PARTICULAR SPECIFICATION

APPENDIX L

HISTORICAL LAND USE SURVEY (HLUS) REPORT

ARUP

Historical Land Use Survey for the Advanced Engineering Study for Cross Island Line Phase 2 (CRL Phase 2) – CR2001

Preliminary Report (CR16)
(CR2001/DOC/DES/0043/-)

18 June 2021

Project No.: 0542170

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18 June 2021

Historical Land Use Survey for the Advanced Engineering Study for Cross Island Line Phase 2 (CRL Phase 2) – CR2001

Preliminary Report (CR16)

Rohan Raja Durai
Partner

Environmental Resources Management (S) Pte Ltd

120 Robinson Road #10-01
T: +65 6324 9636
F: +65 6226 1636

www.erm.com

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Acronyms and Abbreviations

ABC	Active, Beautiful, Clean
AES	Advance Engineering Study
BCA	Building and Construction Authority
bgl	below ground level
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CoC	Contaminant of Concern
CRL	Cross Island Line
DIV	Dutch Intervention Values
DDT	Dichlorodiphenyltrichloroethane
DSTA	Defence Science and Technology Agency
EBS	Environmental Baseline Study
EMA	Energy Market Authority
ERM	Environmental Resources Management (S) Pte Ltd
GIS	Geographic Information Systems
GPR	Ground Penetrating Radar
HDB	Housing Development Board
HLUS	Historical Land Use Survey
JTC	Jurong Town Corporation
LTA	Land Transport Authority
MPA	Maritime and Port Authority
MRT	Mass Rapid Transit
MTBR	Methyl Tertiary Butyl Ether
NEA	National Environment Agency
NHB	National Heritage Board
NLB	National Library Board
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PID	Photoionization Detector
PPE	Personal Protective Equipment
PUB	Public Utilities Board
SHD	Singapore Height Datum
SIP	Sewerage Information Plan
SLA	Singapore Land Authority
SVOC	Semi Volatile Organic Compound
ToR	Terms of Reference
TPH	Total Petroleum Hydrocarbon
URA	Urban Redevelopment Authority

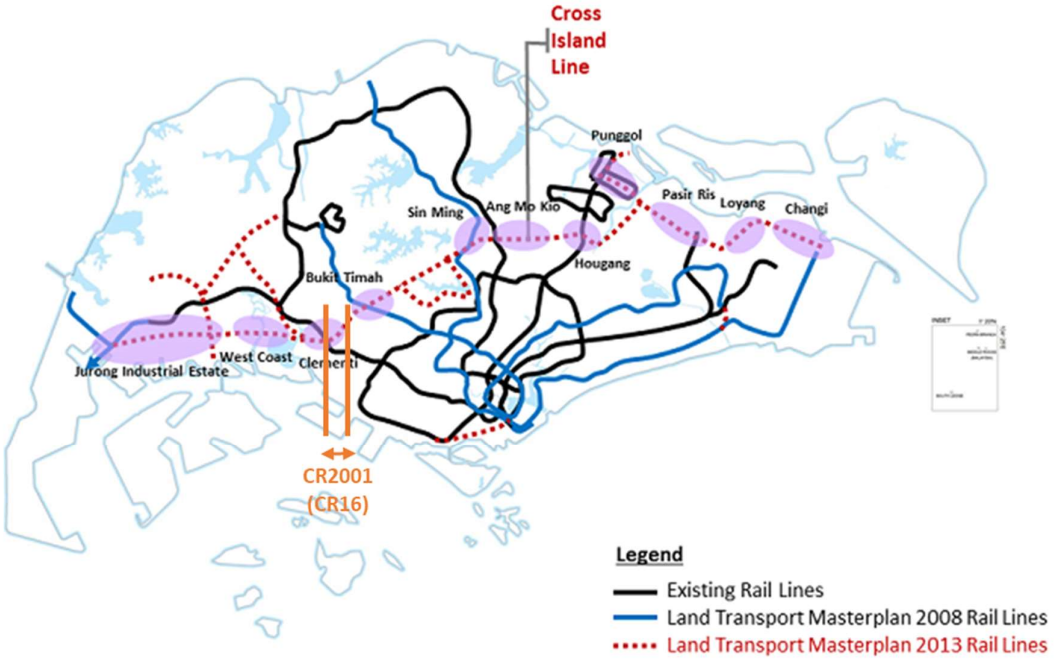
UXO	Unexploded Ordnance
VOC	Volatile Organic Compound
WWII	World War II

1. INTRODUCTION

1.1 Background

The Land Transport Authority (LTA or the Authority) intends to expand the Mass Rapid Transit (MRT) system in Singapore with the construction of the Cross Island Line (CRL). The underground CRL will be approximately 56 km in length and connect Changi to Jurong Industrial Estate, via areas including Loyang, Pasir Ris, Hougang, Ang Mo Kio, Bukit Timah, Clementi and West Coast (*Figure 1.1*).

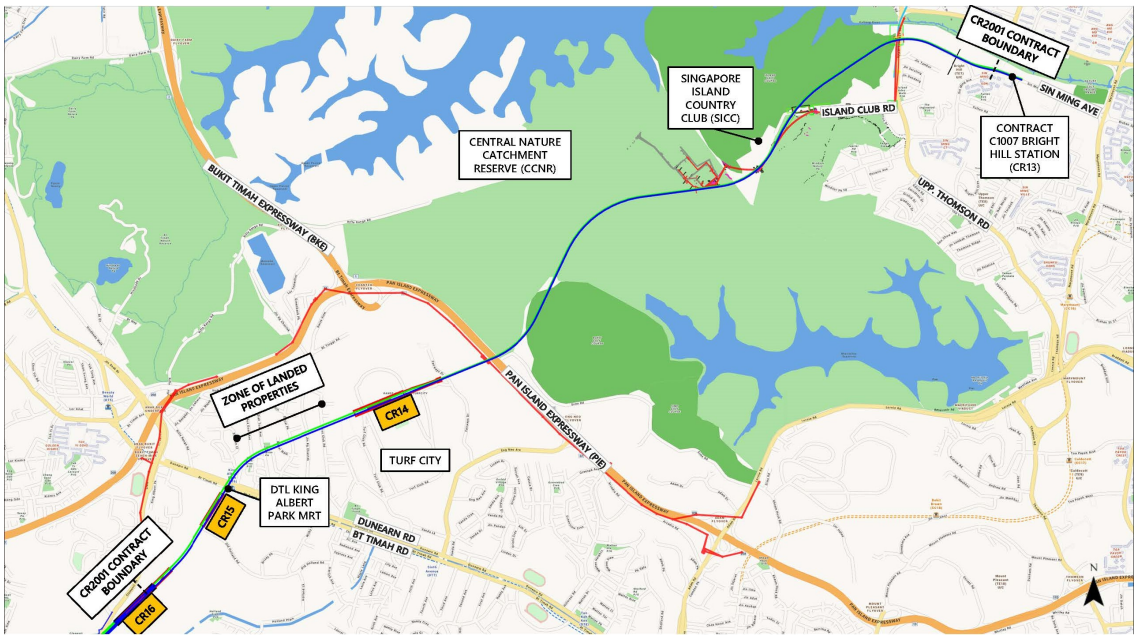
Figure 1.1: Overview of CRL Alignment



Arup Singapore Pte Ltd together with Ong and Ong Pte Ltd have been appointed by the LTA to undertake an Advanced Engineering Study (AES) for Contract CR2001 ('CR2001' or 'the Project') of the proposed CRL Phase 2 of the Singapore Mass Rapid Transit System. The proposed CRL Phase 2 will be an underground 8-car train MRT line with a total route length of approximately 14 km between Bright Hill and Jurong Lake District.

CR2001 covers a section of the eastern leg of the CRL Phase 2 mainline with route length of approximately either 8 km (direct route) serving between Bright Hill and Maju with one station at Turf City (CR14), one interchange station at King Albert Park (CR15) and RTS facility building for each tunnel interval greater or equal to 3.7 km (*Figure 1.2*). CR2001 includes bored tunnel up to Maju station (CR16) which will be designed by LTA's in-house design team.

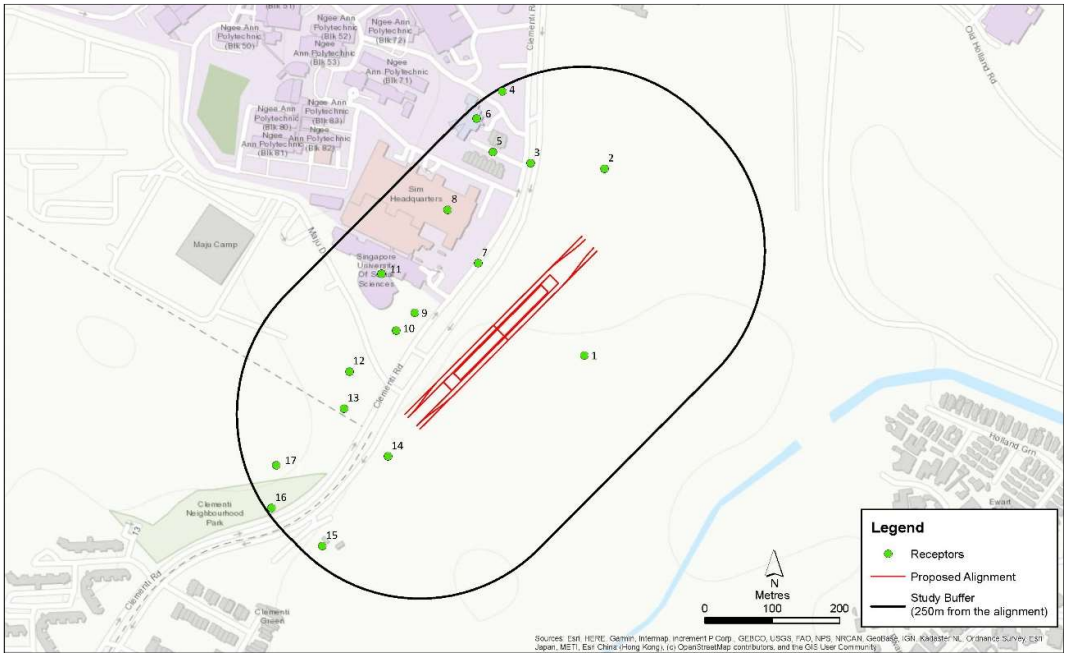
Figure 1.2: Overview of CR2001 Alignment



1.2 Scope

As part of the advanced engineering consultancy services, Environmental Resources Management (S) Pte Ltd (ERM) was commissioned to undertake a Historical Land Use Survey (HLUS). This document presents the study objective, methodology, existing land uses and the historical land use assessment undertaken for the CR16 station. The Study Area covers a 500 m corridor centred around the CR16 station, as shown in *Figure 1.3*.

Figure 1.3: Study Area for CR16 Station



2. CURRENT SITE SETTING

This chapter provides an overview of the topography, geology, hydrogeology and current land uses within the Study Area. The current site setting has been developed from the following:

- Review of publicly available street directories and online resources;
- Review of geological maps of Singapore, such as those produced by the Defence Science and Technology Agency (DSTA); and
- A site walkover conducted on 12 – 13 February 2020.

2.1 Topography

Review of the 1:50,000 Topographical Map of Singapore (*MINDEF, 2011*) indicates that the current topography of the area to be generally flat and low lying at 5 m above mean sea level (msl) with the exception of a 600 m stretch of land along Clementi that has a fairly steep gradient, sloping from 10 m to 58 m above msl.

Based on a review of available topographic maps published between 1953 and 2011, the general topography of the area within the Study Area has changed only slightly over time.

2.2 Geology and Hydrogeology

2.2.1 Geology

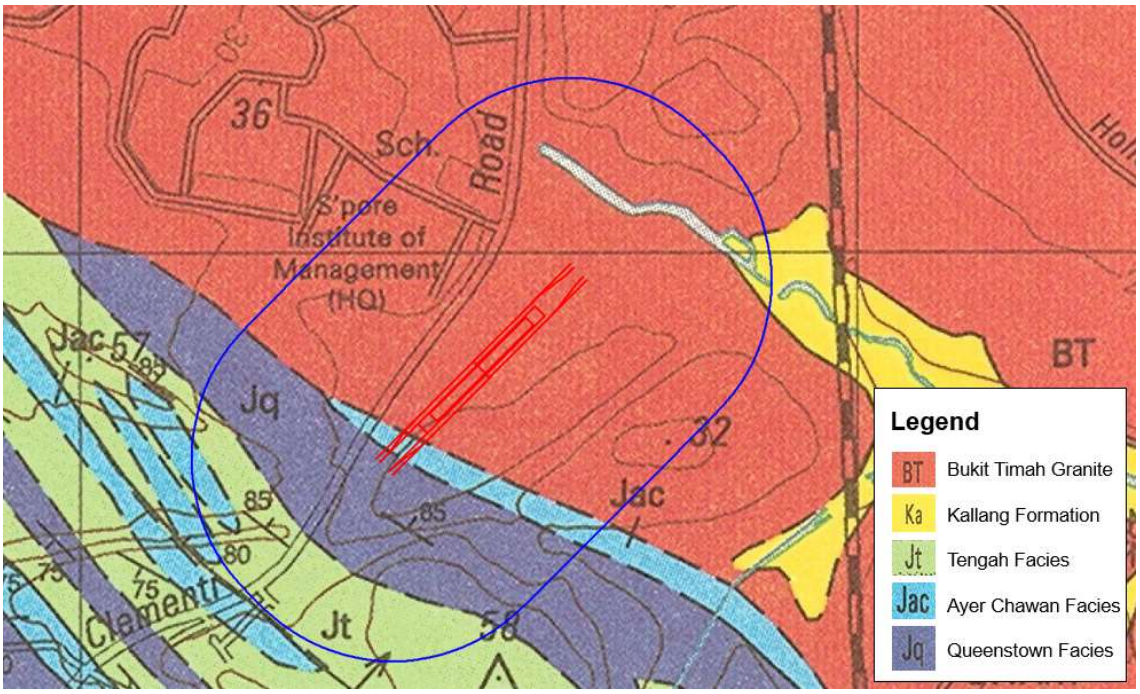
Review of the Geology maps published by Defence Science and Technology Agency *(DSTA, 2009)*, indicates that the regional geology of the CR2001 (CR16) HLUS Study Area comprises of various geological formations, namely Bukit Timah Granite, Jurong Formation (Ayer Chawan Facies, Queenstown Facies and Tengah Facies) and Kallang Formation (Alluvial Member).

Broad descriptions of each geological formation are presented in *Table 2.1* and *Figure 2.1*.

Table 2.1: Geological Formations present at Study Area

Geological Formation	Composition	Occurrence within Study Area
Bukit Timah Granite	■ An array of acid rocks including granite, adamellite, granodiorite and the acid and intermediate hybrids which resulted from the assimilation of basic rock within the granite	■ Exists as a comparatively large land area across from Bukit Timah Road to a point along Clementi Road
Kallang Formation		
Alluvial Member	■ Refers to deposits that vary from pebble beds through sand, muddy sand, and clay to peat	■ Underlies the smallest land area within the Study Area as it fringes the Sungei Ulu Pandan
Jurong Formation		
Tengah Facies	■ Muddy marine sandstone with occasional grit beds and conglomerate	■ Underlies forested areas and residential development along a section of Clementi Road
Ayer Chawan Facies	■ Well bedded marine muddy sandstone and mudstone, often black in colour.	■ Exists as a thin strip across a section of Clementi Road
Queenstown Facies	■ Red to purple mudstone and sandstone with minor conglomerate, with occasional minor tuffs	■ Exists as a comparatively large land area across a forested patch at both sides of Clementi Road

Figure 2.1: Geological Formations within Study Area



2.2.2 Soil Investigation Results

Based on a review of the Soil Investigation results, the elevation at Maju Station is broadly consistent around 20 m Singapore Height Datum (SHD).

At the point of writing, 204 boreholes along the CR2001 alignment had been reviewed. Ground conditions along the CR2001 alignment are likely to be highly variable, including one or more of the following geological material in any given location:

- Engineering Fill – man-made heterogeneous deposit comprising sandy/ clayey materials intermixed with gravel, tar and rock fragments;
- Kallang Formation – ranges from alluvial member (medium dense to very dense clayey gravelly fine to coarse SAND; firm to very stiff fine to coarse sandy CLAY/ SILT) to transitional member (soft to stiff organic peaty sandy CLAY with occasional wood fragments); and
- Bukit Timah Granite Formation – assemblage of various acidic igneous rocks including granite, adamellite, granodiorite and other acidic and intermediate hybrids.

Geotechnical design parameters derived for the proposed CR2001 alignment are summarised in the SI report. Additional site investigation was also recommended to fill in data gaps.

2.2.3 Hydrogeology

Based on existing project data, groundwater levels are typically close to the ground surface, typically less than 5 m below ground level (bgl). However, these levels are likely to fluctuate as a result of seasonal rainfall variations. Long-term monitoring of groundwater conditions along the alignment is essential to establish representative hydrogeological conditions for use in design. Further data pertaining to ongoing and future groundwater monitoring will be included in later revisions of the ARUP Geotechnical Interpretive Report as the design develops.

2.3 Existing Land Use

A site walkover of the CR2001 Study Area from Blackmore Drive to Clementi Avenue 5 was conducted by ERM on 12 and 13 February 2020. The objective of the site walkover was to ground truth the current land uses and identify land use activities with the potential to cause ground contamination within the Study Area. By means of visual inspection, the current land uses were verified, logged and photographed. The existing land uses were also identified from a review of street directories accessed via online portals (*Singapore Street Directory, 2019 and One Map, 2019*).

Based on the Urban Redevelopment Authority's (URA) land use zoning (*URA, 2014*), the categories of land uses currently located within the Study Area are:

- Residential;
- Educational Institution;
- Civic & Community Institution;
- Open Space;
- Park;
- Waterbody;
- Road;
- Utility;
- Agriculture;
- Reserve Site;
- Special Use;
- Future Development; and
- Unused Site.

The current land uses identified within the Study Area are shown on *Figure 2.2* and a full list is available in *Annex A*. A log of the photographs taken during the site walkover is presented in *Annex B*.

2.3.1 Residential

According to the URA's definition of building uses, residential land uses are defined as areas mainly for residential development (*URA, 2014*).

Residential premises within the Study Area include:

- **Terraced Houses**: Rosedale along Clementi Road (ID: 5)

2.3.2 Educational Institution

Educational Institutions are areas intended mainly for educational purposes, including tertiary education *(URA, 2014)*.

Educational Institutions within the Study Area include universities:

- Singapore Institute of Management HQ (SIM HQ) (ID: 8) and Singapore University of Social Sciences (SUSS) along Clementi Road (ID: 11);

2.3.3 Civic & Community Institution

Civic and community institutions are areas used mainly for civic, community or cultural facilities or other similar purposes areas used mainly for religious buildings (*URA, 2014*).

Such institutions within the Study Area include:

- Children's Aid Society (Melrose) located along Clementi Road (ID: 6);

2.3.4 Open Space

Open Spaces located within the Study Area include:

- Forested area to the East of Clementi Road (ID: 1);

2.3.5 Park

Parks are areas used mainly for parks or gardens for the enjoyment of the general public and includes pedestrian linkages (*URA, 2014*).

Parks located within the Study Area include:

- Clementi Neighbourhood Park (ID: 16), located adjacent to Clementi Road;

2.3.6 Waterbody

Waterbodies are areas used or intended to be used for drainage purposes and water areas such as reservoirs, ponds, rivers and other water channels, and may include river, major drain & canal, reservoir and pond (*URA, 2014*).

Waterbodies located within the Study Area include:

- Canal from Ngee Ann Polytechnic through forested area to the East of Clementi Road (ID: 2); and
- Drain between SUSS and an Unused Site to the South (ID: 9);

2.3.7 Road

Roads are areas used or intended to be used for existing and proposed roads *(URA, 2014).*

Major and minor roads within the Study Area are defined based on LTA's categorisation in the *Road Line Plan (LTA, nd)*. Roads categorised as Category 1 and 2 are defined as major roads while roads categorised as Category 3 are defined as minor roads.

According to LTA, roads in Singapore are classified into five categories:

- Category 1: Expressway forms the primary network where all long distance traffic movements should be directed. It is planned to optimise long distance mobility from one part of the island to another.
- Category 2: Major Arterial predominantly carries through traffic from one region to another, forming principle avenues of communication for urban traffic movements. It interconnects expressways and minor arterial as well as with other major arterial roads.
- Category 3: Minor Arterial distributes traffic within the major residential and industrial areas. It is planned to optimise circulation within the area and facilitate through traffic between adjacent towns.
- Category 4: Primary Access forms the link between local accesses and arterial roads. It provides access to developments and through traffic is discouraged. However, where a development is also accessible by a local access road, the access shall be located at the local access road.
- Category 5: Local Access gives direct access to buildings and other developments and should connect only with primary access.

Accordingly, the only major road (Categories 1 and 2) within the Study Area is Clementi Road (ID: 3, 12, 28) and there are no minor roads (Category 3).

2.3.8 Utility

URA defines Utility land plots as areas intended for public utilities and telecommunication infrastructure, including water works, sewage disposal works and other public installations such as electrical substations (*URA, 2014*).

Utility sites located within the Study Area include:

- Electrical Utility Buildings located within residential estates or within compounds of schools and other facilities throughout the Study Area (ID: 4);

2.3.9 Agriculture

Agriculture areas are areas used for agricultural purposes and includes plant nurseries (URA, 2014). Agriculture areas located within the Study Area comprise Corona Florist & Nursery Pte Ltd located along Clementi Road (ID: 15).

2.3.10 Reserve Site

Reserve Sites are areas where the specific land use has yet to be determined (*URA, 2014*). A review of the Masterplan 2014 indicated reserve sites including:

- An approximate 0.05 km^2 plot of forested land extending from Clementi Road to Sunset Way (ID: 17).

2.3.11 Special Use

URA defines Special Use land plots as areas intended for special purposes such as military (*URA, 2014*).

Special Use land areas located within the Study Area include:

- Maju Camp, bounded by Maju Drive and Brookvale Walk (ID: 12)

2.3.12 Future Development

ERM noted ongoing construction works within the Study Area during the site walkover. These future developments include:

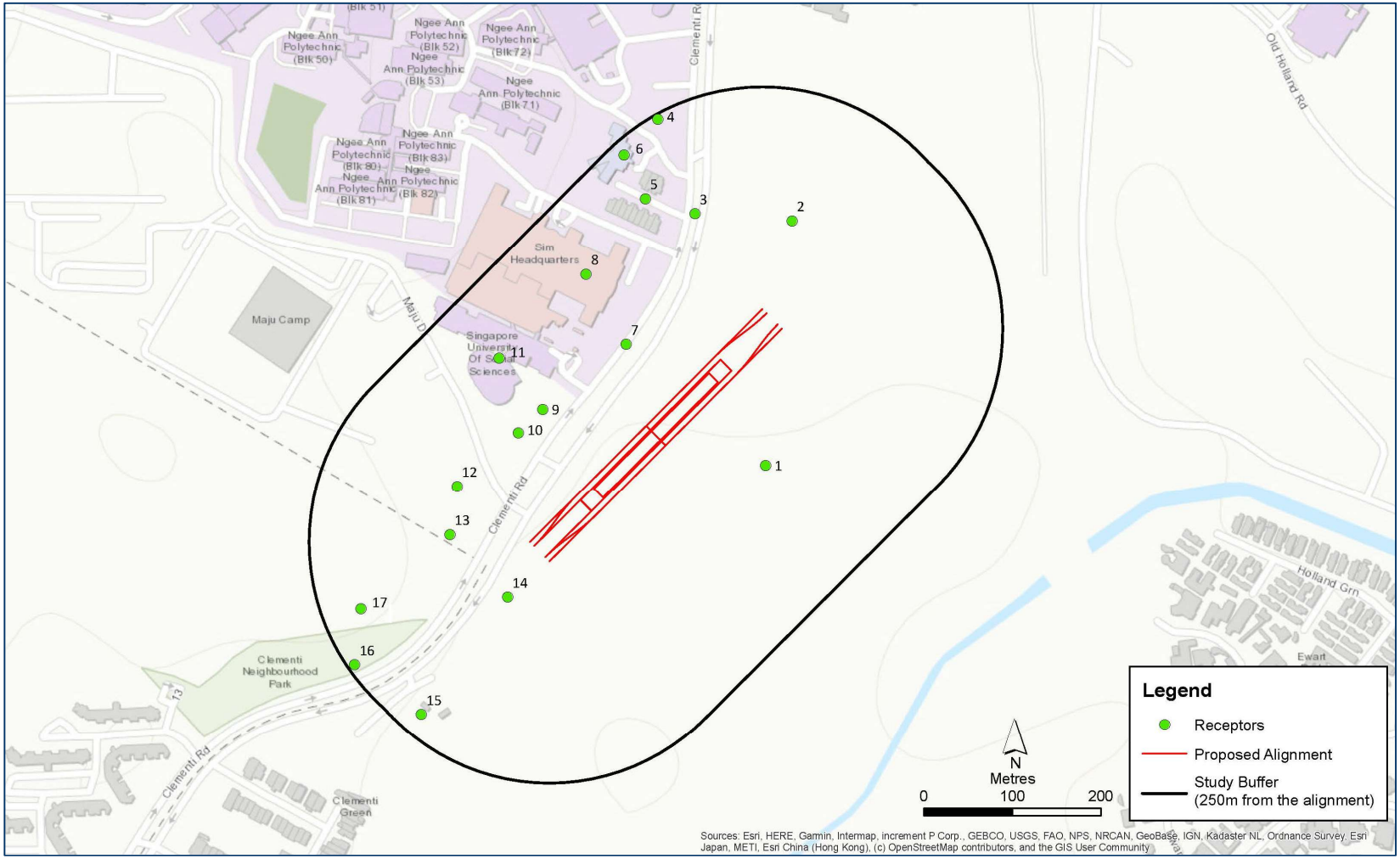
- Extension of Brookvale Walk to Clementi Road along the southern boundary of Maju Camp (ID: 13)

2.3.13 Unused Site

There are several unused sites within the Study Area, including:

- An Unused Site comprising a zinc-roof establishment located along Clementi Road, adjacent to Singapore University of Social Sciences (ID: 10); and
- Old Railway Line, part of the abandoned railway tracks emerging from under Clementi Road leading into the forest (ID: 14).

Figure 2.2: Current Land Use within Study Area



3. HISTORICAL LAND USE

This chapter provides a summary of the historical land uses identified within the Study Area, compiled based on a review of the following:

- Singapore street directories, dating between 1954 and 2009, downloaded from Historical OneMap (http://hm.onemap.sg/);
- Topological maps dating between 1914 and 2005, obtained from the Geographic Information Systems (GIS) Map Resource Unit of the National University of Singapore (NUS) (https://libmaps.nus.edu.sg/);
- Historical maps obtained online from the National Archives of Singapore (http://www.nas.gov.sg/archivesonline/);
- Historical aerial photographs obtained from Google Earth Pro 7.1.2.2041;
- Online resources chronicling the histories of particular landmarks/ localities such as the National Library Board's (NLB) Infopedia, historical blogs etc.; and
- A site walkover conducted on 14 February 2020.

Copies of the street directories and topographical maps used to inform the study have been compiled in *Annex C*. Detailed changes in land use through the years for each of the current landmarks along the alignment can be found in *Annex D*.

The narrative below provides a summary of the land use changes within the Study Area since the founding of modern Singapore in the early 1800s, and specifically through the past six decades, i.e. from 1945 to 2019.

3.1 Land Use Review (Before 1945)

A review of publicly available resources and online databases was undertaken to establish a general history of the land uses within the Study Area from the founding of modern Singapore in the early 1800s to the end of World War II in 1945.

Notable land uses are summarised in chronological order as follows:

- **Rural Villages:** Maps spanning the period 1800 to early 1900s show that residential developments were generally scattered around the hills surrounding Reformatory Road (presently Clementi Road (ID: 3, 7)) and that the surrounding area was predominantly used as rubber plantations. There were no established villages in the region.
- **Plantations:** Unfenced plantations (predominantly rubber plantations) were observed adjacent to the Reformatory Road from the c.1945 map. During the period of World War II (WWII) from 1941-1945, the plantations were left abandoned *(Neo et al., 2012)*, and were gradually overgrown by forest vegetation.
- **Roads, Railway and Bridges:**
  - Reformatory Road was a major road first observed in maps c. 1873. It runs through Singapore from the North Coast to the South Coast (presently Clementi Road (ID: 3)). Over the years, there have been many alterations made to this road, but the section within the Study Area has covered the same route since 1873.
  - Bukit Timah Railway Station was completed in 1903 (*Koh, 2013*). It was one of five stations making up the Singapore-KL Railway route, which connected Tank Road and Kranji and started operations in 1923 after completion of the causeway. In 1932, the completion of the Tanjong Pagar Railway Station meant that the original Bukit Timah Railway Station became obsolete from 1940 onwards. The station only ceased operations and was gazetted for conservation in 2011.

- **Civic and Community Institutions:** The Reformatory School was observed in maps c. 1911 (presently Singapore University of Social Sciences (SUSS) (ID: 11) and Singapore Institute of Management (SIM) (ID: 8)), and was subsequently renamed as Bukit Timah Boys' Home.
- **Natural Features:**
  - Historical maps spanning the period 1800 to early 1900s shows the minor meandering tributary of Sungei Ulu Pandan which branched out from Sungei Pandan in the west. Immediately surrounding it were rubber plantations as in the c.1945 map. Hilly areas are observed inland in maps c. 1914, with elevations of up to 200 m. Some of these hills include Peak Hill and Brahman Ridge.
  - A single patch of jungle can be observed in maps c.1945 near the Reformatory School (presently SUSS (ID: 11) and SIM (ID: 8)).
  - As observed in c.1914 and 1945 maps, there was a minor river cutting into Reformatory Road between Turf Hill and Bukit Pandan, which was likely linked to the reservoir known in the present day as MacRitchie Reservoir. The river was extended past Reformatory Road towards the west between 1914 and 1945.

3.2 Land Use Review (1945 – 1970)

This section summarises the land use in the study area after World War II from 1945 to 1970. Historical maps showed significant development within the Study Area. Natural features were cleared for the development of important roads and railways during this time period.

Notable land use changes observed within this period include:

- **Residential Developments:** Low density, scattered residences around Clementi Road (ID: 3) were observed in the 1960s.
- **Roads and Railway**:
  - Reformatory Road was renamed into Clementi Road (ID: 3) in 1947 (*Remember Singapore, 2012*), and a shortcut was made in the 1960s to circumvent a large bend in the original road as observed in c.1950 maps.
  - Jurong Railway Line (ID: 14) was developed in accordance with the steady growth of Jurong Industrial Estate in the late 1960s. The railway line was constructed from 1963 and was officially opened in 1966. The 19.3 km track ran from the Bukit Timah Railway Station next to King Albert Park, through Pasir Panjang, and ended at Shipyard Road (National Heritage Board, 2019).
- **Commercial Developments:** Corona Florist and Nursery (ID: 15) was established in 1950 *(Web Archives Singapore, n.d.).*
- **Natural Features:** The forest near the Reformatory School was cleared by 1958 to make way for a road cutting through Clementi Road (ID: 3).
- **Plantations:** The rubber plantations adjacent to Clementi Road (ID: 3) were cleared, and became lalang fields during the 1960s, as observed from c.1950 maps.
- **Military Facilities:** Singapore Armed Forces (SAF) Maju Camp (ID: 12) was established as a training site for volunteers of the People's Defence Force (established in 1965) (*MINDEF, 2018*) in the 1960s (*National Archives of Singapore, 2018*).
- **Civic and Community Institutions:** The Children's Aid Society (Melrose) (ID: 6) had purchased a plot of land next to Clementi Road and had its children and staff move in by 1970 *(Children's Aid Society, 2017).*

- **Educational Institutions:**
  - Ngee Ann Technical College moved to their Clementi Road campus in 1968, and is presently known as Ngee Ann Polytechnic (ID: 4).
  - The Bukit Timah Boys' Home was renamed The Gimson School for Boys (presently SUSS (ID: 11)) in 1952 (*The Straits Times, 1952*).
- **Utility Installations:**
  - Ngee Ann Polytechnic Substation (ID: 4) was likely built alongside the Ngee Ann Polytechnic campus (formerly known as Ngee Ann Technical College) in 1968.

