Hong Kong Housing Authority

Agreement No. CB20120293 Planning and Engineering Study for the Public Housing Site and Yuen Long Industrial Estate Extension at Wang Chau

Final Technical Report No.3B (TR-3B) Preferred Option and Technical Assessment – Geotechnical Feasibility and Site Formation Assessment

REP-022-01

Final | April 2014

IMPORTANT – CONFIDENTIALITY

This project and study shall be kept confidential and any information contained in and/or related to the project/study shall not be disclosed to any person not involved in the project/study.

Job number 226464

Ove Arup & Partners Hong Kong Ltd
Level 5 Festival Walk
80 Tat Chee Avenue
Kowloon Tong
Kowloon
Hong Kong
www.arup.com

ARUP

Document Verification

ARUP

Job title		Agreement No. CB20120293 Planning and Engineering Study for the Public Housing Site and Yuen Long Industrial Estate Extension at Wang Chau		Job number 226464
Document title		Final Technical Report No.3B (TR-3B) Preferred Option and Technical Assessment – Geotechnical Feasibility and Site Formation Assessment		**File reference** 22
Document ref		REP-022-01		
Revision	**Date**	**Filename**	REP-022-01 TR-3B Geotech Feasibility and Site Formation.docx	
Final	Apr 2014	**Description**	Final	
			Prepared by	Checked by	Approved by
		Name	[redacted]	[redacted]	[redacted]
		Signature	[redacted]	[redacted]	[redacted]
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
			Issue Document Verification with Document		✓

Contents

Tables

Figures

Figure 9.4.5 – Development Phasing and Key Construction Elements (within Project Site)

Appendices

Appendix A
Aerial Photograph Interpretation

Appendix B
Summary of Available GIU Field and Laboratory Testing Data

Appendix C
Site Reconnaissance

Appendix D
Ground Investigation

Appendix E
Laboratory Testing Report

Appendix F
Geophysical Survey Interpretation

Appendix G
Geotechnical Parameter Plots

1 INTRODUCTION

1.1 Project Background

1.1.1.1 As stated in the Chief Executive's 2011-12 Policy Address, the Administration is committed to expanding the land resources and increasing housing land supply. To meet this policy objective, the Planning Department (PlanD) has carried out a comprehensive review of the areas zoned "Green Belt" (GB) on the Outline Zoning Plans (OZPs) focusing on sites which are no longer green or spoiled. A number of "GB" and "Open Storage" (OS) sites in Wang Chau, Yuen Long were identified as having potential for public housing (PH) development.

1.1.1.2 Subsequently, the Innovation and Technology Commission (ITC) and the Hong Kong Science and Technology Parks Corporation (HKSTP) advised of the need to expand the Yuen Long Industrial Estate (YLIE), in addition to the existing three Industrial Estates (IEs) at Tai Po, Tseung Kwan O and Yuen Long. It was requested to use a portion of the Wang Chau potential housing site for this purpose.

1.1.1.3 After due consideration, an agreement was reached between the Housing Department (HD) and ITC to share the site, tentatively with the northerly portion to be allocated for the YLIE extension (YLIEE), while the remaining south portion would be developed for public housing use. It was further agreed that no Potential Hazardous Installations (PHIs) would be located at the YLIEE so as to minimize the potential adverse impact on the neighbouring PH developments.

1.1.1.4 **Figure 1.1.1** shows the location of the Project site. The PH and YLIEE sites at Wang Chau are zoned GB and OS on the Ping Shan OZP No. S/YL-PS/14. It is currently occupied by open storage, vehicle parks, farmland, fallow land, grassland, rural residential dwellings and temporary structures.

