1. Introduction to the EIA

1.1 Overview

The Cross Island Line (CRL) has been proposed by the LTA to provide a strategic underground rail link to enhance connectivity between the east/northeast and west of Singapore and to meet future transport demands. The CRL will be approximately 50 - 60 km in length and span the length of Singapore, connecting Changi in the east to the Jurong Industrial Estate in the west. A segment of the proposed CRL may pass under or around the Central Catchment Nature Reserve (CCNR). Both proposed alignments are underground.

The LTA has commissioned Environmental Resources Management (S) Pte Ltd to undertake an Environmental Impact Assessment (EIA) of both alternative alignments to determine the potential environmental impacts of each. In addition to the EIA findings, the Government will consider other factors, such as connectivity, travel times and costs, when deciding on the final alignment of the CRL.

1.2 This Document

The LTA has called for EIAs to study the impacts associated with the following works:

- **Phase 1:** site investigation (SI) works comprising the drilling of geological boreholes within the CCNR.
- **Phase 2:** construction and operation (C&O) activities associated with both alignment options.

The Phase 1 EIA was completed and the report was gazetted and published on the LTA website on 5th February 2016. Following this, the SI works were carried out from February to October 2017. The findings of the SI works were used to inform the Phase 2 EIA.

This document presents a Non-Technical Summary (NTS) of the Phase 2 EIA report (also referred to as the C&O EIA). It provides an overview of the site settings for both underground alignment options, and summarises the findings of the EIA for the C&O activities and the mitigation measures required to manage these impacts.

1.3 Scope of the EIA

The key objectives of the Phase 2 EIA are to assess potential impacts and identify mitigation measures to reduce these impacts. The following environmental aspects were identified through a rigorous process that entailed consultation and engagement with stakeholders, and assessed in the Phase 2 EIA:

- Surface water & groundwater
- Noise and vibration
- Air quality
- Ecology & biodiversity
- Visual
- Cultural heritage resources
- Tourism and recreation

In order to facilitate decision-making by the Government on the alignment option, the Phase 2 EIA assesses the C&O activities for both options.

1.4 Approach to addressing data gaps in the EIA

The Phase 2 EIA considered the engineering scheme for both alignment options provided by the LTA. The EIA considered construction and operation activities as well as unplanned events (unintended occurrences) for the two alignment options.

The Precautionary Principle(Footnote 1) as well as professional judgement was adopted to address the following factors during the Phase 2 EIA:

- Where there were limited relevant standards / guidelines or scientific studies to allow for a quantitative assessment for specific impacts; and
- Where the worksites were optimized and subsequently relocated away from the CCNR resulting in limited primary baseline as compared to the Project baseline studies undertaken during Phase 1.

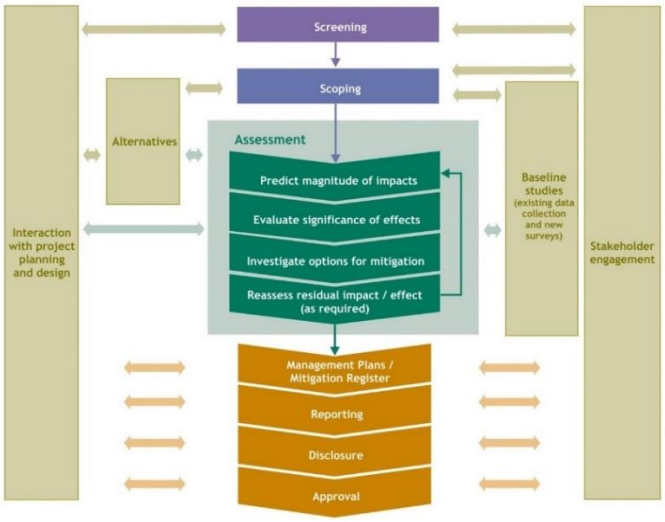
In relation to the limited baseline information for the worksites, LTA will be undertaking further surveys at the Advanced Engineering Study (AES) stage of the Project. Significant changes to the findings within the Phase 2 EIA are not expected despite the limitations above but additional refinement of the mitigation strategies and plans may occur.

(Footnote 1) The Precautionary Principle is an approach that recommends for anticipatory action to be taken, when an activity may result in potential impact but there is limited scientific information on the subject.

1.5 Overview of Impact Assessment Methodology

The impact assessment was undertaken in accordance with a systematic process and followed international guidelines. As per *Figure 1*, the process commences from screening and scoping of possible impacts, and progresses to the assessment of these impacts, identification of mitigation measures and development of management plans for implementation during the Project's construction and operation phases.

Figure 1 Impact Assessment Process



1.5.1 Impact Significance

The significance of predicted impacts was evaluated by considering the magnitude of impact [(Footnote 2)], and the sensitivity, vulnerability and/or importance of the affected resource / receptors. Impact significance was designated using the process shown in *Figure 2* and the matrix shown in *Figure 3*.

Figure 2 Impact Significance Designation Process

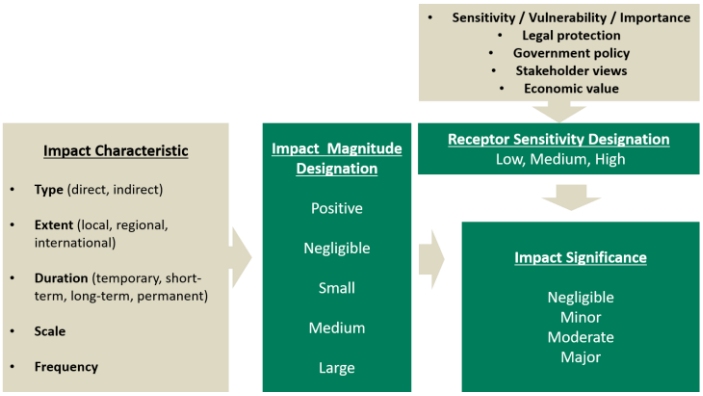


Figure 3 Example Impact Significance Matrix

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

The definitions of sensitivity and impact magnitude vary for different environmental aspects and are described within their respective impact assessment chapters in ***Volume III and Volume IV*** of the Phase 2 EIA.

There are two rounds of assessment undertaken for every impact:

- Pre-mitigation
- Post-mitigation or residual

The derivation of pre-mitigation impact magnitude takes into consideration embedded controls i.e. control measures that are planned as part of the Project design. For this Project, the embedded controls include regulatory requirements and LTA's own specifications and guidelines. These embedded controls provide a comprehensive range of measures to address different environmental impacts.

Refer to ***Volume I, Annex 2*** for more details about the embedded controls considered in this Project.

An explanation of impact significance ratings are outlined below:

- *Negligible*: A resource/receptor will essentially not be affected in any way by a particular activity.
- *Minor:* A resource/receptor will experience a noticeable effect, but the impact magnitude is sufficiently small (with or without mitigation) and/ or the resource/receptor is of low sensitivity/vulnerability/importance that additional mitigation is not required. In either case, the magnitude should be well within applicable standards.
- *Moderate*: Where impacts are within statutory/accepted standards. Where there are no established thresholds, a Moderate impact significance would indicate that impacts are at a level where mitigation measures are required.

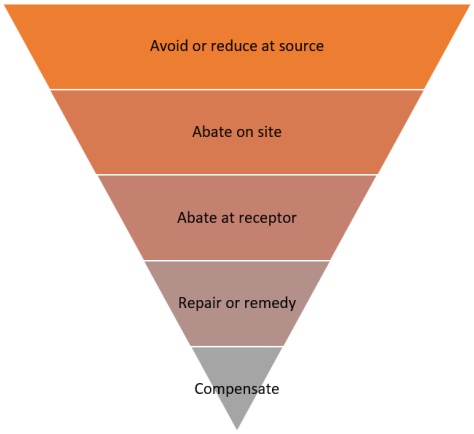
[(Footnote 2)] Includes consideration of likelihood of occurrence, for unplanned events (see *Section 2.4* of this NTS)

- *Major:* One where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors.
- *Critical:* Similar definition as *Major*, but is only applicable to the biodiversity assessment and when *Large* Impact Magnitudes interact with habitats with high biodiversity value[(Footnote 3)].

1.5.2 Mitigation Measures

Once pre-mitigation impact significances were evaluated, mitigation options were identified according to the Mitigation Hierarchy presented in *Figure 4*. The priority in mitigating impacts is to first avoid the impact, for example through the relocation of worksite or review of construction method. Mitigation measures lower down in the hierarchy were considered only when avoidance or reduction is not feasible from a safety or engineering perspective.

Figure 4 Mitigation Hierarchy



After identification of the mitigation measures for the Project, the residual (post-mitigation) impact magnitude and impact significance was then evaluated.

The objective of mitigation measures in managing assessed impacts is to reduce impacts to a level that is as low as reasonably practicable (ALARP).

1.5.3 Unplanned Events

Unplanned events are unintended occurrences during the construction and operation phase of the Project. A list of the unplanned events considered in the Phase 2 EIA can be found in ***Section 2.4*** of this document.

Likelihood of Unplanned Events

The likelihood of each event was designated based on LTA's technical assessment as well as a review of historical tunnelling projects undertaken by the LTA.

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

The impact significance of unplanned events is undertaken according to *Figure 2*, with the additional consideration of the likelihood of these events occurring, in accordance with the matrix in *Figure 5*.

Figure 5 Impact Significance Matrix (Unplanned Event)

Post-Likelihood Impact Significance		Likelihood of Occurrence		
		Unlikely	Possible	Likely
Pre-Likelihood Significance	Negligible	Negligible	Negligible	Negligible
	Minor	Minor	Minor	Minor
	Moderate	Minor	Moderate	Moderate
	Major	Moderate	Major / Critical	Major / Critical

As per the process shown in *Figure 1*, LTA, ERM and the Engineering Feasibility Consultant (initial phase) conducted iterative discussions and engaged with stakeholders throughout the EIA process, to determine a feasible Project design that avoided and reduced the impacts as much as possible.

An important outcome of such discussions and engagements was the key engineering design considerations presented in ***Volume I, Chapter 2 Project Description*** of the Phase 2 EIA, and summarised in ***Section 2.3*** of this NTS.

1.6 Baseline

A baseline study for an EIA is typically conducted to establish the existing conditions of the Study Area. The Study Area for the Project is shown in *Section 2, Figure 6*. The Project baseline study

[(Footnote 3)] (i) Habitat of significant importance to Critically Endangered and/or Endangered species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes.

was undertaken in 2014 and 2015 during the Phase 1 EIA. Findings from the baseline study were subsequently presented in *Volume II* of the Phase 1 EIA Report for the Project.

***Volume II* of the Phase 2 EIA Report** is an addendum to the baseline study for the Phase 1 EIA Report. It contains:

- An updated site setting as of 2019
- Supplementary flora and fauna data obtained for Phase 2 worksites
- Geology and groundwater results from historical SI works and SI works completed in or near the CCNR in 2017 as part of Phase 1

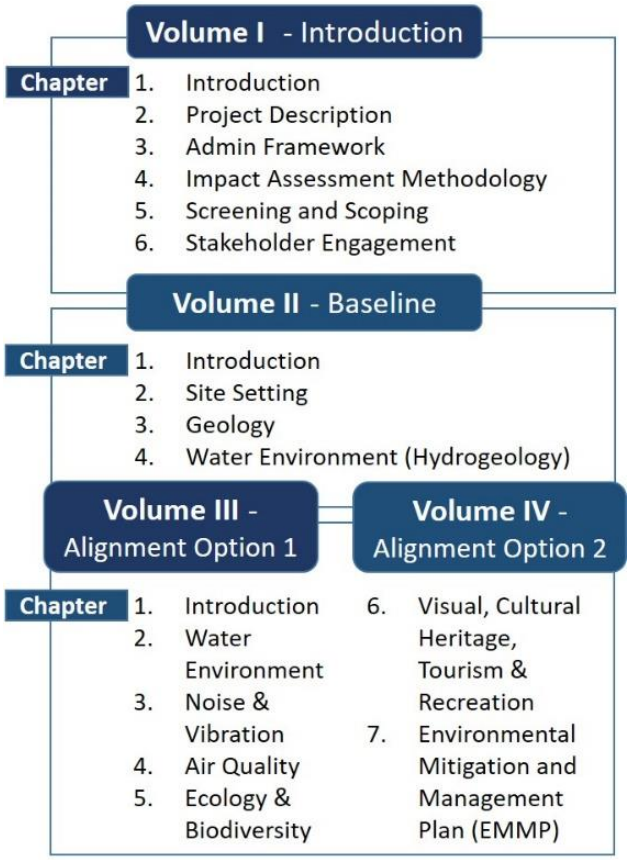
The baseline update for the Project has been developed from review of existing information gathered from online sources, the SI works undertaken in 2017 and/or from observations made during rapid site specific surveys.

Further details on the information sources and baseline findings are reported within the respective impact assessment chapters in ***Volume III* and *Volume IV***.

As noted above, the Phase 2 worksites were identified and finalised through an iterative process in the Project planning and feasibility design (see *Figure 1*). Detailed baseline studies will be conducted and captured in a separate study as part of the AES stage of the Project.

1.7 Guide to the EIA

The EIA is structured as follows:



Impacts on surface water, groundwater, noise, vibration and air quality may have knock-on effects on ecological receptors. All effects on ecological receptors are considered in ***Chapter 5, Ecology and Biodiversity*** for both Alignment Options (***Volume III and Volume IV***).

2. The Project

2.1 Alignment Options

The Project involves the consideration of the two underground Alignment Options as shown in *Figure 6*.

Alignment Option 1

A single bored underground tunnel approximately 4 km long, which would pass under an area from the Singapore Island Country Club (SICC) Island Golf Course to the Pan Island Expressway (PIE). Approximately 2 km of the tunnel would pass underneath the CCNR MacRitchie area, other sections of the tunnel would pass below some forested areas outside the CCNR boundary, such as the fringes of Windsor Nature Park, and areas north of SICC's Bukit-Sime golf course and west of the PIE. Two aboveground construction worksites will be required, which will be located outside the CCNR.

Alignment Option 2

Twin bored underground tunnels approximately 9 km in length, which would skirt around the CCNR. The tunnel alignment would travel below the SICC Island Golf Course, running parallel to Upper Thomson Road, beneath Lornie Road and the PIE after Adam Road. This alignment would travel below residential housing in the Thomson area and tunnel in close proximity to Bukit Brown Cemetery and several other underground infrastructures such as the DTSS, power cable tunnels and MRT tunnels. Three aboveground construction worksites will be required, which will be located outside the CCNR.

2.2 Key Features

Broadly speaking, the construction phase will involve the building of the following key features required for the operation of the CRL and defined in *Table 1*.

Table 1 Key Features of the Project C&O Phase

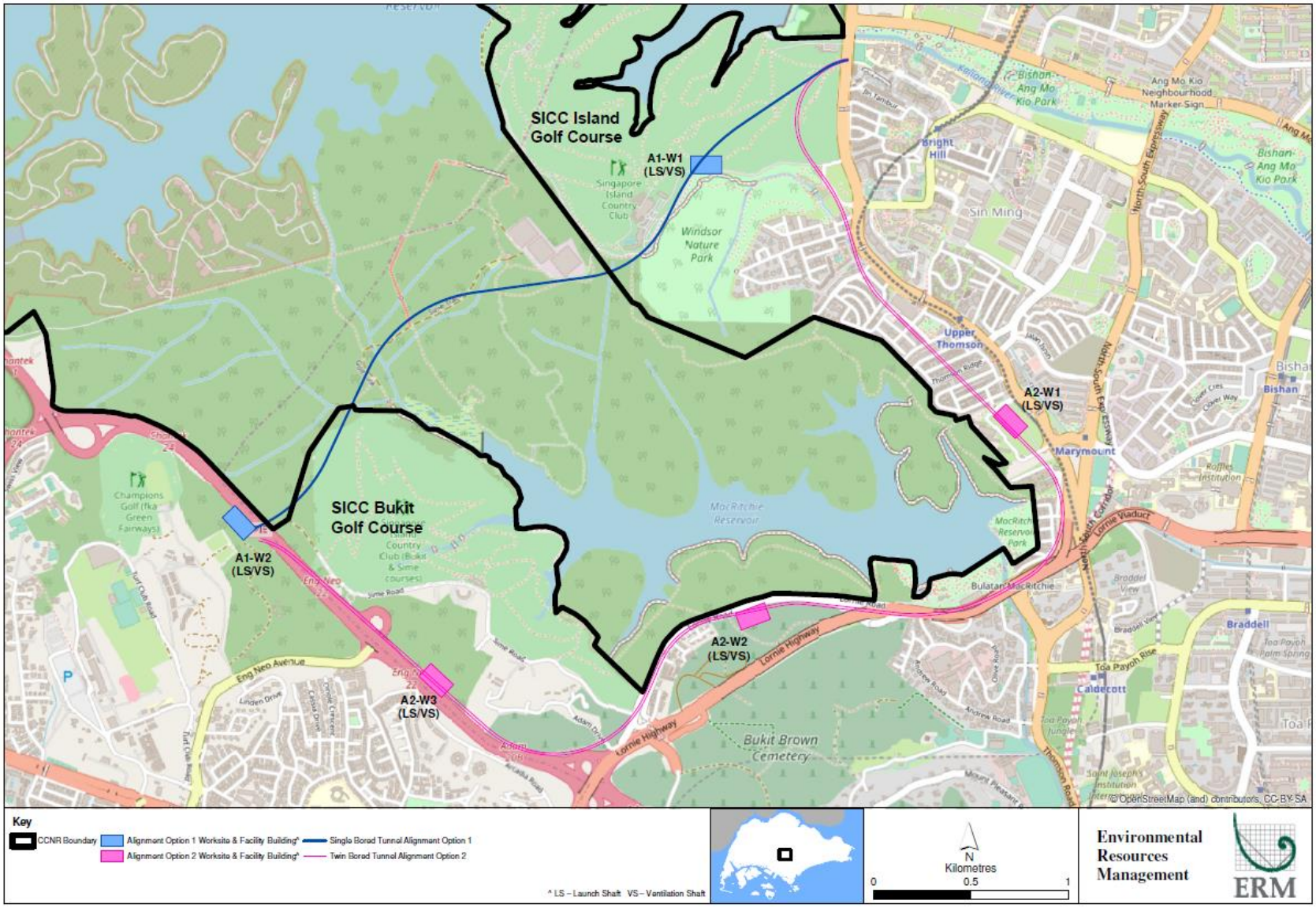
Key Feature	Description
Access Road	Temporary access road paved with hardcore or milled waste, for use by construction vehicles accessing and exiting the worksites during the construction phase, and permanent access road paved with asphalt to be constructed for facility buildings for use by maintenance vehicles during the operation phase
Tunnel	**Alignment Option 1** Single bored tunnel of around 12.5 m external diameter housing two rail tracks **Alignment Option 2** Twin-bored tunnels of around 7 m external diameter each, constructed 6 m apart, housing one rail track in each tunnel
Cross Passageway	**Alignment Option 1** For safe evacuation of passengers during an emergency event, cross passage doors within the single bored tunnel will be provided at 250 m intervals. Separate construction of cross passageway will not be required. **Alignment Option 2** For safe evacuation of passengers during an emergency event, underground passageways connecting the two tunnels at 250 m intervals will be constructed.
Launch/ Retrieval Shaft [Note 1,2]	Subsurface shafts for launching or retrieval of Tunnel Boring Machines (TBMs) at the start and end of a tunnel drive
Facility Building / Ventilation Shaft [Note 3]	Aboveground structure (average height of 10 m) to house the electric substation, Ventilation Shaft and other electrical and mechanical installations, as well as provide ingress and egress to responders and facilitate the evacuation of commuters during an emergency Subsurface ventilation shaft is to connect the tunnel to the surface for venting during normal train operations or a fire emergency event within the tunnels. Ventilation shafts will be housed within Facility Buildings

[Note 1] Launching or retrieval shafts are temporary structures to be used in the construction phase. For this Project, these shafts will be used to create the permanent ventilation shaft to be used in the operation phase.
[Note 2] The size of the temporary worksite required for TBM launching and retrieval is about 15,000 m^2.
[Note 3] The footprint of the permanent facility building (including ventilation shaft) is approximately 2,800 m^2.

The construction methods that will be adopted for the key features are the same for both Alignment Options. The main differences are the quantity and location of these key features/worksites along each Alignment Option, as shown in *Figure 6*.

The Phase 2 EIA considers the site-specific setting and sensitivity of receptors located near each alignment. The site setting, receptors and impact for Alignment Option 1 and Alignment Option 2 are respectively summarised in ***Section 3*** and ***Section 4*** of this NTS.