3.3 Land Use Review (1971 – 1990)

Land use changes observed within this period include:

- **Civic and Community Institutions:** Gimson School was renamed as Singapore's Boys' Home and Ngee Ann Technical College was renamed to Ngee Ann Polytechnic.
- **Roads and Railways**: Minor alterations to Clementi Road was made (straightening).

3.4 Land Use Review (1991 – 2010)

Historical maps showed developments in the Study Area were made to raise the standard of living within the residential estates. The Jurong Railway ceased operations to make way for future efficient rapid transport systems. Educational institutions were also established. SUSS (ID: 11) was also constructed during this time period.

Notable land use changes observed within this period include:

- **Roads and Railways**:
  - The Jurong Railway ceased operations in the mid-1990s in favour of more efficient methods of transportation *(National Heritage Board, 2019)*.
  - By 1991, Lorong Tandan, Lorong Shahada and a part of Lorong Gaung were demolished. Maju Drive, which presently borders Maju Camp (ID: 12) was also constructed.
- **Educational Institutions**:
  - The Singapore's Boys' Home was relocated to Jurong in 1999 (Lee, 1995), and in its vacated space, the Singapore Institute of Management (SIM) (ID: 8) was built and officially opened in 2001. Expansion efforts to double its capacity began in 2009 *(SIM, n.d.)*.
  - Construction works for SUSS (ID: 11) began in 2009.
- **Natural Reserves and Parks:** Clementi Neighbourhood Park (ID: 16) was built by 2000 as observed from Google Earth Historical Imagery.

3.5 Land Use Review (2011 – 2019)

Historical maps showed the Study Area mainly underwent upgrading works. Singapore Institute of Management was expanded for the inclusion of Singapore University of Social Sciences within the same campus.

Notable land use changes observed within this period include:

- **Roads:** Clementi Road (ID: 3) was widened from into a 4-lane road from a 3-lane road, with roadworks completed in 2018.
- **Educational Institutions**: The expansion efforts of the SIM campus (ID: 8) was completed in 2014 *(SIM, n.d.)*. Construction of SUSS (ID: 11) began in 2009 and was completed in 2012.

- **Construction Works**: Ongoing construction works were observed during the site walkover along the southern boundary of Maju Camp, which is likely the extension of Brookvale Walk Road to Clementi Road (ID: 13).

4. ASSESSMENT

4.1 Introduction

The objective of this HLUS is to use available secondary information sources and information gathered during the site walkover to identify:

(i) Areas (hotspots) which due to their present or past land use are likely to have caused the release of significant quantities of contaminants into the underlying soil, and

(ii) Possible buried structures that may hinder excavation works and cause delays to the project.

Chapter 2 and *Chapter 3* have served to provide insights into the activities that have occurred or are currently occurring at each plot of land underlying the Study Area.

Chapter 4 – Sections 4.2 to 4.3, report the screening of the land uses within the Study Area for the likelihood of contamination in the underlying soil, and provide comment on the potential severity of contamination at the site. This approach seeks to further characterise the likely nature and extent of contamination at each plot of land in order to better inform future investigation and remediation methods.

Section 4.4 identifies potential locations and the extent of buried structures along the alignment.

4.1.1 Evaluating Contamination Severity

After identifying whether a particular site is a likely source of contamination, the severity of contamination has been evaluated using a matrix that considers the following:

- **Degree of toxicity** of contaminants present at the site, viewed with respect to the likely effects contaminants might have on receptors. As the main pathways of exposure for workers are when they come into contact with or inhale vapours from contaminated soil, the toxicities have been considered with respect to dermal contact and inhalation. The following category definitions have been adopted:
  - *Low*: Contaminant is an irritant upon dermal contact and/ or inhalation.
  - *Medium*: Contaminant is corrosive upon dermal contact and/ or causes effects on top of respiratory irritation upon inhalation (e.g. disorientation, nausea) but not amounting to death.
  - *High*: Contaminant is potentially fatal or extremely hazardous upon inhalation, regardless of its effects on the skin.

  In addition to inherent toxicity, additional factors included in the consideration for degree of toxicity are:
  - Concentration of contaminant; and
  - Potential quantities of contaminants present.
- **Spatial extent** of potential contamination within the 0.41 km^2 Study Area, with thresholds as follows:
  - *Localized*: 1-5% of the Study Area
  - *Medium*: 6-40% of the Study Area
  - *Pervasive*: More than 40% of Study Area

  In assigning the spatial extent of contamination from leaks or spills, additional factors included in the consideration are:
  - Permeability of the underlying soil/fill; and
  - Likely quantities spilled each occasion.

The permeability of each geological formation has been assigned based on ERM's technical experience in similar projects:

- *Bukit Timah Granite:* Low to medium permeability with a typical permeability coefficient range of 1 x 10^{-6} in sand to 1 x 10^{-8} m/s in clay *(ARUP, 2020);*
- *Kallang Formation:* Low to medium permeability with a typical permeability coefficient range of between 1 x 10^{-7} m/s *(ARUP, 2020);* and
- *Jurong Formation:* Low to medium permeability with a typical permeability coefficient range of between 1 x 10^{-6} m/s to 1 x 10^{-9} m/s *(Sharma et al., 1999)*.

The contamination severity (Low, Medium or High) adopted for the HLUS, and the Toxicity and Spatial Extent rating combinations from which they are derived, are presented in *Table 4.1*. This matrix has been adopted by ERM in previous HLUS reports submitted to and approved by LTA.

Table 4.1: Contamination Severity Matrix

Toxicity	Spatial Extent (as % of 1.27 km² Study Area)		
	Localized (1-5%)	Medium (> 5 – 40%)	Pervasive (> 40%)
Low	Low	Low	Medium
Medium	Low	Medium	High
High	Medium	High	High

4.2 Hotspots Identified from Current & Historical Land Uses

The land use at a site can be indicative of potentially contaminating activities that have occurred there, making the plot of land a source of contamination at some stage in its history.

From the survey of current and historical land uses, a number of potential land use "hotspots" (i.e. sites that could potentially be sources of contamination) have been identified along the CR2001 (CR16) alignment and HLUS Study Area. The nature of some of the likely materials stored, handled, utilised and potentially disposed at these hotspots is such that there is a potential for contamination of soil and groundwater resources. Potential sources of current or historical impact may include:

- Use of potentially contaminated fill material in construction or land reclamation activities;
- Inappropriate storage and disposal of hazardous waste;
- Discharge of products due to accidental spills, leaks and releases in storage, transport and from utility equipment;
- Uncontrolled discharge of potentially contaminating wastewater;
- Known ground contamination incidents or soil quality data;
- Unexploded ordnance from historical military conflicts; and
- Differential settlement of land in the area, which may lead to equipment damage and subsequent release of materials.

The potential land use hotspots identified from the study are illustrated on *Figure 4.1* and summarised in *Table 4.2.*

Table 4.2: Potential Land Use Hotspots

Receptor ID	Hotspot	Location	Distance and Orientation from Project Alignment
Existing Roads Along the Alignment			
3	Clementi Road	From Ngee Ann Polytechnic to Clementi Neighbourhood Park	0 m
Utility Facilities			
4	Ngee Ann Polytechnic Substation	Along Clementi Road	240 m northwest
Agricultural / Horticultural Sites			
15	Corona Florist & Nursery Pte Ltd	On the East of Clementi Road, North of Clementi Cres	213 m west
Transport Facilities			
14	Old Railway Line	Short segment runs parallel to Clementi Road (near Corona Florist) and then intersects Clementi Road at North of Corona Florist	59 m west
Future Developments			
13	Extension of Brookvale Walk to Clementi Road	Along Clementi Road adjacent to Maju Camp	90 m west

4.3 Evaluation of Contamination Severity

4.3.1 Existing Roads within Study Area

The construction of CR2001 (including CR16 station) will involve a combination of tunnelling and cut and cover works along the alignment within the Study Area. Roads have been identified as a potential hotspot due to drips and leaks of fuel and oil from vehicles on the roads migrating over time to unpaved ground.

There is only one major road currently found within the Study Area – Clementi Road (Receptor ID: 3). Clementi Road is a major arterial road which predominantly carries traffic from one region to another and experiences heavy traffic throughout the periods of the day especially during peak hours. In addition, ERM observed from the site walkover that a proportion of traffic on this major road comprised heavy vehicles. Given the heavy traffic, there is a possibility that at some point in time, fuel leaks and spills from vehicles would have occurred. An online search also yielded a recent record of prior spills or leaks on the road in 2017 *(Lam, 2017)*.

Clementi Road was established before 1873, and was formerly known as Reformatory Road before the 1940s.

4.3.1.1 Severity of Contamination

The predicted severity of contamination present at ground underlying roads throughout the Study Area is summarised in *Table 4.3*.

Table 4.3: Existing Roads – Severity of Contamination

Component	Rating	Justification
Toxicity	Medium	The principal contaminants to the underlying soil potentially are fuel (diesel and petrol) leaks from vehicles on roads. These contaminants are known to irritate skin upon dermal contact and cause disorientation and nausea upon inhalation.

Component	Rating	Justification
		Considering the volume of diesel and petrol stored in fuel tanks of vehicles are small in volume, quantities of leaked fuel and oil entering the soil is therefore likely to be minimal. Other than a minor spill in 2017 as mentioned earlier, no other records of accident or leakage have been found. There was some news coverage around the incident as the leakage resulted in a traffic accident. The oil (covering an area of 1 m by 3 m) was cleared with a hose and chemical solvents. While death can result from extreme levels of exposure to diesel vapour, the concentration and quantities of contaminants present within soil underlying existing roads is unlikely to approach such dangerous levels. Therefore, toxicity has been evaluated as Medium.
Spatial Extent	Medium	Roads occupy a significant area within the Study Area. The abovementioned road was constructed early in history, before 1873. It is unlikely that these roads had layered asphalt surface when they were first established. Layered asphalt surfaces decreases the permeability of the road surfaces and offer underlying soil a layer of protection from potential fuel spills and leaks. Nonetheless, as these roads continue to be major roads today, they are regularly maintained. Given the footprint of the road compared to the Study Area (approximately 0.0375 km^2; 9.2% of Study Area) and the low to medium permeability of the underlying geology, the spatial extent of contamination is considered Medium.
Evaluation	**Medium**	

4.3.2 Utility Facilities

Several utility facilities are located throughout the Study Area. Electrical utility facilities, especially transformers/electrical substations which make up a majority of the utility facilities identified, have been recognized as a potential hotspot due to the possible leak of contaminants such as Polychlorinated biphenyls (PCBs). The facilities include:

- Ngee Ann Polytechnic Substation (Receptor ID: 4)

Most, if not all, of these electrical utility facilities are distribution substations as part of Singapore's electricity transmission network. As such, contractors must comply with Energy Market Authority of Singapore's (EMA) *Transmission Code* which ensures that the transmission system and equipment design meet international standards and have adequate protection against lightning strike and fire *(EMA, 2017)*.

Additionally, a review of the PUB Sewerage Information Plan (SIP) shows the presence of an existing pumping main and abandoned pumping main along Clementi Road, at the southern tip of the CR16 station. Contractors must comply with PUB's *Code of Practice on Sewerage and Sanitary Works* to ensure that all development and construction activities do not damage public sewers.

4.3.2.1 Severity of Contamination

The predicted severity of contamination present at ground underlying the utility facilities is summarised in *Table 4.4*.

Table 4.4: Utility Facilities – Severity of Contamination

Component	Rating	Justification
Toxicity	Medium	The principal contaminants to the underlying soil potentially are PCBs leaks from the utility facilities onto road/surfaces. These contaminants are known to irritate skin upon dermal contact and cause breathing difficulties and nausea upon inhalation. Long-term health effects such as cancer and liver damage can also result from extreme levels of exposure to PCBs. However, the quantities of contaminants potentially present within soil underlying existing utility facilities is not expected to approach such levels. Therefore, the toxicity of contaminants is evaluated to be Medium.
Spatial Extent	Localized	There are many electrical utility buildings found within the Study Area, in residential estates and compounds of various institutions, industrial and commercial areas. Nonetheless, the electrical utility buildings occupy only a small area within the Study Area (~ 0.1% of Study Area). Any leaks from electrical utility buildings are unlikely to enter the soil as these buildings have concrete flooring. Furthermore, the underlying geology has low to medium permeability and would constrain the spatial extent of contamination, if any. Therefore, the toxicity of contaminants is evaluated to be Localized.
Evaluation	**Low**	

4.3.3 Agricultural / Horticultural Sites

Agricultural and horticultural activities within the Study Area includes a plant nursery. Corona Florist & Nursery (ID: 15) was established in 1950, and has been in operation at the current site since then.

Agricultural and horticultural activities may adversely affect the soil environment when agrochemicals such as fertilisers and pesticides are used. Fertilisers are sources of heavy metal, such as Mercury, Cadmium, Arsenic, Lead, Copper and Nickel, and radionuclides, such as Uranium-238, Thorium and Polonium-210. Pesticide and fungicides use results in residues in soils including glyphosate and its metabolite AMPA, DDTs, fungicide boscalid, epoxiconazole and tebuconazole. Nonetheless, these contaminants are usually present in small amounts.

4.3.3.1 Severity of Contamination

The predicted severity of contamination present at ground underlying the agricultural sites is summarised in *Table 4.5*.

Table 4.5: Agricultural Sites – Severity of Contamination

Component	Rating	Justification
Toxicity	Low	The principal contaminants present in pesticides, herbicides, insecticides and fertilisers are known to irritate skin upon dermal contact and cause disorientation and nausea upon inhalation. The *Environment Protection and Management Act*, which was

Component	Rating	Justification
		passed in 1999, regulates storage, use and dealing of hazardous substances. While Corona Florist & Nursery was established since 1950, improvements in agrochemical technology and production have lowered toxicity of agrochemicals over the years. Furthermore, during the site visit, ERM observed that the Corona Florist & Nursery only houses potted plants within the compound. No planting activities on bare soil was observed. Toxicity is therefore evaluated as Low.
Spatial Extent	Low	The area occupied by the Corona Florist & Nursery is small relative to the Study Area (approximately 0.0071 km^2; 1.7% of Study Area). Furthermore, the underlying geology has low to medium permeability and would constrain the spatial extent of contamination, if any. Spatial extent is therefore evaluated to be Low.
Evaluation	**Low**	

4.3.4 Medical Facilities

Medical facilities found within the Study Area include clinics, dental clinics, veterinary clinics and nursing homes. Clinics, dental clinics and veterinary clinics are situated on the 1st storey of residential estates.

A clinic of similar scale to the ones found within the Study Area would typically store pharmaceutical products in small volume containers. The *Poisons Act* and associated rules were introduced in 1939 to regulate the importation, possession, sales, and safe handling of potent medicinal substances (poisons). It is stipulated within the Act that any storage of poison shall be in a container impervious to the poison and sufficiently stout to prevent leakage from the container arising from handling and transport. Therefore, pharmaceutical products are expected to be managed and disposed of in a responsible manner at the medical centre, such that it does not give rise to suspicion of contamination at the site.

Waste generated from health care activities includes medical equipment and devices such as used needles and syringes; soiled dressings and bedding; anatomical waste; and pharmaceutical products. This waste is potentially infectious, hazardous or radioactive and would typically be collected separately from general wastes, and contained to prevent exposure and risks to waste handlers, prior to proper treatment via incineration. Any impact to the ground due to the on-site collection and storage of medical wastes for incineration would be small in scale due to the short duration of storage.

4.3.4.1 Severity of Contamination

The predicted severity of contamination present at ground underlying the medical facilities is summarised in *Table 4.6*.

Table 4.6: Medical Facilities – Severity of Contamination

Component	Rating	Justification
Receptor ID 36, 54: Clinics, Dental Clinics and Veterinary Clinics at 1st storey of residential estates		
Toxicity	Medium	Medical waste and pharmaceutical products are known to be highly toxic contaminants that can comprise infectious waste and bio-toxic compounds. However, the scale of operations at the medical facilities appears small and hence it is unlikely to

Component	Rating	Justification
		generate large quantities of chemicals and medical waste. It is also expected that most areas within the facilities are paved. Therefore, a Medium toxicity rating is assigned.
Spatial Extent	Localized	The medical facilities' activities occur over a small footprint relative to the Study Area (< 0.1 % of Study Area). Any contamination, albeit highly unlikely, is also likely to be localized as the buildings have concrete flooring and the underlying geology has low to medium permeability. As such, the spatial extent of contamination is considered Localized.
Evaluation	**Low**	
Receptor ID 58: Nursing Home		
Toxicity	Medium	The range of pharmaceutical products stored and medical and bio-hazardous waste generated by nursing homes is anticipated to be different from those generated by small clinics located at the 1st storey of residential estates due to the different capacities and types of patients they serve. Nonetheless, these are still highly toxic contaminants. Nursing homes operate at a greater scale compared to aforementioned clinics. Therefore the volume of pharmaceutical products, medical and bio-hazardous waste and medical equipment is expected to be higher. Nevertheless, any impact to the ground due to the on-site collection and storage of medical wastes for incineration would be small in scale due to the short duration of storage. As such, the toxicity has been evaluated as Medium.
Spatial Extent	Localized	Whilst the nursing home occupies a greater geographical area compared to clinics, the nursing home activities still occur over a small footprint relative to the Study Area (< 0.1 % of Study Area). Similarly, any contamination, albeit highly unlikely, would be localized due to limited contact with soil and the low to medium permeability of underlying geology. Therefore, the spatial extent of contamination is considered Localized.
Evaluation	**Low**	

4.3.5 Transport Facilities

Based on site walkover and desktop review of historical land use, the Jurong Railway (ID: 14) was identified to be within the Study Area. Jurong Railway was developed in the late 1960s, comprising a 19.63 km track running from Bukit Timah Railway Station next to King Albert Park, through Pasir Panjang and ending at Shipyard Road. The majority of the railway track has been removed but some sections of the railway tracks are still intact, albeit rusting.

4.3.5.1 Severity of Contamination

The predicted severity of contamination present at ground underlying the transport facilities is summarised in *Table 4.7*.

Table 4.7: Transport Facilities – Severity of Contamination

Component	Rating	Justification
Receptor ID 14: Old Jurong Railway		
Toxicity	Medium	The principal contaminants to the underlying soil are potentially PAHs, PCBs, oil-derived products, pesticides and heavy metals, which are known to be contaminants with medium to high toxicity. The main source of contamination is fuel (diesel) leaks from trains onto tracks. These contaminants are known to irritate skin upon dermal contact and cause disorientation and nausea upon inhalation. Likely quantities of leak for each occasion are also expected to be small. There were no records of major spills or leaks on the Jurong Railways. While death can result from extreme levels of exposure to diesel vapour, the concentration of contaminants present within soil underlying the railway is not expected to approach such levels. Therefore, toxicity is evaluated to be Medium.
Spatial Extent	Localized	Any potential leaks from the passing trains or the railway tracks would have likely been localized due to the low to medium permeability of underlying geology and the movement of the trains. Furthermore, given the small footprint of the railways compared to the Study Area (< 5 % of Study Area for each), the spatial extent of contamination is considered Localized.
Evaluation	**Low**	

4.3.6 Future Developments

During the site walkover and from map reviews, construction areas or areas marked for future development were noted. The site boundaries of future developments identified within the Study Area are presented in *Figure 4.1*. The developments include:

- Extension of Brookvale Walk to Clementi Road (Receptor ID: 13)

The main concerns of contamination at future developments stem from:

- Existing underlying layer of contaminated fill;
- Backfilling using contaminated fill or fill of unknown origin; and
- Accidental spills and leaks of diesel, fuel, lubricants etc. to bare earth.

For sites under the purview/governance of LTA, contractors overseeing works on suspected contaminated ground are required to conduct soil testing to identify the presence of contaminants in the ground in order to prevent exposure of workers to potential health risks. This is in accordance to LTA's general specifications for safety, health and environment. Contractors are required to undertake measures to alleviate the risks where reasonably practicable, such as removal of contaminated soil from the site *(LTA, 2012)*.

In addition to LTA's specific requirements, all developers in Singapore must comply with the Building and Construction Authority's (BCA) conditions for reuse or recycling of excavated soil material which ensures that only uncontaminated soil (i.e. meets the guidelines set by the MPA), are reused for backfilling *(BCA, 2008)*.

As most of the construction works currently being carried out along the proposed Project alignment are overseen by dedicated authorities, they will be required to adhere to the relevant construction guidelines targeted at protecting the environment. Therefore, it is assumed that any areas of severe contamination would have been removed from worksites and disposed of appropriately.

Nevertheless, there is still a risk of spills and leaks of contaminants to the ground from equipment maintenance and refuelling activities. As these sites have not been paved, there is a possibility for spilled contaminants to permeate into underlying soil. The volumes spilled are however, unlikely to be large.

4.3.6.1 Severity of Contamination

The predicted severity of contamination present at ground underlying future developments is summarised in *Table 4.8*.

Table 4.8: Future Developments – Severity of Contamination

Component	Rating	Justification
Toxicity	Medium	Given the strict regulatory requirements surrounding work at contaminated areas, it is assumed that any historical areas of contamination that could impact health and safety at the sites would have been actively managed by the site contractor. The remaining source of contamination stem from spills and leaks of small quantities of fuel, lubricants and chemicals associated with equipment maintenance and refuelling on site. This mix of chemicals and quantities used are expected to be similar to the types of substances present at heavy vehicle storage areas (fuel, diesel, lubricants). These contaminants are known to irritate skin upon dermal contact and may cause serious effects on the respiratory system upon prolonged exposure at high concentrations. While death can result from extreme levels of exposure to diesel vapour, the quantities of contaminants present within soil underlying these sites is unlikely to approach such levels. Hence, a Medium toxicity rating has been assigned.
Spatial Extent	Medium	The footprint of these construction sites are small relative to the Study Area (< 5 % of Study Area for each site). Given the quantities of contaminants are small, they are unlikely to affect a large area of underlying soil. Furthermore, the underlying geology has low to medium permeability. However, considering that these construction sites are sited on bare, unlined earth, this study will adopt a conservative approach that potentially repeated spills of small quantities of contaminants may not be constrained to a localized area.

Component	Rating	Justification
		Therefore, the spatial extent of contamination is evaluated to be Medium.
Evaluation	**Medium**	

4.3.7 Summary

Table 4.9 summarises the predicted severity of contamination for each hotspot identified from the HLUS. Note that the severity was developed based on two components of analysis – estimated toxicity of contaminant and likely spatial extent of contamination, if present.

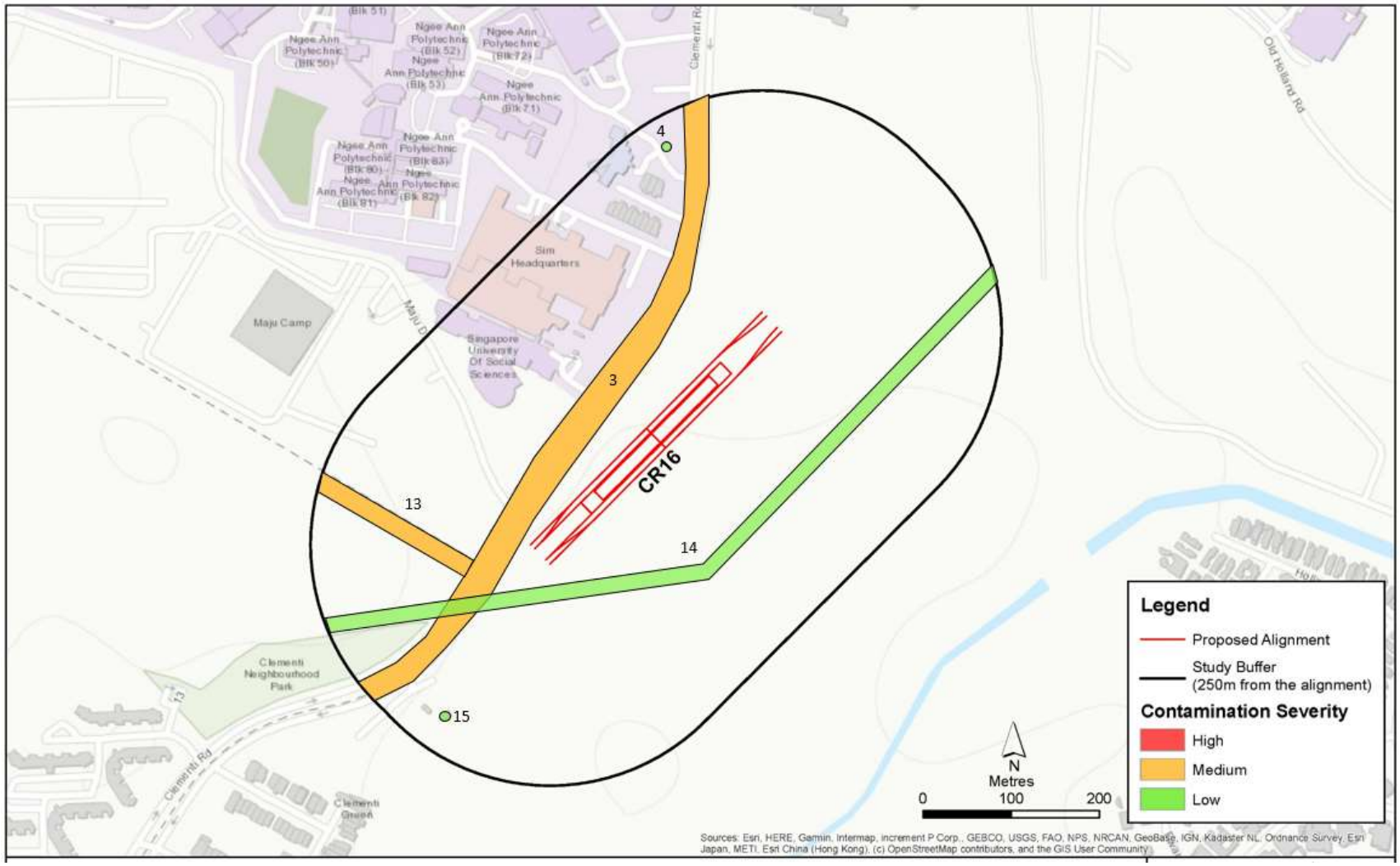
Figure 4.1 presents all hotspots discussed above and their corresponding contamination severity rating.

Table 4.9: Contamination Severity at Hotspots

Receptor ID	Hotspot	Source of Contamination	Toxicity	Spatial Extent	Severity of Contamination
Existing Roads					
3	Clementi Road	Accidental spills and leaks of fuel from passing vehicles	Medium	Medium	Medium
Utility Facilities					
4	Ngee Ann Polytechnic Substation	Accidental leaks of fuels and chemicals onto unpaved surfaces	Medium	Localised	Low
Agricultural / Horticultural Sites					
15	Corona Florist & Nursery Pte Ltd	Discharge of pesticides/fertilizers (chemicals and heavy metals) onto unpaved surfaces	Low	Localised	Low
Transport Facilities					
14	Old Jurong Railway	Accidental spills and leaks of fuel from passing trains	Medium	Localised	Low
Future Developments (Ongoing Construction)					
13	Extension of Brookvale Walk to Clementi Road	Accidental spills and leaks of fuel and chemicals during construction	Medium	Medium	Medium

Note:
It is to be noted that the permeability of the underlying soil at the sites has not been measured and are estimates based on available soil investigation reports and description of the soil types.

Figure 4.1: Hotspots and Contamination Severity



4.4 Buried Structures, Objects & UXO

The scope of this report includes the identification, based on the available information, of potential buried structures or features that the Project will need to be aware of prior to excavation works. Structures or features may include, building piling, human remains or unexploded ordnance (UXO).

4.4.1 Evaluation

4.4.1.1 Buried Structures & Objects

The project involves tunneling beneath existing establishments. This increases the likelihood of encountering buried structures or features. However, tunneling typically occurs at a depth that avoids existing buried structures such as building foundations.

It is unclear at the time of writing which areas or buildings will be demolished as part of the Project; however it is assumed that any buried foundations and piling associated with these structures will be cleared as part of the Project.

A review of the historical maps did not identify any historical building with potential buried structures from demolition works. However, a review of the PUB sewerage information plan for the area showed the presence of an existing pumping main and abandoned pumping main along Clementi Road. These buried PUB utilities will be in close proximity to the southern corner of the proposed CR16 station. Abandoned pumping mains are typically sealed with cement mortar, in accordance with PUB's *Code of Practice on Sewerage and Sanitary Works*.

4.4.1.2 Buried UXO

Based on a review of online sources, Singapore was bombed twice during World War II – once in 1941 by the Japanese and then in 1945 by the American forces. It appears that aerial attacks targeted key military facilities and did not target the Clementi area. However, it is likely that there were heavy fighting as the Japanese advanced towards the City via the Reformatory Road (presently Clementi Road). Furthermore, a WWII bomb relic was recently found at a construction site near the junction of Clementi Road and Commonwealth Avenue West in 2009 *(Liew, 2009)*, less than 1 km from the CR16 Station but outside the Study Area. Given the documented bomb relics and extensive military use of the site since early 20th century, there remains a potential to encounter isolated examples of UXO and potential presence of smaller UXO (e.g. unexploded hand grenades) within the Study Area.

Based on the secondary data review undertaken for this HLUS, the Project Site may have associated buried such as UXO in view of wartime bombing and extensive military use throughout history.

5. CONCLUSIONS & RECOMMENDATIONS

A summary of the HLUS findings is presented in this Chapter along with recommended actions targeted at managing environmental and human health risks during construction.

5.1 Summary of HLUS Findings

5.1.1 Methodology

The current and historical land use within the Study Area was informed through a desktop review of the following resources:

- Singapore street directories, dating between 1954 and 2009, downloaded from Historical OneMap (http://hm.onemap.sg/);
- Topological maps dating between 1914 and 2005, obtained from the Geographic Information Systems (GIS) Map Resource Unit of the National University of Singapore (NUS);
- Historical maps obtained online from the National Archives of Singapore (http://www.nas.gov.sg/archivesonline/);
- Historical aerial photographs obtained from Google Earth Pro 7.1.2.2041;
- PUB sewerage information plan purchased for the area;
- Online resources chronicling the histories of particular landmarks/ localities such as the National Library Board's (NLB) Infopedia, historical blogs etc.; and
- Geology of Singapore, published by the Defence Science and Technology Agency (DSTA).

A site walkover was conducted through the Study Area on 14 February 2020 to verify current land use.

The historical and current land use informed the identification of areas of potential contamination within the Study Area. A contamination severity ranking was developed, with contamination severity determined based on a combination of the anticipated toxicity of contaminants and spatial extent of contamination.