1.1.1.5 Ove Arup & Partners Hong Kong Limited (Arup) was commissioned by Hong Kong Housing Authority (HKHA) under entrustments from the Government of the Hong Kong Special Administrative Region (HKSAR) & Hong Kong Science and Technology Parks Corporation (HKSTP) to conduct the Planning and Engineering Study for Public Housing Site and YLIEE at Wang Chau (the Study), which will examine the feasibility on developing public housing and YLIEE at Wang Chau by conducting planning, engineering and environmental assessments to formulate proposal for the PH site and YLIEE, and the implementation strategies and programme for the proposed development.

1.2 Objectives of the Assignment

1.2.1.1 Following on the endorsement of the Technical Report (TR) on Option Generation, Evaluation and Preliminary Assessments (TR-2) in the Study Steering Group Meeting on 28 June 2013, a preferred development option has been formulated. According to the Clause 5.3(c) of the brief, technical assessments are required to demonstrate the feasibility of the preferred development option.

1.2.1.2 The Technical Report (TR-3) – Preferred Option and Technical Assessments under this P&E study is to undertake the technical assessments including traffic and transport assessments, drainage and sewerage impact assessment, water supply and utilities impact assessments, geotechnical assessments, foundation assessment, natural terrain hazard study, environmental impact assessment, financial assessment, air ventilation assessment and land requirement study to confirm the feasibility of the preferred development option and ascertain the implications that may arise.

1.2.1.3 The overall objective of the Study is to examine the feasibility of PH and YLIEE sites at Wang Chau, taking into account the environmental, planning, urban design, traffic and transport, geotechnical, foundation, landscaping, sewerage, drainage, water supply and other engineering/infrastructure matters, air ventilation, socio-economic, financial, provision of Government/Institutional and Community (G/IC) facilities, open space, recreation and retail facilities; formulate and evaluate different development options as well as identify the preferred option; recommend optimal and practicable development schemes with parameters; propose necessary infrastructure upgrading works with schematic design; and prepare an implementation programme.

1.2.1.4 The Study will form the basis for implementation of the PH and YLIEE sites under the rezoning and Environmental Impact Assessment Ordinance (EIAO) (Cap. 499) processes.

1.2.1.5 Specifically, the objectives of the Study are set out as follows:

- identify opportunities, constraints and key issues confronting the public housing project and YLIEE, and highlight the problems that might affect their overall development;
- formulate development options and carry out preliminary feasibility assessments to derive practicable development parameters and schemes for the public housing project and YLIEE;
- formulate land use proposals and delineate development boundaries for the PH site, YLIEE and other associated infrastructures and facilities;
- evaluate the development options against a set of clearly defined principles, objectives and associated performance criteria as agreed with the Director's Representative;

- confirm the feasibility of the public housing project and YLIEE and associated infrastructures and facilities by undertaking a series of technical assessments including traffic and transport, sewerage, drainage, water supply, utilities, geotechnical, slope stability and site formation works, foundation, urban design, landscape and visual, air ventilation, natural terrain landslide hazard, hazard potential of industrial installation, land contamination, ecology and cultural heritage etc;
- confirm the environmental acceptability of the PH and YLIEE sites as well as the associated infrastructure works by conducting comprehensive environmental studies which shall include (i) Environmental Assessment Study (EAS) for confirming the environmental acceptability of the proposed developments, particularly the proposed housing development which is subject to environmental impact from the existing and planned developments and environment in the vicinity, (ii) Land Contamination and Remediation Assessment with carrying out the necessary site investigation (SI) and laboratory testing (LT) for the assessment; and (iii) Environmental Impact Assessment (EIA) for confirming the environmental acceptability of the impact arising from the proposed developments, particularly YLIEE on the existing developments and proposed developments, including the proposed housing development, in the vicinity; whereas the EIA shall include, inter alia, cultural heritage impact assessment and ecological impact assessment; the EIA shall be carried out for, but not limited to, the following designated projects:
  - this planning and engineering study for the Site under Schedule 3 of EIAO;
  - YLIEE under Schedule 2 of EIAO; and
  - any other facilities, works and projects identified in the Study for supporting the PH and/or YLIEE sites and falling within Schedule 2 or 3 of EIAO.
- formulate a strategy for public consultation/engagement and undertake the public consultation/engagement accordingly; explore good development concepts from the community, and gauge public feedback through the public consultation/engagement activities;
- recommend practicable and cost effective measures to mitigate the constraints and problems identified, including but not limited to environmental mitigation, geotechnical works, slope works, site formation works, natural terrain hazard mitigation works, road and infrastructural works required for the proposed PH and YLIEE sites, as well as innovative approaches to deal with the interface problem between public housing and YLIEE;
- provide recommendations on site formation works, natural terrain hazard mitigation works, slope works, road works and other infrastructure works, G/IC facilities as well as alternative mitigation measures to suit the proposed schemes with schematic design to be shown on plans and sections in enough details to