Figure 6 Location of Project Alignment Options (Tunnel) and Key Features /Worksites



As shown in *Figure 6*, both Alignment Option 1 worksites and worksites A2-W2 and A2-W3 along Alignment Option 2 are located within forested areas located outside the CCNR. Worksite A2-W1 is located within an urbanised setting along Upper Thomson Road.

2.3 Key Engineering Design Considerations

The design of Alignment Option 1 and Alignment Option 2 was informed by several engineering considerations.

Key engineering design considerations are further detailed in ***Volume I, Chapter 2 Project Description, Section 2.4*** of the Phase 2 EIA.

2.3.1 Alignment Option 1

The initial concept design for both alignment options involved the consideration of twin bored tunnels, which is a typical configuration for most of the existing MRT lines in Singapore. For evacuation purposes, cross passageways are needed to be constructed between the twin bored tunnels at regular intervals (see *Table 1*). Due to the depth of the tunnel for Alignment Option 1 (*Section 2.3.1*), rock excavation involving controlled blasting or mining, would be required for the construction of cross passageways at regular intervals along the tunnel. As a mitigation measure, a large single bored tunnel configuration was adopted as this eliminates the need for cross passageways construction below the CCNR. The means for evacuation of passengers will be through the provision of cross passage doors within the single bored tunnel (see *Table 1*).

The single bored tunnel for Alignment Option 1 was designed to be constructed at a depth of about 70 m below average ground level, to ensure that tunnelling will be undertaken within granite rock at all times when undercrossing the CCNR. As granite rock is competent ground (the strongest and hardest type of rock found in Singapore), any tunnel excavated within this rock type will be able to stand for long periods with no or minimal support. This extra measure in addition to the engineering safe-to-build tunnel designs insures against any unplanned events (e.g. risk of excessive ground settlement, water drawdown, slope failure) occurring below the CCNR. With this design, these unplanned events occurring due to tunnelling works under the CCNR are unlikely. The engineering team considered a range of factors to identify the preferred depth profile of the tunnel, such as possible launch shaft locations, limits to the gradient of the tunnel for train operations and the depths of granite rock based on the Phase 1 site investigation results. The vertical tunnel alignment for Alignment Option 1 is shown in *Figure 7.*

Several options were considered for launch shaft locations some of which were within the SICC Bukit golf course or Windsor Nature Park. These options were removed from consideration due to the need for worksite clearance in close proximity to the CCNR. The final worksite locations (see *Figure 6*) are located more than 50 m from the CCNR boundary.

In general, key features of Alignment Option 1 to reduce overall impacts:

- Single bored tunnel used instead of twin bored tunnels to remove need for rock excavation during cross passage construction
- Tunnel has been lowered to a greater depth so that it will be completely in granite rock
- All aboveground worksites/structures are located outside of the boundary of CCNR

2.3.2 Alignment Option 2

The twin bored tunnels for Alignment Option 2 was designed to be constructed at depths of around 45 m below average ground level. The tunnel depth and twin bored configuration of Alignment Option 2 was chosen to minimize the impact to surface structures and underground infrastructures along the route.

The tunnel depth for Alignment Option 2 was selected to avoid major underground infrastructures which already exist in the vicinity, such as the Circle Line MRT tunnels, Thomson-East Coast Line MRT tunnels, Deep Tunnel Sewerage System (DTSS) tunnel and Singapore Powergrid's high voltage power cable tunnel. These infrastructures are located in close proximity to Alignment Option 2 where it runs parallel to Upper Thomson Road and Lornie Road. Given the need to link up to underground stations for the CRL to the east and west it was not feasible for Alignment Option 2 to be tunnelled below these underground infrastructure. Tunnelling below such depths would require very steep tunnel gradients beyond the typical operational limits for such underground railways and very deep permanent facility buildings which are impractical for operation. The vertical tunnel alignment for Alignment Option 2 is shown in *Figure 8*.

As Alignment Option 2 may require tunnelling under a mix of soil and rock conditions in localised areas, ground improvement works from the surface may be required. Such works are typically carried out to avoid the risk of excessive ground settlement when tunnelling in mixed face conditions as part of LTA's engineering safe-to-build tunnel designs. Unlike Alignment Option 1 (where such works would not be possible in the CCNR), ground improvement works from the surface for Alignment Option 2 may be carried out. The risk of excessive ground settlement is unlikely to occur based on LTA's past experience so long as the inherent set of embedded controls, such as ground improvement works, are applied during tunnelling works with strict operational control.

In view of the existing underground infrastructures and presence of buildings, a twin bored configuration was chosen for Alignment Option 2. This allows greater flexibility in manoeuvring the TBM to avoid such underground structures.

In general, key features of Alignment Option 2 to reduce overall impacts:

- Tunnel depth designed to minimise impact on existing buildings and underground infrastructure
- Twin bored tunnel to allow greater flexibility for TBM to avoid underground structures

2.4 Unplanned Events

As noted in *Section 1.3.3* above, unplanned events are unintended occurrences that may happen during the construction and operation phase of the Project.

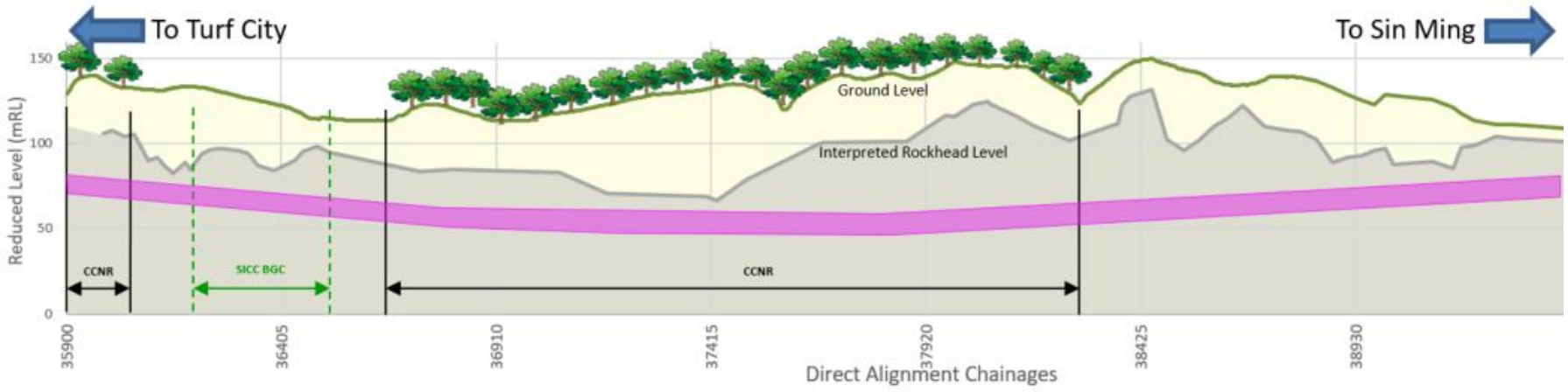
Key engineering design measures and controls will be in place to prevent or reduce the risk of these events occurring as far as possible. In addition, response plans have also been identified to reduce the extent and duration of any impacts should such an unplanned event occurs. The following unplanned events were identified and have been assessed as indicated in the Phase 2 EIA:

- Excessive ground settlement during tunnelling (unlikely)
- Slope failure within the CCNR during tunnelling (unlikely)
- Drawdown of streams during tunnelling (unlikely)
- Accidental spills into surface waterbodies during construction (possible)
- Fire during construction (unlikely) and operation (possible)
- Total breakdown of tunnel boring machine (unlikely)
- Excessive groundwater seepage into operating tunnel (unlikely)

The likelihood of each unplanned event was evaluated based on LTA's technical assessment and a review of historical tunnelling projects undertaken by the LTA. The evaluation of likelihood is detailed in ***Volume III, Annex 1.0*** and ***Volume IV, Annex 1.0 of the Phase 2 EIA*** for Alignment Option 1 and Alignment Option 2 respectively.

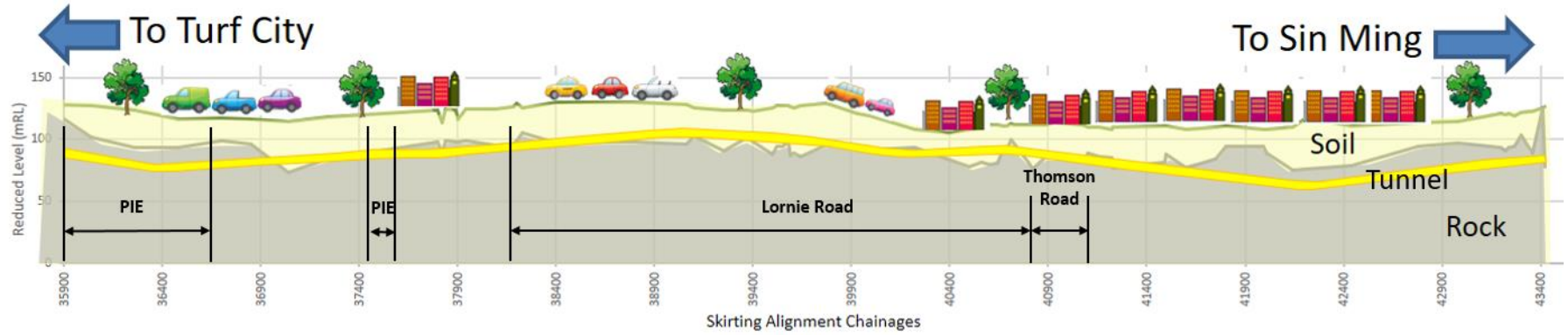
The findings for unplanned events for Alignment Option 1 is presented in *Section 3, Table 11 and Table 15* of this NTS; and in *Section 4, Table 24* and *Table 28* of this NTS for Alignment Option 2.

Figure 7 Vertical Tunnel Alignment along Alignment Option 1



Source: LTA

Figure 8 Vertical Tunnel Alignment along Alignment Option 2



Source: LTA

3. Alignment Option 1

3.1 Site Setting

Alignment Option 1 comprises a single bored tunnel approximately 4 km long, which will pass under an area from the SICC Island Golf Course, under the CCNR and the PIE. As shown in *Figure 9*, both the aboveground construction worksites for Alignment Option 1 are located outside of the CCNR boundary. They are:

- **A1-W1 (LS/VS):** area located along the Island Club Road, between the SICC's Bukit golf course and the fringes of Windsor Nature Park, comprising regeneration forest with a mix of mature trees and saplings (see *Figure 10* and *Photo 1*).
- **A1-W2 (LS/VS):** area located across the PIE from the west of the CCNR, comprising mature regeneration forest (see *Figure 11* and *Photo 2*).

The receptors are recreational users of golf courses and park trails near worksites A1-W1 and A1-W2, and fauna and flora within the forested areas around Windsor Nature Park and the CCNR.

3.2 Baseline Environment

The baseline environment around the Alignment Option 1 worksites and tunnel alignment are summarised in *Table 2*.

Table 2 Alignment Option 1, Summary of Baseline Environment

Environmental Aspect	Activities / Sources of Impact
Surface water	**A1-W1:** Surface waterbodies comprise roadside drains along Island Club Road, which discharge to a stream network located south of Island Club Road within the Windsor Nature Park. **A1-W2:** Surface waterbody comprises a roadside drain parallel to the PIE, which drains either north into the MacRitchie Reservoir catchment area, or south into the Marina Reservoir catchment area.
Groundwater	Groundwater levels varied between 3 to 4 m bgl. Shallow groundwater levels (0 to 1 m bgl) are expected to occur in low lying wetland areas adjacent to streams and MacRitchie Reservoir. Site investigation data indicates limited hydraulic connectivity between surface waterbodies and groundwater within Bukit Timah granite bedrock.
Ambient Noise	**A1-W1:** Noise levels at the edge of the CCNR are due to vehicular noise along the PIE and are within the range of 60-63 dB(A) in the day, and around 55 dB(A) at night. **A1-W2:** Noise levels are due to vehicular traffic along Island Club Road, which closes at 7 pm. Levels are within the range of 60-65 dB(A) in the day, and 45-50 dB(A) in the night. Noise levels along the CCNR trails vary with human activity and can be as low as 45-50 dB(A) or as high as 60-70 dB(A).
Groundborne Noise & Vibration	Baseline vibration levels along the tunnel alignment are likely due to continuous contribution from vehicular traffic along PIE or Upper Thomson Road, and intermittent contribution from CCNR trail users. These were measured to be within the range of approximately 0.2 to 0.9 mm/s peak particle velocity.
Air Quality	Baseline sources of dust (PM_{10} or $PM_{2.5}$) are due to vehicular emissions along Upper Thomson Road and the PIE. Short-term measurements showed levels were within air quality targets.

Environmental Aspect	Activities / Sources of Impact
Ecology & Biodiversity	**Tunnel Alignment:** passes under the CCNR and within forest patches on either side of the CCNR, comprising Primary Forest, Regeneration Forest A, Wetland Marsh, Wetland Forest, Regeneration Forest B and Isolated Forest habitat types. Over 413 vascular plant species, 218 bird species, 30 mammal species, 56 reptile species, 17 amphibian species, 178 butterfly species, 82 odonate species and 24 freshwater fish species of conservation interest have been recorded within the Project Study Area, a majority of which were recorded within the CCNR. **A1-W1:** comprises habitat classified as Regeneration Forest A, where species of conservation interest such as the Raffles' Banded Langur, Sunda Pangolin and the Lesser Mousedeer have been observed. **A1-W2:** comprises habitat classified as Isolated Forest, due to the disconnection from the CCNR by the PIE, where species of conservation interest such as the Sunda Pangolin and the Malayan Colugo have been observed.

Figure 9 Location of Alignment Option 1 and Key Features /Worksites

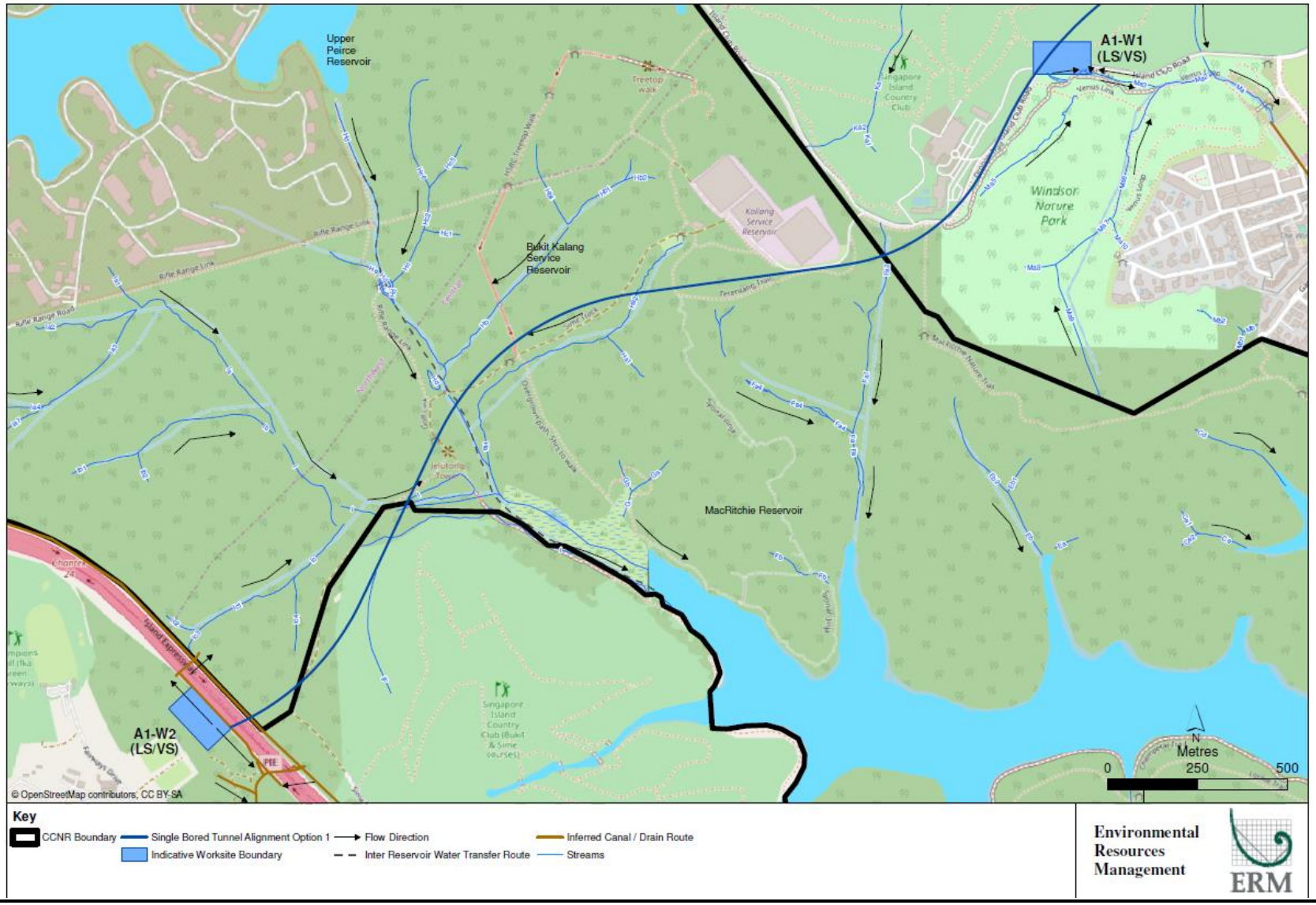


Figure 10 Aerial View of A1-W1 (LS/VS) Worksite

Photo 1 Street View of Existing Conditions at A1-W1 (LS/VS) Worksite (Vantage point indicated by arrow in Figure 10)

Figure 11 Aerial View of A1-W2 (LS/VS) Worksite

Photo 2 Street View of Existing Conditions at A1-W2 (LS/VS) Worksite (Vantage point indicated by arrow in Figure 11)

3.3 Sources of Impact

The EIA has assessed impacts associated with the both the construction and operation phases of Alignment Option 1.

The activities and sources of impact assessed for the construction phase are summarised in *Table 3*.

Table 3 Alignment Option 1, Construction Impact Sources

Environmental Aspect	Activities / Sources of Impact
Surface water & Groundwater	• Worksite clearance • Generation of liquid waste • Establishment of worksite • Underground construction • Operation of slurry type TBM • Discharge of firewater* • Accidental spillage/leakage of hazardous material* • Spillage/overflow of untreated effluents* • Slope failure* • Excessive ground settlement* • Excessive water ingress during tunnelling*
Ambient Noise	Construction activities at aboveground worksite
Groundborne Noise & Vibration	• Rock excavation • Piling • Tunnelling works
Air Quality	• Dust generation from earthworks • Movement of construction vehicles and equipment
Ecology & Biodiversity	• Loss of vegetation and habitat resources • Habitat fragmentation • Disturbance to wildlife (workers, dust settlement, noise, vibration and illumination) • Pollution of aquatic habitats • Injury/mortality from vehicle strike • Fire* • Spillage/overflow of untreated effluents* • Excessive ground settlement*
Visual	• Activities at aboveground worksites • Presence of workers
Tourism & Recreation	Temporal disruption or closure of recreational facilities
*Unplanned event	

The activities and sources of impact assessed for the operation phase are summarised in *Table 4*.

Table 4 Alignment Option 1, Operation Impact Sources

Environmental Aspect	Activities / Sources of Impact
Surface water & Groundwater	• Increase of surface runoff • Excessive groundwater seepage into tunnel* • Discharge of firewater* • Accidental spillage/leakage of hazardous material *
Ecology & Biodiversity	• Presence of facility building • Increase of surface runoff • Impact on habitat resources and/or fauna injury/mortality in the event of a fire*
*Unplanned event	

3.3 EIA Findings

The overall Phase 2 EIA findings for Alignment Option 1 are presented in the following subsections:

Construction Phase

- *Section 3.3.1* - Impacts to non-ecological receptors due to routine construction activities
- *Section 3.3.2* - Impacts to ecological receptors due to routine construction activities
- *Section 3.3.3* - Impacts to all receptors due to unplanned events during construction

Operation Phase

- *Section 3.3.4* - Impacts to all receptors due to routine operation activities
- *Section 3.3.5* - Impacts to all receptors due to unplanned events during operation

Summary for Alignment Option 1

- Impact pre-mitigation generally ranges from moderate to critical
- Impacts post-mitigation will be largely reduced to either minor or moderate
- Moderate indicates small effects that are around the existing conditions and /or accepted standards

- During construction works, pre-mitigation impacts to human receptors (noise, air, visual impacts) and ecological receptors (streams, forest habitat resources and wildlife species) were assessed to be of *Moderate* to *Critical* significance. Additional mitigation measures were identified, which reduced residual impact significance to *Moderate*. This is with the exception of streams located near A1-W1 and A1-W2 worksites, where sedimentation may result in *Critical* impact during the initial site clearance prior to set up of Earth Control Measures Systems. It is noted however that this assessment is conservative as sedimentation may only occur in the event of heavy rainfall, when ECM is being set up.
- The EIA also considered unplanned events during construction, and identified potential *Moderate* impacts that may arise in the unlikely event of a fire or an accidental spill / overflow of the Earth Control Measures System at the worksites, or excessive ground settlement during tunnelling. Embedded controls and additional mitigation measures have been identified to manage the risk of occurrence and impacts associated with unplanned events.
- During operation of the Facility Buildings, pre-mitigation impacts to wildlife species was assessed to be *Major*. Additional mitigation measures were identified to reduce disturbance impacts to wildlife due to the presence of the Facility Buildings to *Moderate*.
- The EIA also considered the unplanned event of a fire occurring during operation of the Facility Buildings, and identified *Moderate* impacts to surrounding streams, forest habitat resources and wildlife species. Embedded controls and engineering design of the Facility Building have been identified to manage the risk of a fire occurring, and to limit the impacts associated with fire response measures.
- In general, with the implementation of additional mitigation measures, the impacts associated with the construction and operation of the Project will be reduced to as low as reasonably practicable.