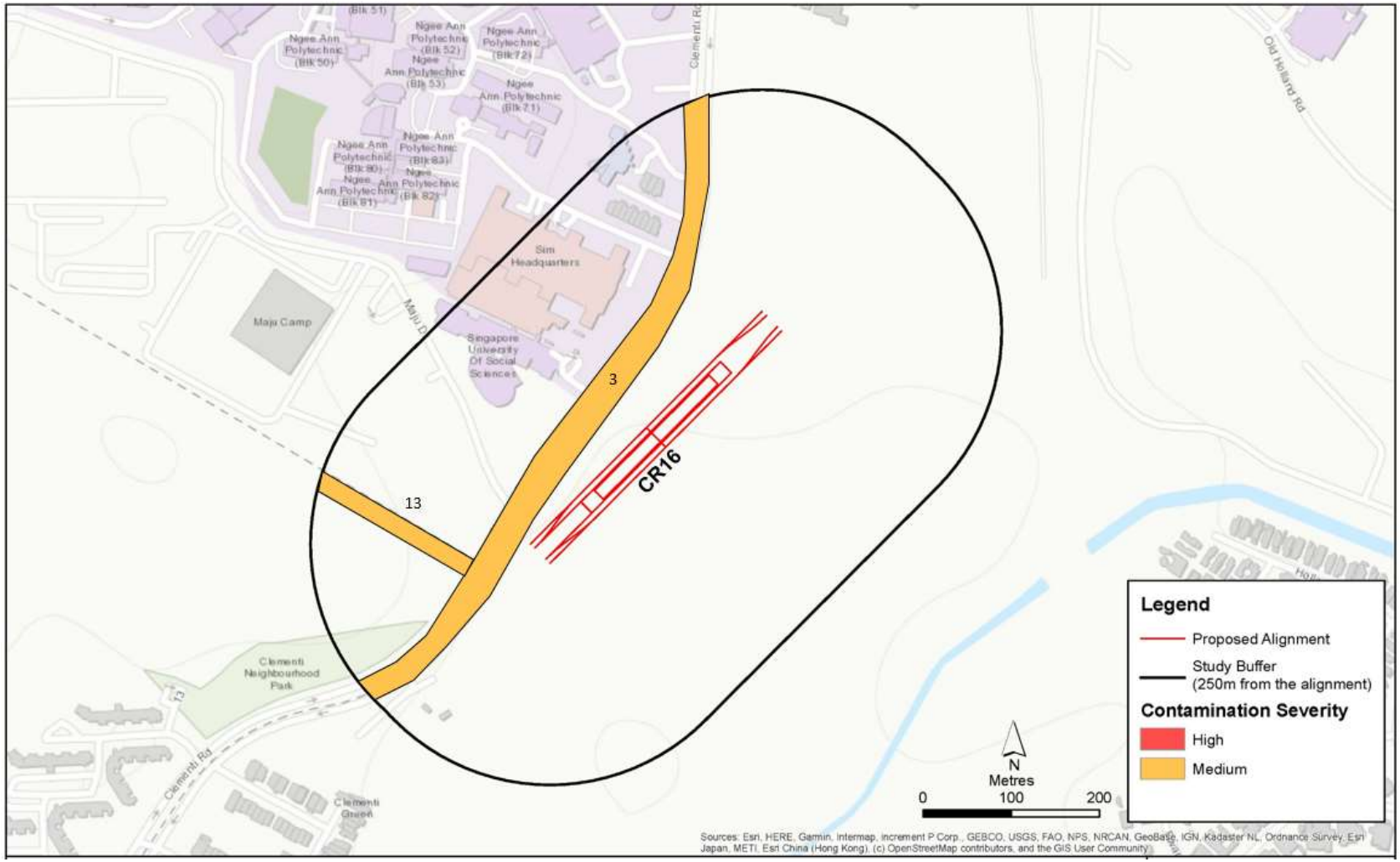
5.1.2 Findings

A summary of land use hotspots with a *Medium* and *High* contamination severity ranking is presented in *Table 5.1*. The locations of these hotspots within the Study Area are presented in *Figure 5.1*.

Table 5.1: Land Use Hotspots

Receptor ID	Hotspot	Source of Contamination	Toxicity	Spatial Extent	Severity of Contamination
Future Developments (Ongoing Construction)					
3	Clementi Road	Accidental spills and leaks of fuel from passing vehicles	Medium	Medium	Medium
13	Extension of Brookvale Walk to Clementi Road	Accidental spills and leaks of fuel and chemicals during construction	Medium	Medium	Medium

Figure 5.1: Hotspots within Study Area



5.2 Spoil Disposal Options

Excavation of material during construction of CR2001 will likely involve the initial segregation of materials in the following categories:

- Tarmac / concrete;
- Fill material;
- Kallang Formation;
- Jurong Formation; and
- Bukit Timah Granite.

The excavated material will likely be disposed of via the following disposal routes:

- Recycling, for example as backfill, soil stabilisation, grouting works or road construction;
- Disposal at offshore disposal sites and land reclamation sites; and
- Treatment and disposal via a licensed toxic industrial waste (TIW) contractor.

The disposal options presented above are governed by various authorities and subject to guidelines and/or international regulatory standards.

5.2.1 Building and Construction Authority (BCA) Guidelines

BCA has published a guide to the use of recycled materials as part of their Sustainable Construction series. This document contains a set of guidelines for the management and disposal of excavated materials which will be relevant to the Project.

Excavated good earth and soft clay may be disposed at designated areas for future use as reclamation material. In general, good earth is defined as a mixture of coarse-grained and fine-grained soil, while soft clay comprises of Kallang Formation soils and marine clay. Soft clay may also be used for backfilling, soil erosion control and slope stabilisation after it has been processed into a suitable material (*BCA, 2008*).

In instances where excavated material is suspected to be contaminated[1], the heavy metal concentrations must be confirmed to fall below MPA-specified limits prior to recycling (*Table 5.2*). Contaminated materials that meet MPA guidelines for heavy metal content can be manufactured into ceramic aggregates for future use. The MPA limits are as follows:

Table 5.2: MPA Guidelines for Dumping of Materials at MPA managed sites

S/N	Contaminants	Limit in mg/kg dry weight
1	Arsenic	30
2	Copper	55
3	Cadmium	1
4	Chromium	50
5	Lead	65
6	Mercury	0.8
7	Zinc	150
8	Nickel	35

[1] Defined as any excavated earth or dredged materials that contain amounts of any of the contaminants listed in the guidelines on metal content given by the Maritime and Port Authority of Singapore. These include chromium, nickel, copper, zinc, arsenic, cadmium, mercury and lead.

It is noted that soil which does not meet the MPA guidelines for heavy metal content is categorised as contaminated material, and cannot be recycled until proper treatment to ensure levels of contaminants are within acceptable limits.

5.2.2 Maritime and Port Authority (MPA) Guidelines

Approval from MPA must be obtained prior to the disposal of land-based excavated material at offshore disposal or land reclamation sites. The approval is based on whether the heavy metal content of the material falls within MPA guidelines (*Table 5.2*). As part of the submissions for approval, the contractor is also required to (i) conduct spoil sampling, (ii) undertake in-situ grid sampling surveys and (iii) soil chemical testing prior to excavation and submission of spoil quality manifests *(MPA, 2014).*

If excavated material contains heavy metals above the stipulated limit, it will not be accepted for disposal at land reclamation sites. In these instances, MPA recommends that the contractor approach companies with the technology and capacity to treat the materials for recycling purposes.

5.3 Recommendations

5.3.1 Minimising Exposure Risk to Construction Workers

The main pathways of contaminants to humans are typically through inhalation of vapours, dermal contact and accidental ingestion. Therefore, it is recommended that equipment such as a gamma meter and a photoionization detector (PID) be used to periodically measure the presence of radioactive materials and volatiles during any excavation work. Appropriate personal protective equipment (PPE), including gloves and respirators, should also be supplied to construction workers.

Visual and olfactory inspections of the excavation worksite should also be undertaken throughout the construction phase to detect potential contamination. Work should be stopped upon detection of contamination. All construction workers should receive appropriate training in this area. Good personal hygiene practices should also be taught and enforced to minimise dermal contact, inhalation and accidental ingestion of any contamination.

A project specific Spoil Management and Disposal Plan should be developed prior to commencement of the construction work. This Plan will flesh out the abovementioned procedures in greater detail and assign roles and responsibilities to key staff on site.

5.3.2 Determining Soil Quality for Appropriate Disposal

Based on an understanding of the disposal pathways of excavated material in Singapore and the types of spoil the Project is likely to generate, the following is expected of the Project:

- Materials such as tarmac and concrete materials will likely be sold to licensed collectors for recycling and reused in other construction sites outside the Study Area.
- For excavated materials that are contaminated, the Project would be required to undertake a heavy metal test on the spoil before deciding if these can be manufactured into ceramic aggregates or a specialist recycling company engaged[2].
- For excavated good earth and soft clay, they may be disposed of at designated areas for further use as reclamation material. These may also be subjected to chemical tests if they are to be disposed of at MPA managed sites.

A number of hotspots have been identified within the Study Area that could have been sources of contamination to the underlying soil. In view of the (i) criteria for acceptance of excavated soil at

[2] Based on the BCA's Guide on the Use of Recycled Materials

MPA-managed sites and (ii) eventual need to undertake a heavy metal test on spoil to determine its mode of disposal, it is recommended that the Project:

- Analyse soil investigation data for soil underlying the proposed alignment, as available from geotechnical soil investigation work and surrounding roadworks; and
- Undertake a targeted Phase II Environmental Borehole Investigation to determine if the land use hotspots have impacted the material to be excavated and the risk of construction worker exposure from any contamination identified at these land use hotspots.

5.3.2.1 Analysis of Soil Sampling Data

The construction of CR2001 will likely involve a geotechnical soil investigation phase. Chemical testing of soil from drilled cores can be conducted in parallel with the soil investigation works, with a particular focus on areas that are suspected to be of Medium to High contamination severity.

There are several LTA-run projects within the Study Area that would have also conducted their own soil investigation or spoil sampling. The data from these projects could be used to further inform the spoil quality and inform the disposal process for spoil generated from CR2001.

5.3.2.2 Targeted Phase II Environmental Borehole Investigation

As outlined in the Project Terms of Reference (ToR), a HLUS is an initial step in determining potential soil quality in the project area. To assess the land use hotspots identified in this HLUS further, a targeted Phase II Environmental Investigation could be undertaken. Given the existence of local guidelines on soil and groundwater investigation, ERM recommends that both the JTC's *Guideline on Environmental Baseline Study (EBS) (2019 Edition) (JTC, 2019)* and Singapore Land Authority's (SLA's) *Environmental Site Assessment Guidelines for State Land (2nd Edition)* (SLA, 2018) be used as reference for the drilling and sampling methodology adopted for the targeted Phase II.

Table 5.3 below presents the possible contaminants of concern (CoC) from the Areas of Potential Concern described in JTC's *EBS Guideline*:

Table 5.3: Type of Industry and Possible CoCs

Area of Potential Concern	Possible CoCs
Future Development (on-going construction)	TPH, heavy metals, solvents, volatile organic compound (VOCs) and semi volatile organic compound (SVOCs) and specific chemicals relevant to the facilities' operations

**The above listed chemicals are some typical contaminants of concern; the list is not exhaustive.*

In the event of suspected contaminated soil, the responsible parties (e.g. the contractor) are advised to refer to the Netherlands Soil Remediation Circular (Rijkswaterstaat Environment, 2013), which is referenced in JTC's *EBS Guideline* for the list of testing parameters. If the testing indicates that the site is contaminated, a Site Assessment Study and Remediation of Contaminated Site Plan shall be conducted as per SS 593: *2013 Code of Practice for Pollution Control* Section 7 on Control of Land Pollution and Remediation of Contaminated Sites and in accordance to JTC's *EBS Guideline*.

Recommended areas where boreholes should be selected are where soil will likely be excavated for the Project (i.e. cut and cover locations for station footprints); in general proximity of the land use hotspot identified; in accordance with the minimum borehole number required by the SLA (2018) and where there are no known physical access restrictions. The marking out of areas for further investigation should consider the presence of existing utilities or permitting restrictions. At the time of writing, information on the Project worksites (with the exception of station locations) and presence of utilities or critical infrastructure was not available.

A very high-level recommendation of borehole locations, intervals and depths of soil and groundwater sampling has therefore been undertaken, on the basis of SLA's guidelines. These are summarised in

Annex E. Exact borehole locations should be reviewed once further Project details and information on underground utilities and critical infrastructure are available. In addition, should information around localised groundwater flow direction be made available, the locations of boreholes should be adjusted to allow the placement of boreholes in the hydraulic up and down gradient of the proposed cut-and-cover area.

It should be noted that the targeted Phase II investigation is only designed to assess potential impact to the soil due to the identified land use hotspots. It will not determine the overall quality of soil along the alignment which may require disposal from the CR2001 construction and tunnelling works. In the event the Project wishes to dispose of spoil via land reclamation for instance, more detailed soil investigation has to be undertaken at the sampling intervals and depths as stipulated in MPA's guidelines. A sampling plan must be submitted to and approved by the MPA prior to commencement of sampling.

5.4 Groundwater Disposal

It is noted that although the focus of this study is the historical land use and associated impacts to spoil which will be excavated as part of the works, impact to groundwater should also be considered.

In the event of groundwater discharge being required, groundwater quality assessments will be required to assess the composition for appropriate disposal, e.g. in the case of disposal to storm water drains, the groundwater quality will need to comply with the requirements of the *Environmental Protection and Management (Trade Effluent) Regulations* for controlled watercourses, and the Public Utilities Board's (PUB) *Code of Practice on Surface Water Drainage*. Depending on the concentrations measured, groundwater treatment may be required on site or by a third party to reduce levels to within acceptable limits prior to discharge.

5.5 Underground Structures & Features

5.5.1 Objects of Cultural Value

Should historical artefacts be encountered during excavation works, the National Heritage Board (NHB) should be contacted to determine the need for a formal archaeological excavation. It is recommended that in the event that such sites are encountered, excavation works should be stopped and the appropriate local agencies be contacted. Such a process should be incorporated in a Cultural Heritage Chance Find Procedure within the Construction Environmental Management Plan for the Project. In the unlikely event that human remains are encountered during excavation works, the NEA should be contacted to undertake the process of exhumation.

5.5.2 Buried UXO

In view of the history of the area, it is recommended that the Project consider engaging specialists to undertake UXO detection surveys, prior to excavation works within the whole Study Area to safeguard against risks associated with unexploded ordnance.

Notwithstanding the above, it is also recommended that a UXO Chance Find Procedure be developed and incorporated within the emergency response plan for the project, detailing the steps to be taken in the event that suspected UXO (e.g. WWII Ordnance) are encountered during the construction works, to facilitate prompt, efficient and appropriate responses to such an event.

5.5.3 Buried Structures

Given the unknown nature of the subsurface characteristics in some areas along the proposed alignment, it is recommended that best management practices be adopted during the initial excavation stage of the Project to ascertain the presence of any historical ground structures, including the abandoned pumping main along Clementi Road. This may involve developing a subsurface clearance plan for these areas that will be implemented prior to excavation. This subsurface

clearance plan should include procedures to use a ground penetrating radar (GPR) or similar device, as appropriate, to scan key areas of concern and highlight any buried structures.

5.6 Results of Phase II Environmental Borehole Investigation

5.6.1 Background and scope undertaken

Between January and February 2021, an Environmental Baseline Study (EBS) was undertaken by Singapore Environmental Consultancy and Solutions Pte Ltd (SECS), who acted on behalf of Kwang Sing Engineering Pte Ltd. (KSE) (Report reference: LTA/WSO-GTT-GTT-C1066-00024 (Draft Report)). KSE was engaged by LTA to carry out Site Investigation Works for CONTRACT C1066 SITE INVESTIGATION WORKS FOR LTA PROJECTS WSO-GTTGTT- C1066-00024 Site Investigation Works from Tuas to Changi (1W91) – the EBS report can be referred to in *Annex F*.

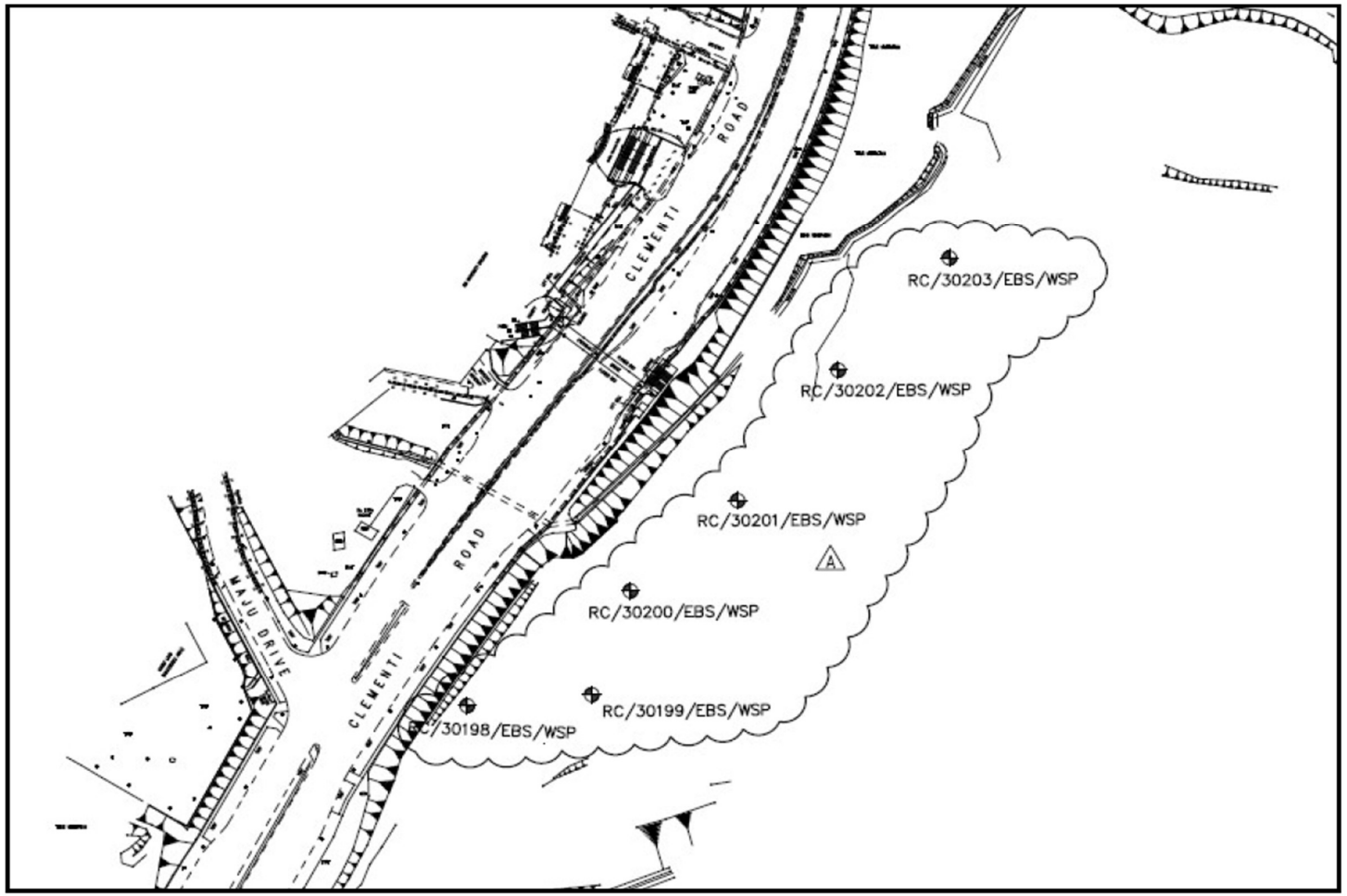
As part of the EBS, the following key scope of work were undertaken:

- Drilling of six boreholes for the collection of soil samples
- Completion of these boreholes as groundwater monitoring wells for the collection of groundwater samples.
- Submission of 26 soil samples and 7 sets of groundwater samples to the laboratory inclusive of two soil duplicates and one groundwater duplicate for analysis in accordance to the analytical suite detailed in Table 1 of the 2013 Netherlands Soil Remediation Circular with the exception of organotin compounds and extractable organic halogens. It was noted that in addition to the parameters within the Dutch Standards (as per stated in Annex E – Borehole Sampling Recommendations), the collected groundwater samples were also analysed for the following parameters:
  - Organic matter (total nitrogen, total phosphorus, faecal coliform) by APHA – 4500 (J) and APHA 9222D
  - Heavy metal (manganese, vanadium) by APHA 3120B
  - Chloride contents – soil only by BS1377 Pt 3
  - Sulphate contents – soil only by BS1377 Pt 3
  - List of parameters listed in the NEA allowable limits for trade effluent discharge to Watercourse or Controlled Watercourse
  - List of parameters listed in the PUB allowable limits for trade effluent discharge to Public Sewer

  In line with the purpose of this HLUS and recommendations stated in Annex E, only the laboratory analytical results for relevant parameters under the 2013 Dutch Standards suite have been reviewed.

Figure 5.2 shows the location of the boreholes and monitoring wells.

Figure 5.2: Locations of Boreholes and Monitoring Wells



Source: LTA/WSO-GTT-GTT-C1066-00024 (Draft Report)

5.6.2 Site observations

5.6.2.1 Geology

Based on the bore logs of the six boreholes, fill materials (predominantly firm, slightly Sandy SILT with rootlets) were encountered from ground surface to 1.20m bgl. Underlying the fill material were mainly stiff to very stiff slight sandy silt, and stiff to very stiff slightly sandy silt.

5.6.2.2 Hydrogeology

The static water table were measured at depths ranging from 1.31m to 6.37m bgl, or from reduced elevations of 113.24 to 121.26 m RL (relative level, based on Singapore Height Datum with mean sea level set at 100.000 m elevation). The predominant groundwater flow direction was reported to be towards northwards.

5.6.3 Results

The results from the laboratory analysis of collected soil and groundwater samples were compared against the Dutch Intervention Values (DIV) as listed in the 2013 Netherlands Soil Remediation Circular.

The Dutch guidelines are internationally recognised and widely used both locally in Singapore and internationally as guidance level for assessing the potential for impact in soil and groundwater. The DIV is used a screening concentration to indicate the environmental quality level above which the maximum allowable risks of adverse effects on humans and the environment are considered potentially unacceptable.

As stated in the JTC Guideline on EBS (2019 Edition) and SLA Environmental Site Assessment Guidelines for State Land (2nd Edition), concentrations of contaminants present at the site should be compared against DIVs where appropriate. In cases where concentrations exceeded DIVs, initial risk assessment would be required.

No exceedances of the DIVs for all tested parameters were reported in the analysis report of the collected soil and groundwater samples.

5.6.4 Conclusion

Based on the results of the environmental assessment, potential impact to the soil due to the identified land use hotspots is likely to be minimal. It should be noted that due to the limited number of boreholes and samples, this environmental investigate does not determine the overall quality of soil along the alignment which may require disposal from the CR2001 construction and tunnelling works. Recommendations stated in *Section 5.3* on identification of impacted soil, protection of construction workers and the development of a Spoil Management and Disposal Plan should still be considered. In the event the Project wishes to dispose of spoil via land reclamation for instance, requirements stated in Section 5.2 should be considered and followed.

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ANNEX A LIST OF CURRENT LAND USE

ANNEX A: CURRENT LAND USES IDENTIFIED WITHIN STUDY AREA

Receptor ID	Land Use	Section of Alignment	Land Use Type	Shortest Distance from Alignment	No. of Storeys	Land Use Description
1	Forested Area to the East of Clementi Road	Clementi Road	Open Space (Note 1)	0.0	NA	Huge patch of forested area that extends from Clementi Road to Holland Link to the East and Ulu Pandan Road to the South.
2	Drain outlet from Ngee Ann Polytechnic through Forested Area	Clementi Road	Waterbody (Note 1)	142.3	NA	Drainage from under Ngee Ann Polytechnic into forest next to Clementi Road. Very large capacity, steady slow stream into stagnant pool in forest
3	Clementi Road (Road)	Clementi Road	Road	0.0	NA	A dual four-lane road that starts at Bukit Timah Road and ends at West Coast Highway. Observed with heavy traffic.
4	Ngee Ann Polytechnic Substation	Clementi Road	Utility (Note 1)	240.4	2	Electrical substation within Ngee Ann Polytechnic
5	Rosedale Terrace Houses (479-501 Clementi Road)	Clementi Road	Residential	145.4	3	Private property, main windows not pointed towards alignment, slightly elevated land.
6	Children's Aid Society (Melrose)	Clementi Road	Civic & Community Institution	221.4	2	Private property, elevated land, open windows towards alignment.
7	Overhead Bridge across Clementi Road	Clementi Road	Road	29.5	NA	Bridge from SUSS across Clementi Road.
8	Singapore Institute of Management	Clementi Road	Educational Institution	107.6	4	University
9	Canal between SUSS and Unused Site (ID: 15)	Clementi Road	Waterbody (Note 1)	92.2	NA	Small stagnant stream
10	Unused Site	Clementi Road	Unused Site	107.6	1	Zinc-roof establishment with overgrown grasses within the facility. Low fences are observed to surround the facility.
11	Singapore University of Social Sciences (SUSS)	Clementi Road	Educational Institution	97.8	10	University established since 2017.
12	Singapore Armed Forces (SAF) Maju Camp	Clementi Road	Special Use	99.6	NA	Military camp
13	Construction Site next to Maju Camp	Clementi Road	Future Development (Note 1)	90.0	NA	Purpose unclear; likely for the extension of Brookvale Walk to the South of Maju Camp.
14	Old Railway Line	Clementi Road	Unused Site	59.0	NA	Abandoned railway tracks emerging from under Clementi Road leading into forest. Tracks wrapped in vegetation.
15	Corona Florist & Nursery Pte Ltd	Clementi Road	Agriculture (Note 1)	213.0	1	A commercial development specialising in landscaping needs, from design through to implementation. On extremely elevated land, right above alignment, right next to forest.
16	Clementi Neighbourhood Park	Clementi Road	Park	240.0	NA	A small park on elevated land right next to forest, with a fitness corner undergoing construction and slated for completion by 2Q2020.
17	Forested Area to the West of Clementi Neighbourhood Park	Clementi Road	Reserve Site	114.0	NA	Forested area that is bounded by the Clementi Neighbourhood Park and SAF Maju Camp.

NOTE 1: Categorised based on site observation as land use was not indicated/inaccurate on URA Masterplan 2014.

ANNEX B PHOTOGRAPH LOG

Annex B - Photograph Log

Photo 7*:*
Forested Area to the East of Clementi Road (ID: 1)

Photo 8*:*
Canal from Ngee Ann Polytechnic through Forested Area (ID: 2)

Photo 9*:*
Clementi Road (ID: 3)

Photo 10*:*
Ngee Ann Polytechnic Substation (ID: 4)

Photo 11*:*
Rosedale Terrace Houses (479-501 Clementi Road) (ID: 5)

Photo 12:
Children's Aid Society (Melrose) (ID: 6)

Project: CR2001 HLUS

Client : Arup Singapore Pte Ltd

ERM

Annex B - Photograph Log

Photo 13*:*
Overhead Bridge across Clementi Road (ID: 7)

Photo 14*:*
Singapore Institute of Management HQ (ID: 8)

Photo 15*:*
Drain between SUSS and Private Property (ID: 9)

Photo 16*:*
Unused Site (ID: 10)

Photo 17*:*
Singapore University of Social Sciences (SUSS) (ID: 11)

Photo 18:
Construction Site next to Maju Camp (ID: 13)

Project: CR2001 HLUS

Client : Arup Singapore Pte Ltd

ERM

Annex B - Photograph Log

Photo 19*:*
Old Railway Line (ID: 14)

Photo 20*:*
Corona Florist & Nursery Pte Ltd (ID: 15)

Photo 21*:*
Corona Florist & Nursery Pte Ltd (ID: 15)

Photo 22*:*
Corona Florist & Nursery Pte Ltd (ID: 15)

Photo 23:
Clementi Neighbourhood Park (ID: 16)

Photo 24:
Clementi Neighbourhood Park (ID: 16)

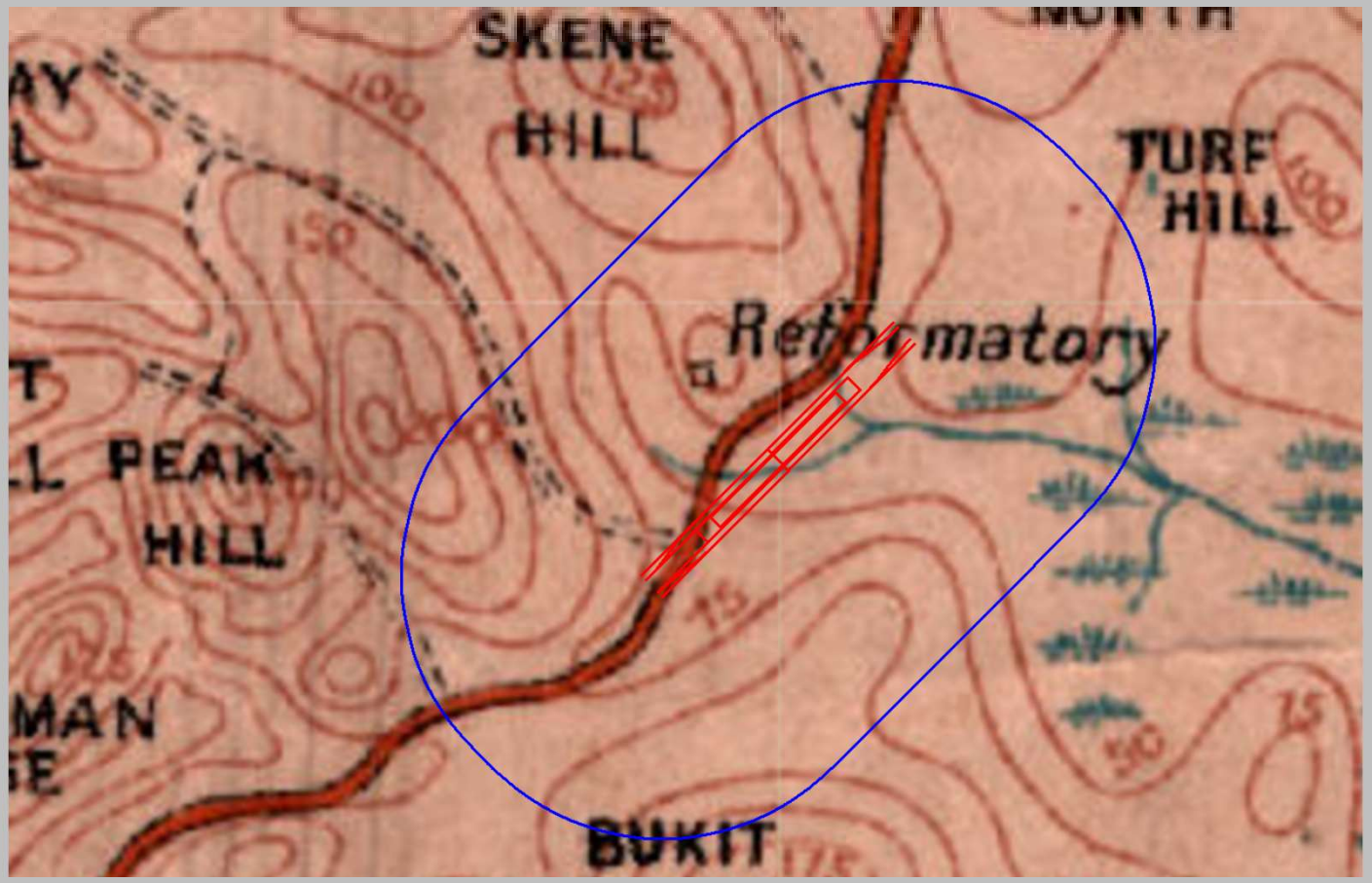
Project: CR2001 HLUS

Client : Arup Singapore Pte Ltd

ERM

ANNEX C HISTORICAL MAPS

Figure C-1



Legend

250 m from Alignment

CR2001 Alignment

Source

Topographical Map 1914, NUS Geography. https://libmaps.nus.edu.sg/

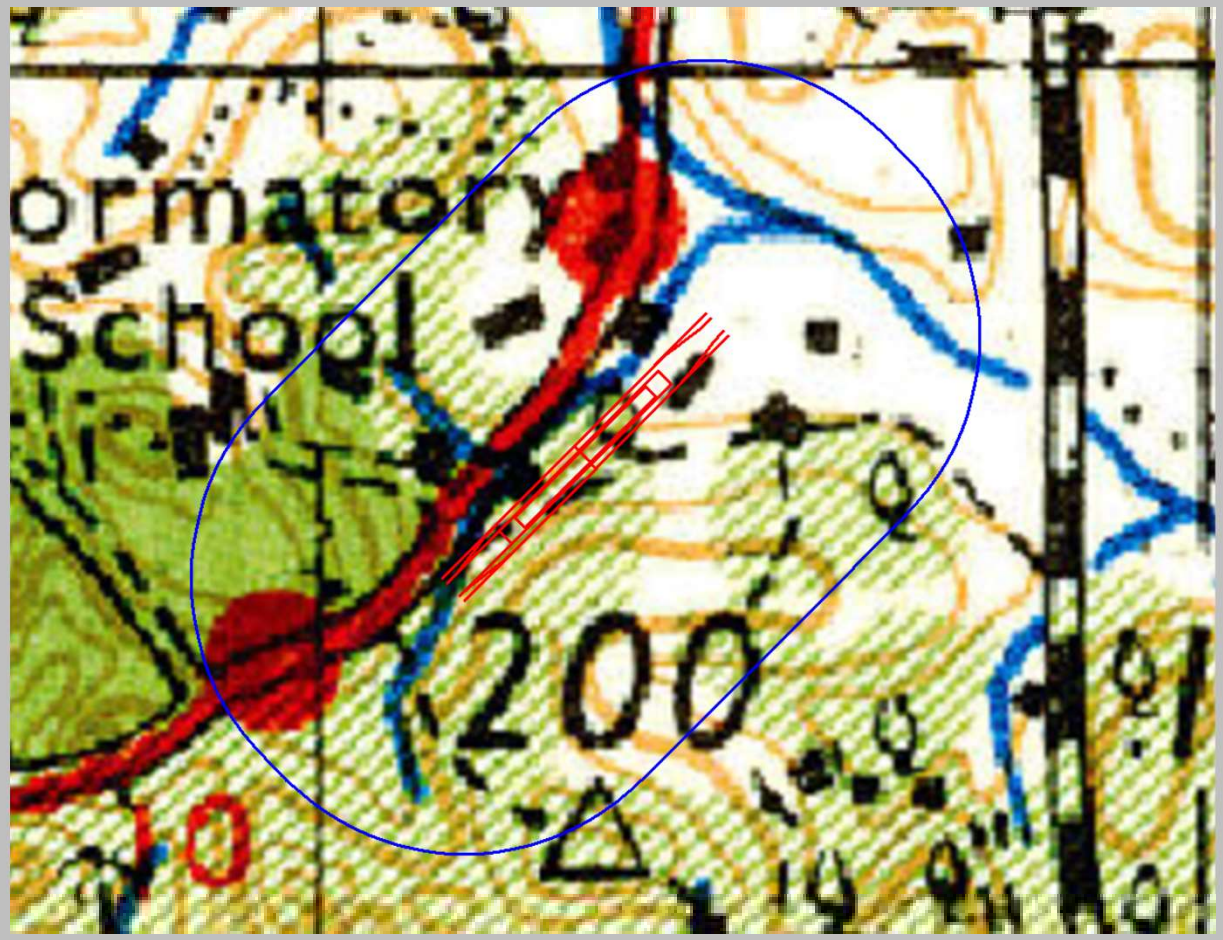
Note: Map shows approximate location of study area.