demonstrate their feasibility to the satisfaction of the relevant departments and authorities;

- carry out preliminary design of the engineering works to cope with the development of the Site with preparation of schematic layout plans and preliminary engineering study to facilitate detailed design of these engineering works to proceed after this Study;
- carry out SI and LT where necessary and conduct preliminary engineering study, geotechnical assessment, natural terrain hazard study and the necessary mitigation measures for the proposed development and the required infrastructure so that the detailed design can be proceeded immediately after this Study;
- facilitate timely implementation of the sites and infrastructure developments by recommending a suitable implementation programme/framework including implementation packages, land requirement and rehousing;
- examine and advise the financial implications of the site developments, including land resumption and clearance costs, as well as infrastructure costs;
- facilitate rezoning of the sites for public housing use and IE use;
- provide support to fulfil the requirement of EIAO for implementation of the engineering feasibility study and designated projects under EIAO and to prepare all necessary reports, documents and materials for the EIAO process and associated public consultation and presentations.

1.3 The Study Assignment

1.3.1.1 The Study is divided into two phases, namely Phase 1- Technical Feasibility Study Stage and Phase 2 - Public Consultation, Rezoning and EIAO Stage. Phase 2 Study will have two options, namely Phase 2A - Public Consultation, Rezoning and EIAO Stage for both PH site and YLIEE site and Phase 2B – Public Consultation, Rezoning and EIAO Stage for PH site only.

1.3.1.2 Phase 2A Study covers the services for the overall development option that both PH site and YLIEE site will proceed for further study at a later stage of or after Phase 1 Study. Phase 2B Study is for the overall development option that only PH site will proceed for further study at a later stage of or after Phase 1 Study, i.e. study for YLIEE will not be further pursued.

1.3.1.3 The assignment of the Study will include the following main tasks at each phase:

Phase 1 -Technical Feasibility Study Stage

- Task 1 – prepare an inception report for the Study;
- Task 2 – establish a baseline profile of the Study Area and its relationship with the adjoining areas and conduct a review of the issues that affect the sites;

- Task 3 – establish guiding principles and formulate initial options for the public housing project and YLIEE with reference to the baseline profile under Task 2 above and target industry sectors;
- Task 4 – carry out preliminary feasibility assessments of various aspects to demonstrate the feasibility of the initial development options;
- Task 5 – evaluate the initial development options against the pre-determined criteria and derive a preferred development option for the public housing project and the YLIEE;
- Task 6 – update/undertake planning and technical assessments as well as EAS and EIA to confirm the feasibility of the preferred development option;
- Task 7 – conduct a financial assessment/appraisal of the development, comprising separately for the housing development and YLIEE; and to give an recommendation on whether each portion of the project is viable;
- Task 8 – prepare the Preliminary Outline Development Plan (PODP) together with the Preliminary Urban Design and Landscape Plan (PUDLP) and Preliminary Master Layout Plan (PMLP) for the proposed developments with recommended plot ratio, population, height restriction, block no. and storeys etc.;