3.3.1 Construction Phase (Non-Ecological Receptors)

Pre-mitigation impact to water resources near Alignment Option 1 worksites due to construction activities, were assessed to be of *Major* significance. Pre-mitigation impacts due to air and visual impacts to human receptors near both worksites, as well as noise impact to residents at Windsor Park estate during night-time works at worksite A1-W1, were assessed to be of *Moderate* significance.

Mitigation measures, such as the diversion of water discharge points from the worksites to drains that are not connected to nearby stream systems, and the installation of visually compatible noise barriers, will be implemented to reduce impacts. These measures result in residual impacts being reduced to *Negligible* to *Minor* significance in the assessment.

The impact significance of construction activities were assessed, before and after mitigation measures are implemented i.e. pre-and post-mitigation. The post-mitigation impacts, i.e. after additional mitigation measures are introduced beyond the embedded controls, are referred to as Residual impacts. These are presented for each worksite and the general tunnel alignment for non-ecological resources in *Table 5* and *Table 6*.

For those impacts of *Moderate* or *Major* significance in *Table 5*, residual impacts have been summarised in *Table 6* taking into account the additional mitigation measures summarised in *Table 7*. *Table 6* shows that residual impacts to human receptors due to construction activities for Alignment Option 1 can all be reduced to *Minor* or *Negligible* significance, i.e. they can be managed to well within applicable standards.

Table 5 Alignment Option 1, Pre-Mitigation Impact Significance for Construction Activities (Non-Ecological Resources)

W1 A1-W1 worksite W2 A1-W2 worksite Tunnel alignment		Sensitivity / Vulnerability / Importance of Resource or Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible W1 Vibration W2 Noise / Vibration Groundwater	Negligible
	Small	Negligible	Minor W1 W2 Groundwater Vibration	Moderate
	Medium	Minor	Moderate W1 Noise / Air / Visual W2 Air / Visual	Major
	Large	Moderate	Major W1 W2 Surface water	Major

Table 6 Alignment Option 1, Residual Impact Significance for Construction Activities (Non-Ecological Resources)[Note 1]

W1 A1-W1 worksite W2 A1-W2 worksite Tunnel alignment		Sensitivity / Vulnerability / Importance of Resource or Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible W1 Surface water^ / Noise W2 Surface water^	Negligible
	Small	Negligible	Minor W1 W2 Air / Visual	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

Note 1: Pre-mitigation impacts of Negligible and Minor significance in Table 5 remain the same and are not included in Table 6.

^Residual impact to streams may remain Major *for up to the 1st month of construction. This is a conservative assessment to account for short-term sedimentation effects on streams when rainfall occurs during site clearance at aboveground worksites, prior to the complete set up of mitigation measures such as the Earth Control Measures system.*

Table 7 Alignment Option 1, Additional Mitigation Measures during Construction (Non-Ecological Resources)

Environmental Aspect	Implementation of Additional Mitigation Measure
Surface water	• Pre-mitigation impact on stream Ma was assessed to be *Major* due to sedimentation arising from soil erosion at the A1-W1 worksite. Hence, additional mitigation measures including phased site clearance and the diversion of Earth Control Measures System discharge outlets away from drains connected to stream Ma, have been adopted that brings down the residual impact significance to *Negligible*. • Pre-mitigation impact on stream IC was assessed to be *Major* due to sedimentation arising from soil erosion at the A1-W2 worksite. Hence, additional mitigation measures including phased site clearance and the diversion of Earth Control Measures System discharge outlets away from the northbound drain connected to stream IC, have been adopted that bring down the residual impact significance to *Negligible*.
Ambient Noise	• Pre-mitigation noise impact to residences in Windsor Park estate were assessed to be *Moderate* during night-time activities at the A1-W1 worksite. Hence, additional mitigation measures including the minimisation of vehicular movement and number of equipment operating in the night, and the erection of noise barriers, have been adopted that can bring down the residual impact significance to *Negligible*.
Air Quality	• Pre-mitigation impact to human receptors at the SICC Island Clubhouse and the Bukit Timah Saddle Club were assessed to be *Moderate* due to elevated dust from earthworks at the worksites. Hence, additional mitigation measures such as twice daily checks to ensure prompt clean up of earth spillage on haulage routes and continuous monitoring of dust levels, have been adopted to bring down residual impact significance to *Minor*.
Visual	• Pre-mitigation impact to the visual amenity of human receptors at the SICC Island golf course, the CCNR and Windsor Nature Park trails, and the Bukit Timah Saddle Club were assessed to be *Moderate* due to the presence of the worksites. Hence, additional mitigation measures have been adopted, including replanting of greenery around the worksite boundary and the use of non-reflective material for hoardings/noise barriers to increase visual compatibility of the worksite with the surroundings. The implementation of these mitigation measures will bring down the residual impact significance for both worksites to *Minor*.

3.3.2 Construction Phase (Ecological Receptors)

Pre-mitigation impacts to regeneration forest habitats and terrestrial/aquatic species at worksites A1-W1 and A1-W2, in particular those of conservation significance or interest, will range from *Minor* to *Major* significance due to worksite clearance and construction works at both worksites. Impact to a stream system within Windsor Nature Park near worksite A1-W1, and the MacRitchie catchment connected downstream of drains from worksite A1-W2, due to potential sedimentation during construction, has been assessed as *Critical*.

A range of mitigation measures will be implemented to reduce impacts during worksite clearance and construction works at both worksites e.g. wildlife shepherding and hoarding strategy during worksite clearance, installation of artificial crossing aids to reduce impact of habitat fragmentation etc. These measures result in residual impacts being reduced to *Moderate* significance to habitat resources and wildlife species at both worksites, which is deemed to be as low as reasonably practicable.

Residual impact to the stream system within Windsor Nature Park and catchment of MacRitchie Reservoir was reduced to *Negligible* through the diversion of discharge point to drains that are not connected to the stream systems. Similarly, the residual impact of vibration at the surface within the CCNR during tunnelling works can be reduced to *Negligible* through the monitoring, assessing and reviewing of vibration in advance of the TBM, so further mitigation measures can be implemented to reduce vibration levels to below the background levels within the CCNR.

The impact significance of routine construction activities were assessed, before and after mitigation measures are implemented i.e. pre-and post-mitigation. The post-mitigation impacts, i.e. after additional mitigation measures are introduced beyond the embedded controls, are referred to as Residual impacts. These are presented for each worksite and the general tunnel alignment for ecological resources in *Table 8* and *Table 9* respectively.

For those impacts of *Moderate* or *Major* significance in *Table 8*, residual impacts have been summarised in *Table 9* taking into account the additional mitigation measures summarised in *Table 10*. *Table 9* shows that residual impact magnitudes for ecological receptors can be reduced to *Medium* through the implementation of mitigation measures.

Table 8 Alignment Option 1, Pre-Mitigation Impact Significance for Construction Activities (Ecological Resources)

W1 A1-W1 worksite W2 A1-W2 worksite Tunnel alignment [S] – Species [H] Habitat		Sensitivity / Vulnerability / Importance of Ecological Resource or Receptor		
		Low	**Medium**	**High**
Magnitude of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Small	**Negligible**	**Minor** W1 [H] Habitat fragmentation W2 [H] Loss of habitat [H] Habitat fragmentation	**Moderate** W1 [S] Exacerbation of edge effects W2 [H][S] Exacerbation of edge effects [S] Habitat fragmentation [S] Disturbance to wildlife
	Medium	**Minor**	**Moderate** W1 [H] Loss of habitat	**Major** W1 [S] Loss of habitat [H] Exacerbation of edge effects [S] Habitat fragmentation [S] Disturbance to wildlife [S] Increased injury from vehicle strike W2 [S] Loss of habitat [S] Disturbance to wildlife [S] Increased injury from vehicle strike
	Large	**Moderate**	**Major**	**Major / Critical** W1 W2 [H][S] Pollution of aquatic habitat

Table 9 Alignment Option 1, Residual Impact Significance for Construction Activities (Ecological Resources) [Note 1]

W1 A1-W1 worksite W2 A1-W2 worksite Tunnel alignment [S] Species [H] Habitat		Sensitivity / Vulnerability / Importance of Ecological Resource or Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible W1 W2 [S][H] Pollution of aquatic habitat^ [S] Disturbance to wildlife
	Small	Negligible	Minor	Moderate* W1 W2 [S] Loss of habitat [H][S] Exacerbation of edge effects [S] Habitat fragmentation [S] Disturbance to wildlife [S] Increased injury from vehicle strike
	Medium	Minor	Moderate* W1 [H] Loss of habitat	Major
	Large	Moderate	Major	Major / Critical

Note 1: Pre-mitigation impacts of Negligible *and* Minor *significance in Table 8 remain the same and are not included in Table 9.*

^Residual impact to aquatic habitats may remain Critical *for up to the 1st month of construction. This is a conservative assessment to account for short-term sedimentation effects on streams when rainfall occurs during site clearance at aboveground worksites, prior to the complete set up of mitigation measures such as the Earth Control Measures System.*

**Residual impact assessment took into account the implementation of mitigation measures to reduce impacts to as low as reasonable practicable.*

Table 10 Alignment Option 1, Mitigation Measures during Construction (Ecological Resources)

Ecological Impact	Implementation of Mitigation Measure
Loss of habitat	• Pre-mitigation impact significance due to loss of vegetation and habitat resources from worksite clearance for establishment of the construction worksite, was assessed to be *Major* for species at both worksites, and Moderate for habitat at A1-W1 worksite. This would involve clearance of 1.5 ha of forested land, 1.2 ha of which would be replanted at the end of the construction period. Additional mitigation measures have been adopted, which would include surveys within the worksite to identify flora species of conservation interest for salvage, transplantation and/or relocation; and implementation of a wildlife shepherding, hoarding and tree felling strategy to minimise the risk of mortality / injury of species during worksite clearance. Implementation of these mitigation measures will reduce residual impact significance to *Moderate*. This potential loss of habitat at A1-W1 and A1-W2 worksites, originally a concern, has been addressed. A more detailed presentation of the assessment is appended in *Appendix 1.0* of this NTS (prepared by Anthony O'Dempsey LTA's Independent Reviewer for the Phase 2 EIA).
Exacerbation of edge effects	• Pre-mitigation impact significance due to exacerbation of edge effects at the fringes of Windsor Nature Park regeneration forest after worksite clearance at A1-W1 worksite, was assessed to be *Major*. Pre-mitigation impact significance to species at both worksites, and the isolated forest habitat at A1-W2 worksite was assessed to be *Moderate*. Additional mitigation measures have been adopted, which would include planting of worksite perimeter with shrubs and saplings of native species, and monthly monitoring of edge vegetation healthy by arborists. Implementation of these mitigation measures will reduce residual impact significance to *Moderate* at A1-W1 worksite.

Ecological Impact	Implementation of Mitigation Measure
Habitat fragmentation	• Pre-mitigation impact significance due to habitat fragmentation to species from worksite clearance and construction activities was assessed to be *Major* at A1-W1 worksite, and *Moderate* at A1-W2 worksite. Additional mitigation would include the installation of artificial crossing aids such as poles and rope bridges designed for arboreal species such as the Malayan Colugo and the Raffles' Banded Langur, and daily inspections of a wildlife passageway culvert across Island Club Road for A1-W1 worksite. Implementation of these mitigation measures will reduce residual impact significance to *Moderate*.
Disturbance to wildlife	• Pre-mitigation impact significance due to disturbance to wildlife from construction activities at both worksites was assessed to be *Major*. Additional mitigation measures have been adopted, which would include the avoidance of upward lighting to minimise illumination levels during night-time works at the worksite, and scheduling the change of shifts during sunrise and sunset so noise levels are reduced during periods dominated by fauna vocalisations. Implementation of these mitigation measures will reduce the residual impact significance to *Moderate*. • Pre-mitigation impact significance due to disturbance to wildlife from groundborne vibration from tunnelling works under the CCNR was assessed to be Moderate at shallower portions of the tunnel. Additional mitigation measures will include vibration monitoring in advance of the TBM to assess and review when vibration levels will exceed background levels, so as to inform the TBM operator of the need to implement controls such as slowing down the TBM cutterhead rotation in order to reduce vibration levels. Implementation of these mitigation measures will reduce the residual impact significance to *Negligible*. This is because the assessed vibration level, as a result of the mitigation measures, is lower than the ambient vibration level. The effect of vibration on ecological receptors within the CCNR during tunnelling, originally a concern, has been addressed. A more detailed presentation of the approach and assessment undertaken to address vibration effects for Alignment Option 1 is appended in *Appendix 1.0* of this NTS.
Increased injury from vehicle strike	• Pre-mitigation impact significance due to increased injury or mortality of wildlife from vehicle strikes from construction traffic associated with both worksites, was assessed to be *Major*. Additional mitigation measures include the enforcement of speed limits along Island Club Road and the design of site hoardings that take into account the local site context. Implementation of these mitigation measures will reduce the residual impact significance to *Moderate*.
Pollution of aquatic habitat	• Pre-mitigation impact significance due to increased sedimentation of stream Ma located downgradient of A1-W1 worksite, and stream IC near A1-W2 worksite, were assessed to be *Critical*. Additional mitigation measures include the prohibition of discharges from these worksites into drains connected to these streams, and regular inspections and monitoring to enforce this throughout the construction period. Implementation of these mitigation measures will remove the pathway between the worksite and the streams, and thereby reduce residual impact significance to *Negligible*. The potential impact to the natural stream system passing through the Windsor Nature Park and the MacRitchie catchment area, originally a concern, has been addressed. A more detailed presentation of the assessment for both the A1-W1 and A1-W2 worksites is appended in *Appendix 1.0* of this NTS.

3.3.3 Construction Phase (Unplanned Events)

Unplanned events are unintended occurrences. Those unplanned events with Moderate impacts are (a) fire, (b) excessive ground settlement during tunnelling, and (c) accidental spill or overflow of Earth Control Measures System at the A2-W2 worksite. Except for (c) which is *Possible*, these unplanned events are *Unlikely*. All other unplanned events are *Minor* in impact. Risks will be managed through the implementation of embedded controls such as enforcement of proper handling and management of flammable materials onsite, and monitoring of TBM operations. Response plans will also be in place to ensure impacts are minimized in extent should such unplanned events occur.

Unplanned events were also assessed for the construction phase. The findings are presented for each worksite and the general tunnel alignment in *Table 11*. These take into consideration the embedded controls that will be put in place to minimize the likelihood of these unplanned events occurring, and the response plans when such unplanned events should occur.

Table 11 Alignment Option 1, Impact Significance for Unplanned Events during Construction

Unplanned Event	Likelihood of Occurrence[Note 1]	A1-W1 (LS/VS)	A1-W2 (LS/VS)	Tunnel Alignment
Surface water				
Discharge of firewater	Unlikely	Negligible	Negligible	n/a
Accidental spillage/leakage of hazardous material	Possible	Minor	Minor	n/a
Spillage/ overflow of untreated effluents	Possible	Minor	Minor	n/a
Slope failure	Unlikely	n/a	n/a	Minor
Excessive ground settlement	Unlikely	n/a	n/a	Moderate
Groundwater				
Discharge of firewater	Unlikely	Negligible	Negligible	Negligible
Accidental spillage/leakage of hazardous material	Possible	Minor	Minor	Negligible
Slope failure	Unlikely	n/a	n/a	Minor
Excessive ground settlement	Unlikely	n/a	n/a	Moderate
Water drawdown during tunnelling	Unlikely	n/a	n/a	Negligible
Ecology & Biodiversity				
Excessive ground settlement	Unlikely	n/a	n/a	Moderate
Fire	Unlikely	Moderate	Moderate	n/a
Spillage/overflow of untreated effluent into surface waterbodies	Possible	Moderate	Moderate	n/a

Note 1: An example of how the likelihood of an unplanned event was designated, is the evaluation for likelihood of excessive ground settlement. From LTA's technical assessment as well as a review of historical tunnelling projects undertaken by the LTA in full face rock conditions (as in the case of Alignment Option 1), excessive ground settlement has not occurred. Taking into consideration the embedded controls that will be implemented during tunnelling works with strict operational management, the likelihood of excessive ground settlement occurring during tunnel was evaluated to be Unlikely.

Impact to habitat resources (including streams) and wildlife in the unlikely event of excessive ground settlement during tunnelling is assessed to be *Moderate*. Embedded engineering controls are in place to minimise the risk of excessive ground settlement occurring. Monitoring of the TBM will be undertaken during tunnelling to ensure prompt response at the onset of abnormal conditions, to ensure the extent of any ground settlement will be kept to a minimum.

The potential impacts to the CCNR associated with excessive ground settlement during tunnelling, originally a key concern, were addressed. A more detailed presentation of the assessment is appended in *Appendix 1.0* of this NTS.

The impact to water resources and habitat resources and wildlife in the unlikely event of a fire at the worksites during construction is assessed to be *Moderate*. Embedded engineering controls are in place such as enforcement of proper handling and management of flammable materials on site to ensure that the risks are managed, and the use of onsite sump to contain firewater for appropriate disposal to ensure that there are no discharges to nearby streams.

The impact to water resources such as streams located near the A1-W1 and A1-W2 worksites, in the event of a spill or the overflow of the Earth Control Measures System, is assessed to be *Moderate*. Embedded controls include the sizing of the Earth Control Measures System components e.g. perimeter drains, sedimentation pond etc with the capacity for exceptional rainfall events. As an additional mitigation measure, the discharge outlets of the Earth Control Measures System will be diverted so that these do not connect to streams within Windsor Nature Park or the MacRitchie Reservoir, throughout the construction period.

The stability of the slope where Alignment Option 1 crosses below the Sime Stream Valley, originally a concern, was addressed. A more detailed presentation of the assessment is appended in *Appendix 1.0* of this NTS.

3.3.4 Operation Phase

Pre-mitigation impacts were assessed to be *Minor* for surface waterbodies due to an increase in surface runoff from the Facility Buildings at both A1-W1 and A1-W2. Pre-mitigation impacts were assessed to be *Major* for wildlife species due to potential behavioural changes and risk of species being trapped within the Facility Buildings during operation.

Additional mitigation measures were implemented to manage the impacts to wildlife species. These include the sensitive design and location of facility buildings, and protocols for proper removal of any roosts found within the Facility Building premises. Residual impact to wildlife species due to the presence of Facility Buildings was therefore reduced to *Moderate* significance, which is as low as reasonably practicable.

The impact significance of sources of impacts during the operation phase were assessed, before and after mitigation measures are implemented i.e. pre-mitigation and post-mitigation (Residual). These are presented for each worksite and the general tunnel alignment in *Table 12* and *Table 13* respectively.

For those impacts of *Moderate* or *Major* significance in *Table 12*, residual impacts have been summarised in *Table 13* taking into account the additional mitigation measures summarised in *Table 14*. *Table 13* shows that residual impact magnitudes for receptors can be reduced to *Small* through the implementation of mitigation measures.

