Contract CR2005
Provision of Services to Conduct Environmental Impact Study

Environmental Impact Study (Clementi Forest and Maju Forest)

Study Stage: Final

Volume 4 of 5

Submitted by:
AECOM Singapore Pte Ltd

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12. Ground-borne Vibration

12.1 Introduction

This section presents the assessment of vibration impacts arising from the construction and operational phases of the Project on ecologically sensitive receptors within the Study Area. Ground-borne vibration from construction and operational activities may be felt by or cause a disturbance, especially to the ecological receptors in close proximity to the Project.

It should be highlighted that the floral component of biodiversity is not considered to be sensitive to vibration impact. Hence this section only focuses on the impact on the faunal component. Ground-borne noise is generated by the vibration of walls, ceilings and floors inside buildings. Hence ground-borne noise impacts only occur to receptors inside buildings rather than outside in the open. In this assessment, it has been assumed that ground-borne noise impact is only relevant for a [human] receptor inside a building. With the ecological receptors in the Biodiversity Study Area around CRL2 alignment being individuals and populations in the open, ground-borne noise impacts due to construction and operational phases do not apply to these receptors. Hence these have been scoped out from the assessment in this Study.

The critical steps for conducting the ground-borne vibration impact assessment are as follows:

- Define the Study Area (Section 12.2).
- A baseline vibration study to determine the current vibration levels in the Study Area.
- Review secondary baseline vibration monitoring data.
- Establish assessment criteria for the ground-borne vibration impact assessment.
- Identify activities in Project construction and operational phases which may cause significant ground-borne vibration impact to the fauna in the Study Area.
- Identify and classify the sensitivity of the faunal receptors in the Study Area.
- Identify minimum controls to be implemented by the engineering team for managing or avoiding ground-borne vibration impacts in the construction and operational phases.
- Predict ground-borne vibration levels from significant activities on the faunal receptors assuming minimum controls are in place.
- Recommend additional mitigation measures to be implemented if required.
- Determine the overall significance of the residual ground-borne vibration impacts after commitment to and implementation of the mitigation measures; and

12.2 Methodology

The sections below outline the methodology used in the ground-borne vibration impact assessment for both construction and operational phases, including the determination of the Study Area and baseline vibration.

12.2.1 Baseline Vibration Study

The baseline vibration study aims to understand the existing vibration levels at the sensitive receptors. These are used to establish the impact assessment criteria and as a reference for monitoring during the Project's construction, operational or both phases. The baseline study comprises monitoring carried out (primary data collection) and data measured previously for other projects (secondary). The Peak Particle Velocity (PPV) vibration metric has been used throughout.

12.2.1.1 Primary Data Collection (Survey & Sampling)

AECOM conducted baseline ground-borne vibration monitoring at two (2) locations within the Study Area (see Table 12-1), as these were considered representative of the baseline vibration levels of the impacted biodiversity areas.

The ground-borne vibration equipment used to collect the data above is the Svantek 977 with the SV80 single-axis accelerometer. As a recap, the vibration monitoring locations were initially selected at the Inception stage based on the following considerations:

- Identification of the vibration sensitive receptors (VSR) nearest to the construction worksite/ Project footprint comprises the fauna of high conservation value.
- VSRs outside the Study Area (100 m from the construction worksite/ Project footprint areas) were not included in the initial assessment.
- VSRs were not used within areas of ongoing construction works for other Projects.
- The closest VSR to the construction worksite areas were selected; and
- Monitoring was conducted at the ground level to capture the baseline vibration based on the existing geological profile experienced by the VSRs.

Baseline ground-borne vibration levels were monitored over 24 hours at 1-minute intervals. The results of baseline ground-borne vibration monitoring levels are reported in Section 12.5.

12.2.1.2 Secondary Data Collection (Review of Background Data)

Secondary data collection of previously measured data was conducted via desktop research or review of resources provided by the Client and those available in the public domain.

This Study reviewed baseline vibration monitoring data from separate studies carried out by LTA. Since the Project uses baseline data from different sources, the data processing differs. Where available, the Project reviewed and processed the raw data to minimise inconsistencies between data sets. The baseline vibration data are represented by the 99th percentile of the measured PPV values, of which the highest outliers in the data set are removed for this assessment. The baseline vibration monitoring data from secondary data collection are summarised in Table 12-2, which were used to generate the Vibration Intensity Threshold as detailed in Section 12.2.2

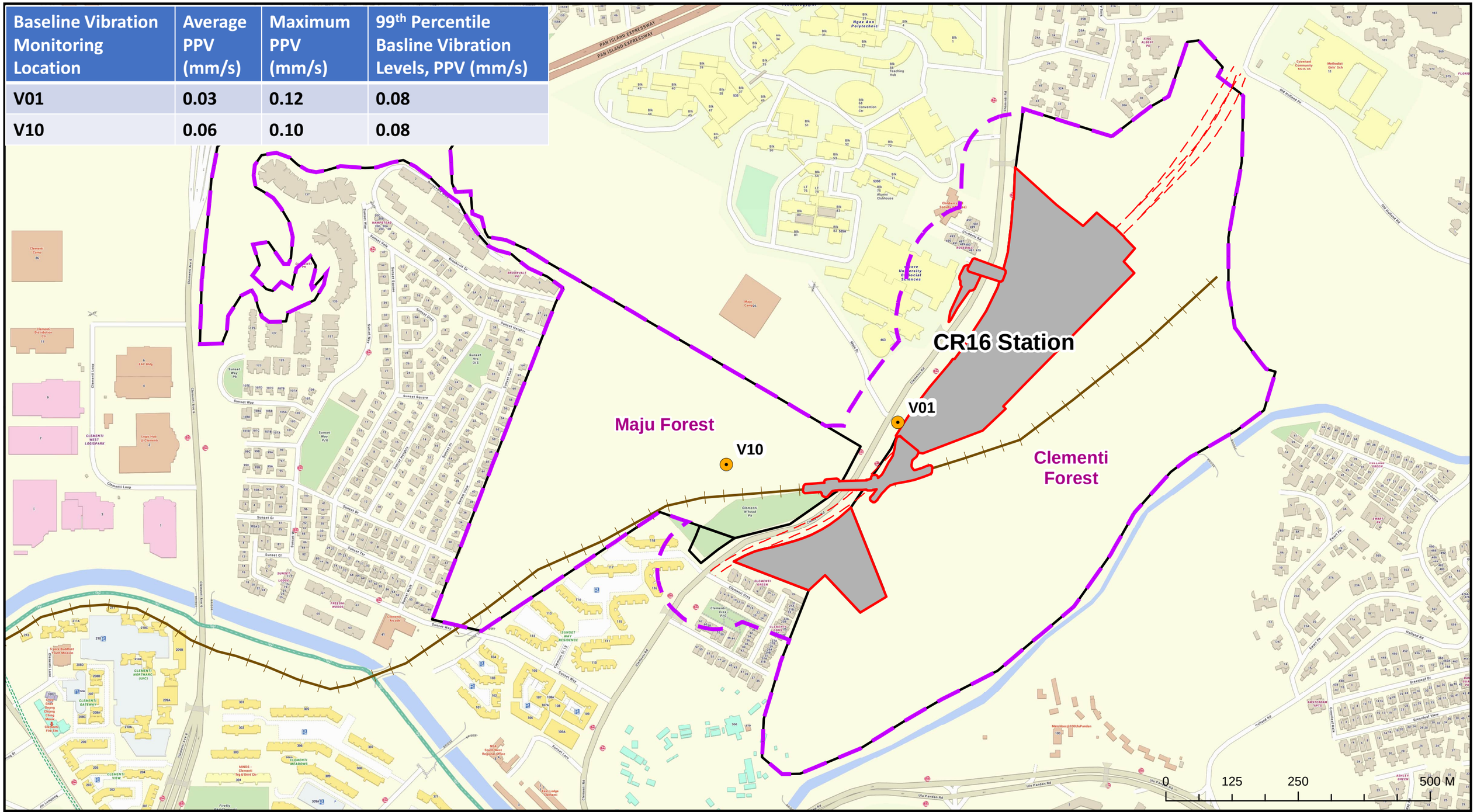
Table 12-1 Baseline Vibration Monitoring Locations

Monitoring Location (see Figure 12-1)	Nearest Construction Worksite Area/Project Footprint	Sensitivity of Receptor	Justification	Photo of Monitoring Location
V01: Within Clementi Forest	CR16 Worksite inside Clementi Forest	Priority 1	Clementi Forest is a construction area of the Project for CR16. The expected baseline ground-borne vibration level is expected to represent the Study Area of a similar geological profile.	
V10: Within Maju Forest	CR16 Station Entrances (Maju Forest)	Priority 1	The monitoring location is within Maju Forest. The expected baseline ground-borne vibration level is expected to represent the Project activities to the west of Clementi road, such as the exit/entrance to the station (CR16).	

Table 12-2 Baseline Ground – borne Vibration Monitoring Data from Secondary Source

Baseline Vibration Monitoring Location	Monitoring Duration	Monitoring Data	Source
Windsor (A2)	13 February – 20 February 2020	Average PPV Level is 0.21 mm/s	Environmental Baseline Report for Proposed Water Pipelines from Bukit Kallang to Upper Thomson Road [R-58]
Inside CCNR	June – July 2019	0.254 – 0.508	LTA's CCNR EIA Report Volume 3 [R-57]
Note: The details for baseline vibration monitoring under LTA's separate study - Ground borne Noise and Vibration Study Report will be provided once available in later stage of the Project.			

Baseline Vibration Monitoring Location	Average PPV (mm/s)	Maximum PPV (mm/s)	99th Percentile Basline Vibration Levels, PPV (mm/s)
V01	0.03	0.12	0.08
V10	0.06	0.10	0.08



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area
- Baseline Vibration Monitoring Location

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

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Project Title :
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Figure Title :
BASELINE GROUND-BORNE VIBRATION MONITORING LOCATIONS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-1	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.2.2 Assessment Criteria

The study assesses the vibration impacts on the structural integrity of the burrows belonging to the fossorial species and the behaviour of the ecologically sensitive receptors in the biodiversity area.

Currently, there are no applicable Singapore or international standards or guidelines that assess the impacts of ground-borne vibration from the construction and operation of the railway on faunal/ ecological receptors. Based on the literature review, the impacts on the behaviour of ecological species and burrow collapse depend on the vibration level and the frequency of vibration.

Some species (burrowing rodents, ground spiders and termites.) use low amplitude and low-frequency vibration as a communication mechanism for fossorial fauna (animals adapted to living underground, often by digging burrows and tunnels). It is assumed that while their typical sensitive frequencies are within the range of frequencies anticipated to be produced by construction activities, the amplitudes of their vibration communications are typically below the baseline vibrations determined during the study. Therefore, fossorial fauna occupying the site can potentially accommodate construction induced vibration through frequency discrimination or otherwise due to the transient nature of construction vibration. This field of study is data deficient in the international arena and, in particular, the local context of Singapore to explore any deducible impact analysis. Therefore, this assessment has not considered the frequency range of construction vibration.

Vibration magnitude can impact a living being in two ways: 1) structural damage to its home/ abode (in the context of fauna, burrows for fossorial mammals), and/or 2) behavioural impact, which includes but is not limited to feeding and mating. While some information on the impact on fauna from vibration levels in other contexts is available, there is limited or no data available to correlate vibration levels to behavioural impact on fauna. Therefore, a criterion has been developed based on the step change of the Human Comfort Criteria

Note that once structural damage occurs, it can potentially lead to fauna mortality. Hence the likelihood aspect of the assessment was removed, and the impact was assessed using intensity. However, behavioural impacts may be temporary or permanent; therefore, the likelihood/duration of impact was important in this case.

Note that there is minimal literature on how vibration may impact fauna. Therefore, this area requires several studies before reliable criteria can be established. A criterion has been developed based on the Human Comfort Criteria step change in the absence of reliable criteria.

12.2.2.1 Structural Integrity Criteria for Burrows

The literature review on the impact of vibration on fauna found insufficient data to provide reliable criteria. The available data are presented in Table 12-3 and include well-established criteria for buildings from the FTA [R-54] and information on the collapse of rat burrows [W-84].

Based on these data, it was determined that a PPV of 10 mm/s causes partial burrow collapse. Thus, a threshold of 5 mm/s was used to screen out activities (i.e., 50% of the threshold identified in the study, activities such as rock breaking and excavation) assessed for structural impact in this study as nature's ecological structures (such as burrows for fossorial species) may be susceptible to vibration damage and collapse, thus entombing the fossorial species. Since the impacts could impact mortality rates of the fossorial species, an assessment using a vibration threshold is most conservative for this Project. The vibration threshold for partial burrow collapse in a desert environment is 10 mm/s PPV [W-84]. Hence, it should be noted that the vibration threshold causes site-specific burrow collapses. To avoid an overly onerous assessment that may be impractical for the Singapore context, This Study suggests taking the 80% value of the upper vibration threshold as the assessment criteria. Thus, a vibration threshold of PPV 8 mm/s is recommended for the assessment.

Table 12-3 discusses the vibration thresholds for structural damage.

Table 12-3 Vibration Thresholds for Structural Damage

Structure of Concern	PPV (mm/s)
Reinforced-concrete, steel or timber (no plaster) [R-54]	13
Engineered concrete and masonry (no plaster) [R-54]	8

Structure of Concern	PPV (mm/s)
Non-engineered timber and masonry buildings [R-54]	5
Buildings are extremely susceptible to vibration damage [R-54]	3
Partial Burrow collapse for Kangaroo Rat in Desert conditions [W-84].	10

12.2.2.2 Behavioural Criteria for Fauna

Vibration affects fauna in several ways (refer to Section 12.4.2). For a detailed assessment, vibration frequency and amplitude must be studied extensively before reliable impact criteria can be adopted across various Projects.

Fauna of conservation species such as straw-headed bulbul (*Pycnonotus zeylanicus*) and Sunda pangolin (*Manis javanica*) have been observed to inhabit both Clementi Forest and Maju Forest (Section 7.4), with a baseline vibration level of PPV 0.08 mm/s at both sites (Section 12.4.2). However, further vibration monitoring and ecological surveys would be required to determine the extent of habitation and the corresponding vibration levels across both areas.

Straw-headed Bulbul
(Source:https://ebird.org/species/sthbul1)

Sunda pangolin (Manis javanica)
(Source:https://www.pangolinsg.org/pangolins/sunda-pangolin/)

Researchers studying the behaviour of laboratory mouse rats (a highly adaptable species) found transient responses in their creatures, including abrupt freezing of motion, contorted postures, and a wide range of responses [W-91]. The vibrations that cause these responses are from 70 to 100 Hz at PPV 1.1 - 2.0 mm/s, lasting between 2 and 10 seconds. Animals did not exhibit any behavioural response or impact when exposed to PPV 0.1 mm/s at 70 to 100 Hz.

Whilst the mouse rats used in this study seem to adapt to human movements and presence, the fauna in the wild are considered to be shyer and may not be used to fluctuations in vibration caused by human intervention such as sudden vibration from piling, rock breaking and excavation as well as bulldozer movements in the vicinity of their home range.

Guidance on human response to vibration in buildings is available from BS 5228-2:2009+A1:2014, BS 6472-1:2008 and BS 6472-2:2008. This guidance advises that humans respond differently according to individual sensitivities and the vibration time (day or night).

Whilst human response and faunal behaviour are not directly comparable, a grading of impact intensity (negligible, low, medium and high) for fauna has been derived based on the step change of human response from BS 5228-2_2009+A1_2014 (human comfort criteria) and the 99th percentile of baseline vibration for the Study Area (Table 12 4). The difference between impact intensity values was also used to derive each vibration threshold curve for the assessment. The following explains how the impact intensity criteria are developed:

- Step 1: Calculate step increment between each threshold of the Human Comfort Criteria (see column 3 of Table 12-4).
- Step 2: Apply the calculated step increment to the baseline of 0.08 mm/s to obtain the absolute values for impact intensity (see column 4 of Table 12-4).

- Step 3: Calculate the difference (delta) between absolute values (see column 5 of Table 12-4).
- Step 4: PPV values below baseline are not assessed. Hence, the first threshold (T1) would start from ambient (see row 2 of Table 12-5).
- Step 5: Add the first delta value to the baseline to obtain T1 (see row 3 of Table 12-5).
- Step 6: Add the second delta value to T1 to obtain T2 (see row 4 of Table 12-5).
- Step 7: For Clementi and Maju Forests, T3 ranges from T2 to Windsor's fourth absolute value (2.49) (see row 5 of Table 12-5).
- Step 8: For Clementi and Maju Forests, T4 ranges from T3 to Windsor's fifth absolute value (4.99) (see row 6 of Table 12-5).

The step-change in vibration intensity thresholds for Clementi Forest and Maju Forest is presented in Table 12-4.

In addition to using these derived criteria to complete the evaluation, the Study considers the known behaviour of the animals, the intensity of behavioural changes, and the extent of impacts on the home range.

Table 12-4 Step Change in Vibration Intensity Thresholds

Based on Human Comfort Criteria BS5228-2: 2009+A1:2014			Criteria for Fauna	
Impact Intensity (Human Comfort Criteria)	Human Response Absolute Level PPV (mm/s)	Relative Change from Previous Intensity Level	Absolute Values Impact Intensity for Clementi Forest and Maju Forest	Difference between Impact Intensity Values for Clementi Forest and Maju Forest
Just perceptible in most sensitive situations	0.14	-	0.08	
Just perceptible in residential	0.3	0.3 / 0.14 = 2.14	0.16	0.08
Complaints in residential	1.0	1.0 / 0.3 = 3.33	0.51	0.35
Intolerable	10	10.0 / 1.0 = 10	2.49 4.99 (Use the same Absolute Values from Windsor)	No difference required, use the same Absolute Values from Windsor

The difference between impact intensity values was used to generate the thresholds and their ranges as seen in Table 12-5.

Table 12-5 Thresholds for Vibration Impact Assessment

Threshold	Range for Clementi Forest and Maju Forest
-	< Ambient (0.08)
T1	Ambient + 0.08 = 0.16
T2	T1 + 0.35 = 0.51
T3	T2 (0.51) to 2.49
T4	T3 (2.49) to 4.99
> T4	> T3 (2.49) to 4.99

While birds tend to move away from more easily and find other sources of habitation, fossorial animals may find it harder to do so and may/ may not adapt to the conditions. With the paucity of information coupled with the myriad behaviours of fauna, vibration impacts are hard to predict. Therefore, as a conservative approach, species deep in the forest have different behaviours than those living near the road. Species may habituate to the road vibration levels for their activities, while species living deep in the forest are more sensitive to vibration levels. This is a conservative approach that may not represent fauna adaptation capability. However, this study erred on caution due to the paucity of information on vibration impacts on fauna.

The sections below detail how this approach was materialised into intensity criteria and likelihood for predicting and evaluating impacts.

12.2.2.3 Determining Impact Intensity

For the construction phase, the assessment in this Report predicts the ground-borne vibration impacts during identified stages of the construction phase. AECOM referred to *BS 5228-2:2009+A1:2014, BS 6472-1:2008, BS 6472-2:2008* and *the FTA Transit Noise and Vibration Impact Assessment Manual (2018*) for guidance in predicting vibration levels of the construction activities for this EIS.

To determine the impact on structural damage to burrows, if the predicted vibration level is greater than PPV 5 mm/s, it may result in severe impacts such as fauna mortality in some cases. Impacts from these construction activities will be assessed in this Study, emphasising the intensity of impact with an objective for it to be kept as low as reasonably practicable below a threshold value of 8 mm/s PPV (see Section 12.2.2.1).

For behavioural impact assessment, the fauna is mobile within the Biodiversity Study Area and neighbouring areas, which are wooded and provide appropriate habitat. The Biodiversity Study Area that faunal species use for their feeding, resting and breeding is their home range. It is anticipated that a high impact intensity over a small fraction of the home range could be considered a low impact as the fauna are mobile. Also, a low impact intensity over a large fraction of the home range could be considered low. Hence these two parameters are not independent, and an impact intensity matrix has been derived for this Study.

Table 12-6 Impact Intensity Assessment for Construction and Operational Vibration

Area Affected (ha)	Impact Intensity				
6 < area	Negligible	Low	Medium	High	High
4.8 < area ≤ 6	Negligible	Low	Medium	Medium	High
2.4 < area ≤ 4.8	Negligible	Low	Low	Medium	High
1.2 < area ≤ 2.4	Negligible	Negligible	Low	Medium	Medium
0 < area ≤ 1.2	Negligible	Negligible	Low	Medium	Medium
Ambient Level	**Ambient to T1**	**T1 to T2**	**T2 to T3**	**T3 to T4**	**> T4**

12.2.3 Prediction and Evaluation of Impact Assessment

The assumptions, predictions and evaluation of impact assessment methodology for the construction and operational phases are presented in this section. Based on the geographical profile study conducted (refer to Section 4.7), the local geological profile along the Project alignment is mainly dominated by GIII to GVI of Bukit Timah Granite towards the north-east of the alignment. SII to SVI Jurong Formation rocks are also present nearer to CR16 station and entrances near Clementi Forest.

The baseline and vibration levels from the construction activities were predicted using coding in ArcGIS. Based on the matrix, the Impact Intensity is identified depending on the ambient surface thresholds and the area of each zone. This would be used to identify Impact consequences and, subsequently, Impact Significance. This Study, therefore, proposes the impact assessment criteria in Table 12-6. For the construction phase, the assessment in this Report predicts the ground-borne vibration impacts during identified stages of the construction phase. AECOM referred to BS 5228-2:2009+A1:2014, BS 6472-1:2008, BS 6472-2:2008 and the FTA Transit Noise and Vibration Impact Assessment Manual (2018) for guidance in predicting vibration levels of the construction activities for this EIS.

Where available, local data have also been used to increase the accuracy of the predictions to account for local ground conditions, including rock breaking and excavation and TBM activities.

To determine and quantify impact amplitude for the operational phase, a separate study carried out by LTA provided inputs on predicted vibration levels from the operation of the trains.

12.2.3.1 Construction Phase

12.2.3.1.1 *Identification of Potential Sources of Impacts*

As described in Section 3.2, there are several potential ground-borne vibration impacts in a typical underground railway construction phase, such as vibratory piling, bulldozing, rotary compacting, and tunnel boring. Simultaneous equipment operation could increase vibration levels substantially, but predicting any cumulative increase is impossible without a detailed construction programme. FTA Transit Noise and Vibration Impact Assessment Manual (2018) [R-54] states that potential effects from construction vibration for each piece of equipment will be assessed individually. Both underground and above-ground construction works are expected at the CR16 worksite.

12.2.3.1.2 *Identification of Sensitive Receptors*

Ecologically sensitive receptors at Clementi Forest and Maju Forest may be impacted by the construction and operation of the Project. Sensitive receptors are identified based on the Study Area (i.e., the Biodiversity Study Area around the construction worksites during the construction phase; the Biodiversity Study Area around the rail alignment during the operational phase). Based on the experience of similar projects and studies on the impact on humans, it is anticipated that effects from construction and operation generated vibration will not generally occur outside the vibration Study Area as the vibration levels by this distance typically tend to dissipate to insignificant levels. If an impact is significant within the entire Study Area, such as rock breaking and excavation, the Study Area was increased to assess and envelope a more expansive area until the impact dissipates to near ambient conditions. Vibration sensitive receptors are sub-categorised into three categories: Priority 1, Priority 2 and Priority 3 (from the most sensitive to the least) based on the known impact of vibration and species sensitivity in the available literature. Urban areas such as houses, and existing roads are not assessed.

12.2.3.1.3 *Understanding of Baseline Conditions*

Primary and secondary data were used to establish the baseline conditions of vibration levels from existing natural and anthropogenic (human) sources. Where adequate baseline monitored data were available, the regression method was used to determine the vibration levels at different distances from the source.

12.2.3.1.4 *Predicting Ground-borne Vibration*

BS 5228-2:2009+A1:2014, BS 6472-1:2008 and BS 6472-2:2008 have been used to guide the assessors on predicting the ground borne vibration impacts during identified stages of construction phases. Some details on this methodology is provided below.

12.2.3.1.4.1 Rock breaking and Excavation

The maximum instantaneous charge (MIC) will be calculated as part of the assessment. For the impact assessment, the depth of the rock breaking source is assumed to be 27 m (at CR16 worksite) below ground surface based on the latest design levels available at the time of writing of this section. The calculated MIC will be the maximum magnitude allowed for the rock breaking such that the ground-borne vibration levels and air over pressure levels will meet the project criteria. For a conservative calculation of the ground-borne noise, the entire transmission path is assumed to be rock, and no damping is applied.

The prediction in the EIS is highly conservative and provides a high-level impact assessment of the vibration impacts on ecologically sensitive receptors. A study [W-86] states that variations in geological profile (as excavation is sequentially carried out) can change the vibration attenuation significantly; the vibration on the ground surface is much smaller than below the ground surface; the vibration wave attenuation of rock is much lower than that in soil.

As mentioned in Section 12.2.2.1, the vibration threshold used for assessing structural integrity is PPV 8 mm/s.

Using the guidance of a trial rock breaking report given by the Client [O-10], this Study predicts the vibration levels emitted for the various MIC and slant distance combinations for the construction vibration impact assessment. The empirical relationship between predicted vibration level, PPV (mm/s), $MIC\ (W)$ (kg) and distance, x (m), is expressed in the equation below:

$$\boldsymbol{PPV = K(\frac{W^a}{R^b})}$$

PPV is the peak particle velocity in millimetres per second (mm/s)

K is the site constant of 700 mm/s

a is the site constant coefficient of 0.7

b is the site constant coefficient of 1.5

W is the Maximum Instantaneous Charge in (kg)

R is the distance to monitoring structure, m

12.2.3.1.4.2 Vibratory Piling

The activities detailed in this section were predicted to exceed PPV 8 mm/s, therefore, this was assessed for structural and behavioural impacts on the fauna.

The study assessed vibratory piling for the mitigated scenarios where temporary and permanent drain diversions were required, and also for the entrances of the CR16 Station. The ground-borne vibration levels caused by vibratory piling were predicted using the steady-state method stated in BS5228-2:2009+A1:2004.

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

Where:

v_{res} is the resultant ppv, in millimetres per second (mm/s)

k_v is the scale factor, where 60.0 is used

δ is 1.4 at steady-state operations

$1 \leq x \leq 100$ m

x is the distance measured along the ground surface, m

12.2.3.1.4.3 Bulldozing

Bulldozing was also assessed for base and mitigated scenarios for Maju and Clementi Forests.

The vibration level from the bulldozer is predicted using the formula from the FTA [R-54]. The bulldozer is generally mobile as it tends to move around the worksite. However, for the construction vibration impact assessment, the bulldozer is assumed to be stationary. The equation is used to predict the vibration attenuation over distance.

$$PPV_{equip} = PPV_{ref} \times (\frac{7.62}{D})^{1.5}$$

Where:

PPV_{equip} is the peak particle velocity of the equipment adjusted for distance, mm/s

PPV_{ref} is the source reference vibration level at 7.62 m, mm/s

D is the distance from the equipment to the receiver, m

Note that the equation is based on point sources with normal propagation conditions.

The activities detailed in this section were predicted to be much lower than PPV 2 mm/s, therefore, assessed for behavioural impacts on the fauna only.

The vibration source levels from typical large and small bulldozers are provided in Table 12-7. It presents the average source level in terms of velocity. The approximate rms vibration velocity level was calculated from the PPV limits using a crest factor of 4, representing a $PPV - rms$ difference of 12 dB. Note that although the table gives one level for each piece of equipment, there is considerable variation in reported ground vibration levels from construction activities. The EIS assessed the vibration impacts from a typical large bulldozer in Section 12.7.

Table 12-7 Vibration Source Level for Construction Equipment from FTA [R-54]

Equipment	PPV at 25 ft (7.62 m), mm/s
Large Bulldozer	2.26
Small Bulldozer	0.08

12.2.3.1.4.4 Vibratory Compactor

The vibration level from the vibratory compactor is predicted using the formula from BS5228-2:2009+A1:2004. The vibratory compactor is used during the construction at CR16 worksite. For the construction vibration impact assessment, the vibratory compactor is assumed to be stationary. The equation is used to predict the vibration attenuation over distance.

$$PPV_{equip} = K\sqrt{n}\left(\frac{A}{x+L}\right)^{1.5}$$

Where:

PPV_{equip} is the peak particle velocity of the equipment, mm/s

K is the scale factor, where 75.0 is used

n is the number of vibrating drums (assuming 1 for this assessment)

A is the amplitude of the vibrating drum, mm, where 2.05 mm is used for High vibration and 0.87 mm is used for Low vibration based on the Sakai 10 tonne compactor

x is the distance from the vibrating drum

L is the width of the vibrating drum

The EIS assessed the vibration impacts from a typical large vibratory compactor. Note that the elevation near the temporary road access differs slightly. However, landfilling was not included in our assessment.

12.2.3.1.4.5 Tunnel Boring / Pipe Jacking

This study assessed the vibration impacts for tunnel boring in CR16 (base and mitigated scenarios). The vertical alignment in the Biodiversity Study Area remains the same for the base and mitigated scenarios controlled by the level below the rock head.

Pipe jacking is required for the pumping's main sewage system which lies at a depth of 7 m. However, there is limited guideline for vibration impact assessment due to pipe jacking. According to the Federal Highway Administration's Road Tunnel Design Guidelines, pipe jacking machines are considered a type of tunnel boring machine, with main differences of machine diameter and best suited ground condition. Since pipe jacking machines can be used for any ground condition, this study assumes the tunnel boring machine method to conduct vibration impact assessment.

TBM FAMILY OF MACHINES (From Kessler & Moore,)		
Machine Type	**Typical Machine Diameters**	**Ground Condition TBM is Best Suited For**
Pipe Jacking Machines	Up to approx. 10 – 13 ft (3 - 4m)	Any ground
Small Bore Unit (SBU)	Up to 6.6 ft (2m)	Any ground
Shielded TBMs	6.6 – 46 ft (2 to 14m) plus	Soft ground above the water table
Mix Face TBMs	6.6 – 46 ft (2 to 14m) plus	Mixed ground above the water table
Slurry TBMs	6.6 – 46 ft (2 to 14m) plus	Coarse-grained soft ground below the water table
EPB TBMs	6.6 – 46 ft (2 to 14m) plus	Fine-grained soft ground below the water table
Hard Rock TBMs	6.6 – 46 ft (2 to 14m) plus	Hard rock
Reamer TBMs	Various	Hard rock
Multi-head TBMs	Various	Various

Figure 12-2 Family of Machines for Tunnel Boring

The ground-borne vibration levels caused by tunnel boring / pipe jacking were predicted using the method stated in BS5228-2:2009+A1:2004. The geological profile is typically not homogamous; however, to simplify the process for the assessment, it is assumed to be. The predicted results will potentially be highly conservative since the formula is applicable for soil types.

$$v_{res} \leq \frac{180}{r^{1.3}}$$

Where:

v_{res} is the resultant ppv, in millimetres per second (mm/s)

$10 \leq r \leq 100$ m

r is the slope distance from the tunnel crown, in metres (m)

12.2.3.1.5 *Classification of Overall Consequence*

A consequence category is derived based on receptor sensitivity and impact intensity, as shown in Section 6.4.2.1. The ground-borne vibration impact assessment uses a matrix method to determine the overall consequence in Table 6-6.

12.2.3.1.6 *Establishing Impact Significance*

To assess the likelihood for various construction phases in this Report, the following reasoning is given to establish the levels assumed. The approximate number of days within a construction timeline is calculated from the start date to the end date included. Refer to Table 12-8 for the likelihood evaluation for construction activities for the construction vibration impact assessment.

Table 12-8 Likelihood Evaluation for Construction Activities for Ground-borne Vibration Impact Assessment

Activity	Frequency of Exposure	Likelihood of Occurrence
Rock Breaking and Excavation	• Work period = 1 • Active vibration period for Machinery = 1 • 1 x 1 = 1	**Certain**
Vibratory Piling	• Work period = 0.5 • Active vibration period for Machinery = 0.5 • 0.5 x 0.5 = 0.25	**Possible**
Bulldozer	• Work period = 0.5 • Active vibration period for Machinery = 0.5 • 0.5 x 0.5 = 0.25	**Possible**
Vibratory Compactor	• Work period = 0.5 • Active vibration period for Machinery = 0.14 • 0.5 x 0.14 = 0.07	**Less Likely**
Tunnel Boring Machine (TBM) / Pipe Jacking	• Work period = 1 • Active vibration period for Machinery = 0.72 • 0.72 x 1 = 0.72	**Certain**

*Bulldozers may be used during groundworks; the actual duration is challenging to predict; this conservative assumption is for the operation to be not higher than 15 % of the construction period.

In the operational vibrational impact assessment, the trains operate between 5.30 am and around midnight daily. Train-induced vibration occurs during the operation unless there is an unplanned or catastrophic event that results in the service's cessation. The duration of the ground-borne vibration impacts experienced by the receptor is only whilst the train is passing. Hence it is overly onerous to assume that the impact is continuous. According to a separate study carried out by LTA [O-17], based on the train's length, speed and frequency, the likelihood of occurrence for a single passage passing by a receptor is **Possible** since the operational vibration is present 23% of the time within 24 hours.

The separate study carried out by LTA [O-19] also studied the combined vibration results of simultaneous trains passing in both directions as an upper limit. It assumed that simultaneously passing trains occurred at all points along the alignment, but only in specific locations. Therefore, the combined vibration levels give an overestimate of impact. A recent study by LTA showed that the maximum levels were similar between one single pass by and a

simultaneous pass-by. Therefore, the vibration impact for two simultaneous trains passing each other is scoped out of the Report.

In this work, the predicted vibration from the train on the nearest track is therefore taken as a representative vibration level for the operational impact assessment.

12.2.3.1.7 *Minimum controls*

The study assumes some standard good practices in the industry as minimum controls contractor will undertake. for the purposes of impact assessment. Refer to Section 12.6 for details on minimum controls during construction and operational phase.

12.2.3.1.8 *Mitigation Measures and Adaptive Monitoring Programme Recommendation*

Based on the impact evaluation outcome, ground-borne vibration mitigation measures will be recommended for the affected ecologically sensitive receptors using the principle of elimination/avoidance, minimisation (substitution), minimisation (engineering controls), minimisation (administrative controls), remedy/repair/restore and compensation/offset. In addition, an environmental monitoring program is proposed to validate the findings of the EIS report. Works will be controlled or re-evaluated if the monitored levels are significantly different from the predicted levels.

12.2.3.1.9 *Establishing Residual Impact Significance*

With the mitigation measures included in the assessment, a residual impact significance using the same significance matrix was re-evaluated. Ideally, this residual impact should be reduced to insignificant levels or as low as reasonably practicable using cost-benefit analysis. An iterative process of suggesting mitigating measures and re-assessing was used where required.

12.2.3.2 Operational Phase

Independent noise and vibration consultants have carried out operational phase impact predictions under a separate study by LTA [O-14]. The findings which are available at the time of writing of this Report are summarised here.

Based on the information from LTA, the general prediction model is described as below:

- Source of vibration.
- Propagation path of vibration; and
- Receptor response.

The vibration source was determined from vibration measured on the track slab of an existing operational underground railway alignment. A tunnel on the MRT Circle Line was used.

A two dimensional (plane strain) finite element model (FEM) was used to estimate the change in the vibration transfer functions from source to receptor due to the different soil characteristics between the measured site and the CLR2 alignment, plus changes in tunnel depth and receptor distance.

The separate study carried out by LTA used GIS to calculate the expected vibration levels (in decibels, VdB) at the surface level for different tunnel depths along the alignment, based on:

- The horizontal and vertical alignment details from drawings reference PCRLSWD-PP9400, dated 29 January 2021, provided by LTA. It should be noted that LTA has calculated vibration levels based on a maximum tunnel depth of 50 m for this Report.
- Referring to Section 4.7, the geological information for the Project describes the two main formations along the alignment:
    - Bukit Timah Granite Formation, partly with Kallang Formation on the top layer; and
    - Jurong Formation, partly with Kallang Formation on the top layer.
- Twin bore tunnels.
- Non-ballasted track.

- Standard rail fastening with static stiffness of 21 kN/mm[8].
- Other train characteristics include:
    - Number of cars: 8
    - Total train mass (tare condition): 40 ton
    - Unsprung mass: 7.2 ton

As part of the separate study carried out by LTA, validation measurements were conducted to compare the results of the modelling with the measured data:

- Trackside and surface measurements for two locations and the Circle Line - PSA Club (Telok Blangah) on Jurong Formation and Singapore Polo Club (Caldecott) on Bukit Timah Granite Formation.
- Surface measurement at one location along Circle Line - University Road Park.

Based on the predicted vibration levels from the separate study carried out by LTA, this Study carried out an environmental impact assessment on the ecological receptors identified at Maju Forest and Clementi Forest (i.e. Biodiversity Study Areas) according to the impact evaluation matrix stated in Section 6.4.2. The assessment results are presented and discussed in Section 12.9.2.

12.3 Potential Sources of Ground-borne Vibration Impacts

12.3.1 Construction Phase

The potential sources of ground-borne noise and vibration impacts during the construction phase are listed in Table 12-9.

Table 12-9 Potential Sources of Ground-borne Vibration Impacts during Construction Phase

Construction Activity	Associated Impacts
• Compacting of concrete using the vibrator equipment • Piling works for Station and entrances • Tunnel boring / pipe jacking using the TBM • Rock breaking and excavation • Bulldozer for worksites • Heavy construction vehicles such as bulldozers and vibratory compactors • Other Construction Equipment • Stationary equipment with diesel engines	• Structural Damage • Ecological Foraging Behaviour

Based on the review and the evaluation of the proposed construction methods for CRL2, the critical sources of construction induced vibration are rock breaking and excavation, piling and tunnel boring works. The associated ground-borne vibration impacts from these activities works may cause disturbance to the ecological foraging behaviour of the receptors near the construction area.

12.3.1.1 Rock breaking

Rock breaking works will potentially be carried at CR16 worksites. When a charge is detonated in a rock breaking hole, much of the energy is used to break up the rock and displace it from its original position. However, there is always some energy left over and this is converted into vibration that travels away from the rock breaking area through the ground. As the ground-vibration attenuates with increasing distance away from the rock breaking-hole. The ground-borne vibration level is controlled by the rock breaking design, the distance to the rock breaking, charge weight and the intervening geology.

Rock breaking induced vibration is impulsive in nature and the duration of each event is dependent on the magnitude of the charge. The variable effects of a rock breaking include the number of delay intervals and charge quantities, the method of rock breaking, separation distance between the charge and the rock breaking site and the geological profile between the receptors and the rock breaking site. It is typically measured in terms of unfiltered time histories of three component particle velocities from which the peak values can be identified. Typically, soft

[8] Baseplate pads are installed under the baseplate to reduce vibrations caused by wheel and track irregularities.

ground conditions (clay, sand, alluvial) transmit less ground-borne vibration compared to hard ground conditions (granite, rocks). Vibration associated with breaking is predominantly due to the air overpressure exciting the building elements of receptor buildings rather than ground-borne vibration.

12.3.1.2 Tunnel Boring / Pipe Jacking

Tunnel boring will occur along the entire alignment of CRL2 while pipe jacking will occur for utility works. Ground-borne vibration will potentially be prominent on the overlying ground surface and buildings. Typical sources of ground-borne vibration during the tunnelling process include tunnel boring machines, road headers and excavators, tunnel segmental lining placement and hydraulic drilling.

12.3.1.3 Vibratory Compactors

Vibratory compactors will be used for temporary road diversions. The construction ground-borne vibration impacts generated from vibratory compactors will depend on the type of compactor use (low or high). Generally, to keep the vibration levels low during construction activities, a low amplitude vibratory compactor is preferred. For the purpose of this study, assessments were conducted for both low and high vibratory compactors.

12.3.1.4 Heavy Construction Vehicles

Traffic vibration is mainly due to heavy vehicles passing at relatively high speed on a road with an uneven surface profile. Interaction between wheels and road surface causes a dynamic excitation which generates waves propagating in the soil and to nearby sensitive receptors. The road induced ground-borne vibration impacts is usually minimal unless there are frequent potholes in the road and the heavy construction vehicles are travelling at high speed to and from the worksites. In this case, high vibration activities such as piling works will generate more ground-borne vibration compared to heavy construction vehicles.

12.3.2 Operational Phase

During operational phase, the vibration sources will potentially be the operation of the CRL2 alignment and traffic in the Study Area. Train induced vibration is mainly caused by the roughness of the wheel and rail. Vibration from operating trains is also dependent on the resonance frequencies of the train suspension system and track support system. These mechanical systems have resonances that results in increased vibration response

Traffic vibration is mainly due to heavy vehicles passing at relatively high speed on a road with an uneven surface profile. Interaction between wheels and road surface causes a dynamic excitation which generates waves propagating in the soil and to the foundations of nearby sensitive building receptor structures. During operational phase, the sources of vibration are presented in Table 12-10.

Table 12-10 Potential Sources of Environmental Impacts during Operational Phase

Operation Activity	Potential Source of Impacts	Potential Associated Impacts
• CRL2 Alignment • Road Traffic	• Ground-borne vibration • Structure-borne vibration	• Ecological Foraging Behavior disruption and potential displacement over a period of time

Based on the land use of the Project site, the presence of heavy vehicles at relatively high speed will be rare. Given that the construction of roads in Singapore will relatively have an even surface profile, it is unlikely that the road traffic will cause high ground-borne vibration levels in the Project site and will not have a significant impact on nearby sensitive receptor buildings and ecological receptors. Section 12.9.2 discusses the impact prediction and evaluation during the operational phase.

12.4 Identification of Ground-borne Vibration Sensitive Receptors

Ecologically sensitive/ faunal receptors within the Study Area may be impacted by the construction and operation of the Project. It is anticipated that effects from construction and operation generated vibration will not occur outside the vibration Study Area based on the experience of similar projects on the impact on humans. If an impact is significant within the whole Study Area, this area is typically increased to assess and envelope a wider area.

In addition, since there are urban patches of land nearby which may not be suitable to support the presence of fauna, this Study will assess these regions as “Not Assessable”.

12.4.1 Habitat Receptor Sensitivity to Ground-borne Vibration

A desktop review of available studies was conducted to categorise the various ecological receptors in the Study Area. The species are first evaluated for their sensitivity towards ground-borne vibration and further classified into Priority 1, Priority 2 and Priority 3 based on their Conservation Significance.

The habitats are classified into Priority 1 (secondary forests), Priority 2 (forest fragments) and Priority 3 (Clementi Park and managed vegetation), with Priority 1 being the most sensitive. All urban areas such as houses, and existing roads are not assessed as they are not a natural stronghold for fauna.

12.4.2 Fauna Receptor – Species Sensitivity to Ground-borne Vibration

The prioritisation of the ecological sensitive receptors within the ecological sensitive sites follows the approach listed in order below:

1. The actual presence or likely presence (from records) from faunistic field assessment conducted
2. The conservation significance or importance of the identified ecological receptors
3. The ecological receptor's likely sensitivity to vibration impacts

Based on faunistic field assessment within the ecological sensitive sites, the receptors of concern in line with the biodiversity section are discussed below.

The full list of ecological sensitive receptors are shown in Appendix O.

12.4.2.1 Clementi Forest

The field assessment documented 210 species, including three species that are not listed as probable species (two birds and one reptile). This recorded assemblage was dominated by bird (75) and butterfly (49) species (refer to Table 12-11). Amongst these, 18 species of conservation significance were also recorded, including two species of non-probable occurrence (Table 7-27).

12.4.2.2 Maju Forest

The field assessment recorded 131 species with more than half of the recorded assemblage dominated by bird (48 species) and butterfly (33 species) (refer to Table 12-12). A total of 10 species of conservation significance were recorded (Table 7-15).

Table 12-11 Receptor Importance at Clementi Forest

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Odonate	*Gynacantha bayadera*	Small Duskhawker	Vulnerable	Least Concern	Priority 1
Odonate	*Copera vittata*	Variable Featherlegs	Vulnerable	Least Concern	Priority 1
Butterfly	*Borbo cinnara*	Formosan Swift	Endangered	Not Assessed	Priority 1
Butterfly	*Troides helena cerberus*	Common Birdwing	Not assessed; CITES protected (Appendix II)	Vulnerable	Priority 1
Reptile	*Dogania subplana*	Malayan Forest Softshell Turtle	Critically Endangered	Least Concern	Priority 1
Bird	*Nisaetus cirrhatus*	Changeable Hawk-Eagle	Endangered	Least Concern	Priority 2
Bird	*Spilornis cheela*	Crested Serpent Eagle	Critically Endangered	Least Concern	Priority 2
Bird	*Anthracoceros albirostris*	Oriental Pied Hornbill	Critically Endangered	Critically Endangered	Priority 2
Bird	*Vanellus indicus*	Red-wattled Lapwing	Endangered	Least Concern	Priority 1
Bird	*Chrysococcyx xanthorhynchus*	Violet Cuckoo	Endangered	Least Concern	Priority 2
Bird	*Gallus gallus*	Red Junglefowl	Endangered	Least Concern	Priority 1

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Bird	*Loriculus galgulus*	Blue-crowned Hanging-parrot	Endangered	Least Concern	Priority 2
Bird	*Psittacula longicauda*	Long-tailed Parakeet	Vulnerable	Not Assessed	Priority 2
Bird	*Pycnonotus zeylanicus*	Straw-headed Bulbul	Endangered	Critically Endangered	Priority 2
Bird	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 2
Bird	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 2

Table 12-12 Receptor Importance at Maju Forest

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Bird	*Accipiter trivirgatus*	Crested Goshawk	Critically Endangered	Least Concern	Priority 2
Bird	*Nisaetus cirrhatus*	Changeable Hawk-Eagle	Endangered	Least Concern	Priority 2
Bird	*Gallus gallus*	Red Junglefowl	Endangered	Least Concern	Priority 1
Bird	*Loriculus galgulus*	Blue-crowned Hanging-parrot	Endangered	Least Concern	Priority 2
Bird	*Pycnonotus zeylanicus*	Straw-headed Bulbul	Endangered	Critically Endangered	Priority 2
Bird	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 1
Bird	*Psittacula longicauda*	Long-tailed Parakeet	Not Assessed	Vulnerable	Priority 2
Reptile	*Pseudorabdion longiceps*	Dwarf Reed Snake	Least Concern	Endangered	Priority 1
Mammal	*Manis javanica*	Sunda Pangolin	Critically Endangered	Critically Endangered	Priority 1

This section presents the literature review of the fauna species sensitivity towards ground-borne vibration.

Species that prefer such burrow habitats include the golden mouse, dusky-footed wood rat, brush mouse and pinion mouse as the presence of predators such as foxes, racoons, skunks and coyotes leave their habitats due to ground-borne vibration within the road surface [W-41]. Burrowing and ground-dwelling mammals are considered highly vibration sensitive (Šklíba et al., 2008). Therefore, this study considers this behaviour to be representative of small mammals that move on land and are assumed to experience high sensitivity to ground-borne vibration for this assessment.

About invertebrates, bees often build hives on trunks and in hollows, which may be sensitive to vibrations. Bees are capable of hearing airborne sounds (Krichner et al., 1991) and so are auditory sensitive. They also use their systems of vibration to communicate within the hive.

Adult odonates are not ground-dwelling and therefore not vibration-sensitive. Though most aquatic invertebrates are less impacted by low-frequency noises characteristic of anthropogenic sources, as macropredators odonate nymphs have prey (tadpoles and fishes) that may be behaviourally impacted by low-vibration sounds (Nedwell et al., 2003; Castaneda et al., 2020) and as such are treated as vibration-sensitive.