Phase 2A or Phase 2B- Public Consultation, Rezoning and EIAO Stage

- Task 9 - conduct a public consultation/engagement on the PODP;
- Task 10 – refine relevant assessments conducted in Phase 1 in the light of the outcome of the public consultation/engagement giving rise to a revised development options and prepare the Recommended Outline Development Plan (RODP) together with the Recommended Urban Design and Landscape Plan (RUDLP) and Recommended Master Layout Plan (RMLP) for the proposed developments;
- Task 11 – examine the implementation mechanism, approaches and framework for the implementation of the proposed developments, provide details of land requirement to assess the broad cost and revenue for the developments, associated infrastructure/facilities and land acquisition and prepare outline development programme;
- Task 12 – facilitate rezoning of the sites for public housing use, IE use and other associated uses (for Phase 2A or 2B Study where applicable);
- Task 13 – advise and assist the Employer to fulfil the requirement of EIAO for implementation of the engineering feasibility study and designated projects under EIAO;
- Provide the required technical input for Government to prepare the project definition statement(s) and technical feasibility statement(s) to create Category C and/or B items for individual associated/infrastructural projects for implementing the

developments; conduct preliminary environmental review of non-designated projects;

- Task 14 – prepare a Final Report, Executive Summary for the Study.

1.4 Purpose of this Report

1.4.1.1 The Technical Report (TR-3) – Preferred Option and Technical Assessments is to undertake the technical assessments (including traffic and transport assessments, drainage and sewerage impact assessment, water supply and utilities impact assessments, geotechnical assessments, foundation assessment, natural terrain hazard study, environmental impact assessment, financial assessment, air ventilation assessment and land requirement study) to confirm the feasibility of the preferred development option and ascertain the implications that may arise.

1.4.1.2 This report forms part of TR-3 and includes the geotechnical feasibility/assessment study, site formation assessment, geotechnical ground investigation and laboratory testing. The purpose of the geotechnical assessment is to ascertain the implications that may arise from development of the preferred option as set out in TR2;

1.4.1.3 The purpose of the geotechnical feasibility assessment is to identify all potentially significant geotechnical constraints associated with the proposed development, and recommend solutions for these constraints.

1.4.1.4 The purpose of the site formation assessment is to determine geotechnical and other physical constraints on site formation and determine site formation layout, levels and fill requirements for the proposed developments;

1.4.1.5 As the proposed Geotechnical Ground Investigation (GI) and Laboratory Tests (LT) commissioned under this study was prevented due to local protest and prevention of access to proposed borehole locations, ground investigation should be carried out during detailed design stage.

1.4.1.6 In accordance with Clauses 5.3(c)(x), (xv) and (xvi) of the Brief, this report includes the following:

- A comprehensive desk study review of existing topographical maps, aerial photographs, published geological maps and memoirs, existing ground investigation and laboratory testing data, other relevant geotechnical records and reports, and land use maps;
- Identification of significant geotechnical constraints and feasible, practical solutions for the proposed developments;
- Scope of the proposed ground investigation required for this stage of study;
- Extent and significance of Natural Terrain Hazards within the adjacent slopes and requirements for mitigation measures;

- Identification, review, and evaluation of existing registered features adjacent to and within the sites, and the potential risk or impact imposed on the proposed development and infrastructure by these features;
- Foundation requirements and preliminary programme for foundation works;
- An assessment of blasting requirements;
- A proposal for site formation design including details of site formation levels, ground profile, and required retaining wall and slope works, taking into consideration geotechnical/traffic/environmental constraints, land-use proposals, the requirements of the drainage/sewerage systems and existing infrastructure, presented as a series of plans and cross sections;
- An assessment of suitability of materials underlying the proposed site formation areas and identification of any ground improvement measures required, including de-contamination;
- An estimate of the quantity of earthworks for each phase of the development and an overview of the options for fill sourcing/ spoil re-use and disposal;
- An assessment of the impact of the site formation process on water quality and recommendations for mitigation measures to minimize any adverse impacts.