1914

Overview

- **Natural Features:** Hilly Area, with some swampy areas at low elevation
- **Roads:** Reformatory Road (presently Clementi Road) was already present by 1914

Figure C-2



Legend

250 m from Alignment

CR2001 Alignment

Source

Topographical Map 1945, NUS Geography. https://libmaps.nus.edu.sg/

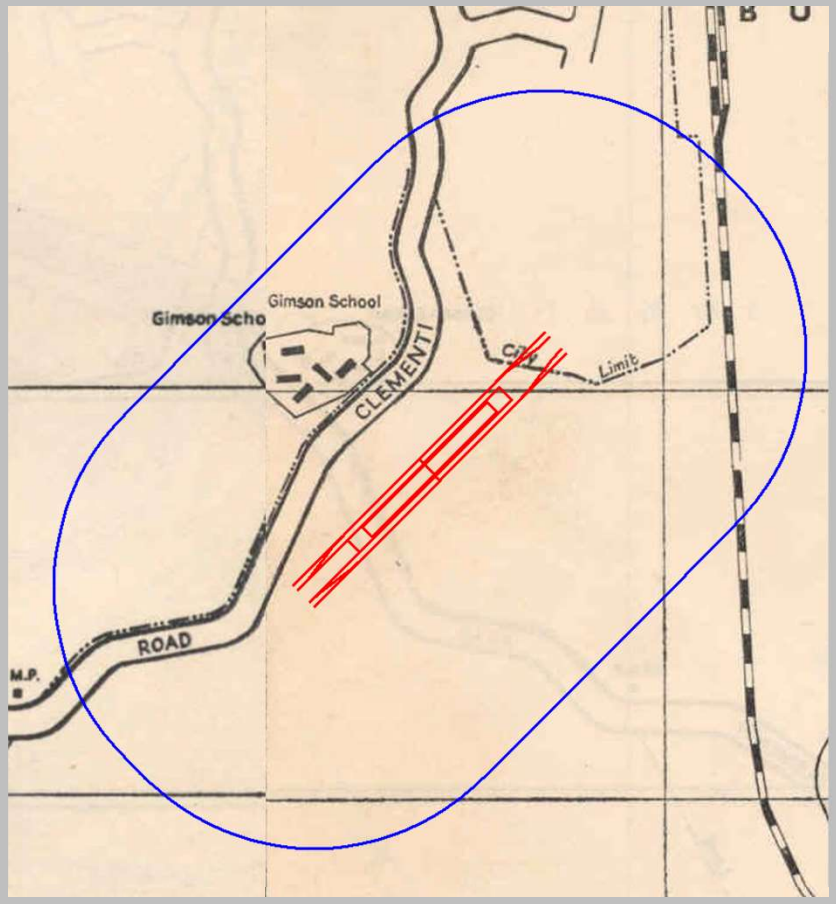
Note: Map shows approximate location of study area.

1945

Overview

- **Civic & Community Institutions:** Reformatory School
- **Natural Features:** Still generally Hilly Area
- **Agriculture:** Tree Cultivation, Rubber Plantation

Figure C-3



Legend

250 m from Alignment

CR2001 Alignment

Source

Historical OneMap, 1958, Street Directory. Downloaded from http://hm.onemap.sg/

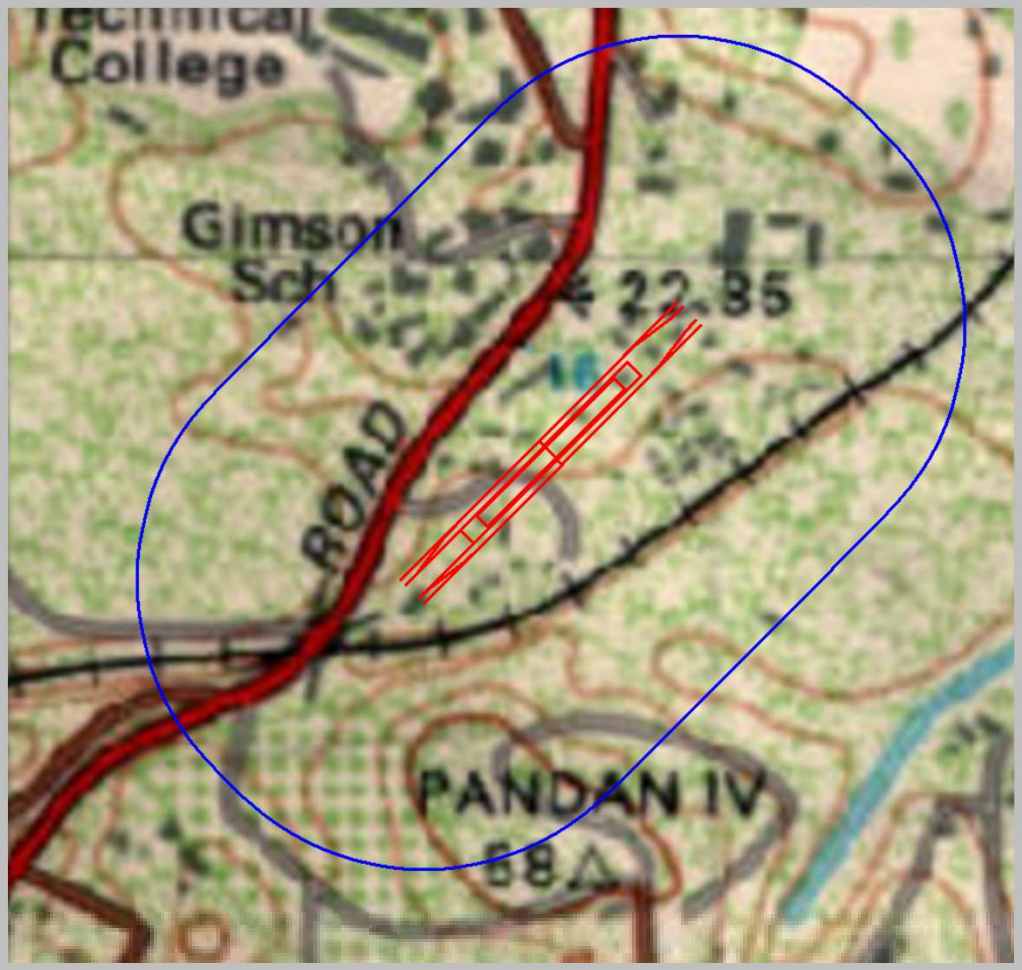
Note: Map shows approximate location of study area.

1958

Overview

- **Civic & Community Institutions:** Reformatory School renamed as Gimson School

Figure C-4



Legend

250 m from Alignment

CR2001 Alignment

Source

Topographical Map 1975, NUS Geography. https://libmaps.nus.edu.sg/

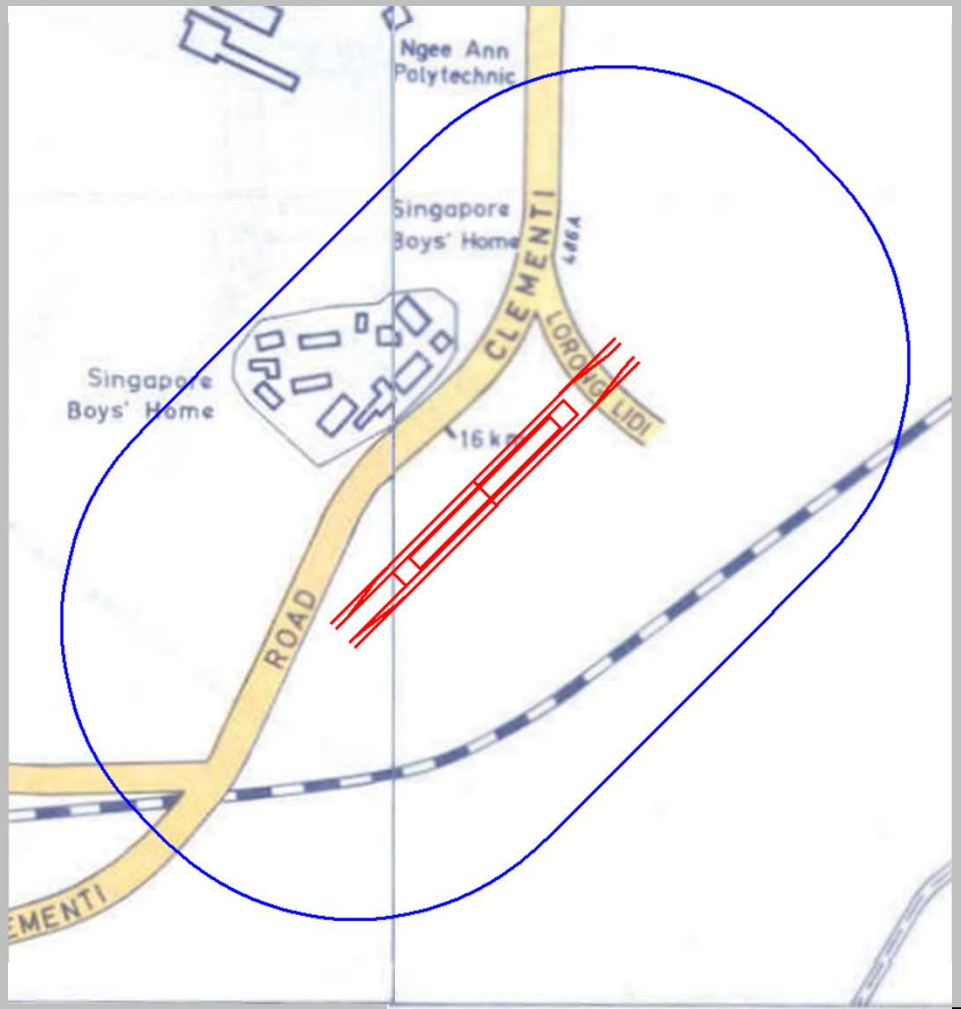
Note: Map shows approximate location of study area.

1975

Overview

- **Agriculture:** Sundry Tree Cultivation (including Clementi Park), Minor Cultivation
- **Civic & Community Institutions:** Gimson School
- **Educational Institutions:** Ngee Ann Technical College (presently Ngee Ann Polytechnic)
- **Roads**: Clementi Road

Figure C-5



Legend

250 m from Alignment

CR2001 Alignment

Source

Historical OneMap, 1984, Street Directory. Downloaded from http://hm.onemap.sg/

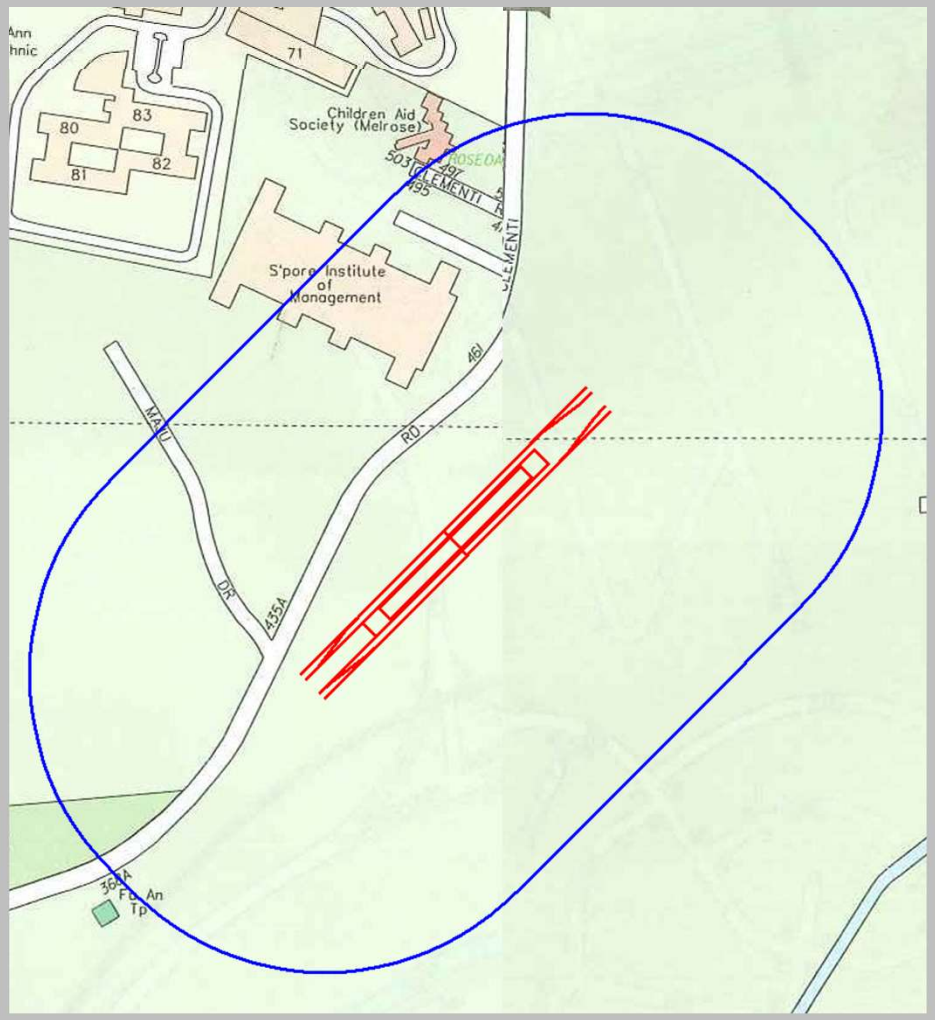
Note: Map shows approximate location of study area.

1984

Overview

- **Civic & Community Institutions:** Gimson School renamed as Singapore Boys' Home (by 1981)
- **Educational Institutions:** Ngee Ann Technical College renamed as Ngee Ann Polytechnic

Figure C-7



Source
Historical OneMap, 2000, Street Directory. Downloaded from http://hm.onemap.sg/

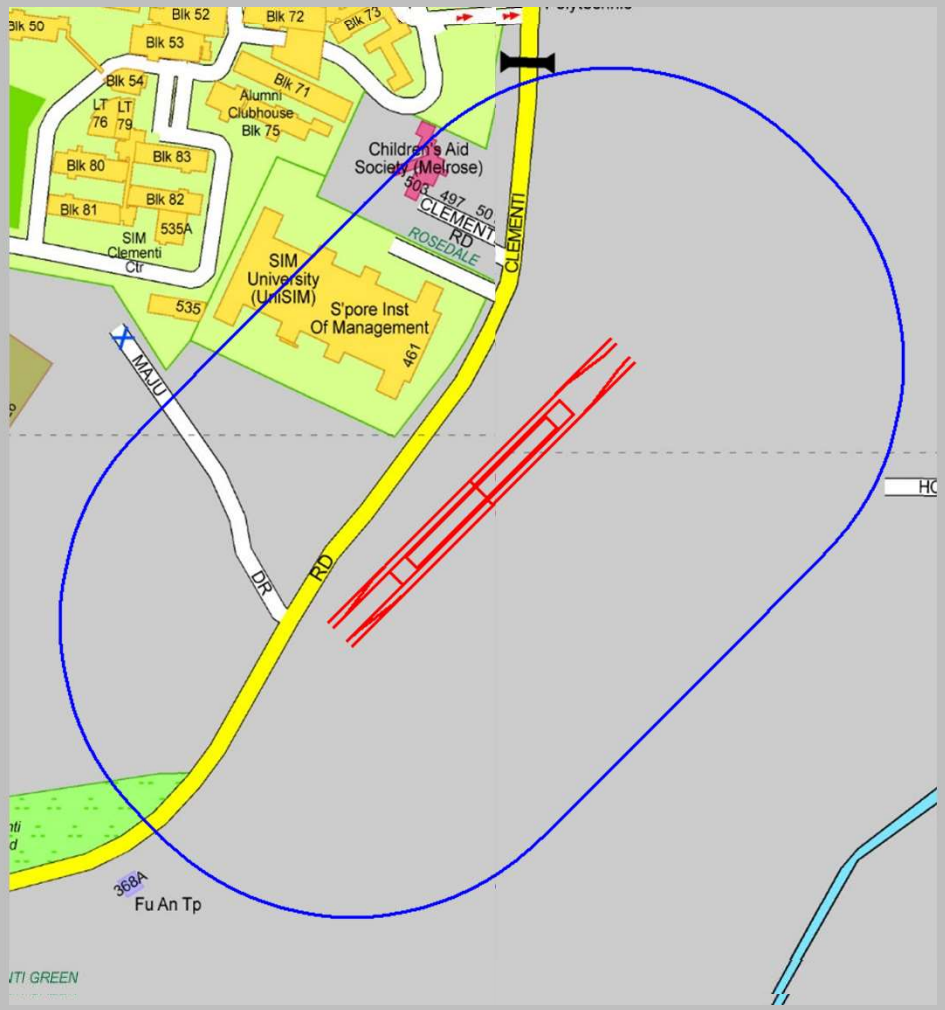
Note: Map shows approximate location of study area.

2000

Overview

- **Civic & Community Institutions:** Children's Aid Society (Melrose) had been established
- **Residential:** Rosedale Terrace Houses had been established
- **Educational Institutions:** Singapore Institute of Management (SIM) had been established

Figure C-8



Legend

250 m from Alignment

CR2001 Alignment

Source

Historical OneMap, 2009, Street Directory. Downloaded from http://hm.onemap.sg/

Note: Map shows approximate location of study area.

2009

Overview

- **Military Facilities:** Maju Camp observed on map (presently extends into Study Area)

Figure C-9

Legend

250 m from Alignment

CR2001 Alignment

Source

Google Earth, 2012. Downloaded from Google Earth Pro

2012

Overview

- **Educational Institutions:** Singapore University of Social Sciences (SUSS) was under construction

Figure C-10

Legend

250 m from Alignment

CR2001 Alignment

Source

Google Earth, 2017. Downloaded from Google Earth Pro

2017

Overview

- **Educational Institutions:** Construction of Singapore University of Social Sciences (SUSS) was completed and it was established in 2017

ANNEX D LIST OF HISTORICAL LAND USE

ANNEX D: HISTORICAL LAND USES IDENTIFIED

Receptor ID	Land Use	Section of Alignment	Historical Land Use Changes				
			2011 - 2019	1991 - 2010	1971 - 1990	1945 to 1970	Before 1945
1	Forested Area to the East of Clementi Road	Clementi Road	Forested since at least 2000 As of 2012, contains a number of endangered species of flora and some species previously presumed to have been extinct.		1971: Sundry tree cultivation 1975-1983: Sundry tree cultivation and rubber plantation 1987: Sundry tree cultivation	1963: Jurong Line section of KTM railway was developed. Late 1960s: Low densitiy settlements developed, and fruit trees and other fruit crops cultivated	1920s: was a rubber plantation 1940s: Rubber plantation abandoned around WWII time of 1941-1945 1943: Vegetation
2	Drain outlet from Ngee Ann Polytechnic through Forested Area	Clementi Road	2015: Google Earth Historical Imagery showed that prior to 2015, it has not been concretised.			Ngee Ann College was moved to Clementi campus in 1968	NUS Historical Maps show that the waterbody has been present since at least 1914.
3	Clementi Road (Road)	Clementi Road	Road widening project (3-lane to 4-lane in both directions) was completed in April 2018.			1947: Renamed from "Reformatory Road" to "Clementi Road"	Existed as Reformatory Road since 1873 (although shape altered)
4	Ngee Ann Polytechnic Utility	Clementi Road		2000: Google Earth Historical Imagery shows the facility has been present since at least 2000.		1950: Bare land 1958: Unknown building/settlement Ngee Ann Polytechnic established since 1963 (then Ngee Ann Technical College)	
5	Rosedale Terrace Houses (479-501 Clementi Road)	Clementi Road		Built in 1990 1995: Historical maps show the houses have been present since 1995. 2000: Google Earth Historical Imagery shows the houses have been present since at least 2000.	1975: Sundry tree cultivation	1950: Shrubland/forested area	

ANNEX D: HISTORICAL LAND USES IDENTIFIED							
Receptor ID	Land Use	Section of Alignment	Historical Land Use Changes				
			2011 - 2019	1991 - 2010	1971 - 1990	1945 to 1970	Before 1945
6	Children's Aid Society (Melrose)	Clementi Road	26 Jul 2013: Expanded capacity by creating a Youth Wing 16 Dec 2019: Melrose Home has moved from Clementi to 35 Boon Lay Avenue, Singapore 649962.	2000: Google Earth Historical Imagery and historical maps show the facility has been present since at least 2000.		1950: Wooded area Built by 1970 Late 1960s (post independence): Children's Aid Society purchased the property Apr 1970: Children and staff moved to live there	
7	Overhead Bridge across Clementi Road	Clementi Road	Retrofitted with lift in between 2011-2019.	Google Earth Historical Imagery shows the facility was constructed between 2002 and 2008.	1975: Sundry tree cultivation	1953: Belukar	1911: Part of The Reformatory, a Boys' Home which has since relocated to Jurong
8	Singapore Institute of Management	Clementi Road	2014: Expansion efforts concluded, at a final area of 110,000 m2	1993: Sundry tree cultivation 1999: Boy's Home was relocated to Jurong 2001: Singapore Institute of Management was opened. Built by 2001 2009: Expansion efforts began to double its capacity	1971: Sundry tree cultivation and lalang/shrub 1974: Part of a main road and grassland	1950: Plantation, wooded area and buildings/settlements 1958: Buildings/settlements and tree cultivation	1911: Part of The Reformatory, a Boys' Home which has since relocated to Jurong
9	Canal between SUSS and Unused Site (ID: 15)	Clementi Road			1975: Sundry tree cultivation	1953: Belukar	1945: Rubber Tree Cultivation
10	Unused Site	Clementi Road		2000: Google Earth Historical Imagery shows the facility has been present since at least 2000.	Built between 1983-1987	1945: Tree cultivation 1950: Wooded area/grassland 1953: Bekular	

ANNEX D: HISTORICAL LAND USES IDENTIFIED							
Receptor ID	Land Use	Section of Alignment	Historical Land Use Changes				
			2011 - 2019	1991 - 2010	1971 - 1990	1945 to 1970	Before 1945
11	Singapore University of Social Sciences (SUSS)	Clementi Road	2017: SUSS was established.	2000-2009: Forested area Google Earth Historical Imagery shows that construction works of SUSS were observed to start by 2009.	1975-1991: Gimson School renamed as Singapore Boys' Home	1954-1969: Renamed as Gimson School	Before 1950s: The Reformatory/Reformatory School which has since relocated to Jurong
12	Singapore Armed Forces (SAF) Maju Camp	Clementi Road		By 1991, Lorong Tandan, Lorong Shahada and a part of Lorong Gaung were demolished. Maju Drive, which presently borders Maju Camp, was also built. 2000: Google Earth Historical Imagery shows the facility has been present since 2000.	1975: Sundry Tree Cultivation	1960s: Established to train volunteers of the Peoples Defense Force, which was established on Oct 1965. Camp was functional from 8 April 1967 onwards. 1969-1991: Part of roads named Lorong Gaung, Lorong Tandan and Lorong Shahada which no longer exist.	Jungle
13	Construction Site next to Maju Camp	Clementi Road			1975: Sundry tree cultivation		Jungle
14	Old Railway Line	Clementi Road	Retrofitted to cater for Clementi Road widening.	Mid 1990s: Jurong Railway ceased operations in favor of more efficient transportation methods.		1963: Construction of Jurong Railway began 1966: Completion of Jurong Railway for logistical transportation. Tracks ran from Bukit Timah Railway station, under Clementi Rd and ended at Shipyard Rd in Jurong	Jungle

ANNEX D: HISTORICAL LAND USES IDENTIFIED							
Receptor ID	Land Use	Section of Alignment	Historical Land Use Changes				
			2011 - 2019	1991 - 2010	1971 - 1990	1945 to 1970	Before 1945
15	Corona Florist & Nursery Pte Ltd	Clementi Road		2000: Google Earth Historical Imagery shows the facility has been present since 2000.	1975: Minor Cultivation	1945: Tree Cultivation 1950: It was established	1945: Rubber Tree Cultivation
16	Clementi Neighbourhood Park	Clementi Road		Historical maps show the Clementi Neighbourhood Park existing by 2000.	1969-1981: Part of road (Old Clementi Road) which no longer exists. 1975: Sundry Tree Cultivation	1945: Jungle 1953: Minor Cultivation 1969-1981: Part of road (Old Clementi Road) which no longer exists.	
17	Forested Area to the West of Clementi Neighbourhood Park	Clementi Road			1975: Sundry Tree Cultivation (Clementi Park)	1953: Belukar 1960s: Part of a road (Lorong Gaung) that no longer exists. 1966-1971: Lalang fields 1969-1981: Part of road (Old Clementi Road) which no longer exists.	1945: Rubber Tree Cultivation

ANNEX E BOREHOLE SAMPLING RECOMMENDATIONS

RECOMMENDED BOREHOLE LOCATIONS

At the time of writing, one (1) cut-and-cover worksite, which is CR16 Maju Station, has been identified in CR2001.

There have been no potential hotspots identified near or at the proposed CR16 worksite. It is noted however that large volumes of spoil will be excavated from this worksite. It is noted that contractors will only undertake environmental sampling of spoil during construction works if the spoil is to be sent to MPA managed sites, or if there is suspected contamination on the basis of visual observation. As a precautionary measure, it is recommended that environmental borehole and groundwater samples be undertaken at this stage to ascertain possible contamination.

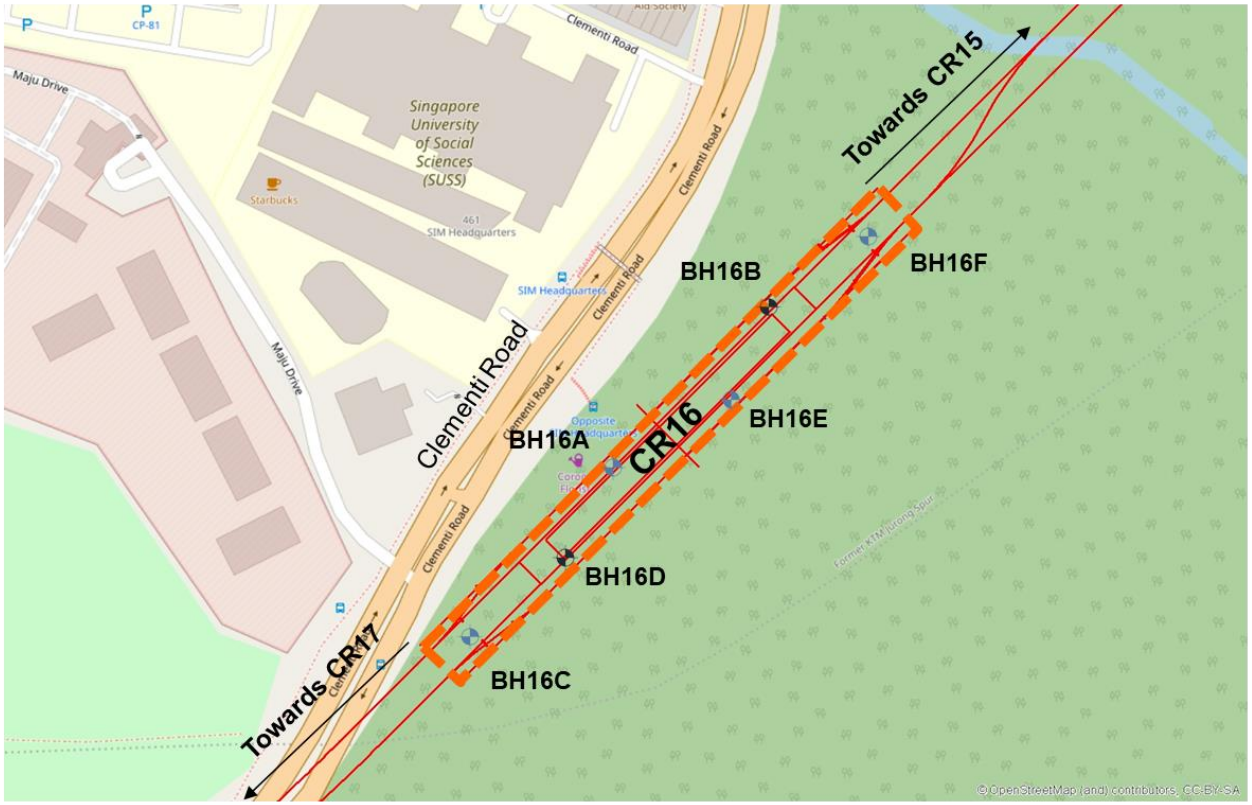
Environmental borehole sampling has been recommended at this worksite. The number of boreholes and sampling intervals and parameters have been recommended with reference to the SLA's *Environmental Site Assessment Guidelines for State Land (2018 Edition).* As a preliminary step, it is recommended that the soil and groundwater samples are tested for the full suite of parameters listed in the *Dutch Guidelines for Soil Protection, Circular on target values and intervention values for soil remediation (revised 2013 edition)*.