Table 12 Alignment Option 1, Pre-Mitigation Impact Significance for Operation Activities

W1 A1-W1 worksite W2 A1-W2 worksite Tunnel alignment E - Ecology [S] – Species [H] Habitat		Sensitivity / Vulnerability / Importance of Resource or Receptor		
		Low	**Medium**	**High**
Magnitude of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Small	**Negligible**	**Minor** W1 W2 Surface water	**Moderate** W1 E[S][H] Pollution of aquatic habitat
	Medium	**Minor**	**Moderate**	**Major** W1 W2 E[S] Disturbance due to presence of permanent structure
	Large	**Moderate**	**Major**	**Major**

Table 13 Alignment Option 1, Residual Impact Significance for Operation Activities[Note 1]

W1 A1-W1 worksite W2 A1-W2 worksite Tunnel alignment E - Ecology [S] – Species [H] Habitat		Sensitivity / Vulnerability / Importance of Resource or Receptor		
		Low	**Medium**	**High**
Magnitude of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Small	**Negligible**	**Minor**	**Moderate*** W1 E[S] Disturbance due to presence of permanent structure E[S][H] Pollution of aquatic habitat W2 E[S] Disturbance due to presence of permanent structure
	Medium	**Minor**	**Moderate**	**Major**
	Large	**Moderate**	**Major**	**Major**

Note 1: Pre-mitigation impacts of Negligible *and* Minor *significance in Table 12 remain the same and are not included in Table 13.*
**Residual impact assessment took into account the implementation of mitigation measures to reduce impacts to as low as reasonable practicable.*

Table 14 ***Alignment Option 1, Additional Mitigation Measures during Operation***

Environmental Aspect	Implementation of Additional Mitigation Measure
Ecology & Biodiversity	Pre-mitigation impact significance due to disturbance to species i.e. change of behaviour or entrapment during the operational lifespan of both Facility Buildings, was assessed to be *Major*. Additional mitigation measures include the adoption of natural materials and vertical greening to ensure the design of the facility building and security fences are wildlife friendly, and coordination with NParks for the safe removal of any roosts and nests identified during maintenance inspections. Implementation of these mitigation measures will reduce the residual impact significance to *Moderate*.

3.3.5 Operation Phase (Unplanned Events)

Unplanned events are unintended occurrences. The unplanned events with *Moderate* impacts are (a) discharge of firewater and (b) fire. Risks will be managed through the implementation of embedded controls. The Facility Buildings will be designed with fire detection and automatic response systems, and will be constructed with materials to maximize the containment of fire within the site. The site's detention tank will be designed to contain the firewater generated from a response to the fire, so that this can be collected for proper disposal offsite. This will reduce impacts to as low as reasonably practicable.

Unplanned events were assessed for the operation phase. The findings are presented for each worksite and the general tunnel alignment in *Table 15*. These take into consideration the embedded controls that will be put in place to minimize the likelihood of these unplanned events occurring, and the response plans when such unplanned events should occur.

Table 15 Alignment Option 1, Impact Significance for Unplanned Events during Operation Phase

Environmental Aspect	Likelihood of Occurrence	A1-W1 (LS/VS)	A1-W2 (LS/VS)	Tunnel Alignment
Surface water				
Discharge of firewater	Possible	Moderate	Moderate	n/a
Groundwater				
Accidental leakage/spillage of hazardous material	Possible	n/a	n/a	n/a
Discharge of firewater	Possible	n/a	n/a	n/a
Ecology & Biodiversity				
Fire	Possible	Moderate	Moderate	n/a

4. Alignment Option 2

4.1 Site Setting

As shown in *Figure 12*, the aboveground construction worksites for Alignment Option 2 would be located as follows:

- **A2-W1 (LS/VS):** vacant land located between Lakeview Estate and Upper Thomson Road (see *Figure 13* and *Photo 3*).
- **A2-W2 (LS/VS):** area located at the edge of Bukit Brown Cemetery along Lornie Road, comprising mature regeneration forest (see *Figure 14* and *Photo 4*).
- **A2-W3 (LS/VS):** edge of the area between Adam Drive and the Pan Island Expressway (PIE), comprising a mix of cleared grass land and a portion of mature regeneration forest (see *Figure 15* and *Photo 5*).

The receptors are residents near A2-W1, A2-W2 and A2-W3, visitors/recreation users of trails within Bukit Brown Cemetery, and fauna and flora within the forested area of A2-W2 and A2-W3.

4.2 Baseline Environment

The baseline environment around the Alignment Option 2 worksites and tunnel alignment are summarised in *Table 16*.

Table 16 Alignment Option 2, Summary of Baseline Environment

Environmental Aspect	Activities / Sources of Impact
Surface water	**A2-W1:** Worksite is surrounded by a series of urban surface drains/ roadside drains, which connect to the Upper Thomson Road canal that feeds into the Marina Reservoir. **A2-W2:** Worksite is bounded to the north by a surface drain along Lornie Road. The outfall location from this surface drain is inferred to be part of the central watershed within the Marina Reservoir catchment area. **A2-W3:** Several natural streams are located within the worksite. These feed into a concrete canal which flows out of the worksite to a roadside drain along the PIE, which is part of the Marina Reservoir catchment area.
Groundwater	Groundwater levels varied between 3 to 5 m bgl. Shallow groundwater levels (0 to 1 m bgl) are expected to occur in low lying wetland areas adjacent to Bukit Brown streams and MacRitchie Reservoir. Site investigation data indicates limited hydraulic connectivity between surface waterbodies and groundwater within Bukit Timah granite bedrock.
Ambient Noise	**A2-W1:** Noise levels along Upper Thomson Road are due to vehicular traffic and remain fairly constant at a range of 70-80 dB(A) throughout the day and night. **A2-W2:** Noise levels along Lornie Road and Thomson Road are due to vehicular traffic. Levels are around 70 dB(A) in the day, and up to 61 dB(A) in the night. **A2-W3:** Noise levels along Lornie are due to vehicular traffic and remain fairly constant at a range of 77-82 dB(A) during the day, and 71-73 dB(A) in the night.
Groundborne Noise & Vibration	Baseline vibration levels were measured along Upper Thomson Road and Lornie Road and are likely due to continuous contribution from vehicular traffic along these roads. These were measured to be within the range of approximately 0.5 to 0.9 mm/s peak particle velocity.
Air Quality	Baseline sources of dust (PM_{10} or $PM_{2.5}$) are due to vehicular emissions along Upper Thomson Road, Lornie Road and the PIE. Short-term measurements showed levels were generally within air quality targets.

Environmental Aspect	Activities / Sources of Impact
Ecology & Biodiversity	**Tunnel Alignment:** passes along the existing expressway and under various habitats including Regeneration Forest A, Recreational Facility, Isolated Forest and Developed Area habitats. **A2-W1:** comprises habitat categorized as Recreational Facility, which is an open green area west of Upper Thomson Road and is surrounded by developed areas ie residences and construction sites. The worksite is lined with a few mature *Samanea saman* trees, which may attract common urban wildlife species such as the Javan Myna, Yellow-vented Bulbul and Plaintain Squirrel. **A2-W2:** comprises habitat classified as Isolated Forest, due to the disconnection from the CCNR by Lornie Road. Worksite lies at the edge of the Bukit Brown Cemetery, which has been found to contain a good diversity of birds including forest-dependent species and nationally threatened species, such as the Black-Headed Bulbul, Thick-billed Green Pigeon and Chestnut-bellied Malkoha. The habitat has the potential of supporting other species of conservation significance such as the Sunda Pangolin which have been reported in the vicinity. The worksite lies in close proximity to tributaries to the Bukit Timah Stream, which connects to Mount Pleasant Stream and eventually into the Whampoa Canal. A total of 11 species of fish have been found in these streams, 4 of which are native. **A2-W3:** comprises habitat classified as Regeneration Forest A, and includes scrubland vegetation and large native trees. Based on sighting and roadkill records in the vicinity of Adam Drive, the Sunda Pangolin has been observed in this habitat. Based on anecdotal evidence, the habitat may also support other species of conservation significance such as the Slow Loris. Several natural streams are located within the worksite, which connect to a concrete canal flowing out to drains along the PIE. No aquatic species of conservation interest were observed at these streams.

Figure 12 Location of Alignment Option 2 and Key Features /Worksites

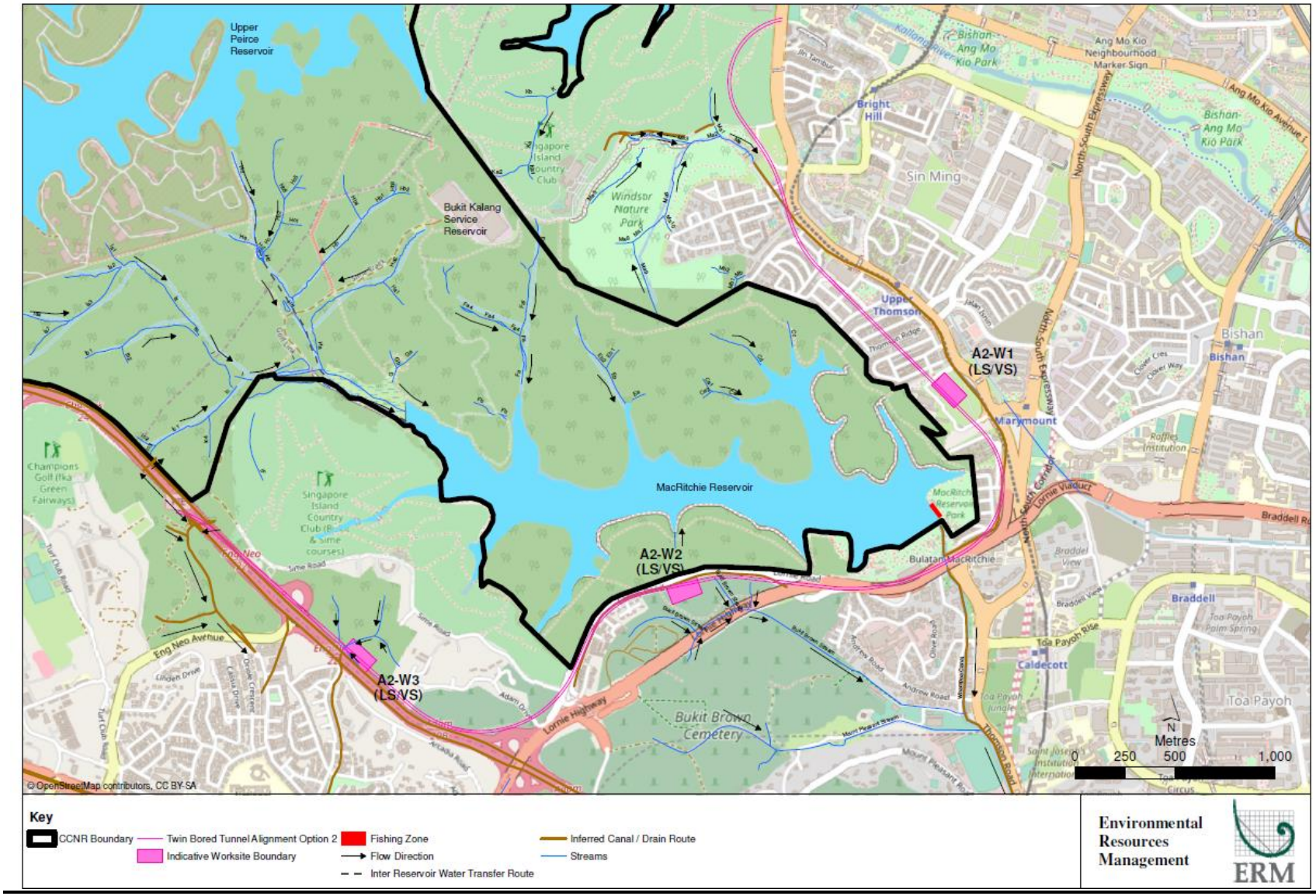


Figure 13 Aerial View of A2-W1 (LS/VS) Worksite

Photo 3 Street View of Existing Conditions at A2-W1 (LS/VS) Worksite (Vantage point indicated by arrow in Figure 13)

Figure 14 Aerial View of A2-W2 (LS/VS) Worksite

Photo 4 Street View of Existing Conditions at A2-W2 (LS/VS) Worksite (Vantage point indicated by arrow in Figure 14)

Figure 15 Aerial View of A2-W3 (LS/VS) Worksite

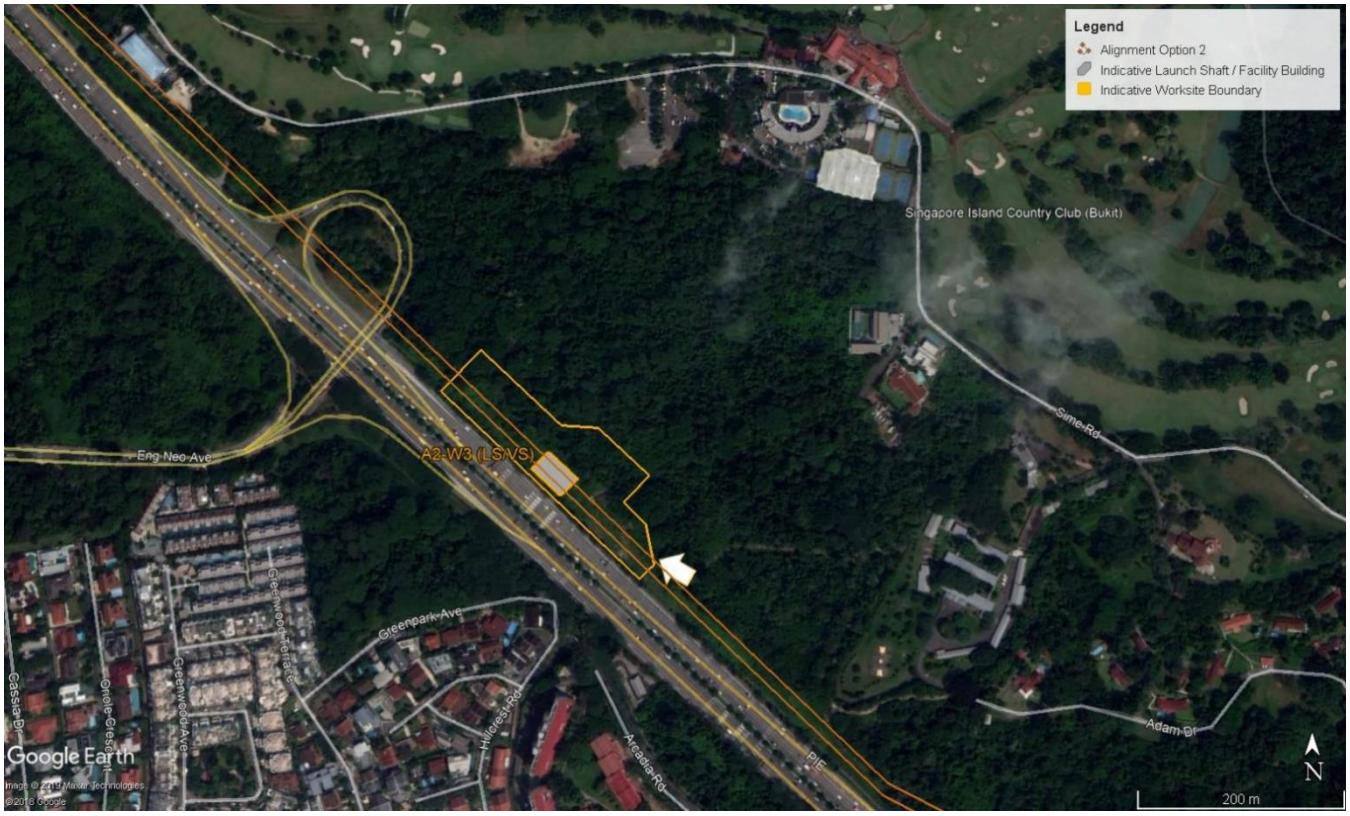


Photo 5 Street View of Existing Conditions at A2-W3 (LS/VS) Worksite (Vantage point indicated by arrow in Figure 15)

Source: Anthony O'Dempsey

4.3 Sources of Impact

The EIA has assessed impacts associated with both the construction and operation phases of Alignment Option 2.

The activities and sources of impact assessed for the construction phase are summarised in *Table 17*.

Table 17 Alignment Option 2, Construction Impact Sources

Environmental Aspect	Activities / Sources of Impact
Surface water & Groundwater	• Worksite clearance • Generation of liquid waste • Establishment of worksite • Underground construction • Operation of slurry type TBM • Discharge of firewater* • Accidental spillage/leakage of hazardous material* • Spillage/overflow of untreated effluents* • Excessive ground settlement* • Excessive water ingress during tunnelling*
Ambient Noise	Construction activities at aboveground worksite
Groundborne Noise & Vibration	• Rock excavation • Piling • Tunnelling works
Air Quality	• Dust generation from earthworks • Movement of construction vehicles and equipment
Ecology & Biodiversity	• Loss of vegetation and habitat resources • Habitat fragmentation • Disturbance to wildlife (workers, dust settlement, noise, vibration and illumination) • Injury/mortality from vehicle strike • Fire* • Spillage/overflow of untreated effluents* • Excessive ground settlement*
Visual	• Activities at aboveground worksites • Presence of workers
Cultural and Historical Heritage	• Worksite clearance within Bukit Brown Cemetery • Excessive ground settlement*
Tourism & Recreation	Temporal disruption or closure of recreational facilities
*Unplanned event	

The activities and sources of impact assessed for the operation phase are summarised in *Table 18*.

Table 18 Alignment Option 2, Operation Impact Sources

Environmental Aspect	Activities / Sources of Impact
Surface water & Groundwater	• Increase of surface runoff • Discharge of firewater* • Accidental spillage/leakage of hazardous material*
Ecology & Biodiversity	• Presence of facility building • Increase of surface runoff • Impact on habitat resources and/or fauna injury/mortality in the event of a fire*
*Unplanned event	

4.3 EIA Findings

The overall Phase 2 EIA findings for Alignment Option 2 are presented in the following subsections:

Construction Phase

- *Section 4.3.1* - Impacts to non-ecological receptors due to routine construction activities
- *Section 4.3.2* -Impacts to ecological receptors due to routine construction activities
- *Section 4.3.3* - Impacts to all receptors due to unplanned events during construction

Operation Phase

- *Section 4.3.4* - Impacts to all receptors due to routine operation activities
- *Section 4.3.5* - Impacts to all receptors due to unplanned events during operation

Summary for Alignment Option 2

- Impacts pre-mitigation generally range from moderate to critical
- Impacts post-mitigation will be largely reduced to either minor or moderate, with the exception of visual amenity at A2-W1 which remains at major
- Moderate indicates small effects that are around the existing conditions and/or accepted standards

- During construction works, pre-mitigation impacts to human receptors (noise, groundborne noise, vibration, air, visual impacts) and ecological receptors (forest habitat resources and wildlife species) were assessed to be of *Moderate* to *Major* significance. Additional mitigation measures were identified, which reduced residual impact significance to *Moderate*. This is with the exception of visual impacts for high-rise residents near A2-W1 (*Major*)
- The EIA also considered unplanned events during construction, and identified potential *Moderate* impacts that may arise in the unlikely event of a fire at the A2-W2 and A2-W3 worksites, or an accidental spill / overflow of the Earth Control Measures System at the A2-W2 worksite, or excessive ground settlement during tunnelling. Embedded controls and additional mitigation measures have been identified to manage the risk of occurrence and impacts associated with such unplanned events.
- During operation of the Facility Buildings at A2-W2 and A2-W3, pre-mitigation impacts to wildlife species was assessed to be *Major*. Additional mitigation measures were identified to reduce disturbance impacts to wildlife due to the presence of the Facility Buildings to *Moderate*.
- The EIA also considered the unplanned event of a fire occurring during operation of the Facility Buildings at A2-W2 and A2-W3, and identified *Moderate* impacts to surrounding forest habitat resources and wildlife species. Embedded controls and engineering design of the Facility Building have been identified to manage the risk of a fire occurring, and to limit the impacts associated with fire response measures.
- In general, with the implementation of additional mitigation measures, the impacts associated with the construction and operation of the Project will be reduced to as low as reasonably practicable.

4.3.1 Construction Phase (Non-Ecological Receptors)

Pre-mitigation, noise and visual impacts to residential receptors near A2-W2, and vibration impacts to residential receptors along shallower portions of the tunnel were assessed to be *Moderate*. Pre-mitigation impact to the fringe of Bukit Brown Cemetery, where the A2-W2 worksite is located, which is a cultural heritage resource, was also assessed to be *Moderate* due to worksite clearance at A2-W2 worksite. Pre-mitigation impacts due to increased dust around all worksites, visual impacts for high-rise residents near A2-W1, and increased noise levels during night-time works at the A2-W1 and A2-W3 worksites were assessed to be *Major*.

A range of mitigation measures will be implemented at all worksites e.g. installation of aesthetically compatible noise barriers, provision of advanced notification of tunnelling operations to affected receptors etc. This may result in a reduction of most residual impacts to *Moderate* significance. This is with the exception of high-rise residential receptors overlooking the A2-W1 worksite, where the residual impact magnitude can be reduced from *Large* to *Medium;* however, residual impact significance will remain as *Major*.

Similar to Alignment Option 1, the impact significance of normal construction activities were assessed, before and after mitigation measures are implemented i.e. pre-and post-mitigation. The post-mitigation impacts, i.e. after additional mitigation measures are introduced beyond the embedded controls, are referred to as Residual impacts. These are presented for each worksite and the general tunnel alignment for non-ecological resources in *Table 19* and *Table 20* respectively.