1.4.1.7 The overall aim is to demonstrate the feasibility of the proposed developments from a geotechnical perspective and present a feasible preliminary design for site formation works.

1.5 Structure of this Report

1.5.1.1 The structure of this Technical Report is as follows:

Section 1 Introduces the project background, objectives and the main tasks of the Study, as well as the purpose of this report.

Section 2 Presents the preferred development option.

Section 3 Presents details of the desk study sources and site reconnaissance.

Section 4 Presents a description of the site including location, topography, site development history and existing land use.

Section 5 Presents details of the ground investigation and laboratory testing works under this study.

Section 6 Presents the anticipated ground model developed from the desk study, site reconnaissance and ground investigation data.

Section 7 Presents a description of the engineering properties of soil and rock material expected within the sites.

Section 8 Presents a summary of the geotechnical feasibility assessment including foundation requirements, natural terrain hazards, existing man-made geotechnical features and blasting requirements.

Section 9 Presents a summary of the site formation assessment including the proposed site formation layout, slope and retaining wall requirements, material suitability and ground treatment requirements, cut and fill volumes, location of stockpiling areas and potential sources and disposal options, and impact on drainage, sewerage and water quality.

1.6 Nomenclature and Abbreviations

1.6.1.1 The following **Table 1.1** lists out the meaning of abbreviation for expressions adopted in this report:

Table 1.1.1: Abbreviations

Abbreviations	Term
API	Aerial Photograph Interpretation
CDF	Channelised Debris Flow
CE –	Conservative Event
DEM	Digital Elevation Model
ENTLI	Enhanced Natural Terrain Landslide Inventory
EPD-	Environmental Protection Department
GB	Green Belt
GEO	Geotechnical Engineering Office of Hong Kong
GFA	Gross Floor Area
G/IC	Government/ Institution/ Community
GI –	Ground Investigation
GIU	– Geotechnical Information Unit
HA –	Housing Authority
HKGS	– Hong Kong Geological Survey
LOS	Local Open Space
LPM	– Landslide Prevention and Mitigation
NTH	– Natural Terrain Hazards
NTHM	– Natural Terrain Hazard Mitigation
NTHS	– Natural Terrain Hazard Study
OHL	– Open Hillslope Landslide
OS	Open Storage
OZP	Outline Zoning Plan
PFC-	Public Fill Committee
PH –	Public Housing
PR	Plot Ratio
PTI	Public Transport Interchange
SIS	– Slope Information System
TR-2	Technical Report No. 2
TR-3	Technical Report No. 3

Abbreviations	Term
TR-3B	– Technical Report No. 3B
VE	Village Environs
YLIE	Yuen Long Industrial Estate
YLIEE	Yuen Long Industrial Estate Extension (This Project)

2 PREFERRED OPTION

2.1 Site Location

2.1.1.1 The Project site is bounded by the existing YLIE, Fuk Hi Street and Fuk Hing Garden and Sai Tau Wai to the east, Long Ping Road and Long Ping Estate to the south, Kai Shan to the west, as well as Shing Uk Tsuen, Tai Tseng Wai and Ng Uk Tsuen to the north as indicated in **Figure 1.1.1**.

2.2 Existing Conditions

2.2.1.1 According to the approved Ping Shan OZP No. S/YL-PS/14, the PH and YLIEE sites are currently zoned as "Green Belt" (GB) and "Open Storage" (OS) (**Figure 2.1.1**). It is occupied by open storage, vehicle parks, farmland, fallow land, grassland, rural residential dwellings and temporary structures.

2.2.1.2 The surrounding areas of the Project site are characterized by a mixture of various land use zonings as well as different existing major land uses. These include high-rise residential development, villages and low-rise residential developments, natural landscapes, burial grounds and graves, industrial uses, major roads and railway tracks.