Lepidopteran larvae (caterpillars) are known to respond to low-frequency vibrations to avoid insect predators and parasites (Taylor, 2009). Some adult butterflies are known to make use of airborne sounds to avoid predators (Fournier, 2011). Night-flying butterflies and moths are also known to be highly dependent on hearing to avoid bat predation (Yack & Fullard, 2000). As such, lepidopterans are considered highly vibration sensitive species, although such species are usually most attuned to the high frequency sounds produced by bats.

All fully aquatic species are known to be negatively impacted by low-frequency vibrations (Nedwell et al., 2003; Castaneda et al., 2020). As such, all aquatic species are considered high vibration-sensitive species.

Tadpoles are treated together with other aquatic species and are regarded as vibration sensitive. Ground-dwelling frog species are vibration-sensitive.

Snakes, in general, are deaf as they do not have ears, thus it is usually vibration energy that impacts the behaviour of these creatures. Therefore, they are startled by sudden/fast movements sources causing vibrations that propagate through the ground to them.

Malayan Colugo (*Galeopterus variegatus*) are nocturnal mammals and spend the majority of their lives in trees and move by gliding from tree to tree. There is insufficient research or literature on the impacts of vibration on these animals. [P–57] A study was conducted by radio tracking 32 lemuroid ringtail possum (*Hemibelideus lemuroides*), and movement monitored at a narrow 7 m wide road and an 80 m wide powerline, However, no possums were observed crossing roads or the powerline corridor at ground level or residing in the intervening matrix, more due to loss of canopy connectivity which has a negative impact on their movements. In consideration that they spend the majority of their time above ground on trees, these creatures will potentially experience low sensitivity to ground-borne vibration for this assessment.

There is insufficient research or literature on the impacts of vibration on the Greater Mouse-eared Bats. However, a study was conducted to study piling induced vibration impacts on Pilbara Leaf-Nosed and Ghost Bat. [P–58] and [P–59]. A Study was conducted on a drill that penetrated a cavity at the rear of an unoccupied cave in Pilbara region of Western Australia. Vibration levels of 0.4 - 0.6 mm/s and noise level of 60 dB(A) were recorded at 50 m away and this unlikely cause the bats to abandon the cave. Roosting bats are negatively impacted by vibrations and are considered vibration-sensitive (Voigt & Kingston, 2016). In consideration of the above, this Project assumes that the bats studied in this Study will behave similarly to the above thus these fauna species will potentially experience high sensitivity to ground-borne vibration.

Ground-dwelling species of birds are considered highly sensitive towards vibration. Resident swiftlets which breed and roost in caves and culverts are also considered sensitive to vibrations (Chia et al., 2019).

Terrestrial bird species like the Red Junglefowl (*Gallus gallus*) is usually found in a mix both open ground and dense vegetation. Such places may be around human activities or living areas and it will also travel through forests to other clearings or food sources. Assuming that these species are accustomed to movements in the ground, they are less likely to be impacted by ground-borne vibration unless the ground-borne vibration levels become significantly higher than what they are used to.

Aerial birds are known to live the majority of their lives in flight thus they are potentially less impacted by construction induced vibration. Hence, these birds will potentially experience low sensitivity to ground-borne vibration for this assessment.

Arboreal birds are known to spend most of their time in trees and dense foliage. They will perch and roost in trees as well as forage in holes and tree cavities looking for insects and seeds. Little research or studies have shown the impacts of ground-borne vibration on them. Considering their behaviour, these birds will potentially experience low sensitivity to ground-borne vibration for this assessment.

There have been studies on exposure of benthic invertebrates to sediment vibration and studies on exposure of invertebrates to substrate-borne vibrations conducted. However, there is not sufficient evidence to suggest how ground-borne vibration impacts the behaviour of non-benthic invertebrates hence it is assumed that the species identified for the assessment will potentially experience low sensitivity to ground-borne vibration for this assessment.

Spiders of all kinds have long been known to be sensitive to vibratory stimulation since vibrations on their webs or foliage alert them to the presence of prey. If the vibrations are within a defined frequency and amplitude range, spiders attack the vibration source. Vibrations with characteristics outside these biologically meaningful ranges do not induce an attack response. There is insufficient evidence to suggest that the ground-borne vibration emitted during the construction and operation will be within the biologically meaningful ranges. Considering the above, this assessment assumes that the species identified for this assessment will have similar behaviour and will potentially experience moderate sensitivity to ground-borne vibration for this assessment.

Studies have been conducted on the behaviour of vibration energy in water bodies caused by underwater drilling and breaking. Based on the research, propagation of the vibration energy is frequency dependant as the medium profile of land and water is not the same. There is research that shows aquatic vertebrates have a lateral line that

they use to sense vibrations in the water and perceive their surroundings. Thus, this assessment assumes that the fishes will potentially experience high sensitivity to ground-borne vibration for this assessment.

Airbreathing walking catfish like the *Clarias cf. batrachus* and swap eel *Monopterus iavanensis* can move overland over short distances. There is insufficient evidence to suggest the magnitude of ground-borne vibration impacts on them. However, in consideration of their behaviour on land, the assessment assumes that they will potentially experience high sensitivity to ground-borne vibration for this assessment.

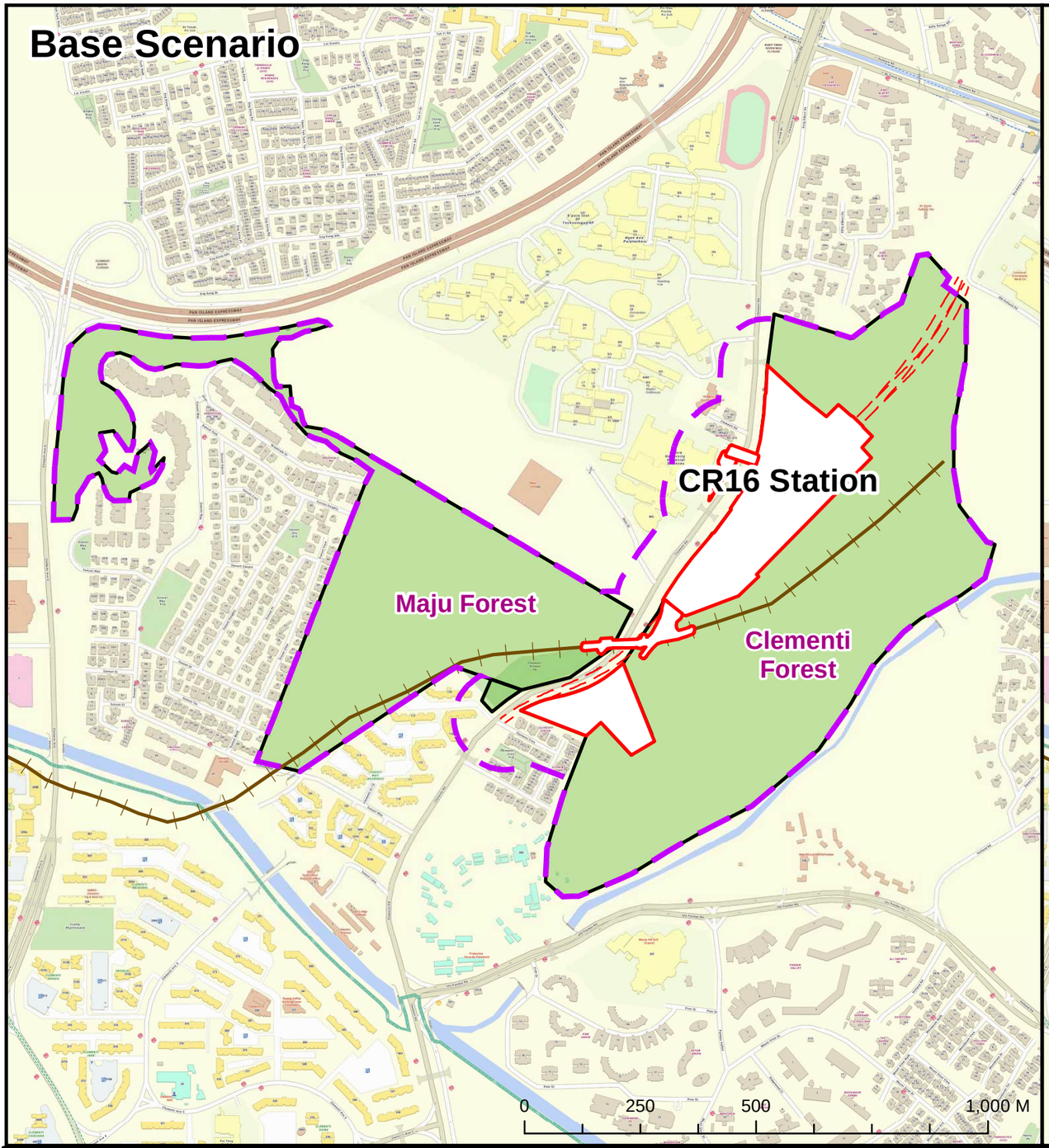
During the dry season, snakeheads like the Channa striata can burrow in the mud for survival. There is insufficient evidence to suggest the magnitude of ground-borne vibration impacts on them. However, in consideration of their behaviour on the wetland, the assessment assumes that they will potentially experience high sensitivity to ground-borne vibration for this assessment.

The vibration thresholds (PPV, mm/s) from the above literature review are summarised in Table 12-13.

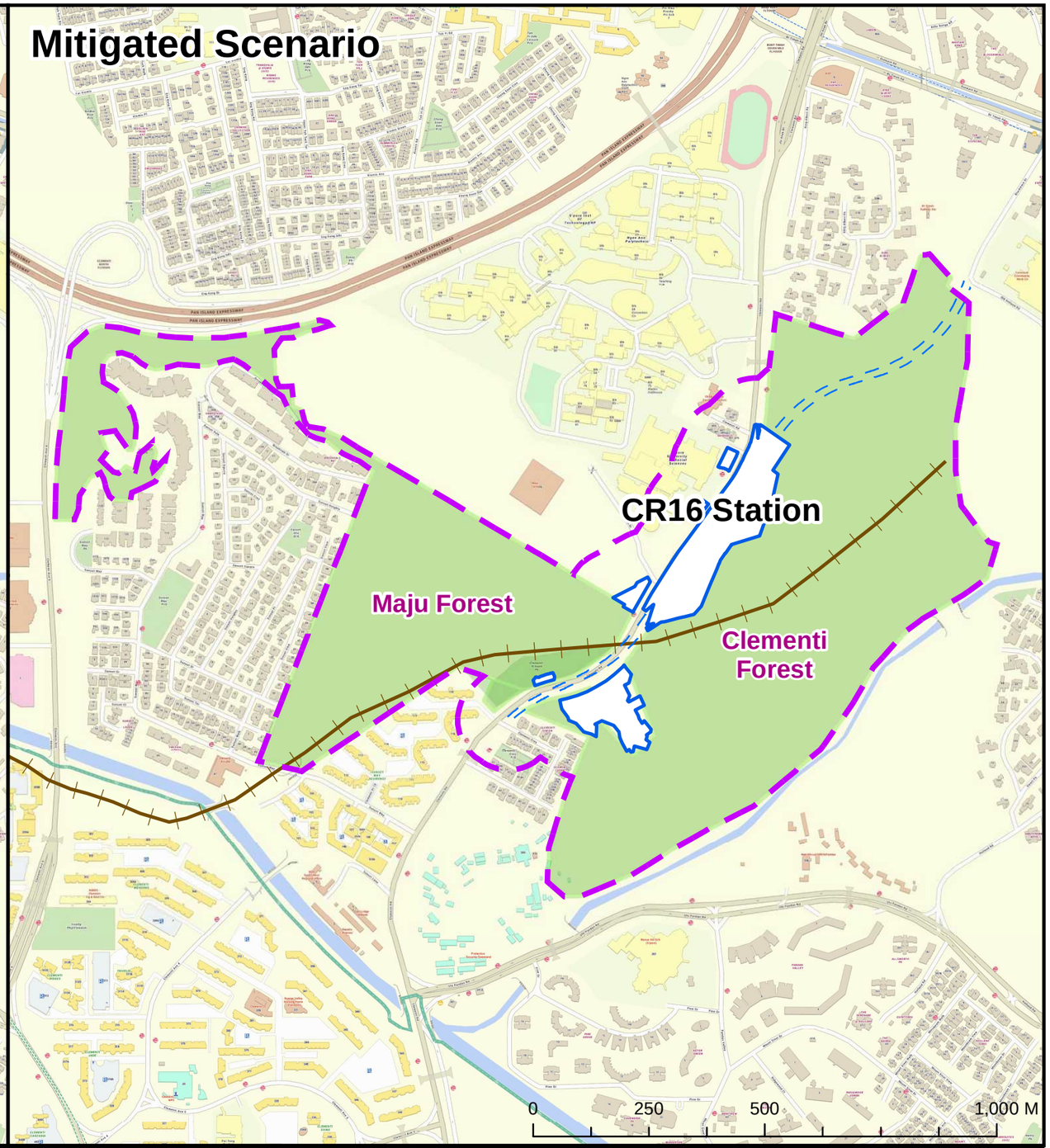
Table 12-13 Summary of Vibration Thresholds (PPV, mm/s) from Literature Review

Receptors	Vibration Thresholds, PPV, mm/s
Bees	0.02
Caterpillars (*Lipidopteran larvae)*	0.61
Fish	0.531 - 1.11
Frogs	0.00159
Pilbara Leaf-Nosed and Ghost Bat	0.40 - 0.60
Snakes	0.0016
Rats	0.30 – 9.70
Mice	0.40 – 1.80
Pigs	8.80
Tortoise	10.00 – 25.40
Rhesus monkeys	52.00

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
GROUND-BORNE VIBRATION SENSITIVE ECOLOGICAL RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-3	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

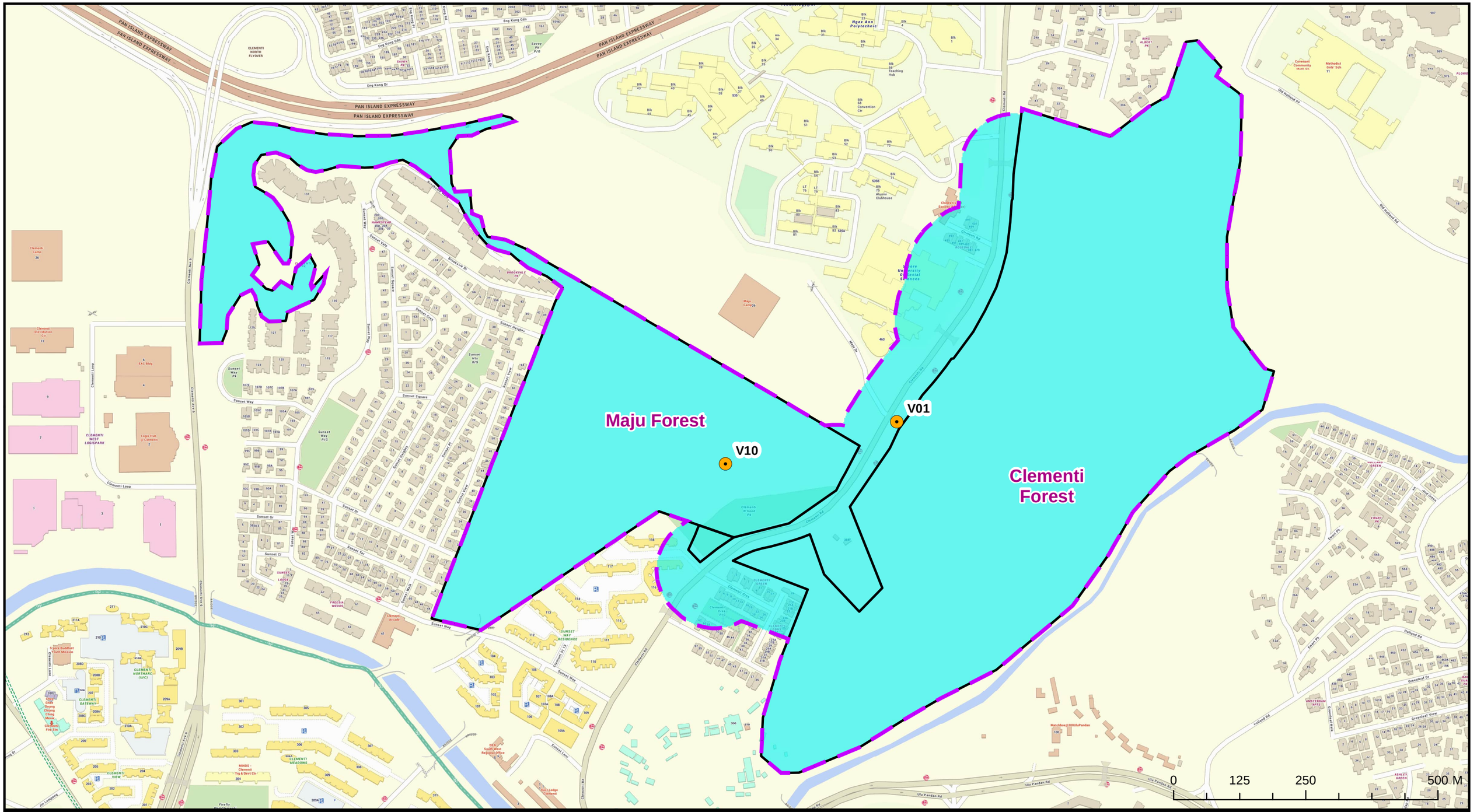
Note: Source of basemap - OneMap

12.5 Baseline Ground-borne Vibration Levels

Baseline ground-borne vibration monitoring has been conducted on two (2) locations (see Figure 12-4) which are in proximity to the sensitive receptors and are representative of the baseline vibration levels of the sensitive receptors. The 99th percentile baseline ground-borne vibration monitoring results are summarised Table 12-14. A detailed baseline ground-borne vibration monitoring report is presented in Appendix P.

Table 12-14 99th percentile Baseline Ground-borne Vibration Monitoring Results

Baseline Vibration Monitoring Location	Date & Time	99th Percentile Baseline Ground-borne Vibration Levels mm/s
V01: Within Clementi Forest	14th June 2020– 15th June 2020	0.08
V10: Within Maju Forest	28th April 2022 to 7th May 2022	0.08



Legend

- Baseline Vibration Monitoring Location
- Vibration Study Area
- Biodiversity Study Area

Predicted Vibraiton Level, PPV (mm/s)

- 0.08

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
PREDICTED AMBIENT VIBRATION LEVELS AT MAJU AND CLEMENTI FOREST

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-4	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.6 Minimum Control for Potential Impacts

12.6.1 Construction Phase

This section proposes minimum controls, or standard practices commonly implemented in Singapore for similar construction activities, that are assumed to be implemented for impact assessment. The minimum control measures are summarised Table 12-15

Table 12-15 Minimum Controls (Ground-borne Vibration)

Potential Source of Impacts	Minimum Controls
• Compacting of concrete using the vibrator equipment; and • Tunnel boring using the TBM. • Heavy construction vehicles such as bulldozers, vibratory compactors and pipejacking • Other Construction Equipment • Stationary equipment with diesel engines	• Conduct dilapidation surveys of burrows when the predicted vibration levels approach or exceed a level of 80 % of the lowest criteria, in this case, ecological criteria. • Use low vibration equipment and construction techniques. • Limiting the rotational speed of the cutting surface of the TBM or the thrust force and the progress rate of the tunnel boring. • See minimum controls in rock breaking and excavation in Section 12.5. • Impose and signpost a maximum speed limit of 25 km/hr on paved or surfaced haul roads and 15 km/hr on unpaved haul roads and work areas within the worksite, as well as local access roads leading to the worksite.

12.6.1.1 Utility Works

The construction activities for utility work emit high vibration levels, thus the activities may potentially cause significant vibration impacts to the receptors. Therefore, assessment was conducted and shown in Section 12.8.

12.6.1.2 Tri-axle Trucks

In general, tri-axle trucks, compared to tandem trucks, have an extra axle and suspension, allowing better loading on the frame and giving additional stability. Therefore, the load they carry in each trip is higher than the standard truck and can significantly minimise the number of truckloads required along this road during the construction phase. Thus, as the tri-axle truck travels along the access roads, the vibration caused by the wheels and road surfaces can be minimised more due to the reduction in the number of trips. As per the discussion with LTA, there is also a need for the traffic controller to release 3 trucks at a time.

12.6.1.3 Tunnel Boring / Pipe Jacking

Mitigation measures for tunnel boring are limited. If the project requirements permit, it might be possible to control the vibration levels at source by limiting the rotational speed of the cutting surface of the TBM or the thrust force and the progress rate of the tunnel boring. If circumstances do not permit the above, other mitigation measures include limiting the working hours for tunnel boring and pipe jacking and developing an engagement community programme will be considered. Lubricant injection can also help to mitigate vibration by reducing frictional resistance and jacking force.

12.6.2 Operational Phase

This section proposes minimum controls or standard practices commonly implemented as ground-borne vibration control measures. A summary of minimum control measures is presented in Table 12-16. Concrete material/density will be determined by the Contractor at a later stage.

Table 12-16 Minimum Control Measures

Minimum Controls
Train, track and tunnel design
Maintenance of vertical track alignment at the relevant longitudinal wavelengths
Maintenance of roughness of the rail head and wheel thread at the relevant longitudinal and circumferential wavelengths, respectively.
Maintenance of resilient elements in track construction, e.g. rail pads
Maintenance of rail joints, switches and crossings.

12.7 Prediction and Evaluation of Ground-borne Noise and Vibration Impacts

This section details the vibration impact assessment for construction and operational activities on the biodiversity areas Clementi Forest and Maju Forest. The predicted vibration levels from the activities are assessed for the following:

1. Impacts on the structural integrity for the burrows of fossorial species (where applicable).
2. Behavioural impacts on the ecologically sensitive receptors.

12.7.1 Construction Phase (Base Scenario)

The base case here is the worksites proposed at the onset of the construction of the alignment and station.

12.7.1.1 Structural Integrity of Burrows and Impacts on Fauna (Base Scenario)

Based on the baseline fauna survey, fossorial species were sighted and recorded at the Biodiversity Study Areas – Clementi Forest and Maju Forest. The study predicted vibration levels of various construction activities for the assessment.

The construction activities were assessed for the base scenario which is summarised in Table 12-17. Out of the six assessments, only rock breaking and excavation had an exceedance of 8.23 mm/ from the vibration threshold of 8 mm/s, thus burrow collapse may occur resulting in the entombment of the impacted fauna, causing mortality.

As the depth of the source becomes deeper than 27 m below ground, the predicted vibration levels decrease and eventually have fewer exceedances against the vibration threshold level for partial burrow collapse. Nevertheless, for precautionary purposes and to further ensure no damage/collapse of burrows, the appointed Contractor should hold conversations with a wildlife expert to ensure that the impact's magnitude and duration are appropriate. It should be noted that minimal or no ecological use of the worksite happens during the active construction because of high levels of human activity. This type of communication can prove beneficial for controlling the impact and learning about the local fauna and their behaviour from this activity. The study recommends using control over the threshold value in the Biodiversity Study Areas accompanied by constant monitoring.

Table 12-17 summarises the assessment of vibration exceedances against the PPV, 8 mm/s vibration threshold.

Table 12-17 Summary of Maximum Predicted PPV for Construction Activities (Base Scenario)

Construction Worksite and Activities	Maximum Predicted PPV (mm/s)		Exceedances of Vibration Threshold for Partial Burrow Collapse, mm/s	
	Maju Forest	Clementi Forest	Maju Forest	Clementi Forest
Rock Breaking and Excavation	3.4	16.2	-	8.2
Vibratory Pile Driver Entrances	0.1	2.9	-	-
Bulldozing	1.5	1.5	-	-
Tunnel Boring Machine (Hypothetical Overall[9])	1.3	1.9	-	-
Tunnel Boring Machine Spot 1	0.8	1.7	-	-
Tunnel Boring Machine Spot 2	0.02	1.9	-	-

12.7.1.2 Behavioural Impacts on Fauna (Base Scenario)

The assessments in this section focus on the behavioural impacts on Priority 1 fauna receptors within Clementi Forest and Maju Forest. A summary of the impact significances and behavioural impacts can be seen in Table 12-18 and from Figure 12-5 to Figure 12-10.

[9] The hypothetical overall of TBM was assessed as full affected alignment. It should be noted that in reality, the tunnel boring machine will only bore section by section along the alignment at a rate of 7 m/ day. Thus, this assessment also identified the key spots for detailed hotspot analysis of TBM passage impact on fauna at any particular time.

Table 12-18 Predicted Impact Significances and Behavioural Impacts of Construction Activities for Base Scenario

Construction Worksite and Activities	Base Scenario Impact Significance	
A1-W2 Worksite	**Maju Forest**	**Clementi Forest**
Rock Breaking and Excavation	Moderate – Major	Moderate – Major
	Impacted Area (ha)	
	Moderate, 10.4 Major, 2.4	Moderate, 26.9 Major, 7.2
Vibratory Pile Driver Entrances	Minor	Minor
Bulldozer	Negligible - Moderate	Minor - Moderate
	Impacted Area, ha	
	Moderate, 0.2	Moderate, 3.4
Tunnel Boring Machine (Hypothetical overall[10])	Minor – Major	Minor – Major
	Impacted Area, ha	
	Moderate, 5.4 Major, 0.5	Moderate, 16.6 Major, 8.8
Tunnel Boring Machine at Spot 1	Minor – Moderate	Minor - Moderate
	Impacted area, ha	
	Moderate, 2.1	Moderate, 4.6
Tunnel Boring Machine at Spot 2	NA	Minor – Moderate
	Impacted Area, ha	
	NA	Moderate, 4.6

Summary:

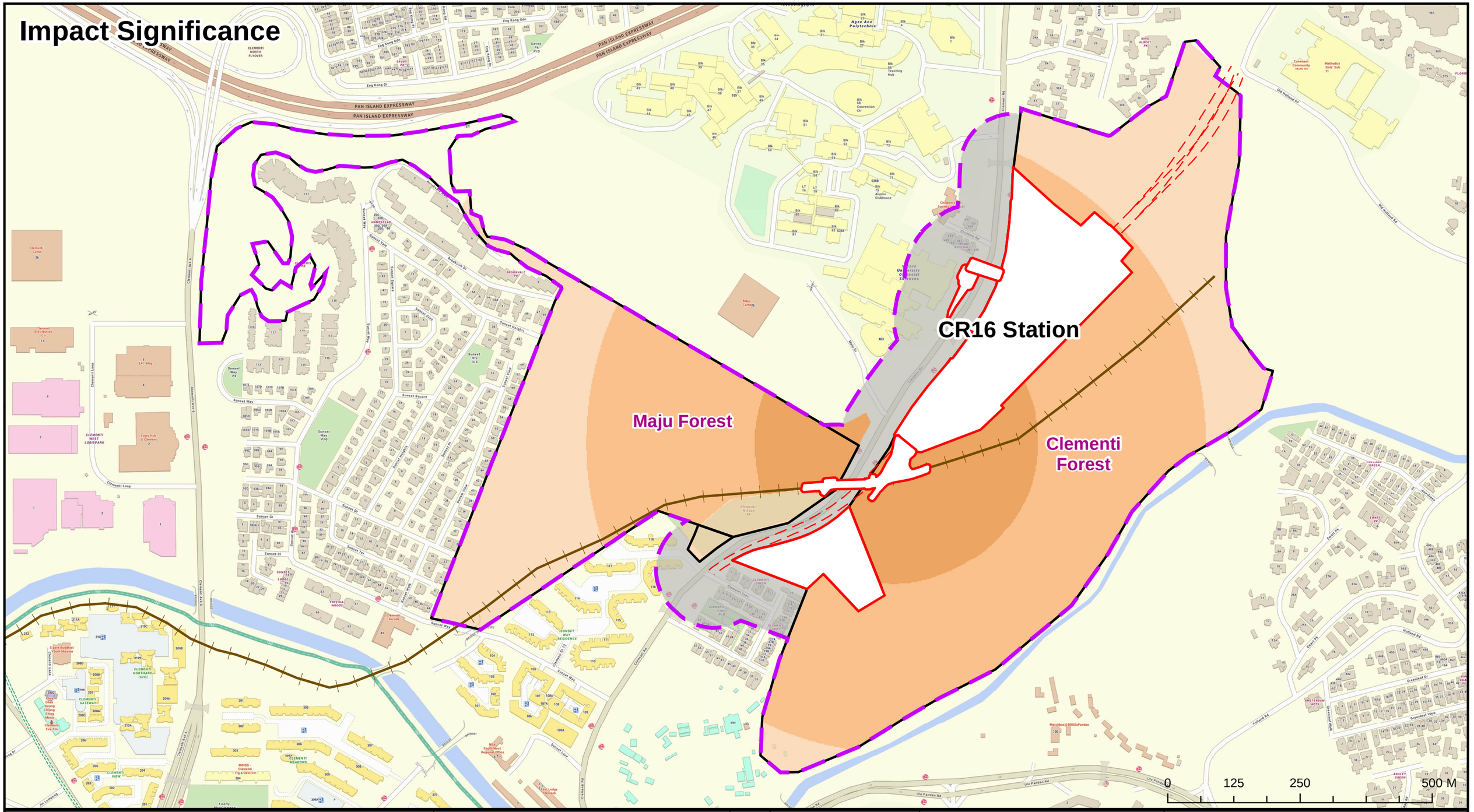
Overall, the construction activities produce impact significances of Minor, Moderate and Major.

- For Minor impact significances, some sensitive fauna may be impacted, while other species may avoid the area because of the increased levels of activity in the area. Many species would become habituated to the tunnel boring machine and would return to normal activity in a few days when the machine has passed by.
- For Moderate impact significances, it may impact sensitive fauna on their day-to-day activities (communication/ foraging/ breeding activities) for a short period in the zone of impact and may leave the area. Displacement is expected to be temporary, and they are expected to return after a while.
- For Major impact significances, it may cause permanent effects and affected indicator species are not expected to adapt to using this area. Reasonable to assume that vibration from tunnel boring may impact part of their habitat (pangolins' burrows), breeding and foraging opportunities. The mousedeer (*Tragulus kanchil*) and Sunda pangolin (*Manis javanica*) may move out of affected areas during the day and return at night to forage in these areas where food sources are available nearby.
    - During rock breaking and excavation, sensitive fauna may also flee, freeze or be frightened by the instantaneous vibration.

Thus, mitigation measures are recommended as discussed in Section 12.8.

[10] The hypothetical overall of TBM was assessed as full affected alignment. It should be noted that in reality, the tunnel boring machine will only bore section by section along the alignment at a rate of 7 m/ day. Thus, this assessment also identified the key spots for detailed hotspot analysis of TBM passage impact on fauna at any particular time.

Impact Significance



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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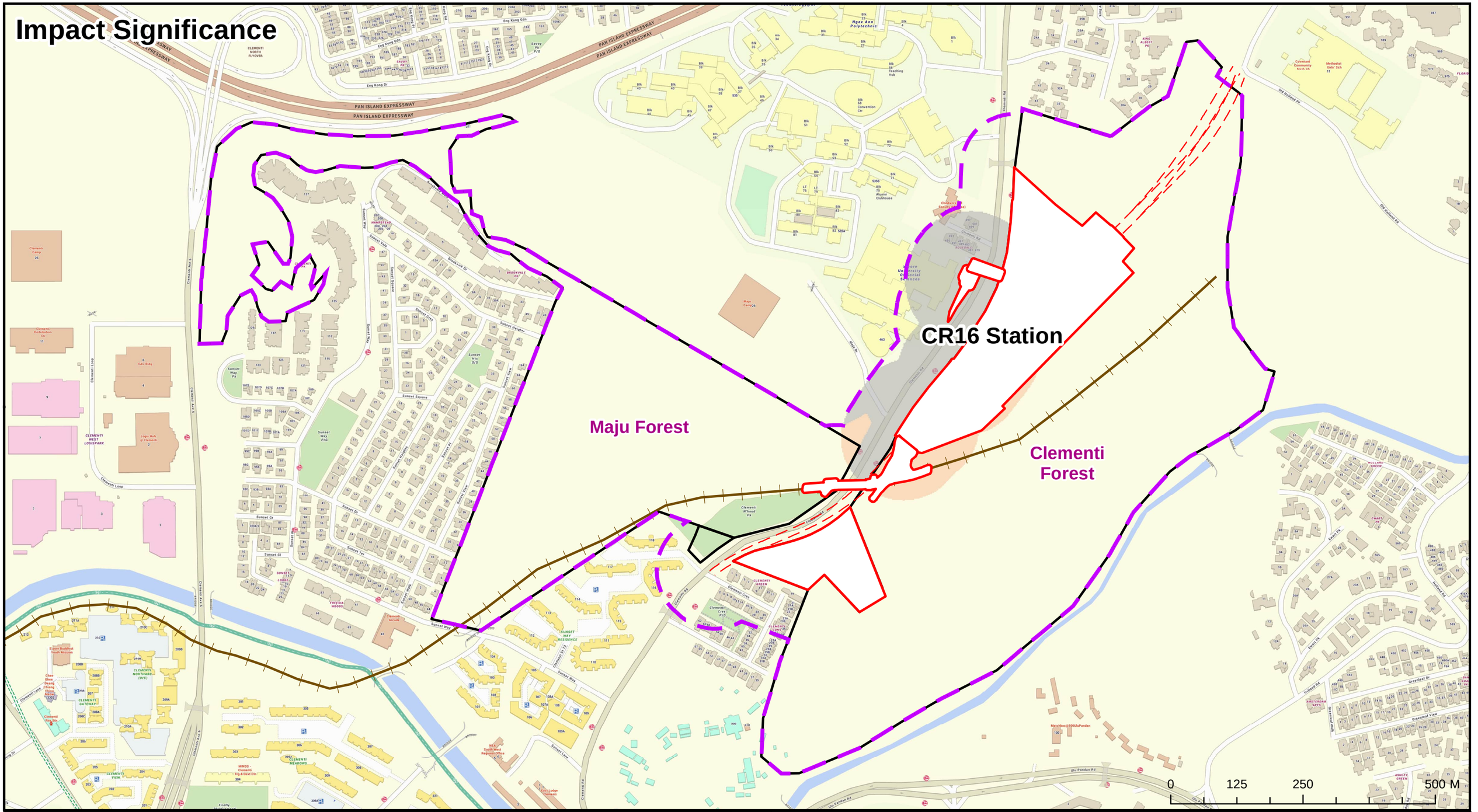
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR ROCK BREAKING AND EXCAVATION BASE SCENARIO

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-5	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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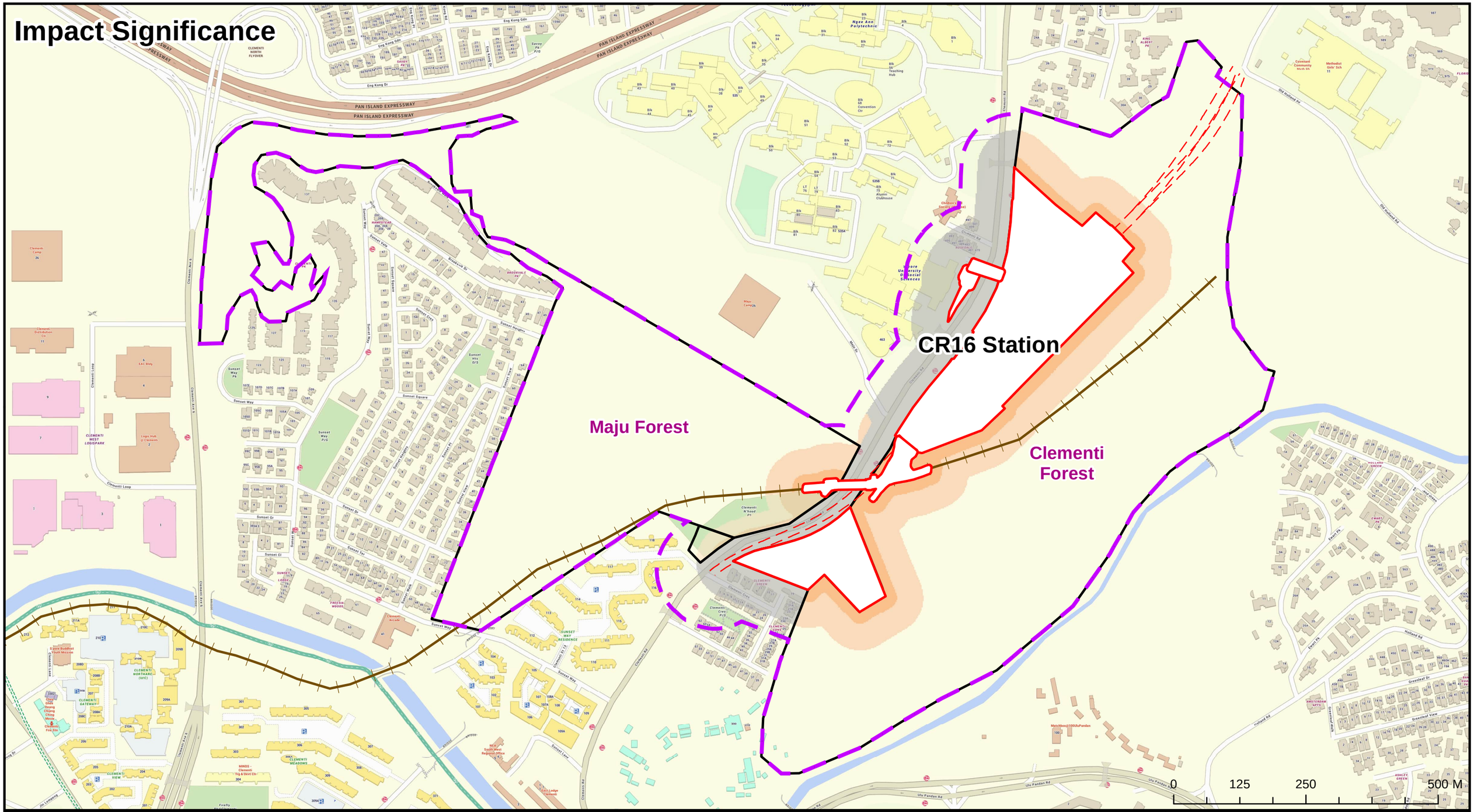
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR VIBRATORY PILE DRIVER FOR ENTRANCES BASE SCENARIO

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-6	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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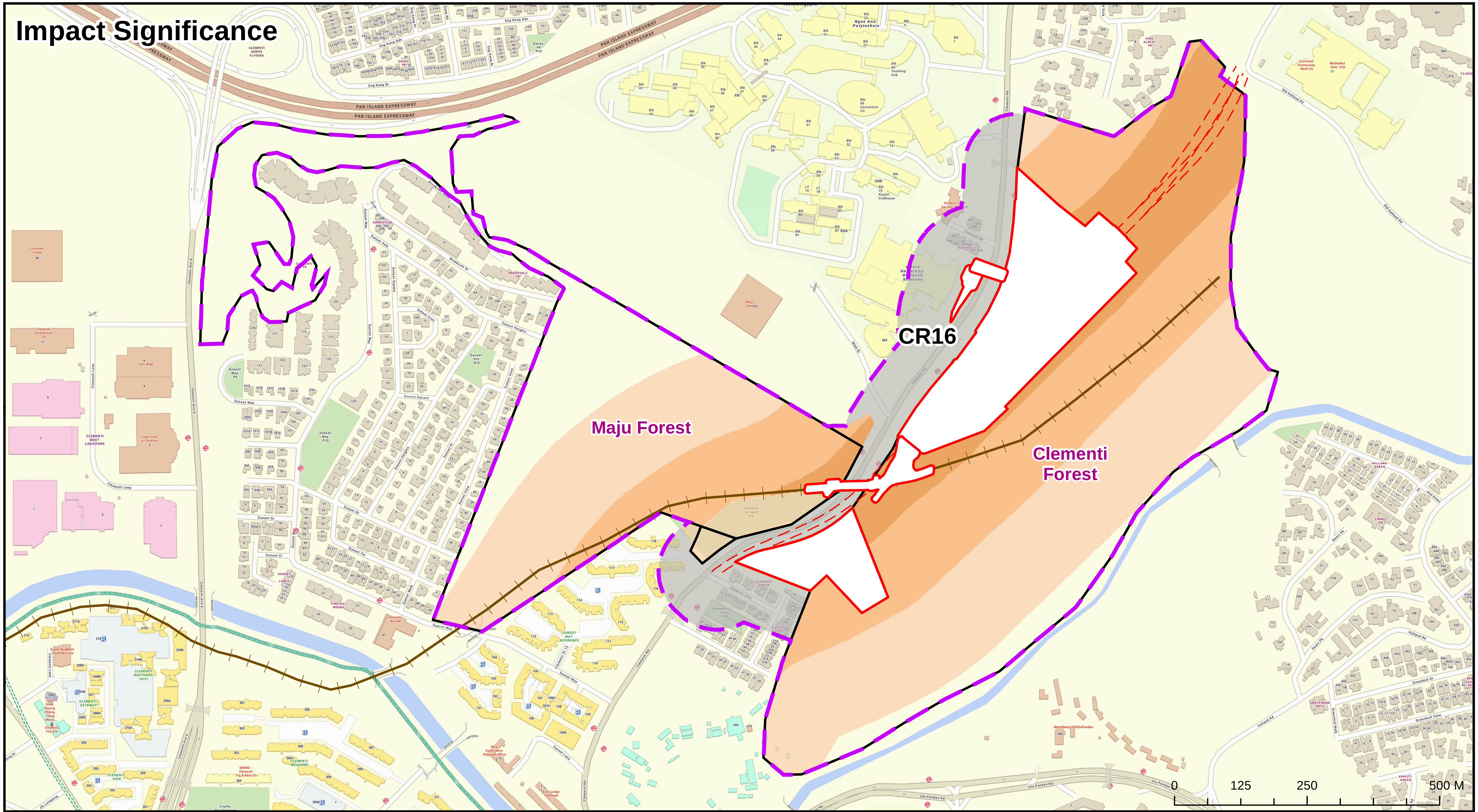
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR BULLDOZING BASE SCENARIO

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-7	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement : NA

LTA Endorsement : NA

Consultant : AECOM

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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND
MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR
TUNNEL BORING MACHINE
BASE SCENARIO

Designed	Checked	Approved
EGY	JAG/NHT	JAG

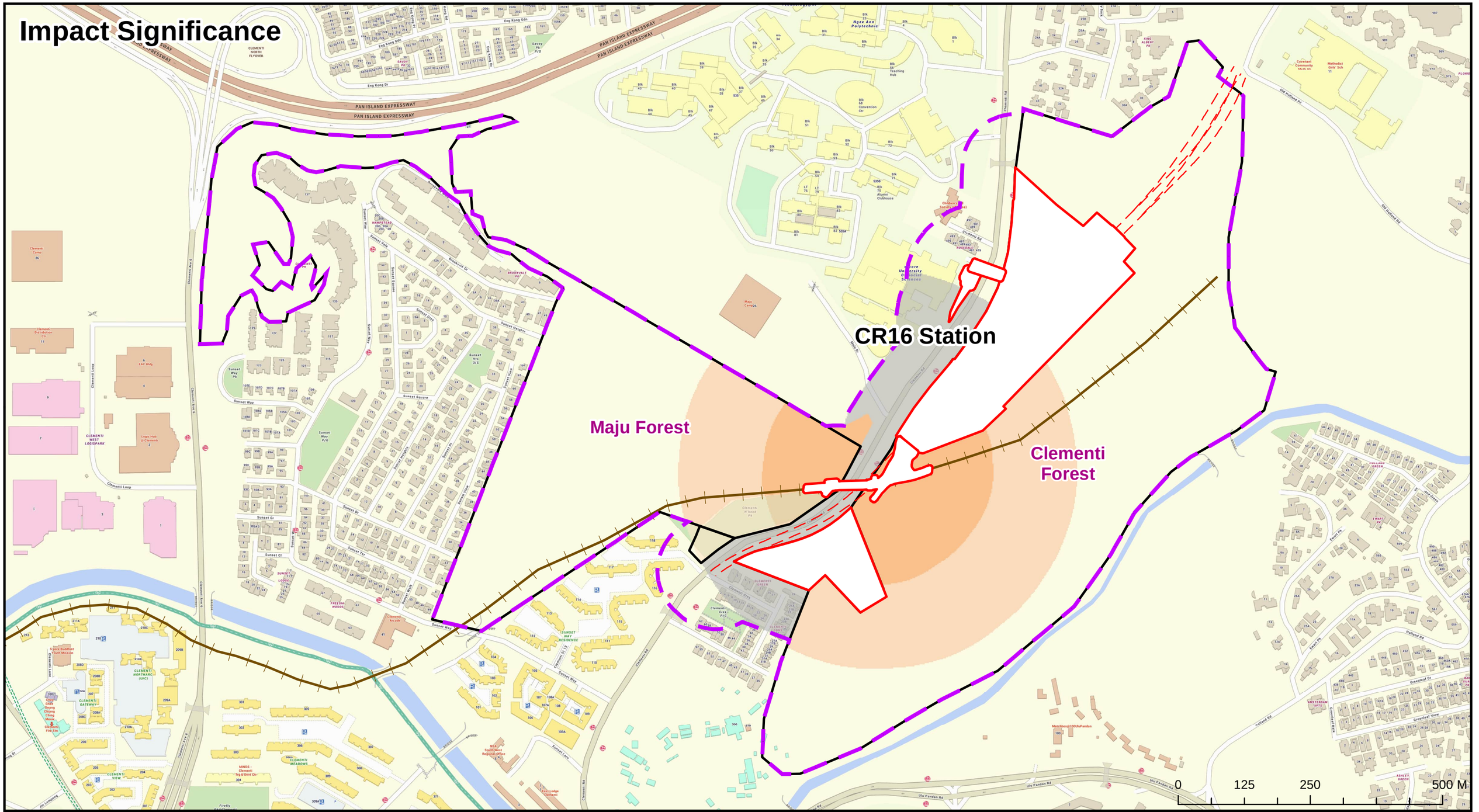
Drawn: EGY
Date: JUL 2022

Figure No. : 12-8
Rev. A
Sheet 1 of 1

CAD File Name : NA
A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR TUNNEL BORING MACHINE SPOT 1 BASE SCENARIO

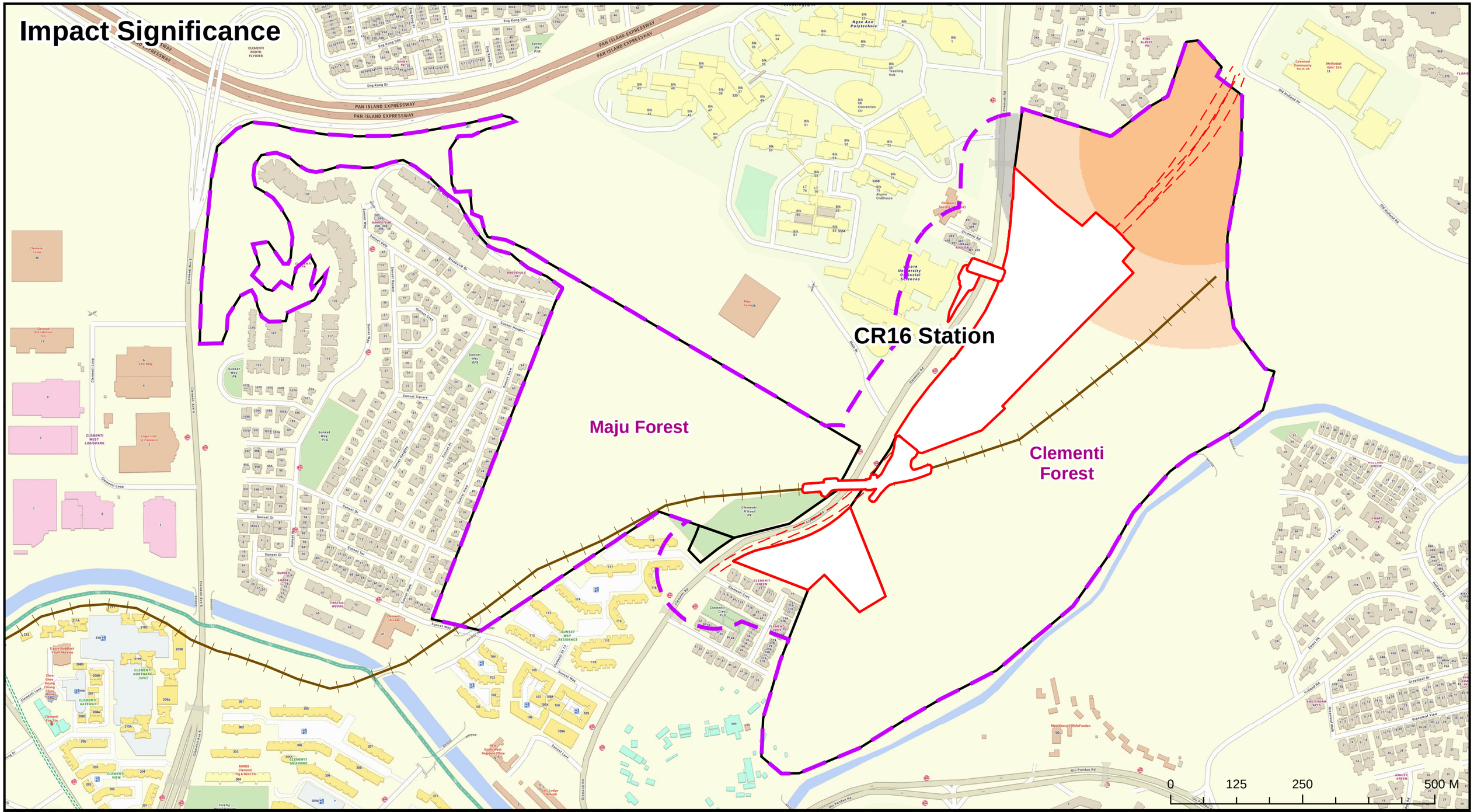
Designed	Checked	Approved
EGY	JAG/NHT	JAG
	Drawn EGY	Date JUL 2022

Figure No. : 12-9 | Rev. A | Sheet 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND
MAJU FOREST)**

Figure Title :
**VIBRATION ASSESSMENT FOR
TUNNEL BORING MACHINE
SPOT 2
BASE SCENARIO**

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-10	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.8 Recommended Mitigation Measures for Construction Phase

Based on best practices for building near a nature reserve or an area of high biodiversity value, mitigation measures for construction vibration impacts on sensitive fauna species are recommended.

