settlement (maximum 10 mm) and therefore no impacts to aboveground critical infrastructure during the tunneling of Contract T208.

Based on LTA's interpretation of the geological profile presented in *Vol II, Section 4.7.4* and *Vol II, Figure 4.9*, the overall interpreted rock head is above the proposed tunnel depths along most of Alignment Option 1. There is a potential for the tunnel to encounter mixed face conditions only while approaching Bright Hill (outside of CCNR).

With reference to *Vol II, Figure 3.6,* the proposed tunnel will generally be located beneath the rock head, with the drilling works undertaken indicating an average depth of rock cover (Footnote 2) of approximately 19 m above the tunnel along Alignment Option 1. While the TBM will be operating for the full construction duration within abrasive ground conditions, the structural integrity of the rockhead is deemed to be sufficient to ensure that pressure at the TBM excavation face will not fluctuate significantly.

The following embedded controls as listed in *Volume I, Annex 2.0, Table A2.7* will be implemented:

- Use of slurry type closed shield TBM that exerts a positive pressure at the cutter head through the injection of bentonite slurry from a feeding pipe during the TBM operation. Tunnel segment linings will be installed as the TBM advances along the tunnel alignment and will be waterproofed in accordance to standards detailed in *LTA's Materials & Workmanship Specification for Civil & Structural Works, Jun 2010 Edition*, to limit groundwater ingress during tunneling works.
- Close monitoring of mining KPIs will be ensured, which involves adherence to the proposed Slurry properties that will be developed by the contractor's engineer. Mining KPIs include the set of parameters to be adopted for the TBM and slurry properties during tunneling, and will be adjusted when required. Examples of TBM KPIs include the face pressure, advanced speed, revolution speed, while slurry KPIs include viscosity, pH, filter cake etc. Adjustment of, and adherence to, mining KPIs will mitigate against the risk of excessive ground settlement during TBM Operation while tunneling through the expected mixed face. The LTA site team will be involved in the supervision and sampling/testing exercises undertaken by the contractor
- The tunnel shall be continuously and fully supported with a permanent lining designed to support the full overburden including water load with minimal deformation during the work. In soil or mixed face conditions, the lining should satisfy the load combinations and distortion loads requirements. Segmental pre-cast concrete lining shall consist of a number of pre-cast segments bolted together to form rings.
- Ground improvement measures such as grouting shall be adopted where necessary to further limit the risk of ground collapse, etc. A suitable grout mix shall be proposed for each set of ground conditions to be encountered along the tunnel drive. Ground improvement, if necessary, will be conducted from within the tunnels under CCNR. The grout shall be sufficiently fluid as to ensure that it flows freely under pressure into all parts of the space to be filled. All grout mixes and injection methods shall be submitted to the Engineer for acceptance.

(Footnote 2) Rock cover refers to the thickness of rock above the tunnel crown. Rock cover is not a buffer distance ie distance between tunnel crown and nearest affected building.

- The excavation method shall be chosen so as to minimise the settlement and disturbance of the groundmass to ensure the structural integrity of existing surface and underground structures in the vicinity of excavation works.
- Excavation shall be appropriate to the size of the underground opening and to prevailing ground conditions. Excavation will be subject to acceptance by the Engineer at all times.
- Adequate training and supervision will be provided to the TBM staff and operators.
- Regular maintenance inspections will be carried out at the front of the TBM using access through a chamber known as the manlock, under compressed air to stabilise the face. During the inspections, workers will access to the front of the TBM to change the cuttertools, when necessary, and to inspect any presence of boulders to remove any blockages.
- Advance probe drilling will be conducted ahead of the excavation face where necessary, with details of drilling parameters and other relevant observations recorded for later interpretation. This will allow for further operational measures to be undertaken to minimise the risk of collapse when encountering zones of weaknesses or fault zones.
- The TBM is designed to stop drilling when it detects a drop in pressure. The leakage rate into the tunnel is strictly controlled to maintain the water table and the structural stability of foundations to limit excessive ground settlement/subsidence. Embedded controls on groundwater leakage rates into the tunnel include a high level of water proofing with an allowable leakage rate of 2 ml / m^2 / h on the tunnel lining. The specified degree of water-tightness shall be achieved within 100 m of the tunnel face during construction and maintained thereafter, as stipulated in *LTA's Materials & Workmanship Specification for Civil & Structural Works, Jun 2010 Edition*, to ensure minimal groundwater ingress to the shaft.
- Use of co-extruded single composite gasket consisting of an elastomeric material and hydrophilic facing material for waterproofing throughout the segmental tunnel linings.
- Ground loss from the face and tail void or over-break, etc will be minimised by providing adequate support to the face and continuous tail void grouting.

The combination of interpretations from borehole logs, HDC and geophysical surveys have been used to develop a robust understanding of the geological profile at depth to a reasonable degree; sufficient to ensure that embedded controls can be planned when regions of higher degrees of weathering and fracturing extent are expected during tunnelling.

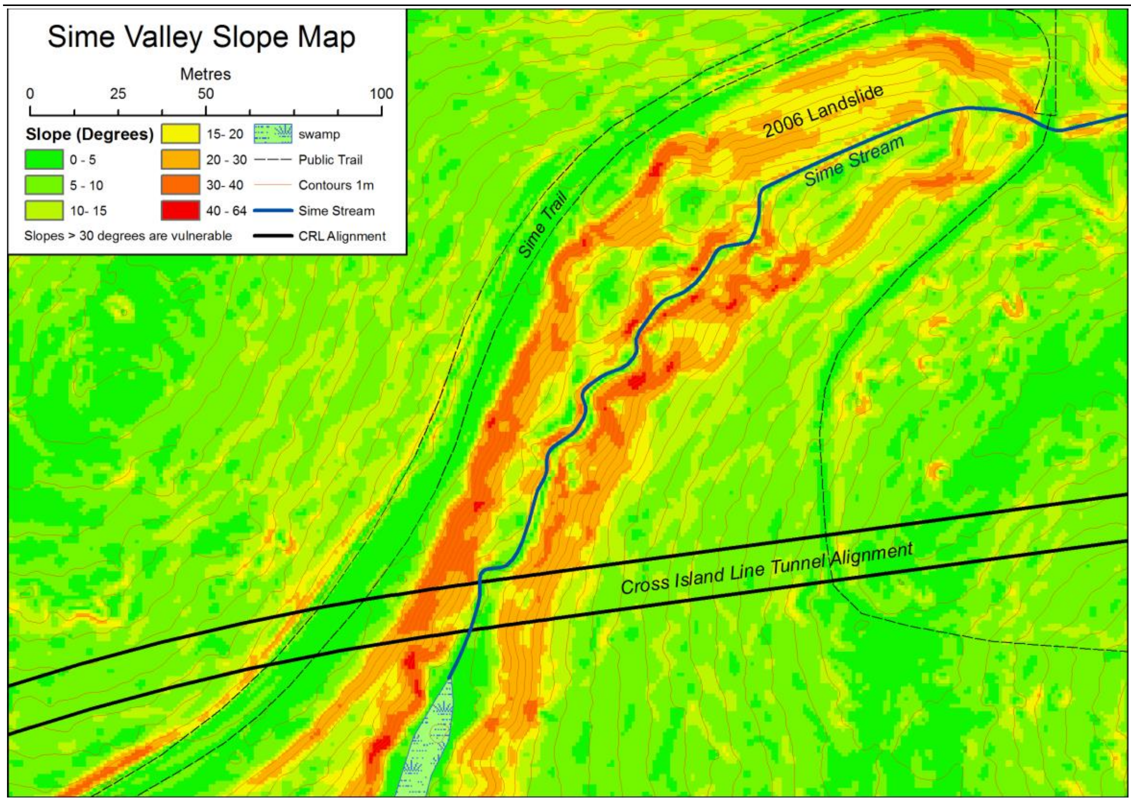
The likelihood of excessive ground settlement occurrence is therefore evaluated to be *Unlikely*.

A1.2.2 Slope Failure

The terrain of the land within the CCNR comprises undulating slopes, in particular at the approach of natural stream tributaries. Based on topographical contours, the existing slope near Sime Stream Valley was found to be the steepest under which the proposed Alignment Option 1 tunnel passes through. The occurrence of a slope failure in the CCNR in the event of tunnelling works for the direct alignment option was identified as a risk due to the prior occurrence of a slope failure within this valley in 2006.

The location of the slope underlying Alignment Option 1 relative to the location of the historical slope failure is shown in *Figure A.1*. The slope failure in 2006 was further analysed by an independent reviewer to determine if causal factors would still be applicable to the slope interfacing with the CRL alignment[38]. A summary of the analysis is presented herein to inform the likelihood of a slope failure occurring due to Project tunnelling works.

Figure A.1: Sime Valley Slope Map



Source: O'Dempsey A, 12 March 2019

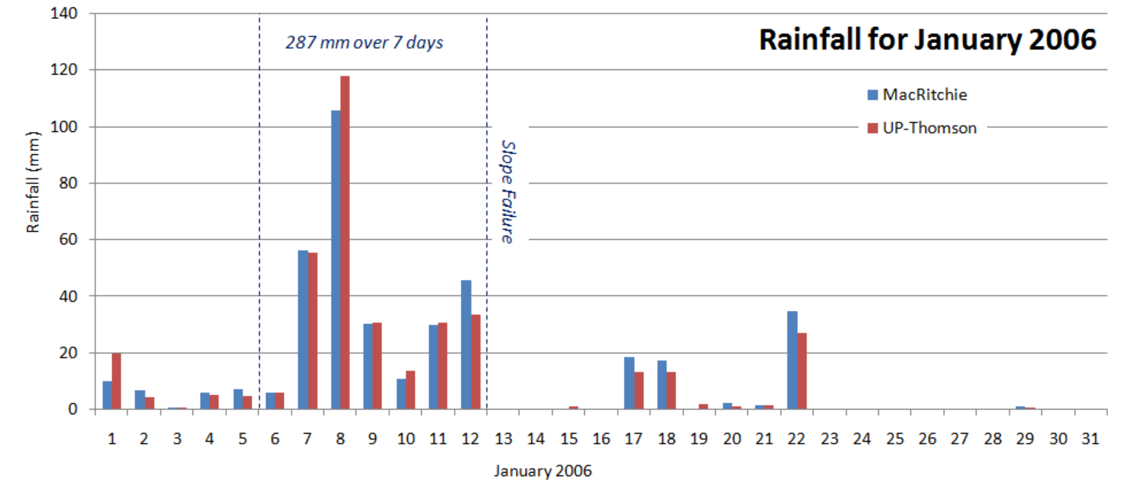
A preliminary assessment of the slope failure 2006 highlighted the following potential contributing factors:

- Accumulation of heavy surface runoff at the brow of the slope after prolonged heavy downpour for 7 days preceding the slope failure (see *Figure A.2*); and

- Possible weakening of the slope due to scouring of the base of the slope by an existing natural stream ie undercut erosion.

High Rainfall Intensity

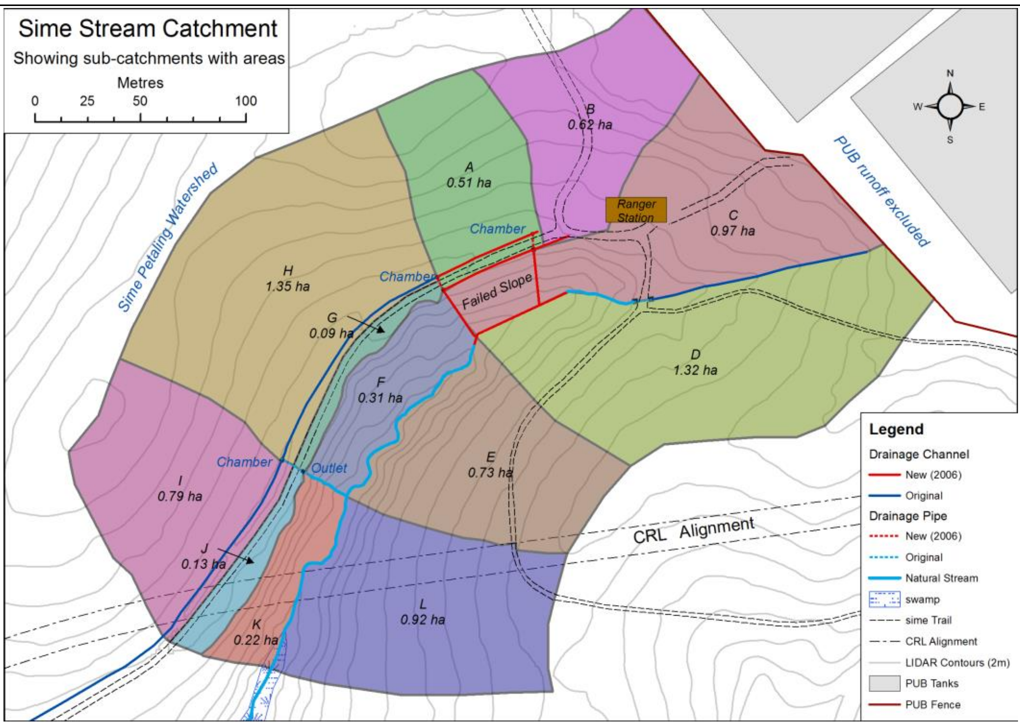
Figure A.2: NEA Rainfall for MacRitchie and Upper Thomson Weather Stations (Jan 2006)



Source: O'Dempsey A, 12 March 2019

Prior to the slope failure, the access road to the Tree Top Walk was generally observed to serve as the main conduit for channelling runoff across the Sime Trail and directly onto the failed slope in the event of a heavy rainfall. The delineation of sub-catchment areas within the Sime Valley is shown in *Figure A.3*, which indicates a total catchment of 1.13 ha (areas A and B) for the historical slope, and 0.22 ha (areas G and J) for the slope overlying Alignment Option 1. The smaller catchment area for the slope near Alignment Option 1 is owing to the presence of a drain which intercepts runoff from the larger sub-catchment areas H and I to the west.

Figure A.3: Sime Stream Catchment and Sub-Catchment Areas

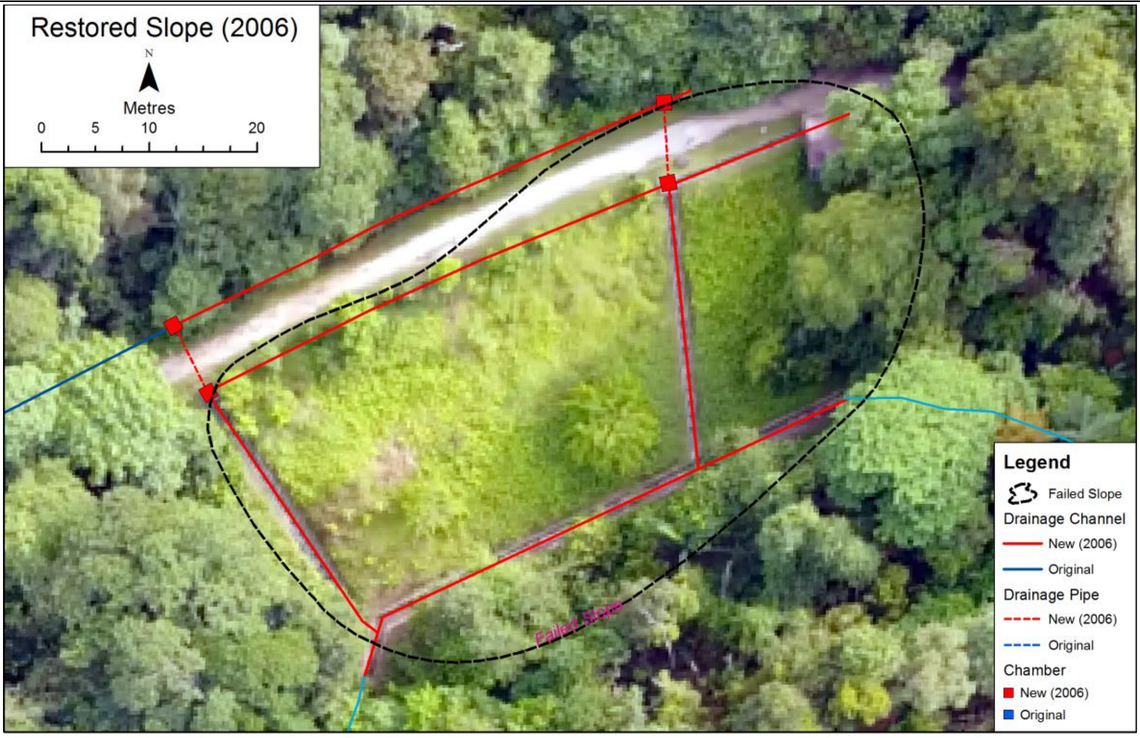


Source: O'Dempsey A, 12 March 2019

It is further noted that the brow of the failed slope being fed by sub-catchment areas A and B is around 60 m in length, whereas that of the slope overlying Alignment Option 1 is approximately 100 m for sub-catchment area J. Considering the rainfall volume from a once in 5 year storm, the runoff intensity at the brow of the failed slope was 431 m^3/hr as compared to 51 m^3/hr for the slope overlying Alignment Option 1. This is largely due to the lack of drainage infrastructure at the brow of the slope which failed. The saturation of the ground due to the accumulation of a substantially greater amount of runoff water than normal, led to an increase of pore pressure which resulted in a decrease in the shear strength within the soil mass, thereby leading to geological collapse of the slope.

Following the failure of the slope in 2006, reparation works were undertaken which included the installation of drainage south of sub-catchment area A in December 2007 (see *Figure A.4*). The slope has been stable to date, which attests to the contribution of a drainage system in reducing the runoff flow intensity on the brow of the slope.

Figure A.4: Repaired Slope and Installed Drainage Infrastructure



Source: O'Dempsey A, 12 March 2019

Undercut Erosion

Apart from the accumulation of rainfall at the brow of the slope, the scouring away of the base of the slope may also have contributed to the failure of the slope in 2006. The scouring of the slope base occurs due to the presence of the Sime Stream. Undercutting of the slope occurs at the bends of the stream due to the natural process of erosion. The presence of undercutting erosion at bends in the Sime Stream was noted during a field visit on 19 November 2018, where undercut faces between 1 to 3 m in height were observed. It is noted however that the undercut erosion was less than 1 m at the slope face overlying Alignment Option 1. It is therefore considered that undercut erosion will not be a significant factor affecting slope stability in the immediate vicinity of the tunnel alignment.

Taking into account the presence of a drainage system at the brow, and the limited undercut erosion observed at the base, it is concluded that the slope overlying Alignment Option 1 is relatively stable. The likelihood of a slope failure due to tunnelling is *Unlikely*.

A1.2.3 Excessive Water Ingress to Tunnel

Construction Phase

Excessive water ingress into the tunnel may occur when the TBM encounters fractures in the Bukit Timah granite rock, or encounters a mix of soil and rock conditions ie mixed face. Where there is hydraulic connectivity between surface waterbodies and the groundwater table, excessive water ingress into the tunnel may lead to drawdown on surface streams.

A review of available literature indicates that water ingress have occurred during tunnelling works undertaken at depth (ie up to 60 m bgl) within Bukit Timah Granite formation, such as for Downtown Line 2[(39)] and the North-South Transmission Cable Tunnel Contract 3[(40)]. The risk of encountering highly fractured zones of granite or mixed face conditions was attributed to the undulating nature of the Bukit Timah Granite formation in Singapore.

The engineering embedded controls as described in *Volume I*, Section *2.5.4.1* will be undertaken to minimise the risk of water ingress when encountering fractures or fault zones:

- Design of Alignment Option 1 tunnel alignment beneath the CCNR to be tunneled at depths so as to ensure the TBM will be operated fully within rock conditions.

- Use of a slurry type close shield TBM, which exerts positive pressure to the tunnel face to minimise water ingress and ensure stabilization of the tunnel face.

- Advance probing will be undertaken during operation of the TBM to inform the operators on ground conditions ahead of the TBM cutterhead.