For those impacts of *Moderate* or *Major* significance in *Table 19*, residual impacts have been summarised in *Table 20* taking into account the additional mitigation measures summarised in *Table 21*. *Table 20* shows that residual impacts to human receptors due to construction activities for Alignment Option 1 can largely be reduced to *Moderate* significance, i.e. as low as reasonably practicable. This is with the exception of residual *Major* visual impacts to high-rise residential receptors overlooking the A2-W1 worksite.

Table 14 Alignment Option 2, Pre-Mitigation Impact Significance for Construction Activities (Non-Ecological Resources)

W1 A2-W1 worksite
W2 A2-W2 worksite
W3 A2-W3 worksite
Tunnel alignment

Magnitude of Impact	Sensitivity / Vulnerability / Importance of Resource or Receptor		
	Low	**Medium**	**High**
Negligible	**Negligible**	**Negligible** W1 Groundwater W2 W3 Vibration Groundwater	**Negligible**
Small	**Negligible**	**Minor** W1 Surface water / Vibration W2 W3 Surface water / Groundwater	**Moderate**
Medium	**Minor** W3 Visual	**Moderate** W2 Noise / Visual / Cultural heritage Vibration	**Major** W1 W2 W3 Air
Large	**Moderate**	**Major** W1 W3 Noise	**Major** W1 Visual

Table 19 Alignment Option 2, Residual Impact Significance for Construction Activities (Non-Ecological Resources)[Note 1]

W1 A2-W1 worksite
W2 A2-W2 worksite
W3 A2-W3 worksite
Tunnel alignment

Magnitude of Impact	Sensitivity / Vulnerability / Importance of Resource or Receptor		
	Low	**Medium**	**High**
Negligible	**Negligible**	**Negligible**	**Negligible**
Small	**Negligible**	**Minor** W2 Visual / Cultural heritage	**Moderate*** W1 W2 W3 Air
Medium	**Minor**	**Moderate*** W1 W2 W3 Noise Vibration	**Major** W1 Visual
Large	**Moderate**	**Major**	**Major**

Note 1: Pre-mitigation impacts of Negligible *and* Minor *significance in Table 19 remain the same and are not included in Table 20.*
**Residual impact assessment took into account the implementation of mitigation measures to reduce impacts to as low as reasonable practicable.*

Table 20 Alignment Option 2, Additional Mitigation Measures during Construction (Non-Ecological Resources)

Environmental Aspect	Implementation of Additional Mitigation Measure
Ambient Noise	• Pre-mitigation noise impact to nearby residences were assessed to be *Major* during night-time activities at the A2-W1 and A2-W3 worksites, and *Moderate* during night-time activities at A2-W2 worksite. Hence, additional mitigation measures have been adopted which include the minimisation of vehicular movement and number of equipment operating in the night, and the erection of noise barriers. Implementation of these additional mitigation measures will reduce the residual impact significance to *Moderate* i.e. as low as reasonably practicable.
Groundborne Noise and Vibration	• Pre-mitigation impacts to residents / pre-school attendees due to short-term groundborne noise during tunnelling works, were assessed to be *Moderate*. Additional mitigation measures will largely comprise vibration and groundborne noise monitoring at sensitive receptors, and provision of advanced notification when the TBM is scheduled to operate under and in close proximity to receptors. Stakeholder engagement will also be undertaken to explore the necessity and feasibility of temporary relocation of residents of dwellings where groundborne noise is predicted to exceed 40 dB(A), during operation of TBM. Implementation of these additional mitigation measures will reduce the residual impact significance to *Moderate* i.e. as low as reasonably practicable.
Air Quality	• Pre-mitigation impact to nearby residences were assessed to be *Major* due to elevated dust from earthworks at all the worksites. Hence, additional mitigation measures have been adopted which include stockpile management to minimise the quantity and duration of soil stored at the worksites, and twice daily checks to ensure prompt clean up of earth spillage on haulage routes and continuous monitoring of dust levels. Implementation of these additional mitigation measures will reduce the residual impact significance to *Moderate* i.e. as low as reasonably practicable.
Visual	• Pre-mitigation impact to the visual amenity of high-rise residents at Lakeview Estate was assessed to be *Major* due to the presence of the A2-W1 worksite. Hence, additional mitigation measures have been adopted, including erection of noise barriers at height to block the line of sight of residents and the design of these barriers to be as visually compatible to the surrounding environment as possible. The implementation of these mitigation measures will bring down the residual impact magnitude from Large to Medium, i.e. *Major* significance.
Cultural Heritage	• Pre-mitigation impact to a cultural heritage resource, Bukit Brown Cemetery, was assessed to be *Moderate* due to worksite clearance to establish the A2-W2 worksite. Hence, additional mitigation measures have been adopted, which include careful documentation of historical and genealogical information of all graves within the footprint of the A2-W2 worksite and within a 15 m buffer of the A2-W2 worksite and tunnel alignment. A separate study will also be carried out to estimate the number of graves that may be affected by the worksite layout, in the event that Alignment Option 2 is selected. Implementation of these additional mitigation measures will reduce the residual impact significance to *Minor*.

4.3.2 Construction Phase (Ecological Receptors)

Pre-mitigation impacts to forest habitats and wildlife species, in particular those of conservation significance or interest, will range from *Minor* to *Major* significance due to worksite clearance and construction works at A2-W2 and A2-W3 worksites. Pre-mitigation impacts to ecological receptors at the A2-W1 worksite is assessed to be *Negligible* due to the highly urbanised setting.

A range of mitigation measures will be implemented to reduce impacts during worksite clearance and construction works at both worksites e.g. wildlife shepherding and hoarding strategy during worksite clearance, enforcement of speed limits along access roads etc. The measures were assessed to reduce residual impacts to *Moderate* significance in relation to habitat resources and wildlife species at A2-W2 and A2-W3 worksites, which is deemed to be as low as reasonably practicable.

The impact significance during the construction phase were assessed before and after mitigation measures are implemented i.e. pre-mitigation and post-mitigation (Residual). These are presented for each worksite and the general tunnel alignment in *Table 21* and *Table 22* respectively.

For those impacts of *Moderate* or *Major* significance in *Table 21*, residual impacts have been summarised in *Table 22* taking into account the additional mitigation measures summarised in *Table 23*. *Table 22* shows that residual impact significance for receptors can be reduced to *Moderate* through the implementation of mitigation measures i.e. as low as reasonably practicable.

Table 21 Alignment Option 2, Pre-Mitigation Impact Significance for Construction Activities (Ecological Resources)

W1 A2-W1 worksite W2 A2-W2 worksite W3 A2-W3 worksite Tunnel alignment [S] – Species [H] Habitat	Sensitivity / Vulnerability / Importance of Ecological Resource or Receptor		
Magnitude of Impact	**Low**	**Medium**	**High**
Negligible	**Negligible**	**Negligible**	**Negligible**
Small	**Negligible** W1 [S][H] Loss of habitat [S][H] Exacerbation of edge effects [S] Disturbance to wildlife [S] Increased injury from vehicle strike	**Minor** W2 W3 [H] Habitat fragmentation W3 [H] Loss of habitat [H] Exacerbation of edge effects [S] Disturbance to wildlife	**Moderate** W2 [H] Exacerbation of edge effects W2 W3 [S] Exacerbation of edge effects [S] Habitat fragmentation
Medium	**Minor** W3 [S][H] Pollution of aquatic habitat	**Moderate** W2 [H] Loss of habitat	**Major** W2 W3 [S] Loss of habitat [S] Disturbance to wildlife [S] Increased injury from vehicle strike
Large	**Moderate**	**Major**	**Major / Critical**

Table 22 Alignment Option 2, Residual Impact Significance for Construction Activities (Ecological Resources) *[Note 1]*

W1 A2-W1 worksite W2 A2-W2 worksite W3 A2-W3 worksite Tunnel alignment [S] Species [H] Habitat	Sensitivity / Vulnerability / Importance of Ecological Resource or Receptor		
Magnitude of Impact	**Low**	**Medium**	**High**
Negligible	**Negligible**	**Negligible**	**Negligible**
Small	**Negligible**	**Minor**	**Moderate*** W2 [H] Exacerbation of edge effects W2 W3 [S] Exacerbation of edge effects [S] Loss of habitat [S] Habitat fragmentation [S] Disturbance to wildlife [S] Increased injury from vehicle strike
Medium	**Minor**	**Moderate*** W2 [H] Loss of habitat	**Major**
Large	**Moderate**	**Major**	**Major / Critical**

Note 1: Pre-mitigation impacts of Negligible and Minor significance in Table 21 remain the same and are not included in Table 22.
**Residual impact assessment took into account the implementation of mitigation measures to reduce impacts to as low as reasonable practicable.*

Table 23 Alignment Option 2, Mitigation Measures during Construction (Ecological Resources)[Note 1]

Ecological Impact	Implementation of Mitigation Measure
Loss of habitat	• Pre-mitigation impact significance due to loss of vegetation and habitat resources from worksite clearance for establishment of the construction worksite, was assessed to be *Major* for species at A2-W2 and A2-W3 worksites, and Moderate for habitat at A2-W2 worksite. This would involve clearance of 1.5 ha of forested land, 1.2 ha of which would be replanted at the end of the construction period. Hence, additional mitigation measures have been adopted, which would include surveys within the worksite to identify flora species of conservation interest for salvage, transplantation and/or relocation; and implementation of a wildlife shepherding, hoarding and tree felling strategy to minimise the risk of mortality / injury of species during worksite clearance. Implementation of these mitigation measures will reduce residual impact significance to *Moderate* i.e. as low as reasonably practicable.
Exacerbation of edge effects	• Pre-mitigation impact significance due to exacerbation of edge effects was assessed to be *Moderate* for the Primary and Regeneration Forest A habitats at the fringes of CCNR north of Lornie Road and the A2-W2 worksite, and wildlife species around the A2-W2 and A2-W3 worksites. Additional mitigation measures have been adopted, which would include planting of worksite perimeter with shrubs and saplings of native species, and monthly monitoring of edge vegetation health by arborists. Implementation of these mitigation measures will result in a *Moderate* residual impact significance at A2-W2 and A2-W3 worksites i.e. as low as reasonably practicable.
Disturbance to wildlife	• Pre-mitigation impact significance due to disturbance to wildlife from construction activities at A2-W2 and A2-W3 worksites was assessed to be *Major*. Additional mitigation measures have been adopted, which would include the avoidance of upward lighting to minimise illumination levels during night-time works at the worksite, and scheduling the change of shifts during sunrise and sunset so noise levels are reduced during periods dominated by fauna vocalisations. Implementation of these mitigation measures will reduce the residual impact significance to *Moderate*.
Increased injury from vehicle strike	• Pre-mitigation impact significance due to increased injury or mortality of wildlife as a result of construction traffic associated with A2-W2 and A2-W3 worksites, was assessed to be *Major*. Additional mitigation measures include the enforcement of speed limits along access roads to the worksites and the design of site hoardings that take into account the local site context. Implementation of these mitigation measures will reduce the residual impact significance to *Moderate*.

Note 1: No additional mitigation measures were identified although pre-mitigation impact of habitat fragmentation due to worksite clearance at A2-W2 and A2-W3 worksites was assessed to be Moderate*. This is because the siting and configuration of the A2-W2 and A2-W3 worksites at the fringes of the forested habitats was designed to minimize impact magnitude to Small, which is as low as reasonably practicable.*

4.3.3 Construction Phase (Unplanned Events)

Unplanned events are unintended occurrences. Those unplanned events with *Moderate* impacts are (a) fire, (b) excessive ground settlement during tunnelling, and (c) accidental spill or overflow of Earth Control Measures System at the A2-W2 worksite. Except for (c) which is *Possible*, these unplanned events are *Unlikely*. All other unplanned events are *Minor* in impact. Risks will be managed through the implementation of embedded controls such as enforcement of proper handling and management of flammable materials onsite, and adequate sizing of the Earth Control Measures System with the capacity to cope in exceptional rainfall events. Response plans will also be in place to ensure impacts are minimized in extent should such unplanned events occur.

Unplanned events were assessed for the construction phase. The findings are presented for each worksite and the general tunnel alignment in *Table 24*. These take into consideration the controls that will be put in place to minimize the likelihood of these unplanned events occurring, and the response plans when such unplanned events should occur.

Table 24 Alignment Option 2, Impact Significance for Unplanned Events during Construction

Unplanned Event	Likelihood of Occurrence [Note 1]	A2-W1 (LS/VS)	A2-W2 (LS/VS)	A2-W3 (LS/VS)	Tunnel Alignment
Surface Water					
Accidental leakage/spillage of hazardous material	Possible	Minor	Minor	Minor	n/a
Discharge of firewater	Unlikely	Minor	Minor	Minor	n/a
Spillage/overflow of effluents	Possible	Minor	Minor	Minor	n/a
Excessive ground settlement	Unlikely	n/a	n/a	n/a	Moderate
Groundwater					
Excessive water ingress during tunneling	Unlikely	n/a	n/a	n/a	Negligible
Excessive ground settlement	Unlikely	n/a	n/a	n/a	Moderate
Discharge of firewater	Unlikely	Negligible	Minor	Minor	Negligible
Accidental spillage/leakage of hazardous material	Possible	Negligible	Minor	Minor	Negligible
Ecology & Biodiversity					
Excessive ground settlement	Unlikely	n/a	n/a	n/a	Moderate
Fire	Unlikely	Minor	Moderate	Moderate	n/a
Spillage/overflow of untreated effluent into surface waterbodies	Possible	n/a	Moderate	Negligible	n/a
Cultural and Historical Heritage					
Excessive ground settlement	Unlikely	n/a	Minor	n/a	Minor

Note 1: An example of how the likelihood of an unplanned event was designated, is the evaluation for likelihood of excessive ground settlement. Alignment Option 2 may involve tunnelling under a mix of soil and rock conditions at localised areas. From LTA's technical assessment as well as a review of historical tunnelling projects undertaken by the LTA, the likelihood of excessive ground settlement is evaluated to be Unlikely *so long as embedded controls are implemented during tunnelling works with strict operational management.*

Impacts to habitat resources (including streams) and wildlife in the unlikely event of excessive ground settlement during tunnelling were assessed to be *Moderate*. Embedded engineering controls are in place to minimise the risk of excessive ground settlement occurring. Monitoring of the TBM will be undertaken during tunnelling to ensure prompt response at the onset of abnormal conditions and to ensure the extent of any ground settlement will be kept to a minimum.

The impact to forest habitat resources and wildlife in the unlikely event of a fire at the worksites during construction was assessed to be *Moderate*. Embedded engineering controls will be in place including enforcement of proper handling and management of flammable materials on site to ensure that the risks are managed.

The impact to Bukit Brown stream located downgradient of the A2-W2 worksite, in the event of a spill or the overflow of the Earth Control Measures System, was assessed to be *Moderate*. Embedded controls include the sizing of the Earth Control Measures System components e.g. perimeter drains, sedimentation pond etc with the capacity to handle exceptional rainfall events.

4.3.4 Operation Phase

Pre-mitigation impacts were assessed to be *Negligible* to *Minor* for water resources due to an increase in surface runoff from all Facility Buildings. Pre-mitigation impacts were assessed to be *Major* for wildlife species due to potential behavioural changes and risk of species being trapped within the Facility Buildings at A2-W2 and A2-W3 during operation.

Additional mitigation measures were implemented to manage the impacts to wildlife species. These include the sensitive design and location of facility buildings, and protocols for proper removal of any roosts found within the Facility Building premises. Residual impact to wildlife species due to the presence of Facility Buildings at A2-W2 and A2-W3 was therefore reduced to *Moderate* significance, which is as low as reasonably practicable.

The impact significance of sources of impacts during the operation phase were assessed, before and after mitigation measures are implemented i.e. pre-mitigation and post-mitigation (Residual). These are presented for each worksite and the general tunnel alignment in *Table 25* and *Table 26* respectively.

For those impacts of *Major* significance in *Table 25*, residual impacts have been summarised in *Table 26* taking into account the additional mitigation measures summarised in *Table 27*. *Table 26* shows that residual impact magnitudes for receptors can be reduced to *Small* through the implementation of mitigation measures.

Table 25 Alignment Option 2, Pre-Mitigation Impact Significance for Operation Activities

W1 A2-W1 worksite W2 A2-W2 worksite W3 A2-W3 worksite Tunnel alignment E - Ecology [S] – Species [H] Habitat		Sensitivity / Vulnerability / Importance of Resource or Receptor		
		Low	**Medium**	**High**
Magnitude of Impact	**Negligible**	**Negligible**	**Negligible** W1 Groundwater	**Negligible**
	Small	**Negligible** W2 E[S][H] Change in hydrology	**Minor** W1 W2 W3 Surface water W2 W3 Groundwater	**Moderate**
	Medium	**Minor** W1 E[S] Disturbance due to presence of permanent structure	**Moderate**	**Major** W2 W3 E[S] Disturbance due to presence of permanent structure
	Large	**Moderate**	**Major**	**Major**

Table 26 Alignment Option 2, Residual Impact Significance for Operation Activities[Note 1]

W1 A2-W1 worksite W2 A2-W2 worksite W3 A2-W3 worksite Tunnel alignment E - Ecology [S] Species [H] Habitat		Sensitivity / Vulnerability / Importance of Resource or Receptor		
		Low	**Medium**	**High**
Magnitude of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Small	**Negligible**	**Minor**	**Moderate** W2 W3 E[S] Disturbance due to presence of permanent structure
	Medium	**Minor**	**Moderate**	**Major**
	Large	**Moderate**	**Major**	**Major**

Note 1: Pre-mitigation impacts of Negligible *and* Minor *significance in Table 25 remain the same and are not included in Table 26.*

Table 27 Alignment Option 2, Additional Mitigation Measures during Operation

Environmental Aspect	Implementation of Additional Mitigation Measure
Ecology & Biodiversity	Pre-mitigation impact significance due to disturbance to species i.e. change of behaviour or entrapment during the operational lifespan of Facility Buildings at A2-W2 and A2-W3, was assessed to be *Major*. Additional mitigation measures include the adoption of natural materials and vertical greening to ensure the design of the facility building and security fences are wildlife friendly, and coordination with NParks for the safe removal of any roosts and nests identified during maintenance inspections. Implementation of these mitigation measures will reduce the residual impact significance to *Moderate*.

4.3.5 Operation Phase (Unplanned Events)

Unplanned events are unintended occurrences. The unplanned event with Moderate impact is fire. Risks will be managed through the implementation of embedded controls. The Facility Buildings will be designed with fire detection and automatic response systems, and will be constructed with materials to maximize the containment of fire within the site. This will reduce impacts to as low as reasonably practicable.

Unplanned events were assessed for the operation phase. The findings are presented for each worksite and the general tunnel alignment in *Table 28*. These take into consideration the controls that will be put in place to minimize the likelihood of these unplanned events occurring, and the response plans when such unplanned events should occur.

Table 28 Alignment Option 2, Impact Significance for Unplanned Events during Operation Phase

Environmental Aspect	Likelihood of Occurrence	A2-W1 (LS/VS)	A2-W2 (LS/VS)	A2-W3 (LS/VS)	Tunnel Alignment
Surface water					
Discharge of firewater	Possible	Minor	Minor	Minor	n/a
Groundwater					
Accidental leakage/spillage of hazardous material	Possible	n/a	n/a	n/a	n/a
Discharge of firewater	Possible	n/a	n/a	n/a	n/a
Ecology & Biodiversity					
Fire	Possible	Negligible	Moderate	Moderate	n/a

5. Environmental Management & Monitoring Plan (EMMP)

5.1 Overview

The EMMP will be conducted for the selected alignment, whether Alignment Options 1 or 2.

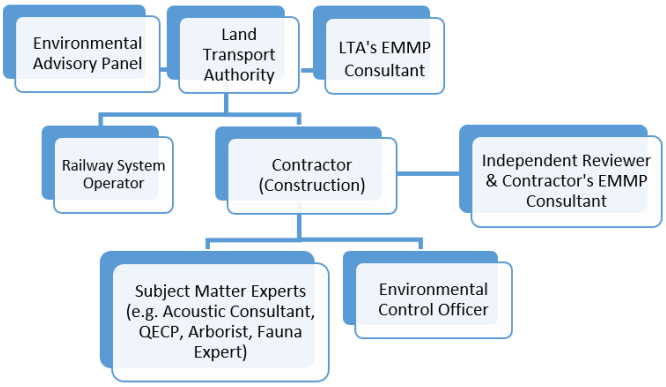
As a result of the EIA, the Project has identified and committed itself to a number of environmental measures designed to mitigate identified adverse impacts. These are compiled in the EMMP presented in ***Volumes III*** **and** ***IV*** of the Phase 2 EIA. Responsibilities for implementing these measures and the means to verify that measures are implemented, are also detailed in the EMMP.