The Contractor will control construction vibration levels using best available techniques (BAT). The construction activities are rock breaking and excavation, vibratory piling and tunnel boring. The Contractor will also ensure that the vibration levels at Maju Forest and Clementi Forest (excluding the worksite area) do not exceed PPV, 8 mm/s. The full mitigation measures can be seen in Section 13.11.

As mentioned in Table 12-18, behavioural impacts may be identified in different species. Incubating birds of prey may leave their nests due to rock breaking and excavation, resulting in the loss of their chicks or eggs. Accordingly, closely related species, including the red-legged crake, red junglefowl, and long-tailed parakeet, exhibit similar behavioural patterns during the breeding season. Foraging, nesting and roosting are typical bird activities that can be affected. The impacts can be reversed once rock breaking and excavation work has been complete, and when high levels of human activity become more manageable. In addition, bird breeding seasons are observed year-round in Singapore, so significant impacts cannot be avoided.

A summary of mitigation measures is provided below:

- Schedule high vibration activities during the daytime.
- Restrict high vibration activities to below vibration threshold of PPV, 8 mm/s.
- Use of tri-axle trucks to reduce truck trips on the road.
- No night works should be conducted after 7pm for all non-safety critical activities since the site is next to the human and fauna sensitive receptors.
- If there are justified complaints from the construction works, particularly from the piling works, tunnel boring and bulldozer, the operation may need to mitigate vibration levels to the most practical levels.

12.9 Residual Impacts

12.9.1 Construction Phase

The mitigated case here refers to the worksites proposed at the onset of the construction of the alignment and station. Like the worksites, the assessment is split into three stages: Advance Works, Stage 1 and Stage 2.

Based on the assessment results in Section 12.7, the potential impact significances for base scenario during the construction phase is expected to be negligible – major. With the optimised worksites and construction activities, the mitigated scenario is still expected to have an impact significance of negligible – major. Thus, further mitigation measures and implementation of effective management strategies during construction phase are required to potentially reduce the impact significance to moderate.

12.9.1.1 Structural Impacts of Fauna (Mitigated Scenario)

The construction activities were assessed for the mitigated scenario which are summarised in Table 12-19. Out of all the assessments, high amplitude vibratory compactors and rock breaking and excavation had PPV exceeding 5 mm/s. Thus, these activities were screened for partial burrow collapse. Pipe jacking (overall and spot) and vibratory pile drivers for entrances had exceedances from the vibration threshold of 8 mm/s (see Table 12-19), thus partial burrow collapse may occur causing mortality. Hence, further mitigation measurements are required (see Section 13.11.) Results and heatmaps for spot pipe jacking (Advance Works) and low vibratory compactors (Stage 1 and Stage 2) can be seen in Appendix T.

Table 12-19 Summary of Maximum Predicted PPV for Construction Activities (Mitigated Scenario)

Stage	Activity	Max PPV (mm/s)		Exceedances of Vibration Threshold for Partial Burrow Collapse of 8 mm/s, mm/s	
		Maju Forest	Clementi Forest	Maju Forest	Clementi Forest
Advance Works	Vibratory Pile Driver for Temporary Drainage	0.0	3.6	-	-
	Vibratory Pile Driver Permanent Drainage	0.0	0.8	-	-
	Bulldozing	1.5	1.5	-	-
	Pipe Jacking Overall	0.5	9.0	-	1.0**
Stage 1	Bulldozing	0.5	1.5	-	-
	High Vibratory Compactor*	5.2*	5.2*	-	-
Stage 2	Rock Breaking and Excavation*	3	7.1*	-	-
	Vibratory Pile Driver Entrances	8.8	0.5	0.8**	-
	Bulldozing	1.5	1.5	-	-
	High Vibratory Compactor	1.3	4.4	-	-
	Tunnel Boring Machine (Hypothetical Overall)	1.7	2.7	-	-
	Tunnel Boring Machine (Spot 1 - Maju)	1.6	1.3	-	-
	Tunnel Boring Machine (Clementi - Spot)	0.1	2.7	-	-
Operational	Overall	0.2	0.2	-	-
	Spot 1	0.1	0.2	-	-
	Spot 2	0.0	0.2	-	-

Notes:

* Since the PPV has exceeded 5 mm/s (screening criteria), the construction activities were screened for this value.

** Since the PPV has exceeded the threshold of 8 mm/s, the construction activities may potentially cause partial burrow collapse. Thus, additional mitigation measures are required:

1. Ecologists should be present to survey for burrows. If burrows are detected within the Biodiversity Study Areas, camera traps should be deployed to assess fauna activity, if any. If there are no burrows or fauna activity detected, construction works are allowed to be continued.
2. The Contractor will control construction vibration levels for high vibratory compactors, pipe jacking and vibratory piling using best available techniques (BAT). The Contractor will ensure that the vibration levels at Maju Forest and Clementi Forest (excluding the worksite area) for any construction activities do not exceed PPV, 8 mm/s.
3. Further details on duration of monitoring per construction activity can be seen in Section 13.11.

12.9.1.2 Behavioural Impacts on Fauna (Mitigated Scenario)

Comparisons were made between the base and mitigated impact significances for all three stages as seen in Table 12-20. Since the impact significances for some of the construction activities in the mitigated scenarios were **major**, additional mitigation measures were introduced, and the resultant impact significance were determined. The heatmaps can also be seen in Figure 12-11 to Figure 12-22.

Table 12-20 Comparison between Base and Mitigated Impact Significances with Mitigation Measures for Mitigated Scenario

Construction Worksite and Activities	Base Scenario Impact Significance Maju Forest	 Clementi Forest	Mitigation Measures	Mitigated Scenario Impact Significance Maju Forest	 Clementi Forest	Changes in Impact Significance (Increased/Decreased/No Change?)	Further Mitigation Measures	Resultant Impact Significance
Advance Works								
Vibratory Piling for Temporary Drainage	NA		NA	NA	Minor	Increased due to additional activity	None required as the impact significance is Minor	**Minor**
Vibratory Piling for Permanent Drainage	NA		NA	NA	Minor	Increased due to additional activity		**Minor**
Bulldozing	Negligible – Moderate Moderate, 0.2 ha	Minor – Moderate Moderate, 3.4 ha	Optimization of the worksite, reducing coverage within Biodiversity Study Areas.	Negligible – Minor	Minor	Reduced impact significance from Moderate to Minor within the Biodiversity Study Areas.		**Minor**
Pipe Jacking (Hypothetical Overall)	NA		NA	Negligible – Minor	Minor – Major Moderate, 13.7 ha Major, 5.4 ha	Increased due to additional activity	1. No night works after 7 pm should be conducted. 2. Temporary barriers (i.e. water barriers of 1 m height) should be implemented along Brookvale Drive and Clementi Road as seen in Figure 13-16. Canvas sheets should also be used to cover the holes on the existing railings along Brookvale Drive and Clementi Forest. Hoardings must be ensured at the worksites and at the existing construction beside Maju Forest. These will potentially mitigate roadkills due to the impacted fauna trying to dash onto a road during the construction activity.	**Negligible – Moderate** Since the impact significance is still Moderate, EMMP measures should be further enhanced, monitored and applied.
Stage 1								
Bulldozing	Negligible – Moderate Moderate, 0.2 ha	Minor – Moderate Moderate, 3.4 ha	Optimization of the worksite, reducing coverage within Biodiversity Study Areas.	Negligible – Minor	Minor	Reduced impact significance from Moderate to Minor within the Biodiversity Study Areas.	None required as the impact significance is Minor	**Minor**
High Vibratory Compactor	NA		NA	Negligible – Minor	Negligible – Minor	Increased due to additional activity		**Minor**
Stage 2								
Rock Breaking and Excavation	Minor – Major Moderate, 10.4 ha Major, 2.4 ha	Minor – Major Moderate, 26.9 ha Major, 7.2 ha	Optimization of the worksite, reducing coverage within Biodiversity Study Areas.	Minor – Major Moderate, 10.4 ha Major, 2.4 ha	Minor – Major Moderate,32.7 ha Major, 8.9 ha	No change but with an increase in impacted area.	1. No night works after 7 pm should be conducted. 2. Temporary barriers (i.e. water barriers of 1 m height) should be implemented along Brookvale Drive and Clementi Road as seen in Figure 13-16. Canvas sheets should also be used to cover the holes on the existing railings along Brookvale Drive and Clementi Forest. Hoardings must be ensured at the worksites and at the existing construction beside Maju Forest. These will potentially mitigate roadkills	**Minor – Moderate** Since the impact significance is still Moderate, EMMP measures should be further enhanced, monitored and applied.

Construction Worksite and Activities	Base Scenario Impact Significance Maju Forest	 Clementi Forest	Mitigation Measures	Mitigated Scenario Impact Significance Maju Forest	 Clementi Forest	Changes in Impact Significance (Increased/Decreased/No Change?)	Further Mitigation Measures	Resultant Impact Significance
							due to the impacted fauna trying to dash onto a road during the construction activity.	
Bulldozing	Negligible – Moderate Moderate: 0.2 ha	Minor – Moderate Moderate: 3.4 ha	Optimization of the worksite, reducing coverage within Biodiversity Study Areas.	Negligible – Minor	Minor	Reduced impact significance from Moderate to Minor within the Biodiversity Study Areas.	None required as the impact significance is Minor	**Minor**
Vibratory Piling for Entrances	NA		NA	Negligible – Minor	Negligible – Minor	Increased due to additional activity		**Minor**
Tunnel Boring Machine (Hypothetical Overall)	Minor – Major Moderate, 5.4 ha Major, 0.5 ha	Minor – Major Moderate, 16.6 ha Major, 8.8 ha	Mitigation measures are not required as it is reasonable to assess the duration of impacts to be transient during the pass-by of a tunnel boring machine in a day.	Minor – Major Moderate, 5.1 ha Major, 0.9 ha	Minor – Major Moderate, 16.2 ha Major, 11.7 ha	No change but with an increase in impacted area.	1. No night works after 7 pm should be conducted. 2. Temporary barriers (i.e. water barriers of 1 m height) should be implemented along Brookvale Drive and Clementi Road as seen in Figure 13-16. Canvas sheets should also be used to cover the holes on the existing railings along Brookvale Drive and Clementi Forest. Hoardings must be ensured at the worksites and at the existing construction beside Maju Forest. These will potentially mitigate roadkills due to the impacted fauna trying to dash onto a road during the construction activity.	**Minor – Moderate**
Tunnel Boring Machine Spot 1	Negligible – Moderate Moderate, 2.1 ha	Minor – Moderate Moderate, 4.6 ha		Negligible – Moderate Moderate, 2.9 ha	Minor – Moderate Moderate, 4.9 ha	No change but with a slight increase in impacted area.	Since the impact significance is still Moderate, EMMP measures should be applied.	**Negligible – Moderate**
Tunnel Boring Machine Spot 2	NA	Minor – Moderate Moderate, 8.4 ha		NA	Minor – Moderate Moderate, 8.7 ha	No change but with a slight increase in impacted area.		**Minor – Moderate**
High Vibratory Compactor	NA		NA	Negligible – Minor	Negligible – Minor	Increased due to additional activity		**Negligible – Minor**

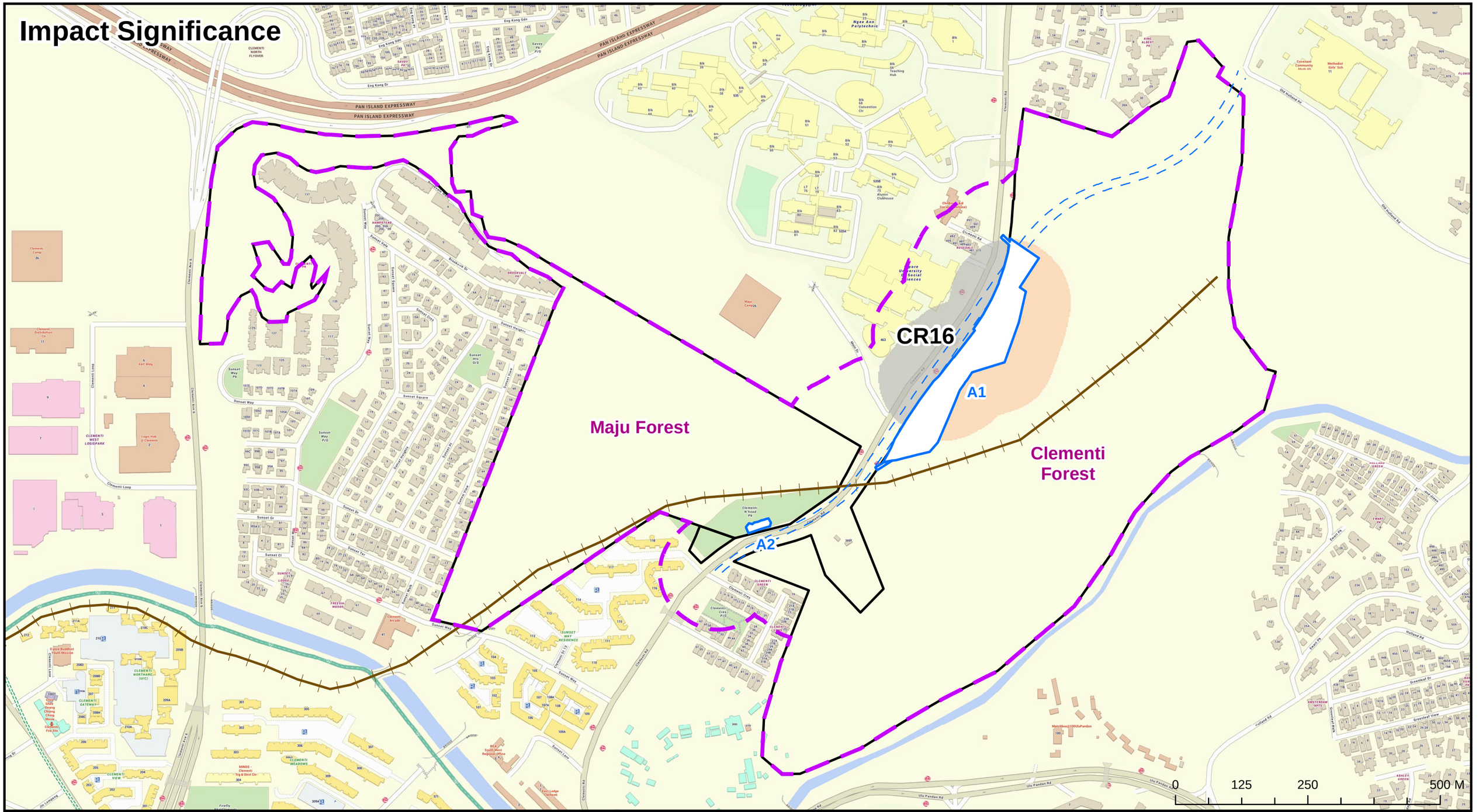
Summary:

Overall, the construction activities produce impact significances of Negligible, Minor, Moderate and Major.

- For Negligible impact significances, there should be no detectable behavioural change to indicator species;
- For Minor impact significances, some sensitive fauna may be impacted, while other species may avoid the area because of the increased levels of activity in the area. Many species would become habituated to the tunnel boring machine and would return to normal activity in a few days when the machine has passed by;
- For Moderate impact significances, it may impact sensitive fauna on their day-to-day activities (communication/ foraging/ breeding activities) for a short period in the zone of impact and may leave the area. Displacement is expected to be temporary, and they are expected to return after a while; and
- For Major impact significances, it may cause permanent effects and affected indicator species are not expected to adapt to using this area. Reasonable to assume that vibration from tunnel boring may impact part of their habitat (pangolins' burrows), breeding and foraging opportunities. The mousedeer (*Tragulus kanchil*) and Sunda pangolin (*Manis javanica*) may move out of affected areas during the day and return at night to forage in these areas where food sources are available nearby.
    - During rock breaking and excavation, sensitive fauna may also flee, freeze or be frightened by the instantaneous vibration.

Thus, future mitigation measures and EMMP are recommended as discussed in Section 13.11.

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Mitigated Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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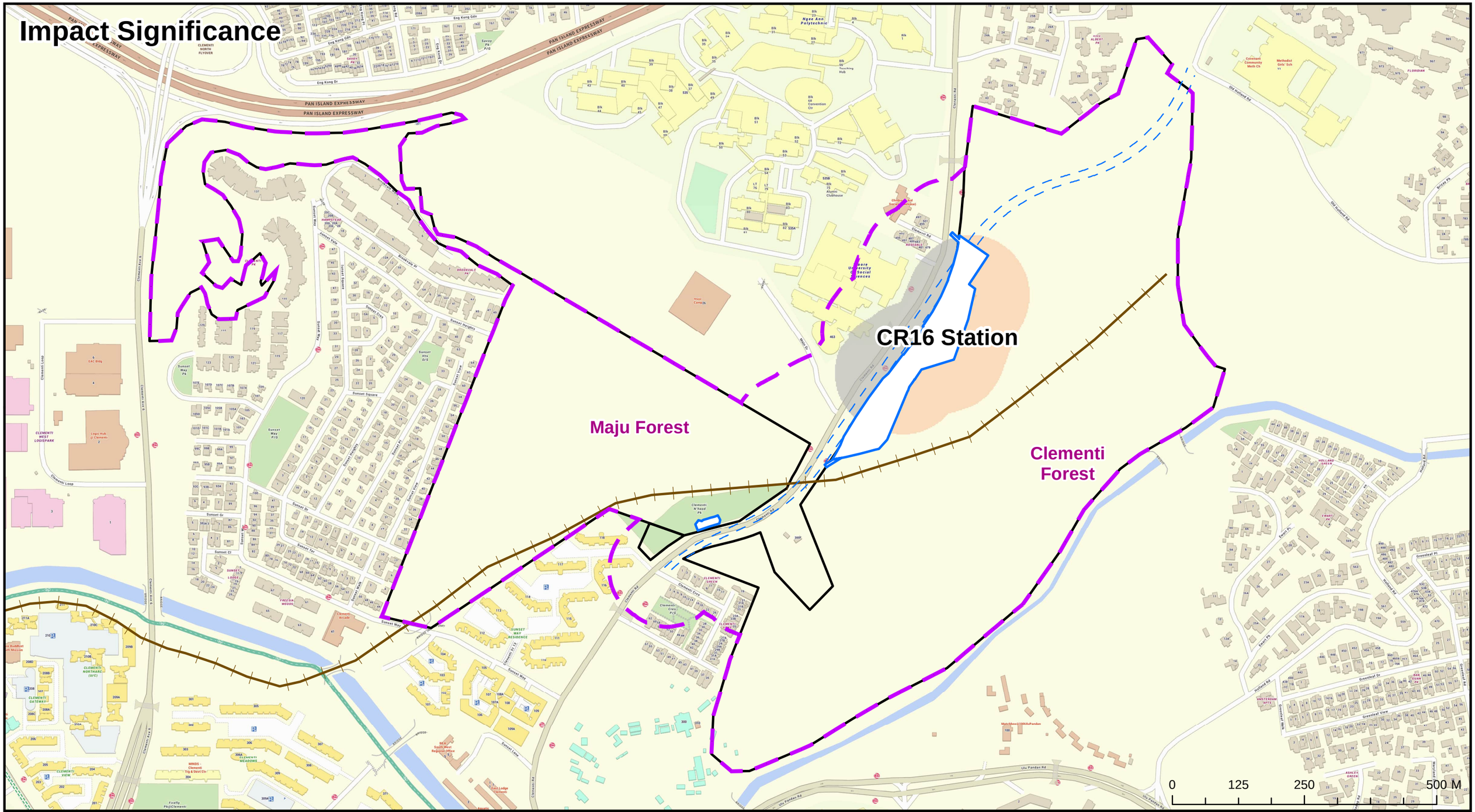
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR VIBRATORY PILE DRIVER DRAIN PERMANENT MITIGATED SCENARIO (ADVANCE WORKS)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-11	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Mitigated Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR VIBRATORY PILE DRIVER DRAIN TEMPORARY MITIGATED SCENARIO (ADVANCE WORKS)

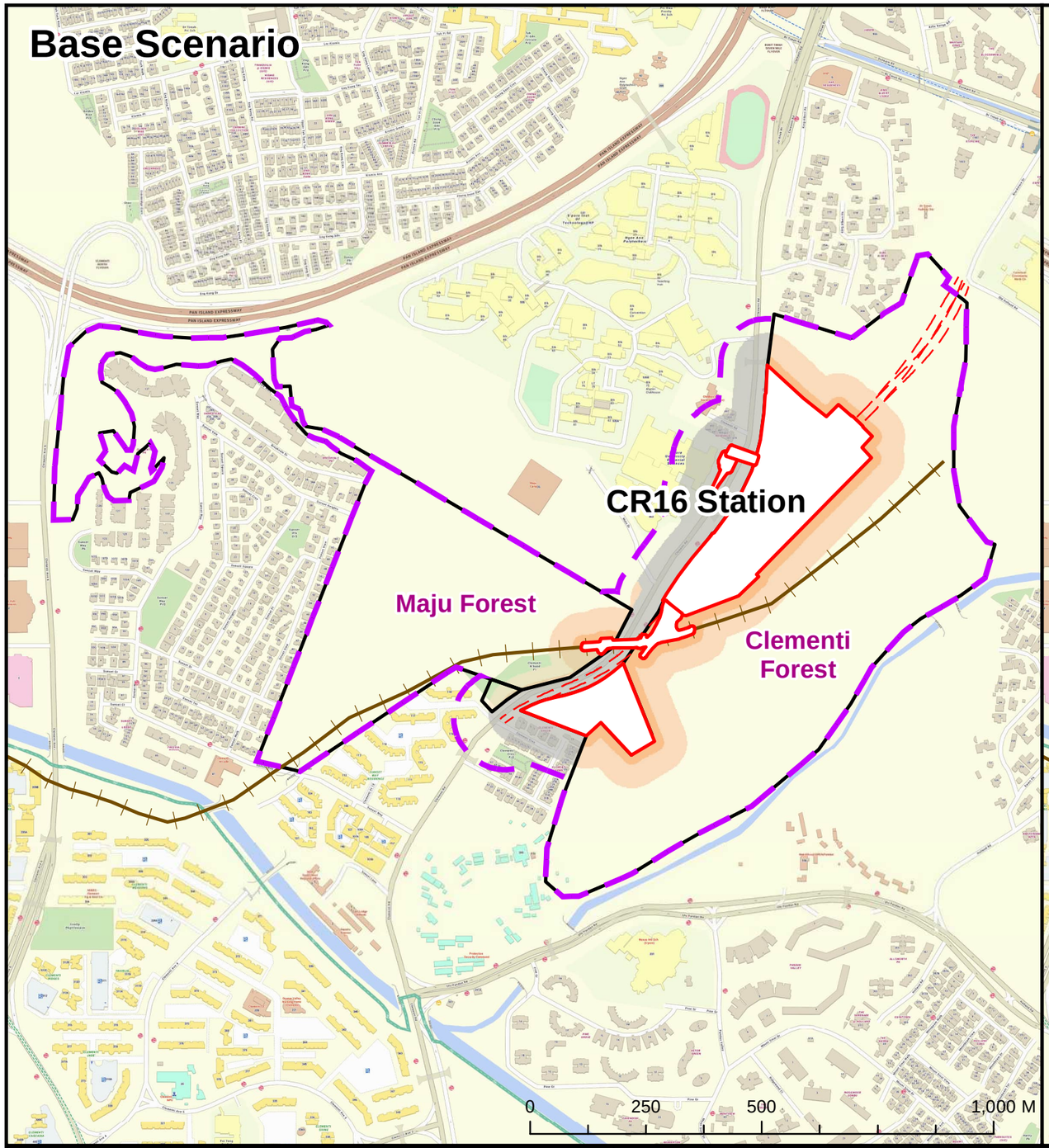
Designed	Checked	Approved
EGY	JAG/NHT	JAG
	Drawn	Date
	EGY	JUL 2022

Figure No. : 12-12 | Rev. : A | Sheet : 1 of 1

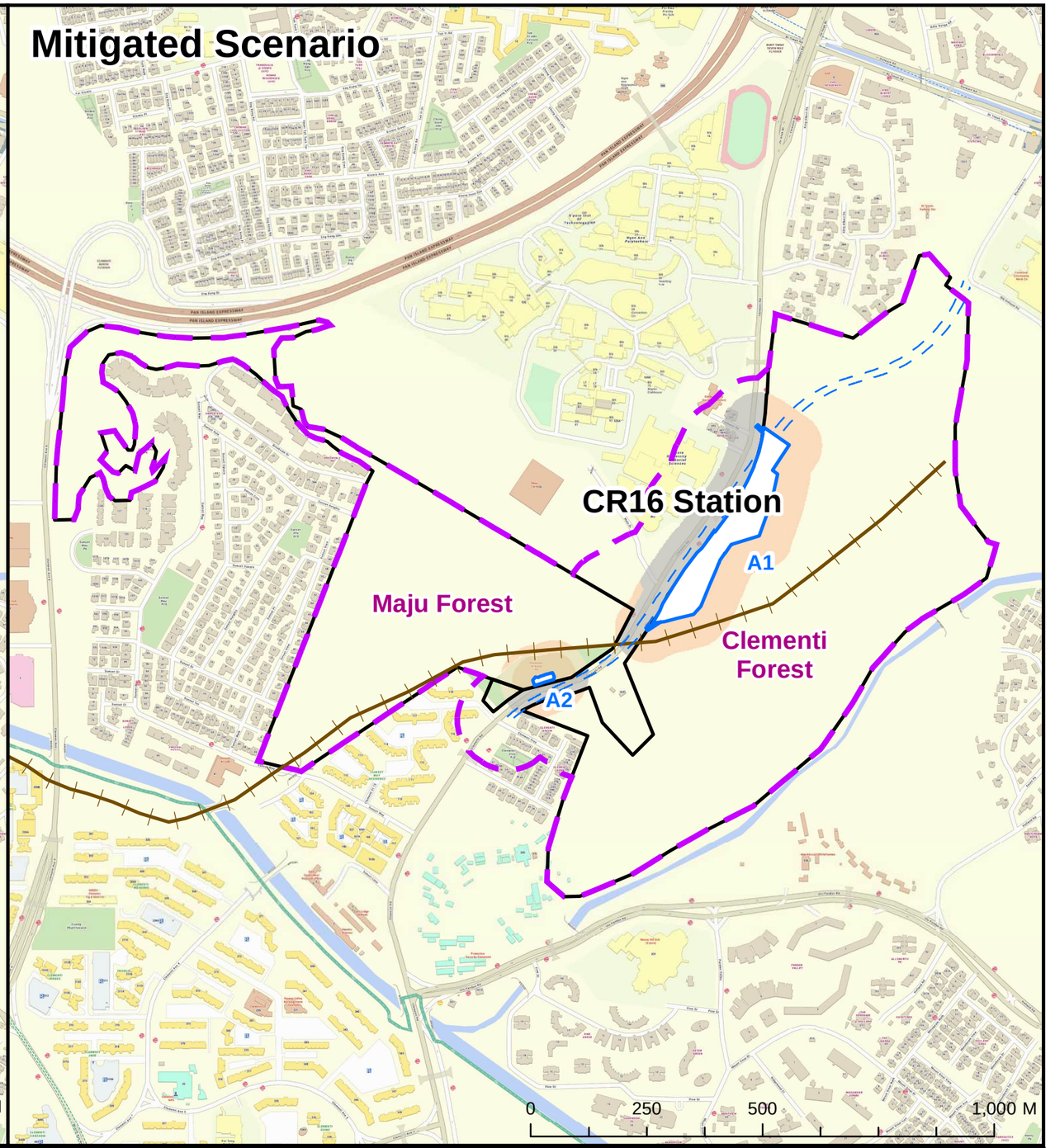
CAD File Name : NA | A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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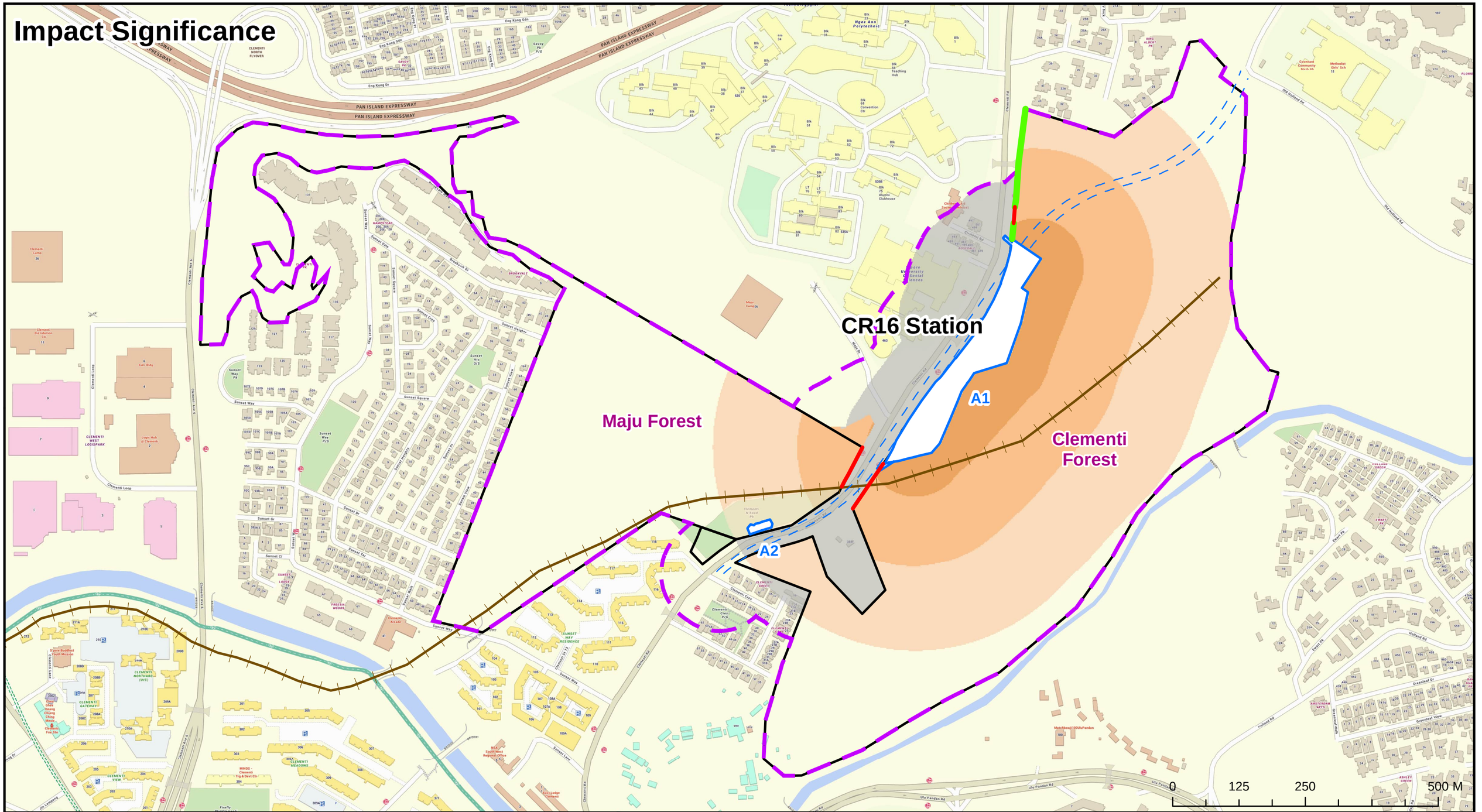
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR BULLDOZING MITIGATED SCENARIO (ADVANCE WORKS)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-13	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Mitigated Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area
- Water-filled Barrier for Advance Works Only (Pipejacking Activity), 220 m
- Existing Fence To Be Covered in Advance Works & Stage 2, 220 m

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR PIPE JACKING MITIGATED SCENARIO (ADVANCE WORKS)

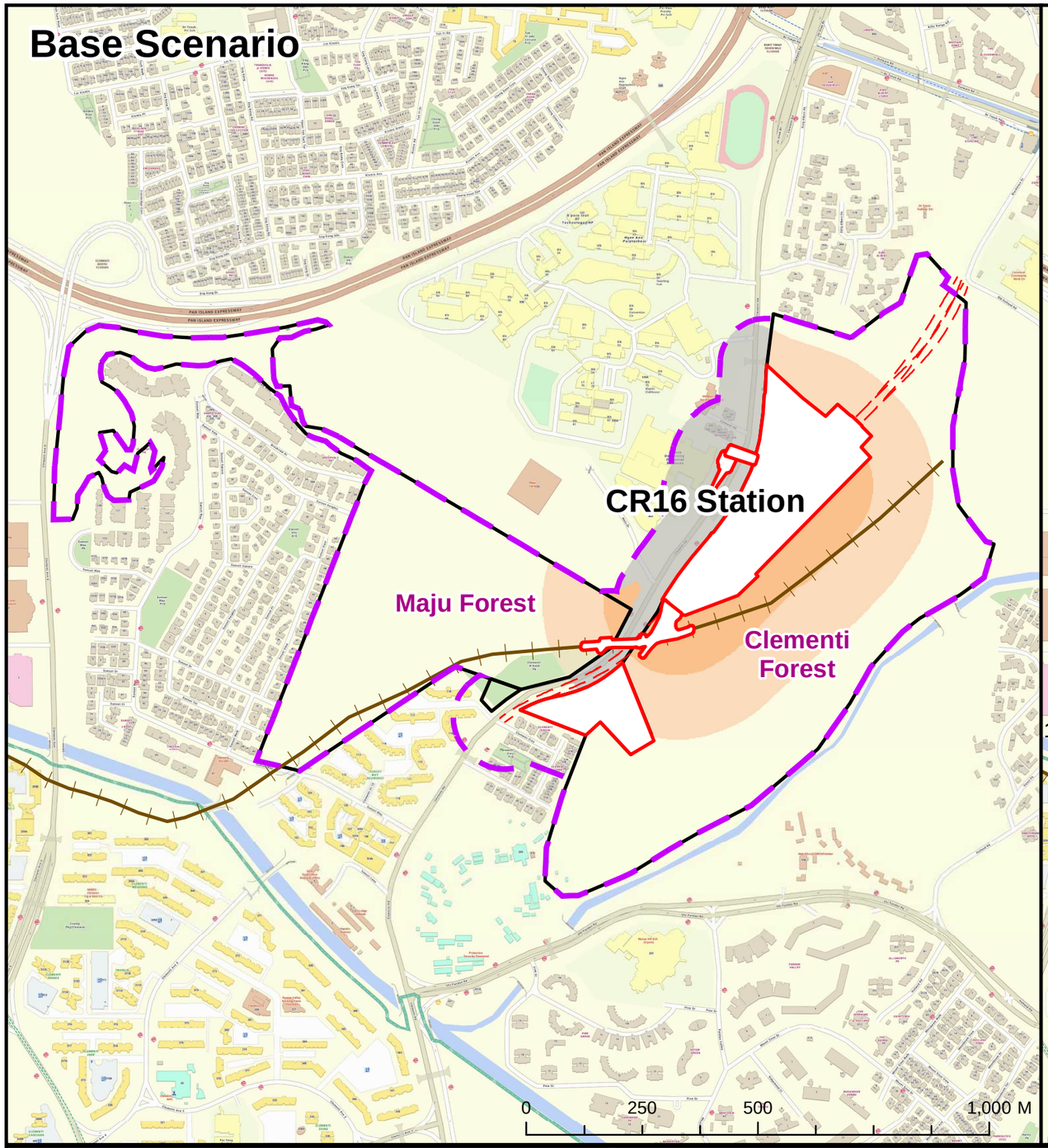
Designed	Checked	Approved
EGY	JAG/NHT	JAG
	Drawn: EGY	Date: JUL 2022

Figure No. : 12-14 | Rev. : A | Sheet : 1 of 1

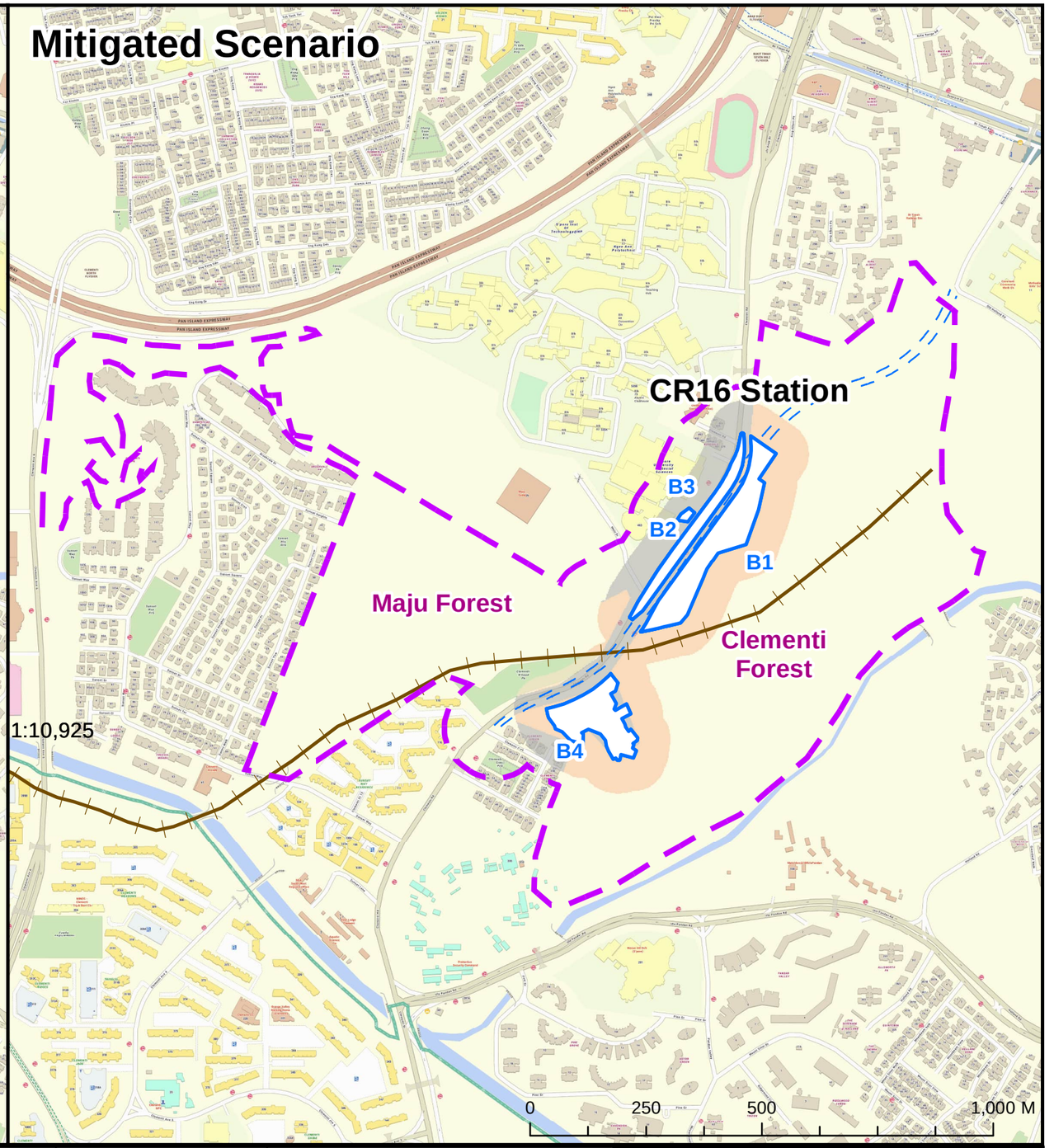
CAD File Name : NA | A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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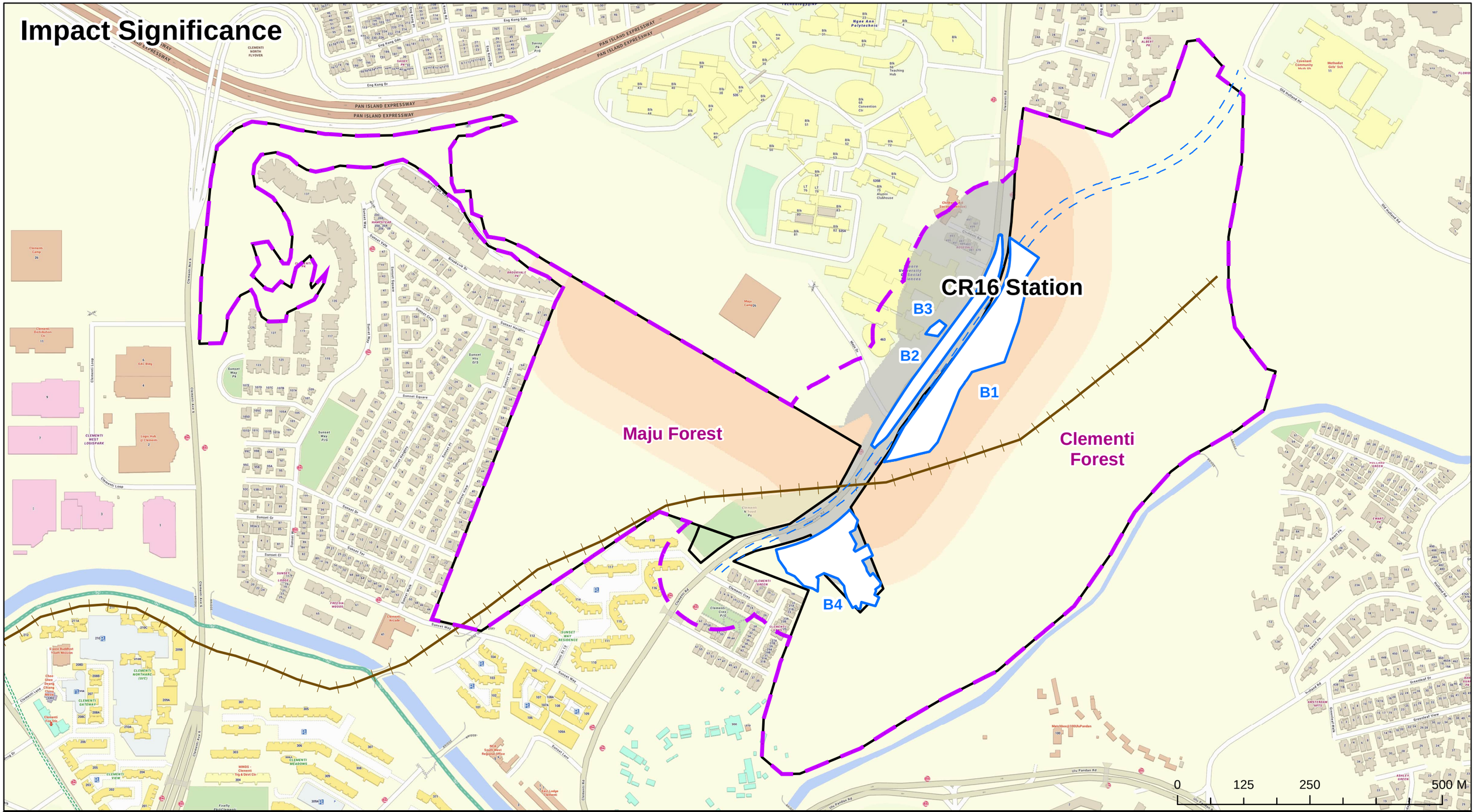
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR BULLDOZING MITIGATED SCENARIO (STAGE 1)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-15	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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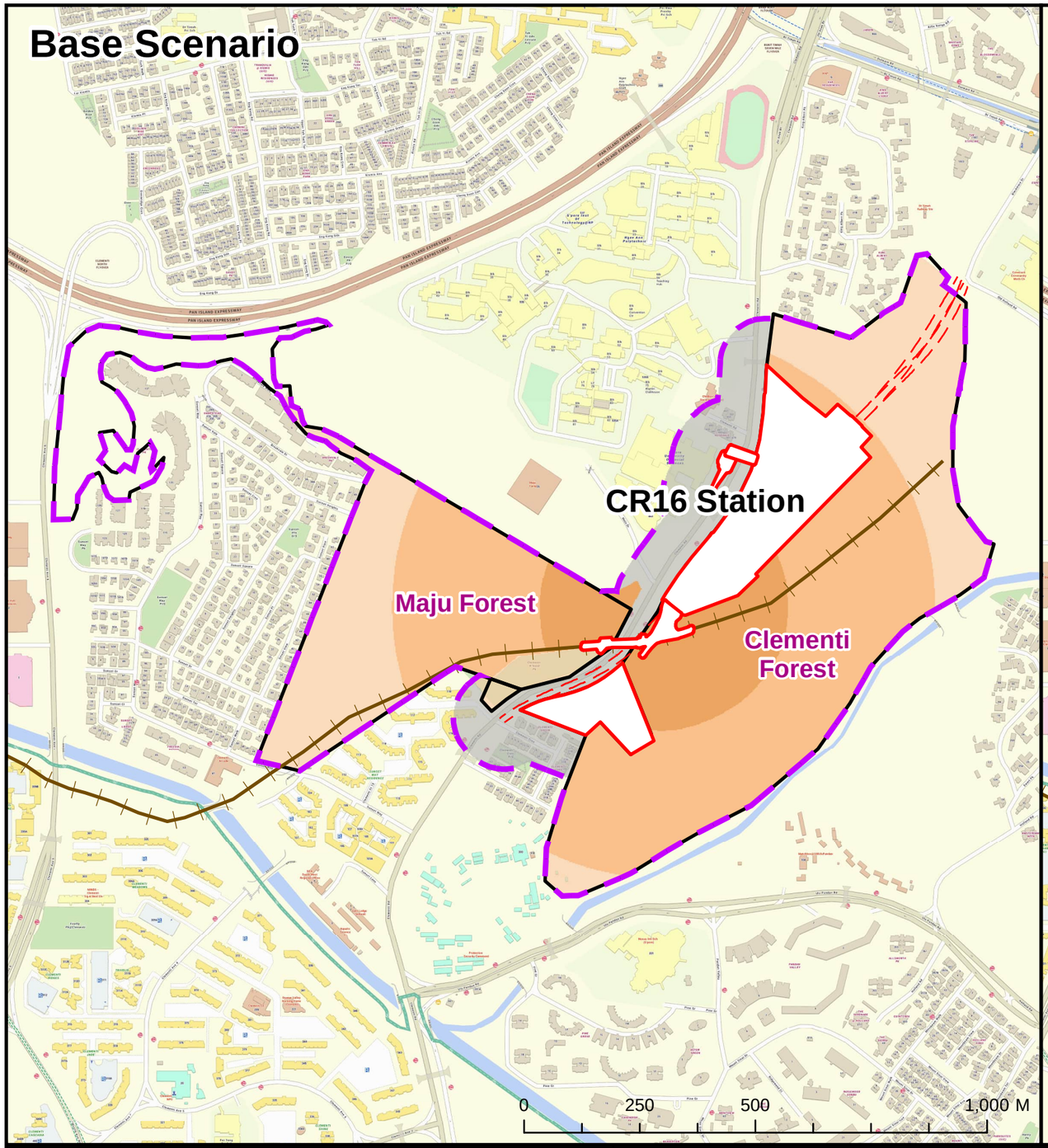
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR HIGH VIBRATORY COMPACTOR FOR TRAFFIC DIVERSION MITIGATED SCENARIO (STAGE 1)