The likelihood of water ingress occurring during tunnelling works is assessed to be *Possible* in light of historical occurrences for Projects undertaken in similar ground conditions.

It is noted that geological information obtained from SI works undertaken for Alignment Option 1 indicates the presence of an aquitard, which limits the hydraulic connectivity between surface waterbodies and groundwater at tunnel depth (see *Volume II*, *Chapter 4.0*, *Section 4.8.3*). It is therefore unlikely that excessive water ingress during tunneling for Alignment Option 1 will give rise to any drawdown of streams within the CCNR.

Operation Phase

Excessive groundwater seepage may occur during the lifespan of the tunnel, due to wear and tear of design controls such as the waterproof lining of the tunnel; or breach of the integrity of the tunnel wall due to concrete spalling. As an embedded control, the tunnel will be inspected regularly to detect anomalies such as cracks or localised groundwater seepage. Anomalies will be reported and repair works such as grouting, will be undertaken promptly to prevent the onset of damage leading to excessive groundwater seepage. There has allegedly been no historical records of excessive groundwater seepage occurring during the operation of existing MRT tunnels in Singapore. In view of the embedded controls, the likelihood of this occurring during the operation phase is assessed to be *Unlikely*.

A1.2.4 Failure of Earth Control Measures System

One of the scenarios which may result in an overflow of effluents from the worksite was the failure of the ECM system. The ECM system is designed to contain, channel, hold and treat surface runoff within the worksite with the objective to prevent heavily silted water from being discharged into surrounding surface waterbodies. An ECM system for a typical construction worksite would comprise perimeter storm water drains, a sedimentation basin or tank and pumps which would be designed with a holding capacity of a once in 5, 10 or 15 year storm. Anecdotal evidence have highlighted that exceptionally heavy rainfall, as can sometimes occur during the monsoon period, can overwhelm the ECM system and result in flooding of the worksite and subsequent uncontrolled discharge to downstream surface waterbodies.

Embedded controls will include:

- The sizing of an ECM system with adequate capacity to cater for exceptional rainfall events such as a once in 10 year storm, in accordance with PUB requirements;
- The storage of spare pumps and pipelines segments at worksites for redundancy, so repairs to the ECM system can be undertaken quickly;
- The use of double containment piping for the ECM pipeline located within the drainage reserve of Island Club Road;
- Regular inspections of ECM system and discharge pipeline to ensure necessary repairs are promptly undertaken throughout the construction phase; and
- The design of the ECM with adequate capacity to cater for a one in 10 year storm, which will double up as a holding pit for firewater till collection by a third party Contractor for off site disposal.

The likelihood of such an unplanned event occurring despite design controls, is assessed to be *Possible.*

A1.2.5 Fire

Construction Phase

The occurrence of a fire was identified as a risk due to the presence of petroleum- and diesel-operated plant, electrical equipment and the storage/handling of flammable materials at the worksite. The undertaking of extensive works within the confined space of a tunnel and launch/ventilation shaft also carries the risk of a fire due to potential build-up of flammable gases. Apart from the safety implications to the workers and nearby receptors, there is a concern that a fire and the emergency response measures may result in direct adverse environmental impacts to the surrounding ecological habitats and nearby surface water drains.

A review of past records indicates that there have been no occurrences of a fire within tunneling worksites or aboveground worksites for LTA projects. It is further noted that current fire safety requirements are prescribed on the Contractor by local regulations as well as LTA requirements [37]. These requirements include the establishment and continual review of a Fire Safety Plan, which will detail preventive as well as responsive measures to a fire emergency. Preventive measures to reduce the likelihood of a fire emergency include and are not limited to the following:

- Regular checking and certification of use of all temporary electrical installations, equipment and tools by a full-time licensed electrical worker.
- Restriction of the volume of petroleum and flammable materials stored at the construction worksite.
- The hoarding/noise barrier for the worksite will be composed of non-combustible material to deter the spread of fire beyond the worksite.
- Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage license, including proper segregation from incompatible chemicals, provision of clear signage indicating flammability and prohibition of ignition sources, management of and controlled access to the storage areas by trained personnel etc.
- Workers will be trained to use firefighting equipment to be provided at the aboveground and underground worksites.
- Provision of adequate ventilation of shafts and tunnel to prevent the build-up of flammable gases and vapours, and that worksites are in compliance with *Workplace Safety and Health (Construction) Regulations 2007* as summarised in *Annex 2.0*. Worksites will also be set up with adequate firefighting facilities to enable a timely response to a fire emergency.

The likelihood of a fire occurrence during the construction phase of the Project is therefore evaluated to be *Unlikely*.

Operation Phase

There are multiple factors that may give rise to a fire emergency during Project operation. A fire could occur due to circumstances within the tunnel itself or within the train during its transit through the tunnel, or due to faulty or old electrical equipment within the facility building.

Embedded controls will include:

- The facility building will be designed with a detention tank for containment of firewater;
- Regular inspections will be undertaken of electrical equipment within the tunnel and facility building;
- Partitions for electrical storage rooms within the facility building will be designed to contain a fire for a minimum period of 4 hours;

- Where the facility building is located near forested areas, a buffer distance of at least 30 m will be maintained between the facility building and the forest edge to minimize the risk of fire spreading to the surrounding vegetation;
- Practical measures will be undertaken during maintenance works to minimize the risk of ignition of flammable materials handled or stored at temporary worksites within the tunnel;
- In addition, the operation of the Project will be undertaken in accordance with the LTA's Code of Practices for rail operators, which will include the following[(9)]:
    - *Competency Management System* to ensure that maintenance crew and operating staff are adequately trained and competent;
    - *Rail Incident Management Plan* detailing response protocols during a train disruption, which will be reviewed for compliance against LTA's Rail Incident Management Framework;
    - Prescriptive requirements on the frequency and extent of repair and maintenance, in accordance with industry best practices; and
    - Annual simulation exercise (table top exercise for the first two years, and ground deployment in the third year and thereafter) to assess and enhance the readiness of operation systems in responding to incidents.

In the event of an emergency within the tunnel, ventilation fans installed within the tunnel will be used to extract the smoke, which will be vented to the atmosphere via the ventilation shafts/facility buildings. Firefighting installations such as the automatic sprinkler system will also be activated as a first line of response within the tunnel and at the facility building. In the event of a large fire, firefighters will be deployed to the site. Firewater will be channeled via perimeter drains to a holding sump within the site, until collection by a third party contractor for offsite disposal.

There have been a couple of recorded fire occurrences within the MRT tunnel system in the past five years. A fire occurred in 2013 within the tunnel near Newton station due to the short-circuiting of a cable [(41)], and the LTA recorded another trackside fire that occurred in the tunnel between Marina Bay and Raffles Place MRT in 2017 [(42)]. There has also reportedly been an electrical fire at the aboveground Ang Mo Kio MRT station in 2015 [(43)].

The likelihood of a fire occurrence during the operation phase of the Project is therefore evaluated to be *Possible*.

A1.2.6 Total Breakdown of TBM during Tunneling

The total breakdown of the TBM during tunneling may occur due to wear and tear resulting in failure of machine components beyond repair, or due to unplanned events such as geological collapse at the TBM cutterhead during excessive ground settlement or excessive water ingress.

Embedded controls will include:

- Commissioning of new bespoke TBM(s) for the Project.

- Regular shutdown of the TBM during tunneling for maintenance.
- Storage of spare cutting tools and systems part on site to allow for the prompt replace of worn parts.
- Measures to prevent the occurrence of excessive ground settlement and/or excessive water ingress during tunnelling such as:
  - Design of Alignment Option 1 tunnel alignment beneath the CCNR to be tunneled at depths so as to ensure the TBM will be operated fully within rock conditions.
  - Use of a slurry type close shield TBM.
  - Advance probing to identify ground conditions ahead of the TBM cutterhead.
  - Grouting to be undertaken from within the tunnel for Alignment Option 1, for stabilization of fractured rock or soil conditions identified ahead of the TBM. These works to be undertaken in advance of the TBM.

The likelihood of total TBM breakdown is assessed to be *Unlikely* as there have reportedly been no total breakdowns occurring during tunneling works for LTA projects.

Annex 2.0

A-frame Rotary Borehole Rig Vibration Results

AD-HOC
GROUND VIBRATION MONITORING

Report Prepared by:

SETSCO SERVICES PTE LTD
18, TEBAN GARDENS CRESCENT
SINGAPORE 608925
TEL : 65667777
FAX : 65667718

(Business Reg. No. : 196900269D)

For:

ERM SINGAPORE
120 Robinson Road
#10-01
Singapore 068913

ATTN: Ms Rosalind Finney

1. Background

1.1 Setsco Services Pte Ltd was engaged by ERM Singapore for provision of measurement services to undertake ground vibration measurements at Pierce Secondary School, along Sin Min Walk – see Figure 1.1 below. The location of the A-frame drilling machine is marked by  below.

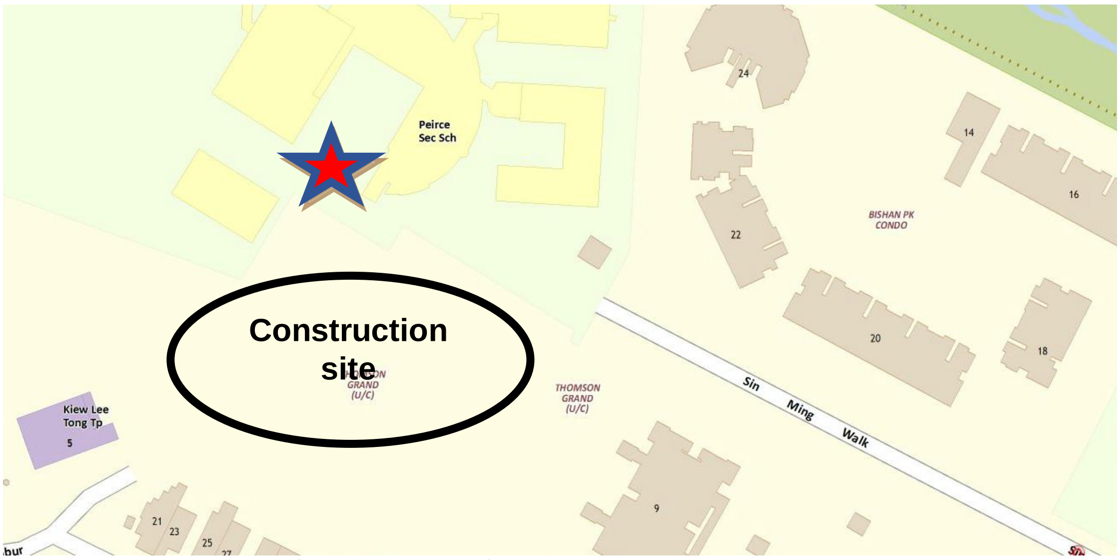


Figure 1.1: Location of measurement.

1.2 This document presents the results of the vibration measurement conducted at the site on the 20th April 2015 between 1430 and 1630.

1.3 The measurements were performed with an A-frame borehole drilling machine in operation and ground vibration levels were recorded at defined distances away from the drilling machine.

1.4 The objective of the measurement is to establish the typical ground vibration response at various distances from an operational A-frame rotary borehole drilling machine.

2. Site Condition and Measurement

2.1 It was observed that there was also ongoing construction at the Bright Hill MRT Station and tunnels located along Sin Ming Avenue. About 400m southeast of the measurement site. See Figures 2.1 and 2.2 below.

Figure 2.1: Nearby construction site.

` **Figure 2.2:** Nearby construction site.

2.2 Six location points were selected for the measurements – namely Point A, Point B, Point C, Point D, Point E, Point F and point G referenced to the A-frame drilling machine.

- Point A – 2m away
- Point B – 3m away
- Point C – 5m away
- Point D – 15m away
- Point E – 11m away
- Point F – 20m away
- Point G – Baseline

Measurement was taken on the grass patch.

2.3 Vibration measurements were performed using a tri-axial accelerometer (for the X, Y and Z-axis representing the three orthogonal directions) attached to a steel rod embedded 1 meter into the ground as shown in Figure 2.3 below.

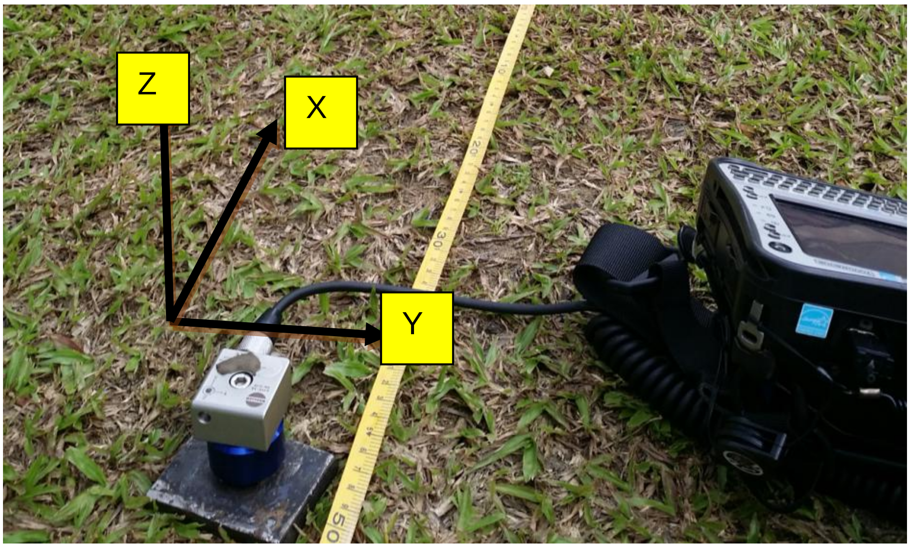


Figure 2.3: Measurement setup and measurement axis.

2.4 For each measurement point, vibration levels were recorded over a time period of approximately 5 minutes.

2.5 Table 2.1 below details the instrumentation used for the vibration measurements. All instrumentation has been verified to traceable standards by the manufacturer within the least 2 years. A copy of the equipment calibration certificate is attached in Appendix A.

Table 2.1: Instrument used during survey.

Item	Manufacturer	Type	Description	S/No.
1	Adash	SAB	Signal Analyser Box	624127
2	Adash	Tri-axial Accelerometer	Accelerometer with sensitivity of 100mV/g	

2.6 The external environmental condition during the attended survey period was dry with low wind. The external temperature was around 32-35 Degree Celsius during the attended measurements.

3. Results

3.1 The following section presents the results of the measurement.

3.2 Figures 3.1 presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location A.

3.3 Results presented in Figures 3.1 below shows that higher vibration was measured in the transverse direction compared to the vertical direction and the highest vibration level was measured at 148 Hz.

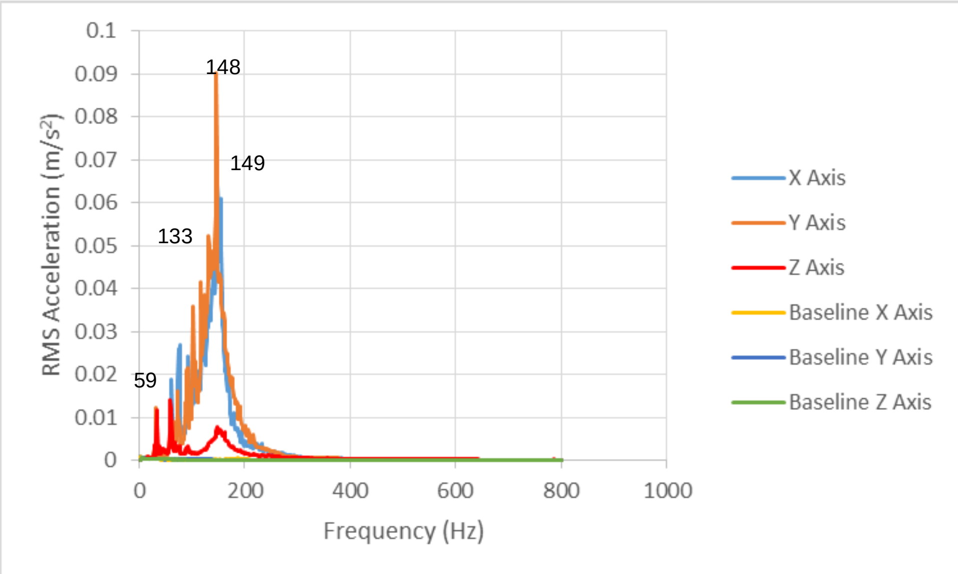


Figure 3.1: RMS vibration acceleration frequency spectrums measured at Location A.

3.4 Figures 3.2 presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location B.

3.5 Results presented in Figures 3.2 below shows higher vibration levels measured in the transverse direction compared to the vibration measured in the vertical direction. The highest vibration level was measured at 141 Hz in the X-axis.

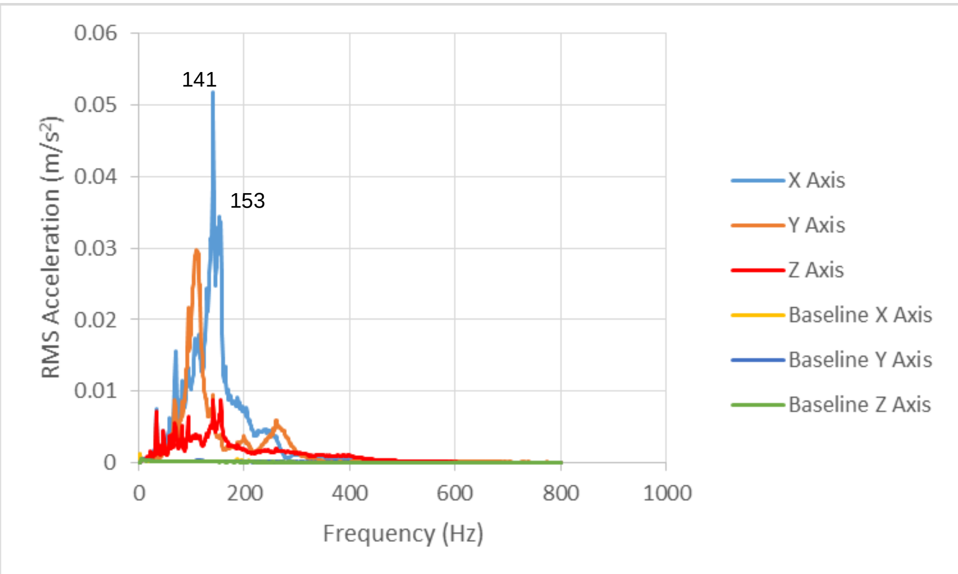


Figure 3.2: RMS vibration acceleration frequency spectrums measured at Location B.

3.6 Figures 3.3 below presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location C.

3.7 Results presented in Figures 3.3 below shows that the highest vibration level was measured at 112 Hz in the X-axis. Higher vibration levels measured in the X and Y axis compared to those measured in the Z axis.

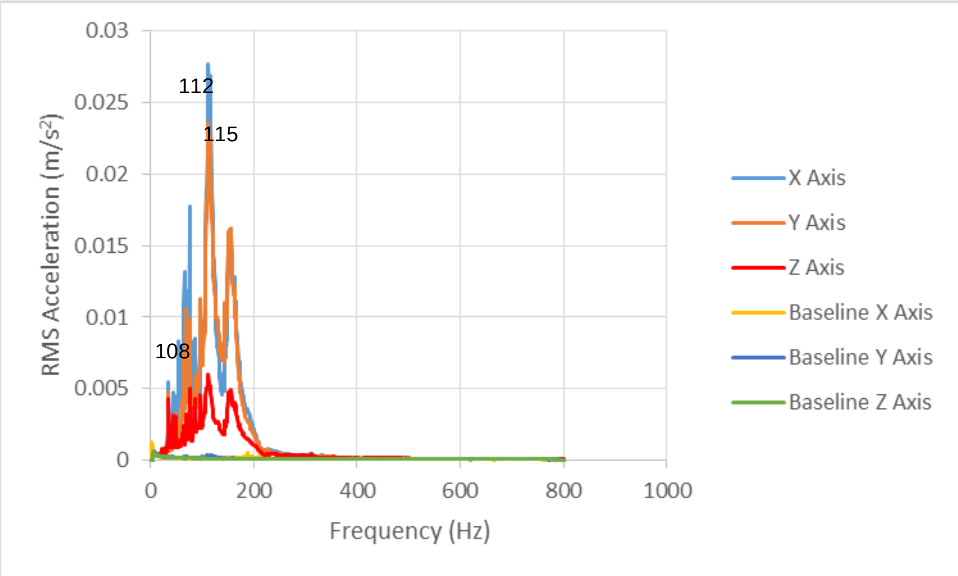


Figure 3.3: RMS vibration acceleration frequency spectrums measured at Location C.