LTA will assume overall accountability for the environmental performance and regulatory compliance of the Project during the construction works. In line with this, the LTA will undertake routine audits of the worksites to verify that the Contractors are implementing the mitigation measures outlined in the EMMP as well as statutory requirements and other LTA requirements.

5.2 Key Management Measures

The LTA will oversee and audit the contractor(s) for the construction and operation phase of the Project. Expertise will be contracted to support the implementation of the EMMP, as shown in *Figure 16*.

Figure 16 Organisation Structure for Management of Project



LTA will set up an independent Environmental Advisory Panel (EAP) comprising external subject matter experts to provide the LTA with a forum for discussion and guidance on decision-making in relation to the overall environmental management of the Project.

5.3 Key Mitigation Measures

Mitigation measures were identified through consultation with the Project planning and engineering design team, as well as stakeholders, to ensure that these measures can be undertaken. Key mitigation measures are summarized below.

5.3.1 General

Key mitigations measures applicable for either Alignment Option 1 or 2:

- A 30m buffer for worksites that are in areas with connectivity to natural streams will be established.
- The EMMP will be further reviewed during the AES stage of the Project when the detailed design of the Project is developed, and include measures related to the protection of fauna and flora during the construction.
- Dedicated LTA staff with the guidance of an independent EAP will be available to oversee all environmental aspects of the construction including review and enhancement of the EMMP.
- As part of the EMMP, wildlife shepherding will be undertaken along with the hoarding and a tree felling strategy during clearance at the worksites.
- Specialists will be engaged to conduct tree inspections for any trees scheduled for tree felling/transplantation.
- Contractors will undergo biodiversity awareness training on how to manage wildlife encounters. Contractors will be strictly prohibited from handling/touching any wildlife encountered, including forcing movement of wildlife away from the work areas. In the event that wildlife are encountered and do not move away from the transportation route or worksite, Contractors will notify NParks and await further instructions.

- Native species will be replanted upon the completion of construction works.
- Planning to ensure that noisy works such as site clearance, construction of launch shaft and facility buildings are undertaken in the daytime as far as possible.
- Worksite lighting to be directed within the worksite to prevent light spillage.
- Noise barriers will be erected at the worksites to manage noise emissions.
- Management of vibrations from construction through the use of a new TBM, close monitoring of tunnel boring machine operating parameters and timely engagement of nearby stakeholders.
- Perform continuous monitoring of PM_{10} (particulate matter in air) upwind and downwind of the worksites.
- Use water suppression during excavation and earth handling at exposed areas under dry weather to reduce the emissions of dust.
- A feedback procedure will be established to log and ensure timely responses to concerned raised by stakeholders.

5.3.1 Alignment Option 1

Additional key mitigation measures specific to this alignment if chosen:

- Onsite treatment of wastewater and the subsequent offsite discharge to a nearby surface drain will be strictly prohibited at A1-W1. This is to avoid the potential for wastewater to enter into the adjacent natural stream. Instead, wastewater will be stored in tanks for offsite disposal by contractors.
- Monthly water sampling of the stream within Windsor Nature Park to ensure no accidental spills or leaks from worksite A1-W1.
- Routine water monitoring throughout the construction phase to demonstrate that the Earth Control Measures system is ensuring compliance against relevant limits for discharge to surface drains.

  Vibration to be monitored at selected locations on the ground surface in advance of the tunnel boring machine (TBM). Vibration to be forecasted and reported to the TBM operator so further mitigation measures can be implemented to ensure vibration at ground surface remain below background levels within CCNR.

5.3.2 Alignment Option 2

Additional key mitigation measure specific to this alignment if chosen:

- Undertake documentation of historical and genealogical information of all graves both within the worksite/tunnel footprint and within a 15 m buffer of the A2-W2 worksite and tunnel.

Further details of all mitigation measures for both alignments can be found in ***Volumes III and IV*** of the EIA Report.

6. Conclusion

6.1 Overview

The Phase 2 EIA has been undertaken following a systematic and rigorous process and in accordance with international guidelines, for the two underground Alignment Options:

- **Underground Alignment Option 1:** for the CRL option passing under the CCNR
- **Underground Alignment Option 2:** for the CRL option skirting around the CCNR.

The EIA includes an addendum to the baseline study undertaken in 2014 and 2015 for the Project. This addendum comprises an updated site setting as of 2019, and summarises the geology and groundwater-related results from historical SI works and SI works completed in or near the CCNR during Phase 1 of the Project.

Where there are limited baseline data or relevant standards / guidelines, the Precautionary Principle and professional judgement have been adopted for the impact assessment.

The impact assessment took into account engineering design considerations and controls embedded in the Project design. Where potential impacts are Moderate, Major or Critical, mitigation measures have been identified for the management of the identified impacts to as low as reasonably practicable (ALARP). These measures have been consolidated in an Environmental Management and Monitoring Plan (EMMP), which will define responsibilities for implementation and monitoring during the construction phase.

After implementation of the mitigation measures as described above, the potential impacts associated with the site construction works for Alignment Options 1 and 2 are expected to be reduced. Residual impacts (i.e. after mitigation) which have been assessed to be potentially of *Moderate* or *Major* significance, are as follows:

6.2 Alignment Option 1

No residual impacts associated with Alignment Option 1 were identified as having *Major* significance. The following residual impacts were considered to be potentially of *Moderate* significance due to construction activities at worksites A1-W1 and A1-W2 located outside the CCNR:

- Loss of vegetation and habitat resources;
- Exacerbation of edge effects;
- Habitat fragmentation;
- Disturbance to wildlife (workers, dust settlement, noise, vibration and illumination); and
- Injury/mortality of wildlife from vehicle strike due to increase in vehicle movement.

The impact significance of the following unplanned events during Project construction is assessed to be *Moderate*:

- Excessive ground settlement at worksites A1-W1, A1-W2 or along the tunnel alignment;
- Fire at worksites A1-W1 and A1-W2; and
- Spillage/overflow of untreated effluent into surface waterbodies downgradient of worksite A1-W1.

Residual impact during the Project operation phase was considered to be potentially of *Moderate* significance due to the presence of the facility buildings at A1-W1 and A1-W2, and increased surface runoff from the facility building premise to the stream system in Windsor Nature Park located downgradient of A1-W1.

The impact on habitat resources and/or fauna injury/mortality in the event of a fire at the facility buildings located outside the CCNR is assessed to be of *Moderate* significance.

6. Conclusion

6.3 Alignment Option 2

Major residual impact was assessed to visual amenity for high-rise residents due to the presence of worksite A2-W1.

The following residual impacts were considered to be potentially of *Moderate* significance due to construction activities:

- Disturbance effects due to noise at all aboveground worksites;
- Short-term disturbance to residents / pre-school attendees due to groundborne noise along the tunnel alignment; and
- Disturbance and/or health effects from dust generation associated with earthworks and movement of construction vehicles and equipment at all worksites.

The following residual impacts were considered to be potentially of *Moderate* significance due to construction activities at worksites A2-W2 and A2-W3:

- Loss of vegetation and habitat resources;
- Exacerbation of edge effects;
- Habitat fragmentation;
- Disturbance to wildlife (workers, dust settlement, noise, vibration and illumination); and
- Injury/mortality of wildlife from vehicle strike due to increase in vehicle movement.

The impact significance of the following unplanned events during Project construction is assessed to be *Moderate*:

- Excessive ground settlement along the tunnel alignment;
- Fire at worksites A2-W2 and A2-W3; and
- Spillage/overflow of untreated effluent into surface waterbodies downgradient of worksite A2-W2.

Residual impact during the Project operation phase was considered to be potentially of Moderate significance due to the presence of the facility buildings at A2-W2 and A2-W3. The impact on habitat resources and/or fauna injury/mortality in the event of a fire at the facility buildings at A2-W2 and A2-W3 is assessed to be of Moderate significance.

6.4 Next Steps

The Phase 2 EIA report (also referred to as the C&O EIA) provides an overview of the site settings for both alignment options, and the findings of the EIA for the C&O activities and the mitigation measures required to manage these impacts. These EIA findings presented herein will support decision-making on the final alignment of the CRL. The decision on the final alignment will take into account factors such as connectivity, travel times, costs, as well as impact on home owners and the environment.

Further baseline surveys will be undertaken at the worksites for both alignments during the AES stage of the Project. The baseline surveys associated with the AES stage of the Project are not anticipated to significantly change the findings within this Phase 2 EIA apart from additional refinements to the mitigation measures and monitoring plans.

Appendix 1.0 Non-Technical Summary
(Anthony O'Dempsey, LTA Independent Reviewer of the Phase 2 EIA)

ADDRESSING KEY BIODIVERSITY CONCERNS FOR CROSS ISLAND LINE

The Cross Island Line Phase 2 Environmental Impact Assessment (EIA) provides environmental assessments for the construction and operation of two alignment options – Alignment Option 1 and Alignment Option 2 as illustrated in Figure 1 below. This document provides a summary of the key concerns to ecological receptors and significant mitigation measures discussed in the EIA.

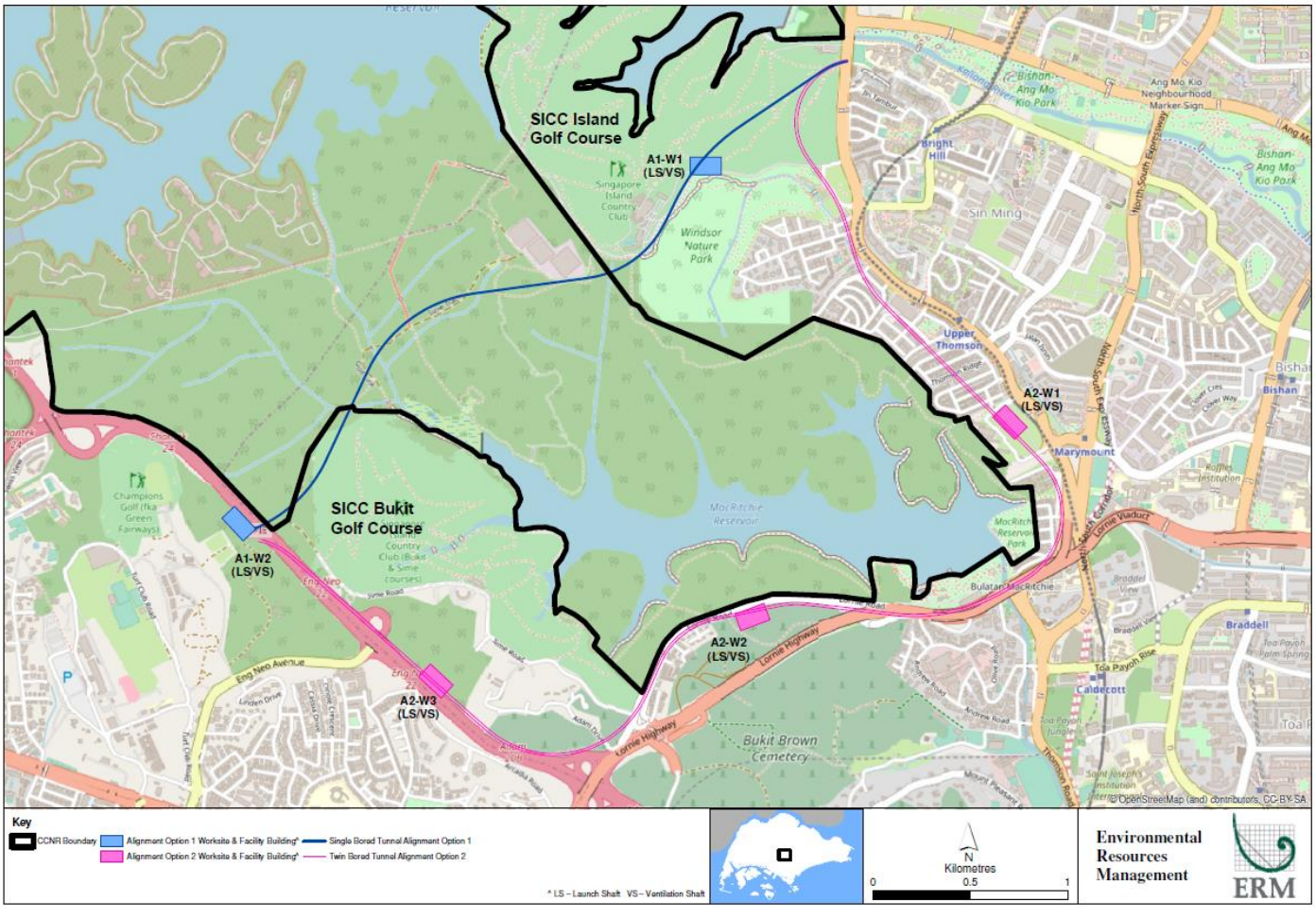


Figure 1: Overview of CRL Underground Alignment Options 1 & 2.

Key Concerns for Alignment Option 1

The key concerns for ecological receptors due to Alignment Option 1 include the impacts during worksite construction and operation as well as tunnelling operations beneath the CCNR. Both worksites are situated on land zoned as Residential in the current URA Master Plan 2014; though they are currently within undeveloped forested areas adjacent to, or in close proximity to designated nature areas. Worksite A1-W1 is fully within the catchment of a natural stream system passing through Windsor Nature Park while A1-W2 is partially within the catchment of a natural stream system passing through the CCNR. Both worksites are nominally 1.5 hectares in size.

Habitat Loss Due to Site Clearing at A1-W1

The forested area adjacent to Windsor Nature Park not only provides extended foraging space and shelter for native fauna originating from within the Windsor Nature Park, it also forms part of the connectivity pathway between the northern and southern sections of the CCNR. It is through this area that the Raffles Banded Langur is thought to have recently established residence within the southern MacRitchie forests of the CCNR. This forested area is also part of a known habitat for fauna of conservation significance including the Sunda Pangolin, Lesser Mouse Deer, Malayan Colugo and Horsfields Flying Squirrel.

The A1-W1 worksite once cleared would represent up to 15% of the 10 hectare forested area adjacent to Windsor Nature Park and in an area where the forest edges on either side of Island Club road are in close proximity, as such this area represents a useful, though not the only, road crossing opportunity for fauna.

Mitigation measures prescribed to minimise impacts due to forest clearing include the following:

Minimise Worksite Footprint	While nominally 1.5 hectares in size, this worksite will be reduced in size, where practicable, by moving non-worksite-essential equipment, material storage and site-office to suitable nearby locations that are less impactful to the habitat. The trade-off to this approach is higher heavy vehicle traffic on Island Club Road due to the need to move resources between the alternate storage facilities and the worksite as well as costs due to loss of efficiency in the operation. The objective of space reduction is to keep the eastern boundary of the worksite as far as practicable to the western extent of the forested area and to minimise road frontage as much as possible. The space reduction will facilitate the continued ability of fauna to move between the forested area and the Windsor Nature Park. The specific details of space allocation and availability of alternative auxiliary sites will fall into the scope of the Advanced Engineering Study.
Wildlife Shepherding	At the time of clearing, professional fauna consultants will be engaged to shepherd fauna away from the affected area. The fauna consultant will also be called upon provide a fauna management plan which will include a specification for location/extent of hoarding required for the worksite.
Recovery of flora	Flora species of conservation significance that are suited to transplantation will be recovered from the worksite.
Replanting of affected area	At the end of the project, the affected area will be reforested with suitable native species. The EIA recognises through its assessments that it will take several years before the reforested area returns to a functional habitat comparable to the original forested area.

Management of Liquid Waste at A1-W1

The A1-W1 worksite is situated fully within the catchment of a natural stream system that passes through the Windsor Nature Park (Figure 2). This natural stream is host to native aquatic and stream dependant fauna some of which are considered to be of conservation interest. The stream is considered to be particularly vulnerable to siltation and pollution due to its low flow rates and occasional ponds where suspended particles of undesirable materials can precipitate or accumulate resulting in damage to the habitat. The public walking trails within the park have been specifically designed to facilitate safe public access to the streams for the purpose of enjoyment and appreciation of the richness of the aquatic habitats.

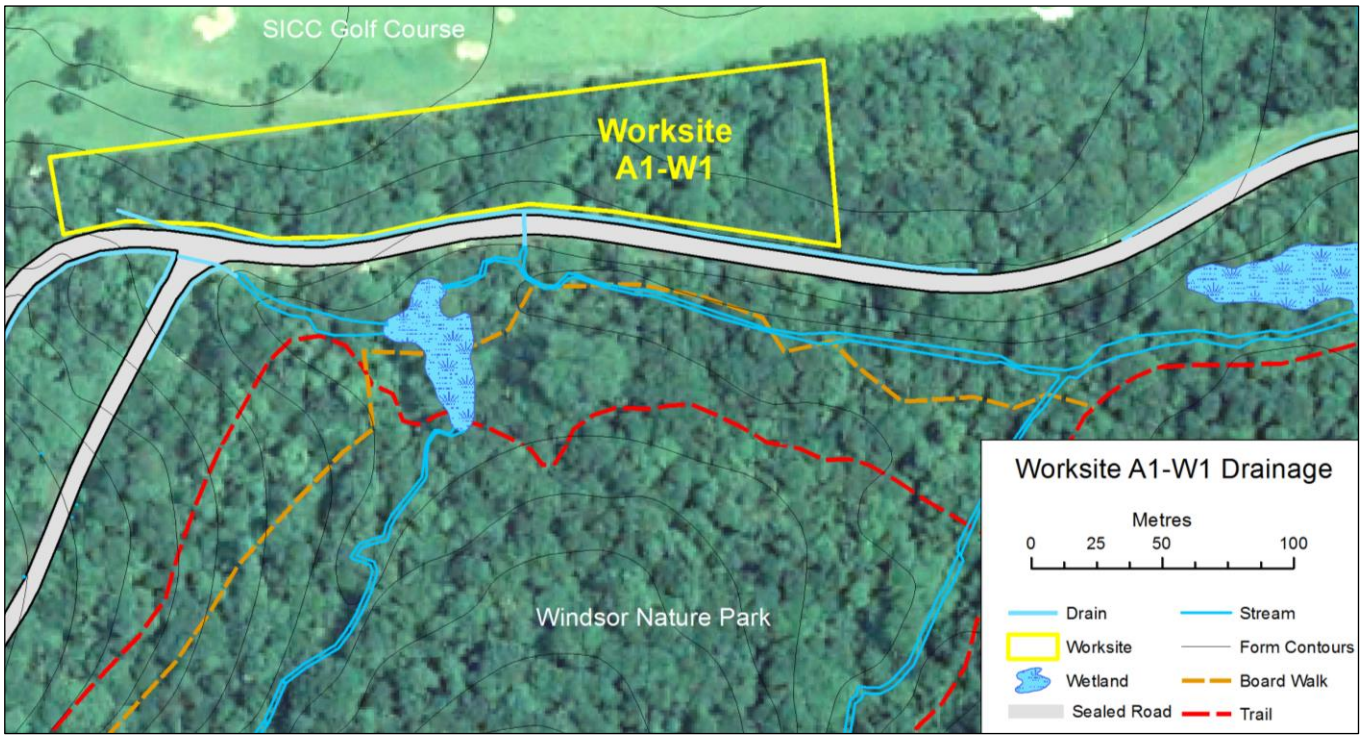


Figure 2: Worksite A1-W1 with drainage.

Mitigation measures prescribed to protect the aquatic and riparian habitat associated with the stream are as follows:

Conservative ECM Design	Conservative (over-capacity) design of the Earth Control Measures (ECM) including sumps and treatment plant will be determined at the Advanced Engineering Study stage in consultation with PUB. The recommendation is that the ECM capacity be designed to accommodate a higher rate of rainfall than would be usual for a 1.5 ha worksite in consideration of the need to protect the natural stream from silt and other unwanted materials originating from the worksite should the site receive excessive rainfall.
Redirection of ECM outflow	The outflow from the ECM plant will be redirected to the existing PUB drainage infrastructure at a point downstream from the natural stream system via a system of pipes that skirt the Windsor Nature Park. The detailed design of this diversion system will be undertaken during the Advanced Engineering Study stage and in consultation with PUB. The diversion of ECM outflow will avoid the deposition of silt and unwanted materials into the slow moving stream system where they may otherwise have precipitated resulting in long term impact on aquatic fauna.
Sequence of Works	The EIA recognises that the stream will be exposed to risk of siltation during the initial phase of site preparation. Careful control of the timing and sequencing of site drainage infrastructure development will be undertaken as follows: ▪ Minimum clearing for establishment of ECM plant will be undertaken during dry months of the year. ▪ Ancillary infrastructure (piping) will be initially established in readiness for immediate connection to the ECM plant once it is established. ▪ Careful implementation of embedded controls such as silt fences and catch drains as ECM is established. ▪ Remaining site preparation will proceed only after ECM plant is fully established and operational.