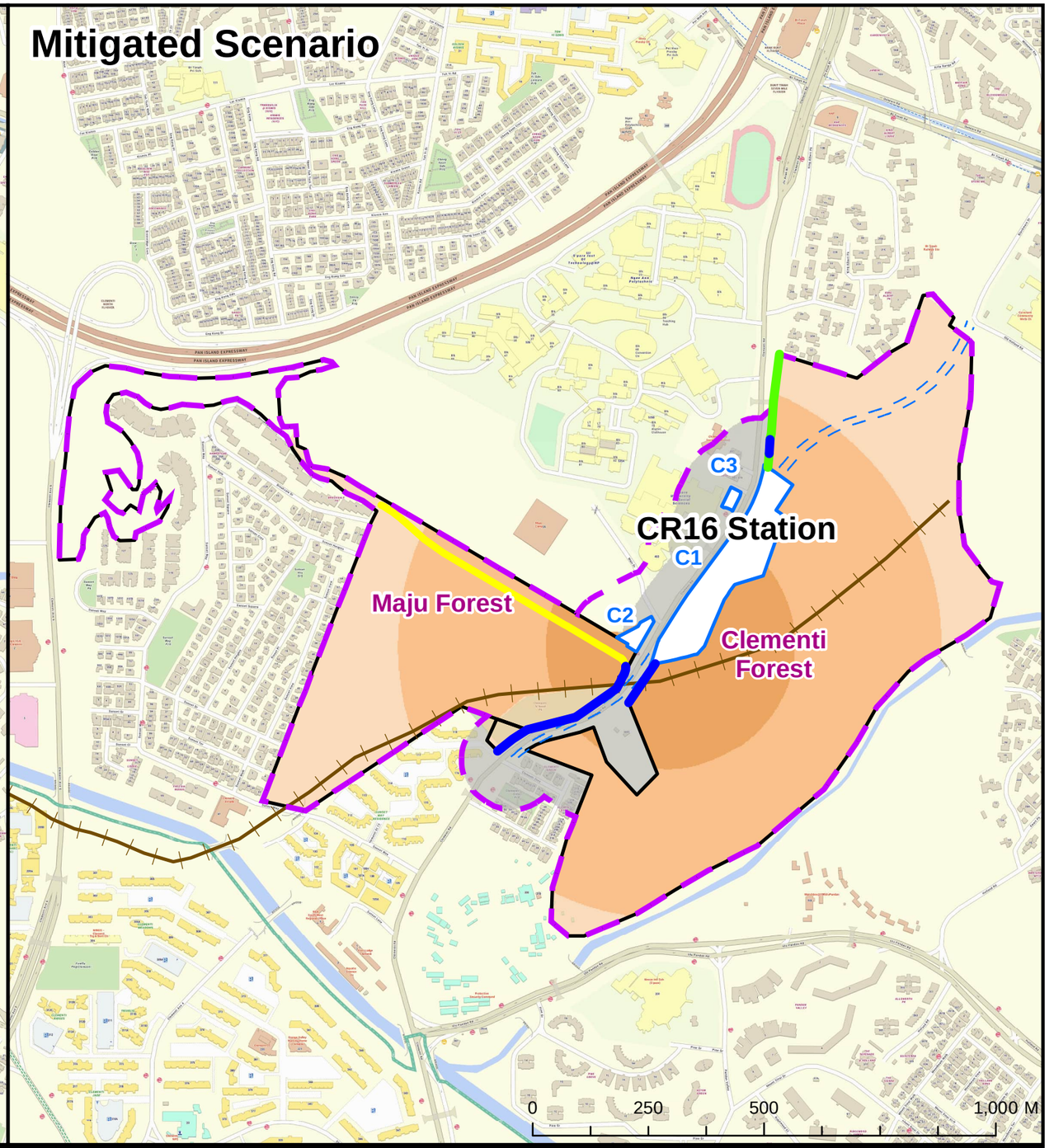
Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-16	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area
- Water-filled Barrier for Stage 2 Only (Rock Breaking & TBM), 480 m total
- Permanent Wire Mesh Fencing To Be Covered in Stage 2, 635 m
- Existing Fence To Be Covered in Advance Works & Stage 2, 220 m

Impact Significance

- Below Ambient
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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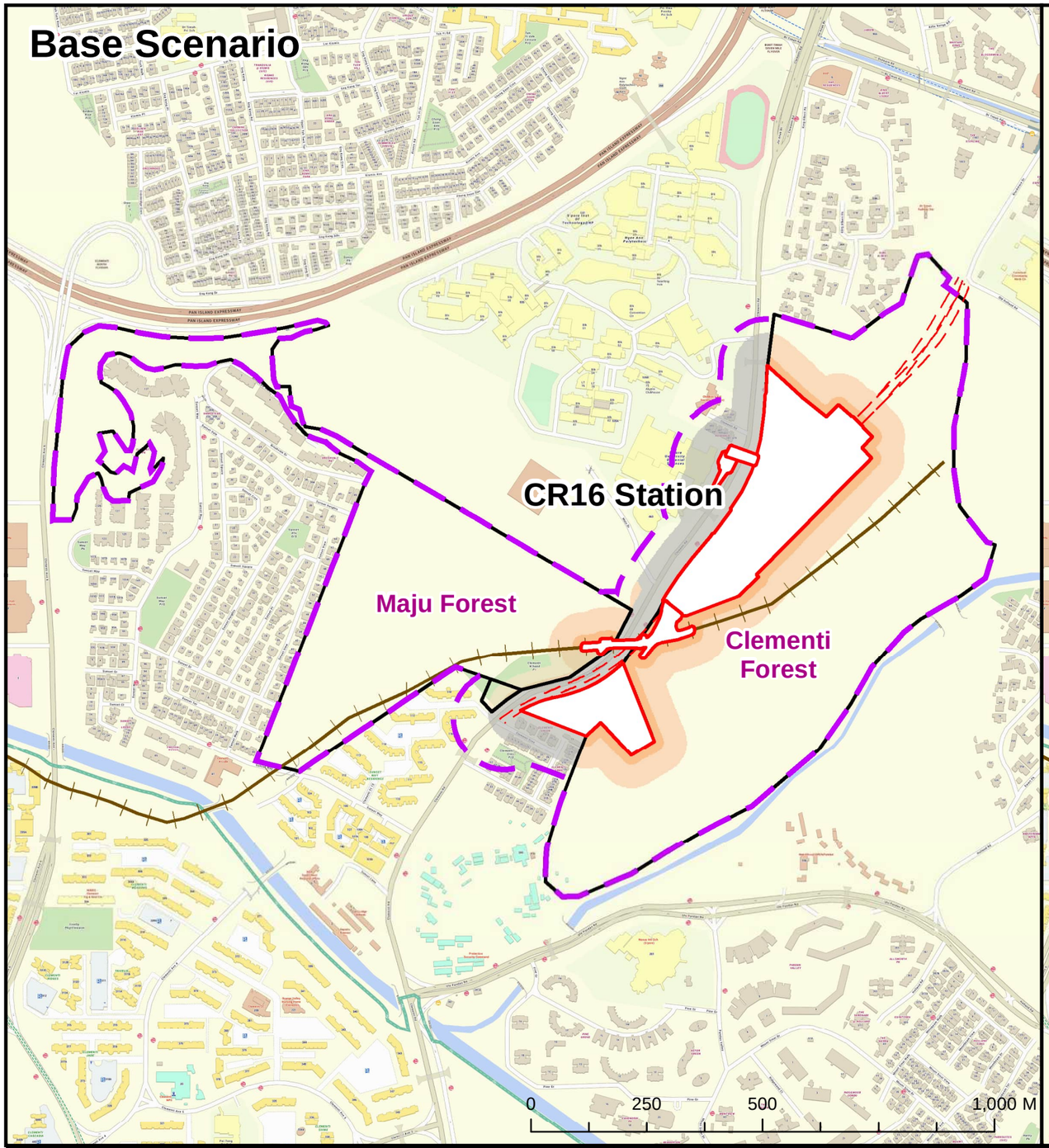
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR ROCK BREAKING AND EXCAVATION MITIGATED SCENARIO (STAGE 2)

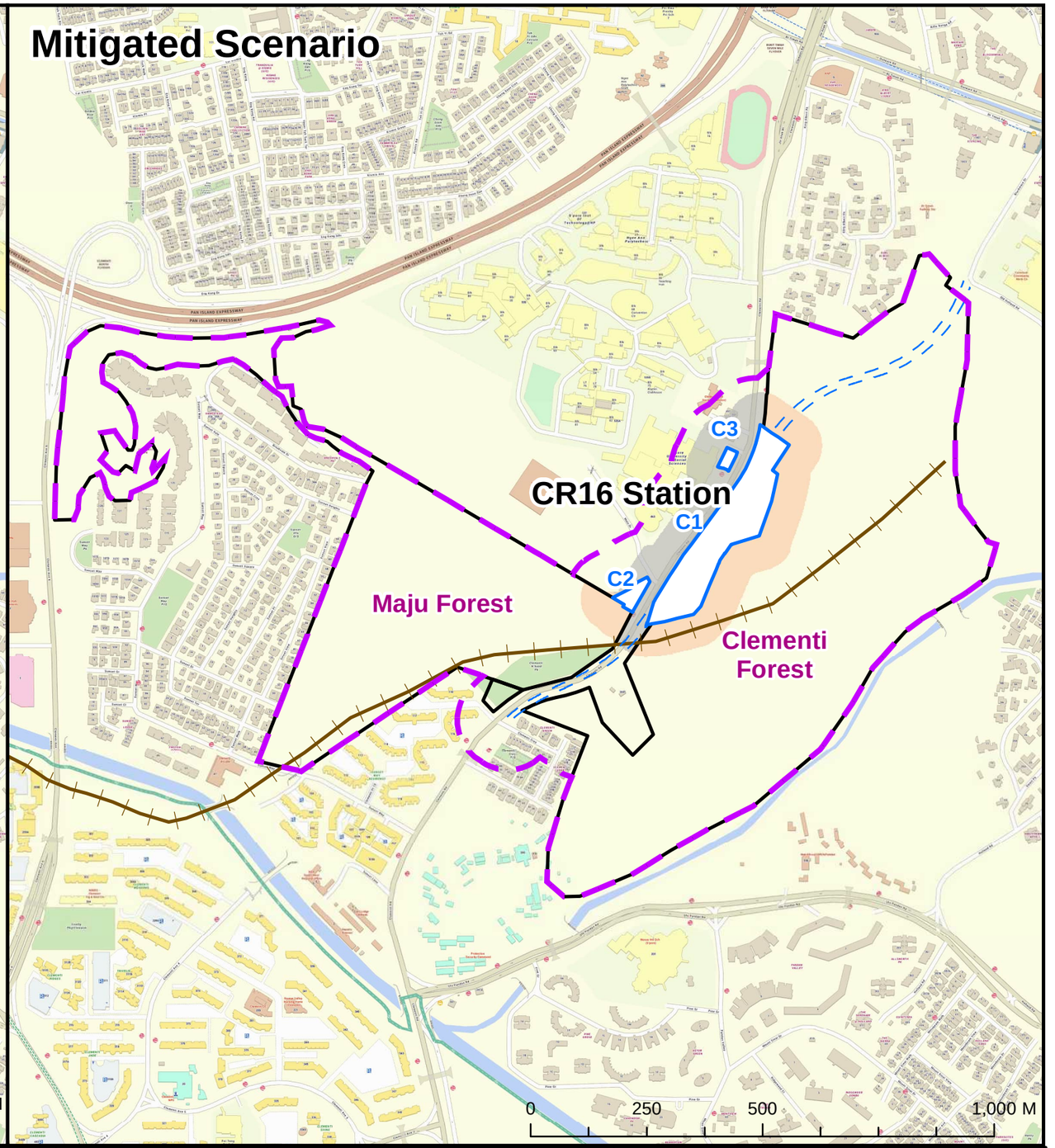
Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-17	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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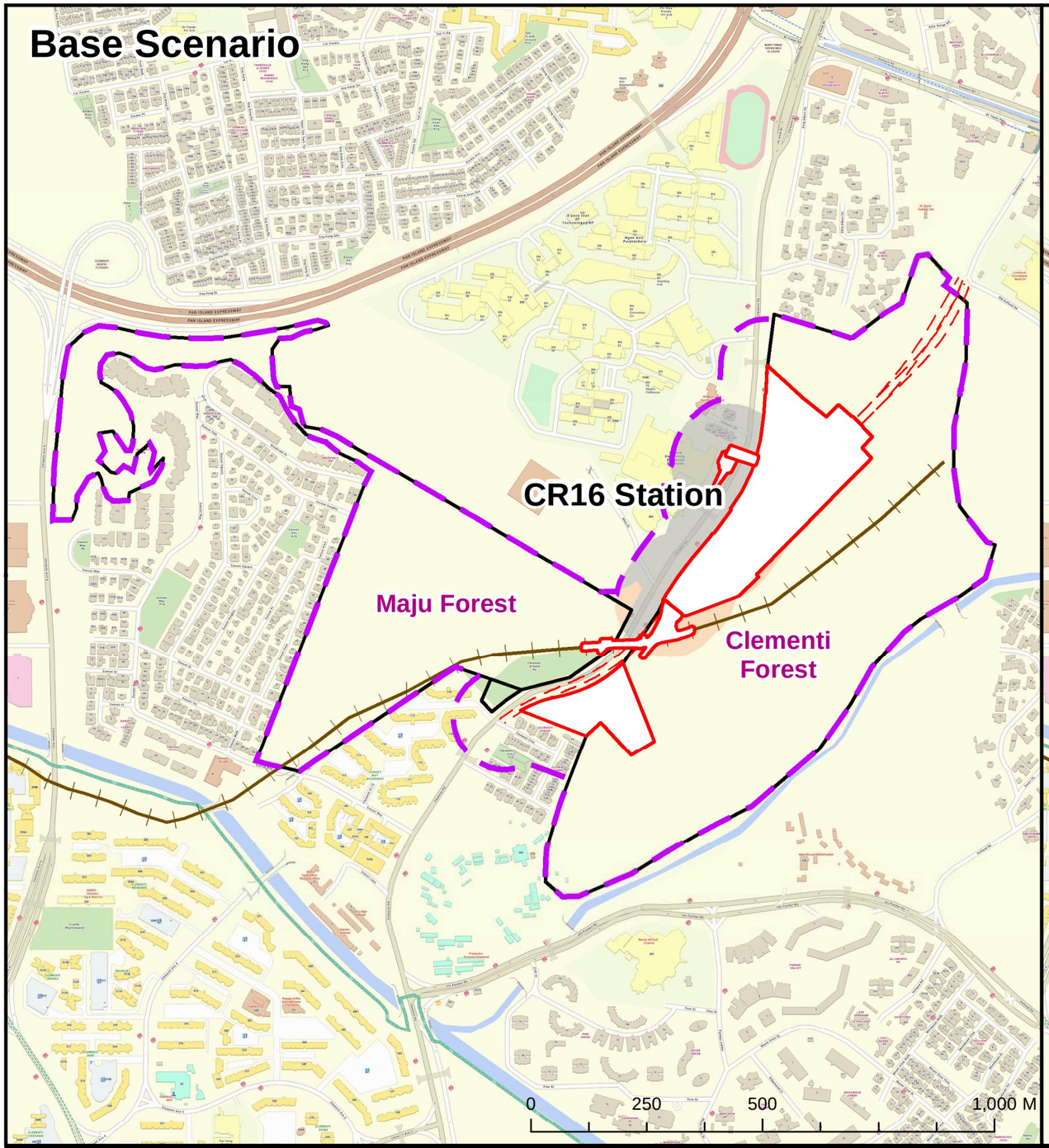
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCACE COMPARISON FOR BULLDOZING MITIGATED SCENARIO (STAGE 2)

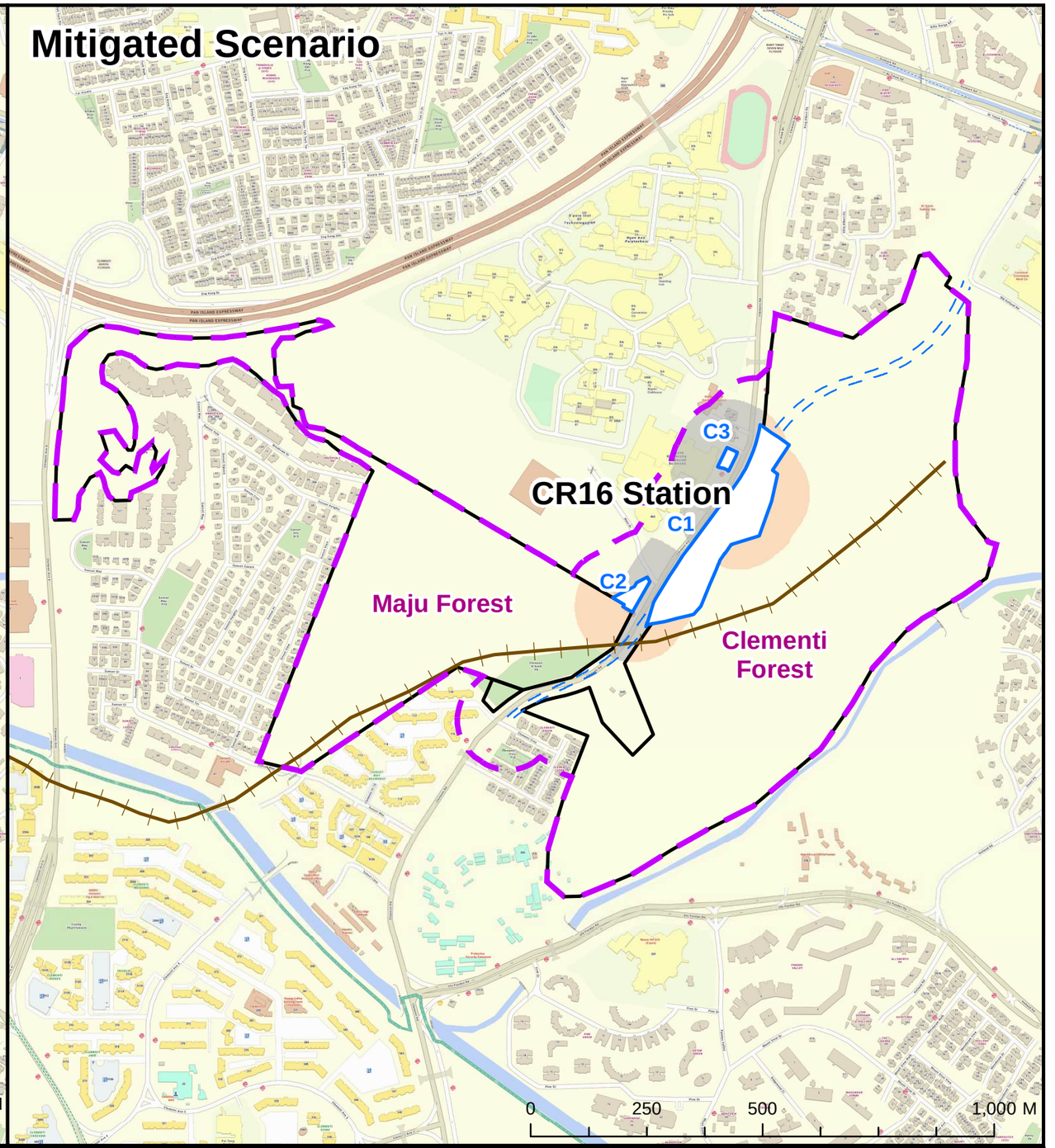
Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-18	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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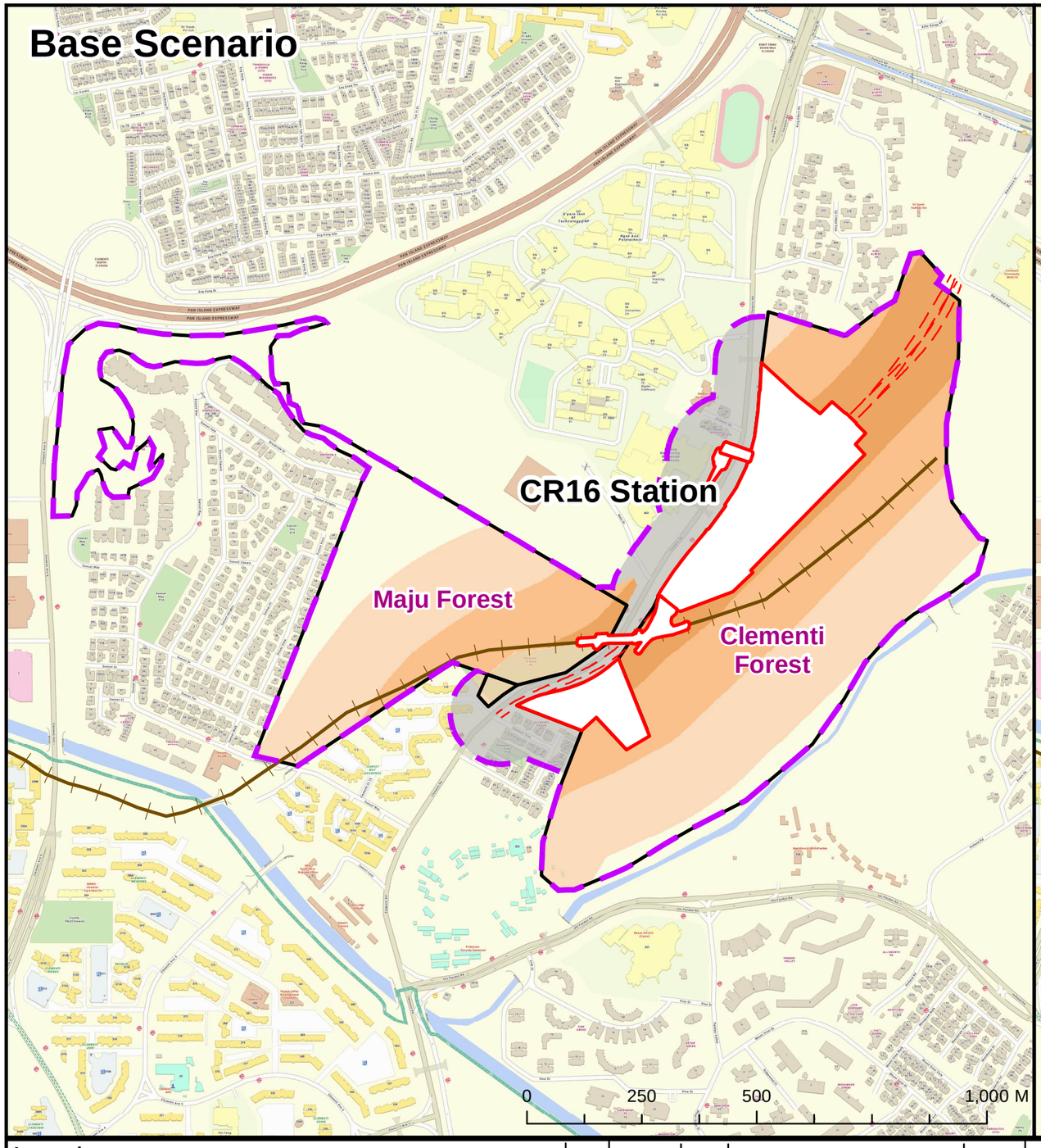
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR VIBRATORY PILE DRIVER ENTRANCES MITIGATED SCENARIO (STAGE 2)

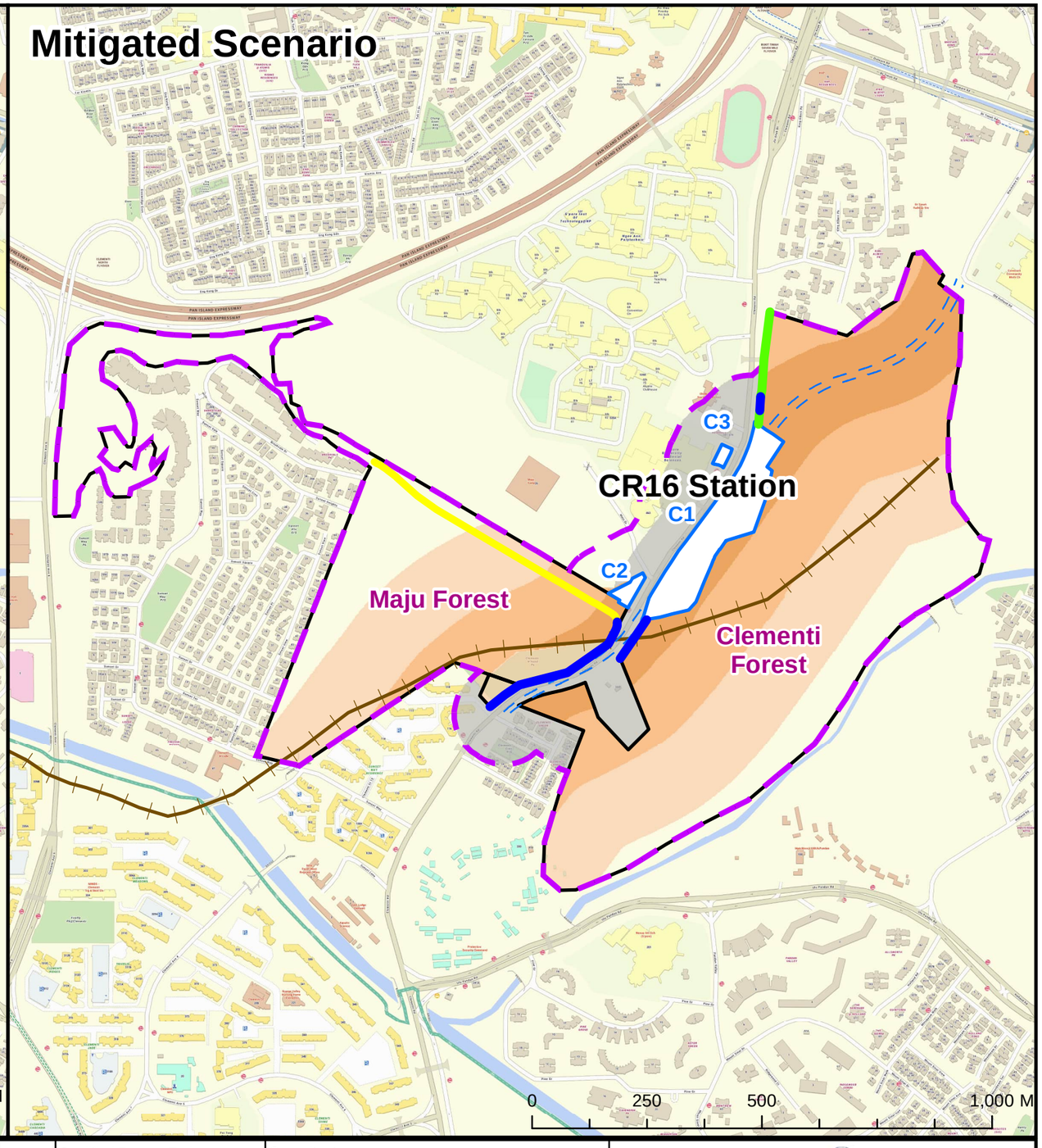
Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-19	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area
- Water-filled Barrier for Stage 2 Only (Rock Breaking & TBM), 480 m total
- Permanent Wire Mesh Fencing To Be Covered in Stage 2, 635 m
- Existing Fence To Be Covered in Advance Works & Stage 2, 220 m

Impact Significance

- Below Ambient
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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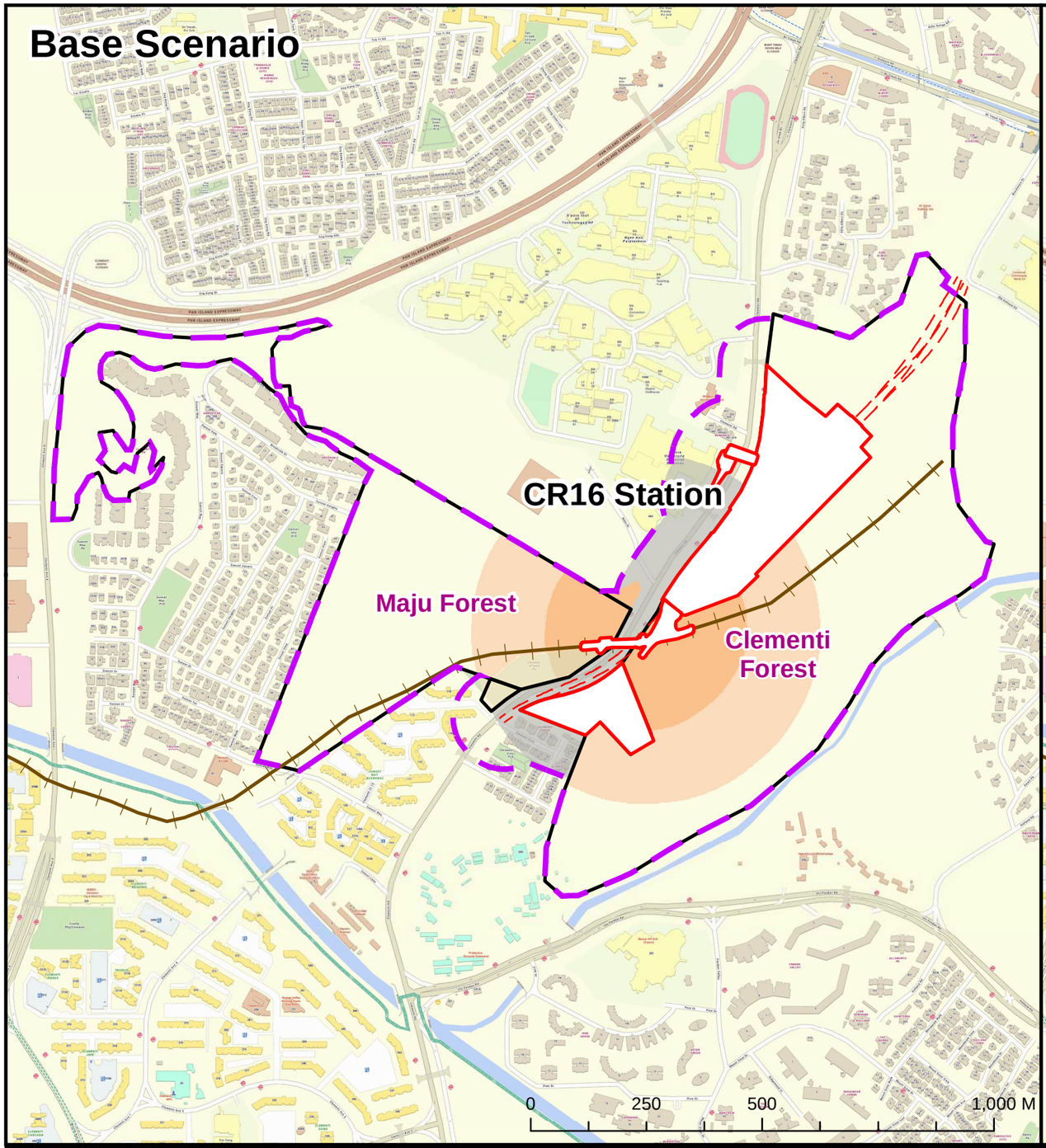
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR TUNNEL BORING MACHINE MITIGATED SCENARIO (STAGE 2)

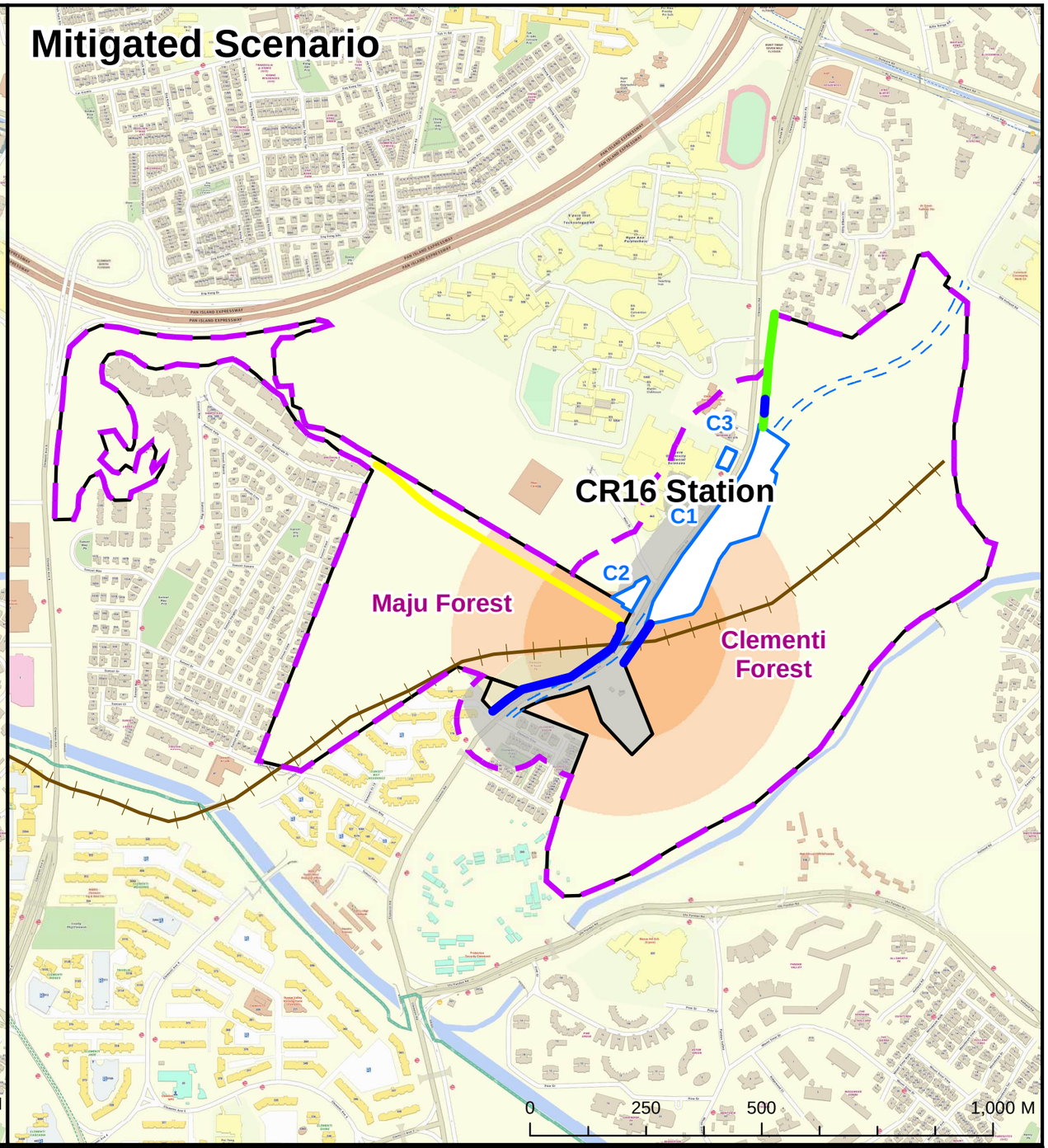
Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-20	-	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area
- Water-filled Barrier for Stage 2 Only (Rock Breaking & TBM), 480 m total
- Permanent Wire Mesh Fencing To Be Covered in Stage 2, 635 m
- Existing Fence To Be Covered in Advance Works & Stage 2, 220 m

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

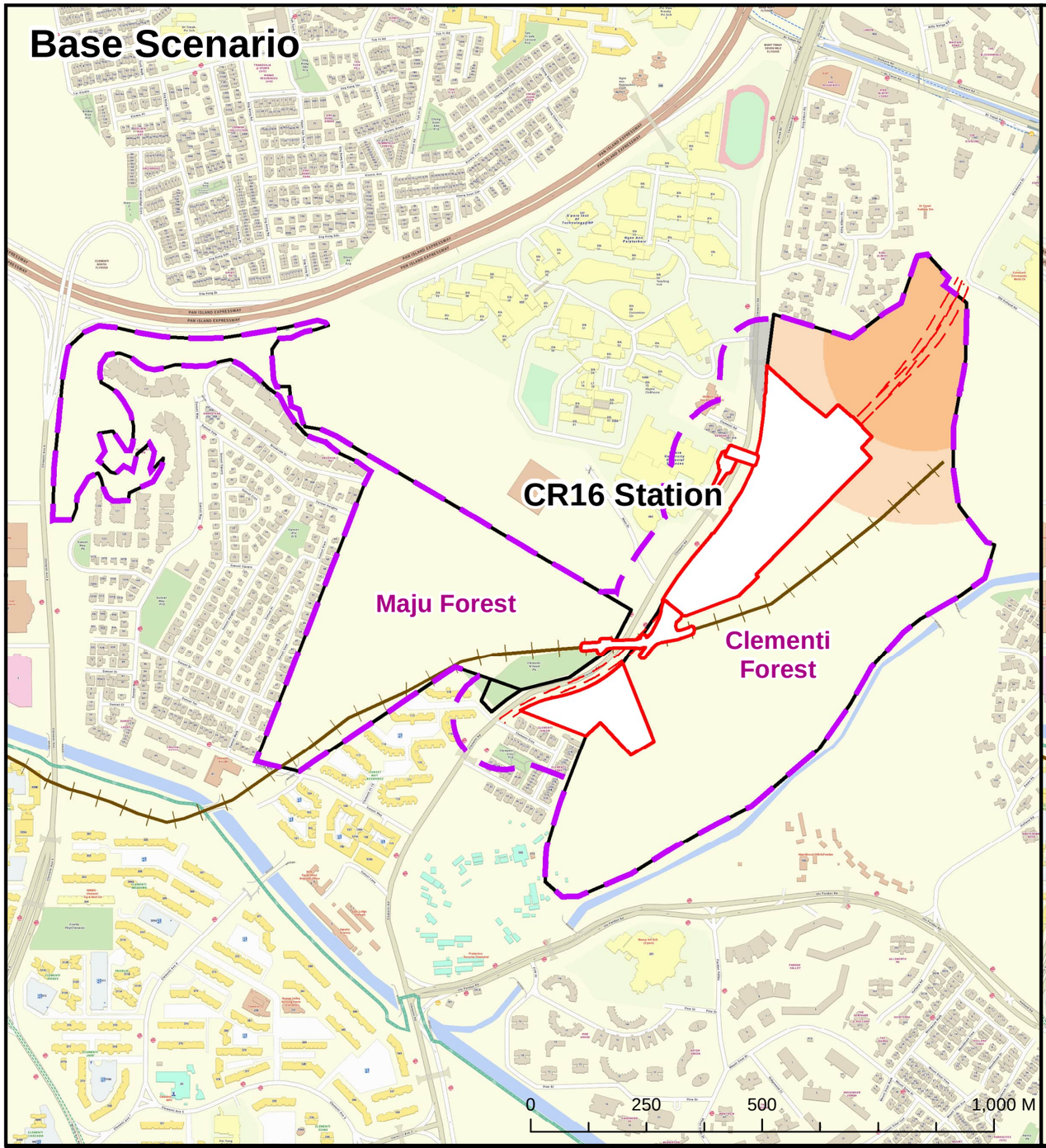
Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR TUNNEL BORING MACHINE SPOT 1 MITIGATED SCENARIO (STAGE 2)

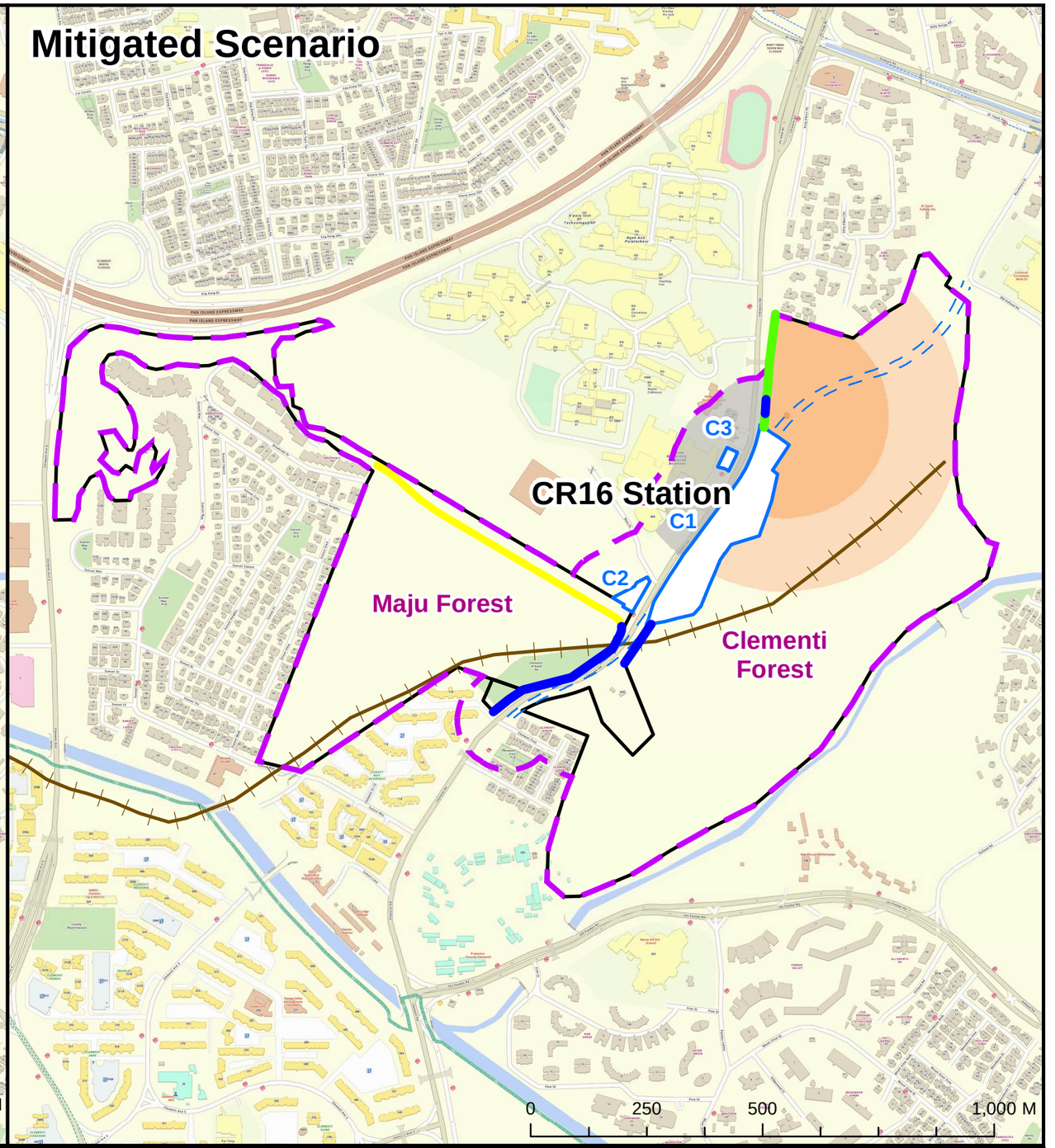
Designed	Checked	Approved
EGY	JAG/NHT	JAG
	Drawn: EGY	Date: JUL 2022

Figure No. : 12-21 | Rev. : A | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area
- Water-filled Barrier for Stage 2 Only (Rock Breaking & TBM), 480 m total
- Permanent Wire Mesh Fencing To Be Covered in Stage 2, 635 m
- Existing Fence To Be Covered in Advance Works & Stage 2, 220 m

Impact Significance

- Below Ambient
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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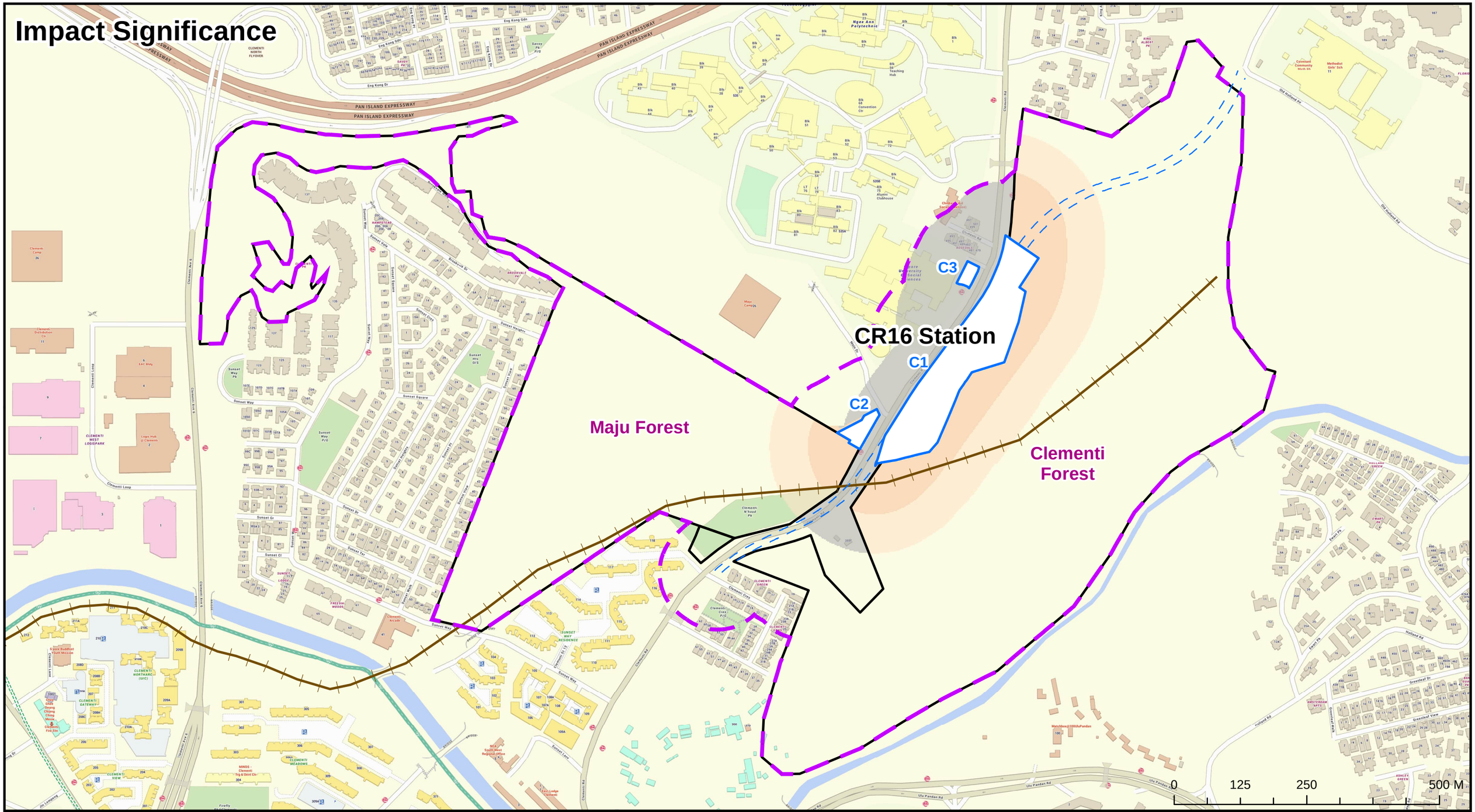
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
IMPACT SIGNIFICANCE COMPARISON FOR TUNNEL BORING MACHINE SPOT 2 MITIGATED SCENARIO (STAGE 2)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-22	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Mitigated Scenario Construction Worksite Footprint
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND
MAJU FOREST)**

Figure Title :
**VIBRATION ASSESSMENT FOR
HIGH VIBRATORY COMPACTOR
FOR TRAFFIC DIVERSION
MITIGATED SCENARIO (STAGE 2)**

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-23	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.9.2 Operational Phase

The standard trackform of the alignment and a tunnel depth of 25m to 48m is unlikely to cause significant vibration impacts to the sensitive fauna species. As the wheel-rail interaction generates the vibration, Maintenance of the railway tracks and wheels is required to preserve the levels of vibration emitted to the surroundings.