3.8 Figures 3.4 presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location D.

3.9 Results presented in Figures 3.4 below shows that the highest vibration level was measured at 127 Hz in the X-axis.

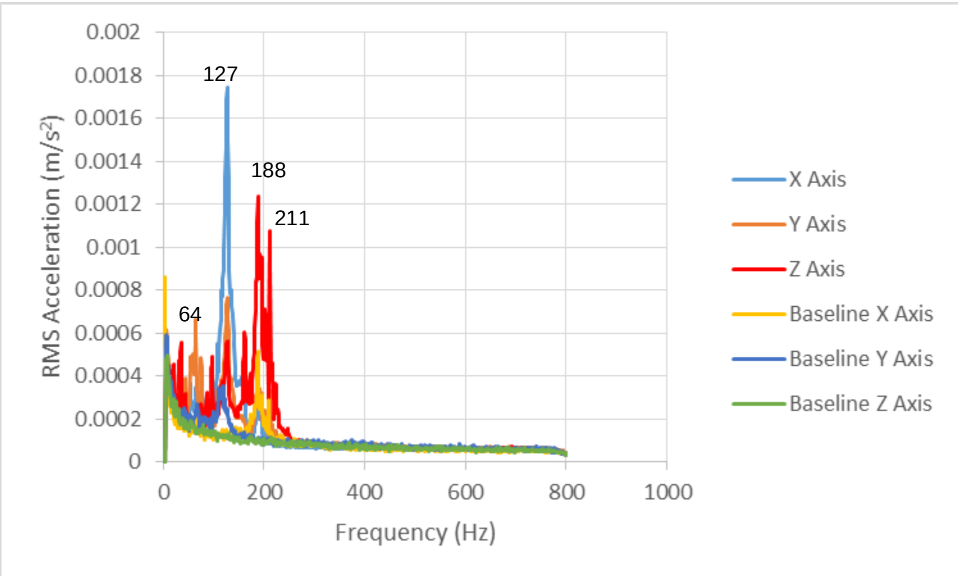


Figure 3.4: RMS vibration acceleration frequency spectrums measured at Location D.

3.10 Figures 3.5 presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location E.

3.11 Results presented in Figures 3.5 below shows that the highest vibration level was measured at 167 Hz in the X-axis.

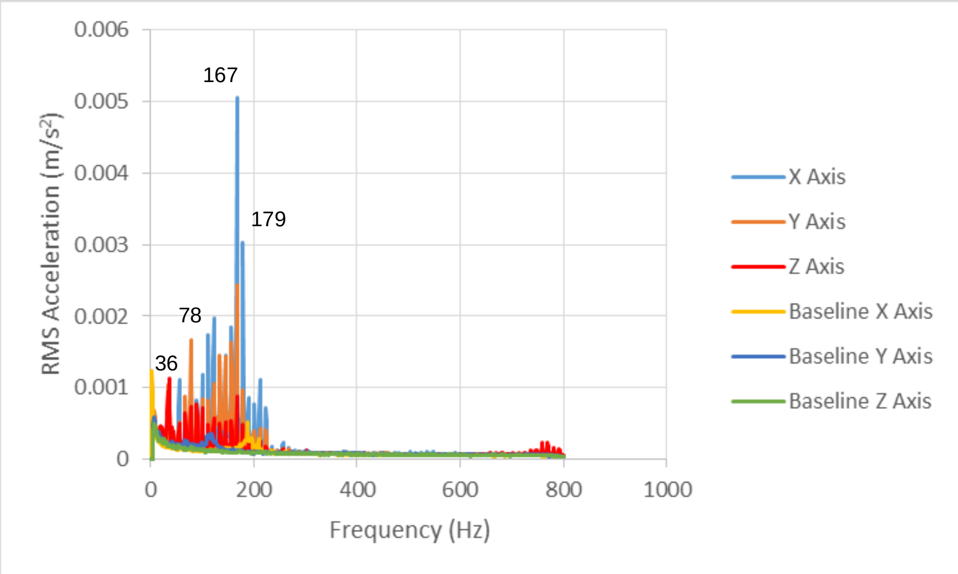


Figure 3.5: RMS vibration acceleration frequency spectrums measured at Location E.

3.12 Figures 3.6 presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location F.

3.13 Results presented in Figures 3.6 below shows that the highest vibration level was measured at 212 Hz in the X-axis.

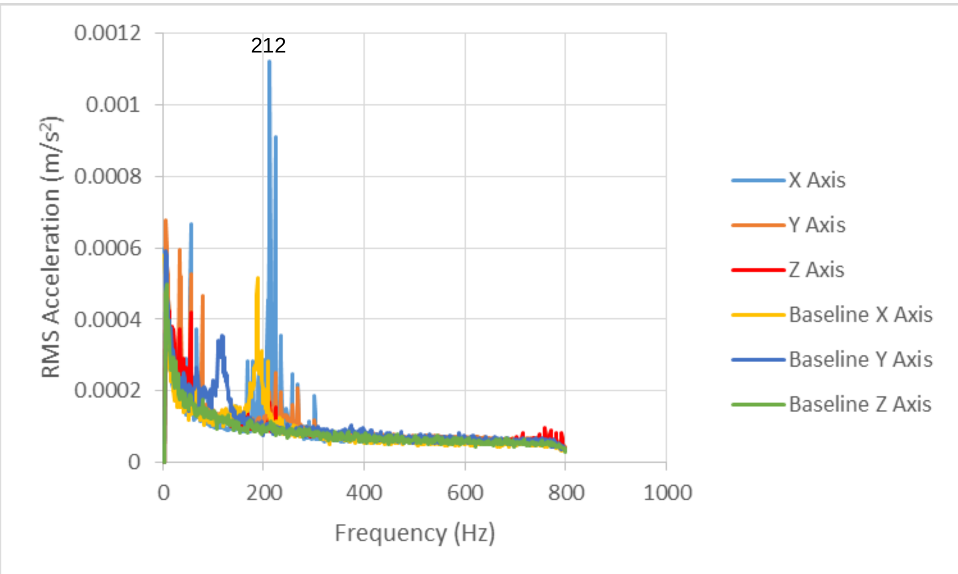


Figure 3.6: RMS vibration acceleration frequency spectrums measured at Location F.

3.14 Figures 3.7 presents RMS vibration acceleration frequency spectrums (X, Y and Z axis) between 1 and 1000 Hz measured at Location G which is used as the baseline noise levels without the A-frame machine in operation.

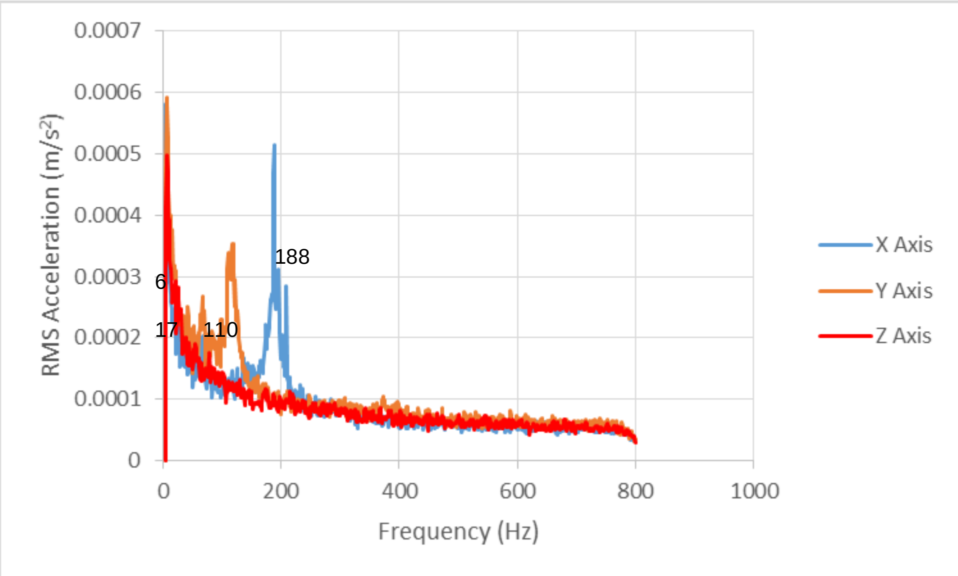


Figure 3.7: RMS vibration acceleration frequency spectrums measured at Location G.

3.15 The results presented in Figures 3.1 to 3.6 above show higher vibration levels measured in the transverse direction than the vibration levels measured in the vertical direction.

3.16 Table 3.1 summarises the dominant frequency components measured at the various measurement locations. The dominant vibration levels measured were generally in the low frequency range up to 220 Hz.

Table 3.1: Summary of dominant frequency components measured at the various measurement locations.

Location Point	Dominant Frequency Component (Hz)
A	34, 59, 133, 148, 149
B	109, 112, 141, 153, 156
C	108, 112, 115
D	64, 127, 188, 211
E	33, 36, 78, 167, 179
F	6, 12, 33, 212
G	6, 17, 110, 188

4. Results (Peak Particle Velocity)

4.1 Figures 4.1 to 4.3 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location A. Figure 4.4 presents the resultant PPV, between 1 and 256 seconds measured at Location A.

4.2 The maximum and minimum PPVs of each axis at Location A are identified and presented in table 4.1.

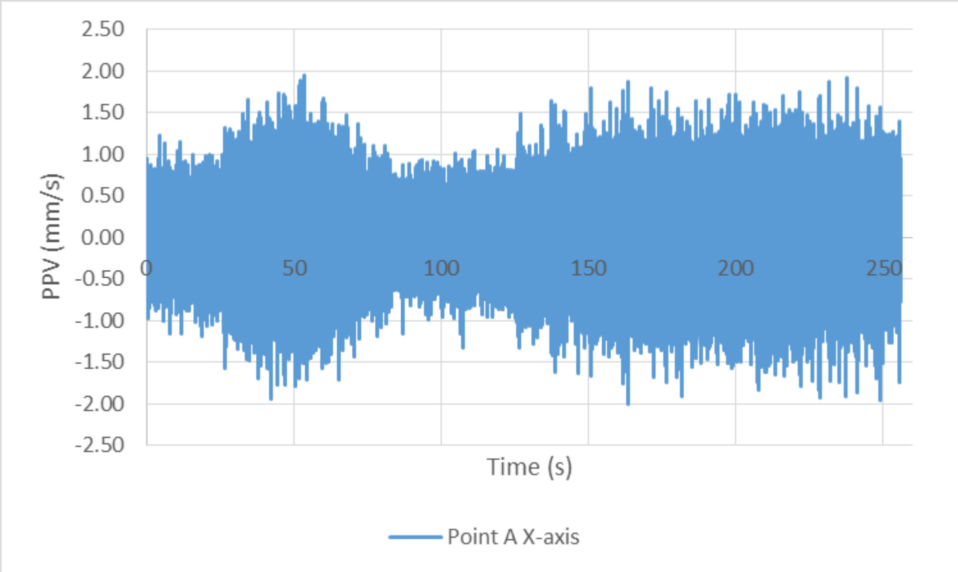


Figure 4.1: X-axis PPV measured at Location A.

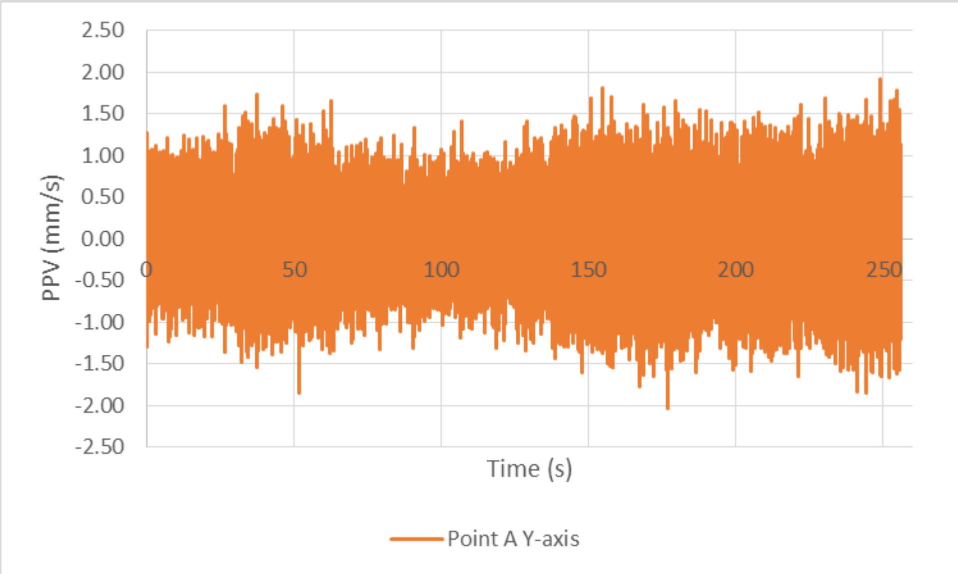


Figure 4.2: Y-axis PPV measured at Location A.

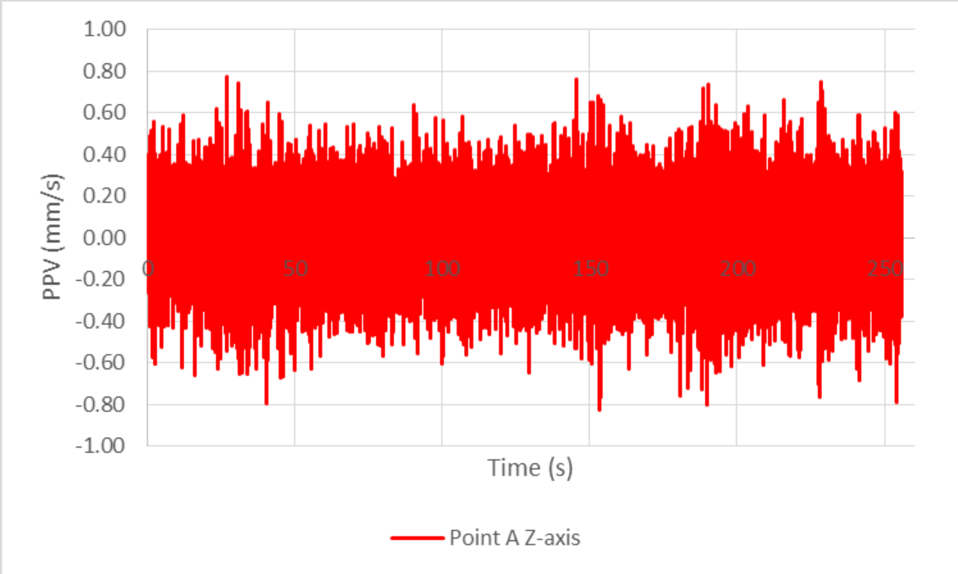


Figure 4.3: Z-axis PPV measured at Location A.

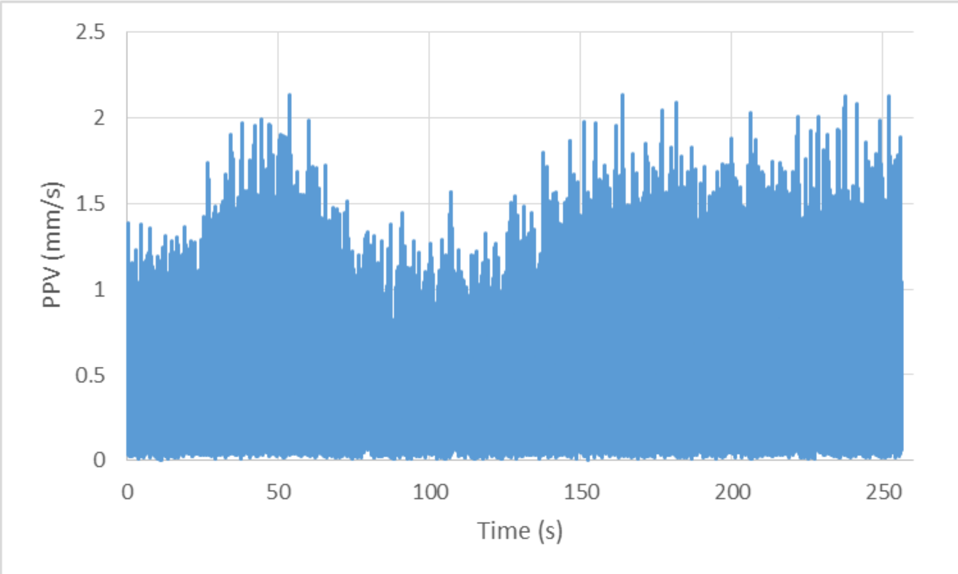


Figure 4.4: Resultant PPV measured at Location A.

Max X (mm/s)	Max Y (mm/s)	Max Z (mm/s)
1.96E+00	1.92E+00	7.75E-01
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-2.00E+00	-2.03E+00	-8.25E-01

Table 4.1: Maximum and minimum PPV at Location A.

4.3 Figures 4.5 to 4.7 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location B. Figure 4.8 presents the resultant PPV, between 1 and 256 seconds measured at Location B.

4.4 The maximum and minimum PPVs of each axis at Location B are identified and presented in Table 4.2.

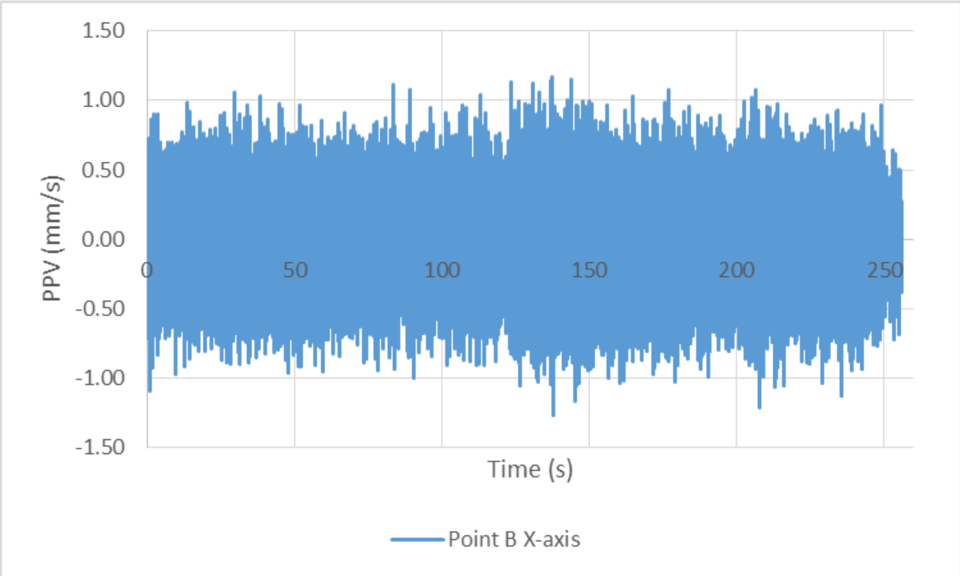


Figure 4.5: X-axis PPV measured at Location B.