The recommended borehole / groundwater well locations and sampling regime is presented in *Table E.1* and shown in *Figure E.1.*

Table E.1: Indicative Environmental Borehole & Sampling

Receptor ID	Hotspot	Possible CoCs	Severity of Contamination	Indicative Cut and Cover Area (m^2)	No. of Boreholes	Test Parameters	Depths & Intervals of Sampling
CR16: Maju							
NA	NA	NA	NA	11,950	6	Standard suite of parameters as per the *Dutch Guidelines for Soil Protection, Circular on target values and intervention values for soil remediation (revised 2013 edition)*	■ 2 m below groundwater level / 6 m below ground level (whichever is deeper) ■ Minimum of 4 soil samples per borehole ○ Samples with high photo-ionization detector (PID) readings, or with the most likely indication of contamination based on visual/odour screening; ○ Samples located at depths where non-aqueous phase liquid (NAPL) is likely to accumulate; ○ Samples collected at the upper or lower boundary of a change in soil type; and ○ For reclaimed lands, fill material samples collected just above original soil.

Figure E.1 Proposed Borehole Sampling Locations for CR16



Key Plan:

Legend:

- Estimated cut-and-cover footprint
- Proposed borehole location
- Proposed borehole converted to monitoring well

Figure E.1*:* Proposed borehole locations for CR2001 CR16 (Maju)

Project: CR2001 HLUS

Client: Arup Singapore Pte Ltd

Table E.1: Recommended Borehole Coordinates

Borehole ID	*Coordinates (Decimal Degrees)*	
CR16: Maju	***Latitude***	***Longitude***
BH16A	1.327586	103.777164
BH16B	1.328383	103.777941
BH16C	1.326747	103.776372
BH16D	1.327121	103.776832
BH16E	1.327912	103.777668
BH16F	1.328714	103.778365

ANNEX F PHASE II ENVIRONMENTAL INVESTIGATION REPORT

KWANG SING ENGINEERING PTE LTD
坤成工程有限公司
2 Penjuru Place
#01-02, 2·8 Penjuru Tech Hub
Singapore 608783
Tel: 6898 3218
Fax: 6898 3228
Email: kse2000@singnet.com.sg
Company Reg No. 198300405C GST Reg No. M2-0050746X

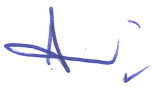
LAND TRANSPORT AUTHORITY
CONTRACT C1066
SITE INVESTIGATION WORKS FOR LTA PROJECTS
SITE INVESTIGATION WORKS FROM TUAS TO CHANGI (1W91)
(WSO-GTT-GTT-C1066-00024)

(Boreholes: RC/30198/EBS/WSP, RC/30199/EBS/WSP, RC/30200/EBS/WSP, RC/30201/EBS/WSP, RC/30202/EBS/WSP & RC/30203/EBS/WSP)

Volume I of I

Soil Investigation Report

Environmental Baseline Study

Prepared	Checked	Approved
May Yi Mon Soe	Wunna Tun	John Chai
Geologist	Technical Manager	Project Manager
		

REPORT No.: LTA/WSO-GTT-GTT-C1066-00024 (Draft Report)
KS19/C1066/WO/00024

DATE: 22nd April 2021

"The results reported herein have been performed in accordance with the terms of accreditation under the Singapore Accreditation Council"

Certification by Professional Engineer for Site Investigation

I, Lee Hiang Meng the Professional Engineer,

PE Registration No. 4067 certify that the Site Investigation Report

LAND TRANSPORT AUTHORITY
CONTRACT C1066
SITE INVESTIGATION WORKS FOR LTA PROJECTS
SITE INVESTIGATION WORKS FROM TUAS TO CHANGI (1W91)
(WSO-GTT-GTT-C1066-00024)
(Boreholes: RC/30198/EBS/WSP, RC/30199/EBS/WSP, RC/30200/EBS/WSP, RC/30201/EBS/WSP, RC/30202/EBS/WSP & RC/30203/EBS/WSP)

Comprising all field and laboratory data, tests and results therein has been carried out by me or under my supervision or direction, and I have verified the accuracy of the information given in the site investigation report, and to the best of my knowledge and belief, all have been prepared in compliance in all respects with the provisions of the Building Control Act and Regulations, relevant Codes of Practice and Standards.

I further certify that I have the appropriate qualifications and experience, and I am familiar with the purpose of the investigation for which this Site Investigation Report is prepared in reference to Project Ref. No. KS19/C1066/WO/00024

Total number of pages in the Site Investigation Report is 126

Professional Engineer for Site Investigation Signature and Stamp

22ND April 2021

Date

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SECS

SINGAPORE ENVIRONMENTAL CONSULTANCY AND SOLUTIONS PTE LTD

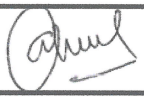
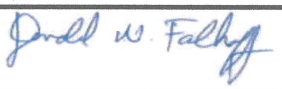
Submitted to:

Land Transport Authority

CONTRACT C1066- SITE INVESTIGATION WORKS FOR LTA PROJECTS

(Clementi Road)

Environmental Baseline Survey

Prepared By:	Checked By:	Approved By:
Dennis Ong	Sathi Krishnan	Donald Folkoff
Senior Environmental Engineer	Environmental Engineer	Director
		

Report No. : SO00167

22nd March 2021

Prepared by:

SECS

SINGAPORE ENVIRONMENTAL CONSULTANCY AND SOLUTIONS PTE LTD

PREFACE

Kwang Sing Engineering Pte Ltd was engaged to carry out Site Investigation Works for CONTRACT C1066 SITE INVESTIGATION WORKS FOR LTA PROJECTS WSO-GTT-GTT-C1066-00024 Site Investigation Works from Tuas to Changi (1W91) for **Land Transport Authority** (LTA). This report details the environmental investigation of Soil and Water Samples undertaken at the site. The analytical suite for soil and groundwater follows the 2000 Dutch Soil Guidelines, adopted by JTC "Guideline on Environmental Baseline Study (2010) Edition" and NEA Allowable Limits for Trade Effluent Discharge to Sewer/ Watercourse/ Controlled Watercourse and under the technical direction of the client. This EBS project is under taken by Singapore Environmental Consultancy and Solutions Pte Ltd (SECS) acting on behalf of Kwang Sing Engineering Pte Ltd.

Project Description

(a) *Title of Project*

LAND TRANSPORT AUTHORITY

CONTRACT C1066 – SITE INVESTIGATION WORKS FOR LTA PROJECTS

WSO-GTT-GTT-C1066-00024 Site Investigation Works from Tuas to Changi (1W91)

(*Boreholes: RC/30198/EBS/WSP, RC/30199/EBS/WSP, RC/30200/EBS/WSP, RC/30201/EBS/WSP, RC/30202/EBS/WSP, RC/30203/EBS/WSP)*

(b) *Client*

Land Transport Authority

(c) *Geotechnical Contractor*

M/s Kwang Sing Engineering Pte Ltd

Project Manager: Mr. John Chai

(d) *Sub Contractor*

Singapore Environmental Consultancy and Solutions Pte Ltd (SECS)

(e) *Duration of Investigation Works*

26th January 2021 to 1st February 2021

Executive Summary

Singapore Environmental Consultancy and Solutions Pte Ltd (SECS) was engaged by **Kwang Sing Engineering Pte Ltd (Kwang Sing)** in November 2020 to perform a series of environmental baseline studies (EBS) on behalf of the **Land Transport Authority (LTA)** for multiple locations for Project C1066. This report details the EBS investigation for six boreholes at Clementi Road as detailed in LTA drawing LC1066CWD-SO0024.

The purpose of this investigation was to establish the baseline level of potential contaminations, if any, in the soil and groundwater based on the laboratory analysis and comparison of selected chemicals of concern in the 2019 JTC EBS Guideline against their respective Dutch Target and Intervention Values (DTVs and DIVs).

The program for Clementi Road consisted of the following tasks.

- Site reconnaissance and detection/marking of underground utilities to determine the borehole locations and interview with John Chai.
- Drilling of six boreholes for the collection of soil samples.
- Completion of these boreholes as groundwater monitoring wells for the collection of groundwater samples.
- Submission of twenty-six (26) soil samples and seven (7) sets of groundwater samples to the laboratory inclusive of 2 soil duplicates and 1 groundwater duplicate for analysis in accordance to the analytical suite detailed under the 2013 Dutch Standards with the exception of organotin compounds and extractable organic halogens.

An initial site inspection and cable detection were conducted on 15th January 2021 prior to the commencement of the drilling works. The drilling works were carried out on 26th January to 1st of February 2021 while groundwater samples were collected on the 3rd February 2021.

A summary of the findings from this investigation is as follows.

- According to the Historical Maps of Singapore (Department of Geography, NUS), the site area and general surroundings consisted of forested areas in the 1800s. Clementi Road was constructed by the early 1870s. while the surroundings consist of forested areas and villages. By 1969, private residential houses were built at the west of Clementi Road, followed by Ngee Ann Polytechnic in the 1970s, Maju Camp in the 1990s, and Singapore Institute of Management in the 2000s. The eastern side of Clementi Road, where the EBS work is done, remains as secondary forest to this date. In the 2019 Master Plan maps, the site is zoned as Residential, but subject to detailed planning, as the site is part of the Clementi Forest.

- Based on the bore logs of the six boreholes, all borehole locations are identified to have backfill. The depth of backfill ranges from ground surface to 1.20m bgl. The fill material consist of firm, slightly Sandy SILT with rootlets. Underlying the fill material can be identified as stiff to very stiff, slight Sandy SILT, typical of the characteristics to the Jurong Formation and stiff to very stiff, slightly Sandy SILT; typical of the characteristics of the Bukit Timah Granite.
- The static water table was measured at depths of from 1.31m to 6.37m below ground level, or from elevations of 113.24 to 121.26 m RL (relative level, based on Singapore Height Datum with mean sea level set at 100.000 m elevation). Based on computer modelling, a larger portion of groundwater appears to flow towards northwards with RC/30199/EBS being the highest reduced level for static water table. Figure 3 is a map of the water table contours and indicates the groundwater flow direction.

- A review of the laboratory analysis results for **soil samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

- A review of the laboratory analysis results for **groundwater samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

- Based on the analytical data, physical site features, geologic settings and land use scenario there would be no need to undertake any form of remediation as the analytical results for the soil and groundwater indicate no critical issues of concern to the site occupants or neighbouring facilities based on the present land use scenario. No previous EBS report was made available to SECS to compared the laboratory reports against at the time of this report.

1.0 Introduction

Singapore Environmental Consultancy and Solutions Pte Ltd (SECS) was engaged by **Kwang Sing Engineering Pte Ltd (Kwang Sing)** in November 2020 to perform a series of environmental baseline studies (EBS) on behalf of the **Land Transport Authority (LTA)** for multiple locations for Project C1066. This report details the EBS investigation for six boreholes at Clementi Road as detailed in LTA drawing LC1066CWD-SO0024.

1.1 Objective

The objective of the baseline study is to evaluate the level of toxic contamination in the soil and groundwater by comparing the concentrations of certain chemicals of concern to a schedule of allowable standards (Dutch Target and Intervention Values). This establishes the soil and groundwater quality beneath the site and assesses any soil and/or groundwater contamination that maybe encountered.

The schedule of standards used to evaluate the analytical results for this study are the Dutch Soil and Groundwater Target and Intervention Values found in the 2013 Soil Remediation Circular (referred to as the "Dutch Standards") which are the standards adopted by the JTC as specified in the 2019 EBS Guidelines as a means of determining the contamination status of the soil and groundwater samples tested.

1.2 Scope of Work

The scope of work and dates when the sampling program was undertaken are detailed in the following sections.

The program for Clementi Road environmental baseline study consisted of the following tasks.

- Site reconnaissance and detection/marking of underground utilities to determine the borehole locations and interview with John Chai.
- Drilling of six boreholes for the collection of soil samples.
- Completion of these boreholes as groundwater monitoring wells for the collection of groundwater samples.
- Submission of twenty-six (26) soil samples and seven (7) sets of groundwater samples to the laboratory inclusive of 2 soil duplicates and 1 groundwater duplicate for analysis in accordance to the analytical suite detailed under the 2013 Dutch Standards with the exception of organotin compounds and extractable organic halogens.

An initial site inspection and cable detection were conducted on 15th January 2020 prior to the commencement of the drilling works. The drilling works were carried out on 26th January to 1st of February 2021 while groundwater samples were collected on the 3rd February 2021.

1.3 Assessment Criteria and Report Structure

In Singapore no specific criteria exist to address the level of soil and groundwater contamination. The JTC has adopted the Target and Intervention Values for soil and groundwater in the Soil Remediation Circular 2013 published by the Netherlands Ministry of Infrastructure and Water Management as guidelines. DTVs and DIVs were derived using a comprehensive risk-based toxicological model. These criteria when compared to the concentrations of compounds measured in the soil and groundwater samples collected during the field program provides a preliminary contamination level assessment of the site. The Dutch Values specify two levels, which are defined in the Netherlands as follows:

- A Target Value that represents the target or background concentration and below which would indicate that the land is not contaminated;
- An Intervention Value, level above which indicates some levels of serious contamination exists and that of some form of remediation would be required which could range from natural attenuation and further monitoring to a risk assessment and/or active remediation that may include soil/groundwater removal or treatment.

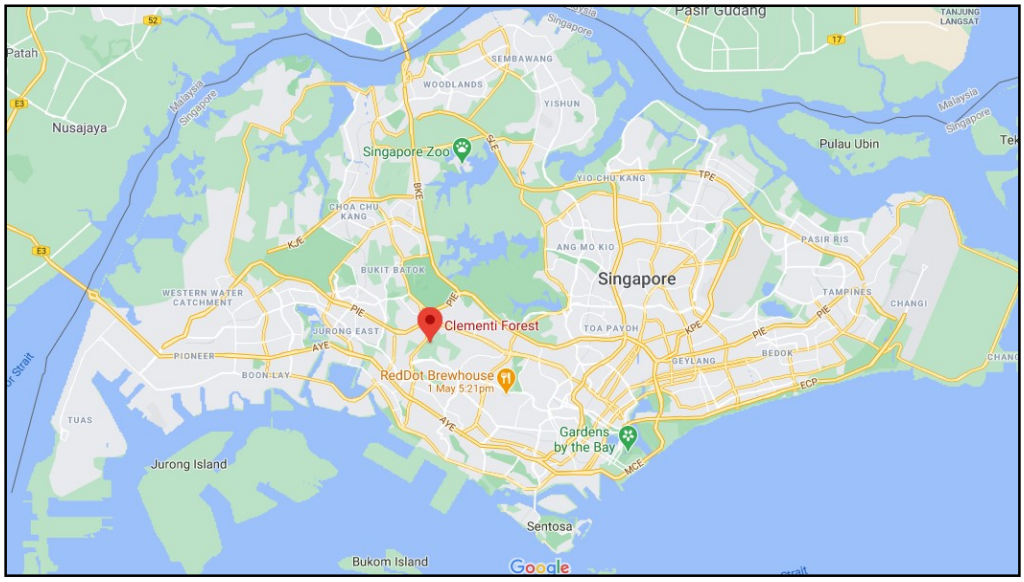
The analytical results of this investigation have been compared to the Intervention Values as a means of determining the potential contamination level for the soil and groundwater samples tested. It should be noted that the target and intervention values are based on background conditions of the Netherlands for the protection of multi-functional land, subsurface drinking water resources, and the surrounding ecosystem. This report documents the findings of the intrusive investigation and describes the methodology used for the field program and laboratory testing. The analytical results for the soil and groundwater are assessed as a means of determining the contamination level of the site. Based on the findings and conclusions, recommendations for future action are detailed. Site location plans with sample locations and groundwater contour maps are included under the figures attached to the report. The appendix section includes the boring logs, certified laboratory reports and photographs.

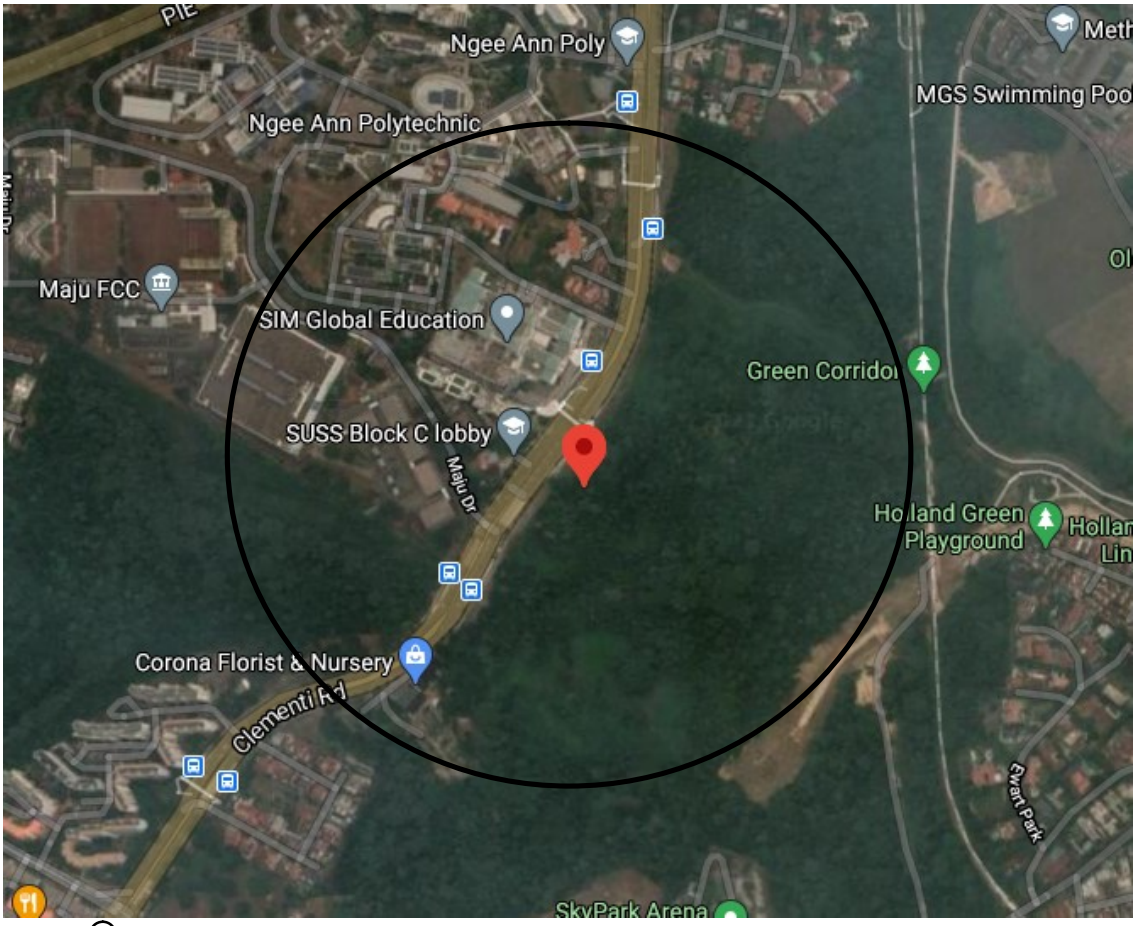
2.0 Site Settings

2.1. Site Locations and Layout

The site location is located along the forested area west of Clementi Road, directly opposite Maju Camp, in the western region of Singapore. The boreholes are located on soil surface inside a secondary forest.

Figure 1 – Location Map





2.2 Site Activities

There are no site activities at the site as the area is a forested.

2.3 Surrounding Land Use

Current land uses immediately adjacent to the six boreholes in Clementi Road are described as follows:

- North – Singapore Institute of Management; a private university
- South – Clementi Forest which beyond it are private condominiums
- East – Clementi Forest which beyond it are private residential areas
- West – Maju Camp, which is military camp occupied by the Singapore Armed Forces.

The nearest sensitive receptors nearby are the university and polytechnic west to the site. The closest water body is the Pandan River located about 1.35km south to the site.

2.4 Physical Settings

2.4.1 Physiograph/Surface Drainage

The terrain of the subject site is characterised as hilly with elevations ranging from 114.55m to 123.07m RL (relative level, based on Singapore Height Datum with mean sea level set at 100.000 m elevation). No surface drainage was observed inside site at the time of inspection. The overall surface runoff from site will penetrate through the soil terrain on site.

2.4.2 Soil Stratigraphy/Geology

A review of the Geological Map of Singapore, Sheet 4, Jurong (Defence Science and Technology Agency, 2009) indicates that the site is underlain with Jurong Formation and the Bukit Timah Granite.

Based on the bore logs of the six boreholes, all borehole locations are identified to have backfill. The depth of backfill ranges from ground surface to 1.20m bgl. The fill material consist of firm, slightly Sandy SILT with rootlets. Underlying the fill material can be identified as stiff to very stiff, slight Sandy SILT, typical of the characteristics to the Jurong Formation and stiff to very stiff, slightly Sandy SILT; typical of the characteristics of the Bukit Timah Granite.

The Jurong formation is a sedimentary rock formation that covers the south-west portion of the island of Singapore. The formation was laid down in the late Triassic to early or middle Jurassic geologic periods. It consists of dolomite, limestone, mudstone, sandstone, shale, and conglomerates that have been acutely folded and faulted as the result of tectonic plate movement.

The Bukit Timah Granite Formation is one of the oldest geological formations in Singapore and is found mostly in the central and northern parts of Singapore. It is an intrusive type of igneous rock formed more than 230 million years ago during the Triassic Period. The rock in the formation varies from granite to granodiorite and various dykes are included in the formation.

The static water table was measured at depths of from 1.31m to 6.37m below ground level, or from elevations of 113.24 to 121.26 m RL (relative level, based on Singapore Height Datum with mean sea level set at 100.000 m elevation). Based on computer modelling, a larger portion of groundwater appears to flow towards northwards with RC/30199/EBS being the highest reduced level for static water table. Figure 3 is a map of the water table contours and indicates the groundwater flow direction.

2.5 Site History

According to the Historical Maps of Singapore (Department of Geography, NUS), the site area and general surroundings consisted of forested areas in the 1800s. Clementi Road was constructed by the early 1870s. while the surroundings consist of forested areas and villages. By 1969, private residential houses were built at the west of Clementi Road, followed by Ngee Ann Polytechnic in the 1970s, Maju Camp in the 1990s, and Singapore Institute of Management in the 2000s. The eastern side of Clementi Road, where the EBS work is done, remains as secondary forest to this date. In the 2019 Master Plan maps, the site is zoned as Residential, but subject to detailed planning, as the site is part of the Clementi Forest.

3.0 Site Inspection

3.1 General

A site inspection and cable detection were carried out on prior to the field program for the installation of the monitoring wells to assess for any visual contamination in terms of stressed vegetation, stained ground or waste material of which there were no indications.

3.2 Surface Conditions and Drainage

The site is currently located on soil surface and forested areas. No surface drainage was observed inside site at the time of inspection. The overall surface runoff from site will readily penetrate the soil surface on site.

3.3 Hazardous Substances and Waste Management

No underground petroleum or chemical tanks were found on site during site inspection.

3.4 Physical Evidence of Contamination

No odours or stressed vegetation were noted during the site inspection and field program. There are no storage pits, ponds or lagoons on the site.

3.5 Potential Areas of Concern and Contaminants of Concern

As the site was allocated for recreational and residential usage based on the latest URA Master Plan (2019) and per the environmental baseline study being executed under the 2019 JTC EBS Guideline, a comprehensive range of contaminants was analyzed.
Based on the site inspection, neighbouring properties and site history, there are no potential hazards which could contaminate the soil and groundwater.
The discussion of the sampling and analysis program is detailed in section 4.0 (Field Program and Analytical Parameters) of this report.

4.0 Field Program and Analytical Parameters

4.1 General

A field program of soil and groundwater sampling was proposed to obtain soil and groundwater samples from the site. The drilling works were carried out on 26th January to 1st of February 2021 while groundwater samples were collected on the 3rd February 2021. The drilling contractor under instruction of an Environmental Engineer from SECS carried out the soil sampling. The program consisted of the installation of six boreholes with the submission of four soil samples from each borehole for analytical testing. The borings were completed with water standpipes to act as groundwater monitoring wells for the collection of groundwater samples and the measurement of static groundwater levels to determine the direction of groundwater flow. Soil and groundwater samples were analysed based on the laboratory selection and comparison of selected chemicals of concern in the 2019 JTC EBS Guideline against their respective Dutch Target and Intervention Values (DTVs and DIVs).

4.2 Preliminary Investigation Findings

The objectives of conducting a preliminary investigation (PI) are:

1. To develop a preliminary conceptual site model (CSM);
2. To identify potential sources of contamination and recognised environmental conditions (RECs) in connection with the historical and current site activities;
3. To identify potential migration pathways, transport mechanisms and exposure pathways of the soil and groundwater contamination;
4. To identify the potential on-site and off-site human and environmental receptors;
5. To identify the potential impacts of contamination to on-site and off-site receptors;
6. To gather information useful for developing the sampling program for the EBS; and
7. To identify potential off-site sources of contamination that could affect the environmental condition of the site.

A preliminary investigation conducted found that:

- Given the historical and current site activities, as well as its land use zoning, there are limited potential areas of concern.
- Potential contaminants of concern may be present that could affect construction workers engaged in any demolition/ addition and alteration works as well as future site occupants.

The conceptual site model is described using a brief narrative detailing the relevant physical characteristics of the site as they would relate to land use and exposure of any potential contaminants in the soil or groundwater to potential receptors that

would include site occupants, neighbouring properties and or physical receptors such as the site boundary. This preliminary conceptual site model is based on limited background information and would be refined as more drilling information is obtained.

The following assumptions were made for developing the conceptual site model:

- According to the 2019 URA Masterplan, the proposed future land use at the site will remain as industrial zone (site is zoned as Business 2).
- Redevelopment/ excavation works may result in exposure to any potential deeper contaminated soil.
- The soil properties are based on visual manual classification made on site. Estimates of soil permeability were made based on soil type and hydraulic gradient were based on the water table surface map compiled during the site investigation.

Table 4.2 Preliminary Conceptual Site Model

Source	Exposure Media	Exposure Route	Potential Receptor
Potential contaminants in soil exceeding DIV	Soil	Dermal Contact, Incidental Ingestion	Future construction worker engaged in excavation
Potential contaminants in groundwater exceeding DIV	Aquifer discharge to surface water/ sediments	Dermal Contact, Incidental Ingestion	Future construction worker engaged in excavation
	Groundwater	Volatilization from groundwater into air	Current and future site occupants and construction workers

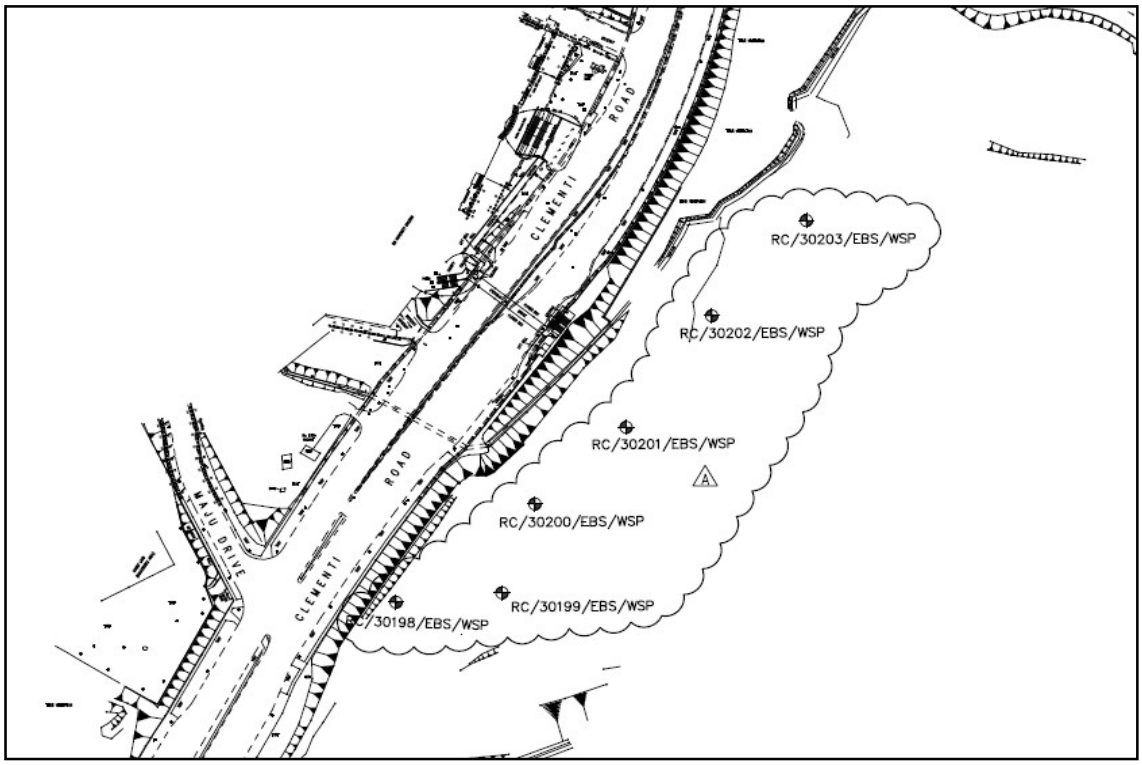
4.3 Number and Location of Boreholes

Six boreholes designated as RC/30198/EBS to RC/30203/EBS were drilled to termination depth from 7.50m bgl to 10.50m bgl. The borings were completed as groundwater monitoring wells with slotted UPVC casings installed in the borehole and the annulus backfilled with filter sand and annular seals. The borings were located to represent a geographic spread across the site. These locations were as follows:

- RC/30198/EBS: 34363.88N, 21670.70E
- RC/30199/EBS: 34368.56N, 21722.88E
- RC/30200/EBS: 34413.70N, 21739.07E
- RC/30201/EBS: 34452.60N, 21783.86E
- RC/30202/EBS: 34509.16N, 21826.01E
- RC/30203/EBS: 34557.53N, 21872.45E

The well locations are shown in Figure 2 below, with photos attached in Appendix C.

Figure 2 Site Layout Plan with Borehole/Monitoring Well Locations



4.4 Soil Sampling

After ensuring there are no underground utilities up to 3.0m, or to the depth of any suspected utility, whichever deeper, the borehole will be advanced using hand auger methods to the water table where the borehole begins to collapse or where soil resistance to hand auger drilling becomes too difficult. Soil samples will be collected from the inner core of the hand auger barrel. Hydraulic rotary drilling will be used to advance the borehole beyond the depth capability of the hand auger. A small 4hp rotary drive will be used to advance a spiral auger between the appropriate soil sampling interval and to the termination depth of 6m or 2m below groundwater level, whichever is deeper. For reclaimed lands where original soil is present underneath the reclamation fill, at least 40% of total boreholes should be drilled down to 2 m below the original soil to provide a better characterisation of the fill material and underlying original soil. The diameter of the spiral auger will be smaller than the diameter of the hand auger. The drilling, sampling and logging of the soil borings are carried out in accordance with the following protocols:

- BS EN 1997-2:2007 EN7 Part 2 (Code of Practice for Site Investigations & Testing)
- ASTM D5730 Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone and Groundwater,
- ASTM D4700 Standard Guide for Soil Sampling from the Vadose Zone
- USEPA Environmental Response Team SOP 2012 (Soil Sampling)

The near surface sample will be collected at 0.5m from the hand auger (US EPA SOP2012). Soil sampling will begin at the 0.5m horizon below existing ground level (bgl) and at each subsequent 1.5m interval until the termination depth is reached. Soil samples will be collected using either a standard penetration tests (SPT) split spoon or 75mm diameter Shelby Tube sample (USEPA SOP 2012). No water should be used during the boring if possible.

All drilling implements such as steel casings/rods, and bits were decontaminated prior to their insertion into the boreholes by rinsing with potable water mixed with Decon 90, a phosphate-free laboratory detergent, water wash with brushes and a final potable water rinse.