The maximum PPV for Clementi Forest and Maju Forest are summarised in Table 12-21. The respective figures can be seen in Figure 12-24 to Figure 12-26.

The detailed impact assessment results of these vibration sources are in Table 12-21.

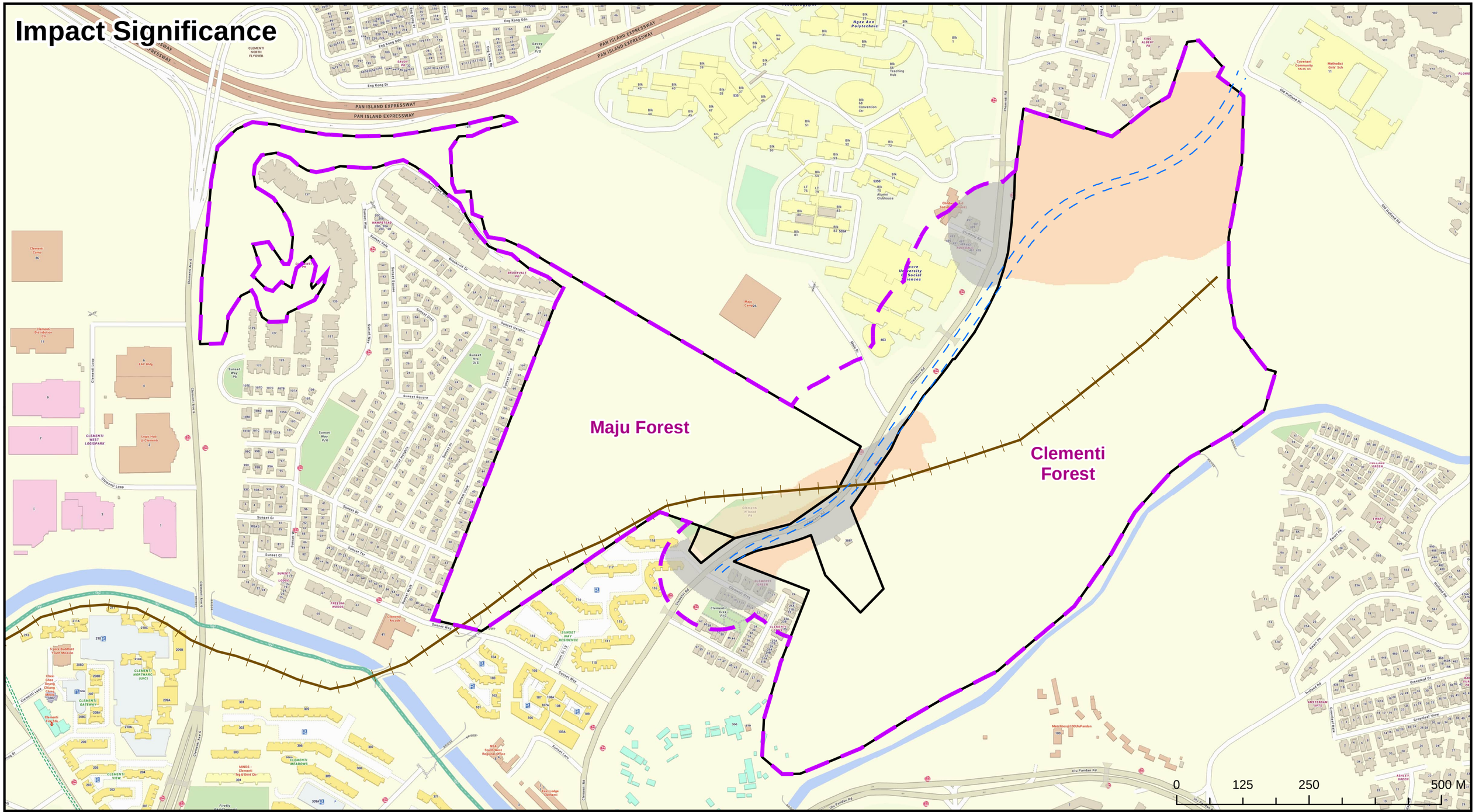
Table 12-21 Results of Operational Impact Assessment at Clementi Forest and Maju Forest

Operational Vibration Impact Assessment	Max PPV Outside Worksite and within Biodiversity Study Area (Maju Forest), mm/s	Max PPV Outside Worksite and within Biodiversity Study Area (Clementi Forest), mm/s	Vibration Threshold for Damage/Collapse of the Burrow, PPV, mm/s	Evaluation Outcome
Train Mitigated Alignment Scenario Overall	0.18	0.22	8	Unlikely to cause damage/collapse to the burrow
Train Mitigated Alignment Scenario Spot 1	0.14	0.17	8	
Train Mitigated Alignment Scenario Spot 2	0.00	0.16	8	

Table 12-22 Mitigated Alignment Scenario Impact Significances for Operational Activities at Biodiversity Study Areas

	Mitigated Alignment Scenario Impact Significance		Behavioural Impacts on Ecological Receptors at Vibration Biodiversity Study Areas
	Biodiversity Study Area – Clementi Forest	Biodiversity Study Area – Maju Forest	
Full Alignment Analysis	**Negligible – Minor**	**Minor**	For all mitigated alignment operational activities that have an impact significance of **minor**, despite the increase in vibration levels, fauna species are likely to adapt to the operational activities and would potentially return to their normal activity and habitat.
Spot 1 and 2 Analysis	**Negligible**	**Minor**	

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE MITIGATED SCENARIO

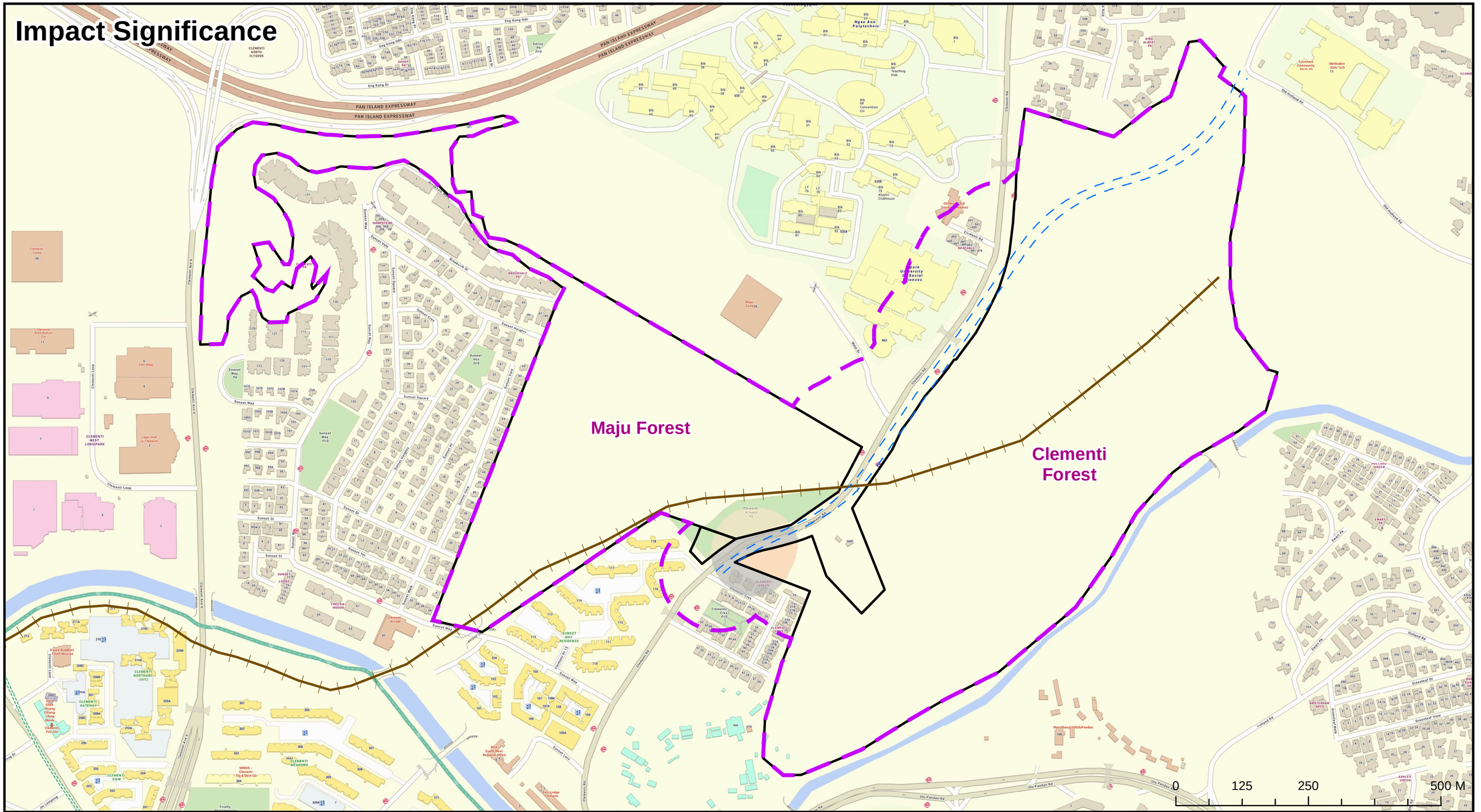
Designed	Checked	Approved
EGY	JAG/NHT	JAG
	Drawn: EGY	Date: JUL 2022

Figure No. : 12-24 | Rev. : A | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

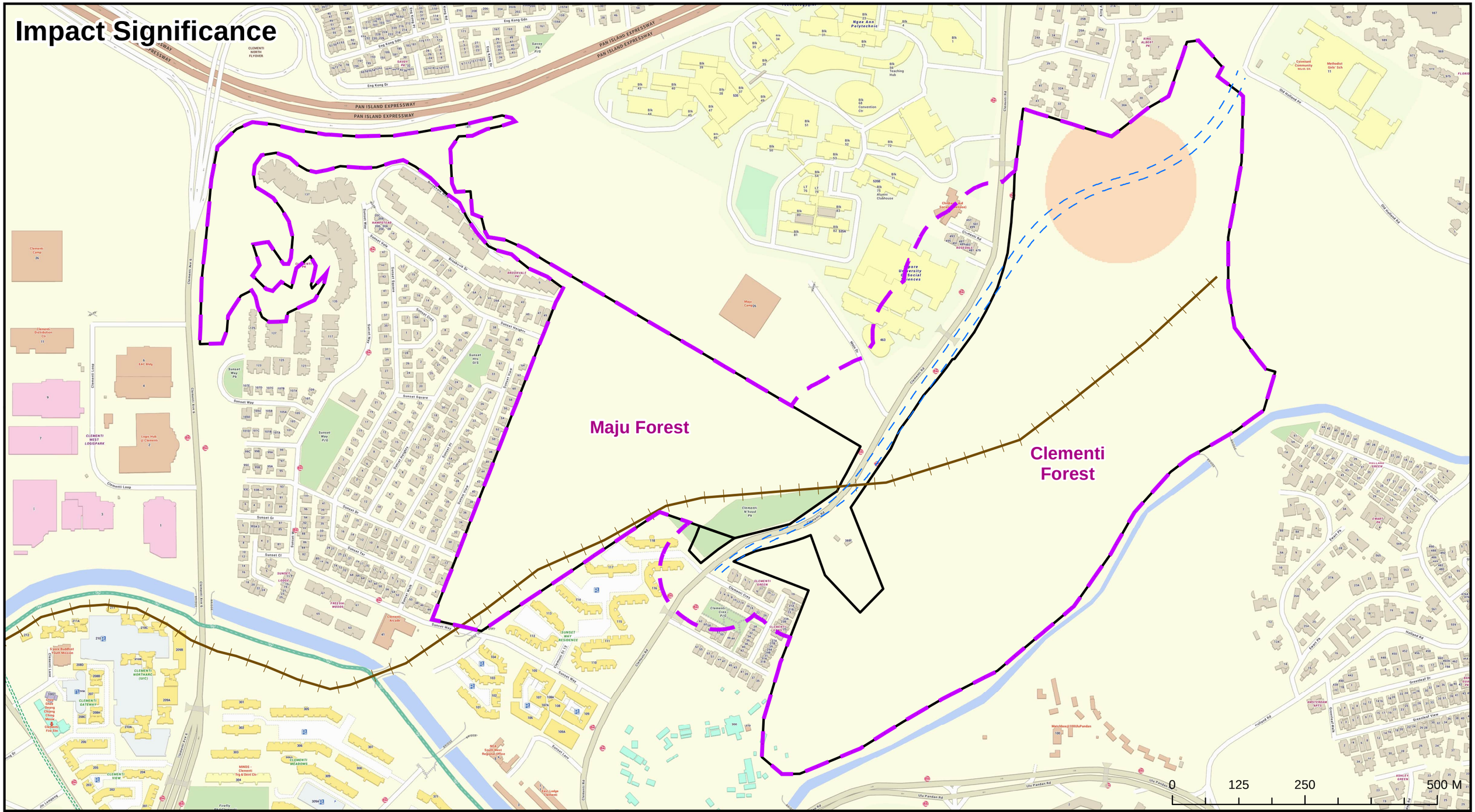
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE
SPOT 1
MITIGATED SCENARIO

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-25	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Vibration Study Area
- Old Jurong Railway Corridor
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	JUL 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG
-	MAY 2022	EGY	EIS (Clementi Forest and Maju Forest)	JAG/NHT	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (CLEMENTI FOREST AND MAJU FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE
SPOT 2
MITIGATED SCENARIO

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG/NHT	JAG	12-26	A	1 of 1
	Drawn EGY	Date JUL 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.10 Cumulative Impacts with Other Major Concurrent Projects

Regarding Section 3.4.1, there are other major concurrent developments during the construction and operational phases of this Project. The ground-borne vibration cumulative impacts from these developments are discussed in this section qualitatively.

12.10.1 Construction Phase

Other worksites include PUB DTSS2 Proposed manholes and pipelines, Proposed Brookvale Drive Project, Old Jurong Line Nature Trail and Clementi Forest Stream Nature Trail near CR16 worksites. During the writing of this Report, there is limited information regarding construction activities to be reviewed; hence cumulative impacts are not assessed quantitatively.

The construction schedule for PUB DTSS2 Proposed manholes and pipelines might overlap with this Project's. However, typical construction methods for manholes and pipelines are unlikely to cause higher vibration levels than this Project's. Hence this Project's worksite activities are the primary source of impact within the vibration Biodiversity Study Area.

The construction timeline for the Proposed Brookvale Drive Project is different from this Project's; hence overlapping works such as piling is unlikely to happen, causing high cumulative vibration levels.

12.10.2 Operational Phase

During the operational phase of this Project, the track works attenuate the ground-borne vibration levels caused by moving trains. The levels are insignificant in the cumulative impact of other significant concurrent developments. No mitigation is required at the tracks.

12.11 Summary of Key Findings

The Study assesses the impact of construction ground-borne vibration on the impacted areas within the biodiversity areas such as Clementi Forest and Maju Forest.

The Study reviewed several works of literature to gather information on vibration thresholds of fauna. Research shows that vibration thresholds for fauna are species-specific. There is a limited amount of information in this area for the indicator species for the Study. The Study uses the step threshold endured by humans as a basis to form a criterion for the vibration impact assessment.

The Study assesses vibration impacts from construction and operational phases on the potential of burrow damage/collapse for fossorial species (i.e. structural impact assessment) and the ecological behaviour of the sensitive receptors. The biodiversity habitats/fauna species classifies in Priorities 1, 2 and 3 as ecologically sensitive receptors based on their ecological values and sensitivity towards vibration. The indicator species includes pangolin. The Study assesses predicted vibration levels from the construction and operational phases of the Project. It evaluates against the impact assessment matrix for impact intensity, consequence, likelihood and impact significance on the ecological behaviours of the ecologically sensitive receptors.

12.11.1 Summary of Construction Activities

The Study predicted vibration levels for various construction equipment at the CR16 worksite for unmitigated and mitigated scenarios. The vibration levels are assessed according to the impact assessment matrix.

For the unmitigated scenario, the bulldozer causes minor – moderate vibration impact significance at Clementi Forest and negligible – moderate vibration impact significance at Maju Forest. Avoiding construction work at night could reduce the vibration impacts impact significance from moderate to **minor** at Clementi Forest and Maju Forest.

Low and high amplitude vibratory compactor causes **negligible – minor** impact significance in the mitigated scenario. As high vibratory compactors produced PPVs exceeding 5 mm/s, the Contractor should use best available techniques (BAT) and control construction vibration levels to PPV, 8 mm/s at vibration sensitive biodiversity areas.

Tunnel boring vibration levels predicted using the BS5228-2:2009+A1:2004 method cause minor – major impact significance at Clementi Forest and Maju Forest. Hence mitigation measures are recommended for the mitigated scenario to reduce the impact significance to **minor – moderate**.

There is pipe jacking in the mitigated scenario during Advance Works for utility. The vibration levels may cause partial burrow collapse and cause **negligible – major** impact significance on the ecological receptors. As the depth of works (for the pipes) is very willow (7 m only), other construction methods are unlikely to mitigate vibration levels. The worksite needs to avoid exceedances at PPV, 8 mm/s, which is the threshold for burrow damage/collapse to control vibration impacts.

During Stage 2 in the mitigated scenario, there are rock breaking and excavation activities. This construction method produces high vibration levels, thus causing impacts on the structural integrity of burrows; and **minor-major** impact significance on ecological receptors. The rock breaking and excavation works must limit their vibration emission levels to PPV, 8 mm/s in areas with potential burrows to avoid damage/collapse of the burrow entombing the fauna.

At Maju and Clementi Forest, before the construction activities commence, a 220 m long temporary barrier (e.g. water-filled barrier of 1 m height) will also be set up at specific locations along Clementi Road for pipe jacking (Advance Works). The Client has confirmed on 31st May 2022 that Brookvale Drive will still be under construction during Advance Works. Hence, existing hoardings will be present to replace water barriers during this stage. Where there are no hoardings from Brookvale Drive leading to Clementi Road, water barriers have to be implemented. More water barriers will have to be added along Clementi Road at Stage 2 when rock breaking and excavation and tunnel boring begins. At this stage, the temporary barrier should have a total length of 480 m. In addition, 635 m of the permanent wire meshed fences along Brookvale Drive from a residential project must also be covered with canvas sheets. At both Advance Works and Stage 2, hoardings must be included at the worksites and canvas sheets must be added onto existing railings (220 m long) along Clementi Road to cover holes on the railings. These will potentially mitigate roadkills due to the impacted fauna trying to dash onto a road during the construction activities, reducing the impact significance to **moderate**.

12.11.2 Summary of Operational Activities

Operational vibration impact assessment results indicate that standard track form and deep tunnel depth are sufficient to mitigate vibration impacts on sensitive fauna species. The residual impact significance on ecological behaviour with mitigation measures is **minor** in Clementi Forest and Maju Forest.

12.11.3 Summary of Concurrent Activities

There is other significant concurrent development during the construction and operational phase of this Project. The study assesses cumulative vibration impacts qualitatively. During the construction phase of this Project, there are ongoing construction works at PUB Deep Tunnel Sewerage System Phase 2 (DTSS), road construction works, and residential development works. The ground-borne vibration caused by rock breaking, piling works, and tunnel boring for this Project is the dominant vibration source within the vibration Biodiversity Study Area. The construction schedule of these ongoing works and the schedule of this Project for high vibration activities are drastically different in construction timelines. Therefore, overlapping schedule for high vibration works such as piling at both sites is unlikely to happen. The vibration levels caused by ongoing works at other sites are insignificant in the cumulative impact assessment.

12.11.4 Conclusion

Overall, there are **negligible – major** residual impacts during the construction phase due to tunnel boring, pipe jacking, rock breaking and excavation at Clementi Forest and Maju Forest. The study recommends controlling vibration levels emitted to PPV, 8 mm/s where burrows of fossorial species are sighted to prevent damage/collapse of the burrows and entombing the species. Further mitigation measures include setting up temporary barriers (i.e. water barriers of 1 m height) along roads near the worksite and EMMP measures to reduce the impact significance to **negligible – moderate.** Concurrent construction activities at nearby works are unlikely to cause more impacts on the vibration Biodiversity Study Areas. Moving trains induce low ground-borne vibration levels and are insignificant to cause vibration impacts on the ecological receptors. Thus, there are no residual impacts for the operational phase.

Table 12-23 Summary of Ground-borne Vibration Impact Assessments

Sensitive Receptor	Impact Significance with Minimum Controls	Residual Impact Significance with Mitigation Measures (if required)	Final Impact Significance with Further Mitigation Measures (if required)
Construction Phase			
Clementi Forest	Negligible - Major	Negligible - Major	Negligible – Moderate (see Note 2)
Maju Forest	Negligible - Major	Negligible - Major	Negligible – Moderate (see Note 2)
Operational Phase			
Clementi Forest	Minor	Minor (see Note 1)	Minor (see Note 1)
Maju Forest	Minor	Minor (see Note 1)	Minor (see Note 1)

Note:

1. The initial impact assessment with minimum controls was considered insignificant (Negligible to Minor), no residual impact assessment was undertaken, hence the impact significance remained the same. Note that this does not indicate that impacts are completely eliminated.
2. Construction activities such as pipe jacking, rock breaking and excavation and tunnel boring produce high PPV levels at the biodiversity sensitive receptors. It is essential to implement EMMP measures to reduce the impact significance to **Moderate**.

13. Proposed Environmental Monitoring and Management Plan

The proposed EMMP is prepared for environmental impacts of the construction, commissioning and operational phases associated with the Project in overall for comprehensiveness of the study as well as to provide an overall picture of the potential roles and responsibilities required during each phase of the Project. The coverage of the proposed EMMP involves the environmental parameters that were assessed, namely air quality, airborne noise, ground-borne vibration, hydrology and surface water quality, soil and groundwater, and biodiversity. The EMMP details how the key mitigation measures recommended from the impact assessment/study are to be implemented and specifies environmental monitoring measures to assess the effectiveness of the proposed mitigation measures.

- During construction phase, this document is intended to provide a broad framework for various players in the construction phase to develop a more contract-specific EMMP, as per their responsibilities in Section 13.4 in order to comply with LTA's SHE specifications and any contract-specific requirements.
- During commissioning phase, this document is intended to provide a broad framework for various players with similar roles and responsibilities from construction phase (see Section 13.4) to further compliment their environmental protection effort by developing and implementing contract-specific EMMP after the completion of all the major construction activities. This is also to ensure smooth transition of the Project before handing over to the Rail Operator in operational phase.
- During the operational phase, this document is intended to provide a brief understanding of the responsibilities of Rail Operator (see Section 13.5) and other relevant personnel who perform or ensure the implementation of minimum control measures as per the relevant legislations and the proposed mitigation measures based on the impact assessment/study findings.

This section outlines the objectives of the EMMP, the Project organisation, describes the roles and responsibilities relevant to implementation of the EMMP, and summarises the EMMP requirements for each discipline. A summary of the proposed EMMP of different phases, incorporated with the relevant minimum controls and key mitigation measures, is provided in Section 13.13.

13.1 EMMP Objectives

The EMMP details the implementation and deliverables of the key mitigation measures recommended from the impact assessment for each technical discipline. The EMMP progressively scrutinises construction, commissioning and operational activities as they ensue and applies flexible monitoring and management procedures to protect the Project's environmental values throughout the Project period. The objective of the EMMP is twofold:

a) Environmental monitoring focuses on overseeing those impacts to the Project's environmental values from construction and commissioning phases are within the anticipated level and tackle unforeseen impacts that may arise; and

b) It also tracks the effectiveness of the recommended mitigation measures to allow amendment or review of the mitigation measures to better address any issues faced during construction, commissioning and operational phases of the Project.

Environmental management employs a more active approach to ensure those impacts on flora and fauna are directly avoided through documentation, auditing and enforcement.

13.2 Project Organisation during Construction and Commissioning Phases

The proposed Project organization and lines of communication with respect to environmental protection works for construction and commissioning phases of this Project are presented in Figure 13-1. The roles and responsibilities of the various parties responsible for implementing the EMMP during the construction and commissioning phases are outlined in Section 13.4.

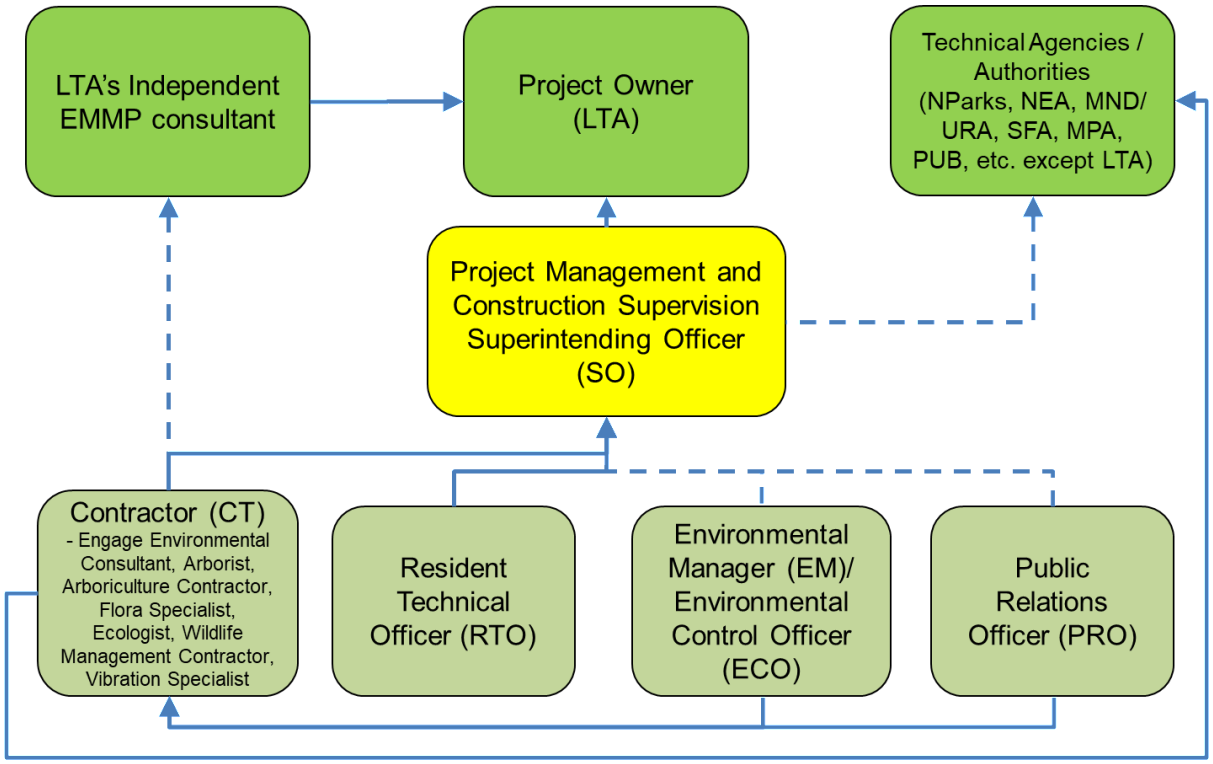


Figure 13-1 Project Organization and Lines of Communication during the Projects' Construction and Commissioning Phases

13.3 Project Organisation during Operational Phase

The proposed Project organization and lines of communication with respect to the general management and implementation of the recommended minimum control measures as well as key mitigation measures during operational phase of this Project are presented in Figure 13-2, forming a typical Environmental Management Committee or as part of the Environmental, Health and Safety (EHS) Committee for a particular organization/operation. The roles and responsibilities of the various parties involved in the operational phase are outlined in Section 13.5.

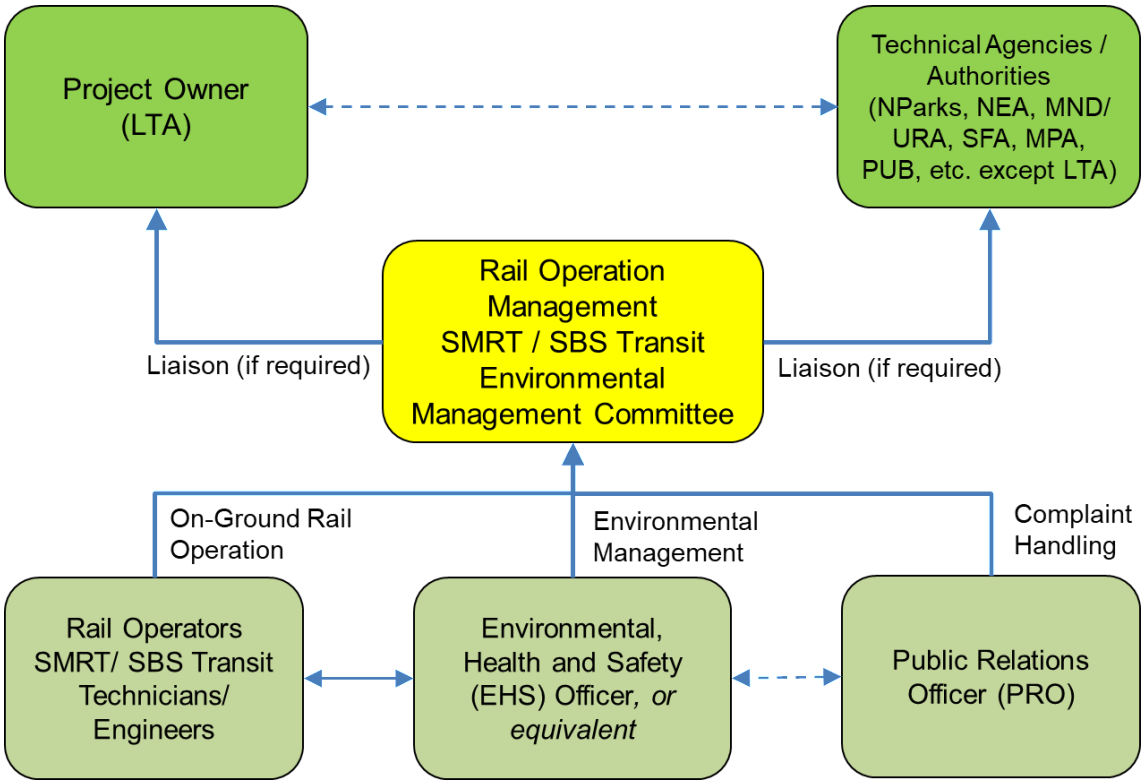


Figure 13-2 Project Organization and Lines of Communication during the Projects' Operational Phase

13.4 Roles and Responsibilities during Construction and Commissioning Phases

This section describes the roles and responsibilities of the EMMP members presented on the organisational chart for construction and commissioning phases in Section 13.2.

13.4.1 Technical Agencies

Technical Agencies constitute but are not limited to NParks, PUB, NEA, and URA. These Agencies will assess and approve the detailed EMMP for the construction and commissioning phases prior to commencement of works and where required during the course of the relevant Project phases.

13.4.2 Project Owner (LTA) and Resident Technical Officer (RTO)

LTA, being the Project owner, oversees the construction and commissioning phases of the Project in accordance with the design. LTA, in conjunction with the Resident Technical Officer (RTO) (Contractor), are required to:

- Ensure resources are available to achieve the requirements of the EMMP;
- Provide leadership in the development and implementation of the EMMP;
- Ensure all environmental incidents and near misses are promptly investigated and reported;
- Resolve any non-compliance issues;
- Record, respond to, and action on any complaints from members of the public, if any, with inputs from the Technical Agencies, if required; and
- Reporting to the Technical Agencies regarding implementation of the EMMP.

13.4.3 Superintending Officer (SO)

The Superintending Officer is responsible for overseeing the construction works undertaken by various staff, Contractors and sub-contractors. The SO should ensure that the construction works are performed by the Contractors and personnel in accordance with the specification, contractual requirements, and EMMP. The SO should also:

- Communicate the requirements of this plan to all staffs, Contractors and sub-contractors;
- Monitor all staffs, Contractor's and sub-contractor's compliance with contract specifications and regulatory requirements, including the implementation of the environmental mitigation and monitoring measures and ensure their effectiveness, and other aspects of the environmental audit program;
- Coordinate with the Project's EM/ECO to monitor and participate in the implementation of the environmental audit program, and ensure that the requirements in the environmental audit program are correctly followed;
- Implement measures to reduce impacts where emission/discharge levels are exceeded;
- Coordinate with the Project Owner and RTO for submission of environmental audit reports;
- Carry out any complaint investigations with PRO (see Section 13.4.4.8);
- Resolve any non-compliance issues; and
- Promote environmental awareness and responsibility and lead by example.

13.4.4 Contractor (CT)

The term "Contractor" refers to all construction Contractors and sub-contractors working onsite at any time, which also the "Occupier of Construction Site" as defined by NEA. In addition to reporting to the SO, the Contractor should:

- Work under the relevant contract scope, specifications, and other tender conditions;
- Ensure that the roles of Environmental Manager (EM), Environmental Control Officer (ECO), Certified Arborist, Arboriculture Contractor, Flora Specialist, Ecologist, Wildlife Management Contractor(s) are adequately resourced;
- Notify the Director-General of Public Health on the employment of ECO (also applicable for EM who will also be an registered ECO in the context of this Project) by submitting the Notification on Employment of Environmental Control Officer (as per the format *in the NEA's Code of Practice of Environmental Control Officers*), as well as to notify in writing to the Director-General of Public Health and to employ another registered ECO/EM within 14 days of the termination of the employment of the originally appointed ECO/EM;
- Employ a temporary ECO or engage a registered Workplace Safety and Health Officer (WSHO) with valid ECO certificate obtained under NEA if both EM and ECO working on the construction site are on leave or absent for more than 5 days, and neither of them can take on the work responsibility of an ECO during the absence period;
- Endorse and submit the Site Environmental Control Programme prepared by the ECO/EM to the Director-General of Public Health at least two weeks before work commences on the construction site;
- Discuss about the Site Environmental Control Report with the EM/ECO within one week on receipt of the report, then countersign and stamp after finalization and implement the recommendations made by the ECO;
- Keep the Site Environmental Control Report available for inspection by the Director-General of Public Health or Public Health Officers when required, as well as to submit when required to so by the Director-General of Public Health;
- Participate in the required environmental site audits (via the SO) undertaken by a registered EM/ECO and undertake any corrective actions;
- Provide up-to-date information and advice to the RTO, SO, EM, ECO, Certified Arborist, Arboriculture Contractor, Flora Specialist, Ecologist, Wildlife Management Contractor(s) regarding any work activities which may contribute or continuously create adverse environmental conditions, or any changes to the work plan;
- Implement measures to reduce impacts where emission/discharge levels are exceeded;
- Prepare a detailed contract-specific EMMP, incorporating the relevant mitigation measures and monitoring works recommended in this study and seek technical Agencies' approval prior to the commencement of any works for the construction and commissioning phases of the Project. This detailed EMMP will include, as a minimum, a Standard Operating Procedure (SOP) detailing:

- Handling and storage of hazardous chemicals;
- Biodiversity management plan;
- Individual environmental management plans as detailed in the LTA's SHE Specifications (air, vector, waste, noise, water pollution management plans);
- Monitoring plans (including but not limited to noise, air, waste, ecology and water pollution);
- Environmental Impact Register;
- Existing legislation and environmental best practices to be implemented; and
- Contingency planning during emergency situations.

13.4.4.1 Environmental Personnel

According to LTA's SHE Specifications, the Contractor will comply with all legislative safety, health and environmental (SHE) requirements as stipulated. SHE personnel refer to Workplace Safety and Health Officer (WSHO) registered with the Ministry of Manpower (MOM) and ECO registered with the NEA. After consultation with LTA, the Contractor will engage the following environmental personnel during the construction and commissioning phases of this Project:

- Environmental Consultant, with strong and relevant experiences in developing and implementing EMMP for similar or larger construction Projects;
- Environmental Manager (EM), who is a NEA-registered ECO with strong and relevant experiences, to oversee/ lead/ guide environmental monitoring and auditing works on the construction site; and
- Environmental Control Officer (ECO), who will assist the EM and is also registered with NEA, to perform and/or ensure implementation of EMMP, mitigation measures and minimum control measures on site.

13.4.4.1.1 *Environmental Consultant*

An environmental consultant will be engaged by the Contractor to develop a contract-specific EMMP for implementation by all parties, including EM/ECO and relevant workers on site. The appointed environmental consultant may be required to re-establish baseline environmental conditions and perform the recommended environmental monitoring works throughout the construction and commissioning phases, as well as to provide environmental advisory services for the Contractor and to liaise with the authorities and stakeholders and/or the independent EMMP Consultant from LTA during external audit (see Section 13.12.1), when necessary.

13.4.4.1.2 *Environmental Manager (EM)/ Environmental Control Officer (ECO)*

General Introduction

The Environmental Control Officer (ECO) Scheme was launched by NEA on 1 April 2000 to advocate good environmental practices within construction sites. Under the Environmental Public Health Act (EPHA), a part-time ECO working at least 15hr/week is required for construction sites with contract sum of between $10 million and $50 million, whereas a full-time ECO working at least 40hr/week must be engaged by construction sites with contract sum exceeding $50 million.

The main role of a registered ECO is to advise the Occupier of the construction site on what needs to be done, which include advising construction site's Contractors on environmental remediation measures, facilitating compliance with the environmental laws, carrying out site inspections and engagement of stakeholders for environmental lapses, as well as educating workers on maintaining good environmental health standards. NEA has also specified that the role of ECO(s) in general would comprise the following aspects:

- Disease-bearing insects and rodents;
- Proper disposal of construction waste/ marine clay;
- Noise, air and water pollution;
- Earth littering;
- Siltation of drains;
- Food hygiene in on-site canteens (if any);
- Proper maintenance of septic tank(s)/ holding tank(s), chemical/ portable toilet(s) and other sanitary facilities; and
- Any other environmental health matters.

The registered ECO(s) will be employed by the Occupier of the construction site (the Contractor) but may not be in any way as an associated body of the Contractor, the SO, or the Project's SHE team.

For this Project

As mentioned, both EM and ECO are environmental control officers registered under NEA. In view of the scale and nature of this Project, during construction and commissioning phases, EM will be the leading role and is expected to have prior experience in EMMP for Projects with biodiversity sensitivity to manage and oversee the overall EMMP implementation and act as the key liaison with Agencies and stakeholders on environmental-related matters when necessary; while the ECO can be the same person if possible, else a supporting role officer who is responsible for most of the implementation of EMMP and relevant environmental measures on ground.

Generally, a NEA-registered ECO (applicable for EM and/or ECO of this Project) will comply with the latest NEA's *Code of Practice for Environmental Control Officers*, where the duties include but not limited to:

- Prepare and submit a Site Environmental Control Programme based on the latest required format in Appendix 2 of the above-mentioned code of practice, within one month after the commencement of works on the construction site to NEA (after reviewed by the Project Owner LTA) via Form SG;
- Prepare and submit the Site Environmental Control Report(s) based on the latest required format in Appendix 3 of the above-mentioned code of practice, after the commencement of construction works, and at least once a month or any other frequency required by NEA and/or LTA throughout the construction and commissioning phases;
- Identify and attend to all environmental issues, inform the Occupier of the construction site accordingly, and recommend measures to rectify the irregularities;
- Assist the authorities to investigate environmental issues and outbreaks of infectious, vector-borne or food-borne diseases on the construction site; and
- Organise campaigns, training, toolbox briefings and other relevant courses to develop the capability of all relevant workers in implementing EMMP, as well as to raise their environmental and biodiversity awareness in maintaining good environmental performance on site.

Resources to implement the environmental monitoring program should be allocated in time to fulfil the environmental audit/ inspection requirements during construction works. The EM/ECO will work closely with other EMMP members to ensure environmental compliance of the construction sites, as well as to ensure proper and safe working condition of relevant construction facilities and equipment:

- Oversee and manage the implementation of minimum control measures, mitigation measures and EMMP on site;
- Coordinate with various parties with respective to EMMP, which include:
    - Liaise with the SO and/or WSHO regarding equipment, locations, and schedule of monitoring and auditing works; and
    - Coordinate among the Client, Contractor, and other personnel within the Biodiversity Team for the implementation of the EMMP measures for biodiversity.
- Formulate and implement the environmental monitoring and audit program as required in this document;
- Monitor compliance with conditions in the EMMP, relevant environmental protection, pollution prevention and control regulations and contract specifications;
- Analyse environmental monitoring data and audit findings, review the adequacy of implementation of mitigation measures, identify adverse environmental impacts, and liaise with the SO;
- Carry out weekly site audits/ inspections against the Contractor's site practices, equipment and work methodologies with respect to pollution control and environmental mitigation, and effect proactive actions to pre-empt problems in coordination with the SO;
- Report the results of the environmental monitoring works and audit program, and any required changes to meet the requirements of the EMMP and legal obligations to the SO in a timely manner; and
- Coordinate the investigation of biodiversity-related incidents;
- Provide solutions and address complaints related to environmental incompliances or related incidents, with cooperation from SO and/or WSHO; and
- Compile and submit the updated findings, along with completed remedial actions supported by photographs to LTA fortnightly in the form of an Environmental Performance Report (also known as Environmental Inspection Report).

13.4.4.2 Arborist

An Arborist certified by the International Society of Arboriculture (ISA) plays an important role as part of the biodiversity monitoring programme during both construction and commissioning phases of this Project. He/She will possess previous work experience in developments of similar size or complexity who is able to demonstrate capability in monitoring and managing all matters related to the adequate and successful conservation of trees and flora within and adjacent to the contract boundary. A detailed description of biodiversity monitoring programme is provided in Section 13.6, where the key responsibilities of the Arborist are listed as follows:

Construction Phase

The key responsibilities of an ISA-certified Arborist during construction phase include but not limited to:

- Carry out tree mapping and assessment;
- Implement tree protection plans;
- Provide advice on tree transplanting;
- Review Contractor's method statements for site clearance, tree felling and setting up of tree protection zones (TPZ);
- Assess forest edge effects and its associated changes;
- Implement tree maintenance and care; and
- Carry out monthly tree inspection and reporting.

Commissioning Phase

The key responsibilities of an ISA-certified Arborist during commissioning phase include but not limited to:

- Implement tree maintenance and care; and
- Carry out monthly tree inspection and reporting.

13.4.4.3 Arboriculture Contractor

The Arboriculture Contractor should meet NParks' safety requirements for work at height and LTA's requirements for temporary works along roadsides. All arboriculture workers engaged by the Arboriculture Contractor to perform tree climbing and chainsaw work will possess a valid basic tree climbing certification based upon demonstrated competence in the Workforce Skills Qualifications (WSQ) module conducted by Centre for Urban Greenery and Ecology (CUGE) or an equivalent WSQ-approved training organisation; and

The arboriculture crew deployed by the Arboriculture Contractor for the Contract will possess the following valid competences:

- Operation of chainsaw for ground work (LS-MT-103E-1);
- Chainsaw safety and maintenance (LS-MT-102E-1);
- Perform formative pruning of young trees (LS-MT-114E-1);
- Provide Arboriculture support on site (LS-MT-116E-1);
- Workplace safety and health – operators (ES-WSH-101G-1);
- Respond to Emergency (LS-HM-208E-1);
- Perform advance rigging and climbing techniques (LS-HM-308S-1);
- Perform aerial tree access and aerial rescue skills (LS-HM-204S-1);
- Implement and apply appropriate risk and safety management to sector practices (LS- BP-301S-1);
- Prepare risk assessment report (LS-HM-406S-1); and
- Operate and work from an elevated work platform (CUGE-ARB-3501).

Construction Phase

The certified Arboriculture Contractor will be responsible for pruning and maintenance of retained trees, as well as felling of trees during the construction phase of this Project.

Commissioning Phase

The certified Arboriculture Contractor will be responsible for pruning and maintenance of retained and newly planted trees, as well as felling of trees (if required) during the commissioning phase of this Project. Arboriculture Contractor is to strictly ensure the felling/transplanting of trees is in accordance to approved plan by NParks.

13.4.4.4 Flora Specialist

For this Project, a Flora Specialist plays an important role in the implementation of flora-related EMMP measures (e.g. Flora Management Plans) as part of the biodiversity monitoring program during both construction and commissioning phases of this Project. He/She will possess previous work experience in developments of similar size or complexity who is able to demonstrate capability in implementing flora management plans. A detailed description of biodiversity monitoring programme is provided in Section 13.6, where the key responsibilities of the Flora Specialist are listed as follows:

Construction Phase

The key responsibilities of a qualified Flora Specialist during construction phase include but not limited to:

- Review soil investigation locations and proposed site access to minimise excessive vegetation removal;
- Identify plant species (e.g., climbers, shrubs, epiphytes, ferns) of value that can be extracted for propagation and harvesting;
- Recommend weed and invasive species management if necessary;
- Review planting palette of reforestation works and ensure that the specifications for planting are met; and
- Carry out monthly flora inspection and reporting.

Commissioning Phase

The key responsibilities of a qualified Flora Specialist during commissioning phase include but not limited to:

- Recommend additional weed and invasive species management if necessary; and
- Carry out monthly flora inspection and reporting.

13.4.4.5 Wildlife Management Contractor

For this Project, the Wildlife Management Contractor (with at least one veterinary professional with experience within the team) would be responsible in carrying out animal rescue, trapping and transport of large fauna if any human-wildlife conflicts are encountered during construction and commissioning phases on site. The Wildlife Management Contractor will be listed under NParks' public register of certified Wildlife Management Contractor and have experience carrying out animals rescue, trapping and transport of large fauna.

A detailed description of biodiversity monitoring programme is provided in Section 13.6, where the key responsibilities of the Wildlife Management Contractor are listed as follows:

Construction Phase

The key responsibilities of a qualified Wildlife Management Contractor during construction phase include but not limited to:

- Carry out fauna rescue and translocation in consultation with attending Ecologist and NParks; and
- Propose trapping of fauna in consultation with attending Ecologist and NParks to satisfy Section 10 of the Wildlife Act.