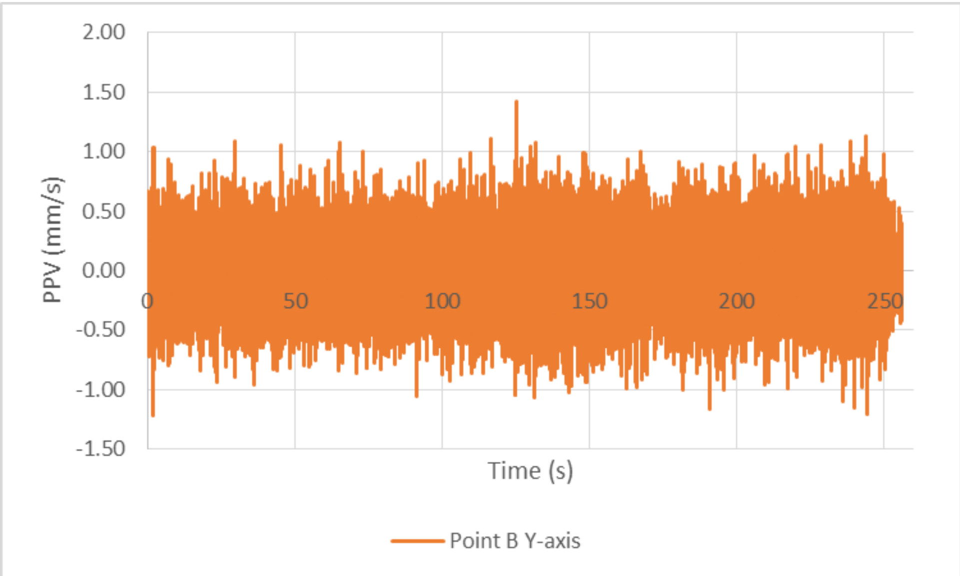


Figure 4.6: Y-axis PPV measured at Location B.

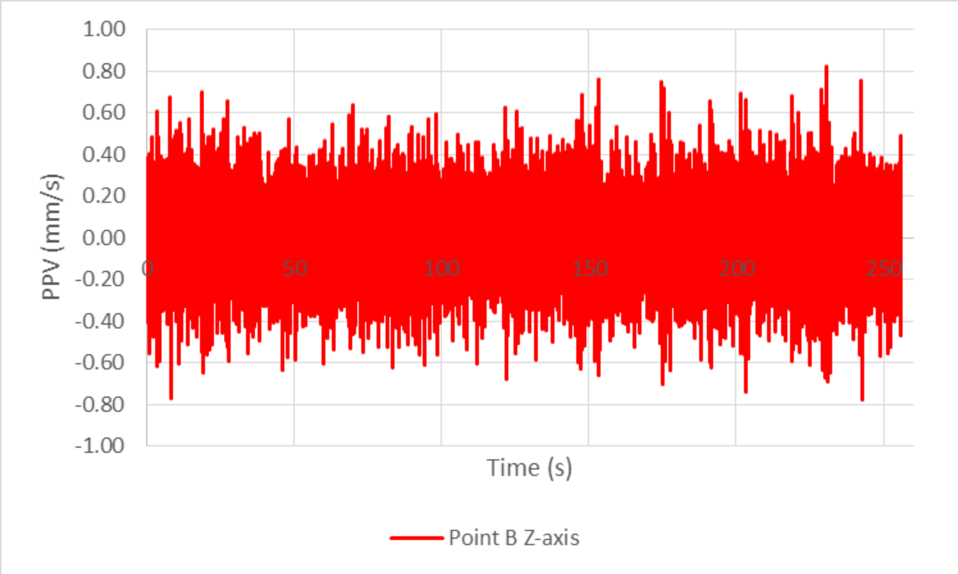


Figure 4.7: Z-axis PPV measured at Location B.

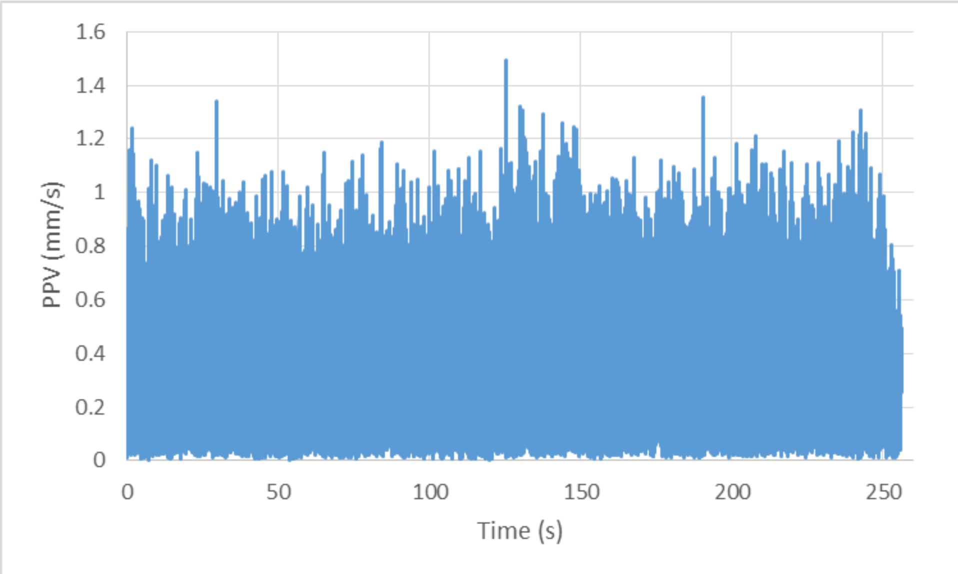


Figure 4.8: PPV measured at Location B.

Max X (mm/s)	Max Y (mm/s)	Max Z (mm/s)
1.17E+00	1.42E+00	8.25E-01
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-1.27E+00	-1.22E+00	-7.77E-01

Table 4.2: Maximum and minimum PPV at Location B.

4.5 Figures 3.9 to 3.11 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location C. Figure 3.12 presents the resultant PPV, between 1 and 256 seconds measured at Location C.

4.6 The maximum and minimum PPVs of each axis at Location C are identified and presented in Table 3.3.

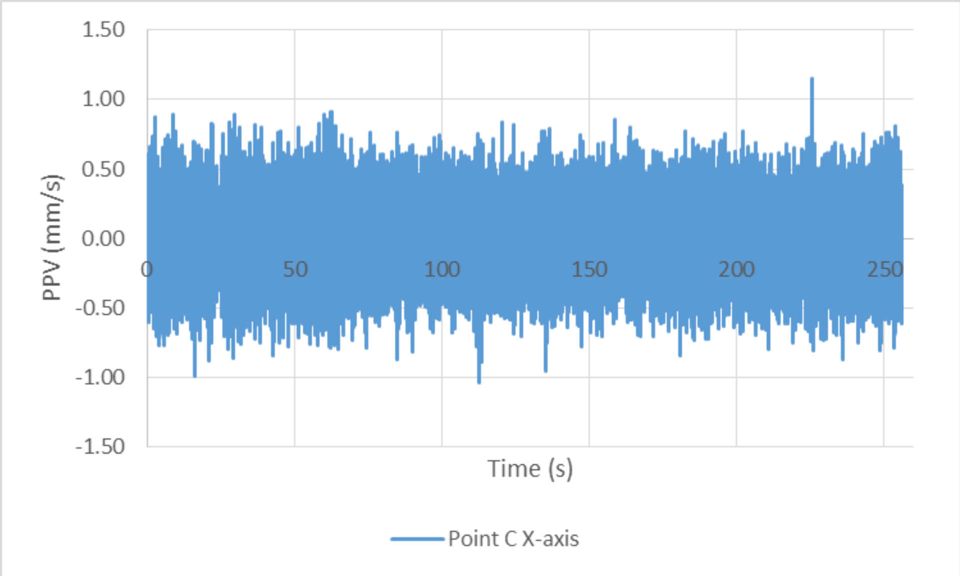


Figure 4.9: X-axis PPV measured at Location C.

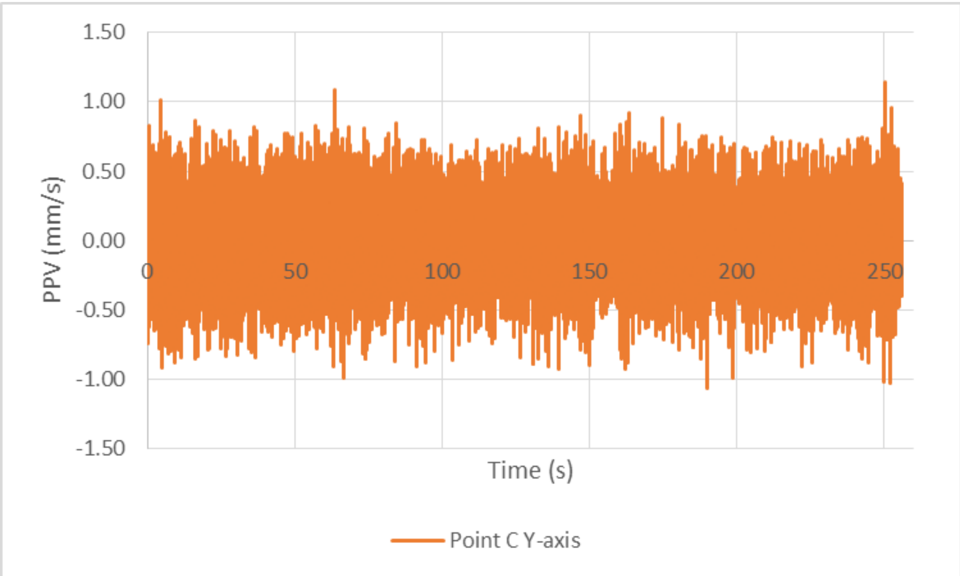


Figure 4.10: Y-axis PPV measured at Location C.

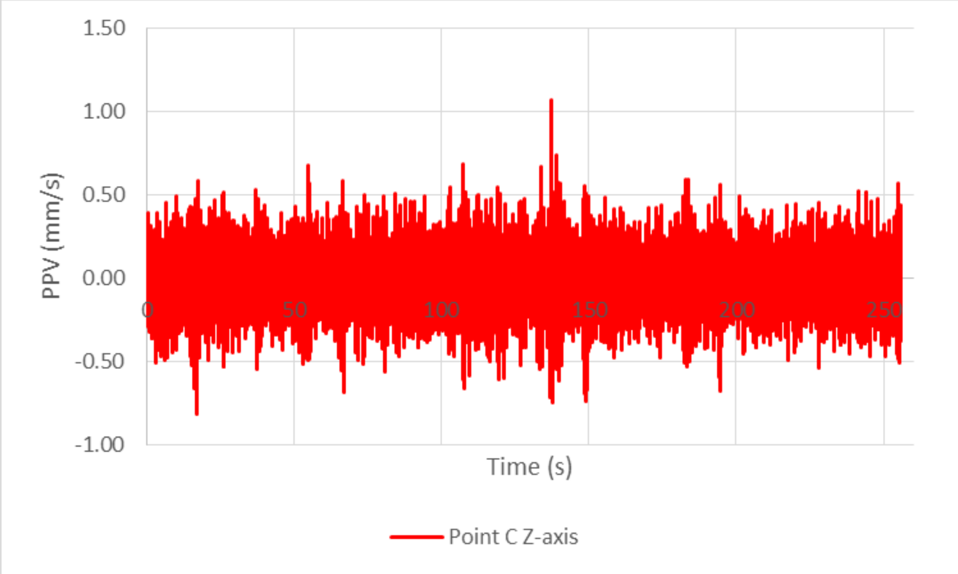


Figure 4.11: Z-axis PPV measured at Location C.

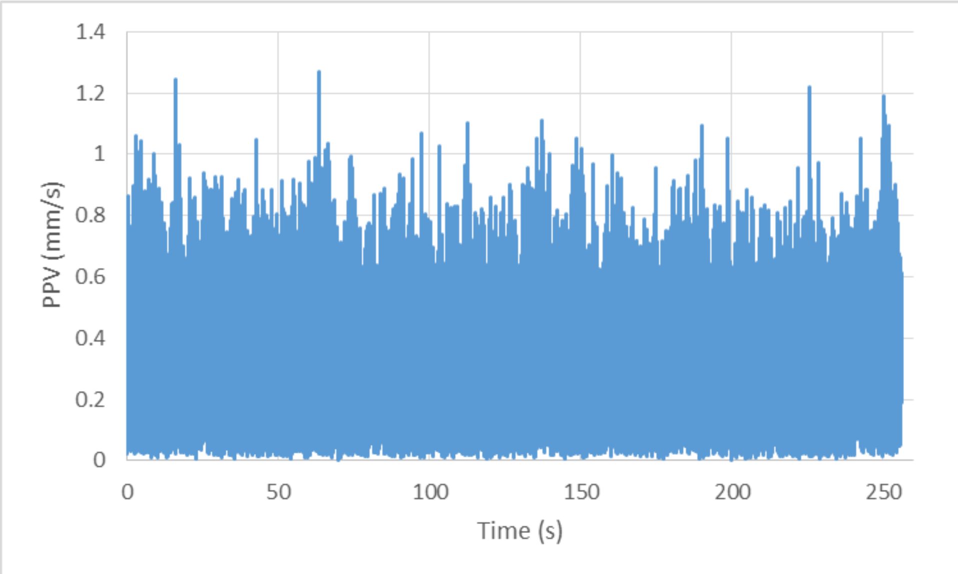


Figure 4.12: PPV measured at Location C.

Max X (mm/s)	Max Y (mm/s)	Max Z (mm/s)
1.15E+00	1.14E+00	1.07E+00
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-1.04E+00	-1.07E+00	-8.14E-01

Table 4.3: Maximum and minimum PPV at Location C.

4.7 Figures 3.13 to 3.15 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location D. Figure 3.16 presents the resultant PPV, between 1 and 256 seconds measured at Location D.

4.8 The maximum and minimum PPVs of each axis at Location D are identified and presented in Table 3.4.

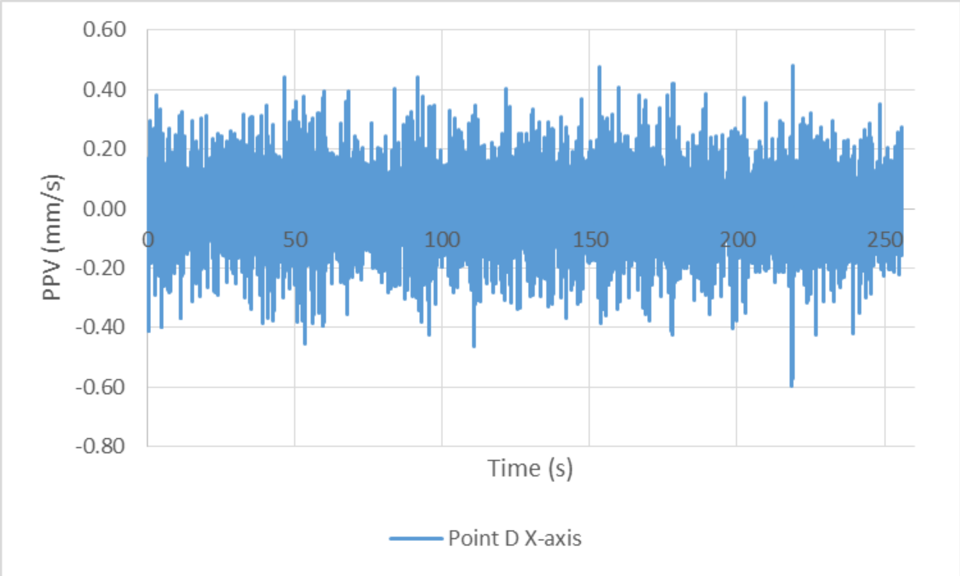


Figure 4.13: X-axis PPV measured at Location D.

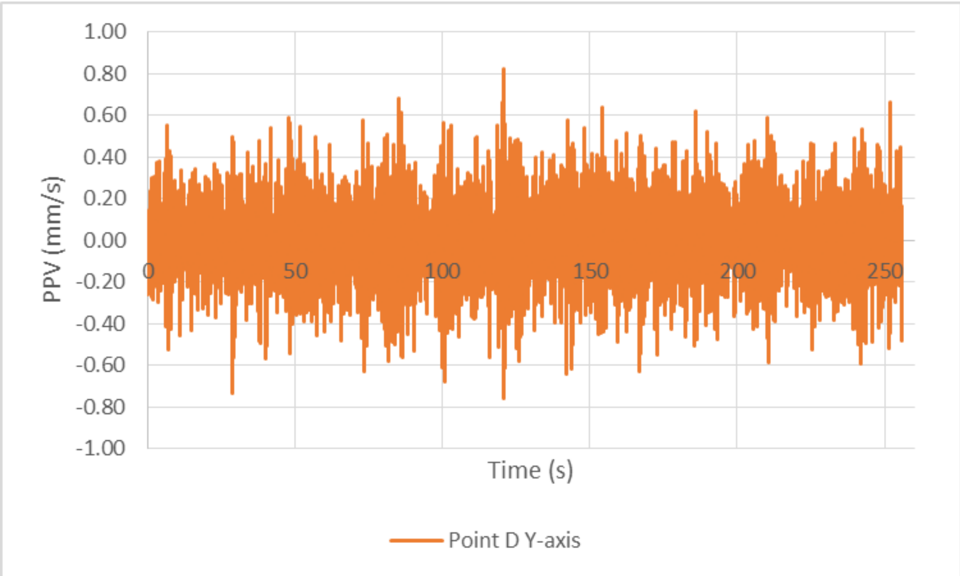


Figure 4.14: Y-axis PPV measured at Location D.

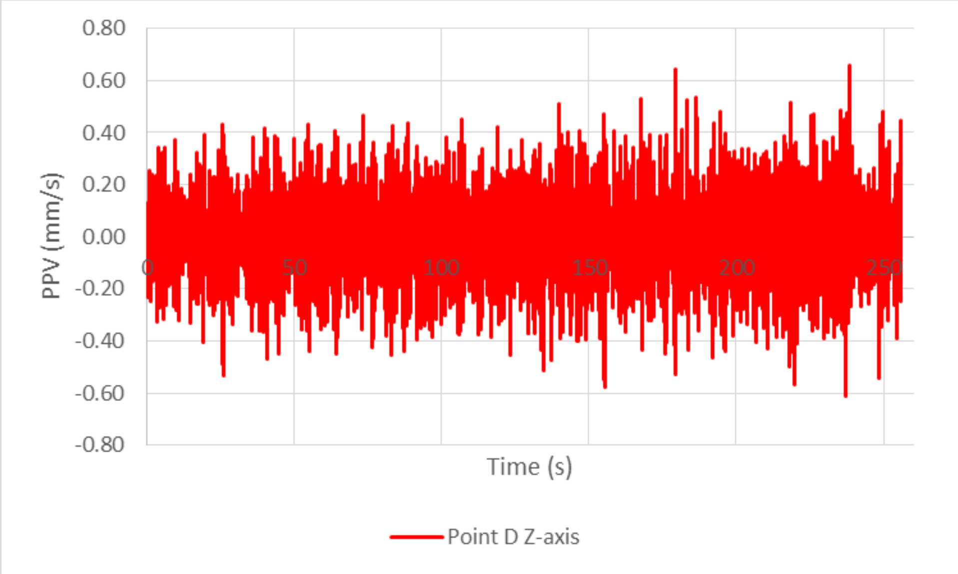


Figure 4.15: Z-axis PPV measured at Location D.

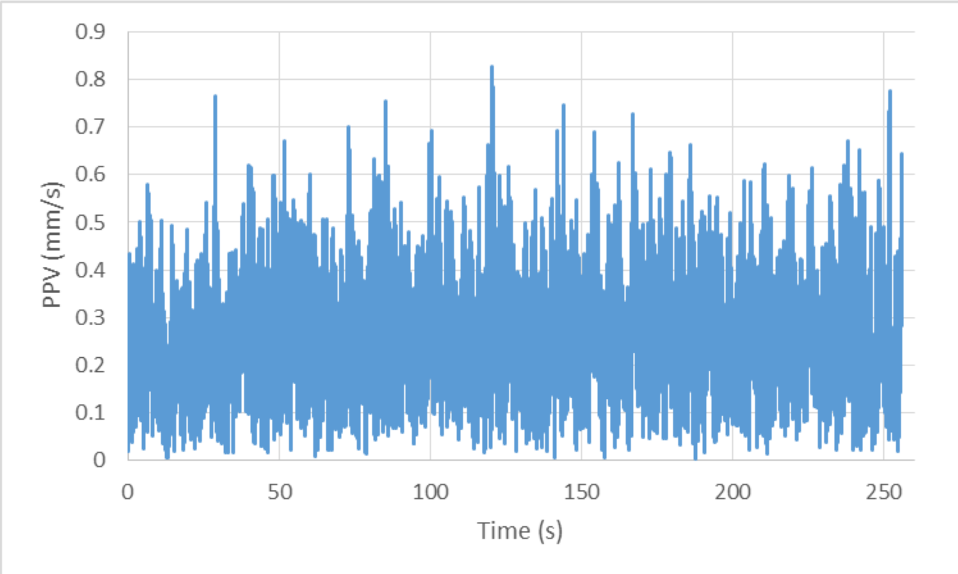


Figure 4.16: PPV measured at Location D.