All sampling and drilling equipment were cleaned before use between boreholes. This includes the metal casing/rod, auger barrel, thin wall tube samplers, spatulas, trowels, scoops and any other equipment used. All cleaning is performed on a clean surface, such as a plastic sheet. The field engineer/scientist wears clean rubber gloves when handling soil samples and cleaned equipment.

The cleaning procedures for all sampling equipment involved:

- Washing in tap water removing gross contamination
- Washing in DECON 90 solution (phosphate-free laboratory detergent)
- Rinsing copiously with tap water
- Rinsing with de-ionised water

Soil samples from each boring were logged based on the Unified Soil Classification System (USCS), together with observations of any obvious contamination properties such as odour or staining. During soil sampling, no odour or oil sheen was observed on site. The soil profiles are displayed as a Log of Boring and presented in Appendix B. Table 4.4 summarizes the descriptions of the soil samples selected for laboratory analysis.

Table 4.4 Summary of Soil Sample Description

BH No.	Sample No.	Depth m bgl	Description
RC/30198	S1	0.5 – 0.7	Firm, yellowish brown, reddish brown and dark grey, slightly Sandy SILT with rootlets (Made ground)
RC/30198	S2	1.5 – 1.7	Stiff to very stiff, yellowish brown, reddish brown and white, slightly Sandy SILT with rootlets. (Residual soil, Jurong Formation)
RC/30198	S5	6.0 – 6.2	
RC/30199	S1	0.5 – 0.7	Firm, brown to dark brown and yellowish brown, slightly Sandy SILT with rootlets (Made ground)
RC/30199	S2	1.5 – 1.7	Stiff to very stiff, yellowish brown, reddish brown and white, slightly Sandy SILT with rootlets. (Residual soil, Bukit Timah Granite)
RC/30199	S4	4.5 – 4.7	
RC/30200	S1	0.5 – 0.7	Firm, brown to dark brown and yellowish brown, slightly Sandy SILT with rootlets (Made ground)
RC/30200	S2	1.5 – 1.7	Stiff to very stiff, reddish brown, yellowish brown and white, slightly Sandy SILT with rootlets. (Residual soil, Bukit Timah Granite)
RC/30200	S4	4.5 – 4.7	
RC/30201	S1	0.5 – 0.7	Firm, brown to dark brown and yellowish brown, slightly Sandy SILT with rootlets (Made ground)
RC/30201	S2	1.5 – 1.7	Stiff to very stiff, reddish brown and yellowish brown, slightly Sandy SILT (Residual soil, Bukit Timah Granite)
RC/30201	S3	3.0 – 3.2	
RC/30202	S1	0.5 – 0.7	Firm, brown to dark brown and yellowish brown, slightly Sandy SILT with rootlets (Made ground)
RC/30202	S2	1.5 – 1.7	Stiff to very stiff, reddish brown and yellowish brown, slightly Sandy SILT (Residual soil, Bukit Timah Granite)
RC/30202	S4	4.5 – 4.7	
RC/30203	S1	0.5 – 0.7	Firm, brown to dark brown and yellowish brown, slightly Sandy SILT with rootlets and brick fragments (Made ground)
RC/30203	S3	3.0 – 3.2	Stiff to very stiff, yellowish brown, reddish brown and white, slightly Sandy SILT with rootlets. (Residual soil, Bukit Timah Granite)
RC/30203	S4	4.5 – 4.7	

4.5 Groundwater Sampling and Well Construction

Groundwater monitoring wells were installed in all the boreholes after the drilling termination depth is reached. A 40mm diameter UPVC riser pipe with slotted screen was installed in the borehole. The annular space around the slotted interval was backfilled with coarse silica sand to act as a filter medium. The top of the filter sand was backfilled to at least 0.5m above the top of the slotted interval and a minimum 0.5m thick bentonite seal was placed above the top of the filter pack. All well standpipes were left with a stick up of around 0.3 m above the ground level. No visual evidence of light or dense non-aqueous phase liquid during well development and sampling.

Prior to sample collection the monitoring wells were purged l dry using an HDPE water well bailer and then allowed to recharge overnight to ensure samples representative of the water in the saturated zone soils was collected. The samples for laboratory analysis were collected using bailers and transferred from the bailer, into clean sample containers containing the appropriate preservative and into 40ml vials for volatile organic compounds. A bottom-emptying device was used to empty the bailer to minimize the loss of volatile species. Groundwater samples will be stored in a cooler box when on site and during transport to the laboratory. Procedures followed during the groundwater sampling are in accordance to USEPA Environmental Response Team SOP 2007 for groundwater sampling.

4.6 Groundwater Hydrology

Depth to groundwater was determined by using a clean water level indicator after bore development and prior to sampling, allowing sufficient time for the static groundwater levels to be established. The static water table depths when referenced to ground levels allow the hydraulic gradient between the wells to be calculated and the general groundwater flow direction to be determined. Table 4.6 presents the reduced ground levels, static water table depths and reduced water table elevations.

Table 4.6 Groundwater Elevation Data

Borehole Number	Ground Surface Elevation (m)	Depth to Static Water Level (m)	Reduced Groundwater Level (m)	Date Of Measurement
RC/30198/EBS	123.05	6.37	116.68	3/2/2021
RC/30199/EBS	125.70	4.44	121.26	3/2/2021
RC/30200/EBS	122.24	4.35	117.89	3/2/2021
RC/30201/EBS	118.70	2.77	115.93	3/2/2021
RC/30202/EBS	116.08	2.03	114.05	3/2/2021
RC/30203/EBS	114.55	1.31	113.24	3/2/2021

Note: Groundwater elevations are based on the Singapore Height Datum with mean sea level set to 100.000m

Based on computer modelling, a larger portion of groundwater appears to flow towards northwards with RC/30199/EBS being the highest reduced level for static water table. Figure 3 is a map of the water table contours and indicates the groundwater flow direction.

Figure 3 - Groundwater Contour Map

* Coordinates are in meters, based on SVY21 datum. Groundwater elevations are based on the Singapore Height Datum with mean sea level set to 100.000m. Elevations shown figure above are in meters.

4.7 Laboratory Testing Program

Chain of Custody

All soil and groundwater samples were collected under chain of custody protocols. Each sample jar was labelled with the following information:
Job number
Project name
Date of sampling
Sample Number
Depth of sample

Chain-of custody documentation was completed on facility. This included the information listed above and if appropriate, the chemical analysis required for each sample. The field engineer/scientist signed the appropriate section of the chain-of-custody form before handing over the samples to the laboratory.

Analytical Testing

The analytical testing suite undertaken for the soil and groundwater samples collected for this investigation was in accordance to the JTC Guideline on Environmental Baseline Study. A summary of the parameters tested is as follows:

- Heavy Metals and Metalloids (12 elements) by USEPA 3051(soil digestion) and APHA-AWWA analytical methods for ICP/AAS.
- Inorganic Compounds (Total Cyanide) by APHA Pt 4500-CN (C.N)
- Aromatic Compounds (Volatile Organic Compounds (VOC)) by USEPA method 8260.
- Aromatic Compounds (Semi-Volatile Organic Compounds (SVOC)) by USEPA method 8270.
- Polycyclic Aromatic Hydrocarbons (PAH) by UESPA method 8270.
- Chlorinated Hydrocarbons (Volatile Organic Compounds (VOC)) by USEPA method 8260.
- Chlorinated Hydrocarbons (Semi-Volatile Organic Compounds (SVOC)) by USEPA method 8270.
- Pesticides by USEPA method 8270.
- Pesticides (maneb) by BCTD/Env/IHM011/2000 (rev (0)).
- Other Pollutants (Volatile Organic Compounds) by USEPA method 8260.
- Other Pollutants (Phthalates and Pyridine) by USEPA method 8270.
- Total Petroleum Hydrocarbons (TPH) by USEPA method 8015 GC.
- Organic Matter – soils only by BS 1377 Pt 2.
- Moisture Content – soils only by BS1377 Pt 3.
- Anions and Chemical Parameters – groundwater only (BOD, COD, TAN, TOC, F, Cl, Br, PO_4, SO_4) by APHA- AWWA standard methods.

Additional parameters added for the analytical testing of soil and water includes:

- Organic matter (total nitrogen, total phosphorus, fecal coliform) by APHA – 4500 (J) and APHA 9222D
- Heavy metal (manganese, vanadium) by APHA 3120B
- Chloride contents – soil only by BS1377 Pt 3
- Sulphate contents – soil only by BS1377 Pt 3
- NEA allowable limits for trade effluent discharge to Watercourse or Controlled Watercourse
- PUB allowable limits for trade effluent discharge to Public Sewer

A total of twenty-six (26) soil samples and seven (7) sets of groundwater samples to the laboratory inclusive of 2 soil duplicates and 1 groundwater duplicate for analysis.
The individual compounds tested and analytical results are detailed in Appendix B (Laboratory Test Report).

5.0 Results from the Soil and Groundwater Sampling Program

The Dutch Soil and Groundwater target and intervention values are defined under *Section 1.3* of this report and form the basis for determining the site's contamination status. Comparison of the analytical results to the Dutch Intervention Values gives the preliminary indication of the contamination level of the site.

5.1 Field Measurements and Well Stabilization

Prior to sampling groundwater from the wells, the following parameters such as pH, temperature, electrical conductivity (EC), and dissolved oxygen (DO) were monitored to ensure groundwater condition is stable and representative of the site conditions. Groundwater is considered stable if the mentioned parameters have less than 10% difference after three consecutive readings, where each reading is taken after removing 1 well volume. It should be noted that wells can be purged dry after removing less than three well volumes. In such cases fresh groundwater coming into the PVC well is considered to be representative of the site and is sampled the following day after being allowed to recover overnight.

The following table highlights parameters recorded from the Groundwater sampling field record. The complete record can be found in the Appendix A1.

Table 5.1 Groundwater Sampling Field Record

Purged (L)	pH	Temp (°C)	EC (µS/cm)	Eh (mV)	DO (mg/L)
Acceptance Criteria	*+/- 0.2*	*+/- 3%*	*+/- 3%*	*+/- 10%*	*+/- 10%*
RC/30198: One well volume = 6 *l* (bailed dry after removing 16 liters)					
6	5.53	27.67	55.95	334.3	5.29
RC/30199: One well volume = 4 *l* (bailed dry after removing 7 liters)					
4	5.20	27.83	62.40	349.1	5.54
RC/30200: One well volume = 7 *l* (bailed dry after removing 18 liters)					
7	5.28	26.82	79.44	360.6	5.71
RC/30201: One well volume = 7 *l* (bailed dry after removing 52 liters)					
7	5.61	26.94	54.05	332.6	5.26
RC/30202: One well volume = 8 *l* (bailed dry after removing 45 liters)					
8	5.49	26.80	68.31	332.3	4.04
RC/30203: One well volume = 9 *l* (bailed dry after removing 24 liters)					
9	616	26.60	249.52	345.8	5.72

5.2 Soil Quality Assessment

Analyses of contaminants of concern were carried out for 16 primary soil samples submitted from five boreholes inclusive of one field duplicate sample. The results are summarized in Table 5.2, while the lab reports are presented in Appendix B.

A review of the laboratory analysis results for **soil samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

Table 5.2 – Soil Quality Assessment of Metals and Metalloids

	Range of values (mg/kg)	DTV (mg/kg)	DIV (mg/kg)	Assessment
Metals and metalloids				
Arsenic (As)	<1.20 – 53.51	-	76	All results were below DIV
Antimony (Sb)	<1.20 – 4.87	-	22	
Barium (Ba)	1.09 – 21.49	-	-	
Cadmium (Cd)	<0.06 – 0.74	-	13	
Chromium (Cr)	2.62 – 37.82	-	-	
Cobalt (Co)	<0.15 – 2.87	-	190	
Copper (Cu)	0.36 – 37.03	-	190	
Mercury (Hg)	<0.27 – 0.45	-	-	
Lead (Pb)	1.83 – 19.67	-	530	
Molybdenum (Mo)	<0.15 – 0.56	-	190	
Nickel (Ni)	<0.30 – 7.33	-	100	
Zinc (Zn)	1.65 – 83.20	-	720	
Inorganic Compounds				
Total Cyanide	<0.50	-	20	All results were below DIV
Benzene	<LOR (0.1)	-	1.1	All results were below DIV
Ethylbenzene	<LOR (0.1)	-	110	
Toluene	<LOR (0.1)	-	32	
Xylene	<LOR (0.2)	-	17	
Styrene	<LOR (0.1)	-	86	
SVOCs	< LOR	-	various	
Polynuclear Aromatic Hydrocarbons				
SVOCs	< LOR	-	40	All results were below DIV
Chlorinated Hydrocarbons				
VOCs	<LOR	-	various	All results were below DIV
SVOCs	< LOR	-	various	
Pesticides				
SVOCs	< LOR	-	various	All results were below DIV
Organotins	< LOR (1.0)	-	2.5	
MCPA	< LOR (1)	-	4	
Other Pollutants				
VOCs	< LOR		various	All results were below DIV
SVOCs	<0.2 – 0.6	-	various	
TPH (total)	<LOR (10)	-	5000	
Additional Parameters				
Total Nitrogen (TN)	18.0 - 317	-	-	
Total Phosphorous (TP)	0.53 – 41.3	-	-	

	Range of values (mg/kg)	DTV (mg/kg)	DIV (mg/kg)	Assessment
Faecal Coliform	<10 - 20	-	-	
Chloride Content	0.071 – 0.52	-	-	
Sulphate Content	<0.0082 – 0.07	-	-	
Manganese	0.32 – 66.2	-	-	
Vanadium	7.99 – 77.4	-	-	

Note. LOR = Limits of Reporting; DTV = Dutch Target Value; DIV = Dutch Intervention Value. LOR < DTV < DIV.

5.3 Groundwater Quality Assessment

Analyses of contaminants of concern were carried out for the samples collected from five boreholes monitoring wells inclusive of one field duplicate sample

A review of the laboratory analysis results for the **groundwater samples** showed that none of the samples tested exceeded their respective Dutch Intervention Values.

The results can be summarized in Table 5.3:

Table 5.3 – Groundwater Quality Assessment of Metals and Metalloids

	Range of values (µg/L)	DTV (µg/L)	DIV (µg/L)	Assessment
Metals and metalloids				
Arsenic (As)	<1.0	10	60	All results were below DIV.
Antimony (Sb)	<1.0	-	20	
Barium (Ba)	2.8 – 59.4	50	625	
Cadmium (Cd)	<0.25	0.4	6	
Chromium (Cr)	<0.10	1	30	
Cobalt (Co)	<1.0	20	100	
Copper (Cu)	<1.5	15	75	
Mercury (Hg)	<0.02	0.05	0.3	
Lead (Pb)	2.5 – 27.2	15	75	
Molybdenum (Mo)	<0.5	5	300	
Nickel (Ni)	<1.5	15	75	
Zinc (Zn)	4.5 – 25.6	65	800	
Anion and Chemical Analysis				
BOD (mg/L)	<2.0	-	-	Values indicates no real groundwater degradation.
COD (mgO2/L)	<50	-	-	
TOC (mg/L)	<1.0	-	-	
Fluoride (mg/L)	<0.5	-	-	
Chloride (mg/L)	2.3 – 9.3	-	-	
Bromide (mg/L)	<1.0	-	-	
Phosphate (mg/L)	<0.08 – 0.21	-	-	
Sulphate (mg/L)	<1.0 – 8.7	-	-	
TAN (mg/L)	<0.01	-	-	
Inorganic Compounds				
Total Cyanide	<20	5	1,500	All results were below DIV
Aromatic Compounds				
Benzene	<20	0.2	30	All results were below DIV.
Ethylbenzene	<20	4	150	

	Range of values (µg/L)	DTV (µg/L)	DIV (µg/L)	Assessment
Toluene	<20	7	1,000	
Xylene	<40	0.2	70	
Styrene	<20	0.6	300	
Phenol	<1.0	0.2	2,000	
SVOCs	< LOR	various	various	
Polynuclear Aromatic Hydrocarbons				
SVOCs	< LOR	various	various	All results were below DIV.
Chlorinated Hydrocarbons				
VOCs	<LOR	various	various	All results were below DIV.
SVOCs	< LOR	various	various	
Pesticides				
SVOCs	< LOR	various	various	All results were below DIV.
Organotins	< 0.4	-	0.7	
MCPA	< 1	-	4	
Other Pollutants				
VOCs	< LOR	various	various	All results were below DIV.
Total Phthalates	<2.0	0.5	5	
Pyridine	<2.0	0.5	30	
TPH (total)	<100	50	600	
Additional Parameters				
Total Nitrogen (TN)	0.53 – 1.98	-	-	
Total Phosphorous, (TP)	0.033 – 0.095	-	-	
Vanadium (V)	<0.005	-	-	
Faecal Coliform	<1.8 - 1600	-	-	

Note. LOR = Limits of Reporting; DTV = Dutch Target Value; DIV = Dutch Intervention Value. LOR < DTV < DIV.

5.4 Sample QA/QC

The QA/QC procedures undertaken in the field program consisted of the testing of field duplicate and split duplicate samples by the laboratory to check the consistency of the results. The field duplicate samples were not made known to laboratory personnel. Four duplicate soil samples from RC/30198/EBS, S1, RC/30200/EBS, S1 were submitted to the laboratory. One duplicate groundwater sample from RC/30201/EBS was submitted to the laboratory.

To assess the precision or the agreements among a set duplicate analysis a calculation of the relative percent difference (RPD) was applied to the sample and its replicate.
The RPD values are determined as follows:

RPD = {(Result 1 - Result 2) / Average} x 100.

The results for the duplicate analysis are attached to the Appendix B laboratory results.

The RPD results are below 30%, which is the acceptable level of precision for field duplicate samples, except for Antimony and Molybdenum in RC/30198/EBS, S1, which exceeded 30% but is less than 10 times the LOR value.

The surrogate spikes, matrix spikes and matrix spike duplicates for the VOC and SVOC are presented in Appendix B. The surrogate and spike recoveries were generally within acceptable limits and the RPD values for the duplicate spikes were generally within the 30% criteria.

Trip blanks and equipment blanks were carried out for soil and groundwater samples during transport and equipment usage. The drilling auger were used to test for all the 6 blanks conducted. None of the parameters tested for were above the laboratory detection limits indicating no contamination during trip or within the equipment.

6.0 NEA Trade Effluent

The allowable limits are defined under the NEA Trade Effluent Discharge Table and form the basis for determining the groundwater contamination status. Comparison of the analytical results to the allowable limits provides the preliminary indication of the contamination status of the groundwater.

All trade effluent results for Turf Club Road were below the guideline limit, except for TSS in RC/30199/EBS (72.7mg/L) which exceeded both watercourse (50mg/L) and controlled watercourse (30mg/L) limit.

A review of the laboratory analysis results for the groundwater samples tested can be seen on Appendix B3.

7.0 PID Reading

PID readings were taken during the soil sampling to provide on-site investigation of samples likely to contain high concentrations of VOCs.

There are no standards for PID as it is deemed as a qualitative reading. The background reading for both Turf Club Road range from 0ppm-0.9ppm. The highest reading from each borehole will be sent to lab for laboratory testing. Full PID reading can be found in Appendix E.

8.0 Conclusions

A summary of the findings from this investigation is as follows.

- According to the Historical Maps of Singapore (Department of Geography, NUS), the site area and general surroundings consisted of forested areas in the 1800s. Clementi Road was constructed by the early 1870s. while the surroundings consist of forested areas and villages. By 1969, private residential houses were built at the west of Clementi Road, followed by Ngee Ann Polytechnic in the 1970s, Maju Camp in the 1990s, and Singapore Institute of Management in the 2000s. The eastern side of Clementi Road, where the EBS work is done, remains as secondary forest to this date. In the 2019 Master Plan maps, the site is zoned as Residential, but subject to detailed planning, as the site is part of the Clementi Forest.

- Based on the bore logs of the six boreholes, all borehole locations are identified to have backfill. The depth of backfill ranges from ground surface to 1.20m bgl. The fill material consist of firm, slightly Sandy SILT with rootlets. Underlying the fill material can be identified as stiff to very stiff, slight Sandy SILT, typical of the characteristics to the Jurong Formation and stiff to very stiff, slightly Sandy SILT; typical of the characteristics of the Bukit Timah Granite.

- The static water table was measured at depths of from 1.31m to 6.37m below ground level, or from elevations of 113.24 to 121.26 m RL (relative level, based on Singapore Height Datum with mean sea level set at 100.000 m elevation). Based on computer modelling, a larger portion of groundwater appears to flow towards northwards with RC/30199/EBS being the highest reduced level for static water table. Figure 3 is a map of the water table contours and indicates the groundwater flow direction.

- A review of the laboratory analysis results for **soil samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

- A review of the laboratory analysis results for **groundwater samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

9.0 Recommendations

Based on the analytical data, physical site features, geologic settings and land use scenario there would be no need to undertake any form of remediation as the analytical results for the soil and groundwater indicate no critical issues of concern to the site occupants or neighbouring facilities based on the present land use scenario.
No previous EBS report was made available to SECS to compared the laboratory reports against at the time of this report.

APPENDICES

TABLES

TABLE 1.1

QUANTITIES OF FIELD WORKS

TABLE 1.1 QUANTITIES OF FIELD WORK

CONTRACT NO : C1066

PROJECT TITLE : SITE INVESTIGATION WORKS FOR LTA PROJECTS

WORKS ORDER : WSO-GTT-GTT-C1066-00024 (1W91)

LOCATION : OFF CLEMENTI ROAD

A - DRILLING/CORING		B- INSITU TEST	
Item No.	**4.1.a**	**8.1.a**	**8.1.b**
	Drilling in Soil (Land)	Environmental Sampling (Soil)	Environmental Sampling (Water)
Unit	m	no.	no.
Borehole No.	**DRILLING**	**BOREHOLE SAMPLING FOR ENVIROMENTAL BASELINE STUDY AND TRADE EFFLUENT DISCHARGE**	
RC/30198/EBS/WSP	10.50	7	1
RC/30199/EBS/WSP	7.50	5	1
RC/30200/EBS/WSP	9.50	7	1
RC/30201/EBS/WSP	8.50	6	1
RC/30202/EBS/WSP	7.50	5	1
RC/30203/EBS/WSP	7.50	5	1
Total	**51.00**	**35**	**6**

TABLE 1.2

QUANTITIES OF LABORATORY TESTS

TABLE 1.2 QUANTITIES OF LABORATORY TESTS

CONTRACT NO. : C1066

PROJECT TITLE : SITE INVESTIGATION WORKS FROM TUAS TO CHANGI

WORKS ORDER : WSO-GTT-GTT-C1066-00024 (1W91)

LOCATION : OFF CLEMENTI ROAD

Borehole No.	Laboratory Test – CHEMICAL TEST: 1.1.b Moisture x 3	4.1.a Organic	4.1.b Sulphate	4.1.c Chloride	4.1.d Magnesium	4.1.e Nitrate	4.1.f Phosphate	4.1.g Sulphide	4.1.h pH Value	4.1.i Fluoride	4.1.j TOC	4.1.k Bromide	4.1.l Total Ammonical Nitrogen	4.1.m Biochemical Oxygen Demand	4.1.n Chemical Oxygen Demand	4.1.o Total Dissolved Solids	4.1.p Total Suspended Solids	4.1.q Temperature	4.1.r Free Chloride	4.1.s Colour	4.1.t Oil & Grease	4.1.u Detergent as MBAS	4.1.v Phenolic Compounds as Phenol	Toxicity Test – Inorganics - Metals (5.1.1.a Arsenic (As), 5.1.1.b Antimony (An), 5.1.1.c Barium (Ba), 5.1.1.d Cadmium (Cd), 5.1.1.e Chromium (Cr), 5.1.1.f Cobalt (Co), 5.1.1.g Copper (Cu), 5.1.1.h Mercury (Hg), 5.1.1.i Lead (Pb), 5.1.1.j Molybdenum (Mo), 5.1.1.k Nickel (Ni), 5.1.1.l Zinc (Zn))	Inorganic Compounds (5.1.2.a Free Cyanide, 5.1.2.b Cyaniode-complex (pH<5), 5.1.2.c Cyaniode-complex (pH>=5), 5.1.2.d Thiocyanate (sum))	Aromatic Compounds (5.1.3.a Benzene, 5.1.3.b Ethylbenzene, 5.1.3.c Toluene, 5.1.3.d Xylene (sum), 5.1.3.e Styrene (=vinylbenzene), 5.1.3.f Phenol, 5.1.3.g Cresol (sum), 5.1.3.h Catechol, 5.1.3.i resorcinol, 5.1.3.j hydroquinone)	Polycyclic Aromatic Hydrocarbons (PAH) (5.1.4.a naphthalene, 5.1.4.b anthracene, 5.1.4.c phenantrene, 5.1.4.d fluoranthene, 5.1.4.e benzo anthracene, 5.1.4.f chrysene, 5.1.4.g benzo(a)pyrene, 5.1.4.h benzo(g,h,i)perylene, 5.1.4.i benzo(k)fluoranthene, 5.1.4.j indeno (1,2,3-c,d) pyrene, 5.1.4.k Sum PAH(Soil <= 10% OM), 5.1.4.l Sum PAH(OM)-(10<Soil<30), 5.1.4.m Sum PAH (Soil > 30% OM))
RC/30198/EBS/WSP (SOIL)	3	3							3															3	3	3	3
RC/30199/EBS/WSP (SOIL)	3	3							3															3	3	3	3
RC/30200/EBS/WSP (SOIL)	3	3							3															3	3	3	3
RC/30201/EBS/WSP (SOIL)	3	3							3															3	3	3	3
RC/30202/EBS/WSP (SOIL)	3	3							3															3	3	3	3
RC/30203/EBS/WSP (SOIL)	3	3							3															3	3	3	3
RC/30198/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1						1	1	1	1
RC/30199/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1						1	1	1	1
RC/30200/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1						1	1	1	1
RC/30201/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1						1	1	1	1
RC/30202/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1						1	1	1	1
RC/30203/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1						1	1	1	1
RC/30198/EBS/WSP (NEA)																								-	-	1	-
RC/30199/EBS/WSP (NEA)																								-	-	1	-
RC/30200/EBS/WSP (NEA)																								-	-	1	-
RC/30201/EBS/WSP (NEA)																								-	-	1	-
RC/30202/EBS/WSP (NEA)																								-	-	1	-
RC/30203/EBS/WSP (NEA)																								-	-	1	-
TOTAL	**18**	**18**	**6**	**6**	**0**	**0**	**6**	**0**	**24**	**6**	**6**	**6**	**6**	**6**	**6**	**0**	**0**	**6**	**0**	**0**	**0**	**0**	**0**	**24**	**24**	**30**	**24**

TABLE 1.2A QUANTITIES OF LABORATORY TESTS

CONTRACT NO. : **C1066**

PROJECT TITLE : **SITE INVESTIGATION WORKS FROM TUAS TO CHANGI**

WORKS ORDER : **WSO-GTT-GTT-C1066-00024 (1W91)**

LOCATION : **OFF CLEMENTI ROAD**

Borehole No.	Toxicity Test — Chlorinated Hydrocarbons (5.1.5.a vinylchloride; 5.1.5.b dichloromethane; 5.1.5.c 1,1 dichloroethane; 5.1.5.d 1,2 dichloroethane; 5.1.5.e 1,1-dichloroethene; 5.1.5.f 1,2-dichloroethene; 5.1.5.g dichloropropanes; 5.1.5.h trichloromethane; 5.1.5.i 1,1,1-trichloroethane; 5.1.5.j 1,1,2-trichloroethane; 5.1.5.k trichloroethane (Tri); 5.1.5.l tetrachloromethane (Tetra); 5.1.5.m tetrachloroethene (Per); 5.1.5.n chlorobenzene(mono,di,tri, tetra,penta,hexa); 5.1.5.o monochlorobenzene; 5.1.5.p dichlorobenzenes; 5.1.5.q trichlorobenzenes; 5.1.5.r tetrachlorobenzenes; 5.1.5.s pentachlorobenzenes; 5.1.5.t hexachlorobenzenes; 5.1.5.u chlorophenols(mono,di,tri, tetra,penta); 5.1.5.v monochlorophenols; 5.1.5.w dichlorophenols; 5.1.5.x trichlorophenols; 5.1.5.y tetrachlorophenols; 5.1.5.z pentachlorophenols; 5.1.5.aa chloronaphtalene; 5.1.5.ab monochloroalilines; 5.1.5.ac polychlorobiphenyls(PCB28,52,101,118,138,153,180); 5.1.5.ad EOX (Extractable Organic Halogenetic Compounds); 5.1.5.ad EXO (Extractable Organic Halogenetic Compounds))	Toxicity Test — Pesticides (5.1.6.a sum (DDT/DDD/DDE); 5.1.6.b sum aldrin, dieldrin, endrin; 5.1.6.c aldrin; 5.1.6.d dieldrin; 5.1.6.e endrin; 5.1.6.f sum α-HCH, β-HCH, δ-HCH; 5.1.6.g a-HCH; 5.1.6.h b-HCH; 5.1.6.i g-HCH; 5.1.6.j atrazin; 5.1.6.k carbaryl; 5.1.6.l carbofuran; 5.1.6.m chlordaan; 5.1.6.n endosulfan; 5.1.6.o heptachloor; 5.1.6.p heptachloor-epoxide; 5.1.6.q maneb; 5.1.6.r MCPA; 5.1.6.s organotin compounds)	Toxicity Test — Other Pollutants (5.1.7.a cyclohexanone; 5.1.7.b phtalates (sum); 5.1.7.c mineral oil; 5.1.7.d pyridine; 5.1.7.e tetrahydrofuran; 5.1.7.f tetrahydrothiophene; 5.1.7.g tribromomethane)
RC/30198/EBS/WSP (SOIL)	3	3	3
RC/30199/EBS/WSP (SOIL)	3	3	3
RC/30200/EBS/WSP (SOIL)	3	3	3
RC/30201/EBS/WSP (SOIL)	3	3	3
RC/30202/EBS/WSP (SOIL)	3	3	3
RC/30203/EBS/WSP (SOIL)	3	3	3
RC/30198/EBS/WSP (WATER)	1	1	1
RC/30199/EBS/WSP (WATER)	1	1	1
RC/30200/EBS/WSP (WATER)	1	1	1
RC/30201/EBS/WSP (WATER)	1	1	1
RC/30202/EBS/WSP (WATER)	1	1	1
RC/30203/EBS/WSP (WATER)	1	1	1
RC/30198/EBS/WSP (NEA)	1	-	-
RC/30199/EBS/WSP (NEA)	1	-	-
RC/30200/EBS/WSP (NEA)	1	-	-
RC/30201/EBS/WSP (NEA)	1	-	-
RC/30202/EBS/WSP (NEA)	1	-	-
RC/30203/EBS/WSP (NEA)	1	-	-
TOTAL	**30**	**24**	**24**