Commissioning Phase

The key responsibilities of a qualified Wildlife Management Contractor during commissioning phase include but not limited to:

- Carry out fauna rescue and translocation in consultation with NParks.

13.4.4.6 Vibration Specialist

- Vibration Specialist, with strong and relevant experiences, to oversee/ lead/ guide vibration monitoring on the construction site, and to ensure it is carried out according to guidelines and standards;

- Vibration Specialist, who shall assist the ECO, to perform and/or ensure implementation of EMMP, mitigation measures and minimum control measures on site.

13.4.4.7 Ecologist

For this Project, an Ecologist plays an important role in the implementation of fauna-related EMMP measures as part of the biodiversity monitoring program during both construction and commissioning phases of this Project, who can also be known as a Fauna Specialist. He/She will possess a degree (or equivalent) in ecology-related fields with experience in implementing fauna management plans. In addition, at least two (2) valid certifications of the following:

- Animal Management Professional Certification Programme (PCP) – Basic Module (CUGE-PCP-7006A)
- Animal Management PCP – Intermediate Elective Module – Mammals (CUGE-PCTP-7006C)
- Animal Management PCP – Intermediate Elective Module – Reptiles (CUGE-PCP-7006B)

A detailed description of biodiversity monitoring programme is provided in Section 13.6, where the key responsibilities of the Ecologist are listed as follows:

Construction Phase

The key responsibilities of a qualified Ecologist during construction phase include but not limited to:

- Carry out fauna monitoring surveys including terrestrial transect surveys, aquatic sampling and camera trapping;
- Implement fauna management during site clearance;
- Carry out pre-felling fauna inspections;
- Carry out monthly fauna inspection and reporting; and
- Facilitate the implementation of the fauna response plan.

Commissioning Phase

The key responsibilities of a qualified Ecologist during commissioning phase include but not limited to:

- Carry out fauna monitoring surveys including terrestrial transect surveys, aquatic sampling and camera trapping; and
- Carry out monthly fauna inspection and reporting.

13.4.4.8 Public Relation Officer (PRO) for Complaint Handling

The Public Relation Officer (PRO) is responsible for handling complaints and managing feedback and investigative work. The PRO will be supported by the Project Owner, RTO, SO, EM/ECO, Contractor representatives, and any other relevant parties.

During the construction and commissioning phases, upon receipt of complaints, the PRO should undertake the following procedures:

- Log the complaint and record the date when the complaint is received onto the complaint database and inform the Project Owner, SO, EM/ECO immediately;
- Investigate the complaint with the EM/ECO to determine its validity and assess whether the source of the problem is due to construction works;
- If a complaint is valid and due to construction works, liaise with the EM/ECO on the mitigation measures and seek agreement from SO;
- Review the current situation and the EM/ECO's and SO's implementation of the mitigation measures;
- Engage the EM/ECO to undertake additional monitoring and auditing to verify the complaint if necessary. Ensure that any valid reasons for complaints do not re-occur by revising the work methods, procedures, machines and/or equipment, etc.;
- Submit a complaint report (as well as the implementation of mitigation measures and the effectiveness of the mitigation measures as advised by the EM/ECO) to the Project Owner, RTO and the SO; and

- Log a record of the complaint, investigation, follow-up actions and the results in the environmental audit reports.

The EM/ECO and SO should provide all the necessary information and assistance to the PRO in order to complete the complaint investigation. Following the investigation, the Contractor should promptly undertake the mitigation measures. The PRO and SO should ensure that the measures have been appropriately implemented. The Contractor, RTO, and SO should also be responsible for the reporting of complaint investigation results and followed up actions to the Project Owner. The complaint investigation report and corrective action plan should be prepared and approved by LTA and/or other relevant Authorities within 24 hr upon receipt of complaints.

13.5 Roles and Responsibilities during Operational Phase

This section describes the roles and responsibilities of the EMMP members presented on the organisational chart for operational phase in Section 13.3.

13.5.1 Technical Agencies

Consultation and engagement with the technical Agencies (e.g. NParks, PUB, NEA, etc) may be required if there are any major environmental concerns affecting their property, land boundary and/or related to the respective scope of responsibilities, or when inputs from technical Agencies are necessary in addressing any major public complaints due to environmental incidents arising from the rail operation (if any) of this Project.

13.5.2 Project Owner (LTA)

The Land Transport Authority (LTA) is a statutory board in Singapore under the Ministry of Transport responsible for public transport in Singapore, which is also the Project owner for this Project.

During the operational phase, under LTA's New Rail Financing Framework (NRFF), LTA owns the rail operating assets (e.g. trains, signalling system) and other associated infrastructure (e.g. viaducts, tunnels, tracks). The role of LTA as the owner involves making decisions on building-up, replacement and upgrading of the rail operating assets and infrastructure, while the licensed rail operator (e.g. SMRT Trains, SBS Transit) is responsible for the operation and maintenance of those assets and infrastructure.

LTA oversees the rail operations and management of the rail operator during the operational phase. In terms of environmental management, the responsibility of LTA includes:

- Regulate the rail operation and maintenance through the stipulated Operating Performance Standard (OPS), Maintenance Performance Standards and ISO14001 Environmental Management System;
- Ensure resources and appropriate personnel are available to achieve the environmental requirements;
- Provide leadership in maintaining overall environmental performance;
- Ensure all environmental incidents and near misses are promptly investigated and reported by the rail operator;
- Resolve any environmental non-compliance issues with the assistance from the rail operator; and
- Record, respond to, and action any complaints from members of the public, if any, with inputs from the Technical Agencies, if required, and
- Liaise with the Technical Agencies regarding any relevant issues arising from the environmental incidents, or environmental reporting and submission (if any) by the rail operator.

13.5.3 Rail Operator

As mentioned in Section 13.5.2, the role of rail operator (e.g., SMRT Trains, SBS Transit) is to operate and maintain the rail operating assets and infrastructure of the owner (LTA) which is governed under the NREF regulatory framework.

The responsibilities of rail operator will include:

- Operate and conduct maintenance by complying with LTA's Operating Performance Standard (OPS), Maintenance Performance Standards and ISO14001 Environmental Management System;
- Allocate sufficient resources and appropriate personnel in maintaining environmental, health and safety of the rail operation;

- Appoint and work with EHS officer or equivalent to ensure environmental, health and safety of rail operations;
- Form an Environmental Management Committee who manage the overall environmental performance and for the decision-making in resolving any environmental-related issues reported by the on-ground rail operators and/or the EHS Officer, which include:
  - Investigate any environmental incidents or near misses identified by the EHS Officer and the on-ground rail operators, and report promptly to LTA;
  - Record, respond to, and take action on any complaints from members of the public, if any, with inputs from the Technical Agencies, if required, and
  - Reporting to LTA and relevant Technical Agencies regarding environmental-related issues.

13.5.4 EHS Officer (or Equivalent)

In general, EHS Officer appointed by the rail operator is responsible for the overall environmental, health and safety during the operational phase of the Project. In terms of environmental management, the EHS Officer is required to:

- Conduct regular site inspections to ensure proper housekeeping as well as implementation of the minimum control measures and the proposed mitigation measures for operational phase in this report;
- Identify, record and report promptly any environmental non-compliance issues, incidents and near misses to the Environmental Management Committee; and
- Report the results of the environmental monitoring program, and any required changes, to meet the requirements of the EMMP to the rail operator and/or LTA in a timely manner.

13.5.5 Public Relation Officer (PRO) for Complaint Handling

The Public Relation Officer (PRO) is responsible for handling complaints and managing feedback and investigative work. The PRO will be supported by the Project Owner, rail operator, EHS Officer and any other relevant parties.

During the operational phase, upon receipt of complaints, the PRO should undertake the following procedures:

- Log the complaint and record the date when the complaint is received onto the complaint database and inform the rail operator and EHS Officer immediately;
- Investigate the complaint with the rail operator's Environmental Management Committee and EHS Officer to determine its validity and assess whether the source of the problem is due to operational works;
- If a complaint is valid and due to operational works, liaise with the EHS Officer on the mitigation measures and seek agreement from the rail operator's Environmental Management Committee;
  - Review the current situation and the EHS Officer's implementation of the mitigation measures;
  - Engage the EHS Officer to undertake monitoring works for inspection purpose as well as to verify the complaint if necessary. Ensure that any valid reasons for complaints do not re-occur by revising the work methods, procedures, machines and/or equipment, etc.;
  - Submit a complaint report (as well as the implementation of mitigation measures and the effectiveness of the mitigation measures as advised by the EHS Officer) to the rail operator and/or LTA; and
  - Log a record of the complaint, investigation, follow-up actions and the results in the environmental inspection report.

The PRO should work with the rail operator's Environmental Management Committee and EHS Officer to gather all the necessary information and resources necessary to complete a complaint investigation. Following the investigation, the Project/ Operation Manager (who leads the Environmental Management Committee) and EHS Officer will undertake appropriate mitigation measures. Follow-up is required by the PRO to ensure that the mitigation measures have been appropriately implemented. The complaint investigation report and corrective action plan should be prepared and approved by LTA and/or other relevant Authorities within 24 hr upon receipt of complaints.

13.6 Biodiversity EMMP Requirements

13.6.1 Construction Phase

At the construction phase, EMMP for both flora and fauna are essential in minimising and managing construction impacts.

13.6.1.1 Flora and Arboriculture Monitoring Programme

The flora and arboriculture monitoring aims to assess the impacts of construction to vegetation and habitat, such as tree health, unauthorised and/or excessive vegetation removal, edge effects, habitat degradation from soil erosion, and rubbish dumping. The programme should include the following:

Arboriculture Monitoring Programme should include the following works:

- Monitoring of the condition of trees at the new forest edge to determine the physiological health and structural stability of trees as edge effects can lead to die back of canopies, and branch and structural failures.
- Review of method statements of construction works in proximity to retained trees, if any, to determine if additional tree removal is required post-site clearance.
- Recommendation of solutions such as design changes, reduction of working space, reduction of TPZ area and reassessment of trees in cases of conflict with proposed works.
- Assessment of physiological health, vigour and structural stability of retained trees. Recommend additional mitigating measures if necessary.
- Assessment of the condition of retained trees, if any, to ensure that there has been no deterioration or mechanical damage and to determine if additional tree removal is required.
- Where a tree exhibits signs of stress, the Arborist should inspect the tree and advise on strategies to reduce further impacts and rehabilitation measures. Where monitoring indicates that drying out or edge impacts are occurring, remediation measures will be undertaken. These measures may be temporary (such as carrying out watering when there is seven continuous days without rainfall). Long-term solutions will be investigated and implemented.
- Inspection of the integrity of TPZs.
- Identification of excessive or unauthorised tree removal.

Flora Monitoring Programme should include the following works:

- Monthly flora inspections will be conducted within the worksite boundary and in forested areas adjacent to the worksite up to 15 m from the hoarding.
- Identification of any unauthorised removal of flora within areas of conservation or beyond the demarcated Project worksite (Figure 13-3).
- Identification of direct/indirect impacts to sensitive vegetation and habitats. Such impacts include soil erosion and degradation that has resulted from construction activities, and unauthorised dumping of waste material, construction debris or oil/chemical leakage.
- Identification of forest edge effects and recommendation of mitigation measures where necessary.
- Assessment of the status of invasive flora species and weeds and recommendation to remove them where necessary.
- Inspection of areas cleared of weeds to detect any seedlings of invasive species.
- Monitoring of the health of all retained and planted flora, including identification of diseases and recommendations for treatment.

Figure 13-3 Monitoring of Vegetation and Trees Along the Hoarding Line for Unauthorised Vegetation Clearance and Forest Edge Effects

13.6.1.2 Flora and Arboriculture Management Programme

The flora and arboriculture management programme aims to manage all matters related to the adequate and successful conservation of trees and vegetation within and adjacent to the contract boundary (up to 15-m from the contract boundary). The programme should include the following works:

Arboriculture Management Programme should include the following works:

- Tree Mapping and Assessment
  - Trees within the worksite boundary, including any construction access roads, will be mapped and assessed by the Arborist before work commencement. These specimens will be tagged with a unique serial number.
  - The physiological health, presence of pests and diseases, and structural stability will be assessed for all trees, single-stemmed palms and strangling Ficus species of $\geqslant$ 1.0 m girth or spread, respectively.
  - Species of conservation significance—i.e., listed in Chong et al. (2009) as nationally Vulnerable, Endangered, Critically Endangered or Presumed Extinct (which indicates a rediscovery)—of $\geqslant$ 0.3 m girth or spread will also be assessed. The locations, girth/spread, and height of these specimens will also be recorded. These specimens will be tagged with a unique serial number.
  - The trees to be felled or retained will be determined by the Arborist.
  - A photographic report will be provided for the trees affected by the proposed works.
  - No trees will be felled without prior approval from NParks.
- Tree Protection
  - Where there are trees to be retained within the worksite, specifications will be formulated by the Arborist for the setting up of tree protection zones (TPZ) to meet NParks requirements (Appendix W).
- Plant Salvaging
  - Viable saplings and conservation significant trees that are suitable for harvesting will be identified by the Arborist. Saplings or trees suitable for transplanting should:
    - Exhibit good physiological health and vigour
    - Have no structural defects

    - Have good branch form
  - The root ball size to be extracted will be based on the girth of the saplings or trees to be harvested as specified in Table 13-1.
  - Prior to transplanting, dead branches and climbers will be cleared from the plant and canopy load and spread will be reduced where necessary, in consultation with the Arborist.
  - Manual trenching will be carried out to determine the shape and size of root ball to be extracted. Where possible, feeder roots will be retained without cutting.
  - The root ball will be bur lapped with cellophane sheet to reduce desiccation effects. When directed by the Flora specialist or Arborist, leaves of the canopy may also need to be enclosed and covered by cellophane or clear plastic bags.
  - The root ball will be secured to the trunk to reduce risk of root ball disintegrating.
  - When handling/carrying the plant, care will be taken not to damage any vegetative parts.
- Tree Transplanting
  - Where trees and vegetation are moved or translocated within the Project area, the Arborist will review the method statement proposed by the tree transplanting Contractor and advise on additional recommendations necessary to ensure the tree's health during transplanting. The transplanting contract will ensure in their best effort, intact and secured root balls at the point of extraction, during the lifting processes and during the installation at the receiving site. The transplant effort will be documented for each individual tree to show intact root balls at all the stages mentioned. Transplanted trees will be managed through adequate watering and monitoring of their health to ensure their long-term survival. Advice will be sought from the Arborist if the tree exhibit signs of stress, e.g. peeling bark, withered leaves.
- Site Clearance and Tree Felling
  - The Contractor's method statements for site clearance, tree felling and setting up of TPZ will be reviewed by the Arborist to ensure compliance to the specifications. The site clearance and tree removal method statements will consider directional felling methods with a hinge and back cut. Trees will not be removed by pushing with an excavator or other heavy machinery. Cranes will be deployed to offset the tension of trunks in the direction of the drop. Interlocking canopy branches will be pruned prior to tree felling.
  - In cases where design changes may affect additional trees or the retained trees, the Arborist will work with the structural engineers and recommend solutions that will meet NParks guidelines.
  - Whenever reasonable and practicable, cleared vegetation at sloped areas will be covered with mulch or with 100% biodegradable fauna-friendly ECBs to control erosion of exposed soil. Exposed ground will be revegetated as soon as possible to stabilise surfaces and minimise re-entrainment of dust and potential for erosion of waste spoil to watercourses.
  - Clearance activities on-site will not occur during rainfall or when storm events are forecast to occur within the vicinity to protect forest edge from wind throw. Where forest edges are exposed to wind, temporary measures (e.g., additional hoarding) will be discussed with the Arborist, and put in place to protect the forest edge during storm events.
  - During site clearance, care will be taken when removing trees in riparian zones to reduce impacts to the bed and banks of waterways.
  - Where practicable, saplings, seeds and seed banks will be retained within the soil profiles for use in forest restoration.
  - Horticultural waste will be removed on the same day. This is essential to reduce risk of fauna taking refuge within the cleared waste if left overnight.
- Tree Maintenance and Care
  - Where disease outbreaks are identified, the Arborist and/or Flora Specialist will advise measures to manage them. Measures can include using selected insecticides/fungicides to control outbreaks; reduction of stressors (dust, water, etc.). The plant may be removed or quarantined if it poses a threat to surrounding individuals.

- Where forest edges are exposed following site clearance and where impacts to vegetation are evident (e.g., vegetation shows signs of drying out), additional watering will be carried out to improve moisture differentials around forest edges.
- The use of herbicides, pesticide will be minimised. If herbicides or pesticides are used within the Project area, techniques that limit spray or non-target spray drift will be used. These techniques include but are not limited to: cut and paint techniques and drilling injection. All use of herbicides and pesticides will be conducted in accordance with the relevant Material Safety Data Sheet (MSDS). Any incidents of off label use, spillage or damage to non-target species will be reported and investigated.
- When the site experiences seven continuous days without rainfall, the Contractor will carry out additional watering of conserved trees within the TPZs and at the forest edge (up to 10 m) around the development boundary.
- Post heavy rainfall, any snapped hanging branches that pose imminent hazards to workers within the site should be removed immediately.

Table 13-1 Minimum Root Ball Diameter to Girth Requirements

Girth (m)	Minimum root ball diameter to extract (m)
<0.1	0.4
0.1–0.2	0.6
0.2–0.3	0.8
0.3–0.4	1.2
0.4–0.5	1.5
>0.5	To be determined by Arborist

Flora Management Programme should include the following works:

- Verification and Review of Footprints for Hoarding, Access Roads and Soil Investigation Works
  - After the worksite hoarding has been installed, the Flora Specialist will conduct and inspection to verify that the footprint is as proposed, and that no excessive vegetation and tree removal has occurred as a result of deviations in the hoarding alignment.
  - The Flora Specialist will review the proposed locations for the soil investigation works and the alignment of the construction access roads with the Client/Contractor. Feasible alternatives, if possible, will be proposed to minimise vegetation and tree clearance.
- Weed and Invasive Species Management
  - Weeds and invasive species will be cleared from the Project area progressively and will be separated and transported to an appropriate disposal location. Transport will occur within a covered vehicle to ensure seed/vegetative matter does not dislodge. All vegetative matter and seeds will be rendered inert at the disposal location through incineration at a licensed waste disposal facility. The Project area will be carefully cleared of all remaining vegetative matter from the weeds/invasive species. Herbicides may be used to render any stumps/root systems inert. The cleared area will be inspected on a monthly basis to detect any seedlings of invasive species. These seedlings will be killed using approved herbicides or removed by hand weeding. Any seedlings or vegetative matter that may sprout will be disposed of at a licensed waste management facility.
  - Specific measures will be undertaken to control and manage flora species within the Project area that have been identified to be invasive (i.e., Spathodea campanulata, Cecropia pachystachya, Falcataria moluccana). The Ecologist will be consulted when managing Falcataria moluccana groves as tall trees may serve as nesting sites for birds of prey. The Ecologist will also be consulted for other weed and invasive species that may also provide important foraging resources. Material imported into the Project area will be checked for contamination from weeds/invasive species seeds/vegetative matter at source. This is particularly important for imported building materials, such as clay and soil. Source site will be inspected to determine presence of weeds/invasive species. Where weeds or invasive species are identified, alternative supply sources or decontamination will occur before the material is transported to site.
- Reforestation Planting Palette and Plant Salvaging for Reforestation and Landscaping

- The planting palette including all flora and grasses used for reforestation and other landscape planting will be from native indigenous stock or non-native species that are not listed as weeds or invasive species or have a low seeding rate. Native indigenous stock can come from salvaged, transplanted and/or pre-grown specimens or potentially from project involving site clearance. However, when such Native indigenous stock is not available, it is also possible to obtain stock from neighbouring countries such as Malaysia.
- All trees transplanted into the Project area will have local provenance or will be from within the Johor region for all SRDB and IUCN listed species. Other species will be obtained within the larger Sunda region. Due diligence will be conducted on suppliers to ensure that the trees are obtained by legal means and are able to be exported/imported to Singapore. All imported trees will be inspected and/or undergo quarantine if required to reduce the chance of transmission of weeds and soil pathogens.
- The success of planting within landscape features will be monitored. Where a planting strategy is not working, an alternative planting strategy will be developed suitable for the location. Temporary measures will be employed to reduce stress on planted individuals. The removal of sources of stress (such as dust) may also be required. If disease outbreaks are present, methods will be used to control the outbreak or remove the diseased individual.
- The flora specialist will also identify other plant material, including ferns, epiphytes, orchids, shrubs, grasses, etc. that are of conservation value and work with NParks for the extraction of these plants by NParks to other sites.
- The flora specialist will formulate a salvaging protocol in consultation with NParks if salvaging of plant material is being carried out on site.

The flora specialists, arborists and the Arboriculture Contractor engaged should meet the expected qualifications as described in Section 13.4.4.4, Section 13.4.4.2 and Section 13.4.4.3 respectively.

Additionally, the Contractor should fulfil the following:

- The Contractor and the attending arborist will complete the 'Verification of Tree Protection Checklist' prior to the start of site clearance (refer to Appendix W: Annex A).
- The Contractor will instil discipline and raise awareness amongst all personnel on measures and mitigations to prevent damage to retained and protected trees throughout construction by including reminders on tree conservation guidelines within their daily toolbox briefings to workers and crane/excavator operators.

13.6.1.3 Fauna Monitoring Programme

Fauna monitoring surveys should comprise of transect surveys and site inspection surveys conducted together, at within and outside of hoarded areas. The programme should include the conducting of monthly diurnal and nocturnal fauna and site inspection surveys beginning one month prior to construction.

13.6.1.3.1 *Faunistic Surveys*

Faunistic surveys are recommended to be conducted along terrestrial sampling routes and aquatic sampling points undertaken during the baseline studies (Figure 13-4 and Figure 13-5). This will include diurnal and nocturnal surveys, and terrestrial transect will have to be conducted in reverse direction on alternate months. All fauna encountered will be identified to species, or the lowest taxonomic level possible. The locations of all fauna sightings will be recorded using a handheld GPS. Important behavioural observations (e.g., displaying, guarding, mating, ovipositing) and plant species that the fauna was observed to be feeding, laying eggs, or nesting on, will be recorded.

Subsequently, camera trap monitoring will also be installed and maintained for the purpose of monitoring impacts to fauna species within the study site during construction phase. Camera traps will be situated as closely as possible to those deployed during construction monitoring. In the event camera trap location falls within worksite, monitoring location would be removed. The camera traps will be deployed at approximately 20–30 cm above ground. They should be operational 24 hours a day and programmed to record a 10-s footage per trigger with a 10-s quiet period following each trigger. Camera trap maintenance and data retrieval should be carried out at least once a month.

All methodology for the faunistic surveys should closely follow that implemented for this impact study as summarised in Table 13-2, so as to ensure that the data collected can be used to compare against the baseline data. Comparison of species presence can be made with the baseline studies, where appropriate, to provide an indication of the changes in fauna diversity. Details of the surveys should be determined in consultation with NParks

and should take into account construction phases, final construction footprint, final development hoarding plan, and baseline studies.

Surveys should target the following fauna groups detailed in Table 13-2.

Table 13-2 Summary of Survey Methods for Each Faunal Group

Faunal Group	Survey Timing (h)	Description
Odonates	0900– 1600	• Diurnal visual encounter surveys along terrestrial sampling routes and aquatic sampling points.
Butterflies	0900–1600	• Diurnal visual encounter surveys along the terrestrial sampling routes.
Freshwater Decapod Crustaceans And Fish	0900–1600	• Diurnal visual encounter surveys along terrestrial sampling routes and aquatic sampling points.
Herpetofauna (Amphibians and Reptiles)	0700–1600, 2000–0000	• Diurnal and nocturnal visual encounter surveys along terrestrial sampling routes and aquatic sampling points.
Birds	0700–1000, 2000–0000	• Diurnal and nocturnal visual and auditory encounter surveys along the terrestrial sampling routes
Non-Volant Mammals	0700–1000, 2000–0000	• Diurnal and nocturnal visual and auditory encounter surveys along terrestrial sampling routes • 18 terrestrial camera traps (i.e. 6 locations in Maju Forest and 12 in Clementi Forest) deployed across the Study Areas
Bats	2000–0000	• Acoustic recording along terrestrial sampling

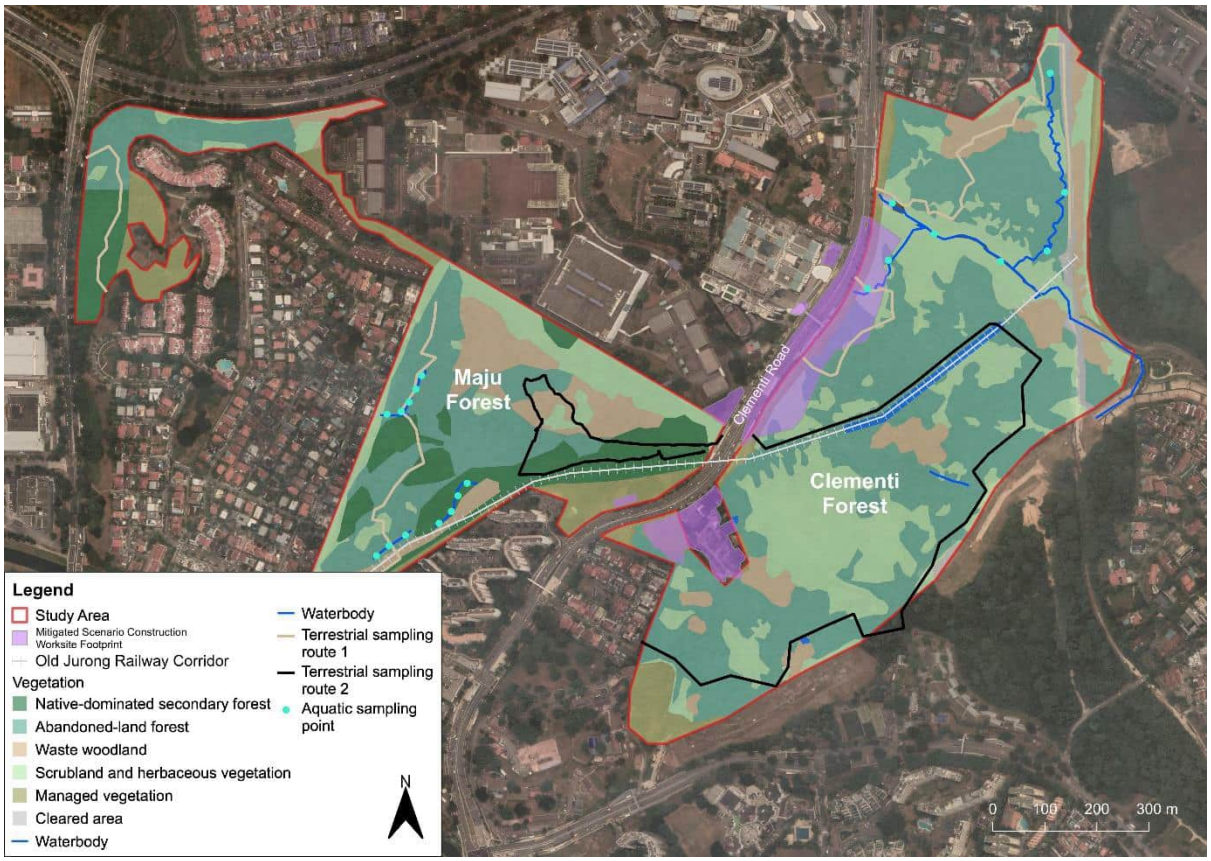


Figure 13-4 Terrestrial Sampling Routes and Aquatic Sampling Points at Maju Forest and Clementi Forest

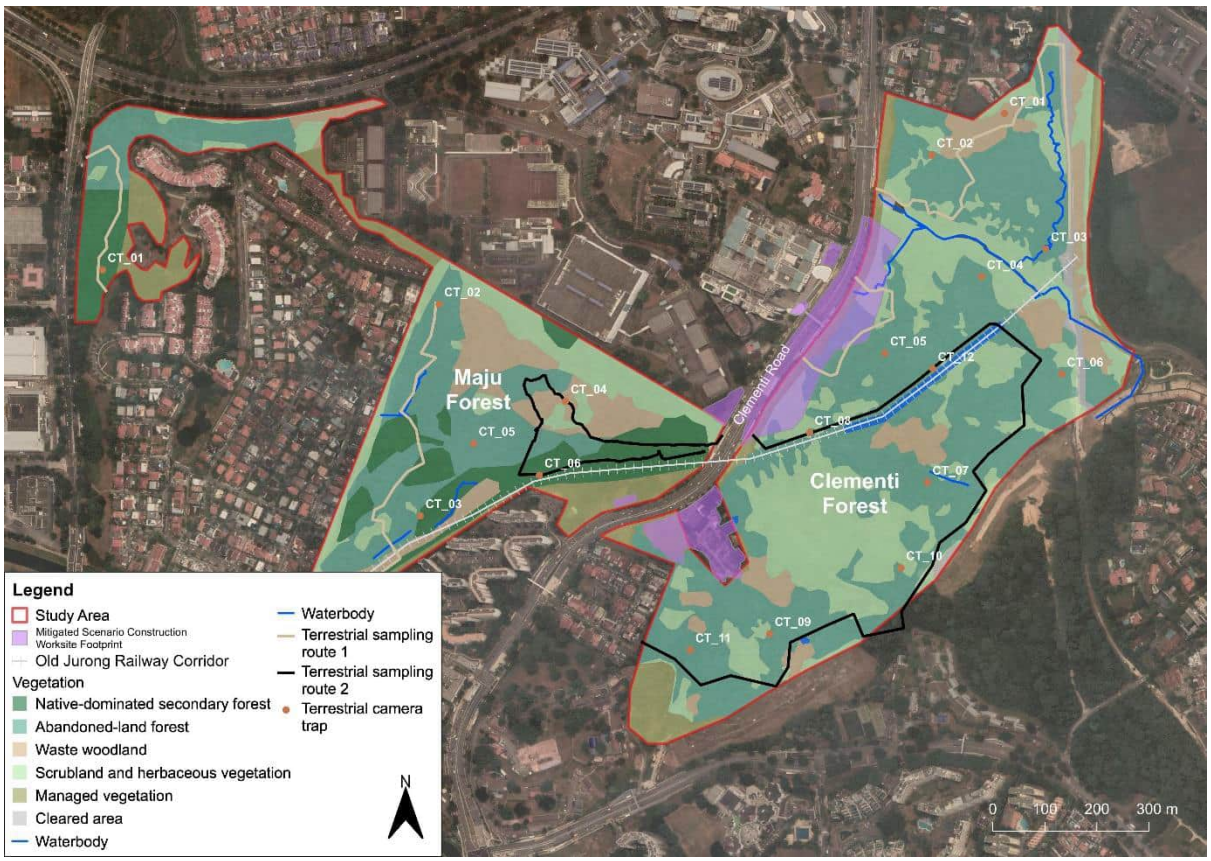


Figure 13-5 Locations of Terrestrial Camera Traps in Maju Forest and Clementi Forest

13.6.1.3.2 *Site Inspections*

Monthly fauna inspections will be conducted by the Ecologist within the worksite boundary. The following will be noted during the inspections (Figure 13-6):

- Visual inspection of sensitive habitats in the vicinity (e.g., streams, forests) to determine if the construction has damaged or affected them.
- Presence of trapped/injured/dead fauna.
- Potential fauna entrapments (e.g., ECBs, TPZs, pits, drains, ponds, trenches, tanks).
- Gaps in hoarding that may allow entry of ground-dwelling fauna.
- Improperly disposed/stored food and food packaging.
- Degradation of adjacent sensitive habitats (e.g., streams, forest).
- Daily roadkill surveys will be conducted by the ECO along roads adjacent to the worksite, up to 500 m from the worksite boundary. A roadkill and investigation register will be maintained. Appropriate mitigation measures will be implemented where necessary.
- Reporting and documentation of all findings and recommendations.
- Visual inspection of sensitive habitats in the vicinity (e.g., streams, forests) to determine if the construction has damaged or affected them.
- Potential fauna entrapments (e.g., ECBs, TPZs, pits, drains, ponds, trenches, tanks).
- Gaps in hoarding that may allow entry of ground-dwelling fauna.
- Improperly disposed/stored food and food packaging.
- Degradation of adjacent sensitive habitats (e.g., streams, forest).
- Daily roadkill surveys will be conducted by the ECO along roads adjacent to the worksite, up to 500 m from the worksite boundary. A roadkill and investigation register will be maintained. Appropriate mitigation measures will be implemented where necessary.
- Reporting and documentation of all findings and recommendations.

Figure 13-6 Photographs Showing Monthly Fauna Monitoring and Inspection On-Site

13.6.1.4 Fauna Management Programme

Fauna management will consist of managing fauna within and around all designated work areas. It consists of pre-site clearance inspections and continued biodiversity awareness training for the site team, tree felling inspections, and fauna response plan in event of animal encounters. The objectives of fauna management are as follows:

- Minimise negative impacts to fauna, particularly to species of conservation interest;
- Inspect hoarded areas for any compromises that may allow smaller-sized animals to enter;
- Prevent human-wildlife conflicts;
- Monitor presence of trapped/injured/dead fauna inside hoarded areas;
- Monitor and compare presence of targeted fauna groups within and outside of hoarded areas; and
- During each survey, fill out Fauna Inspection Form (Appendix V).

13.6.1.4.1 *Biodiversity Awareness Training*

The Ecologist will conduct toolbox briefings on biodiversity awareness to inform site personnel of but not limited to the following:

- Ecological value of the site and its surrounding habitats
- Types of fauna present
- Biodiversity protection strategies
- Site personnel's responsibilities towards biodiversity
- How to respond to fauna encounters
- No feeding of wildlife
- Prevention of roadkill
- Inspection of trees before felling

All site personnel will undergo biodiversity awareness training prior to commencing work at on-site, and regularly (every six months) throughout the duration of the construction. Documentation of such trainings and briefings will be maintained.

13.6.1.4.2 *Fauna Management Pre-Site Clearance*

- The objective of fauna management pre-site clearance is to remove target fauna from the worksite before construction works begin to prevent fauna entrapment, injury and mortality, whilst minimising contact between human and wildlife.
- Target fauna species include ground-dwelling mammals such as the Wild Pig (*Sus scrofa*) and Sunda Pangolin (*Manis javanica*), as well as animals that may be implicated in human-wildlife conflicts (e.g., snakes) during passive wildlife shepherding.
- Plant salvaging, if necessary, should be carried out prior to site clearance.
- Hoarding Installation
  - Hoarding installation will be completed by the Contractor, leaving a 2–6-m wide gaps as the wildlife exit point. The wildlife exit point will be located away from roads. Other than the exit points, the hoarding should not have any gaps and should be flushed to the ground as much as possible. The suitability of the exact location of the exit point will be confirmed on-site by the Ecologist to ensure that shepherded fauna can exit into a forested area with ample cover to minimise stress and the possibility of roadkill.
  - The site should be hoarded up completely eventually, and any wild boar must be removed first, before doing any other clearance. There should be no 2-6m wide gaps until after all wild boars have been removed
  - The hoarding will be at least 2.4-m high, with the surface facing the worksite coloured in white so that it is visually apparent to fauna.
  - The sequence of the hoarding installation will be reviewed by the Ecologist to ensure that disturbance generated by the hoarding installation activities does not cause fauna to venture onto adjacent roads.
  - After hoarding installation is completed, the Ecologist will inspect the hoarding to ensure its integrity and ability to prevent fauna entry/exit.
- Pre-site Clearance Camera Trap Monitoring
  - Camera traps will be deployed within the hoarded worksite at a density of approximately one camera trap per 1 ha over a period of at least seven days prior to site clearance. Additional camera traps may be needed on request from NParks or Ecologist.
  - The camera traps will be approximately evenly spaced throughout the worksite and targeted at strategic locations with signs of fauna use (e.g., clearings, burrows, nests).
  - The camera traps and the data will be retrieved one to two days before the day site clearance is slated to commence to determine the species that are likely to be encountered during the site clearance.
  - Prior to site clearance, site clearance personnel will be briefed by the Ecologist on species that are likely to be encountered during site clearance to prepare them for efficient response during encounters.
- Pre-site Clearance Fauna Inspection

- Prior to site clearance, the Ecologist will conduct a fauna inspection to identify active animal nests, hollows, other nesting structures, and any animals that may potentially get trapped/injured or die during site clearance (e.g., snakes, Sunda pangolin, bamboo bats). Animals that may be implicated in human-wildlife conflict (e.g., snakes) will also be identified.
- Refer to Figure 13-7 for a sample of pre-felling inspection protocol. Refer to Appendix X for Pre-felling Inspection Form.
- The validity of the inspection will be no more than seven days.
- Where fauna is found to be present on vegetation to be cleared, the affected vegetation will be marked with coloured tags/tape. The fauna will be allowed to leave on their own prior to vegetation clearance. Where eggs, chicks, or young fauna are found in nests, they will be allowed to fledge or leave the nests on their own prior to vegetation clearance. The Ecologist will conduct subsequent checks to ascertain that the fauna has left prior to vegetation clearance.
- Where it is not possible or ideal to allow the fauna to leave on its own (e.g., a stranded Sunda pangolin that is unable to move away on its own, a venomous snake that is feasible to catch) relocation will be considered and implemented by certified Wildlife Management Contractors, in consultation with NParks and in accordance with the Fauna Response Plan.
- Where the Ecologist deems there is a risk of injury/death to fauna even though there were no immediately apparent findings during the inspection (e.g., nest in good condition but fauna activity not observed/visible), the Ecologist will be present on-site during the removal of the affected vegetation to facilitate the implementation of the Fauna Response Plan where necessary.
- Elevating equipment will be deployed where necessary and feasible to inspect nests, hollows and other nesting structures.
- Ecologist will submit an inspection report indicating the date of the inspection, tree tag number (and/or location coordinates if untagged), observations, recommended mitigation measures, and photographic evidence within 24 h of the inspection.
- Where bamboo clusters are to be removed, the following steps will be carried out:
- The Ecologist will determine if the affected clusters are potential roosting sites for bamboo bats (*Tylonycteris spp.*).
    - If determined to be a potential roosting site, the Ecologist will carry out a bamboo bat roost emergence survey to determine the presence of bamboo bats. The roost emergence survey will be carried out at least once for each bamboo cluster. The surveys will occur between 1830–2100 h, during which two to three Ecologists will be stationed around each bamboo cluster to observe for bamboo bat activity, and to identify slits in the bamboo stems that are used as roosts. Torches will be used to aid in the detection. Stems bearing active slits will be marked, and the number of bats residing within each slit will be documented.
    - Bat detectors will be deployed to detect the ultrasonic echolocation calls to aid in species identification.
    - If bamboo bats are determined to be present in the affected bamboo clusters, they should be rescued and released. Prior to the removal of the bamboo clusters, the Ecologist will seal the slits of identified roosts with mesh and tape if feasible, and the section of the bamboo stem bearing the roost will be cut with a chainsaw or hand saw and lowered in a controlled manner, ensuring that the section remains intact. The bamboo bats will be held in the extracted bamboo stems if they are still intact. If not, the bamboo bats will be vacated into individual cloth bags.
    - The remaining stems of the bamboo cluster will be cut stem by stem manually (e.g., chainsaw, hand saw, parang) where feasible and deemed safe to do so. Where manual cutting is not feasible, a grabber excavator may be used to remove the stems bit by bit from the base of the cluster. The stems will be kept as intact as possible during felling. Each felled stem will be inspected immediately by the Ecologist for holes those are possibly entrances to roosts of the bamboo bats. All bamboo bats found occupying the bamboo stems will be held within the bamboo stems if they are still intact. Mesh and tape will be used to seal the holes of the roosts. If bamboo stems are too damaged to be sealed, the bamboo bats will be vacated into individual cloth bags.

- If bamboo bats are not determined to be present during the roost emergence survey, the Ecologist may also recommend for the Ecologist to be present during the removal of the bamboo cluster to inspect each stem for roosting bamboo bats.
- After the bamboo clusters and felled stems have been completely removed from the worksite or destroyed, any rescued bamboo bats will be released on the spot and tracked visually until out of sight. If the felling of a bamboo cluster cannot be completed by the end of the day (i.e., 1800 h), any rescued bats will also be released.
- Should trapped/injured/dead bats be encountered, the Fauna Response Plan will be activated.
- Bat handling will be performed by experienced personnel properly trained in bat handling techniques.

- Passive wildlife shepherding involves directional site clearance within the hoarded worksite towards a forested wildlife refuge area (Figure 13-8). The disturbance generated by site clearance activities is expected to encourage target fauna to move out of the worksite on their own.
  - A camera trap will be placed outside of the wildlife exit point throughout the duration of site clearance to monitor entry/exit of target fauna.
  - Site clearance will begin furthest from the exit point and gradually move towards the exit point to flush fauna out of the worksite.
  - The wildlife exit point will be opened by the Contractor before the start of site clearance works each day and closed at the end of each workday and during breaks to prevent fauna from returning to the worksite.
  - Horticultural waste will be removed on the same day to prevent fauna from using it as shelter.

13.6.1.4.3 *Fauna Management Post-Site Clearance*

- After site clearance is completed, the Ecologist will conduct a visual inspection of the cleared worksite for target fauna.
- If there are no trapped fauna, the wildlife exit point will be sealed and the camera trap at the wildlife exit point will be removed.
- If there are trapped fauna, the Ecologist will formulate species-specific methods to remove them in consultation with NParks and in accordance with the Fauna Response Plan.

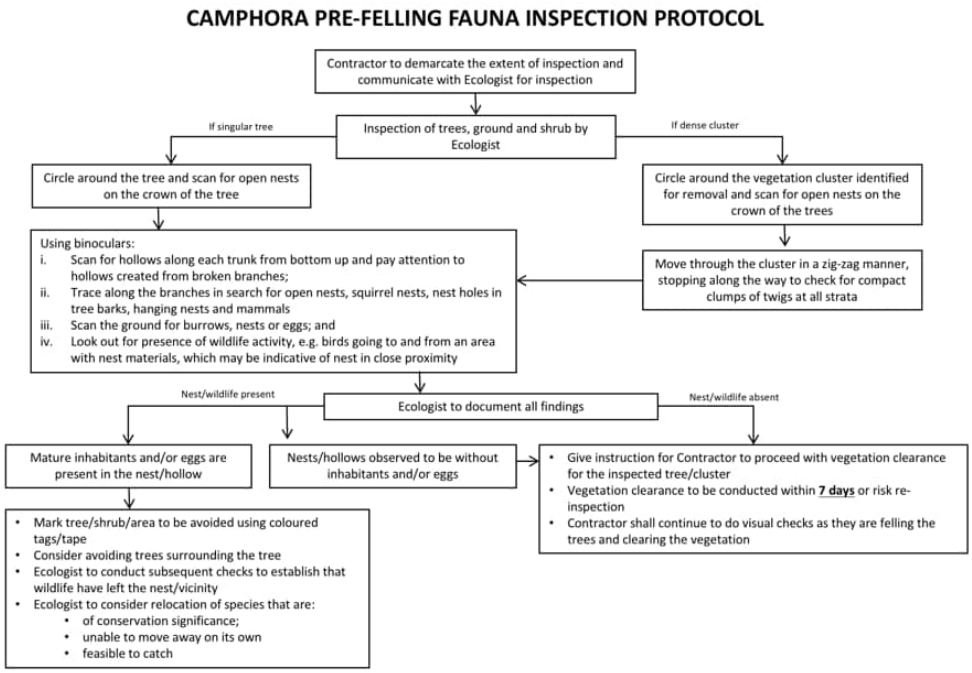


Figure 13-7 Pre-felling Inspection Protocol.

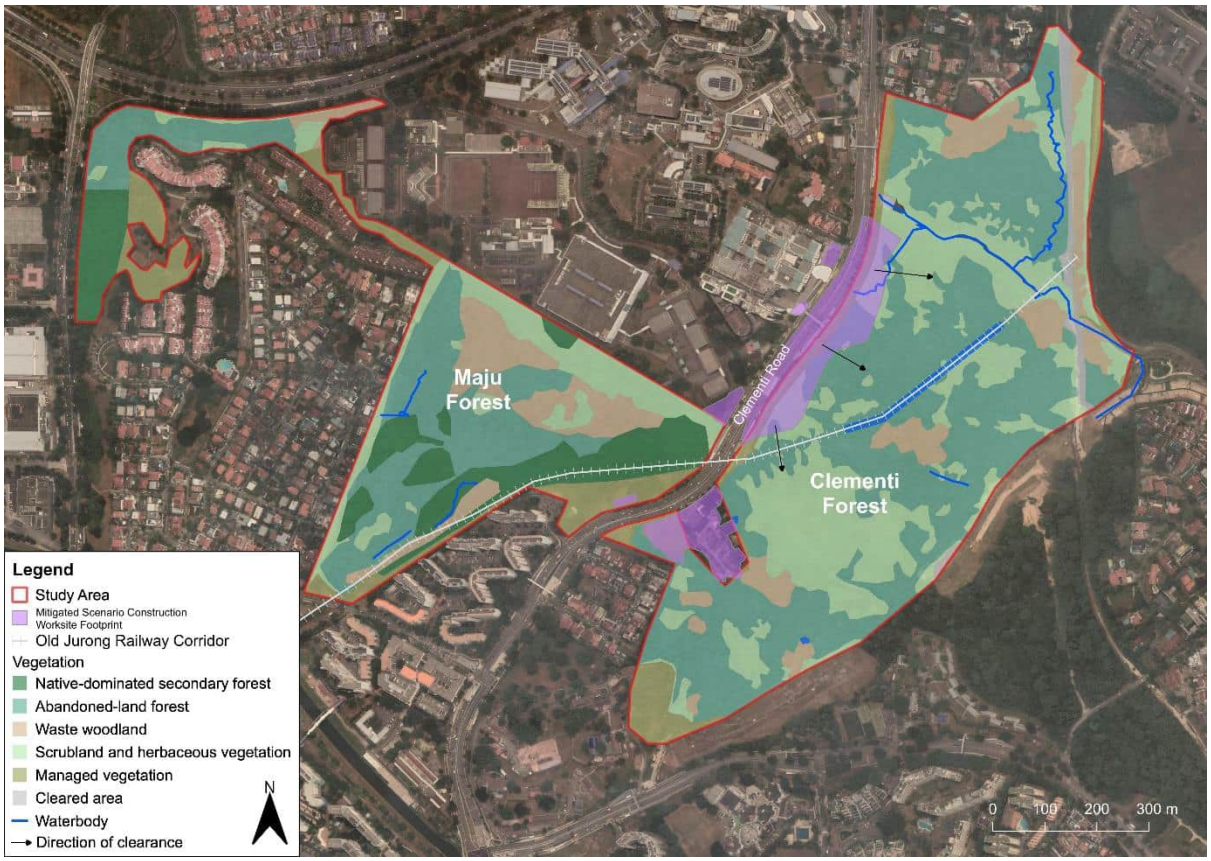


Figure 13-8 Direction of Clearing for Passive Wildlife Shepherding

13.6.1.4.4 *Fauna Response and Rescue Plan*

The Fauna Response and Rescue Plan should be enacted when a trapped/injured/dead/dangerous animal is encountered around or within the worksite. The objective of the wildlife response plan is to minimise animal injury and mortality by responding appropriately to the different scenarios in Figure 13-9. This should be emphasised during the toolbox briefings. All wildlife encounters are to be documented within 24 hours using the Wildlife Incident Form (Appendix U).

Where species of conservation significance are affected by the development, relocation works should be planned (e.g., bamboo bats). where fauna is trapped on-site, options should be explored to remove them from site (e.g., partitioning worksite, use of one-way exit door) (Figure 13-10).