Slope Stability at Sime Stream Valley

Concern for slope stability at the point of Alignment Option 1 crossing below the Sime Stream Valley was identified as a potential risk due to a slope failure that occurred upstream in 2006 after heavy rainfall. The concern is that a combination of high rainfall and vibration from TBM operation immediately below the steep stream embankments could trigger a similar failure event. Upon investigation, it was determined that the 2006 slope failure was most likely due to uncontrolled runoff from the hillside immediately above the failure point having saturated and weakened the Sime Stream Valley slope, resulting in a slope failure and loss of forest habitat. Slope repair, including implementation of enhanced drainage, was undertaken immediately after the event (Figure 3). Further inspection of the vicinity of the intersection of Alignment Option 1 with the Sime Stream Valley has revealed that original drainage channels protecting the slope from runoff from the adjacent hillside are in working condition. There is therefore no possibility of hillside runoff saturating the Sime Stream Valley slope in the manner which caused the 2006 slope failure. Vibration from TBM operation has also been assessed to be below background vibration levels at this location (refer to section **Vibration due to Tunnelling** below). The risk of slope failure due to a combination of high rainfall and TBM vibration is therefore considered to be negligible; however, the EIA recommends monitoring during the time of TBM transit. Monitoring includes assessing rainfall, monitoring surface vibration and visual inspection of the slope for cracks and saturation. Should there be evidence of imminent slope failure, the TBM operations and/or operating parameters will be reviewed by engineers. Potential actions could include the following:

- Temporary halt to operation until water content returns to normal conditions (assuming heavy rainfall).
- Alter operation parameters such as TBM cutterhead rotation speed to reduce vibration.

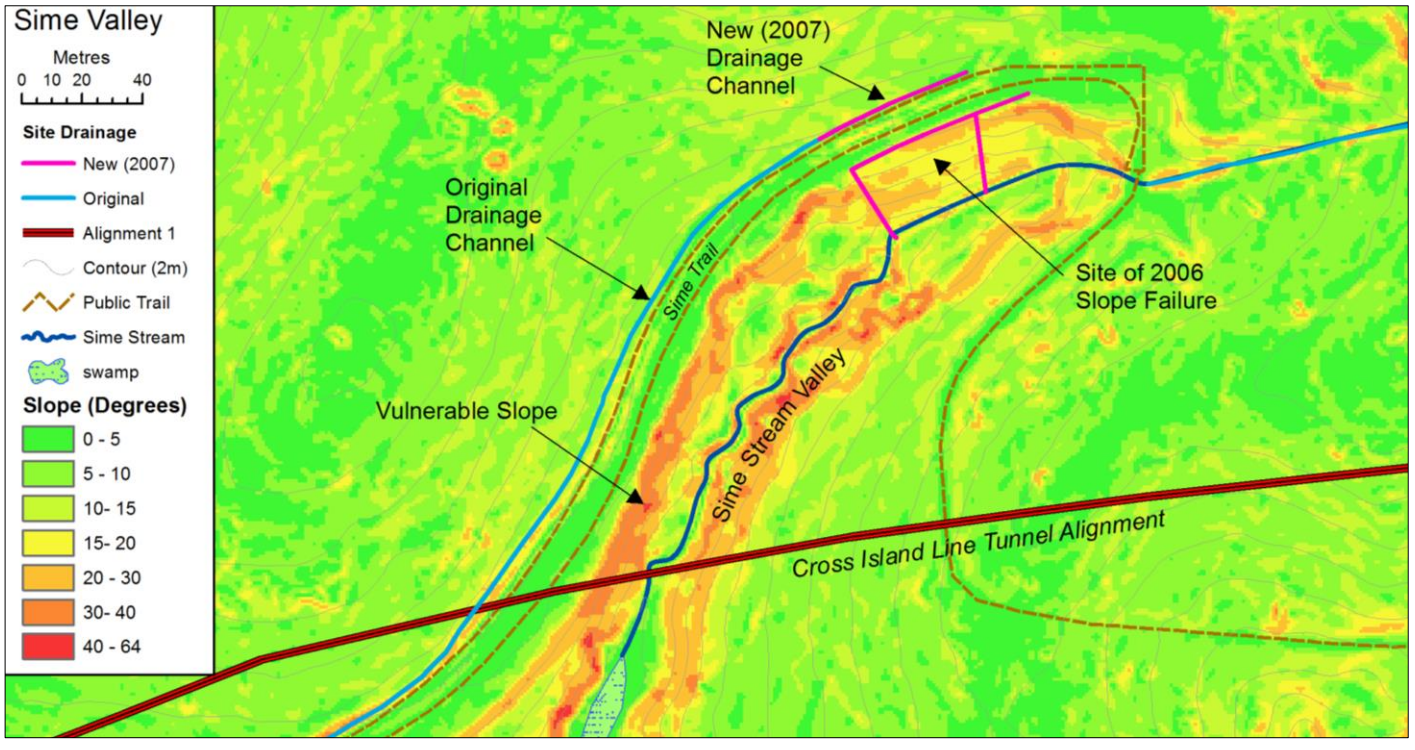


Figure 3: Sime Stream Valley slope map showing existing drainage infrastructure.

Risk of Excessive Ground Settlement and Surface Water Drawdown

Excessive ground settlement due to cavitations/cave-in about the TBM cutterhead and surface water drawdown are two significant concerns when operating a TBM in mixed face conditions (rock and soil). Excessive ground settlement can occur when a TBM is operating close to the surface in mixed rock/soil conditions. Water drawdown is less of a concern due to use of pressurised face TBM equipment. High density (impervious) concrete interlocking and sealed tunnel segments provide long term protection of tunnel from water ingress. Modern TBM equipment utilises a sealed - pressurised compartment at the cutting face where air pressure is maintained equal to the opposing hydrostatic pressure (Figure 4). This opposing pressure stops the ingress of water into the cutterhead compartment.

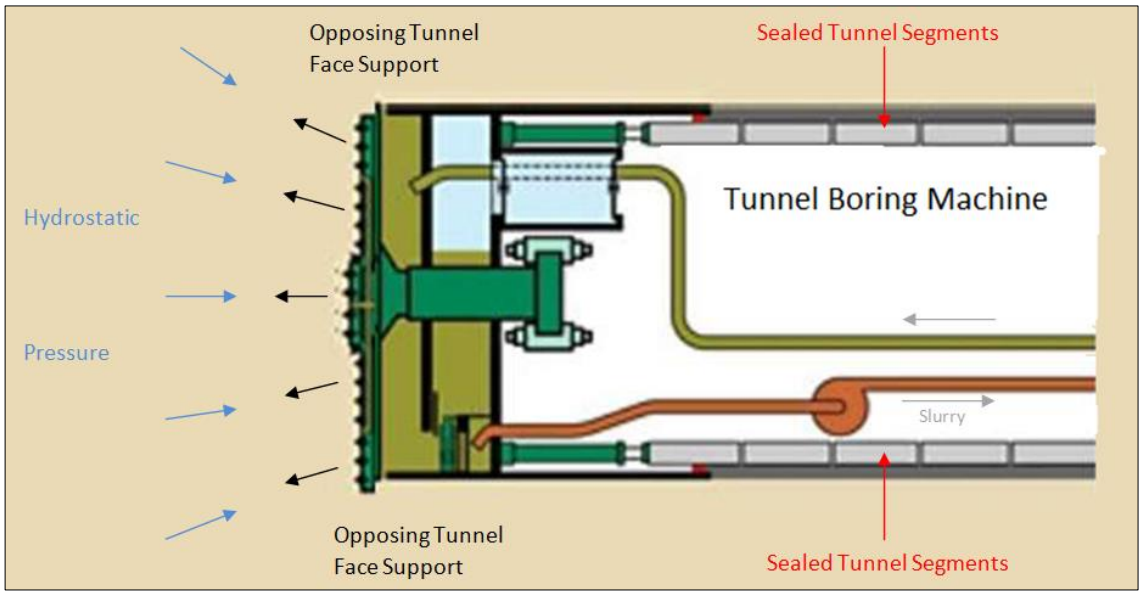


Figure 4: Closed face tunnel boring Machine.

As the TBM progresses with tunnel excavation, low-porosity interlocking tunnel segments are erected behind the TBM cutterhead assembly. The joints between the segments are sealed with non-decomposable Elastomeric Gaskets to protect against water ingress

(Figure 5). Post tunnelling treatment by high pressure grout injection protects against spot leakages that may be detected during the working life of the tunnel.

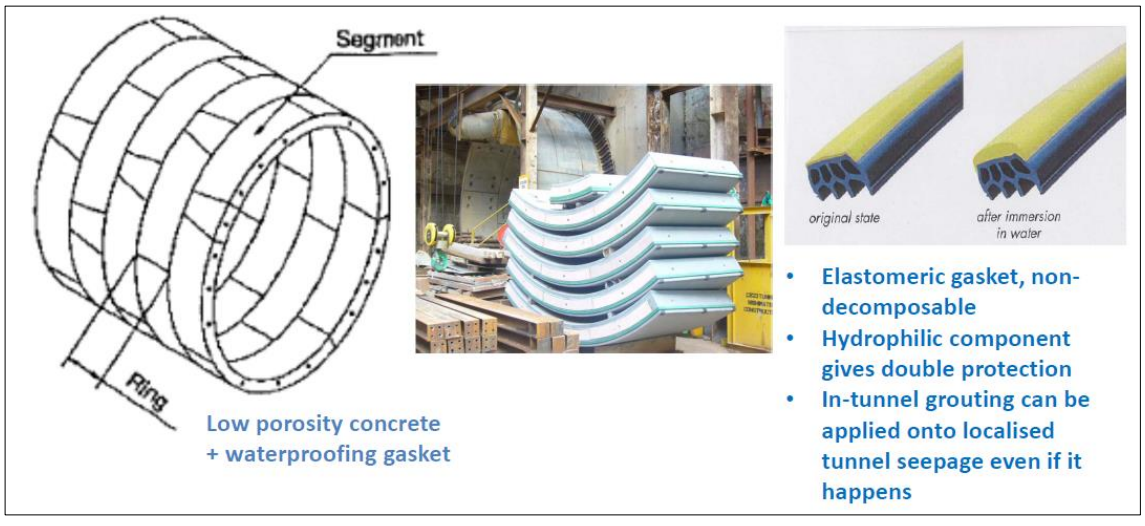


Figure 5: Tunnel Segments sealed with Elastomeric Gasket.

Mitigation measures for protection against ingress of water are as follows:

Vertical Tunnel Alignment	The vertical tunnel alignment has been designed such that all tunneling below the CCNR will occur within competent granite material 70 metres below average ground level. Mixed face (rock/soil) conditions that typically bring the risk of cavitations and cave-in at the TBM cutterhead will be completely avoided. Because the entire length of the tunnel below the CCNR is within rock and exceptionally deep, the risk of sinkholes forming at the surface is negligible.
Slurry Balance TBM	Modern TBM equipment uses the slurry balance system where a pressurized compartment housing the cutter wheel and slurry collection equipment counteracts the incoming hydrostatic pressure. The balanced pressure results in no ingress of ground water into the tunnel as it is being excavated.
Single Bored Tunnel Design	The Alignment Option 1 design calls for a single 12.5 metre diameter single bored tunnel (normally a twin bored tunnel system is prescribed). This arrangement negates the need to mine connection shafts between the tunnels thus avoiding further opportunity for water ingress or cave-in.
Low Porosity Sealed Tunnel Segments	As the tunnel is excavated, low-porosity tunnel segments are interlocked and sealed with non-decomposable Elastomeric gaskets. The interlocked and sealed tunnel segments provide a reliable seal against water ingress into the excavated tunnel.
High Pressure Grout Sealing	During the operational phase, any water ingress identified during tunnel monitoring is sealed by injection of high pressure grout into the space behind the tunnel segments.

Vibration due to Tunnelling Activity

Construction vibration impacts on structures and humans is generally well understood and documented, however the potential impact of construction vibration on fauna is in need of further research. Because of the lack of existing research, vibration impacts on fauna due to the operation of a TBM below the CCNR has been a matter of significant concern for this EIA. The approach adopted in assessing the predicted vibration magnitude and impact has been to rigorously determine the background surface vibration within the CCNR, and then predict any additional vibration that may be contributed by the TBM using the best available predictive methods. Any positive difference between predicted minus background vibration would then be considered against the limited literature, and if necessary, by direct research.

Measurement of background vibration environment was undertaken at nine locations within the CCNR and coincident with the design alignment (Figure 6), these measurements were intended to verify and compliment two earlier measurements undertaken in March 2015 as part of the CRL Phase 1 Site Investigation EIA (refer CRL Phase 1 EIA Volume II). High end monitoring equipment capable of

measuring with a resolution of 0.127 mm/sec was deployed to the site between June and July 2019. The results of this vibration study show that the average ambient surface vibration is $\mu = 0.57$ mm/sec with standard deviation of $\sigma = 0.21$ mm/sec (Figure 7). The results compared favourably with the Phase 1 observations, which resulted in an average ambient vibration of ~0.5 mm/sec at two sites using an instrument of lower resolution. The ambient surface vibration within the CCNR is considered to be due to expressway and local vehicular traffic, nearby construction site operations, and trail usage by recreational users (joggers & hikers) within the CCNR.

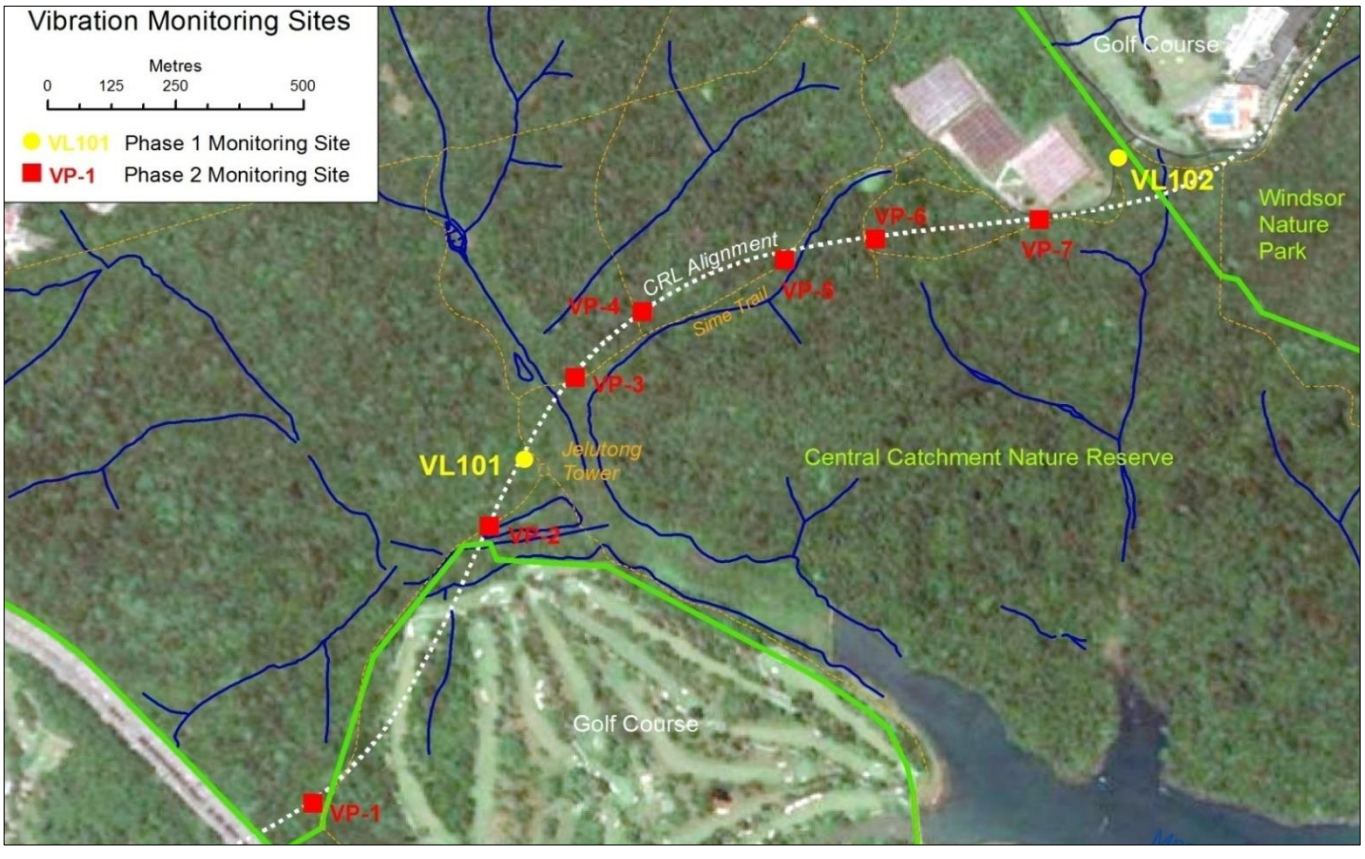


Figure 6: Vibration monitoring locations within CCNR.

Location	VP-1	VP-2	VL101	VP-3	VP-4	VP-5	VP-6	VP-7	VL102
Peak PPV (mm/s)	0.38	0.29	0.53	0.48	0.7	0.93	0.80	0.48	0.63

Figure 7: Results of background vibration measurement (Jun – Jul 2019)

The evaluation of predicted surface vibration was achieved by two independent methods:

- Application of Esvelt's equations calibrated to empirical vibration data from comparable projects obtained from the extant literature; and
- Application of prediction methods documented in the US FTA Noise & Vibration Manual by independent consultants.

Esvelt's Method

$$PPV = \frac{10 * (r_{soil}\beta_{soil} + r_{rock}\beta_{rock}) * D}{r^{n+1}}$$

Where...

Parameter	Value
PPV	Vibration intensity in units of mm/sec
β	Substrate hardness parameter (range 0.25 < β < 1.0)
n	1.35 (determined by calibration)
r	Slope Distance from TBM
D	TBM Cutting wheel diameter (12.5 m)

Rock Type	β
Granite G1/G2, Norite	1.0
Granite G3	0.95
Sandstone	0.75
Mudstone	0.6
Soil G5/G6	0.5

US FTA Method

Engineering consultants Wilkinson & Murray were commissioned by LTA to produce an independent evaluation of surface vibration due to operation of a 12.5 m TBM for a series of discrete points (see table on right). Their method was based on a model presented in the **US FTA Noise and Vibration Manual** and was calibrated to empirical data collected on tunneling projects recently undertaken in Sydney and Hong Kong.

R	RH (m)	PPV mm/sec
45	35	0.25
50	30	0.24
63	52	0.17
68	30	0.15
83	66	0.11
85	25	0.1
87	40	0.1

R=Tunnel Depth, RH=Rock Head Depth, PPV = Peak Particle Vibration

The results of both methods compared favourably with the difference of 0.1-0.2 mm/sec over the range of tunnel depths anticipated within the CCNR. The average between the two methods of vibration prediction has been adopted as the most probable predicted surface vibration. The graph below (Figure 8) illustrates the difference between the two methods of prediction along with the average value fitted curve. The error bars and values shown in Figure 8 represent the difference between the average curve and the two curves representing the two methods of prediction. The differences indicated range between 0.1 and 0.05 mm/sec over the depth range of 50 to 90 metres and would in practice be un-measureable.

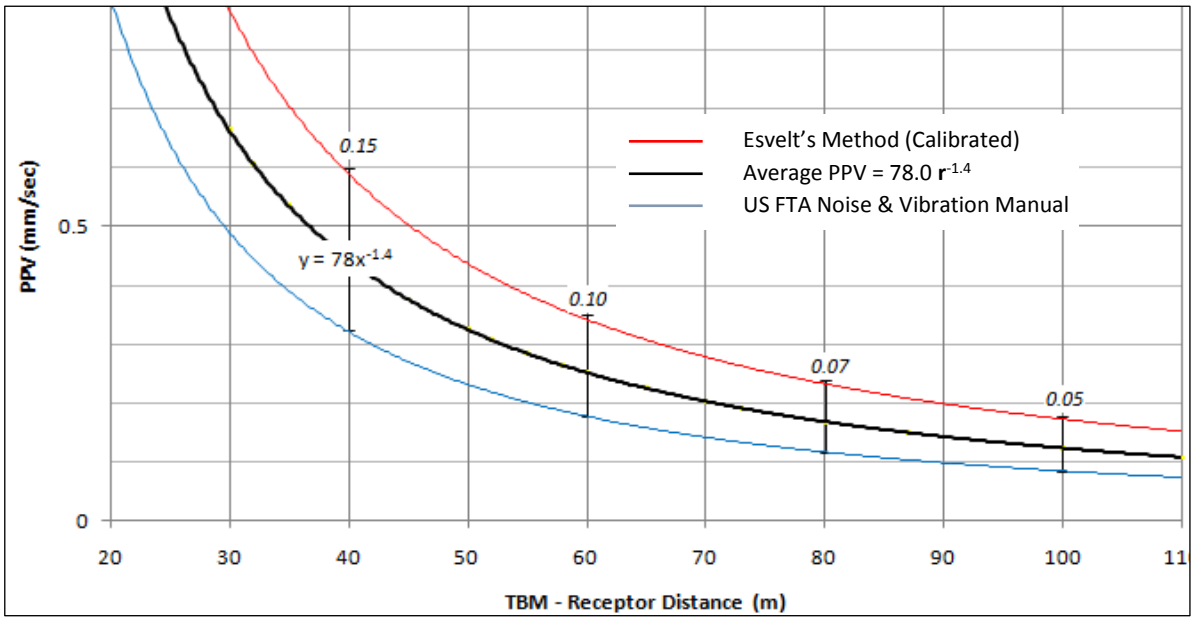


Figure 8: Comparison of vibration prediction methods.