Max X (mm/s)	Max Y (mm/s)	Max Z (mm/s)
4.81E-01	8.24E-01	6.60E-01
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-5.97E-01	-7.58E-01	-6.14E-01

Table 4.4: Maximum and minimum PPV at Location D.

4.9 Figures 4.17 to 4.19 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location E. Figure 4.20 presents the resultant PPV, between 1 and 256 seconds measured at Location E.

4.10 The maximum and minimum PPVs of each axis at Location E are identified and presented in Table 4.5.

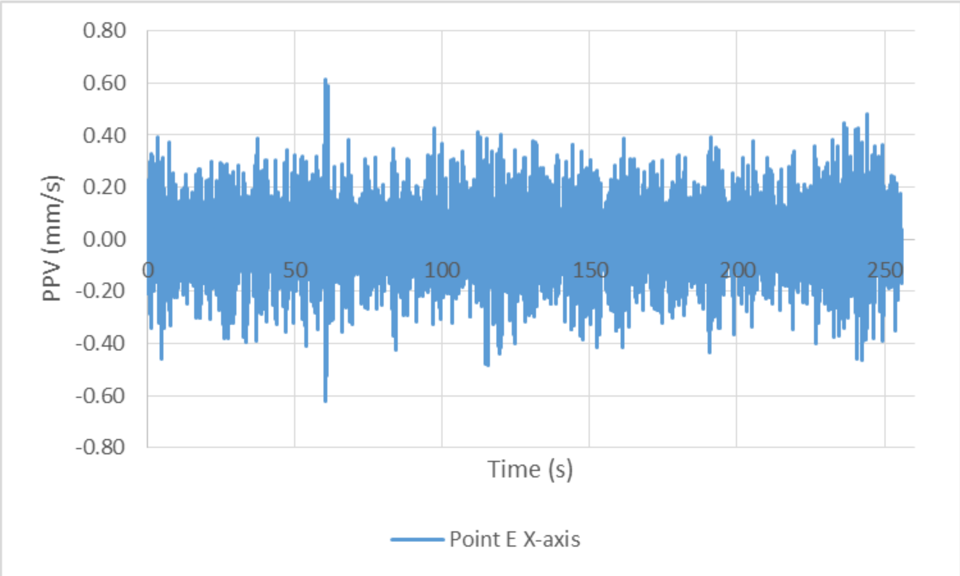


Figure 4.17: X-axis PPV measured at Location E.

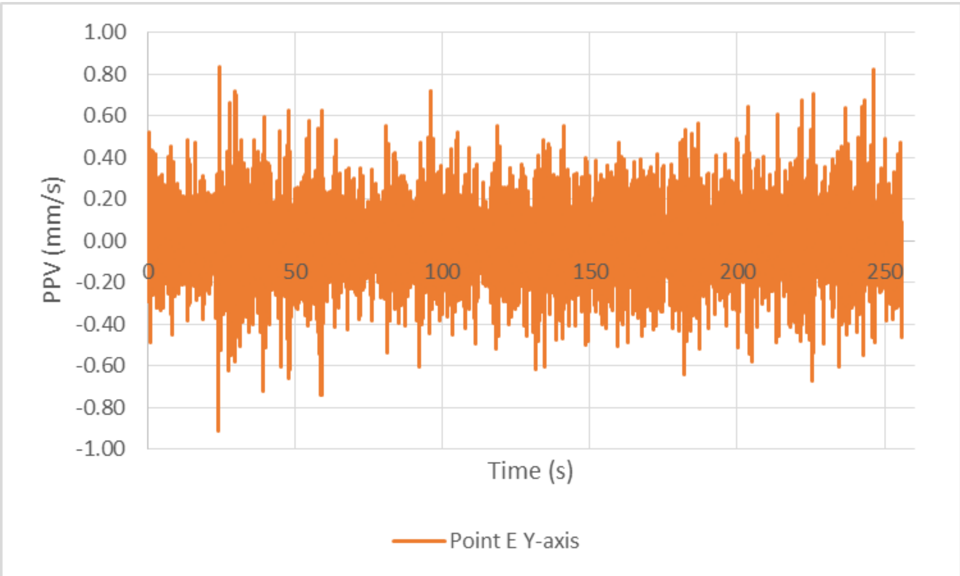


Figure 4.18: Y-axis PPV measured at Location E.

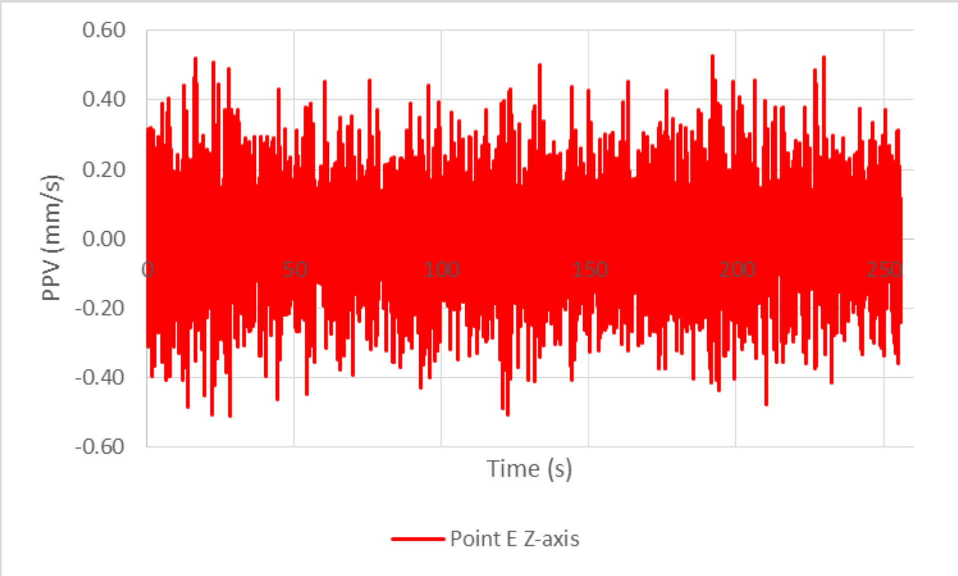


Figure 4.19: Z-axis PPV measured at Location E.

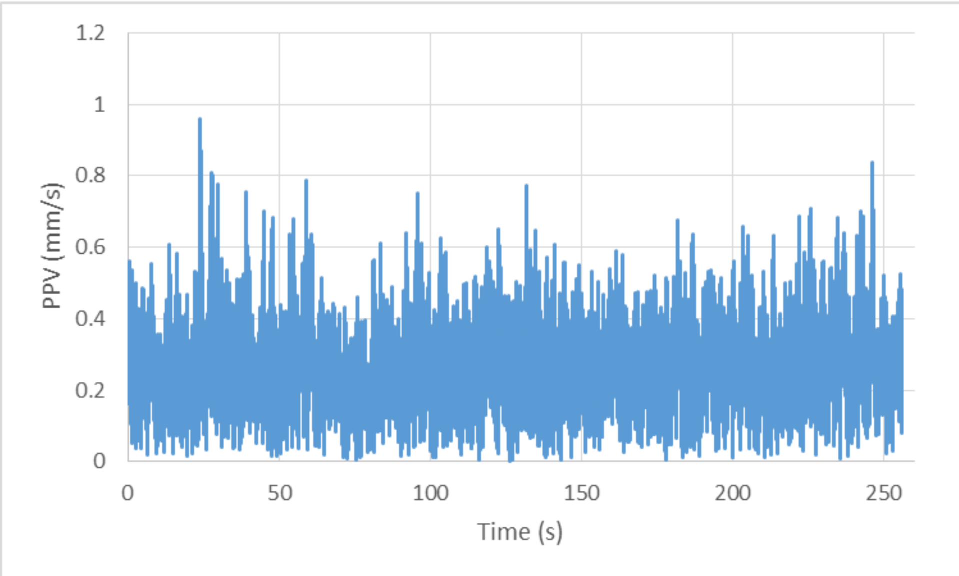


Figure 4.20: PPV measured at Location E.

Max X (mm/s)	Max Y (mm/s)	Max Z (mm/s)
6.15E-01	8.33E-01	5.29E-01
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-6.21E-01	-9.11E-01	-5.10E-01

Table 4.5: Maximum and minimum PPV at Location E.

4.11 Figures 4.21 to 4.23 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location F. Figure 4.24 presents the resultant PPV, between 1 and 256 seconds measured at Location F.

4.12 The maximum and minimum PPVs of each axis at Location F are identified and presented in Table 4.6.

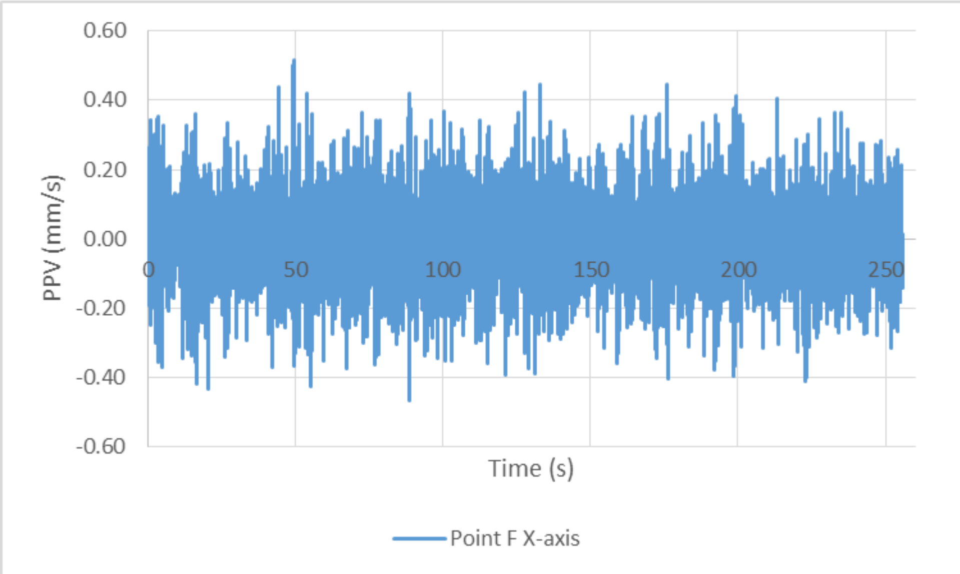


Figure 4.21: X-axis PPV measured at Location F.

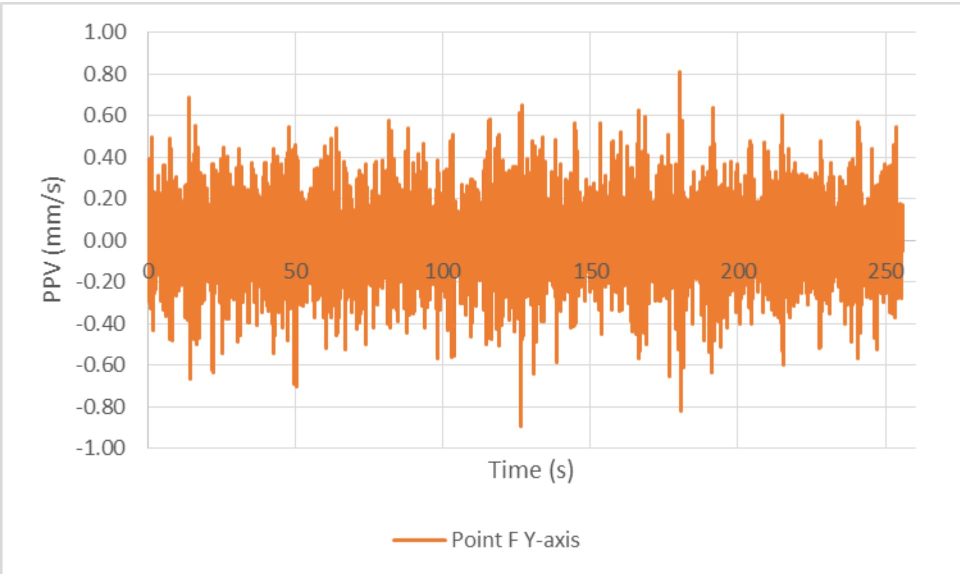


Figure 4.22: Y-axis PPV measured at Location F.

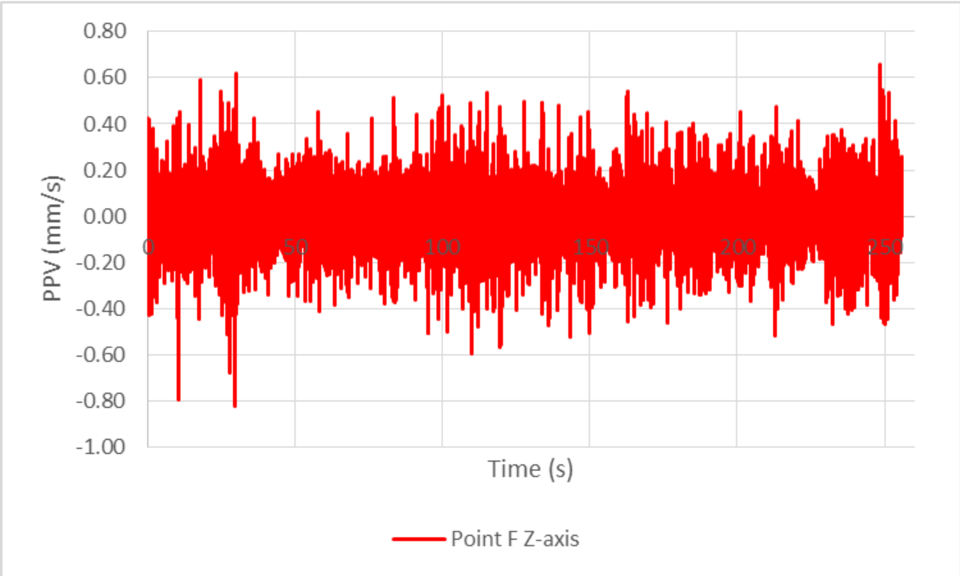


Figure 4.23: Z-axis PPV measured at Location F.

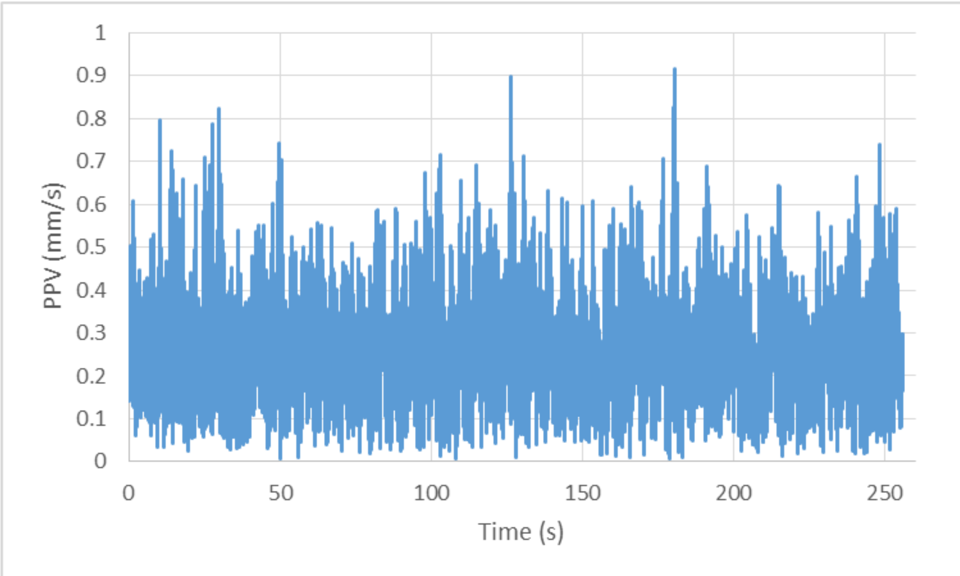


Figure 4.24: PPV measured at Location F.

Max X (mm/s)	**Max Y (mm/s)**	**Max Z (mm/s)**
5.15E-01	8.10E-01	6.55E-01
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-4.67E-01	-8.96E-01	-8.20E-01

Table 4.6: Maximum and minimum PPV at Location F.

4.13 Figures 4.25 to 4.27 present the peak particle velocity (PPV) for X, Y and Z axis respectively, between 1 and 256 seconds measured at Location G. Figure 4.28 presents the resultant PPV, between 1 and 256 seconds measured at Location G.

4.14 The maximum and minimum PPVs of each axis at Location G are identified and presented in Table 4.7.

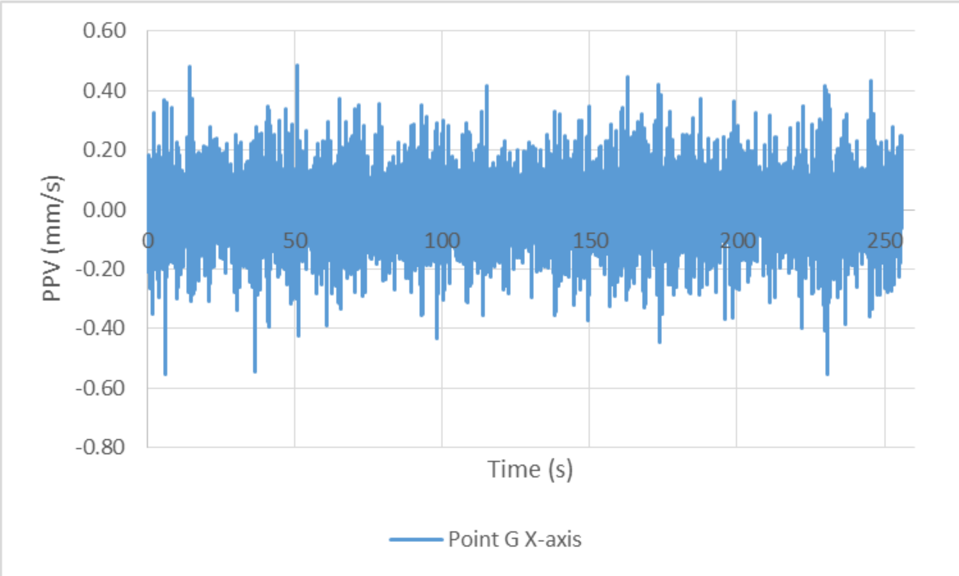


Figure 4.25: X-axis PPV measured at Location G.