In scenarios where certain animal groups are encountered around or within the worksite, external specialists may be contacted to handle the animal. These scenarios are shown below:

- For encounters with snakes that require relocation/handling, a snake specialist should be contacted
- For animal carcasses that require disposal, an animal carcass disposal service should be contacted
- For injured animals that require medical attention, a veterinarian should be contacted

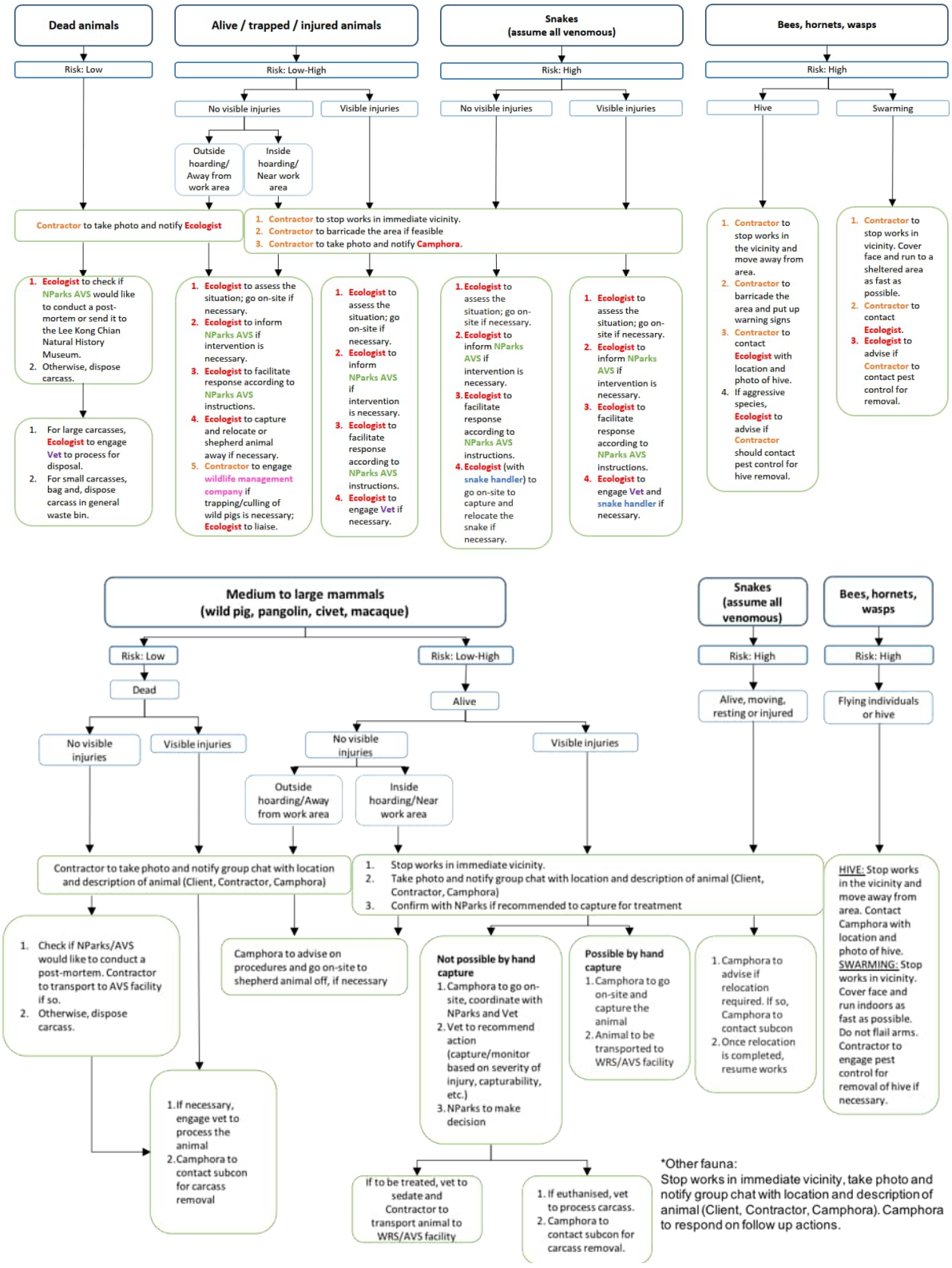


Figure 13-9 Flowchart of the Wildlife Response Plan

Figure 13-10 Example of One-Way Flap Door to Allow Fauna to Exit Independently

13.6.1.4.5 *Light Management*

Night-time works should be avoided to prevent disturbance to nocturnal fauna. It is recommended to restrict working hours to 0700–1900h. Other light management measures include:

- The Contractor will submit a site lighting plan (detailing the type of lights, specifications, numbers, locations, and direction) for all anticipated night works as part of the contract-specific EMMP.
- All lighting will be directed away from adjacent forested areas. Upward and directional lighting into unintended areas will be avoided.
- Where lighting is required to be installed for safety and security purposes, regulatory requirements will be followed.
- Reduce the duration of nocturnal lighting sources by using a timer or movement-based sensor system to turn off lights.
- Lights that have a high UV component will be avoided to reduce impacts on insects.
- Broad spectrum lights will be avoided.
- Provide mitigation measures such as covers and shields where possible.
- The Ecologist will conduct regular checks to ensure that lights are positioned as proposed.
- The lux levels in adjacent forested areas should be monitored. A baseline should be established at least one month before the start of any works, including pre-site clearance works. There should be at least eight light monitors, four 5 m away from worksite and four 30 m away from worksite. Locations to be decided in consultation with NParks prior to start of any works. Data collected as baseline should be used as a comparison during construction phase to ensure that light levels do not exceed those that recorded in the baseline study.

13.6.1.4.6 *Other General Fauna Management Measures*

Besides, the Contractor will be responsible in implementing the other general fauna management measures which include:

- The Contractor will visually inspect the worksite for wildlife prior to the start of construction activities each day.
- The Contractor will maintain the integrity of the worksite hoarding and repair any damages/breaches on a timely basis.
- Upon encountering trapped/injured/dead/dangerous fauna, the Contractor will respond in accordance with the Fauna Response Plan.
- The Contractor will not touch or handle any fauna unless instructed to do so.
- The Contractor will implement all mitigation measures recommended by the Arborist, Flora Specialist, and Ecologist, as far as practicable.

- The Contractor will ensure that all personnel and external visitors limit their movements and activities (including non-work activities such as resting and eating) to within the worksite boundary. There will be strictly no movements into adjacent forested areas.
- Graphical representations of but not limited to the following will be posted around the worksite:
    - No feeding of wildlife
    - No fishing
    - No littering
    - No food or drinks (outside designated eating areas)
    - No cutting of trees or plants
    - No smoking (outside designated smoking areas)
- The Contractor will deploy only 100% biodegradable wildlife friendly (e.g. loose weave, non-welded mesh, rectangle (elongated) mesh) ECBs.
- The Contractor will provide designated sheltered eating areas that are wildlife-proof.
- The Contractor will provide fully covered food storage areas that are wildlife-proof.
- The Contractor will ensure that all pits, drains, ponds, trenches, tanks that are potential fauna entrapments are suitably covered (e.g., using plywood, mesh, tarpaulin) to prevent fauna from falling in.
- The Contractor will trim overhanging vegetation above the worksite hoarding to prevent arboreal fauna from entering the worksite.
- Areas not used should be returned to earth ground and replanted if possible. Planting scheme should be as similar to forest composition to adjacent forest, if not as native as possible. Other than minimising edge effects, it can serve as a natural barrier to light, noise and dust to reduce disturbance. As a general guide, 400 trees should be replanted for every hectare to be reinstated.

13.6.2 Commissioning Phase

At the commissioning phase, arboricultural services and management of flora and fauna are typically not expected. However, regular flora and fauna monitoring for at least six months should still be considered and conducted during the commissioning phase. This is to review the effectiveness of mitigation measures proposed during design phase and rectify biodiversity problems that arise due to operational works.

13.6.2.1 Flora Monitoring Programme

The flora monitoring aims to assess the impacts of operational works to surrounding vegetation and/or adjacent forest, and rectify issues when identified. The programme should include the following:

- Assess impact of operational works on the physiological health and structural stability of vegetation and trees at proximity to the development;
- Determine whether there has been excessive and unauthorised removal of vegetation and trees beyond the development boundary;
- Monitor and assess potential edge effects (e.g., predictable failures, accelerated growth of climbers on canopy, change in species composition at the edge) within vegetation adjacent to the development;
- Determine if there was unauthorised dumping of rubbish (e.g., food materials), construction debris and materials, oil/chemical leakage that may contaminate soil watercourses, from post-construction water bodies post-construction.

13.6.2.2 Fauna Monitoring Programme

The fauna monitoring aims to assess the impacts of operational works to fauna residing within adjacent forest, and rectify issues when identified. The programme should include faunistic surveys. Faunistic surveys are recommended to be conducted along terrestrial sampling routes and aquatic sampling points, and should target the following fauna groups: odonates (dragonflies and damselflies), fish, decapoda, butterflies, herpetofauna (amphibians and reptiles), birds, and mammals. Comparison of species presence can be made with the baseline studies (Figure 13-4 and Figure 13-5), where appropriate, to provide an indication of the changes in fauna diversity.

The methodology for the faunistic surveys should closely follow that implemented for this EIS, so as to ensure that the data collected can be used to compare against the baseline data and data from construction monitoring (Table 13-2).

13.6.3 Operational Phase

At the operational phase, the Rail Operator will ensure minimum controls stated in Section 13.13.3 are adhered to. In addition, as a practice, disturbance should be kept to a minimum.

13.7 Hydrology and Surface Water EMMP Requirements

13.7.1 Construction Phase

13.7.1.1 Monitoring Before Commencement of Site Clearance

One (1) time monitoring for hydrology and surface water quality should be conducted before the construction commencement as a baseline reference for the EMMP.

Prior to construction, the hydrological conditions of drainage system within construction worksite and at immediate vicinity should be monitored and inspected especially during heavy storm event to ensure no flooding. For surface water quality, the baseline monitoring parameters should follow Table 13-4. All the discharge points from construction worksites should follow NEA's Allowable Limits for Trade Effluent Discharge to Watercourse/Controlled Watercourse. Meanwhile, the water quality of sensitive streams (i.e. D/S1 and D/S22 shown in Figure 13-11, should also be recorded and compared with the water quality criteria for aquatic life as listed in Table 13-3 to make sure the aquatic condition will not be impacted by the construction activities.

Table 13-3 Water Quality Guidelines and Criteria

Parameter	NEA Trade Effluent Discharge Limits[a]	International Water Quality Criteria for Aquatic Life[b]
pH	6 - 9	6.5 - 9
Temperature (°C)	45	-
Conductivity (µS/cm)	-	-
Total Dissolved Solids, TDS (mg/L)	1,000	1,000
Dissolved Oxygen, DO (mg/L)	-	> 4.0
Turbidity (NTU)	-	50
Total Suspended Solids, TSS (mg/L)	30 SDA: 50[f]	50
Biological Oxygen Demand, BOD_5 (mg/L)[3]	20	3
Chemical Oxygen Demand, COD (mg/L)	60	25
Total Phosphorous, TP (mg/L)	-	Eutrophic limit: 0.075 mg/L
Orthophosphate, PO_4-P (mg/L)	0.65 (equivalent to 2 as PO_4)	0.033 (equivalent to 0.1 as PO_4)
Total Nitrogen, TN (mg/L)	-	Eutrophic limit: 1.5 mg/L
Nitrate, NO_3-N (mg/L)	4.52 (equivalent to 20 as NO_3)	10 (equivalent to 44 as NO_3)
Ammoniacal Nitrogen (NH_4-N)	-	0.5
Total Organic Carbon (TOC)	-	-
Total Alkalinity	-	-
Oil & Grease - Total (mg/L)	1	0.14
Oil & Grease - Hydrocarbon (mg/L)	-	-
Lead, Pb (mg/L)	0.1	Acute LOEL[5]: 82 Chronic LOEL[5]: 3.2
Zinc, Zn (mg/L)	0.5	0.0085
Mercury, Hg (mg/L)	0.001	0.00016
Enterococcus (cfu/100mL)[4]	-	-

Note:

a. NEA Trade Effluent Discharge Limits for discharge into a controlled watercourse.

Parameter	NEA Trade Effluent Discharge Limits[a]	International Water Quality Criteria for Aquatic Life[b]

b. The sources of international water quality criteria for aquatic life include United Nations Economic Commission for Europe [R-18], United States Environmental Protection Agency [R-19], Australian & New Zealand [R-26], Canada [R-27], Philippines [R-16], and Malaysia [R-28].

c. BOD_5 is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material per litre of sample during 5 days of incubation at 20 °C.

d. *Enterococcus* counts should follow the Singapore's Water Quality Guidelines for Recreational Beaches and Fresh Water Bodies (i.e. ⩽ 200 cfu/100mL)

e. LOEL – Lowest Observed Effect Level

f. The limit value is for TSS discharge into storm water drainage system (i.e. ECM discharge) which referred from Sewerage and Drainage (Surface Water Drainage) Regulations.

13.7.1.2 Monitoring Throughout Construction Period

In order to ensure that procedures are followed appropriately, the construction phase of the Project should be accompanied by an EMMP.

Water quality monitoring is essential as discharge of excess contaminants, especially pH, nutrients and heavy metals, may lead to severe consequences (e.g. algae blooms). Discharges via detention ponds/tanks and ECM ponds/tanks will take place during the construction phase, therefore discharge monitoring on such ponds and tanks was recommended to be undertaken to complement surface water quality to assure compliance with the relevant standards. In addition, due to the ecological importance of streams such as D/S1 and D/S22 as shown in Figure 13-11, it was also recommended to monitor the water quality throughout the construction period to ensure minor construction impacts on the water quality. For all discharge points from construction worksites, it is recommended to monitor water quality following Singapore NEA's Allowable Limits for Trade Effluent Discharge to Watercourse/Controlled Watercourse. Meanwhile, the water quality of sensitive natural streams should also be recorded and compared with the water quality criteria for aquatic life as listed in Table 13-3 to make sure the aquatic condition will not be impacted by the construction activities.

Table 13-4 Recommended Monitoring Program during Construction Phase (Surface Water Quality)

Test	Parameters	Monitoring Recommendation and Frequency
In-situ	Temperature	• Online real time monitoring for turbidity at all the discharge point location at the construction site throughout the construction period • Monthly monitoring for temperature, pH, conductivity, TDS and DO at all the discharge point locations at the construction sites throughout out the construction period • Monthly monitoring for all the in-situ parameters at the sensitive streams including D/S1 and D/S22 throughout the construction period
	pH	
	Conductivity	
	Total Dissolved Solids (TDS)	
	Turbidity and Total Suspended Solids (TSS)	
	Dissolved Oxygen (DO)	
Ex-situ	Biochemical Oxygen Demand (BOD_5)	• Monthly monitoring for all the ex-situ parameters at the discharge point if discharging into public drains during the construction period • Monthly monitoring for all the ex-situ parameters at the sensitive streams including D/S1 and D/S22 throughout the construction period
	Chemical Oxygen Demand (COD)	
	Total Nitrogen (TN)	
	Nitrate (NO_3-N)	
	Ammoniacal Nitrogen (NH_4-N)	
	Total Alkalinity	
	Total Organic Carbon (TOC)	
	Total Phosphorus (TP)	
	Orthophosphate (PO_4-P)	
	Oil & Grease (Total)	
	Oil & Grease (Hydrocarbon)	
	Lead (Pb)	
	Zinc (Zn)	
	Mercury (Hg)	
	Enterococcus	

Test	Parameters	Monitoring Recommendation and Frequency
Note: In addition to the above monitoring list, Contractor is to ensure that the discharge also complies to NEA's allowable limit for trade effluent discharge - in particular the limits for heavy metals (e.g. through monthly testing)		

Beside the water quality monitoring, hydrological conditions of drainage system within construction site and at immediate vicinity should also be closely monitored during construction phase. Before draining to public drains or watercourses, surface runoff from the construction site should be drained to the treatment system to be filtered and to reduce peak runoff based on ECM Guidebook. The hoarding and perimeter drains of the construction site should be inspected daily to ensure no surface runoff flowing out from the site untreated and no clogging which would affect the flow capacity of the drains/streams. During heavy storm event, site inspection should be carried out to ensure no flooding. The discharge of pumped dewatered groundwater or other wastewaters to sensitive aquatic habitats will be prohibited (e.g., natural streams within Clementi Forest and Maju Forest).

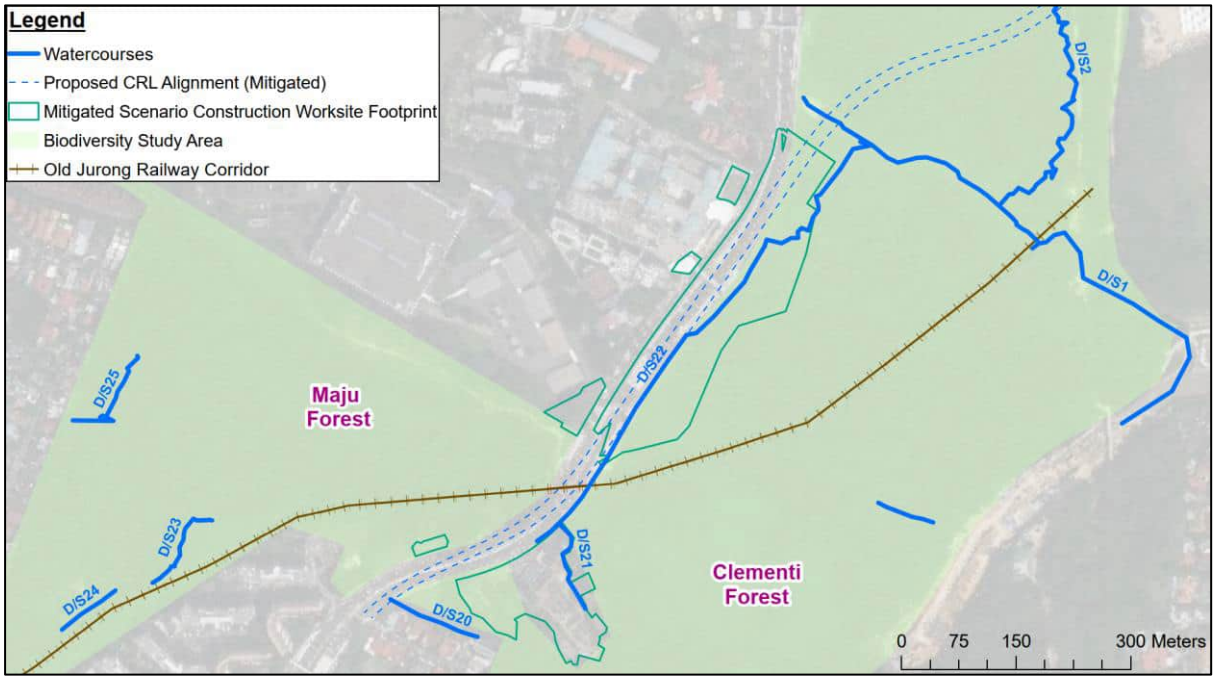


Figure 13-11 Watercourses at Clementi Forest and Maju Forest

13.7.2 Commissioning Phase

The commissioning phase of the Project should be accompanied by an EMMP to ensure the proposed development will have minor impact on the surrounding watercourses. Water quality monitoring is essential as discharge of excess contaminants, especially pH and suspended solids may lead to severe consequences (e.g., water with less clearance) due to the commissioning activities. Hence, due to the ecological importance of streams D/S1 and D/S22, it was recommended to monitor their water quality during the first three (3) months of commissioning phase to ensure minor impacts on their water quality. For main outlets/drains (if any) of the Project site, it is recommended to monitor water quality following Singapore NEA's Allowable Limits for Trade Effluent Discharge to Watercourse/Controlled Watercourse. Meanwhile, the water quality of sensitive streams (i.e. D/S1 and D/S22) should also be recorded and compared with the water quality criteria for aquatic life as listed in Table 13-3 to make sure the aquatic condition will not be impact by the commissioning activities.

Table 13-5 Recommended Monitoring Program during Commissioning Phase (Surface Water Quality)

Test	Parameters	Monitoring Recommendation and Frequency
In-situ	Temperature	Monthly monitoring for all the in-situ parameters at the main outlets/drains (if any) of the Project site, as well as sensitive streams (i.e. D/S1 and D/S22) in the Clementi Forest during the first three (3) months of commissioning phase.
	pH	
	Conductivity	
	Total Dissolved Solids (TDS)	
	Turbidity and Total Suspended Solids (TSS)	
	Dissolved Oxygen (DO)	
Ex-situ	Biochemical Oxygen Demand (BOD_5)	

Test	Parameters	Monitoring Recommendation and Frequency
	Chemical Oxygen Demand (COD)	Monthly monitoring for all the ex-situ parameters at the main outlets/drains (if any) of the Project site, as well as sensitive streams (i.e. D/S1 and D/S22) in the Clementi Forest during the first three (3) months of commissioning phase.
	Total Nitrogen (TN)	
	Nitrate (NO_3-N)	
	Ammoniacal Nitrogen (NH_4-N)	
	Total Alkalinity	
	Total Organic Carbon (TOC)	
	Total Phosphorus (TP)	
	Orthophosphate (PO_4-P)	
	Enterococcus	

For the hydrology monitoring during commissioning phase, drainage system within the site and at immediate vicinity should be inspected especially during heavy storm event to ensure no flooding. Routine audit on the site should be carried out by an independent EMMP consultant during the first three (3) months of commissioning phase.

13.7.3 Operational Phase

During operational phase, hydrology and water quality monitoring and audit is not required.

In general, the Rail Operator will ensure the implementation of minimum control measures according to the relevant legislations (e.g. PUB Code of Practice on Surface Water Drainage, Singapore Sewerage and Drainage (Trade Effluent) Regulations, SS 593: 2013 – Code of Practice for Pollution Control (COPPC), Environmental Protection and Management Act and its associated regulations etc., as listed in Section 15.1); as well as the proposed mitigation measures where the key ones are summarised in Section 13.13.2. General housekeeping and environmental management measures will be applied.

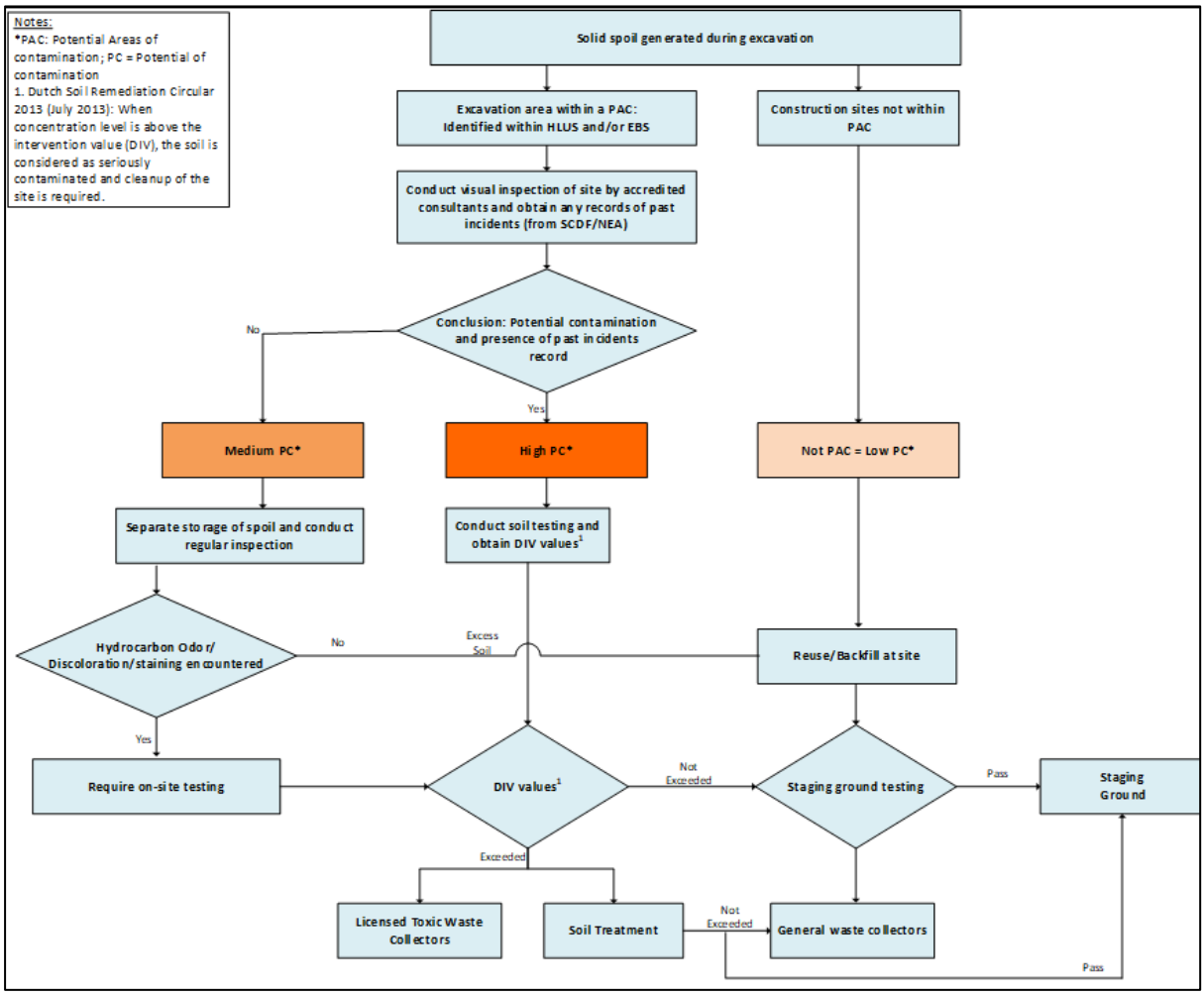
13.8 Soil and Groundwater EMMP Requirements

13.8.1 Construction Phase

A summary of the recommended monitoring for soil and groundwater during the construction phase is provided in the table below.

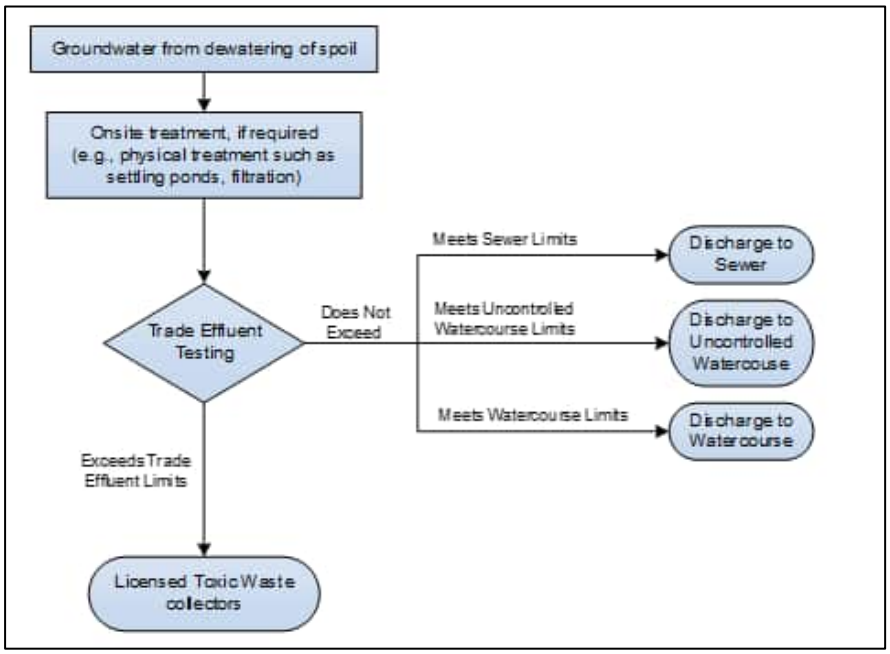
Table 13-6 Recommended Monitoring Program during Construction Phase (Soil and Groundwater)

Location	Parameters	Frequency and Duration
Within the development boundary	Groundwater level	• Continuous monitoring of groundwater level throughout the lifetime of the construction phase as per the instrumentation and monitoring plan developed by the Qualified Professional (QP). • Visual monitoring of spoil generated by the TBM to be conducted daily. Refer to Figure 13-12 and Figure 13-13 for procedures for screening and handling of suspected contaminated soils and groundwaters. • Records on chemical waste from the waste generator should be properly kept and records produced when requested. • Inspection of hazardous chemical/substances storage condition weekly during construction phase. • Routine environmental audit during construction phase.
At locations within the Project site where excavated soil and extracted groundwater are generated and stored	Improper Management of Excavated Soil and Extracted Groundwater	
At locations within the Project site where toxic chemical waste is generated/stored	Toxic Chemical Waste Generation	
At locations within the Project site where hazardous chemicals/substances are used/stored	Improper Handling of Hazardous Chemical/Substances	



Note: DIV standards were developed to assess the acceptability of impacted sites in the Netherlands in support of the Dutch Soil Protection Act. Therefore, it is based on local Dutch ecotoxicology, soil (consisting of 10% organic clay or 25% clay) and climate conditions for residential usage which may not be applicable to conditions in Singapore.

Figure 13-12 Screening and Disposal of Excavated Soils



Note: DIVs for groundwater consider risks to human health and local ecosystems, whichever is more sensitive. When assessing risk to human health, a typical Dutch residential land use setting is considered which includes exposure via potable consumption of groundwater and consumption of home-grown produce which are not common exposure scenarios for Singapore.

Figure 13-13 Disposal of the Groundwater Generated Through Dewatering or Inflow Into Excavations

13.8.2 Commissioning Phase

A summary of the recommended monitoring for soil and groundwater during commissioning phase is provided below in Table 13-7.

Table 13-7 Recommended Monitoring Program during Commissioning Phase (Soil and Groundwater)

Location	Parameters	Frequency and Duration
At locations within the Project site where toxic chemical waste is generated/stored	Toxic Chemical Waste Generation	Monthly monitoring records of the amount and type of toxic chemical waste generated during the first three (3) months of commissioning phase. Monthly inspection of hazardous chemical/substances storage conditions during the first three (3) months of commissioning phase.
At locations within the Project site where hazardous chemicals/substances are used/stored	Improper Handling of Hazardous Chemical/Substances	

13.8.3 Operational Phase

During operational phase of this Project, soil and groundwater monitoring and audit are not required.

It is assumed that the Rail Operator will ensure the successful implementation of minimum control measures (examples shown in the Section 13.13.3 of this report). As the impact on soil and groundwater during the operational phase of this Project is assessed to be minor, no additional soil and groundwater mitigation measures are required in commissioning and operational phases.

13.9 Air Quality EMMP Requirements

13.9.1 Construction Phase

As noted in the mitigation measures (Section 13.13), dust monitoring will be undertaken during the construction phase. Dust deposition monitoring is recommended due to the potential of High consequence dust impact conducted within the ecologically sensitive receptors during construction phase. Based on a review of sensitive receptors around the construction worksite areas, a continuous monitoring program as per Table 13-8 is proposed to be conducted during project construction. The Contractor is also recommended to conduct air quality monitoring of PM_{10} and $PM_{2.5}$ for 1 week prior to site clearance for the re-establishment of latest baseline conditions around the Project area.

Table 13-8 Recommended Monitoring Program during Construction Phase (Air Quality)

Location	Parameters	Frequency and Duration	Triggers
Monitoring at the following location: • Clementi Forest • Maju Forest	PM_{10} and $PM_{2.5}$	Continuous monitoring of PM_{10} and $PM_{2.5}$ for 1 week prior to site clearance averaged over 1-day period	-
	Dust Deposition in $mg/m^2/day$	Continuous monitoring of dust deposition during construction phase averaged over 4-week period	Investigation and corrective actions to be taken, when 1. Any of the following documentation are found inadequate / missing: Air Pollution Control Plan; Compliance certificate of an Off-Road Diesel engine; or Monitoring Log. 2. If the monitored PM_{10} and $PM_{2.5}$ exceed Singapore long term air quality targets. 3. If the dust deposition monitored exceeds 200 $mg/m^2/day$ averaged over 4-week

Location	Parameters	Frequency and Duration	Triggers
			4. If complaints are received due to project activities. 5. If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

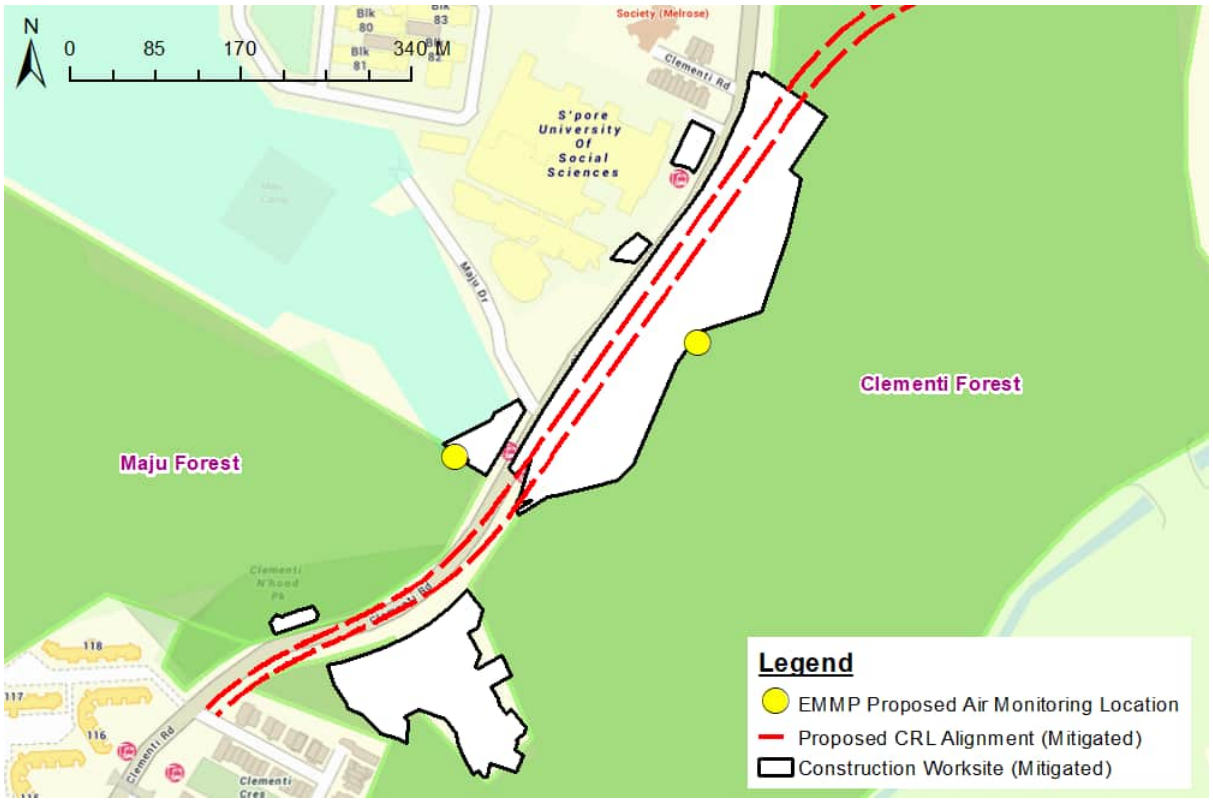


Figure 13-14 Proposed EMMP Air Monitoring Location at Clementi Forest and Maju Forest

13.9.2 Commissioning Phase

During commissioning phase, ambient air quality monitoring may not be required.

13.9.3 Operational Phase

During operational phase, ambient air quality monitoring may not be required.

General housekeeping and environmental management measures will be applied.

13.10 Airborne Noise EMMP Requirements

13.10.1 Construction Phase

The proposed noise monitoring locations and monitoring program as per Table 13-9 are presented in Figure 13-15, along with the noise barriers recommended as mitigation measures. Other key minimum control and key mitigation measures are summarised in Section 13.13.

Table 13-9 Recommended Monitoring Program during Construction Phase (Airborne Noise)

Location (see Figure 13-15)	Parameters	Frequency and Duration
Maju Forest One (1) monitoring location within Maju Forest and closet to construction worksite	$L_{Aeq(12\ hour)}$, $L_{Aeq(1\ hour)}$, and $L_{Aeq(5\ min)}$	• **Prior to site clearance:** To conduct one-time (i.e. 1-week period) airborne noise monitoring at this location to re-establish the baseline noise levels for reference/ comparison purposes before any construction works commence. • **Throughout construction period:** Continuous monitoring at this location for the entire duration of construction.
Clementi Forest: Two (2) monitoring location within Clementi Forest and closest to northern and southern part of construction worksite		• **Prior to site clearance:** To conduct one-time (i.e., 1 week period) at these locations to re-establish the baseline noise levels for reference/ comparison purposes before any construction works commence. • **Throughout construction period:** Continuous monitoring at this location for the entire duration of construction.

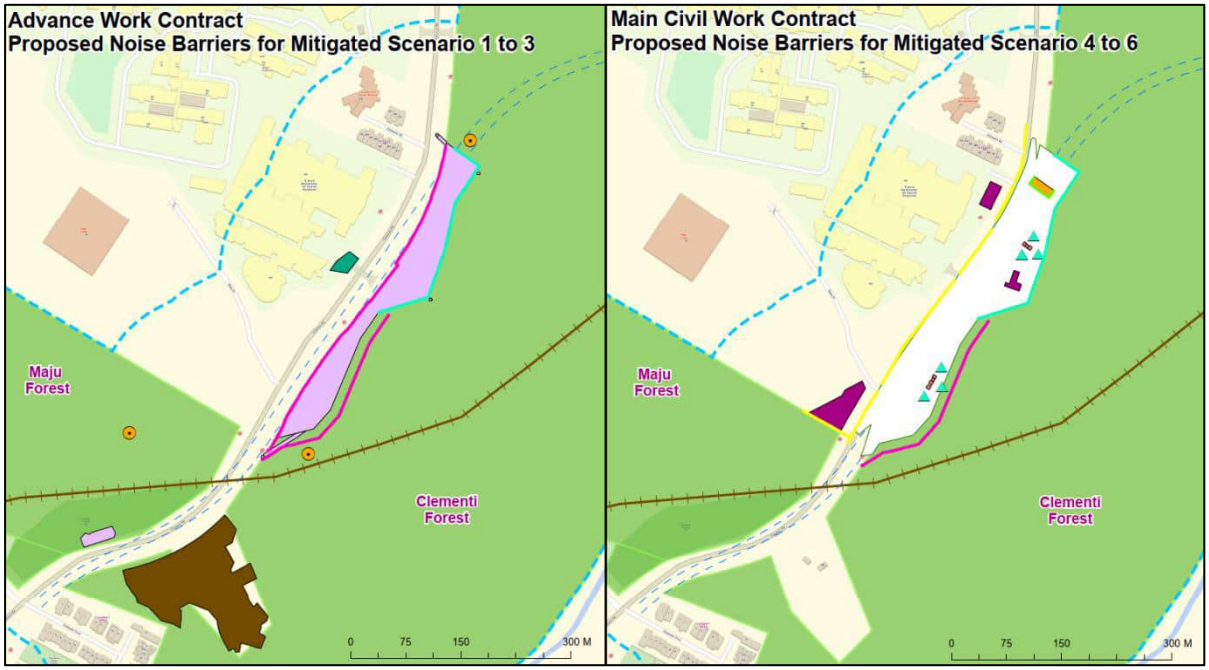


Figure 13-15 Proposed Noise Monitoring Locations with Construction Noise Barriers

13.10.2 Commissioning Phase

During commissioning phase, continuous airborne noise monitoring ($L_{eq\ 5min}$ and $L_{eq\ 1\ hour}$) will be conducted for the three (3) monitoring locations in Maju Forest and Clementi Forest (as per Figure 13-15) for three (3) months of the commissioning phase.

Apart from that, six (6) additional airborne noise monitoring ($L_{eq\ 15min}$) will be required at the east, north and south of the boundary of ventilation shaft at station for one (1) day (24 hours) within the commissioning phase, to monitor the potential airborne noise impact arising from the air conditioning and mechanical ventilation (ACMV) equipment which will be operating during commissioning phase. This indicates a total of nine (9) airborne noise monitoring locations during commissioning phase.

The airborne noise level monitored will comply with the *NEA's Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Building,* however, noise criteria for biodiversity will follow a "no worse off than baseline approach" will be complied. The current set of Project-specific

noise criteria based on baseline noise monitoring in Year 2020 is provided in Table 13-10 below for reference and/or basis of comparison if there is no further update hereafter.

Table 13-10 Project-Specific Noise Criteria for Commissioning Phase (Baseline Measured in Year 2020)

No.	Types of Affected Receptors	$L_{Aeq(15\ min),\ dB}$		
		07:00 – 19:00	19:00 – 23:00	23:00 – 07:00
Maju Forest	Ecologically sensitive receptors	48	49	42
Clementi Forest (Southern)		48	49	42
Clementi Forest (Northern)		66	66	60

***Notes:**
1. Ecological receptor noise impact to be assessed against the baseline noise level as the noise criterion.
2. If there are any noise monitoring works being conducted hereafter, i.e. during actual pre-construction phase (i.e. before actual site clearance) and/or pre-commissioning phase, this Project-specific noise criteria (no worse off than baseline approach) will be updated accordingly and be complied on site.

13.10.3 Operational Phase

During operational phase, airborne noise monitoring and audit are not required. General housekeeping and environmental management measures will be applied.

In general, the Rail Operator will ensure the implementation of minimum control measures according to the relevant legislations (i.e. *NEA's Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Building* and *Technical Guideline for Land Traffic Noise Impact Assessment*), as well as the proposed mitigation measures where the key ones are summarised in Section 13.13.3. If there are any noise monitoring works to be carried out at Maju Forest and Clementi Forest during operational phase in future, the same no worse-off than baseline noise criteria (see Section 13.10.2) will be complied.

13.11 Ground-borne Vibration EMMP Requirements

This section details ground-borne vibration EMMP requirements during construction, commissioning and operational phases.

13.11.1 Construction Phase

During pre-construction and construction phase, vibration monitoring is not required. During the construction phase, the Contractor will control construction vibration levels using the best available techniques (BAT). The Contractor will ensure that the vibration levels for any construction activities at Maju Forest and Clementi Forest (excluding the worksite area) do not exceed Peak Particle Velocity, PPV, 8 mm/s.

Additional requirements are required during pipe jacking and vibratory piling for entrances (Advance Works), rock breaking and excavation stage (Stage 2) and tunnel boring (Stage 2) planned for the worksites at Maju and Clementi Forest as outlined in Section 13.11.1.1 below.

13.11.1.1 EMMP for Structural Integrity of Burrows

The Contractor will control construction vibration levels using the best available techniques (BAT). The construction activities include high amplitude vibratory compactors, pipe jacking and vibratory piling for entrances during Advance Works, and tunnel boring and rock breaking and excavation during Stage 2. The Contractor will ensure that the vibration levels for any construction activities at Maju Forest and Clementi Forest (excluding the worksite area) do not exceed Peak Particle Velocity, PPV, 8 mm/s.

A ground-borne vibration monitoring program will need to be implemented before commencement of construction works (for 1 week period) and throughout construction period, please refer to Table 13-11.

Table 13-11 Recommended Monitoring Program during Construction Phase (Ground-borne Vibration)

Location (see Figure 12-1)	Parameters	Frequency and Duration
Clementi and Maju Forest: One (1) monitoring location each at Clementi and Maju Forest	Peak Particle Velocity, PPV, mm/s	• **Prior to site clearance:** To conduct one-time (i.e. 1-week period) continuous vibration monitoring (Triaxial with 3G remote communication) at these locations to re-establish the baseline noise levels for reference/ comparison purposes before any construction works commence. • **Throughout construction period:** Continuous monitoring at this location for the entire duration of construction.

Additionally, an Ecologist and Environmental Officer will be present to survey for burrows before any construction activities. If burrows are detected within the Biodiversity Study Areas, camera traps should be deployed to assess fauna activity. If there are no burrows or fauna activity detected, construction works can continue.

13.11.1.2 EMMP for Behavioural Impacts of Ecologically Sensitive Species

During pipe jacking (Advance Works), rock breaking and excavation stage (Stage 2) and tunnel boring (Stage 2), the Ecologist will monitor for any fauna behaviour (e.g. dashing onto the road) resulting in road-kill incidents for at least thirty (30) minutes after the event. In addition, there will be Ecologists present to observe fauna movements during these construction activities. Suppose fauna is seen trying to dash onto the road. In that case, construction activities will be immediately suspended, and mitigation measures should be applied to prevent such events from happening in the future.

At Maju and Clementi Forest, before the construction activities commence, a 220 m long temporary barrier (e.g. water-filled barrier of 1 m height) will also be set up at specific locations along Clementi Road for pipe jacking (Advance Works). The Client has confirmed on 31st May 2022 that Brookvale Drive will still be under construction during Advance Works. Hence, existing hoardings will be present to replace water barriers during this stage. Where there are no hoardings from Brookvale Drive leading to Clementi Road, water barriers have to be implemented. More water barriers will have to be added along Clementi Road at Stage 2 when rock breaking and excavation, and tunnel boring begin. At this stage, the temporary barrier should have a total length of 480 m. In addition, 635 m of the permanent wire meshed fences along Brookvale Drive from a residential project must also be covered with canvas sheets. At Advance Works and Stage 2, hoardings must be included at the worksites, and canvas sheets must be added onto existing railings (220 m long) along Clementi Road to cover holes on the railings. These potentially mitigate roadkills due to the impacted fauna trying to dash onto a road during construction. The temporary barriers are shown in Figure 13-16.

However, the Contractor will assess the effectiveness of the temporary barriers and propose improvements if necessary. Effectiveness can be assessed by presence of roadkill (i.e., if road kill occurs, the temporary barriers are deemed ineffective). Furthermore, measures will be taken to identify how fauna reaches the road and measures will be taken to rectify. For instance, if fauna could reach the road through a gap, the gap will be sealed with temporary barriers or canvas sheets. If fauna could break through the implemented barriers, stronger barriers should be replaced.

Lastly, no night work should be conducted after 7 pm for all non-safety critical activities since the site is next to the sensitive receptors.

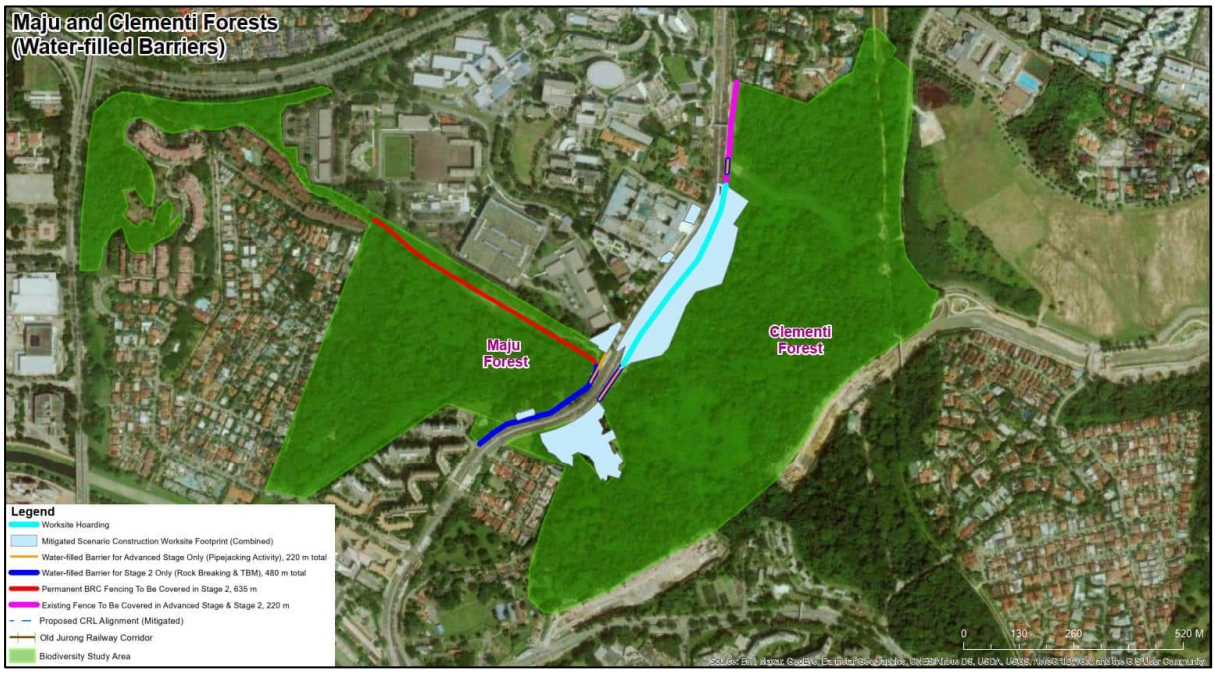


Figure 13-16 Proposed Barriers During Construction Activities

13.11.2 Commissioning Phase

During commissioning phase, vibration monitoring is not required. General housekeeping and maintenance will be applied.