TABLE 1.2B QUANTITIES OF LABORATORY TESTS

CONTRACT NO. : **C1066**

PROJECT TITLE : **SITE INVESTIGATION WORKS FROM TUAS TO CHANGI**

WORKS ORDER : **WSO-GTT-GTT-C1066-00024 (1W91)**

LOCATION : **OFF CLEMENTI ROAD**

Borehole No.	Toxicity Test		
	TCPL (Toxicity Characteristic Leaching Procedure)	Trade Effuent	Others
	5.2.a Arsenic 5.2.b Barium 5.2.c Cadmium 5.2.d Chromium 5.2.e Copper 5.2.f Iron 5.2.g Lead 5.2.h Manganese 5.2.i Mercury 5.2.j Nickel 5.2.k Selenium 5.2.l Silver 5.2.m Zinc 5.2.n TCLP - Cyanide 5.2.o TCLP - Fluoride 5.2.p TCLP - Phenolic compounds as phe	5.3.a Color 5.3.b pH value 5.3.c 5-day Biochemical Oxygen Deman 5.3.d Chemical Oxygen Demand 5.3.e Total Suspended Solids 5.3.f Total Dissolved Solids 5.3.g Chloride as CL^- 5.3.h Sulphate as SO_4^{2-} 5.3.i Sulphide as S^2 5.3.j Cyanide as CN 5.3.k Detergents (LAS as MBAS) 5.3.l Grease and Oil (Total) 5.3.m Grease and Oil (Hydrocarbon) 5.3.n Arsenis as As 5.3.o Boron as B 5.3.p Barium as Ba 5.3.q Berlyllium as Be 5.3.r Cadmium as Cd 5.3.s Chromium as Cr 5.3.t Copper as CU 5.3.u Iron as Fe 5.3.v Lead as Pb 5.3.w Mangenese as Mn 5.3.x Trichlorophenols (sum) 5.3.y Nickel as Ni 5.3.z Phenolic compounds (as Phenols) 5.3.aa chloronaphtalene 5.3.ab Selenium as Se 5.3.ac Silver as Ag 5.3.ad Zinc as Zn 5.3.ae Metals in Total 5.3.af Chlorine as Cl2 5.3.ag Phosphate as $PO4^{3-}$ 5.3.ah Calcium as Ca 5.3.ai Magnesium as Mg 5.3.aj Nitrate as NO_3.	5.4.a Methyl tert-butyl-ether 5.4.b Hexane 5.4.c Heptane 5.4.d Nonane 5.4.e Decane 5.4.f Octane 5.4.g 1,24-trimethylbenze 5.4.h Furan 5.4.i DMF (N,N-dimethylformamide) 5.4.j Turpentine 5.4.k Polybrominated Diphenyl Ether 5.4.l Isobutanol 5.4.m Methyl Ethyl Ketone 5.4.n Methyl Isobutyl Ketone 5.4.o Isopropyl ether 5.4.p Diethyl ether 5.4.q Dimethyl sulphide 5.4.r Dimethyl sulphoxide 5.4.s Carbon Tetrachloride
RC/30198/EBS/WSP (SOIL)	-	-	-
RC/30199/EBS/WSP (SOIL)	-	-	-
RC/30200/EBS/WSP (SOIL)	-	-	-
RC/30201/EBS/WSP (SOIL)	-	-	-
RC/30202/EBS/WSP (SOIL)	-	-	-
RC/30203/EBS/WSP (SOIL)	-	-	-
RC/30198/EBS/WSP (WATER)	-	-	-
RC/30199/EBS/WSP (WATER)	-	-	-
RC/30200/EBS/WSP (WATER)	-	-	-
RC/30201/EBS/WSP (WATER)	-	-	-
RC/30202/EBS/WSP (WATER)	-	-	-
RC/30203/EBS/WSP (WATER)	-	-	-
RC/30198/EBS/WSP (NEA)	1	1	1
RC/30199/EBS/WSP (NEA)	1	1	1
RC/30200/EBS/WSP (NEA)	1	1	1
RC/30201/EBS/WSP (NEA)	1	1	1
RC/30202/EBS/WSP (NEA)	1	1	1
RC/30203/EBS/WSP (NEA)	1	1	1
TOTAL	**6**	**6**	**6**

APPENDIX A

BOREHOLE LOGS AND MONITORING WELL CONSTRUCTION DIAGRAM

LOCATION: Off Clementi Road

BOREHOLE NO.	RC/30198/EBS/WSP
NORTHING (m):	34363.88
EASTING (m):	21670.70
SINGAPORE HEIGHT DATUM :	23.05 m

FIELD TESTS | SPT N VALUE (0 10 20 30 40 50 60 70 80 90 100) | SPT (N)/mm SCR% | FRACTURE PER METER | WEATHERING GRADE (I II III IV V VI) | SINGAPORE HEIGHT DATUM (m) | DEPTH (m) | SAMPLE TYPE | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION | MATERIAL CODE AGS (SG)

DESCRIPTION

Depth (m)	Sample	Geological Classification	Material Code	Description
0.00 – 1.20	S1 (0.50–1.00)	FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Yellowish brown, reddish brown & dark grey, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
1.20 – 10.50	S2 (1.50–2.00), S3 (3.00–3.50), S4 (4.50–5.00), S5 (6.00–6.50), S6 (7.50–8.00), S7 (9.00–9.50)	S(VI)	MS	Stiff to very stiff, Yellowish brown, reddish brown & white, Slightly sandy SILT Residual Soil (JURONG FORMATION) Remark: (Consistency based on visual examination)
21.85				
12.55				
10.50				Borehole was terminated at 10.50m BGL as instructed by LTA. A Water Standpipe was installed at 10.00m BGL. Water table was encountered at 6.10m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
26/01/2021	17:30	10.50	–	6.10

BORING TYPE	RO
DIAMETER(mm)	115
RIG NO.	KS/25

TCR,RQD (%) (20 40 60 80); TCR; RQD

SAMPLE; PRESSURE METER TEST; CORE RUN; VANE SHEAR TEST

PERMEABILITY TEST /PACKER TEST; SPT N VALUE; PS PISTON SAMPLE; TW THIN WALL PUSH IN; MZ MAZIER

UD–THICK WALL–OPEN DRIVE; CR–CORE; SPTLS–SPT LINER; W– WATER; ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT; BD=BULK DENSITY; PD=PARTICLE DENSITY; LL=LIQUID LIMIT(%); PL=PLASTIC LIMIT (%); UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw

DATE OF FIELD WORK: 26/1/2021–27/1/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Swe Zin Thant

SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai

SUPERVISOR: M Thain Zin Chan

DRILLER: KS/Shomon

LOCATION: Off Clementi Road

BOREHOLE NO. RC/30199/EBS/WSP
NORTHING (m): 34368.56
EASTING (m): 21722.88
SINGAPORE HEIGHT DATUM : 25.70m

FIELD TESTS	SPT N VALUE	SPT (N)/mm SCR%	FRACTURE PER METER	WEATHERING GRADE	SINGAPORE HEIGHT DATUM (m)	DEPTH (m)	SAMPLE TYPE	GRAPHIC LOG	GEOLOGICAL CLASSIFICATION	MATERIAL CODE AGS (SG)	DESCRIPTION
					25.20	0			FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
						0.50 S1 1.00					
						1.50 S2 2.00					Stiff to very stiff, Yellowish brown, reddish brown & white, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
						3.00 S3 3.50					
						4.50 S4 5.00					
						6.00 S5 6.50					
					18.20	7			G(VI)	MS	
						8					Borehole was terminated at 7.50m BGL as instructed by LTA. A Water Standpipe was installed at 7.00m BGL. Water table was encountered at 4.20m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
27/01/2021	17:30	7.50	–	4.20

BORING TYPE: RO
DIAMETER(mm): 115
RIG NO.: KS/25

TCR,RQD (%)
TCR
RQD

SAMPLE
PRESSURE METER TEST
CORE RUN
VANE SHEAR TEST
PERMEABILITY TEST /PACKER TEST
SPT N VALUE
PS PISTON SAMPLE
TW THIN WALL PUSH IN
MZ MAZIER

UD–THICK WALL–OPEN DRIVE
CR–CORE
SPTLS–SPT LINER
W– WATER
ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT
BD=BULK DENSITY
PD=PARTICLE DENSITY
LL=LIQUID LIMIT(%)
PL=PLASTIC LIMIT (%)
UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw

DATE OF FIELD WORK: 27/1/2021–27/1/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Wunna Tun

SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai

SUPERVISOR: M Thain Zin Chan

DRILLER: KS/Shomon

	Range of values (mg/kg)	DTV (mg/kg)	DIV (mg/kg)	Assessment
Faecal Coliform	<10 - 20	-	-	
Chloride Content	0.071 – 0.52	-	-	
Sulphate Content	<0.0082 – 0.07	-	-	
Manganese	0.32 – 66.2	-	-	
Vanadium	7.99 – 77.4	-	-	

Note. LOR = Limits of Reporting; DTV = Dutch Target Value; DIV = Dutch Intervention Value. LOR < DTV < DIV.

5.3 Groundwater Quality Assessment

Analyses of contaminants of concern were carried out for the samples collected from five boreholes monitoring wells inclusive of one field duplicate sample

A review of the laboratory analysis results for the **groundwater samples** showed that none of the samples tested exceeded their respective Dutch Intervention Values.

The results can be summarized in Table 5.3:

Table 5.3 – Groundwater Quality Assessment of Metals and Metalloids

	Range of values (µg/L)	DTV (µg/L)	DIV (µg/L)	Assessment
Metals and metalloids				
Arsenic (As)	<1.0	10	60	All results were below DIV.
Antimony (Sb)	<1.0	-	20	
Barium (Ba)	2.8 – 59.4	50	625	
Cadmium (Cd)	<0.25	0.4	6	
Chromium (Cr)	<0.10	1	30	
Cobalt (Co)	<1.0	20	100	
Copper (Cu)	<1.5	15	75	
Mercury (Hg)	<0.02	0.05	0.3	
Lead (Pb)	2.5 – 27.2	15	75	
Molybdenum (Mo)	<0.5	5	300	
Nickel (Ni)	<1.5	15	75	
Zinc (Zn)	4.5 – 25.6	65	800	
Anion and Chemical Analysis				
BOD (mg/L)	<2.0	-	-	Values indicates no real groundwater degradation.
COD (mgO2/L)	<50	-	-	
TOC (mg/L)	<1.0	-	-	
Fluoride (mg/L)	<0.5	-	-	
Chloride (mg/L)	2.3 – 9.3	-	-	
Bromide (mg/L)	<1.0	-	-	
Phosphate (mg/L)	<0.08 – 0.21	-	-	
Sulphate (mg/L)	<1.0 – 8.7	-	-	
TAN (mg/L)	<0.01	-	-	
Inorganic Compounds				
Total Cyanide	<20	5	1,500	All results were below DIV
Aromatic Compounds				
Benzene	<20	0.2	30	All results were below DIV.
Ethylbenzene	<20	4	150	

	Range of values (µg/L)	DTV (µg/L)	DIV (µg/L)	Assessment
Toluene	<20	7	1,000	
Xylene	<40	0.2	70	
Styrene	<20	0.6	300	
Phenol	<1.0	0.2	2,000	
SVOCs	< LOR	various	various	
Polynuclear Aromatic Hydrocarbons				
SVOCs	< LOR	various	various	All results were below DIV.
Chlorinated Hydrocarbons				
VOCs	<LOR	various	various	All results were below DIV.
SVOCs	< LOR	various	various	
Pesticides				
SVOCs	< LOR	various	various	All results were below DIV.
Organotins	< 0.4	-	0.7	
MCPA	< 1	-	4	
Other Pollutants				
VOCs	< LOR	various	various	All results were below DIV.
Total Phthalates	<2.0	0.5	5	
Pyridine	<2.0	0.5	30	
TPH (total)	<100	50	600	
Additional Parameters				
Total Nitrogen (TN)	0.53 – 1.98	-	-	
Total Phosphorous, (TP)	0.033 – 0.095	-	-	
Vanadium (V)	<0.005	-	-	
Faecal Coliform	<1.8 - 1600	-	-	

Note. LOR = Limits of Reporting; DTV = Dutch Target Value; DIV = Dutch Intervention Value. LOR < DTV < DIV.

5.4 Sample QA/QC

The QA/QC procedures undertaken in the field program consisted of the testing of field duplicate and split duplicate samples by the laboratory to check the consistency of the results. The field duplicate samples were not made known to laboratory personnel. Four duplicate soil samples from RC/30198/EBS, S1, RC/30200/EBS, S1 were submitted to the laboratory. One duplicate groundwater sample from RC/30201/EBS was submitted to the laboratory.

To assess the precision or the agreements among a set duplicate analysis a calculation of the relative percent difference (RPD) was applied to the sample and its replicate.
The RPD values are determined as follows:

RPD = {(Result 1 - Result 2) / Average} x 100.

The results for the duplicate analysis are attached to the Appendix B laboratory results.

The RPD results are below 30%, which is the acceptable level of precision for field duplicate samples, except for Antimony and Molybdenum in RC/30198/EBS, S1, which exceeded 30% but is less than 10 times the LOR value.

The surrogate spikes, matrix spikes and matrix spike duplicates for the VOC and SVOC are presented in Appendix B. The surrogate and spike recoveries were generally within acceptable limits and the RPD values for the duplicate spikes were generally within the 30% criteria.

Trip blanks and equipment blanks were carried out for soil and groundwater samples during transport and equipment usage. The drilling auger were used to test for all the 6 blanks conducted. None of the parameters tested for were above the laboratory detection limits indicating no contamination during trip or within the equipment.

6.0 NEA Trade Effluent

The allowable limits are defined under the NEA Trade Effluent Discharge Table and form the basis for determining the groundwater contamination status. Comparison of the analytical results to the allowable limits provides the preliminary indication of the contamination status of the groundwater.

All trade effluent results for Turf Club Road were below the guideline limit, except for TSS in RC/30199/EBS (72.7mg/L) which exceeded both watercourse (50mg/L) and controlled watercourse (30mg/L) limit.

A review of the laboratory analysis results for the groundwater samples tested can be seen on Appendix B3.

7.0 PID Reading

PID readings were taken during the soil sampling to provide on-site investigation of samples likely to contain high concentrations of VOCs.

There are no standards for PID as it is deemed as a qualitative reading. The background reading for both Turf Club Road range from 0ppm-0.9ppm. The highest reading from each borehole will be sent to lab for laboratory testing. Full PID reading can be found in Appendix E.

8.0 Conclusions

A summary of the findings from this investigation is as follows.

- According to the Historical Maps of Singapore (Department of Geography, NUS), the site area and general surroundings consisted of forested areas in the 1800s. Clementi Road was constructed by the early 1870s. while the surroundings consist of forested areas and villages. By 1969, private residential houses were built at the west of Clementi Road, followed by Ngee Ann Polytechnic in the 1970s, Maju Camp in the 1990s, and Singapore Institute of Management in the 2000s. The eastern side of Clementi Road, where the EBS work is done, remains as secondary forest to this date. In the 2019 Master Plan maps, the site is zoned as Residential, but subject to detailed planning, as the site is part of the Clementi Forest.

- Based on the bore logs of the six boreholes, all borehole locations are identified to have backfill. The depth of backfill ranges from ground surface to 1.20m bgl. The fill material consist of firm, slightly Sandy SILT with rootlets. Underlying the fill material can be identified as stiff to very stiff, slight Sandy SILT, typical of the characteristics to the Jurong Formation and stiff to very stiff, slightly Sandy SILT; typical of the characteristics of the Bukit Timah Granite.

- The static water table was measured at depths of from 1.31m to 6.37m below ground level, or from elevations of 113.24 to 121.26 m RL (relative level, based on Singapore Height Datum with mean sea level set at 100.000 m elevation). Based on computer modelling, a larger portion of groundwater appears to flow towards northwards with RC/30199/EBS being the highest reduced level for static water table. Figure 3 is a map of the water table contours and indicates the groundwater flow direction.

- A review of the laboratory analysis results for **soil samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

- A review of the laboratory analysis results for **groundwater samples** tested showed that none of the samples tested exceeded their respective Dutch Intervention Values.

9.0 Recommendations

Based on the analytical data, physical site features, geologic settings and land use scenario there would be no need to undertake any form of remediation as the analytical results for the soil and groundwater indicate no critical issues of concern to the site occupants or neighbouring facilities based on the present land use scenario.
No previous EBS report was made available to SECS to compared the laboratory reports against at the time of this report.

APPENDICES

TABLES

TABLE 1.1

QUANTITIES OF FIELD WORKS

TABLE 1.1 QUANTITIES OF FIELD WORK

CONTRACT NO : C1066

PROJECT TITLE : SITE INVESTIGATION WORKS FOR LTA PROJECTS

WORKS ORDER : WSO-GTT-GTT-C1066-00024 (1W91)

LOCATION : OFF CLEMENTI ROAD

A - DRILLING/CORING		B- INSITU TEST	
Item No.	**4.1.a**	**8.1.a**	**8.1.b**
	Drilling in Soil (Land)	Environmental Sampling (Soil)	Environmental Sampling (Water)
Unit	m	no.	no.
Borehole No.	**DRILLING**	**BOREHOLE SAMPLING FOR ENVIROMENTAL BASELINE STUDY AND TRADE EFFLUENT DISCHARGE**	
RC/30198/EBS/WSP	10.50	7	1
RC/30199/EBS/WSP	7.50	5	1
RC/30200/EBS/WSP	9.50	7	1
RC/30201/EBS/WSP	8.50	6	1
RC/30202/EBS/WSP	7.50	5	1
RC/30203/EBS/WSP	7.50	5	1
Total	**51.00**	**35**	**6**

TABLE 1.2

QUANTITIES OF LABORATORY TESTS

TABLE 1.2 QUANTITIES OF LABORATORY TESTS

CONTRACT NO. : C1066

PROJECT TITLE : SITE INVESTIGATION WORKS FROM TUAS TO CHANGI

WORKS ORDER : WSO-GTT-GTT-C1066-00024 (1W91)

LOCATION : OFF CLEMENTI ROAD

Laboratory Test – CHEMICAL TEST

Borehole No.	1.1.b Moisture x 3	4.1.a Organic	4.1.b Sulphate	4.1.c Chloride	4.1.d Magnesium	4.1.e Nitrate	4.1.f Phosphate	4.1.g Sulphide	4.1.h pH Value	4.1.i Fluoride	4.1.j TOC	4.1.k Bromide	4.1.l Total Ammonical Nitrogen	4.1.m Biochemical Oxygen Demand	4.1.n Chemical Oxygen Demand	4.1.o Total Dissolved Solids	4.1.p Total Suspended Solids	4.1.q Temperature	4.1.r Free Chloride	4.1.s Colour	4.1.t Oil & Grease	4.1.u Detergent as MBAS	4.1.v Phenolic Compounds as Phenol
RC/30198/EBS/WSP (SOIL)	3	3							3														
RC/30199/EBS/WSP (SOIL)	3	3							3														
RC/30200/EBS/WSP (SOIL)	3	3							3														
RC/30201/EBS/WSP (SOIL)	3	3							3														
RC/30202/EBS/WSP (SOIL)	3	3							3														
RC/30203/EBS/WSP (SOIL)	3	3							3														
RC/30198/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1					
RC/30199/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1					
RC/30200/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1					
RC/30201/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1					
RC/30202/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1					
RC/30203/EBS/WSP (WATER)			1	1			1		1	1	1	1	1	1	1			1					
RC/30198/EBS/WSP (NEA)																							
RC/30199/EBS/WSP (NEA)																							
RC/30200/EBS/WSP (NEA)																							
RC/30201/EBS/WSP (NEA)																							
RC/30202/EBS/WSP (NEA)																							
RC/30203/EBS/WSP (NEA)																							
TOTAL	**18**	**18**	**6**	**6**	**0**	**0**	**6**	**0**	**24**	**6**	**6**	**6**	**6**	**6**	**6**	**0**	**0**	**6**	**0**	**0**	**0**	**0**	**0**

Toxicity Test

Borehole No.	Inorganics - Metals (5.1.1.a Arsenic (As), 5.1.1.b Antimony (An), 5.1.1.c Barium (Ba), 5.1.1.d Cadmium (Cd), 5.1.1.e Chromium (Cr), 5.1.1.f Cobalt (Co), 5.1.1.g Copper (Cu), 5.1.1.h Mercury (Hg), 5.1.1.i Lead (Pb), 5.1.1.j Molybdenum (Mo), 5.1.1.k Nickel (Ni), 5.1.1.l Zinc (Zn))	Inorganic Compounds (5.1.2.a Free Cyanide, 5.1.2.b Cyaniode-complex (pH<5), 5.1.2.c Cyaniode-complex (pH>=5), 5.1.2.d Thiocyanate (sum))	Aromatic Compounds (5.1.3.a Benzene, 5.1.3.b Ethylbenzene, 5.1.3.c Toluene, 5.1.3.d Xylene (sum), 5.1.3.e Styrene (=vinylbenzene), 5.1.3.f Phenol, 5.1.3.g Cresol (sum), 5.1.3.h Catechol, 5.1.3.i resorcinol, 5.1.3.j hydroquinone)	Polycyclic Aromatic Hydrocarbons (PAH) (5.1.4.a naphthalene, 5.1.4.b anthracene, 5.1.4.c phenantrene, 5.1.4.d fluoranthene, 5.1.4.e benzo anthracene, 5.1.4.f chrysene, 5.1.4.g benzo(a)pyrene, 5.1.4.h benzo(g,h,i)perylene, 5.1.4.i benzo(k)fluoranthene, 5.1.4.j indeno (1,2,3-c,d) pyrene, 5.1.4.k Sum PAH(Soil <= 10% OM), 5.1.4.l Sum PAH(OM)-(10<Soil<30), 5.1.4.m Sum PAH (Soil > 30% OM))
RC/30198/EBS/WSP (SOIL)	3	3	3	3
RC/30199/EBS/WSP (SOIL)	3	3	3	3
RC/30200/EBS/WSP (SOIL)	3	3	3	3
RC/30201/EBS/WSP (SOIL)	3	3	3	3
RC/30202/EBS/WSP (SOIL)	3	3	3	3
RC/30203/EBS/WSP (SOIL)	3	3	3	3
RC/30198/EBS/WSP (WATER)	1	1	1	1
RC/30199/EBS/WSP (WATER)	1	1	1	1
RC/30200/EBS/WSP (WATER)	1	1	1	1
RC/30201/EBS/WSP (WATER)	1	1	1	1
RC/30202/EBS/WSP (WATER)	1	1	1	1
RC/30203/EBS/WSP (WATER)	1	1	1	1
RC/30198/EBS/WSP (NEA)	-	-	1	-
RC/30199/EBS/WSP (NEA)	-	-	1	-
RC/30200/EBS/WSP (NEA)	-	-	1	-
RC/30201/EBS/WSP (NEA)	-	-	1	-
RC/30202/EBS/WSP (NEA)	-	-	1	-
RC/30203/EBS/WSP (NEA)	-	-	1	-
TOTAL	**24**	**24**	**30**	**24**

TABLE 1.2A QUANTITIES OF LABORATORY TESTS

CONTRACT NO. : C1066

PROJECT TITLE : SITE INVESTIGATION WORKS FROM TUAS TO CHANGI

WORKS ORDER : WSO-GTT-GTT-C1066-00024 (1W91)

LOCATION : OFF CLEMENTI ROAD

Toxicity Test

Group	Item	Test
Chlorinated Hydrocarbons	5.1.5.a	vinylchloride
	5.1.5.b	dichloromethane
	5.1.5.c	1,1 dichloroethane
	5.1.5.d	1,2 dichloroethane
	5.1.5.e	1,1-dichloroethene
	5.1.5.f	1,2-dichloroethene
	5.1.5.g	dichloropropanes
	5.1.5.h	trichloromethane
	5.1.5.i	1,1,1-trichloroethane
	5.1.5.j	1,1,2-trichloroethane
	5.1.5.k	trichloroethane (Tri)
	5.1.5.l	tetrachloromethane (Tetra)
	5.1.5.m	tetrachloroethene (Per)
	5.1.5.n	chlorobenzene(mono,di,tri, tetra,penta,hexa)
	5.1.5.o	monochlorobenzene
	5.1.5.p	dichlorobenzenes
	5.1.5.q	trichlorobenzenes
	5.1.5.r	tetrachlorobenzenes
	5.1.5.s	pentachlorobenzenes
	5.1.5.t	hexachlorobenzenes
	5.1.5.u	chlorophenols(mono,di,tri, tetra,penta)
	5.1.5.v	monochlorophenols
	5.1.5.w	dichlorophenols
	5.1.5.x	trichlorophenols
	5.1.5.y	tetrachlorophenols
	5.1.5.z	pentachlorophenols
	5.1.5.aa	chloronaphtalene
	5.1.5.ab	monochloroalilines
	5.1.5.ac	polychlorobiphenyls(PCB28,52,101,118,138,153,180)
	5.1.5.ad	EOX (Extractable Organic Halogenetic Compounds)
	5.1.5.ad	EXO (Extractable Organic Halogenetic Compounds)
Pesticides	5.1.6.a	sum (DDT/DDD/DDE)
	5.1.6.b	sum aldrin, dieldrin, endrin
	5.1.6.c	aldrin
	5.1.6.d	dieldrin
	5.1.6.e	endrin
	5.1.6.f	sum α-HCH, β-HCH, δ-HCH
	5.1.6.g	a-HCH
	5.1.6.h	b-HCH
	5.1.6.i	g-HCH
	5.1.6.j	atrazin
	5.1.6.k	carbaryl
	5.1.6.l	carbofuran
	5.1.6.m	chlordaan
	5.1.6.n	endosulfan
	5.1.6.o	heptachloor
	5.1.6.p	heptachloor-epoxide
	5.1.6.q	maneb
	5.1.6.r	MCPA
	5.1.6.s	organotin compounds
Other Pollutants	5.1.7.a	cyclohexanone
	5.1.7.b	phtalates (sum)
	5.1.7.c	mineral oil
	5.1.7.d	pyridine
	5.1.7.e	tetrahydrofuran
	5.1.7.f	tetrahydrothiophene
	5.1.7.g	tribromomethane

Borehole No.	Chlorinated Hydrocarbons	Pesticides	Other Pollutants
RC/30198/EBS/WSP (SOIL)	3	3	3
RC/30199/EBS/WSP (SOIL)	3	3	3
RC/30200/EBS/WSP (SOIL)	3	3	3
RC/30201/EBS/WSP (SOIL)	3	3	3
RC/30202/EBS/WSP (SOIL)	3	3	3
RC/30203/EBS/WSP (SOIL)	3	3	3
RC/30198/EBS/WSP (WATER)	1	1	1
RC/30199/EBS/WSP (WATER)	1	1	1
RC/30200/EBS/WSP (WATER)	1	1	1
RC/30201/EBS/WSP (WATER)	1	1	1
RC/30202/EBS/WSP (WATER)	1	1	1
RC/30203/EBS/WSP (WATER)	1	1	1
RC/30198/EBS/WSP (NEA)	1	-	-
RC/30199/EBS/WSP (NEA)	1	-	-
RC/30200/EBS/WSP (NEA)	1	-	-
RC/30201/EBS/WSP (NEA)	1	-	-
RC/30202/EBS/WSP (NEA)	1	-	-
RC/30203/EBS/WSP (NEA)	1	-	-
TOTAL	**30**	**24**	**24**

TABLE 1.2B QUANTITIES OF LABORATORY TESTS

CONTRACT NO. : **C1066**

PROJECT TITLE : **SITE INVESTIGATION WORKS FROM TUAS TO CHANGI**

WORKS ORDER : **WSO-GTT-GTT-C1066-00024 (1W91)**

LOCATION : **OFF CLEMENTI ROAD**

Borehole No.	Toxicity Test		
	TCPL (Toxicity Characteristic Leaching Procedure)	Trade Effuent	Others
	5.2.a Arsenic 5.2.b Barium 5.2.c Cadmium 5.2.d Chromium 5.2.e Copper 5.2.f Iron 5.2.g Lead 5.2.h Manganese 5.2.i Mercury 5.2.j Nickel 5.2.k Selenium 5.2.l Silver 5.2.m Zinc 5.2.n TCLP - Cyanide 5.2.o TCLP - Fluoride 5.2.p TCLP - Phenolic compounds as phe	5.3.a Color 5.3.b pH value 5.3.c 5-day Biochemical Oxygen Deman 5.3.d Chemical Oxygen Demand 5.3.e Total Suspended Solids 5.3.f Total Dissolved Solids 5.3.g Chloride as CL^- 5.3.h Sulphate as SO_4^{2-} 5.3.i Sulphide as S^2 5.3.j Cyanide as CN 5.3.k Detergents (LAS as MBAS) 5.3.l Grease and Oil (Total) 5.3.m Grease and Oil (Hydrocarbon) 5.3.n Arsenis as As 5.3.o Boron as B 5.3.p Barium as Ba 5.3.q Berlyllium as Be 5.3.r Cadmium as Cd 5.3.s Chromium as Cr 5.3.t Copper as CU 5.3.u Iron as Fe 5.3.v Lead as Pb 5.3.w Mangenese as Mn 5.3.x Trichlorophenols (sum) 5.3.y Nickel as Ni 5.3.z Phenolic compounds (as Phenols) 5.3.aa chloronaphtalene 5.3.ab Selenium as Se 5.3.ac Silver as Ag 5.3.ad Zinc as Zn 5.3.ae Metals in Total 5.3.af Chlorine as Cl2 5.3.ag Phosphate as $PO4^{3-}$ 5.3.ah Calcium as Ca 5.3.ai Magnesium as Mg 5.3.aj Nitrate as NO_3.	5.4.a Methyl tert-butyl-ether 5.4.b Hexane 5.4.c Heptane 5.4.d Nonane 5.4.e Decane 5.4.f Octane 5.4.g 1,24-trimethylbenze 5.4.h Furan 5.4.i DMF (N,N-dimethylformamide) 5.4.j Turpentine 5.4.k Polybrominated Diphenyl Ether 5.4.l Isobutanol 5.4.m Methyl Ethyl Ketone 5.4.n Methyl Isobutyl Ketone 5.4.o Isopropyl ether 5.4.p Diethyl ether 5.4.q Dimethyl sulphide 5.4.r Dimethyl sulphoxide 5.4.s Carbon Tetrachloride
RC/30198/EBS/WSP (SOIL)	-	-	-
RC/30199/EBS/WSP (SOIL)	-	-	-
RC/30200/EBS/WSP (SOIL)	-	-	-
RC/30201/EBS/WSP (SOIL)	-	-	-
RC/30202/EBS/WSP (SOIL)	-	-	-
RC/30203/EBS/WSP (SOIL)	-	-	-
RC/30198/EBS/WSP (WATER)	-	-	-
RC/30199/EBS/WSP (WATER)	-	-	-
RC/30200/EBS/WSP (WATER)	-	-	-
RC/30201/EBS/WSP (WATER)	-	-	-
RC/30202/EBS/WSP (WATER)	-	-	-
RC/30203/EBS/WSP (WATER)	-	-	-
RC/30198/EBS/WSP (NEA)	1	1	1
RC/30199/EBS/WSP (NEA)	1	1	1
RC/30200/EBS/WSP (NEA)	1	1	1
RC/30201/EBS/WSP (NEA)	1	1	1
RC/30202/EBS/WSP (NEA)	1	1	1
RC/30203/EBS/WSP (NEA)	1	1	1
TOTAL	**6**	**6**	**6**

APPENDIX A

BOREHOLE LOGS AND MONITORING WELL CONSTRUCTION DIAGRAM

LOCATION: Off Clementi Road

BOREHOLE NO.	RC/30198/EBS/WSP
NORTHING (m):	34363.88
EASTING (m):	21670.70
SINGAPORE HEIGHT DATUM :	23.05 m

FIELD TESTS | SPT N VALUE (0 10 20 30 40 50 60 70 80 90 100) | SPT (N)/mm SCR% | FRACTURE PER METER | WEATHERING GRADE (I II III IV V VI) | SINGAPORE HEIGHT DATUM (m) | DEPTH (m) | SAMPLE TYPE | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION | MATERIAL CODE AGS (SG)

DESCRIPTION

Depth (m)	Sample	Geological Classification	Material Code	Description
0.00 – 1.20	S1 (0.50–1.00)	FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Yellowish brown, reddish brown & dark grey, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
1.20 – 10.50	S2 (1.50–2.00), S3 (3.00–3.50), S4 (4.50–5.00), S5 (6.00–6.50), S6 (7.50–8.00), S7 (9.00–9.50)	S(VI)	MS	Stiff to very stiff, Yellowish brown, reddish brown & white, Slightly sandy SILT Residual Soil (JURONG FORMATION) Remark: (Consistency based on visual examination)
21.85				
12.55				
10.50				Borehole was terminated at 10.50m BGL as instructed by LTA. A Water Standpipe was installed at 10.00m BGL. Water table was encountered at 6.10m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
26/01/2021	17:30	10.50	–	6.10

BORING TYPE	RO
DIAMETER(mm)	115
RIG NO.	KS/25

TCR,RQD (%) (20 40 60 80); TCR; RQD

SAMPLE; PRESSURE METER TEST; CORE RUN; VANE SHEAR TEST

PERMEABILITY TEST /PACKER TEST; SPT N VALUE; PS PISTON SAMPLE; TW THIN WALL PUSH IN; MZ MAZIER

UD–THICK WALL–OPEN DRIVE; CR–CORE; SPTLS–SPT LINER; W– WATER; ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT; BD=BULK DENSITY; PD=PARTICLE DENSITY; LL=LIQUID LIMIT(%); PL=PLASTIC LIMIT (%); UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw

DATE OF FIELD WORK: 26/1/2021–27/1/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Swe Zin Thant

SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai

SUPERVISOR: M Thain Zin Chan

DRILLER: KS/Shomon

LOCATION: Off Clementi Road

BOREHOLE NO. RC/30199/EBS/WSP
NORTHING (m): 34368.56
EASTING (m): 21722.88
SINGAPORE HEIGHT DATUM : 25.70m

FIELD TESTS	SPT N VALUE	SPT (N)/mm SCR%	FRACTURE PER METER	WEATHERING GRADE	SINGAPORE HEIGHT DATUM (m)	DEPTH (m)	SAMPLE TYPE	GRAPHIC LOG	GEOLOGICAL CLASSIFICATION	MATERIAL CODE AGS (SG)	DESCRIPTION
					25.20	0			FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
						0.50 S1 1.00					
						1.50 S2 2.00					Stiff to very stiff, Yellowish brown, reddish brown & white, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
						3.00 S3 3.50					
						4.50 S4 5.00					
						6.00 S5 6.50					
					18.20	7			G(VI)	MS	
						8					Borehole was terminated at 7.50m BGL as instructed by LTA. A Water Standpipe was installed at 7.00m BGL. Water table was encountered at 4.20m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
27/01/2021	17:30	7.50	–	4.20

BORING TYPE: RO
DIAMETER(mm): 115
RIG NO.: KS/25

TCR,RQD (%)
TCR
RQD

SAMPLE
PRESSURE METER TEST
CORE RUN
VANE SHEAR TEST
PERMEABILITY TEST /PACKER TEST
SPT N VALUE
PS PISTON SAMPLE
TW THIN WALL PUSH IN
MZ MAZIER

UD–THICK WALL–OPEN DRIVE
CR–CORE
SPTLS–SPT LINER
W– WATER
ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT
BD=BULK DENSITY
PD=PARTICLE DENSITY
LL=LIQUID LIMIT(%)
PL=PLASTIC LIMIT (%)
UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw

DATE OF FIELD WORK: 27/1/2021–27/1/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Wunna Tun

SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai

SUPERVISOR: M Thain Zin Chan

DRILLER: KS/Shomon

LOCATION: Off Clementi Road

BOREHOLE NO. RC/30200/EBS/WSP
NORTHING (m): 34413.70
EASTING (m): 21739.07
SINGAPORE HEIGHT DATUM : 22.24 m

FIELD TESTS | SPT N VALUE (0 10 20 30 40 50 60 70 80 90 100) | SPT (N)/mm SCR% | FRACTURE PER METER | WEATHERING GRADE (I II III IV V VI) | SINGAPORE HEIGHT DATUM (m) | DEPTH (m) | SAMPLE TYPE | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION | MATERIAL CODE AGS (SG)

DESCRIPTION

Depth (m)	Sample	Geological Classification	Material Code AGS (SG)	Description
0.50	S1(T)	FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
0.80	S1(B)			
1.00				
1.50	S2			
2.00				Stiff to very stiff, Reddish brown, yellowish brown & white, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
3.00	S3			
3.50				
4.50	S4			
5.00				
6.00	S5			
6.50				
7.50	S6			
8.00				
9.00	S7	G(VI)	MS	
9.50				Borehole was terminated at 9.50m BGL as instructed by LTA. A Water Standpipe was installed at 9.00m BGL. Water table was encountered at 5.70m BGL.