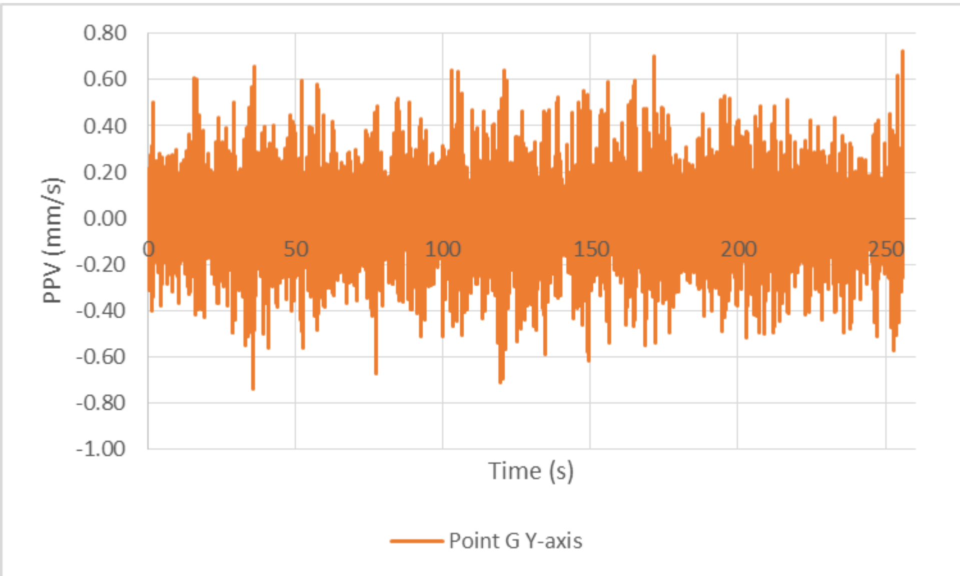


Figure 4.26: Y-axis PPV measured at Location G.

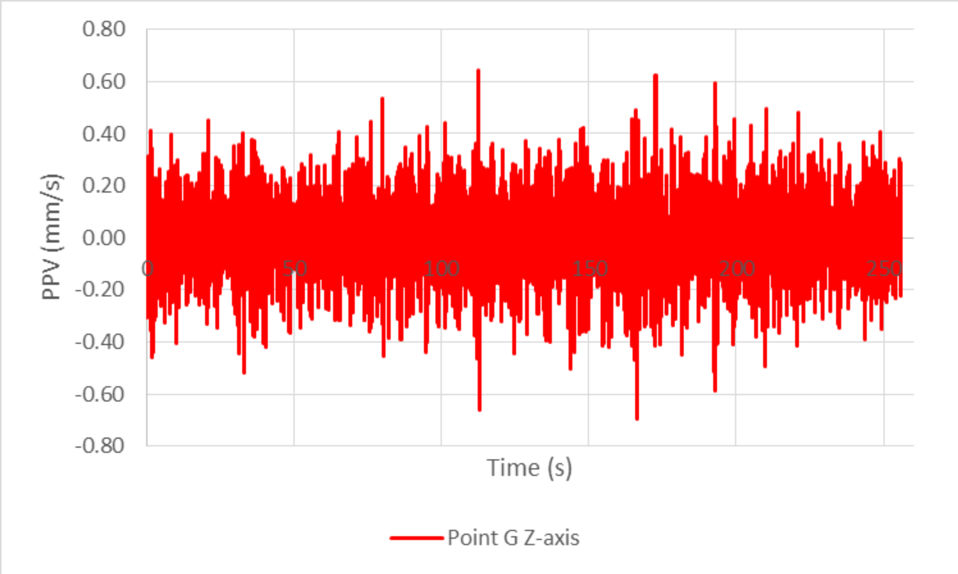


Figure 4.27: Z-axis PPV measured at Location G.

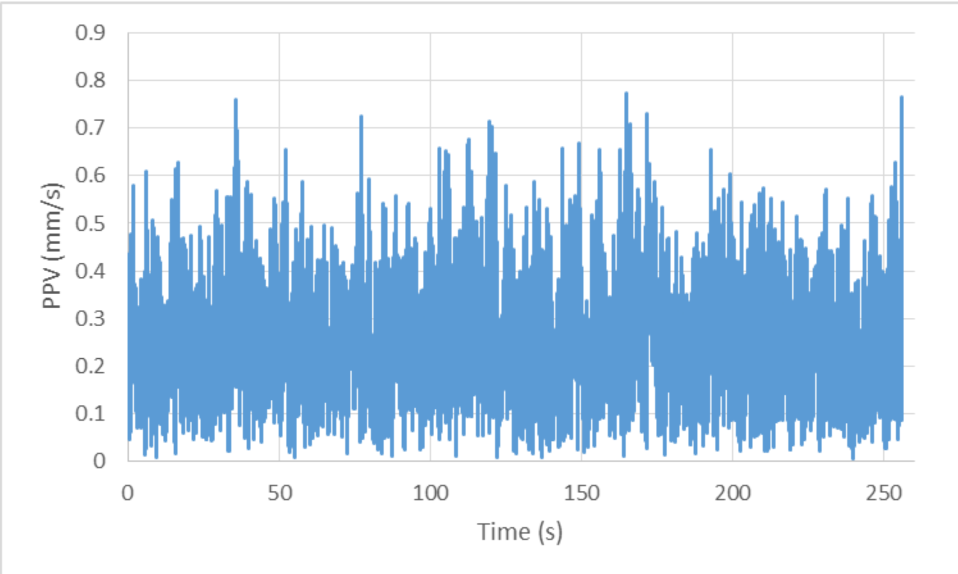


Figure 4.28: PPV measured at Location G.

Max X (mm/s)	Max Y (mm/s)	Max Z (mm/s)
4.85E-01	7.26E-01	6.42E-01
Min X (mm/s)	**Min Y (mm/s)**	**Min Z (mm/s)**
-5.55E-01	-7.40E-01	-6.98E-01

Table 4.7: Maximum and minimum PPV at Location G

Appendix A

Calibration Certificate

VIBRATION & SOUND SERVICES & SALES PTE LTD
59 Ubi Avenue 1, Bizlink Centre #04-17, Singapore 408938
Tel : 65-68440190 Fax : 65-65121903

CERTIFICATE OF CALIBRATION

REFERENCE	:	MCR_ARS_1206_2015_624498
CUSTOMER	:	Affinity Engineering Consultancy Pte Ltd
ADDRESS	:	10 Bukit Batok Crescent. The Spire #08-05 Singapore 658079
DESCRIPTION	:	4-Channel Signal Analyser Box
MODEL	:	A4404
MANUFACTURER	:	Adash
SERIAL NO.	:	624498
DATE CALIBRATED	:	24.12.2014
NEXT DUE DATE	:	24.12.2015
TEMPERATURE	:	25+/- 1 Celsius
HUMIDITY	:	47%

The test results have been verified to be generally within specification UNLESS indicated otherwise. The Laboratory's organisation and practices are derived from ISO/IEC 17025.

The instrument used for this calibration is traceable to National Institute of Standards and Technology (NIST) and Singapore Productivity and Standards Board (PSB). Compliance to ISO/IEC 17025:Ref. No. VSS/5 & Ref. No. VSS/4.

Calibration Equipment Used:

Model / Type	S / No	Next Due
1. Function Generator	08090836	17/07/2015
2. Digital Multi-meter Fluke 77III	708606133X	29/07/2015

The analyser was set to the frequency span form 10 Hz to 1600 Hz with 1600 lines.
Sensor sensitivity set to 100mV/g
Input signal: 159.2 Hz, 100 mV AC, 5V DC offset

Calibration Data

Channel	Velocity		Acceleration	
	Reading	Settings	Reading	Settings
Channel 1	9.82	9.81 ± 0.29 mm/s RMS	9.80	9.81 ± 0.29 m/s^2 RMS
Channel 2	9.81	9.81 ± 0.29 mm/s RMS	9.80	9.81 ± 0.29 m/s^2 RMS
Channel 3	9.81	9.81 ± 0.29 mm/s RMS	9.80	9.81 ± 0.29 m/s^2 RMS
Channel 4	9.81	9.81 ± 0.29 mm/s RMS	9.80	9.81 ± 0.29 m/s^2 RMS

Comments:

All calibration measurement reading is within the accuracy tolerances of ±3%.

Test & Calibrated By:

Raymond Lee
Vibration Engineer

VIBRATION & SOUND SERVICES & SALES PTE LTD
59 Ubi Avenue 1, Bizlink Centre #04-17, Singapore 408938
Tel : 65-68440190 Fax : 65-65121903

CERTIFICATE OF CALIBRATION

REFERENCE	:	MCR_ARS_1103_2015_1015
CUSTOMER	:	Affinity Engineering Consultancy Pte Ltd
ADDRESS	:	10 Bukit Batok Crescent, The Spire #08-05 Singapore 658079
DESCRIPTION	:	Triaxial Accelerometer
MODEL	:	A115-1A
MANUFACTURER	:	Adash.
SERIAL NO.	:	1015
DATE CALIBRATED	:	30.12.2014
NEXT DUE DATE	:	30.12.2015
TEMPERATURE	:	25+/- 1 Celsius
HUMIDITY	:	47%

The test results have been verified to be generally within specification UNLESS indicated otherwise. The Laboratory's organisation and practices are derived from ISO/IEC 17025.

The instrument used for this calibration is traceable to National Institute of Standards and Technology (NIST) and Singapore Productivity and Standards Board (PSB). Compliance to ISO/IEC 17025:Ref. No. VSS/5 & Ref. No. VSS/4.

Calibration Equipment Used:

Type	*S / No*	*Next Due*
1. Shaker System	CM4153	14/03/2015
2. Vibration Analyser	623274	24/12/2015

Procedure:

1. The unit under test is placed on the shaker-table. The shaker is excited by the internal function generator to generate vibrations from pre-determined frequencies and amplitudes.
2. By utilizing the transfer function the sensitivity and the deviation is recorded at different frequencies by the vibration analyser.
3. Test result is shown on calibration data.

Comments:

1. The tests show that the dB variation was within the ± 3 dB for the range 25-2000 Hz for all the 3 axes.

Test & Calibrated By:

Raymond Lee
Vibration Engineer

MCR_ARS_1103_2015_1015

Page 1 of 3

VIBRATION & SOUND SERVICES & SALES PTE LTD
59 Ubi Avenue 1, Bizlink Centre #04-17, Singapore 408938
Tel : 65-68440190 Fax : 65-65121903

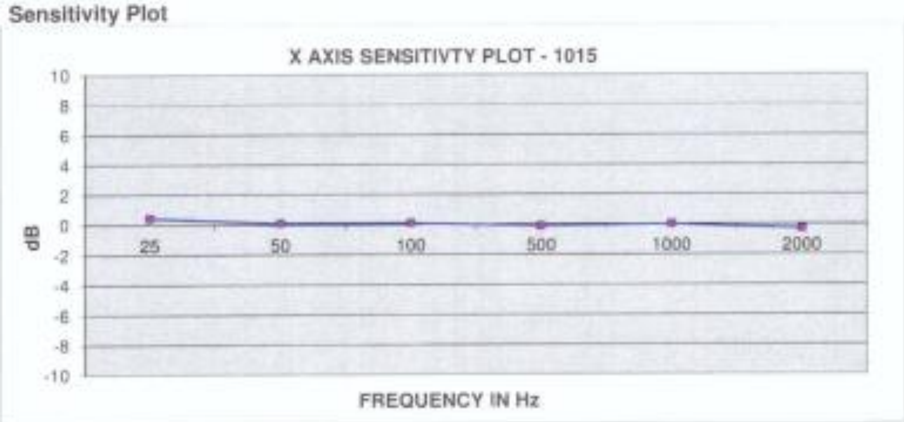
CALIBRATION DATA

Axis : X Direction
Sensitivity @ 100 Hz : 96 mV/g

Data Points

Freq. (Hz)	25	50	100	500	1,000	2,000
Sensitivity	100.8	97.0	97.0	94.7	96.0	92.6
Deviation %	0.05	0.01	0.01	-0.01	0.00	-0.04
dB	0.42	0.09	0.09	-0.12	0.00	-0.31

Sensitivity Plot

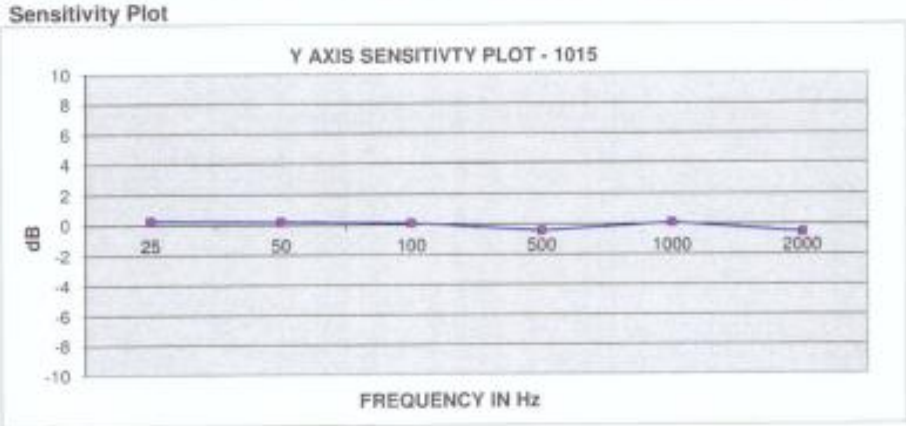


Axis : Y Direction
Sensitivity @ 100 Hz : 96 mV/g

Data Points

Freq. (Hz)	25	50	100	500	1,000	2,000
Sensitivity	98.9	97.9	97.0	91.2	97.0	90.2
Deviation %	0.03	0.02	0.01	-0.05	0.01	-0.06
dB	0.26	0.17	0.09	-0.45	0.09	-0.54

Sensitivity Plot



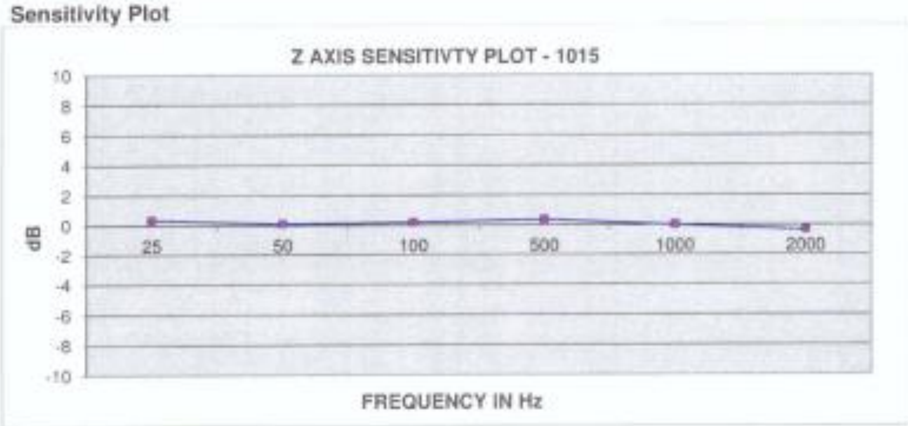
VIBRATION & SOUND SERVICES & SALES PTE LTD
59 Ubi Avenue 1, Bizlink Centre #04-17, Singapore 408938
Tel : 65-68440190 Fax : 65-65121903

Axis : Z Direction
Sensitivity @ 100 Hz : 100 mV/g

Data Points

Freq. (Hz)	25	50	100	500	1,000	2,000
Sensitivity	104.0	101.0	102.0	104.0	100.0	96.0
Deviation %	0.04	0.01	0.02	0.04	0.00	-0.04
dB	0.34	0.09	0.17	0.34	0.00	-0.35

Sensitivity Plot



Annex 3.0

CRL Alignment Option 1 (CCNR) Vibration Analysis Summary Report (Anthony O'Dempsey)

Predicting and Managing TBM Vibration

Potential Negative Impacts due to Noise and Vibration

Anthropogenic noise and vibration are environmental pollutants originating mainly human activities that have some negative impact on fauna. Some natural sources of noise and vibration can also impact fauna, e.g. vibration from earthquakes and tremors. Fauna have three modes of noise or vibration reception – direct hearing through sound pressure waves, sensing through practical vibration through fine hairs or antennae and directly through material or substrate vibration. Negative impacts or responses to these sources of noise and/or vibration include:

Flee / Panic / Hide — The animal is diverted from its normal activity possibly bringing it into conflict with other animals, predators or accidental destruction. As an example some species have been observed to panic and flee upon sensing the initial P and S waves that precede an earthquake.

Distraction — The animal is diverted from its normal activity reducing feeding and mating opportunities for the duration of the noise or vibration. An example of this type of impact might be that some species of termites which are predated upon by ants are vigilant towards the characteristic vibration of predators. Introduction of vibrations of similar frequency and magnitude to that of the predators movements will result in termites reducing or stopping their normal feeding activities for the duration of the introduced vibration;

Masking — The noise or vibration introduced to the environment interferes with normal inter-species communication or predator detection. An example of this type of impact would be the use of leaf blowers and lawn mowers during the early morning at a time when birds and other animals use vocalisation for the establishment of territory or for identifying potential mates;

Destruction — Burrows or other structures used for shelter are damaged or destroyed by the magnitude of vibrations. Examples of this type of impact could be due to earthquakes, or vibrations due to construction activities resulting in burrow collapse causing death, injury or loss of shelter to affected fauna.

Characterising Noise and Vibration

In considering the potential impacts of noise and vibration we identify the following characteristics of potentially impactful noise or vibration[1]. First we recognise that there is a disturbance-interference continuum (Figure 1) that ranges from acute and infrequent interference resulting in startle responses to a cue masking impact for chronic and frequent (or continuous) interference.

Figure 1: The Disturbance-Interference Continuum

[1] This discussion on characterization of noise and vibration has been adapted from: Francis, C. D. and Barber, J. R. (2013), A framework for understanding noise impacts on wildlife: an urgent conservation priority. Frontiers in Ecology and the Environment, 11: 305-313. doi:10.1890/120183

We can further characterise noise and vibration based on frequency, intensity and temporal attributes as illustrated in Figure 2 below:

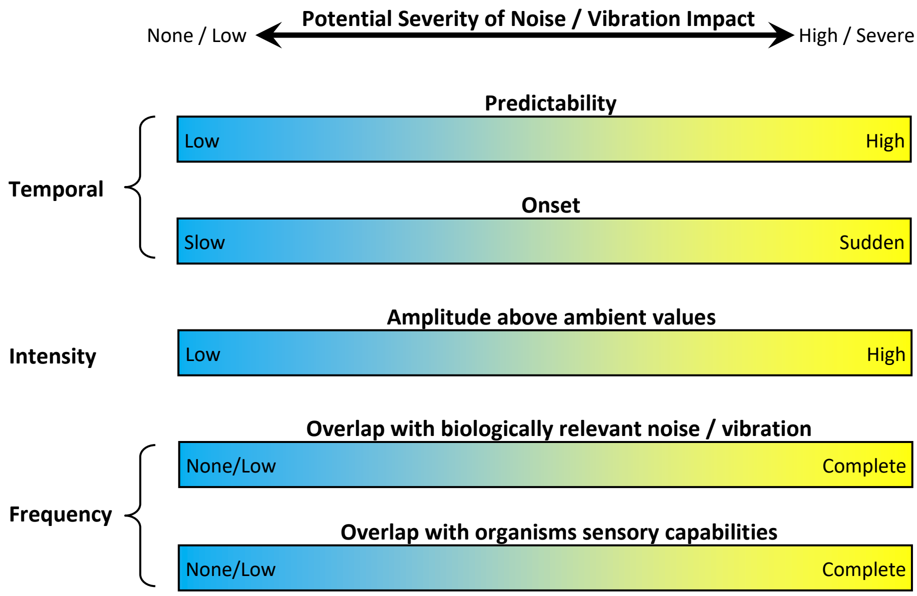


Figure 2: Characteristics of Noise and Vibration applicable to assessing impact on fauna.

Of these characteristics of noise and vibration the primary consideration is for Intensity, if the intensity of noise or vibration introduced to the environment is at or below ambient magnitudes for comparable frequency ranges, the other characters become less relevant to consideration of potential impact.