13.11.3 Operational Phase

During operational phase, vibration monitoring is not required. General housekeeping and maintenance will be applied.

13.12 Environmental Audit

13.12.1 Construction Phase

13.12.1.1 Internal Site Inspection/Audit by EM/ECO

Site surveillance provides a direct means to assess and ensure the Project's environmental protection and pollution control measures are in compliance with the contract specifications and the EMMP. The EM/ECO should inspect the construction activities regularly and routinely to ensure that the appropriate environmental protection and pollution control mitigation measures are properly and timely implemented, based on the EMMP's recommendations. With well-defined pollution control and impact mitigation measures outlined, and a well-established efficient remedial action reporting system, the site inspection is an effective "tool" to ensure acceptable environmental performance at the construction site.

After consultation with Project's SO, the EM/ECO should prepare a procedure for the site inspections, deficiencies, remedial action, and reporting requirements. This documentation will be agreed to by the RTO and Contractor representative, and approved by the Project Owner within 21 days of the commencement of the construction contract.

Weekly site inspections should be carried out by the EM/ECO to ensure the environmental, health and safety measures are properly implemented at all the work areas during the construction phase. The EM/ECO will submit an Environmental Performance/Inspection Report which covers the onsite environmental situation, pollution control and mitigation measures to LTA fortnightly. Offsite environmental situations, which may be affected by onsite activities (directly or indirectly), should also be reviewed.

13.12.1.2 External Environmental Audit by Independent EMMP Consultant

A third party independent EMMP consultant shall be engaged to perform routine environmental audit/ verification checks of the EMMP implementation by the Contractor (for all assessed environmental parameters in ecological perspectives) throughout the construction period. The routine audit includes but not limited to reviewing relevant

documents prepared by Contractor's EMMP consultant, providing ad-hoc advice, assisting in resolving complaints with the Contractor, etc. largely for ecological perspective as LTA in house staff and project staff shall be able to resolve issues related to human impacts.

The external environmental audit exercise would also include the documentation review of on-site monitoring records against the proposed measures and findings in the approved site specific EMMP. This is to ensure proper implementation of minimum control measures, mitigation measures and EMMP proposed in this report, as well as to identify and/or resolve potential environmental incompliances and potential gaps with the findings in report, if any observed during the audit.

13.12.2 Commissioning Phase

It is suggested that the Contractor engage an independent EMMP consultant to perform routine environmental audit parallel to the biodiversity monitoring works. This is to inspect the effectiveness of biodiversity monitoring works and other on-site environmental implementations during the commissioning phase before handing it over to the rail operator.

13.12.3 Operational Phase

An environmental audit by an independent EMMP consultant may not be required during the operational phase of this Project. The EHS Officer and the rail operator will manage the overall environmental performance and ensure the implementation of minimum control measures and mitigation measures proposed in this Report.

13.13 Summary of Proposed EMMP

The framework for the proposed EMMP is detailed below; however, it is essential to note that this is not an exhaustive list of potential impacts, monitoring requirements, and triggers. This EMMP is intended to be a living document and should be reviewed thoroughly by the Client/ Project Owner/ rail operator and the Contractor (CT) before implementation. Development of the following inputs that have not been addressed in this Report by the CT and/or rail operator is also required, including but not limited to:

- Stakeholder Communications Plan;
- Tree Protection Specifications;
- Sapling Harvesting Specifications;
- Tree Transplanting, Maintenance and Care Recommendations (if any);
- Fauna Management Plan;
- Air Pollution Control Plan;
- Noise Management Plan;
- Erosion Control Plan;
- Waste Management Plan;
- Vector Pollution Control Plan
- Site log for all monitoring activities and complaints;
- Construction Logistics Plan;
- Standard Operating Procedures;
- Emergency Response Plan;
- Inventory of wastewater streams;
- Training protocols for staff, where appropriate; and
- Maintenance and Audit Schedules.

13.13.1 Construction Phase

The EMMP for construction phase of the Project is described in Table 13-12.

Table 13-12 Proposed Environmental Monitoring and Management Plan for the Construction Phase

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
General	Exclusion of the evaluation of specific environmental impacts where detailed design is not available for review at the time of writing this Report	• This EIS was conducted based on a preliminary worksite design. • The current worksite design excludes any inputs regarding locations of piezometers, utilities/ road diversion areas, and site elements (e.g. workers dormitory, detention tank, site office etc.). • If this is available at a later stage, the contractor will update the findings of this EIS.	N.A.	N.A.	N.A.	N.A.	CT	N.A.
Biodiversity	Minimisation of construction impacts to flora/vegetation	• Mark out site boundary. • Trees that are to be retained within worksite would require an arborist to clearly mark out Tree Protection Zones where no works are allowed. The Tree Protection Zones should be set up in accordance with NParks guidelines	• Identification of locations, species and quantity of transplant candidates that are affected by construction	Flora and Arboriculture	Within development boundary or 15m beyond the hoarding line, where applicable	Prior to site clearance	CT, EM/ECO, Flora Specialist	N.A.
			• Inspection of integrity of TPZ hoarding • Assessment of tree physiological health and vigour • Determination of presence of mechanical damage to trees that may impair stability • Review of method statements of construction works in proximity to retained trees • Identification of excessive or unauthorised tree removal • Identification of trees that require management and maintenance such as tree care and pruning • Determination of any unauthorised removal of flora within areas of conservation (if any) or beyond the demarcated worksite • Identification of areas with soil erosion and degradation that have resulted from construction activities • Determination of unauthorised dumping of waste material, construction debris or oil/chemical leakage that may contaminate the soil and waterbodies, and/or be detrimental to the vegetation • Identification of areas that are responding poorly due to the development impacts.		Within the development boundary or 15m beyond the hoarding line, where applicable	Monthly for duration of construction	CT, EM/ECO, Flora Specialist, Arborist	
	Minimisation of construction impacts to fauna	N.A.	• Areas not used should be returned to earth ground and replanted if possible. Planting scheme should be as similar to forest composition to adjacent forest, if not as native as possible. Other than minimising edge effects, it can serve as a natural barrier to light, noise and dust to reduce disturbance. As a general guide, 400 trees should be replanted for every hectare to be reinstated.	Fauna	Within development boundary or 15m beyond the hoarding line, where applicable	Post-construction	CT, EM/ECO, Ecologist	N.A.

[11] Resident Technical Officer (RTO) and Site Officers (SO, WSHO and ECO) check the project site for construction progress and implementation of environmental mitigation measures.
[12] If there is trigger then all the mitigation and management measures should be audited in detail for compliance and corrective action must be taken in liaison with the Project Owner.

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		• Before vegetation removal, pre-felling fauna inspection should be conducted by an Ecologist to identify wildlife or nesting structures that are being actively used such as bird nests, tree hollows and burrows.	• Implementation of directional clearing • Inspection for presence of trapped/injured/dead fauna, potential fauna entrapments and gaps in site hoarding Toolbox briefings on biodiversity awareness		Within development boundary or 15m beyond the hoarding line, where applicable	Prior to site clearance	CT, EM/ECO, Ecologist	
		• Follow the measures for physical parameters from the rest of the table.	• Assessment of habitat quality (e.g., water quality, excessive vegetation removal, light management strategies) • Implementation of only 100% biodegradable wildlife friendly (eg. loose weave, non-welded mesh, rectangle (elongated) mesh) ECBs • Establish a comprehensive waste management system and submit a contract-specific Waste Management Plan which details the types of waste generated, location and types of waste management facilities, frequency of disposal, as well as information of waste management contractors. This will act as the guidance for workers to ensure proper implementation of waste management and disposal on site, where the practices will include but not limited to: - Strictly prohibit illegal disposal of construction wastes into streams and storm water channels or other waterbodies - Strictly prohibit littering of food waste and food packaging - Provide sufficient fully covered food waste bins that are secured in a manner that is wildlife-proof - Clear all food waste from the worksite at least once a day - If fauna is found to be active around waste disposal areas, the Contractor will implement measures to reduce the source of the attractant in consultation with the Ecologist • Implementation of proper vector management strategies, where the hierarchy of vector control for construction worksites near the Biodiversity Study Area will be as follows: (a) no thermal fogging to prevent unintended impacts to invertebrate fauna nearby; (b) no chemical insecticides, pesticides and rodenticides will be used for pest control; (c) no sticky traps will be used for pest control.		Within development boundary or 15m beyond the hoarding line, where applicable	Monthly for duration of construction	CT, EM/ECO, Ecologist	
		N.A.	• Conduct biodiversity survey to monitor construction impacts on fauna activity and presence		Adjacent to development boundary	Monthly for duration of construction	CT, EM/ECO	When fauna is encountered within development boundary

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		NA	• Recording of number of occurrences of human-wildlife conflict		Within development boundary	Daily monitoring and record-keeping	CT, EM/ECO	N.A.
Hydrology and Surface Water Quality	• Solid & Toxic Waste Generation • Liquid Effluent and Stormwater Runoff Generation • Improper Management of Chemical Substances	<u>Key Minimum Controls</u> a. Solid & Toxic Waste Generation • Effective ECM and monitoring implemented as recommended in the Code of Practice on Surface Water Drainage to ensure that discharge into the stormwater drainage system does not contain TSS in concentrations greater than the prescribed limits under the Sewerage and Drainage (Surface Water Drainage) Regulations; • Hazardous substances and toxic wastes should be stored on hard stand, under shelter with a kerb around the storage area; • Implementation of CCTV including SIDS at the public drain to monitor the surface runoff discharges from the sites as per the Public Utilities Board of Singapore's (PUB) circular on Preventing Muddy Waters from the Construction Sites (October 2015); and • All wastes will be disposed only in the designated waste disposal facilities and appropriately separated, i.e. by trained workers to properly sort and label the different types of waste (reusable and recyclable waste, toxic and non-toxic waste, etc.). b. Liquid Effluent Generation and Stormwater Runoff • A full inventory of all anticipated wastewater streams and volumes should be finalised before the onset of the construction works; • No unmanaged discharge of wastewater stream permitted; • Reduce, reuse, and recycle hierarchy principle to be applied to wastewater on-site; • Hazardous wastewater, such as oily water, thinners, solvents, or paints, should be stored on hard stand, under shelter with a kerb around the storage area. The wastewater should be removed for treatment and disposal off-site by an approved Waste Management Contractor. Hazardous liquids to be handled as Hazardous Waste; • Adequate drainage, cut-off drains, sump pit, road kerb, piping and toe wall will be designed for channelling of construction process wastewater streams (e.g. concrete batching, wash water, etc.) and stormwater runoff separately through detailed design for capture and treatment in the containment pond/kerbs. Where applicable (e.g. in the vicinity of liquid storage or refuelling areas), this infrastructure will include oil-water separators to capture inadvertent spills or leaked oils or greases; • Contractor will need to seek approval from relevant authorities (i.e. PUB & NEA) as per PUB Sewerage and Drainage (Trade Effluent) Regulations if the wastewater will be disposed to public sewer or NEA's Trade Effluent Discharge Limits to controlled watercourse if the treated trade effluent will be disposed to surface watercourses. If such discharges	N.A.	All water quality parameters identified in Table 13-4. And any flooding issues should be recorded and inspected.	Before every discharge outlet and at the sensitive streams (i.e. D/S1 and D/S22).	One time monitoring prior to site clearance	CT, EM/ECO	Investigation and corrective actions to be taken there is a significant drawdown of groundwater level.

			• Conserve D/S1, no construction/blockage on top of it or in its vicinity, and with no disturbance on its water quality and hydrology (i.e. 30m buffer from both embankments of the stream).
			• Minimise the CR16 worksite to avoid worksite encroachment on D/S21.
			• Flow diversion of D/S22 and discharge water to the main natural stream D/S1. The flow diversion will require PUB's approval and the drain design will follow PUB's Code of Practice on Surface Water Drainage. Any storm discharge from the worksite to the diverted drain will require to meet NEA Trade Effluent Discharge Limits if applicable.
				All water quality parameters identified in Table 13-4.
				And any flooding issues should be recorded and inspected.
					Before every discharge outlet and at the sensitive streams (i.e. D/S1 and D/S22).	• Permanent TSS monitor installed at every discharge outlet;
						• Implementation of CCTV including a SIDS at every discharge outlet to monitor the surface runoff discharges from the sites;
						• Monthly water quality monitoring for all discharge locations during construction phase;
						• Monthly water quality monitoring for the sensitive streams with high ecological importance including D/S1 and D/S22 throughout the construction period;
						• Intensity of the laboratory analysis will be increased (e.g. fortnightly, weekly) if in-situ measurements and/or monthly laboratory results indicate deterioration in the water quality. Intensified monitoring will be carried out until in-situ measurements and/or laboratory results indicate 'normality'/consistency with earlier monitored conditions; and
						• Daily inspection on perimeter drains to ensure no surface runoff flowing out from the site untreated done by the site officer with with routine audit done by independent EMMP consultant.
							CT, EM/ECO	Investigation and corrective actions to be taken, when:
								• The following documentation are found inadequate/missing:
								  • ECM Plan;
								  • Monitoring Log;
								  • Training Log;
								  • Audit Reports;
								• If the monitored parameters exceed applicable values of NEA Trade Effluent Discharge Limits at discharge point (refer to Table 13-3);
								• If the monitored parameters exceed applicable values of Water Quality Criteria for Aquatic Life at natural stream (refer to Table 13-3);
								• If any flooding or clogging issues observed;
								• If complaints are received due to project activities; and
								• If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		are not approved, the trade effluent will be stored, treated or recycled on site and finally disposed off-site; • Contractor will seek for comment and approval from relevant authorities (e.g. SCDF and NEA) on the treated wastewater to be used for firefighting purposes; • The discharge of pumped dewatered groundwater or other wastewaters to sensitive aquatic habitats will be prohibited (e.g. natural streams within Clementi Forest and Maju Forest); • Tunnel washing effluent should be discharged to containment pond/kerbs that are manually collected by operator assigned private wastewater collector to be transferred to wastewater treatment plant; • Appropriate disposal of any waste listed in the Environmental Public Health (General Waste Collection) Regulations by licensed waste operator/collector; • Runoff within, upstream of, and adjacent to the worksite will be effectively drained away without causing flooding in the vicinity; • Appropriate permits for discharge to be obtained from relevant authority prior to discharge. No trade effluent other than that of a nature or type approved by NEA Director-General will be discharged into any watercourse or land; • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to watercourses; and • Geotechnical aspect of site's slope stability (such as Earth Retaining and Stabilising structures (ERSS) to be included in detailed design engineering for the construction stage. c. Improper Management of Chemical Substances • Development of SOP for safe handling, transfer and storage of toxic waste; housekeeping checks once a day to ensure all toxic waste is cleared from site; • Appropriate tests to ascertain the presence/absence of contamination of the excavated earth and sand; • Appropriate fully sheltered storage area with storage volume to be 110% of the largest volume of chemical substances to be stored (kerb up and enclosed on at least 3 sides, covered and with adequate ventilation) for hazardous substances; • Appropriate construction material for toxic waste storage containers with leak detection tests conducted periodically; • Provision of secondary containment for all toxic waste stored in bulk as per the requirements in the COPPC/SS593; • Preparation of an emergency response plan, training of the emergency response team (ERT) to be competent in the response mechanism and provision of response kits for any spillages;					

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		• Consignment notification/tracking system and transport emergency response plan for transport of toxic waste; • Appropriate disposal of toxic waste as per required in the Environmental Public Health (Toxic Industrial Waste) Regulations by licensed waste operator/collector.						
Soil and Groundwater	Decreased groundwater baseflow feeding into the streams	Minimum Controls: ▪ Install piezometers to monitor the changes in groundwater level in compliance with Building Control Regulations 2003 as part of its instrumentation and monitoring plan to be endorsed by the Qualified Professional (QP); and • Proper Earth Retaining Stabilising Structures (ERSS) should be selected and designed to limit groundwater settlement.	▪ Not Applicable.	Groundwater Level	Actual monitoring location to be decided by QP.	To continuously monitor the groundwater level throughout the lifetime of the construction phase.	CT, EM/ECO	Investigation and corrective actions to be taken there is a significant drawdown of groundwater level.
	Improper Management and Disposal of Excavated Soil and Groundwater	• Identify all types of solid waste (e.g. tunnelling waste) and implement comprehensive waste management system at the site in order to ensure proper disposal and prevent pollution to the environment. This contractor should conduct a construction risk assessment and prepare a comprehensive construction health, safety and environment plan. If health impacts to workers are foreseen due to the handling of such waste, necessary precautionary measures as per the safety data sheets (SDS) including personal protective equipment should be implemented on site. • Use approved materials, of the same or better quality as the surrounding area, for backfilling works. All backfilled material will be free of debris, and of good material soil. • Handle and dispose excavated soil following the procedure shown in Figure 13-12. This flow chart explains how to handle excavated soils, and identify potential areas of contamination as well as potential of contamination (POC) in excavated soils. If the POC soils are tested for exceedance in DIVs, the soils can be disposed of to toxic waste collectors or undergo soil treatment. If contaminated soils were sent for treatment to an acceptable standard such as the DIV, the treated soil can be disposed in the staging ground or through a general waste collector, depending on the level of the contaminants during the staging ground testing. • Upon receipt of results on the tested parameters (chemicals, heavy metals) exceeding the regulatory limits, the construction contractor should further assess the potential inhalation and dermal contact impacts of the exceeded parameters to the site workers exposed to areas where soil and/or groundwater contamination is identified. The risk assessment should be conducted before the commencement of construction activities and the findings incorporated into the contractors' construction risk assessment and health, safety and environment plan. If health impacts to workers are foreseen, necessary precautionary measures, as per the respective chemical SDS, should be implemented on site.		Records on waste generated and hazardous chemicals used at the construction site should be properly kept and records produced when requested.	• At locations where excavated soil and extracted groundwater are generated and stored. • At locations where toxic chemical wastes are generated and stored. • At locations where hazardous chemicals/substances are used and stored.	• Monitoring records of the amount and type of toxic chemical waste generated, once a week • Inspection of hazardous chemical /substances storage conditions, once a week. • Routine environmental audit by independent EMMP consultant during construction phase.	CT, EM/ECO	Investigation and corrective actions to be taken, when: • There are no/ poor records of toxic chemical waste amount and type; and • There is evidence of poor handling/ storage of toxic chemical waste and hazardous chemical.

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		• A site management plan should include plans of safe handling, transfer and storage of excavated soils following the procedure in Figure 13-12 • Discharge of extracted groundwater will be to an area approved for such disposal by the NEA and PUB and the proposed location as identified in Figure 13-12 and following the process set out in Figure 13-13. Based on the results of the soil and groundwater baseline study, the detected concentrations in groundwater do not exceed the DIVs. However, it is recommended that the construction Contractor to be vigilant of site conditions and extracted groundwater to be tested at regular intervals, especially for extracted groundwater with oily sheens or noticeable odour. If a contaminant concentration in excess of the DIV is detected, the Contractor will assess the potential inhalation and dermal impacts of the chemical identified and assess potential health and safety considerations for exposure to groundwater before commencement of construction activities. Such contaminated wastewater may need to be disposed of to a licenced toxic waste collector. • Contractor will need to seek approval from relevant authorities (e.g., PUB & NEA) as per NEA's Trade Effluent Discharge Limits if the treated groundwater will be disposed to controlled watercourse If such discharges are not approved, the trade effluent will be stored, treated, or recycled on site and finally disposed of. The extracted groundwater to be discharged should be tested in regular intervals, especially if oily sheens or odour are observed. • Bentonite slurry used in the TBM will be pumped into the slurry treatment plant for recycling, cleaning and removal of native cut material. Treatment methodologies in the slurry treatment plant will include de-sanding (e.g., cyclones) and filtration. Handling and disposal of spoils for disposal after the treatment will follow the procedure in Figure 13-12.						
	Toxic Chemical Waste Generation during Construction Phase	Minimum Controls: • Identify all types of toxic chemical waste and implement comprehensive waste management system at the site in order to ensure proper disposal and prevent pollution to the environment. This contractor should conduct a construction risk assessment and prepare a comprehensive construction health, safety and environment plan. If health impacts to workers are foreseen due to the handling of such waste, necessary precautionary measures as per the safety data sheets (SDS) including personal protective equipment should be implemented on site; • Inspect all equipment prior to entering the site for fuel/hydraulic lines, leaking tanks, and other potential faulty parts that could potentially cause contamination to soil or groundwater; • Dispose all construction debris (under category C&D) at the gazetted Government dumping grounds or at such other sites or locations as directed by NEA; • Store generated toxic chemical waste under shelter within concrete bund walls or in storage containers						

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		with good ventilation. Spill trays will be provided for all waste containers Spill trays will be regularly maintained to prevent rain from washing out the pollutive substances; • Note that the Earth Control Measures (ECM) is for the containment and treatment of silty discharge due to the impact of rainwater. ECM is not meant for the treatment of wastewater due to construction activities (such as pipe-jacking and bore-piling works) which will be treated to comply with the requirements under prevailing legislation; and • Contractor will need to seek approval from relevant authoriries (i.e. PUB & NEA) as per PUB Sewerage and Drainage (Trade Effluent) Regulations if the wastewater will be disposed to public sewer or NEA's Trade Effluent Discharge Limits to controlled watercourse if the treated trade effluent will be disposed to surface watercourses. If such discharges are not approved, the trade effluent will be stored, treated or recycled on site and finally disposed off-site.					
	Improper Handling of Hazardous Chemicals/Substances during Construction Phase	Minimum Controls: • Remove any hazardous substance or chemical if there are safer alternatives; • Ensure all hazardous substance and chemical containers are labelled its movement is recorded and returned to the designated storage areas when not in use; • Assess the SDS of all the hazardous substances and chemicals prior to its entry to site for its suitability in terms of SHE hazards and consider safer alternatives; • Ensure no trade effluent other than that of a nature or type approved by NEA Director-General will be discharged into any watercourse or land; • Ensure all activities involving repair, servicing, engine overhaul works, etc. will be carried out on an area which is appropriately contained (e.g. concreted area and with proper containment/sumps) and all wastes are channelled for appropriate treatment or disposal to meet the regulations; • Store chemicals stored under shelter within concrete bund walls or in storage containers with good ventilation. Spill trays will be provided for all drums, plants and machinery and potential pollutive substances used on site. Spill trays will be regularly maintained to prevent rain from washing out the pollutive substances; and • Provide emergency spill kits on site in the event of any chemical spillages. The emergency response team will also be competent in the use of these spill kits.					
Air Quality	Air quality impact from dust nuisance from the construction activities and gaseous emissions from the construction equipment and vehicles	• The construction footprint will be hoarded on all sides; • No demolition of permanent structure is expected as part of the project; and • Road construction or expansion will be completed first and paved where possible before the construction of other development commences.	General mitigation measures to be implemented throughout construction period. Communications: • Develop and implement a stakeholder communications plan that includes community engagement before work commences on site. • Display the name and contact details of person(s) accountable for air quality and dust issues on the site boundary. This may be the	Dust deposition in $mg/m^2/day$	• Clementi Forest • Maju Forest	• Prior to site clearance: Conduct one-time air quality monitoring of PM_{10} and $PM_{2.5}$ for 1 week at Clementi Forest and Maju Forest, for the establishment of baseline	CT, EM/ECO	Investigation and corrective actions to be taken, when 1. Any of the following documentation are found inadequate / missing: Air Pollution Control Plan; Compliance certificate of an Off-Road Diesel

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		• Implement a wheel washing system (with rumble grids to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable) for local access roads in all construction sites. • Ensure there is an adequate area of hard surfaced road between the wheel wash facility and the site exit, wherever site size and layout permits.	environment manager/engineer or the site manager. • Develop and implement an Air Pollution Control Plan (APCP) Site Management: • Record all dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken. • Make the complaints log available to the local authority when asked. • Record any exceptional incidents# that cause dust and/or air emissions, either on-site or off-site, and the action taken to resolve the situation in the log book. • Hold liaison meetings with other high risk construction sites within 500m of the site boundary, if any, to ensure plans are co-ordinated and dust and particulate matter emissions are minimised. Monitoring: • Undertake regular (daily frequency recommended) on-site and off-site inspections and record results. The log should be made available to the NEA or other Government Agencies if required. Inspections should include regular dust soiling checks of surfaces such as street furniture, cars and window sills within 100m of site boundary. Cleaning should be provided if necessary. • Carry out regular site inspections to monitor and record compliance with the Air Pollution Control Plan. • Increase the frequency of site inspections during prolonged dry or windy conditions. • Conduct monitoring for dust deposition at suitable locations (refer to Section 10 for details) Preparing and maintaining the site: • Plan site layout so that machinery and dust causing activities are located away from receptors, where possible. • Erect hoarding around dusty activities and at the site boundary wherever possible. Boundary screens should be at least as high as any stockpiles or dust emission sources on site. • Fully enclose specific activities where there is a known high potential for dust production and the site will be active for an extensive period of time. • Keep site fencing, barriers, and scaffolding clean by cleaning regularly using wet methods (dry methods may give rise to fugitive dust). • Remove materials that have the potential to produce dust from site as soon as possible, unless being re-used on site. If they are being re-used on-site, stockpiled material should be covered, seeded, fenced or enclosed to prevent fugitive dust formation.			• Throughout construction period: Continuous dust deposition monitoring, averaged over 4-week period • Routine environmental audit by independent EMMP consultant during construction phase.		engine; or Monitoring Log. 2. If the monitored PM_{10} and $PM_{2.5}$ exceed Singapore long term air quality targets. 3. If the dust deposition monitored exceeds 200 mg/m^2/day averaged over 4-week 4. If complaints are received due to project activities. 5. If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
			Operating vehicle/machinery and sustainable travel: • Impose and signpost a maximum-speed-limit of 25 km/hr on paved or surfaced haul roads and 15 km/hr on unpaved haul roads and work areas within the worksite, as well as local access roads leading to the worksite. • Produce a Construction Logistics Plan to manage the sustainable delivery of goods and materials. • Ensure all vehicles and engine powered equipment comply with the legislative requirements of Singapore • Ensure all vehicles and equipment switch off their engines when stationary – i.e., no idling vehicles or engines. Clear signs will be erected at site entrance to inform all visitors. • Where practicable, avoid the use of diesel- or petrol-powered generators and use mains electricity or battery powered equipment Construction: • Only use cutting, grinding or sawing equipment fitted with, or in conjunction with, suitable dust suppression techniques such as water sprays or local extraction e.g., local exhaust ventilation system. • Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate. • Use enclosed chutes and conveyors and covered skips wherever possible. • Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate. • A stringent “Clean as you go” Policy should be implemented on site to ensure no loose dry material is left exposed when not in use. Equipment should be readily available on site to clean and dry spillages, and cleaning should be conducted as soon as reasonably practicable after the event using wet cleaning methods. Waste Management: • Avoid burning of waste or other materials					
			MITIGATION MEASURES FOR EARTHWORKS • Re-vegetate earthworks and exposed areas/soil stockpiles to stabilise surfaces as soon as practicable. • Use Hessian, mulches or soil tackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable. • Only remove the cover in small areas during work and not all at once.					
			MITIGATION MEASURES FOR CONSTRUCTION					

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
			• Avoid scabbling (roughening of concrete surfaces) if possible. • Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place. • Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery. • For smaller supplies of fine powder materials ensure bags are sealed after use and stored appropriately to prevent dust. MITIGATION MEASURES FOR TRACKOUT • Use water-assisted dust sweeper(s) on the access and affected local roads, to remove, as necessary, any material tracked out of the site. This may require the sweeper being continuously in use. • Avoid dry sweeping of large areas. • Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport. • Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable. • Record all inspections of haul routes and any subsequent action in a site log book. • Install hard surfaced haul routes, which are regularly damped down with fixed or mobile sprinkler systems, or mobile water bowsers and regularly cleaned. • Site access gates to be located at least 10m from receptors where possible					
Airborne Noise	Noise from construction machines and equipment, especially rotational and vibratory equipment (e.g. dozers, cranes, excavators, trailers, generators, etc.)	Minimum Controls: • Construction prohibition period should be followed, as per fourth schedule of Environment Protection and Management regulation; • Prepare a Construction Noise Management Plan, to establish baseline monitoring prior to site clearance, plan for monitoring during the construction phase, and procedure for complaint handling; • The Contractor will review the equipment to be used on site and erect localised noise barriers prior to undertaking high noise generating work; • Machines (such as trucks) that may be in intermittent use will be shut down between work periods or will be throttled down to a minimum; • Only well-maintained plants will be utilised on-site and plants will be serviced regularly during the entire construction period; • The number of PMEs will be reduced as far as practicable when construction works are carried out at areas close to the noise sensitive receivers:	MITIGATION MEASURES FOR GENERAL CONSTRUCTION NOISE CONTROL: • Control of noise sources at the source from construction site – Analyse construction inventory list and check equipment causing high noise levels. The equipment with lower noise level hall be prioritised. • Where controlling noise sources at the source is not feasible, acoustic enclosures or sheds are to be introduced to mitigate noise at the source. Typical acoustic enclosure covers the machine as fully as possible (with or without ventilation where applicable) to provide sound insulation. MITIGATION MEASURES FOR CONSTRUCTION NOISE: Noise Barrier of minimum STC 20 are proposed to be erected at all the locations presented in Figure 13-15 in order to mitigate the construction	Leq 12hours, Leq 1hour and Leq 5mins	One (1) location at Maju Forest boundary and closest to construction worksite (see Figure 13-15)	<u>Before commencement of any construction works (including site clearance)</u> • One-time airborne noise monitoring for 1 week at this location, for establishment of latest baseline. <u>During Construction Phase</u> • Continuous monitoring at this location for the entire duration of construction.	CT, EM/ECO	Investigation and corrective actions to be taken, when: 1. Any of the following documentation are found inadequate / missing: • Construction Noise Management Plan; • Monitoring Log. 2. If the monitored parameters exceed applicable values of EPM regulations. 3. If complaints are received due to project activities. 4. If visual non-compliance to any of the minimum control or mitigation
					Two (2) locations within Clementi Forest and closest to northern and southern part of construction worksite	<u>Before commencement of any construction works (including site clearance)</u> • One-time airborne noise monitoring for 1 week at these locations, for		

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
		• Silencers or mufflers on construction equipment will be utilised and will be properly maintained during the construction programme; • Behavioural practices including no shouting, no loud stereos/ radios on site, no dropping of materials from height, no throwing of metal items will be ensured; • Construction respite: Restrict high noise generating drilling activities only in continuous blocks, not exceeding 3 hours each, with a minimum respite period of one hour between each block, if possible; • Periodic noise monitoring by an independent third party, to establish compliance with requirements and to advise on equipment causing concern, and additional potential mitigation measures; • Plan the layout of the site by considering using materials and other large structural equipment as noise barriers; • Plant known to emit noise strongly in one direction will, wherever possible, be orientated so that the noise is directed away from the nearby NSRs; and • Material stockpiles and other structures will be effectively utilised, wherever practicable, in screening noise from on-site construction activities. • The optimisation of worksite to be situated away from the Biodiversity Study Area as far as practicable. • Acoustic sheds should be provided at the locations of the noise generating activity such as operation of hand-held breaker. • All construction works should be conducted within the daytime period. TBM works are to be conducted in the daytime as much as possible.	noise to the noise sensitive receptors. These locations are; For Advance work • 6 m high noise barrier at the west and south-east construction boundary of Advance work worksite fronting noise sensitive receptors, • 12m high noise barrier at north-east construction boundary of Advance work worksite fronting noise sensitive receptors after completion of Advance worksite construction, For Main civil work, • 12 m high noise barrier at the west construction boundary of Main construction work worksite fronting noise sensitive receptors, • Use the existing 6 m high noise barrier from the south-east construction boundary of Advance work) and 12m high noise barrier from the north-east construction boundary of Advance work worksite, • LTA's standard TBM enclosure (one facade opening at northern side) 15m high at boundary of launch shaft. • Above-ground works not critical for safety reasons to be restricted to weekdays (avoiding works on Sunday and Public holidays) • No night works after 7pm for all non-safety critical activities since the site is next to Biodiversity Study Area. • Portable noise barrier were highly recommended close to the noisy equipment/ activities • For noisy machinery such as the Secant Pile Auger - that typically operate for long period, the soundproof baffles can be mounted directly on the machine around the engine cowling.		(see Figure 13-15)	establishment of latest baseline. <u>During Construction Phase</u> • Continuous monitoring at this location for the entire duration of construction.		measures are observed on-site. 5. If there are any cracks / leaks present on the noise barrier erected.
					For all monitoring locations	• Records on noise levels from construction sites should be properly kept and produced when requested.		
Ground-borne Vibration	Ground-borne vibration from construction machines and equipment (e.g. vibratory roller, hydraulic hammer/rock breaker, pipe jacking), rock breaking and excavation and tunnel boring machine.	• Equipment Selection and Maintenance. Associated with the piling during the construction of the vent shafts, cut and cover tunnel, at-grade ramp, plus the operation of the TBM. • Works Scheduling and Respite Periods. • Community Consultation. It is recommended that the surrounding community be notified before commencing any piling and TBM related works, as a matter of good community relations.	• Optimise the worksite for smallest footprint within this area. • Schedule rock breaking and excavation activities during day time. • Restrict high amplitude vibratory compactors, pipe jacking, rock breaking and tunnel boring to below vibration threshold of PPV, 8 mm/s. • Use of tri-axle trucks to reduce truck trips on the road. • No night works should be conducted after 7pm for all non-safety critical activities. • Temporary barriers (i.e. water barriers of 1 m height) should be implemented along Brookvale Drive and Clementi Road as seen in Figure 13-16. Canvas sheets should also be used to cover the holes on the existing railings along Brookvale Drive and Clementi Forest.	PPV, mm/s	Maju and Clementi Forests	• In the event of a valid complaint, until the complaint has been resolved. • Routine environmental audit by independent EMMP consultant during construction phase.	CT, EM/ECO	Investigation and corrective actions to be taken, when: 1. If the monitored parameters exceed applicable limits. 2. If complaints are received due to project activities. 3. If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[11,12]
			Hoardings must be ensured at the worksites and at the existing construction beside Maju Forest. • The Contractor will control construction vibration levels using best available techniques (BAT) for pipe jacking (Advanced Works), high vibratory compactors (Stage 1), vibratory pile drivers for entrances (Stage 2), and tunnel boring (Stage 2) and rock breaking and excavation (Stage 2). • The Contractor will ensure that the vibration levels for any construction activities at Maju Forest and Clementi Forest (excluding the worksite area) do not exceed PPV, 8 mm/s. • Ecologist and Environmental Officer to identify burrows before the start of construction and monitoring burrow collapse during construction activities; • During pipe jacking (Advance Works), rock breaking and excavation stage (Stage 2) and tunnel boring (Stage 2) construction activities, Ecologist will monitor for any fauna behaviour (e.g. dashing onto road) resulting in road-kill incidents, for at least thirty (30) minutes after the event. • If fauna is seen trying to dash onto the road, construction activities will be immediately suspended, and mitigation measures should be applied to prevent such event from happening in the future.					

13.13.2 Commissioning Phase

The EMMP for commissioning phase of the Project is summarised in the following table. The key minimum control measures and key mitigation measures from the operational phase (see respective sections of Section 13) are generally applicable where relevant.

Table 13-13 Proposed Environmental Monitoring and Management Plan for the Commissioning Phase

Environmental Parameter	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[13,14]
Biodiversity	Flora and Arboriculture	• Softscape of operational boundary. Conduct flora surveys in adjacent forest to development boundary.	Monthly for duration of at least 6 months	CT, Floral Specialist, Arborist	N.A.
	Fauna	• Conduct fauna surveys in adjacent forest to development boundary. • Conduct ground-borne and airborne noise monitoring to monitor behaviour of fauna to impacts in tandem with biodiversity camera traps for fauna monitoring (refer to details of noise and vibration monitoring as part of the additional faunistic survey programme in Section 13.6.1.3.		CT, Ecologist	N.A.
Hydrology and Surface Water Quality	All parameters identified in Table 13-5. And any flooding	At the main outlets/drains of the Project site, as well as the sensitive streams in the vicinity of proposed Project (i.e. D/S1 and D/S22) during	Monthly inspection for the water quality and hydrology, especially during heavy storm	CT, EM/ECO	Investigation and corrective actions to be taken, when: • If the monitored parameters of all discharge points exceed applicable values of NEA Trade Effluent Discharge Limits at discharge point (refer to Table 13-3);

[13] Resident Technical Officer (RTO) and Site Officers (SO, WSHO and ECO) check the project site for construction progress and implementation of environmental mitigation measures.
[14] If there is trigger then all the mitigation and management measures should be audited in detail for compliance and corrective action must be taken in liaison with the Project Owner.

Environmental Parameter	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[13,14]
	issues should be recorded and inspected.	the first three (3) months of commissioning phase	event for hydrological conditions during first three (3) months of commissioning phase		• If the monitored parameters of natural streams exceed applicable values of Water Quality Criteria for Aquatic Life at natural stream (refer to Table 13-3); • If any flooding issues observed; • If complaints are received due to Project activities; and • If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.
Soil and Groundwater	• Records on waste generated and hazardous chemicals used at the Project site should be properly kept and records produced when requested.	• At locations where toxic chemical waste are generated and store. • At locations where hazardous chemicals/substances are used and stored.	• Monthly monitoring records of the amount and type of toxic chemical waste generated during first three (3) months of the commissioning phase • Monthly inspection of hazardous chemical/substances storage conditions during first three (3) months of the commissioning phase	CT, EM/ECO	Investigation and corrective actions to be taken, when: • There are no/poor records of toxic chemical waste amount and type; and • There is evidence of poor handling/storage of toxic chemical waste and hazardous chemical.
Airborne Noise	Leq 5min and Leq 1 hour	• Three (3) noise monitoring locations at boundary of Maju Forest and Clementi Forest (see Figure 13-15)	• Continuous monitoring for three (3) months of the commissioning phase	CT, EM/ECO	Investigation and corrective actions to be taken, when: • If complaints are received due to Project activities. • If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.
	Leq15 min	• Six (6) noise monitoring locations at the east, north and south boundary of ventilation shaft (see Figure 13-15)	• Continuous monitoring for one (1) day (24 hours) within the commissioning phase, as per *NEA's Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Building*		
Ground-borne Vibration	PPV, mm/s	N.A.	N.A.	N.A.	N.A.

13.13.3 Operational Phase

The EMMP for operational phase of the project is described in Table 13-14.

Table 13-14 Proposed Environmental Monitoring and Management Plan for the Operational Phase

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Responsibility
Biodiversity	Minimisation of operational impacts to flora/vegetation	• Identify of areas that are responding poorly due to operational activities Ensure that post-construction planting is responding well to development surrounding • Ensure integrity of adjacent forest (if any) Identify signs of edge effects on new forest edge of adjacent forest (if any) • Assessment of habitat quality (e.g., water quality, excessive vegetation removal)	• Flora and Arboriculture	Softscape of operational boundary
			• Ensure integrity of adjacent forest (if any) • Identify signs of edge effects on new forest edge of adjacent forest (if any)	Adjacent forest to development boundary
	Minimisation of operational impacts to fauna	• Inspection for presence of trapped/injured/dead fauna, potential fauna entrapments and gaps in site hoarding • Recording of number of occurrences of human-wildlife conflict Conduct biodiversity survey to monitor construction impacts on fauna activity and presence	• Fauna	Adjacent forest to development boundary
Hydrology and Surface Water Quality	Stormwater Runoff Generation	a. Stormwater Quality: • Adequate drainage, piping and/or channelling of stormwater runoff to be assured through detailed design [such as Active, Beautiful, Clean Water (ABC) Water Design approach] for capture and treatment before discharge into watercourses; • Regular and dedicated procedures for the inspection and maintenance of stormwater collection, storage, and treatment infrastructure, such as pipes, oil water separation, silt screens, etc.; and • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to watercourses. b. Hydrology: • Potential increase of peak-flow due to the change in the land use at the new developments can be mitigated by providing detention ponds/tanks within the Study Area. Detention tanks can capture stormwater during heavy storm events to reduce the peak runoff. Stored water can then be discharged back to the system after the storm event. As required by PUB, the storage system needs to be in place to reduce the peak flow at the operational phase to be the same or less than that of the existing condition; • Active, Beautiful, Clean Water (ABC) Water Design approach can be considered to reduce the peak-flow as well; and • Geotechnical aspect of the site's slope stability (such as ERSS) will be included in detailed design engineering for the operational stage.	• Redesign and reduce proposed footprint areas. • Divert D/S22 permanently and discharge water to the natural stream D/S1. • Area reinstatement with greenery provision to reduce the runoff coefficient which will help to reduce the peak-flow and reduce flood risk at downstream area.	Rail Operator/ EHS Officer
Soil and Groundwater	Generation of small quantities of toxic chemical waste (used fluorescent bulbs, used lead-batteries, used maintenance chemical containers i.e. thinner, paints, lubricants, etc.)	• Store all toxic chemical waste at designated sheltered area provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation. Spill trays will be provided for all chemical drums, plants and machinery and potential pollutive substances used on site. Spill trays will be regularly maintained to prevent rain from washing out the pollutive substances. • Dispose all toxic waste chemicals off-site to licensed TIW collectors for treatment.	Not Applicable	Rail Operator/ EHS Officer
	Improper handling of hazardous chemical/ substances	• Store all hazardous substances/chemicals at designated sheltered area provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation. Spill trays will be provided for all chemical drums, plants and machinery and potential pollutive substances used on site. Spill trays will be regularly maintained to prevent rain from washing out the pollutive substances. • Ensure that all hazardous chemicals/substances are labelled its movement is recorded and returned to the designated storage areas when not in use. • Ensure all activities including repair, servicing, engine overhaul works, etc. involving the use of hazardous chemicals/substances are carried out on an area which is appropriately contained (e.g. concreted area and with proper containment/sumps). • Provide emergency spill kits on site in the event of any chemical spillages. The emergency response team will also be competent in the use of these spill kits. • Ensure no trade effluent other than that of a nature or type approved by NEA Director-General are discharged into any watercourse or land.		

Environmental Parameter	Environmental Issue	Minimum Control Measures	Mitigation Measures	Responsibility
Airborne Noise	Noise from vent shaft operation	**Minimum controls for ACMV noise:** Minimum controls should be applied at the detailed design stage of the development by the appointed M&E consultants. An appointed Noise consultant should validate the noise in accordance with NEA's Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Building. • Use low air-conditioning and mechanical ventilation system equipment; • Ensure that any exhaust outlet or intake from the mechanical ventilation system is designed to be adequately set back as far as possible from the boundary line of the development; • Acoustic treatment for equipment to meet noise level limit at site boundary where necessary; • AC system to be designed with the AHU units placed at appropriate locations as set back from the boundary line of the development as possible; and • Acoustic enclosures for outdoor equipment. **Minimum controls for traffic noise:** Due to the lack of information at this juncture of reporting, assessment, minimum controls and mitigation will be provided by the appointed Noise Consultant during the prelim design stage and in accordance with Technical Guideline for Land Traffic Noise Impact Assessment	• Noise attenuators and other BAT and BEP noise control measures will be utilised • Traffic noise at the drop-off points and parking areas will be mitigated with low speed postings, humps and signage	Rail Operator/ EHS Officer
Ground-borne Vibration	Ground-borne Vibration from the operation of trains	• Train, track and tunnel design; • Maintenance of vertical track alignment at the relevant longitudinal wavelengths; • Maintenance of roughness of the railhead and wheel thread at the relevant longitudinal and circumferential wavelengths; • Maintenance of resilient elements of track construction, e.g. rail pads • Maintenance of rail joints, switches and crossings.	• General maintenance of the railway track and minimising of wheel defects.	Rail Operator

14. Conclusion

In conclusion, the summary of unmitigated impact significance and potential residual impact significance of the assessed environmental aspects for both construction and operational phases are presented in the following tables. The recommended Environmental Monitoring and Management Program (EMMP) measures are summarised in Section 13.

The assessment findings in this Report demonstrated that the optimised CR16 with smaller construction footprint which can avoid encroachment into Stream D/S1 is able to mitigate the environmental impacts during construction phase, therefore it is strongly suggested to adopt the optimised CR16 worksite design for this Project.

Table 14-1 Summary of Potential Residual Impact Significance during Construction Phase (Range if applicable)

Environmental Parameter	EIS Section	Impact Significance with Minimum Controls	Residual Impact Significance with Mitigation Measures (if required)
Biodiversity	Section 7	Negligible to Major	**Negligible to Moderate** (Note 1)
Hydrology and Surface Water Quality	Section 8	Negligible to Major	**Negligible to Minor**
Soil and Groundwater	Section 9	**Negligible to** Minor	**Negligible to Minor**
Air Quality	Section 10	Moderate to Major	**Minor**
Airborne Noise	Section 11	Negligible to Major	**Negligible to Major** (Note 2)
Ground-borne Vibration	Section 12	Negligible to Major	**Negligible to Major** (Note 3)

Note:

1. Though vegetation and habitat loss has been reduced by moving the station footprint away from Clementi Forest and main stream (DS/1 and DS/2), the loss of vegetation due to site clearance from the new worksite would still result in moderate impact for scrubland and herbaceous vegetation. Such vegetation and habitat loss are permanent and irreversible.
2. Due to surrounding extremely low ambient noise levels, sensitive receptor in the close proximity, and undulant terrain with high elevated area which cannot be blocked by the proposed noise barrier.
3. Despite minimum controls, the impact significance still reached Major at Maju and Clementi Forests during rock breaking and excavation, tunnel boring and pipe jacking. Thus, further mitigation measures and EMMP should be implemented to obtain a resultant impact significance to Moderate.

Table 14-2 Summary of Potential Residual Impact Significance during Operational Phase (Range if applicable)

Environmental Parameter	EIS Section	Impact Significance with Minimum Controls	Residual Impact Significance with Mitigation Measures (if required)
Biodiversity	Section 7	Negligible to Major	**Negligible to Minor**
Hydrology and Surface Water Quality	Section 8	Negligible to Moderate	**Negligible to Minor**
Soil and Groundwater	Section 9	Minor	**Minor**
Air Quality	Section 10	Minor	**Minor***
Airborne Noise	Section 11	Negligible	**Negligible***
Ground-borne Vibration	Section 12	Minor	**Minor**

Environmental Parameter	EIS Section	Impact Significance with Minimum Controls	Residual Impact Significance with Mitigation Measures (if required)
Note: * The initial impact assessment with minimum controls was considered insignificant (Negligible to Minor), no residual impact assessment was undertaken, hence the impact significance remained the same.			

14.1 Way Forward

This EIS Final Report presents the impact assessment on the environmental parameters from the preliminary design stage only, where the assessed worksite areas exclude detailed design elements such as locations of piezometers, utilities/ road diversion areas, site elements (e.g., workers dormitory, detention tank, site office etc.), utilities/ road diversion. Will there be any changes to the design of the Project elements in this Report during actual construction phase, the Contractor will take note of the design exclusions and update the findings of this EIS accordingly.

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