SINGAPORE HEIGHT DATUM (m): 21.44 (I–II) / 12.74 (II–III)

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
29/01/2021	17:30	9.50	–	5.70

BORING TYPE: RO
DIAMETER(mm): 115
RIG NO.: KS/25

TCR,RQD (%) (20 40 60 80)
TCR
RQD

SAMPLE
PRESSURE METER TEST
CORE RUN
VANE SHEAR TEST
PERMEABILITY TEST /PACKER TEST
SPT N VALUE
PS PISTON SAMPLE
TW THIN WALL PUSH IN
MZ MAZIER

UD–THICK WALL–OPEN DRIVE
CR–CORE
SPTLS–SPT LINER
W– WATER
ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT
BD=BULK DENSITY
PD=PARTICLE DENSITY
LL=LIQUID LIMIT(%)
PL=PLASTIC LIMIT (%)
UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw
DATE OF FIELD WORK: 29/1/2021–29/1/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Swe Zin Thant
SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai
SUPERVISOR: M Thain Zin Chan
DRILLER: KS/Shomon

LOCATION: Off Clementi Road

BOREHOLE NO. RC/30201/EBS/WSP
NORTHING (m): 34452.60
EASTING (m): 21783.86
SINGAPORE HEIGHT DATUM : 18.70 m

FIELD TESTS	SPT N VALUE	SPT (N)/mm SCR%	FRACTURE PER METER	WEATHERING GRADE	SINGAPORE HEIGHT DATUM (m)	DEPTH (m)	SAMPLE TYPE	GRAPHIC LOG	GEOLOGICAL CLASSIFICATION	MATERIAL CODE AGS (SG)	DESCRIPTION
					18.00	0.50 S1(T) 0.70 S1(B) 1.00			FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
						1.50 S2 2.00					Stiff to Very stiff, Reddish brown & yellowish brown, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
						3.00 S3 3.50					
						4.50 S4 5.00					
						6.00 S5 6.50					
						7.50 S6 8.00					
					10.20	8.50			G(VI)	MS	Borehole was terminated at 8.50m BGL as instructed by LTA. A Water Standpipe was installed at 7.00m BGL. Water table was encountered at 2.70m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
30/01/2021	17:30	8.50	–	2.70

BORING TYPE	DIAMETER(mm)	RIG NO.
RO	115	KS/25

TCR,RQD (%) 20 40 60 80

TCR

RQD

SAMPLE

PRESSURE METER TEST

CORE RUN

VANE SHEAR TEST

PERMEABILITY TEST /PACKER TEST

SPT N VALUE

PS PISTON SAMPLE

TW THIN WALL PUSH IN

MZ MAZIER

UD–THICK WALL–OPEN DRIVE

CR–CORE

SPTLS–SPT LINER

W– WATER

ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT
BD=BULK DENSITY
PD=PARTICLE DENSITY
LL=LIQUID LIMIT(%)
PL=PLASTIC LIMIT (%)
UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw

DATE OF FIELD WORK: 30/1/2021–30/1/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Swe Zin Thant

SHEET NO. <1> / <1>

PROJECT MANAGER: John Chai

SUPERVISOR: Zeyar Win

DRILLER: KS/Shomon

LOCATION: Off Clementi Road

BOREHOLE NO. RC/30202/EBS/WSP
NORTHING (m): 34509.16
EASTING (m): 21826.01
SINGAPORE HEIGHT DATUM : 16.08 m

FIELD TESTS	SPT N VALUE	SPT (N)/mm SCR%	FRACTURE PER METER	WEATHERING GRADE	SINGAPORE HEIGHT DATUM (m)	DEPTH (m)	SAMPLE TYPE	GRAPHIC LOG	GEOLOGICAL CLASSIFICATION	MATERIAL CODE AGS (SG)	DESCRIPTION
				I II III IV V VI	15.38	0.50 S1(T) 0.70 S1(B) 1.00			FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
						1.50 S2 2.00					Stiff to Very stiff, Reddish brown & yellowish brown, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
						3.00 S3 3.50					
						4.50 S4 5.00					
						6.00 S5 6.50					
					8.58	7.50			G(VI)	MS	Borehole was terminated at 7.50m BGL as instructed by LTA. A Water Standpipe was installed at 7.00m BGL. Water table was encountered at 4.70m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
30/01/2021	17:30	7.50	–	4.70

BORING TYPE: RO
DIAMETER(mm): 115
RIG NO.: KS/25

TCR,RQD (%) 20 40 60 80
TCR
RQD

SAMPLE
PRESSURE METER TEST
CORE RUN
VANE SHEAR TEST
PERMEABILITY TEST /PACKER TEST
SPT N VALUE
PS PISTON SAMPLE
TW THIN WALL PUSH IN
MZ MAZIER

UD–THICK WALL–OPEN DRIVE
CR–CORE
SPTLS–SPT LINER
W– WATER
ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT
BD=BULK DENSITY
PD=PARTICLE DENSITY
LL=LIQUID LIMIT(%)
PL=PLASTIC LIMIT (%)
UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw
DATE OF FIELD WORK: 30/01/21–30/01/21

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Swe Zin Thant
SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai
SUPERVISOR: M Thain Zin Chan
DRILLER: KS/Shomon

LOCATION: Off Clementi Road

BOREHOLE NO. RC/30203/EBS/WSP

NORTHING (m): 34557.53

EASTING (m): 21872.45

SINGAPORE HEIGHT DATUM : 14.55 m

FIELD TESTS	SPT N VALUE (0 10 20 30 40 50 60 70 80 90 100)	SPT (N)/mm SCR%	FRACTURE PER METER	WEATHERING GRADE (I II III IV V VI)	SINGAPORE HEIGHT DATUM (m)	DEPTH (m)	SAMPLE TYPE	GRAPHIC LOG	GEOLOGICAL CLASSIFICATION	MATERIAL CODE AGS (SG)	DESCRIPTION
					13.55	0.50 S1 1.00			FILL	MS	Trial Pit (1.00 x 0.80 x 1.50)m3 Hand Auger (1.50–3.00)m Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets & brick fragments (MADE GROUND) Remark: (Consistency based on visual examination)
						1.50 S2 2.00					Stiff to Very stiff, Yellowish brown, reddish brown & white, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
						3.00 S3 3.50					
						4.50 S4 5.00					
						6.00 S5 6.50					
					7.05	7.50			G(VI)	MS	Borehole was terminated at 7.50m BGL as instructed by LTA. A Water Standpipe was installed at 7.00m BGL. Water table was encountered at 4.70m BGL.

Ground Water Level (Measured from Ground Level)

Date (dd/mm/yyyy)	Time (hh:mm)	Borehole Depth (m)	Casing Depth (m)	Water Level (m)
01/02/2021	17:30	6.50	–	4.70

BORING TYPE: RO

DIAMETER(mm): 115

RIG NO.: KS/25

TCR,RQD (%) (20 40 60 80)

TCR

RQD

SAMPLE

PRESSURE METER TEST

CORE RUN

VANE SHEAR TEST

PERMEABILITY TEST /PACKER TEST

SPT N VALUE

PS PISTON SAMPLE

TW THIN WALL PUSH IN

MZ MAZIER

UD–THICK WALL–OPEN DRIVE

CR–CORE

SPTLS–SPT LINER

W– WATER

ATTEMPT–UD,TW,MZ,PS

MC–MOISTURE CONTENT
BD=BULK DENSITY
PD=PARTICLE DENSITY
LL=LIQUID LIMIT(%)
PL=PLASTIC LIMIT (%)
UU/CU=UNCONSOLIDATED /CONSOLIDATED UNDRAINED TEST (kPa)

CLIENT: Land Transport Authority

LOG OF BORING
GEOTECHNICAL STUDY – FIELD INVESTIGATIONS

PROJECT: Site Investigation Works From Tuas to Changi (1W91)

PREPARED BY: Yee Yee Maw

DATE OF FIELD WORK: 1/2/2021–1/2/2021

KWANG SING ENGINEERING PTE LTD

CHECKED BY: Swe Zin Thant

SHEET NO.: <1> / <1>

PROJECT MANAGER: John Chai

SUPERVISOR: M Thain Zin Chan

DRILLER: KS/Shomon

INSTALLATION SHEET

CLIENT: Land Transport Authority	TYPE OF THE INSTRUMENT: Groundwater Monitoring Well (For EBS Boreholes)
PROJECT: Site Investigation Works From Tuas to Changi (1W91)	GROUND LEVEL: 23.05m SHD
LOCATION: Off Clementi Road	TOP OF PIPE LEVEL: 23.05m SHD
CO-ORDINATES: N34363.88m, E21670.70m	INSTALLED BY: M Thain Zin Chan
INSTRUMENTS NO: RC/30198/EBS/WSP	DATE INSTALLED: 27/01/2021

Scale (m)	Graphic Log	Depth (m)	DESCRIPTION
			GROUND LEVEL
0.5			Firm, Yellowish brown, reddish brown & dark grey, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
1		1.20	
1.5			Stiff to very stiff, Yellowish brown, reddish brown & white, Slightly sandy SILT Residual Soil (JURONG FORMATION) Remark: (Consistency based on visual examination)
2			
2.5			
3			
3.5			
4			
4.5			
5			
5.5			
6			
6.5			
7			
7.5			
8			
8.5			
9			
9.5			
10			
10.5		10.50	Borehole terminated at 10.50m BGL

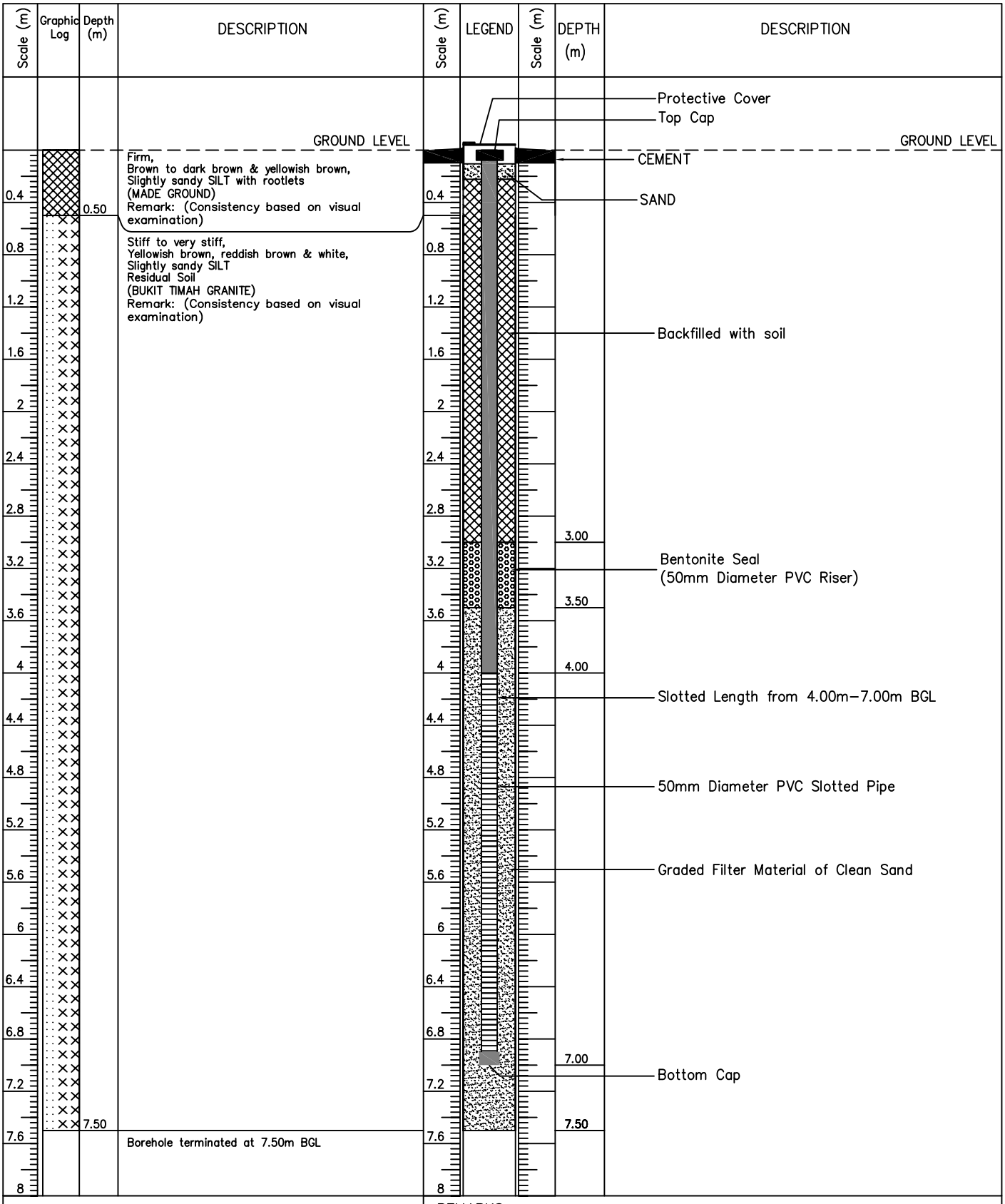
Scale (m)	LEGEND	Scale (m)	DEPTH (m)	DESCRIPTION
				Protective Cover
				Top Cap
				GROUND LEVEL
				CEMENT
0.5				SAND
1				
1.5				
2				
2.5				
3				Backfilled with soil
3.5				
4				
4.5				
5				
5.5				
6			6.00	
6.5			6.50	Bentonite Seal (50mm Diameter PVC Riser)
7			7.00	
7.5				Slotted Length from 7.00m-10.00m BGL
8				
8.5				50mm Diameter PVC Slotted Pipe
9				Graded Filter Material of Clean Sand
9.5				
10			10.00	
10.5			10.50	Bottom Cap

KWANG SING ENGINEERING PTE LTD

REMARKS:

INSTALLATION SHEET

CLIENT: Land Transport Authority	TYPE OF THE INSTRUMENT: Groundwater Monitoring Well (For EBS Boreholes)
PROJECT: Site Investigation Works From Tuas to Changi (1W91)	GROUND LEVEL: 25.70m SHD
LOCATION: Off Clementi Road	TOP OF PIPE LEVEL: 25.70m SHD
CO-ORDINATES: N34368.56m, E21722.88m	INSTALLED BY: M Thain Zin Chan
INSTRUMENTS NO: RC/30199/EBS/WSP	DATE INSTALLED: 27/01/2021



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REMARKS:

INSTALLATION SHEET

CLIENT: Land Transport Authority	TYPE OF THE INSTRUMENT: Groundwater Monitoring Well (For EBS Boreholes)
PROJECT: Site Investigation Works From Tuas to Changi (1W91)	GROUND LEVEL: 22.24m SHD
LOCATION: Off Clementi Road	TOP OF PIPE LEVEL: 22.24m SHD
CO-ORDINATES: N34413.70m, E21739.07m	INSTALLED BY: M Thain Zin Chan
INSTRUMENTS NO: RC/30200/EBS/WSP	DATE INSTALLED: 29/01/2021

Scale (m)	Graphic Log	Depth (m)	DESCRIPTION
			GROUND LEVEL
0.5			Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
1		0.80	Stiff to very stiff, Reddish brown, yellowish brown & white, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
1.5			
2			
2.5			
3			
3.5			
4			
4.5			
5			
5.5			
6			
6.5			
7			
7.5			
8			
8.5			
9			
9.5		9.50	
10			Borehole terminated at 9.50m BGL

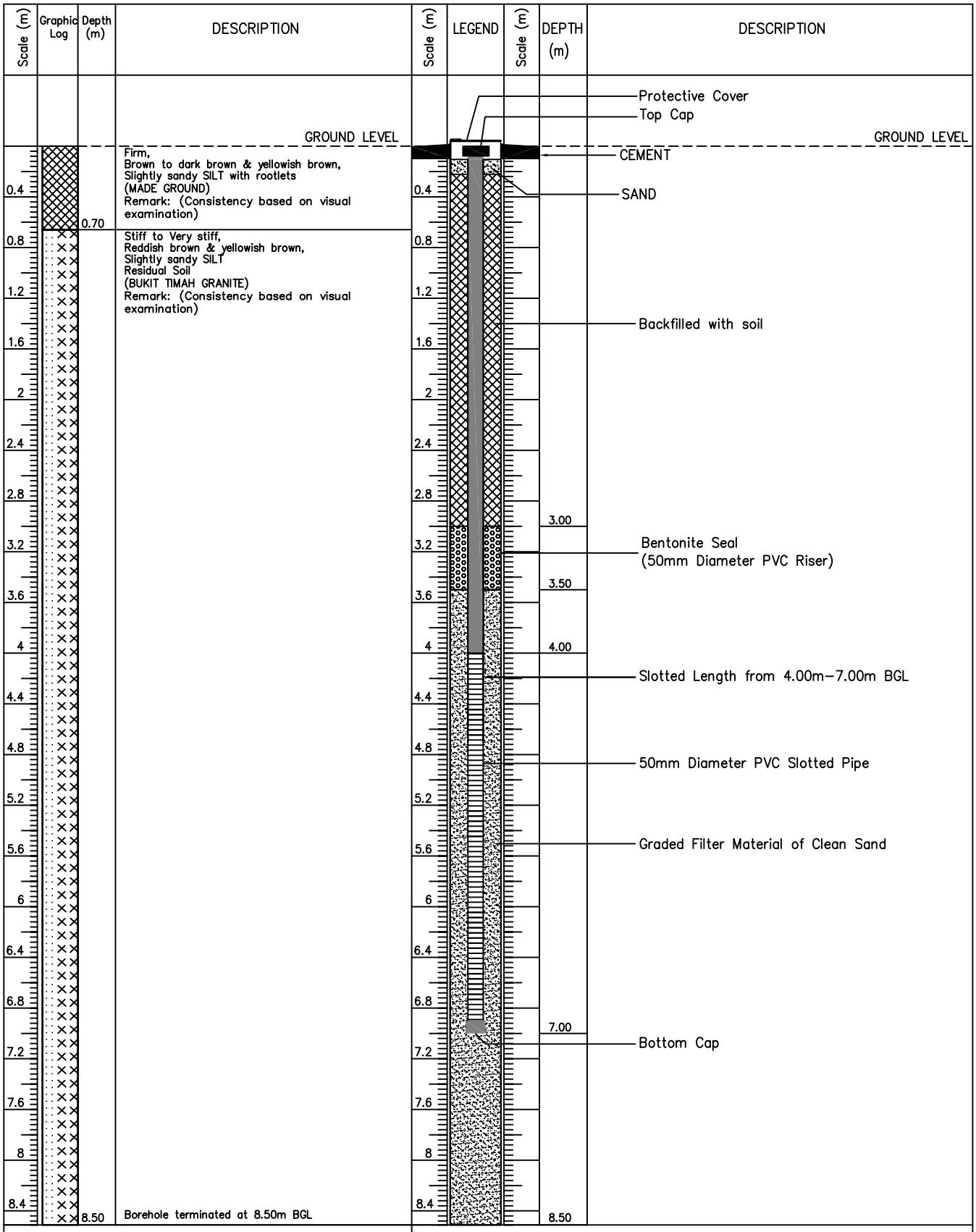
Scale (m)	LEGEND	Scale (m)	DEPTH (m)	DESCRIPTION
				GROUND LEVEL
				CEMENT
0.5		0.5		SAND
1		1		
1.5		1.5		
2		2		Backfilled with soil
2.5		2.5		
3		3		
3.5		3.5		
4		4		
4.5		4.5		
5		5	5.00	
5.5		5.5	5.50	Bentonite Seal (50mm Diameter PVC Riser)
6		6	6.00	
6.5		6.5		Slotted Length from 6.00m-9.00m BGL
7		7		
7.5		7.5		50mm Diameter PVC Slotted Pipe
8		8		
8.5		8.5		Graded Filter Material of Clean Sand
9		9	9.00	
				Bottom Cap
9.5		9.5	9.50	
10		10		

KWANG SING ENGINEERING PTE LTD

REMARKS:

INSTALLATION SHEET

CLIENT: Land Transport Authority	TYPE OF THE INSTRUMENT: Groundwater Monitoring Well (For EBS Boreholes)
PROJECT: Site Investigation Works From Tuas to Changi (1W91)	GROUND LEVEL: 18.70m BGL
LOCATION: Off Clementi Road	TOP OF PIPE LEVEL: 18.70m BGL
CO-ORDINATES: N34452.60m, E21783.86m	INSTALLED BY: M Thain Zin Chan
INSTRUMENTS NO: RC/30201/EBS/WSP	DATE INSTALLED: 30/01/2021



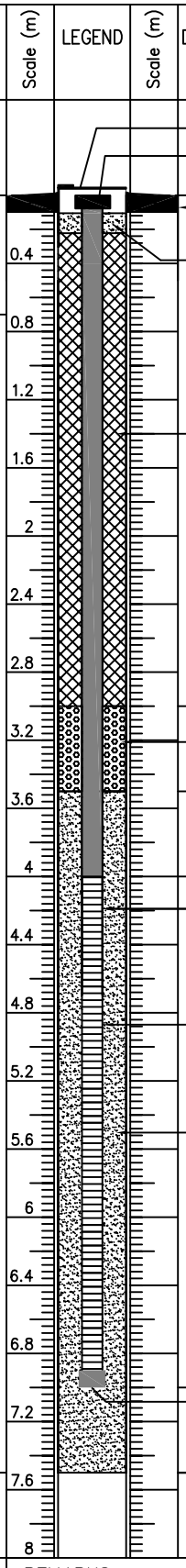
REMARKS:

KWANG SING ENGINEERING PTE LTD

INSTALLATION SHEET

CLIENT: Land Transport Authority	TYPE OF THE INSTRUMENT: WATER STANDPIPE
PROJECT: Site Investigation Works From Tuas to Changi (1W91)	GROUND LEVEL: 16.08m SHD
LOCATION: Off Clementi Road	TOP OF PIPE LEVEL: 16.08m SHD
CO-ORDINATES: N34509.16m, E21826.01m	INSTALLED BY: M Thain Zin Chan
INSTRUMENTS NO: RC/30202/EBS/WSP	DATE INSTALLED: 30/01/2021

Scale (m)	Graphic Log	Depth (m)	DESCRIPTION
			GROUND LEVEL
0.4			Firm, Brown to dark brown & yellowish brown, Slightly sandy SILT with rootlets (MADE GROUND) Remark: (Consistency based on visual examination)
		0.70	
0.8			Stiff to Very stiff, Reddish brown & yellowish brown, Slightly sandy SILT Residual Soil (BUKIT TIMAH GRANITE) Remark: (Consistency based on visual examination)
1.2			
1.6			
2			
2.4			
2.8			
3.2			
3.6			
4			
4.4			
4.8			
5.2			
5.6			
6			
6.4			
6.8			
7.2			
		7.50	Borehole terminated at 7.50m BGL
7.6			
8			



Scale (m)	DEPTH (m)	DESCRIPTION
		Protective Cover
		Top Cap
		GROUND LEVEL
		CEMENT
0.4		SAND
0.8		
1.2		Backfilled with soil
1.6		
2		
2.4		
2.8		
	3.00	
3.2		Bentonite Seal (50mm Diameter PVC Riser)
	3.50	
3.6		
4	4.00	
4.4		Slotted Length from 4.00m-7.00m BGL
4.8		50mm Diameter PVC Slotted Pipe
5.2		
5.6		Graded Filter Material of Clean Sand
6		
6.4		
6.8		
	7.00	
7.2		Bottom Cap
	7.50	
7.6		
8		

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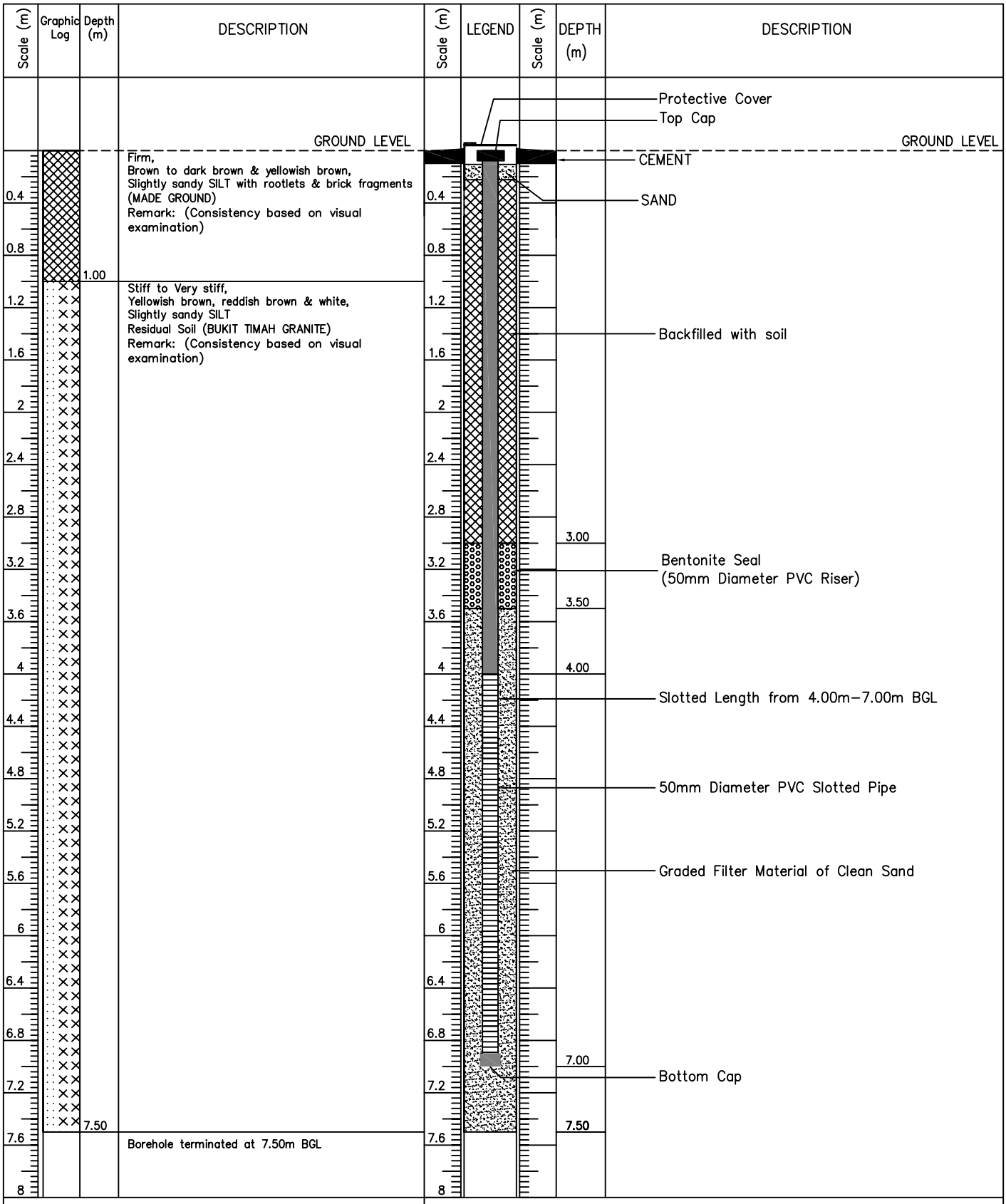
REMARKS:

INSTALLATION SHEET

CLIENT: Land Transport Authority	TYPE OF THE INSTRUMENT: Groundwater Monitoring Well (For EBS Boreholes)
PROJECT: Site Investigation Works From Tuas to Changi (1W91)	GROUND LEVEL: 14.55m SHD
LOCATION: Off Clementi Road	TOP OF PIPE LEVEL: 14.55m SHD
CO-ORDINATES: N34557.53m, E21872.45m	INSTALLED BY: M Thain Zin Chan
INSTRUMENTS NO: RC/30203/EBS/WSP	DATE INSTALLED: 01/02/2021



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ERM Singapore
120 Robinson Road, #10-01
Singapore 068913

T: +65 6324 9636
F: +65 6226 1636

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