Determining Ambient Vibration Levels in CCNR

In order to assess the potential impact of surface vibration due to the operation of a Tunnel Boring Machine (TBM), we first need to establish the ambient vibration environment. Ambient surface vibrations within the CCNR are thought to originate from expressway as well as local vehicular traffic, nearby construction activities as well as joggers and hikers using the internal trails within the nature reserve. Ambient vibration levels within the CCNR were established at nine locations distributed more or less evenly along the proposed alignment within the nature reserve. Vibration measurements were recorded using an **Instatel** Minimate-Plus™ advanced vibration monitor with the following performance specification:

Precision/Resolution:	0.127 mm/sec
Accuracy:	0.5 mm/sec @ 95% confidence
Frequency Range:	2-250 Hz

Monitoring stations VP-1 through VP-7, VL101 and VL102[2] are identified in the map (Figure 3) below and monitoring duration was for 7 days at each site. Vibration Monitoring reports were provided by the civil engineering consultant as follows:

VP-1, VL101, VP-5:	Ambience Vibration Monitoring @ CCNR Report 01.pdf
VP-2, VP-3, VP-4:	Ambience Vibration Monitoring @ CCNR Report 02.pdf
VP-6,VP-7, VL102:	Ambience Vibration Monitoring @ CCNR Report 03.pdf

[2] VL101 and VL102 were originally monitored for 24 hours during the CRL Phase 1 baseline study. These sites were re-measured using the more precise **Instatel** Minimate-Plus™ along with new measurements stations VL-1 through VL-7.

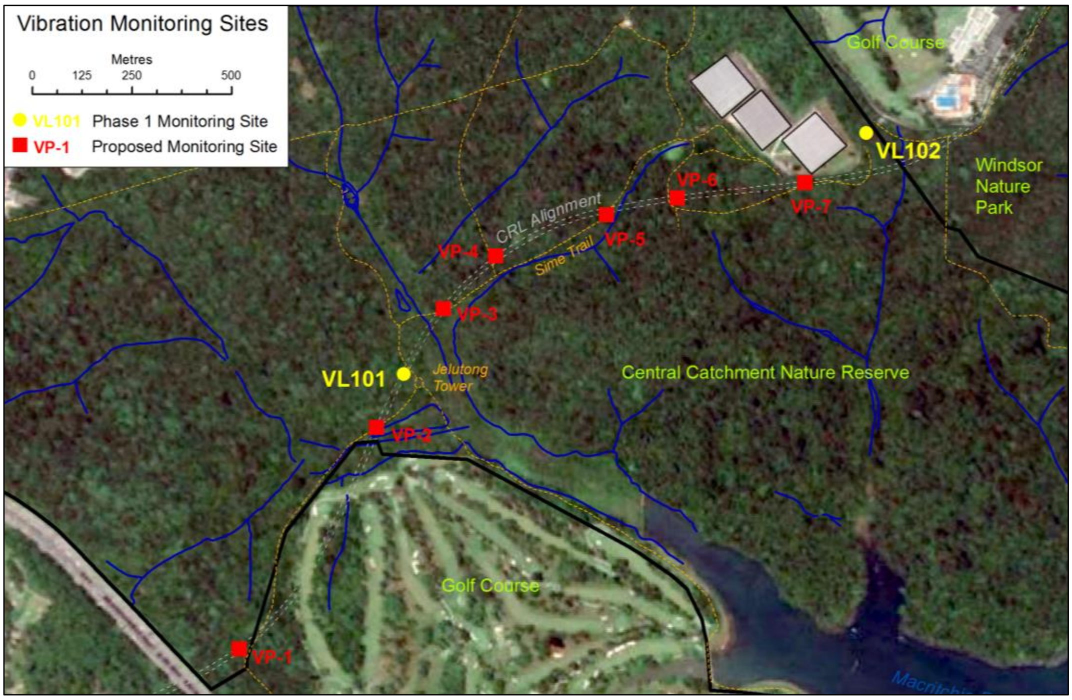


Figure 3: Vibration monitoring sites VP-1 through VP-7, VL101 and VL102 within CCNR.

The Vibration monitoring revealed magnitudes between 0.29 mm/sec and 0.93 mm/sec with mean of 0.57 mm/sec and standard deviation of 0.208 mm/sec. The minimum value occurred about swampy ground[3] near the Jelutong Tower and the maximum value occurred on hard packed ground close to the Kalang Ranger station. These measurements compare favourably with the original baseline vibration monitoring results which indicated a mean ambient vibration of ~0.50 mm/sec[4]. The summary of vibration results in provided in Figure 4 and Figure 5 below:

Baseline Vibration Monitoring (Jun-Jul 2019):

Location	VP-1	VP-2	VL101	VP-3	VP-4	VP-5	VP-6	VP-7	VL102
Peak PPV (mm/s)	0.38	0.29	0.53	0.48	0.7	0.93	0.80	0.48	0.63

Figure 4: Tabulation of summary vibration monitoring results

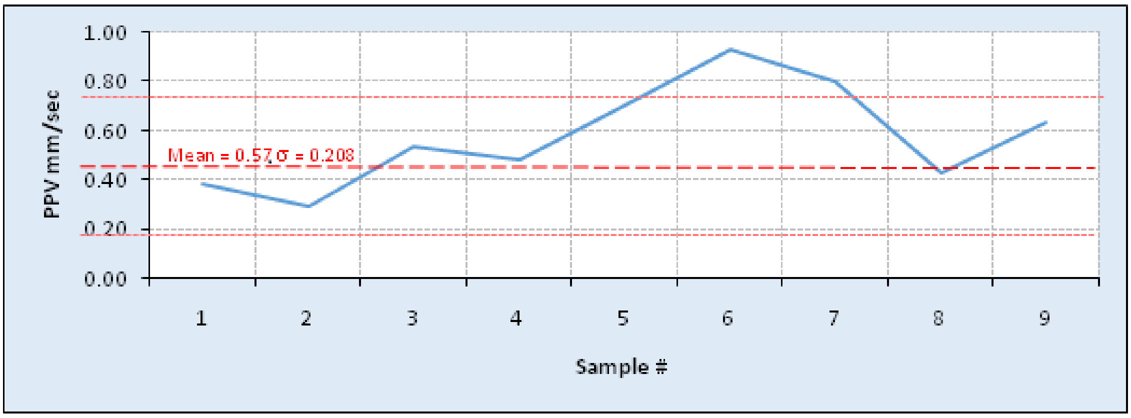


Figure 5: Summary graph of vibration monitoring results.

[3] Lower vibration levels are expected in swampy or moist areas due to the damping effect of water surrounding the soil particles which results in a higher rate of attenuation of transmitted vibration energy.
[4] Refer to CRL Phase 1 Environmental Impact Assessment Vol II for baseline vibration monitoring results.

Prediction of Surface Vibration due to TBM Operation

The prediction of surface vibration due to TBM operation has been achieved by two independent methods:

- Calculation by the author using modified Esvelt's equation with comparison to empirical vibration measurements extracted from the literature.
- Calculation by Engineering Consultants Wilkinson & Murray[5] using a prediction model detailed in the **US FTA Noise and Vibration Manual** and based on measurements taken during construction of the Epping to Chatswood Rail Line in Sydney (Australia) and validated on the Kowloon Southern Link construction in Hong Kong.

Modelling Vibration using Esvelt's Method

The basic Esvelt equation for prediction of surface vibration due to operation of a TBM is as follows:

$$PPV = \frac{10 * \beta * D}{r^n}$$

The parameters used in this equation are described in Table 1 below:

Table 1: Parameters for Esvelt's equation.

Parameter	Value
PPV	Vibration intensity in units of mm/sec
β	Substrate hardness parameter (range 0.25 < β < 1.0)
n	1.35 (determined by calibration)
r	Slope Distance from TBM
D	TBM Cutting wheel diameter (12.5 m)

Values for the parameter β are taken from the Table 2 below:

Table 2: β - (Rock/Soil Hardness Factor)

Rock Type	β
Granite G1/G2, Norite	1.0
Granite G3	0.95
Sandstone	0.75
Mudstone	0.6
Soil G5/G6	0.5

These values for β were estimated (scaled) by calibrating to empirical vibration data obtained for the Melbourne Metro Rail project (6.5 m TBM in sandstone)[6]

The results of this calibration demonstrate a good agreement between the estimated parameters (**β** and ***n***) and the empirical vibration data – giving confidence in the choice of values for β and ***n***. The results are presented graphically in Figure 6 below:

[5] Engineering Consultants Wilkinson & Murray are noise and vibration specialists engaged by LTA to provide an independent assessment of predicted vibration due to TBM operation for Alignment 1.

[6] Report: Melbourne Metro Rail Project - Noise and Vibration Appendix B 20 April 2016 Revision C1

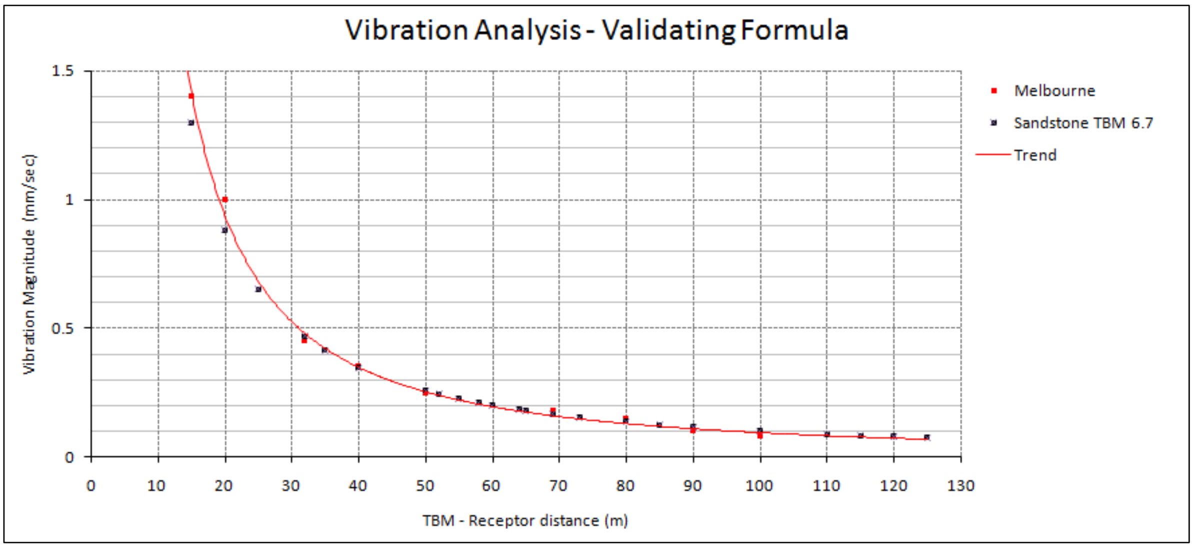


Figure 6: Melbourne Metro Rail data (red dots), Esvelt's equation (black dots) with fitted curve (red line)

Because the substrate below the CCNR is made up of soil (G5/G6) and competent granite rock (G3) we need to modify Esvelt's equation to accommodate the two substrate types. The modification of the formula was achieved by proportioning the β term as follows:

$$PPV = \frac{10 * \beta * D}{r^n}$$

Original Esvelt's equation

$$PPV = 10 * \left(\frac{r_{soil}\beta_{soil} + r_{rock}\beta_{rock}}{r}\right) * D * {}^{1}/_{r^n}$$

Proportioning the value β by the proportions of soil and rock for the location being evaluated. Note that $r = r_{rock} + r_{soil}$

$$PPV = \frac{10 * (r_{soil}\beta_{soil} + r_{rock}\beta_{rock}) * D}{r^{n+1}}$$

Simplification in ***r***

The proportioning of soil / rock is determined from the geotechnical data collected by LTA during the Phase 1 Soil Investigation. The diagram (Figure 7) below illustrates the relative depths of soil and rock substrate below the alignment.

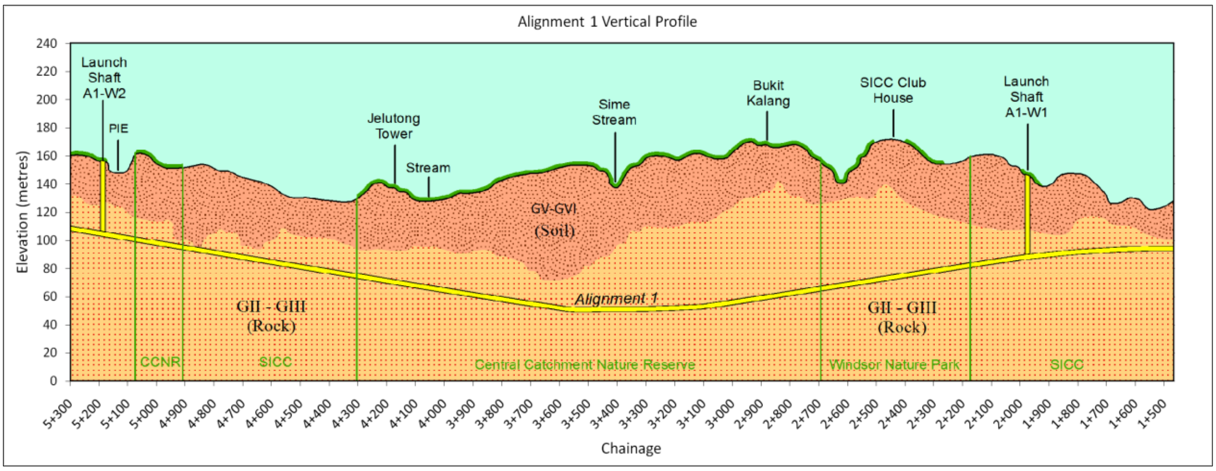


Figure 7: Soil/Rock profile below alignment 1.

By scaling the values for r_{rock} and r_{soil} from this graphic and substituting into the modified Esvelt's equation along with setting D = 12.5 (TBM Diameter), n = 1.35 (from Table 1) and choosing $\beta_{rock\ (G3)}$

and $\beta_{soil\ (G5/G6)}$ from Table 2 we can compute a range of points to which a power curve of the form **y**=a**x**$^{-b}$ can be fitted and used to generalise the predicted surface vibration for various values of ***r***.

The diagram below (Figure 8) illustrates the general curve fitting to the data points computed from the modified Esvelt's equation.

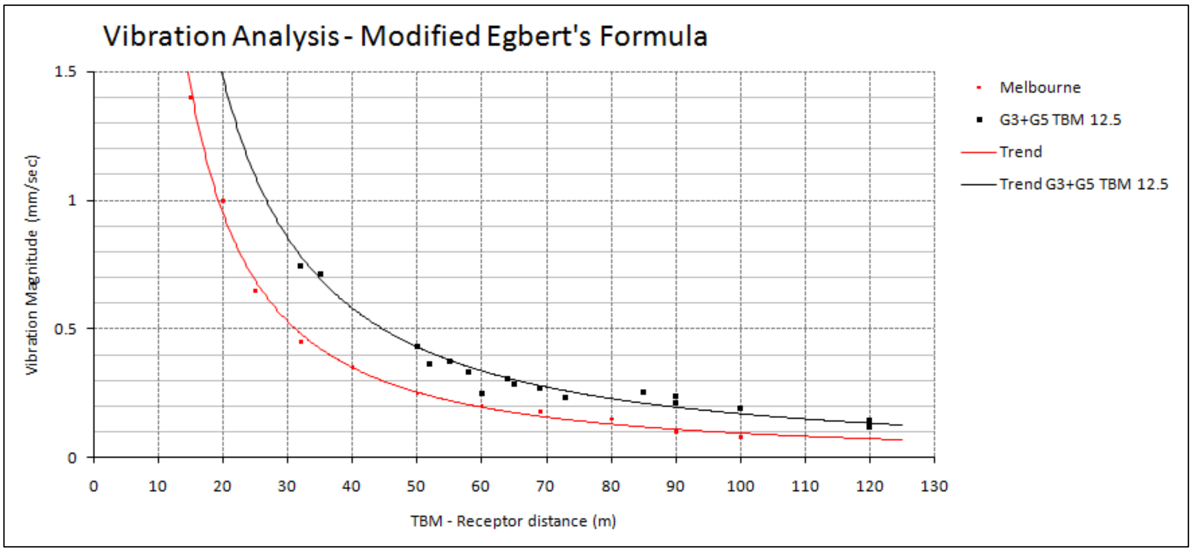


Figure 8: Curve fitting: Modified Esvelt's equation data points (black dots) for 12.5m TBM, Melbourne Metro Rail data points and generalised fitted curve (red dots & line) for a 6.5m TBM are shown for comparison. Note that the data points computed from the modified Esvelt's equation are more scattered due to the varying rock/soil proportions throughout the alignment. Note that the RMS value of the curve fitting (~0.6 mm/sec) is below the minimum measurement resolution of the Instatel minimat-plut™ so the generalised curve is therefore considered sufficiently accurate for prediction of surface vibration.

Vibration Modelling by Wilkinson & Murray

Engineering consultants Wilkinson & Murray were commissioned by LTA to produce an independent evaluation of surface vibration due to operation of a 12.5m TBM. Their method was based on a model presented in the **US FTA Noise and Vibration Manual** and calibrated to empirical data collected on tunnelling projects recently undertaken in Sydney and Hong Kong[7]. Their estimation was scaled to account for the larger 12.5 m TBM proposed for the CRL Alignment 1. The Wilkinson & Murray results are presented in tabular (Table 3) and graphical form (Figure 9) below.

Table 3: Wilkinson & Murray vibration prediction.

R	RH (m)	PPV mm/sec
45	35	0.25
50	30	0.24
63	52	0.17
68	30	0.15
83	66	0.11
85	25	0.1
87	40	0.1

R = Slope distance from surface to TBM
RH = Depth of competent Rock (G3) below surface
PPV = predicted vibration

[7] These projects involved tunnel bore diameters of approximately 7 metres.

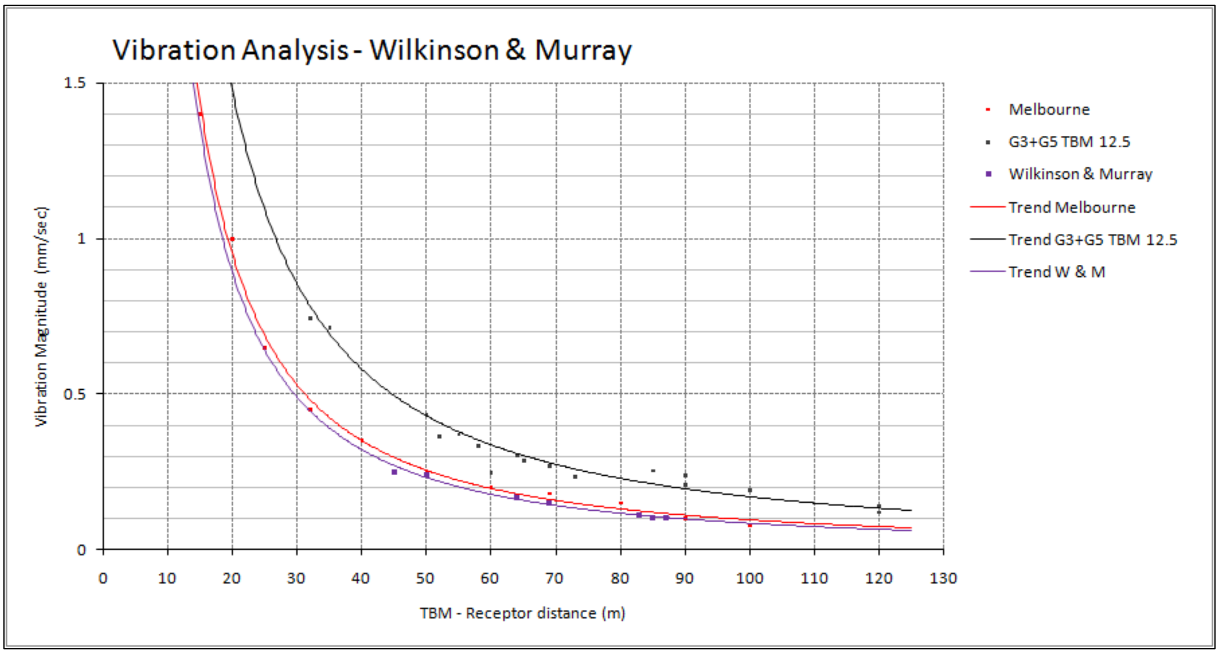


Figure 9: Wilkinson & Murray modelled data (purple dots), fitted curve (purple line) along with Melbourne Metro Rail data (red dots and line) and the modified Esvelt's equation results (black dots and line). Note that the Wilkinson & Murray results are of smaller magnitude compared to the Esvelt's equation vibration prediction.