The predicted surface vibration due to TBM operation at depths ranging from 50 to 90 metres below the surface is below the average background vibration of 0.57 mm/sec. The effect of this vibration will be masked within the white noise of the background vibration. For most of the alignment, and particularly through the most sensitive MacRitchie core forest where the tunnel alignment is at its deepest, the predicted vibration contribution is 0.1-0.2 mm/sec. Towards the western section where the vertical alignment is rising to meet the worksite A1-W2, the predicted vibration also rises and reaches a maximum of 0.4-0.5 mm/sec for a short distance at the extreme western end of the alignment. With the TBM moving at an anticipated rate of 5-7 metres per day, the contributed surface vibration will increase gradually from a datum of 0.1 mm/sec over a period of up to two weeks when a maximum is reached, and then recede at more or less the same rate (Figure 9). The effect of any contributed vibration is therefore considered temporary in nature.

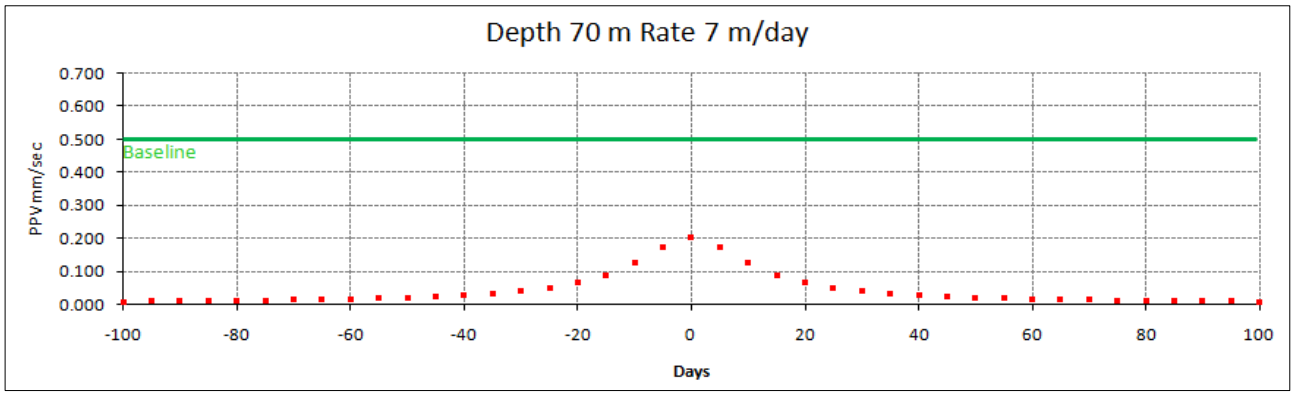


Figure 9: Time-Magnitude graph for a surface point 70 metres above the alignment.

A heat map has been prepared (Figure 10 below) to illustrate the extent and magnitude of the TBM contributed surface vibration.

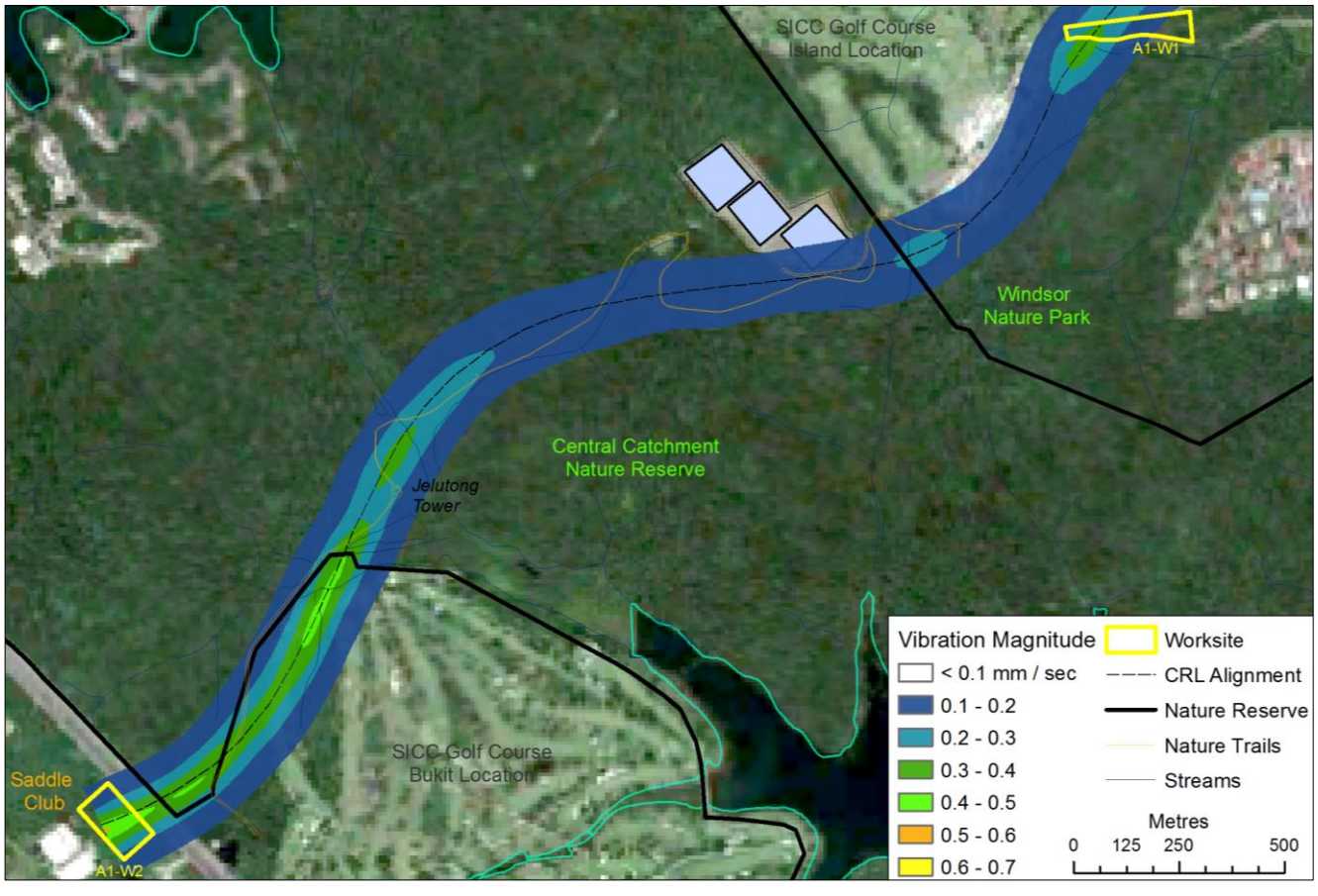


Figure 10: Heat Map Illustrating Magnitude of Vibration Contributed by TBM Operation.

Considering that the magnitude of predicted vibration is below the average background surface vibration as well as the temporary nature of any TBM contributed vibration it has been assessed that the impact on fauna will be negligible. Nevertheless, it is recognised that prediction and reality may vary and appropriate monitoring and mitigation measures are prescribed as follows:

Regular monitoring and forward prediction of TBM contributed vibration.	It is recommended that TBM contributed vibration be monitored on a regular basis. With the availability of empirical vibration data it is possible to use Bornitz equations (which reply on measurements to determine local ground attenuation characteristics) to accurately predict surface vibration as the TBM advances along the alignment. If predicted forward vibrations are estimated to exceed background values mitigation measures (next below) will be applied.
Reduce TBM cutterhead speed and drive force	Should predicted vibration (derived from Bornitz equations) exceed background vibration magnitude, the cutterhead and drive force of the TBM may be reduced. This reduction will result in less energy being imparted to the excavation rock face and subsequently reduce surface vibration. These

	mitigation measures will only be invoked if monitoring and forward prediction anticipate higher than background surface vibration. The downside of this arrangement is that tunneling progress will be affected resulting in longer potential vibration exposure times.
Maintain cutting tools in good condition	Maintaining cutting tools (part of the cutterhead) in good or fresh condition will contribute to reduced vibration. This will be achieved by monitoring and renewing the cutting tools on a more aggressive schedule than is usual practice.

Habitat Loss Due to Site Clearing at A1-W2

Worksite A1-W2 is situated within a more or less continuous patch of regrowth forest dominated by mature Albizia trees and is bounded by Eng Neo Ave to the south, Bukit Tinggi to the north, Champions Golf Club and Bukit Timah Saddle Club to the west and the Pan Island Expressway (PIE) to the east. While the fauna in this area is not extensively documented, it is known that the Sunda Pangolin is present, while other native fauna such as the Malayan Colugo and possibly Lesser Mouse Deer, may be present.

The A1-W2 worksite once cleared would represent up to 7.5% of the 20 hectare forested area and is situated at a choke point between Bukit Timah Saddle Club and PIE.

Mitigation measures prescribed to minimise impacts due to forest clearing include the following:

Refine Worksite Footprint	While nominally 1.5 hectares in size, this worksite will be designed to minimise footprint, and positioning and shape will be determined so that storm runoff can be directed to the south. The worksite also needs to ensure that a reasonable corridor remains between the Bukit Timah Saddle Club facilities to the west and the western edge of the worksite. The specific details of worksite position and shape will be addressed during the Advanced Engineering Study.
Fauna Shepherding	At the time of clearing, professional fauna consultants will be engaged to shepherd fauna away from the affected area. The fauna consultant will also be called upon provide a fauna management plan which will include a specification for location and extent of hoarding required about and beyond the worksite.
Recovery of flora	Flora species of conservation significance that are suited to transplantation will be recovered from the site.
Replanting of affected area	At the end of the project, the affected area will be reforested with suitable native species. The EIA recognises through its assessments that it will take several years before the reforested area returns to a functional habitat comparable to the original forested area.

Management of Liquid Waste at A1-W2

The A1-W2 worksite is situated within two stream catchments, one draining north and east through the CCNR, the second draining south west to a PUB drainage canal (Figure 11). The northern catchment outflow drains to a natural stream that is host to native aquatic and stream dependant fauna some of which are considered to be of conservation interest. The worksite is situated on the top of a ridge which forms the watershed between northern and southern catchments. The worksite design will be refined during the Advanced Engineering phase such that all run-off from the site will be directed after treatment southwards to the PUB canal.

Mitigations prescribed to protect the aquatic and riparian habitat associated with the northern stream are as follows:

Worksite design	Worksite will be located such that with excavation, all storm runoff will flow southwards where it will be collected in a sump and processed to PUB and NEA standards before being released into the PUB drainage system.
Sequence of works	The EIA recognises that the stream will be exposed to risk of siltation during the initial phase of site preparation. Careful control of the timing and sequencing of site drainage infrastructure undertaken as follows: • Minimum clearing for establishment of ECM plant will be undertaken during dry months of the year

- Remaining site preparation will proceed only after ECM plant is fully established and operational.
- Careful implementation of embedded controls such as silt fences and catch drains as ECM is established.

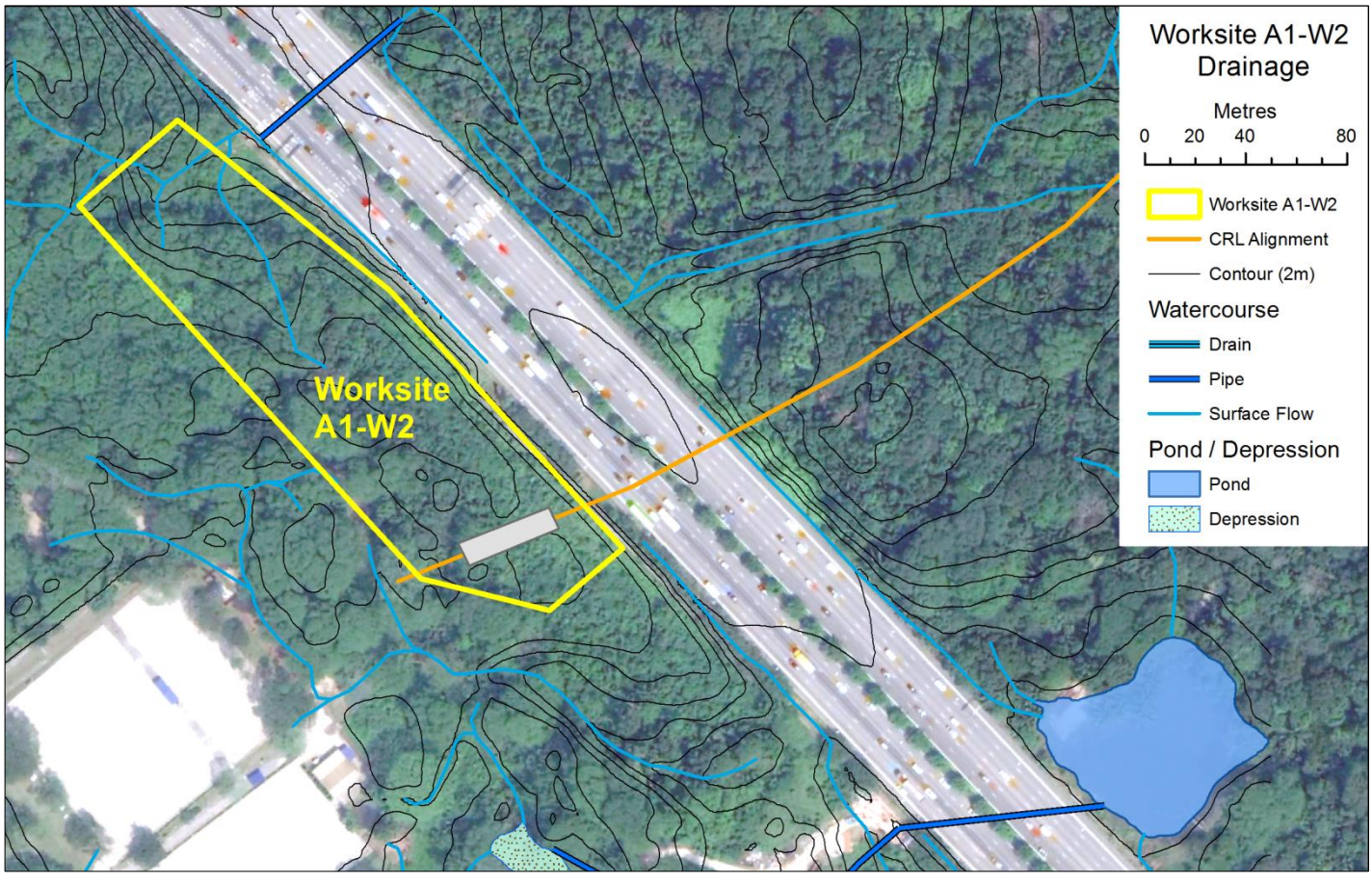


Figure 11: Worksite A1-W2 Drainage and Natural Stream System.

Biodiversity Concerns for Alignment Option 2

Alignment Option 2 includes three worksites; A2-W1 through A2-W3, of these A2-W1 is situated in parkland adjacent to Thomson Road and presents no significant concerns for biodiversity. Establishment of worksites A2-W2 and A2-W3 will require forest clearing. Alignment Option 2 includes mixed face (rock/soil) tunnelling conditions however due to the urban nature of the alignment, it is anticipated that soil conditioning can be undertaken at surface locations without affecting native fauna or flora. Also due to the urban setting of Alignment Option 2, vibration is not considered to be a factor affecting native fauna.

Habitat Loss Due to Site Clearing at A2-W2

Worksite A2-W2 is situated on land designated as Cemetery in the current URA Master Plan 2014. The worksite is nominally 1.5 hectares in size and will represent a loss of approximately 7% from the contiguous forested area between Lornie Road and Lornie Highway (refer Figure 12). The area is thought to host Sunda Pangolin and Malayan Colugo subject to further detailed biodiversity surveys to be undertaken during the Advanced Engineering phase. From a flora and fauna point of view, this site is comparable to worksite A1-W2 of Alignment Option 1.

Figure 12: Worksite A2-W2.

Mitigations prescribed for this site include:

Fauna Herding	At the time of clearing, professional fauna consultants will be engaged to herd fauna away from the affected area. The fauna consultant will also be called upon provide a fauna management plan which will include a specification for location and extent of hoarding required about and beyond the worksite.
Recovery of flora	Flora species of conservation significance that are suited to transplantation will be recovered from the site.
Replanting of affected area	At the end of the project, the affected area will be reforested with suitable native species. The EIA recognises through its assessments that it will take several years before the reforested area returns to a functional habitat comparable to the original forested area.

Habitat Loss Due to Site Clearing at A2-W3

Worksite A2-W3 is situated on land designated as Cemetery in the current URA Master Plan 2014. The worksite is nominally 1.5 hectares in size and will represent a loss of approximately 5% from the contiguous forested area between the PIE and the SICC (Bukit) Golf Course (Figure 13). The area is directly connected to the south-western end of the CCNR by a narrow forested corridor and broken only by a grassed tee off area for one of the golf course fairways. The area of the worksite is known to host Sunda Pangolin, Malayan Colugo and Sunda Slow Loris. Due to the site's direct connection with CCNR, other species such as Lesser Mouse Deer and Horsfields Flying Squirrel are most likely to be found within the area of the worksite. The site is covered by low regrowth forest with occasional large native trees including Terentang, Ketapang and Common Pulai. From a fauna and flora point of view the site is comparable to worksite A1-W1 of Alignment Option 1.

Figure 13: Worksite A2-W3.

Mitigations prescribed for this site include:

Footprint Design	During Advanced Engineering phase, the site footprint will be designed to avoid damage to large native trees that exist in the vicinity of the site. These few trees have been observed to support arboreal mammals such as Malayan Colugo and Slow Loris.
Fauna Shepherding	At the time of clearing, professional fauna consultants will be engaged to shepherd fauna away from the affected area. The fauna consultant will also be called upon provide a fauna management plan which will include a specification for location and extent of hoarding required about and beyond the worksite.
Recovery of flora	Flora species of conservation significance that are suited to transplantation will be recovered from the site.
Replanting of affected area	At the end of the project, the affected area will be reforested with suitable native species. The EIA recognises through its assessments that it will take several years before the reforested area returns to a functional habitat comparable to the original forested area.

Conclusion

From an ecology and biodiversity point of view, the two alignment options are comparable in terms of habitat loss. Both options result in the loss of nominally 3 hectares of regrowth forest:

A1-W1	A2-W3	Both sites feature high level of connectivity with adjacent designated nature areas;
		Both sites are known to support a higher diversity of native fauna; and
		Both sites require careful design to retain forest access for native fauna.
A1-W2	A2-W2	Both sites are separated from designated nature areas by major roads or expressways;
		Both sites are thought to support a similar diversity of native fauna (lesser then A1-W1/A2-W3).

From a hydrographic point of view, the Alignment Option 1 presents greater challenges in that A1-W1 is fully within the catchment of a natural stream system passing through a designated nature area and known to support a variety of fauna species of conservation interest. A1-W2 is partially within the catchment of a stream system that passes through the CCNR. Mitigation measures are prescribed to eliminate concerns for natural stream system siltation or pollution as follows:

A1-W1	Liquid waste from this worksite will be treated to PUB and NEA standards, then redirected by pumping and piping to a suitable PUB drainage system, by-passing the natural stream system; and
A1-W2	The design of the worksite (during AES stage) will allow all liquid waste to be released into PUB drainage system after treatment to PUB and NEA standards. Drainage into the CCNR stream will be completely avoided.

Concerns for Excessive Ground Settlement, Hydrology, Slope Failure and Vibration impacts on flora and fauna for Alignment Option 1 have been assessed and mitigated sufficiently and are not comparable to the situation of Alignment Option 2.

Having regard to the above comparison, it is concluded that with the implementation of EIA prescribed mitigation measures, both alignment options are highly comparable and feasible from a biodiversity impact and management point of view.