In comparing the two methods of vibration prediction the difference ranges from 0.2 mm/sec at 50 m (depth of TBM) to 0.1 mm/sec at 90m (depth of TBM). In view of this small material difference between the two methods along with the fact that there is no compelling reason to favour one method over the other, a mean fitting curve **PPV**=78.0 $\boldsymbol{r}^{-1.4}$ (Figure 10) has been determined for the purpose of predicting surface vibration for Alignment 1.

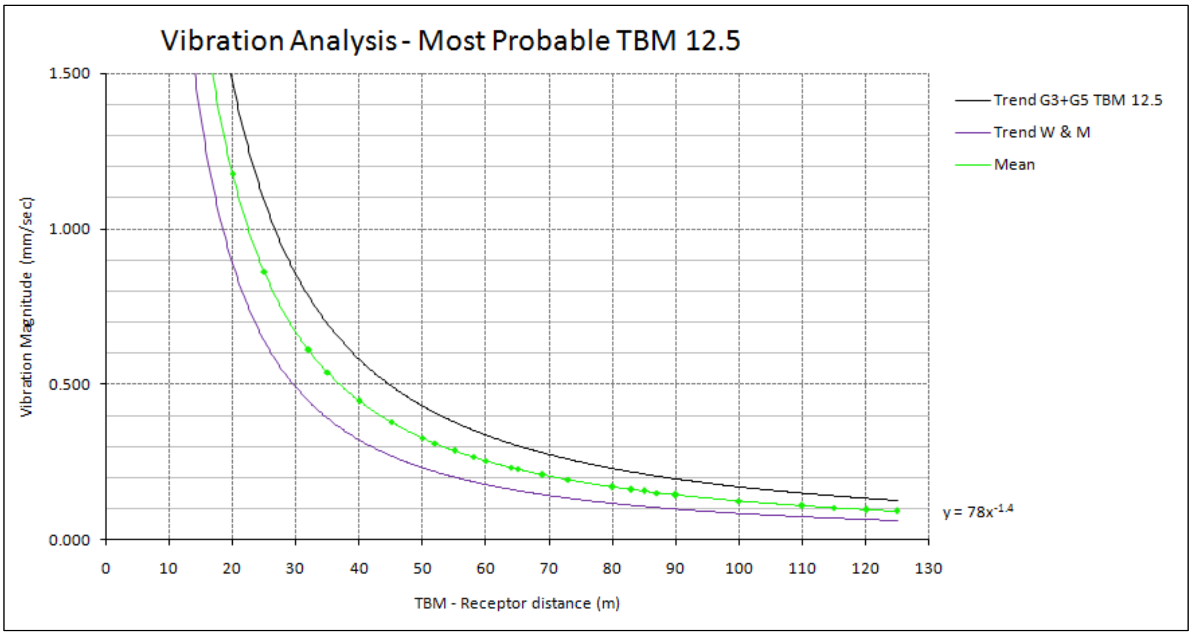


Figure 10: Mean predicted vibration (green dots & line).

The prediction equation **PPV**=78.0 $\boldsymbol{r}^{-1.4}$ has been applied to a grid of points distributed over the extent of Alignment 1 with r values (slope distance from surface to alignment) determined from a LIDAR[8] elevation model and Vertical (Design) Alignment provided by LTA. The resulting predicted

[8] LIDAR data provided by Singapore Land Authority (SLA)

vibration values for each cell were triangulated and converted to a raster dataset which has been rendered as a vibration heat map (Figure 11) below:

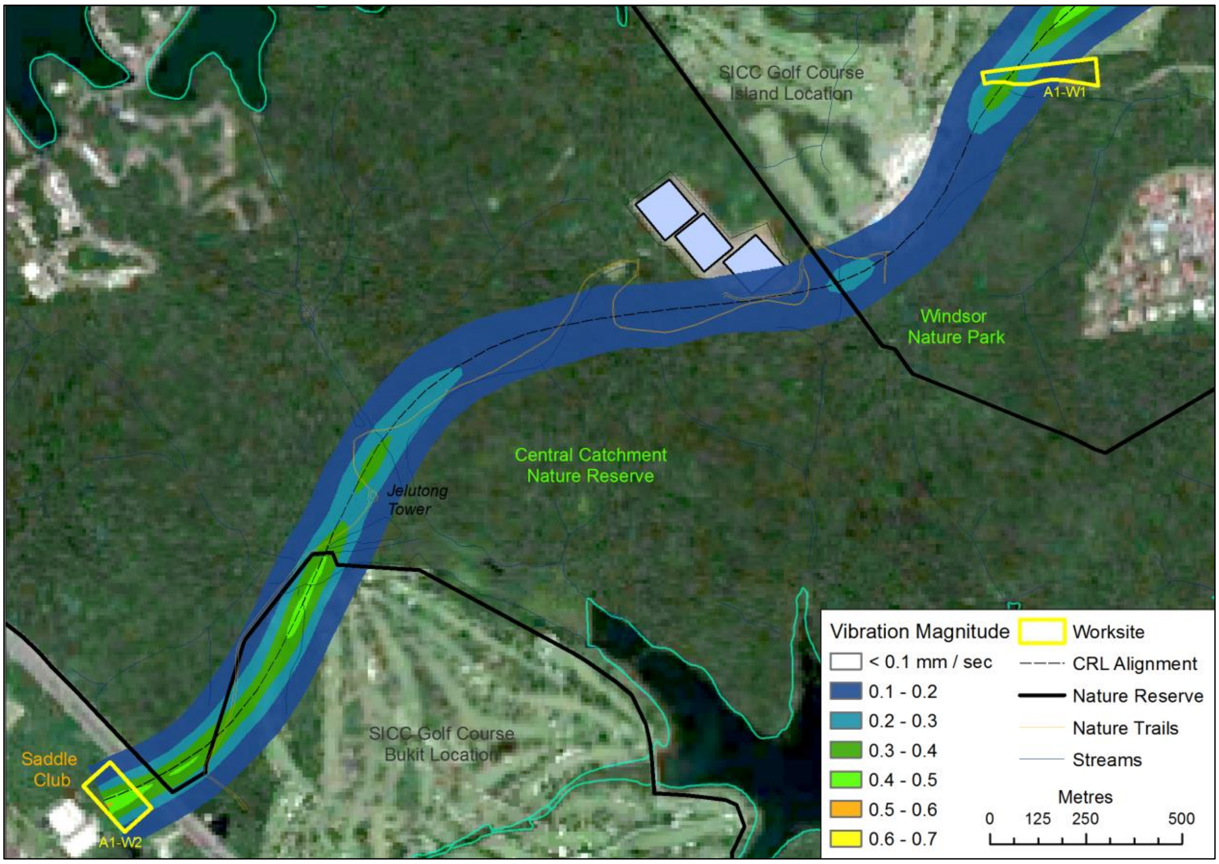


Figure 11: Predicted surface vibration heat map.

The predicted vibration is at all locations below the mean ambient (background) vibration of 0.57 mm/sec. At monitoring location VP-2 (0.29 mm/sec) the predicted vibration is between 0.4-0.5 mm/sec however this location is a swampy area close to the confluence of the Rifle Range and Sime streams where attenuation will be higher. It is considered that the larger predicted value would be an over-estimation (due to the attenuating effect of wet ground) and therefore negligible.

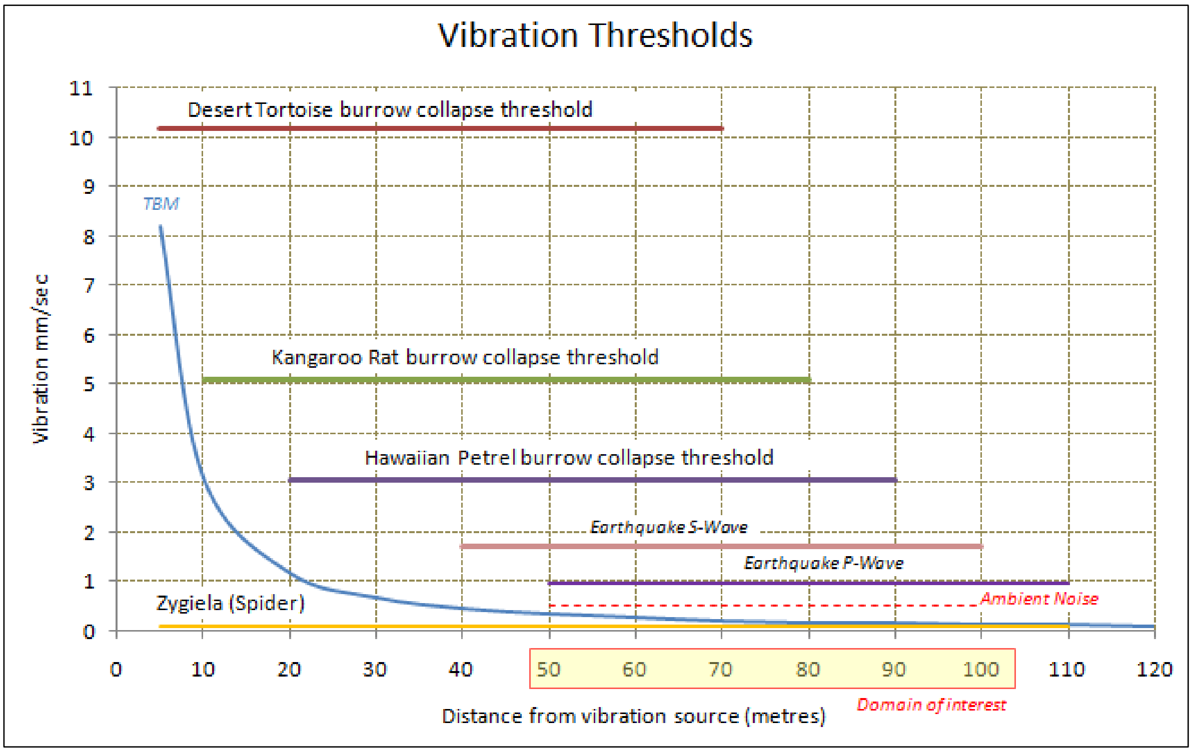
Analysis of Potential Impacts due to Vibration

A literature review was conducted to determine what likely impacts could be anticipated with a view to determine vibration thresholds for various taxa and circumstances, the following table summarises the various papers that were reviewed:

Author	Year	Title
Tarsitano	2001	Vibrational courtship signals of *Zygiella x-notata*
Barth	n/a	Vibrations and Spider Behaviour
Hergenröder & Barth	1983	Vibratory signals and spider behaviour: How do the sensory inputs from the eight legs interact in orientation? https://doi.org/10.1007/BF00606241
Schuch & Barth	1990	Vibratory communication in a spider: female responses to synthetic male vibrations. https://doi.org/10.1007/BF00187328
Barth	n/a	Spider and Vibratory Signals: Sensory Reception and Behavioural Significance
Leonard	2007	Potential Collapse of Hawaiian Petrel Burrows due to vibration
Barneich et al	2004	Two Case Histories of Blast- & Traffic-Induced Vibrations on the Stability of Burrows of Endangered Sensitive Ground Dwelling Animals

Oberst et al	2017	Cryptic termites avoid predatory ants by eavesdropping on vibrational cues from their footsteps. https://onlinelibrary.wiley.com/doi/abs/10.1111/ele.12727
Cristiano Fidani et al	1997	Cows Come Down from the Mountains before the (Mw = 6.1) Earthquake Colfiorito in September 1997; A Single Case Study
Friedemann et al	2013	Nature of Pre-Earthquake Phenomena and their Effects on Living Organisms
Joseph L. Kirschvink	2000	Earthquake Prediction by Animals: Evolution and Sensory Perception
John R. B. Lighton	2005	Shaken, not stirred: a serendipitous study of ants and earthquakes
Helmut Tributsch	2013	Bio-Mimetics of Disaster Anticipation—Learning Experience and Key-Challenges

As a result of the literature review we were able to identify a somewhat limited amount of threshold information. It is noteworthy that much of the scholarly papers on Anthropogenic noise and vibration conclude that while the study of noise and vibration impact on humans is extensive, the study of noise and vibration impacts on fauna is limited and in need of more work by the scholars. The threshold data extracted from the literature is presented in graphical form () below:



It is noteworthy that the micro-fauna such as spiders, and likely other small fauna utilise vibrations for intra-species communication and/or inter-species for identification or pray/predator which are below the predicted TBM vibration. However these taxa also exist within an ambient vibration environment of higher intensity than the predicted TBM vibration. It is presumed (supported by research of Barth and others) that these taxa are able to discriminate the biologically important signals despite potentially being overwhelmed by the intensity of the ambient white noise/vibration.

It is now possible to consider how the predicted surface vibration of the TBM compares to the 5 characteristics of noise/vibration discussed and illustrated in Figure 2 above.

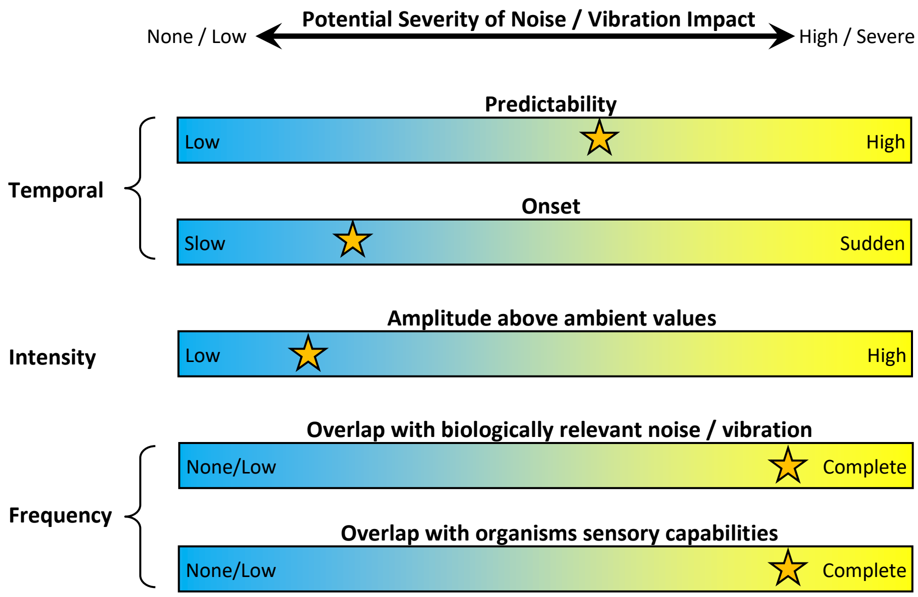


Figure 12: Assessment of TBM vibration characteristics (Yellow stars indicate assessment).

Table 4: Discussion of TBM vibration characteristics.

Temporal	Predictability	The TBM vibration affects any given location for up to 4 weeks with intensity rising from negligible to the maxima (albeit below ambient levels) before falling off. Any unanticipated impact will be temporary in nature lasting a few weeks.
	Onset	The onset of the vibration is gradual potentially taking over 7 -14 days to reach maxima depending on location relative to the TBM
Intensity		Intensity is assessed to be always below mean ambient level.
Frequency	Overlap relevant vibration	N/A due to TBM vibration intensity < ambient
	Overlap sensory capability	N/A due to TBM vibration intensity < ambient

Table 5 below presents the significance of impact assessment. We have chosen to recognise the situation about the vicinity of VP-2 (refer Figure 3 and Figure 11) where predicted vibration exceeds local ambient vibration by 0.1-0.2 mm/sec. In practice we expect the surface vibration to be lower than ambient due to the attenuation effect of the wet ground in that area. Nevertheless we will take the conservative approach and assess the magnitude of impact for this locality as if it were dry ground.

Significance of Impact due to TBM vibration is assessed to be Negligible for most of the Alignment and Moderate in the vicinity of VP-2.

Table 5: Significance of Impact Assessment.

Magnitude Impact	Species Sensitivity	Significance of Impact	Note
Negligible	High	Negligible	For most of the alignment except vicinity of VP-2
Small	High	Moderate	The magnitude of impact is upgraded to Small (from negligible) to address the area about VP-2 where predicted vibration is 0.1-0.2 mm/sec above ambient. This is a conservative consideration because the swampy/moist nature of the area will result in higher attenuation of transmitted vibration energy than was modeled.

Environmental Monitoring and Management for Vibration

Operational Monitoring and Prediction of Vibration

Despite the fact that predicted vibration is always below mean ambient vibration levels there remains a very small possibility due to unanticipated circumstances that vibration could exceed ambient levels at some point along the alignment. It is therefore necessary to regularly monitor the surface vibrations using similar equipment to that used for the nine baseline measurements. With the TBM operating it will be possible to utilise the more rigorous Bornitz equations which require in-field observations of TBM vibration from at least two locations from which ground specific parameters are derived. These parameters are then used to forward compute/predict future vibration magnitudes.

Figure 13: Applying the Bornitz equations to predict vibration.

Note that the more rigorous Bornitz equations could not be used for vibration prediction because the TBM needs to be operating in order to obtain data for the purpose of solving the ground condition parameters **K** and α.

Reacting to Unanticipated High Vibration Prediction

Should the monitoring program predict higher than ambient vibration the prescribed actions are:

- Increase monitoring intensity to verify higher prediction.
- If the surface vibration approaches or exceeds the ambient vibration the cutter head of the TBM should be slowed down by small increments until the monitored surface vibration returns to acceptable range. Reducing the TBM cutter head rotation speed will reduce the amount of source power resulting in a reduced intensity of vibration at the surface (refer Figure 14).
- Use Bornitz equations with updated monitoring data to predict and anticipate when mitigation measures may be relaxed.

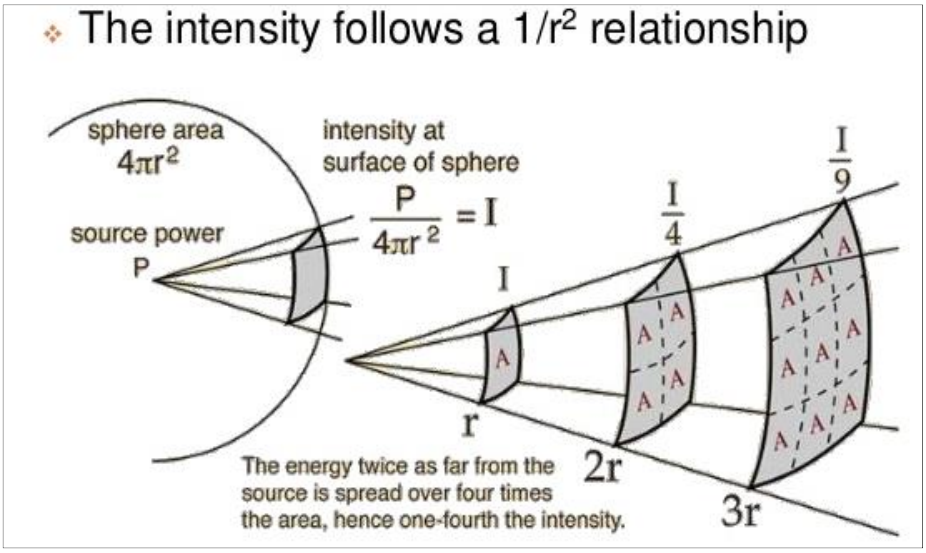


Figure 14: Vibration intensity is a function of source power and distance from TBM.

ERM has over 160 offices across the following countries and territories worldwide

Argentina
Australia
Belgium
Brazil
Canada
China
Colombia
France
Germany
Hong Kong
India
Indonesia
Ireland
Italy
Japan
Kazakhstan
Kenya
Malaysia
Mexico
Mozambique
New Zealand
Norway
Panama
Peru
Poland
Portugal
Puerto Rico
Romania
Russia
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Thailand
The Netherlands
United Arab Emirates
UK
US
Vietnam

ERM's Singapore Office

120 Robinson Road #10-01,
Singapore 068913
T: +65 6324 9636
F: +65 6226 1636

www.erm.com

ERM