2.2.1.3 The Project site is irregular in shape. In terms of topography, it is generally flat on its northern and central portions and has a slightly hilly terrain on the south strip. The major land uses within the Project site include open storage/workshops, residential dwellings, agricultural and vegetated land, nullah with footpaths and watercourses.

2.3 The Preferred Option

2.3.1.1 During the process of option generation, a number of key elements which play determining roles in the formulation of initial development options have been identified. The key elements that have been paid with due respect include the burial ground at Kai Shan, Village Environs (VE) of Wing Ning Tsuen (D.D. 122), VE of Fung Chi Tsuen and Shui Tin Tsuen (D.D 120 & 122) and the Umah International Primary School. A preferred development option for PH site and YLIEE site has been formulated in the TR-2 Option Generation, Evaluation and Preliminary Assessments.

2.3.1.2 Since the approval of TR-2, discussions with various government departments have been carried out; and subsequently the Project site boundary, site layout and development parameters of the preferred option have been slightly refined and optimised to address different concerns of particular departments. This TR-3 is carried out based on the refined preferred option which is illustrated in **Figure 2.1.2**.

2.3.1.3 The revised Project site boundary, land use budget, site layout, urban design element and development scheme with parameters are briefly described in the following sections.

2.4 The Project Site Boundary

2.4.1.1 As recommended in TR-2, the Project site of the original preferred option is about 33.31 ha in size, with about 18.69 ha for the PH site and about 14.62 ha for the YLIEE site.

2.4.1.2 Taking into account the existing burial urns at Kai Shan, impacts to private land lots, woodland cutting, woodland compensation provision, existing boundaries of adjacent VE, interfacing with existing land use zonings and further optimisation of land use between PH and YLIEE sites, some minor refinements have been proposed.

2.4.1.3 The refined development site boundary is shown in **Figure 2.1.2**. With the refinement, the total area of the Project site is about 33.46 ha, with about 18.81 ha for PH site and about 14.65 ha for YLIEE site.

2.5 Land Use Budget

2.5.1.1 Subsequent to the refinement of the Project site boundary, with an aim to keep up with the development intensity and land use mix in the preferred option as generated under the guiding principles and relevant regulations, minor adjustments have also been made onto the land use budget.

2.5.1.2 **Table 2.5.1** below summarizes the land use budget for the refined site boundary.

Table 2.5.1: Proposed land use budget for the refined site boundary

Land Use	Land use budget
PH Site	
Residential	About 14.49 ha
School	About 1.94 ha (3 school sites)
G/IC (Integrated Social Welfare Building)	About 0.47 ha
Public Transport Interchange	About 0.41 ha
Roads, amenity greening and slope	About 1.49 ha
Total site area	**About 18.81 ha**
YLIEE Site	
Industrial	About 11.66 ha
Local Open Space (On-site preserved woodland area)	About 0.27 ha
Roads	About 1.81 ha
Slope	About 0.31 ha
Woodland compensation area & on-site ecological compensation area	About 0.41 ha
Parking Spaces	About 0.19 ha
Total site area	**About 14.65 ha**

2.6 Proposed Development of the PH Site

2.6.1 Guiding Planning Design Principles for the Public Housing Site

2.6.1.1 There are three major planning & urban design guiding principles followed in the design of the preferred option. These include:

- Establishing view corridors to Kai Shan - This is achieved by aligning the northern road toward the foothills of the mountain, by strategically placing the schools to provide visual and spatial relief around the taller residential structures, and by utilizing the 50-metre buffer area separating the public housing site from the proposed industrial estate extension site.
- Placing public functions closer to the existing road networks - Commercial activities and the public transport interchange (PTI) have been placed along Fuk Hi Street and Long Ping Road in order to serve the greater community.
- Creating a tapering building height profile. The buildings taper down from 41 to 31 storeys. The tapering occurs at 5-storey intervals, in order to minimize the effect of the flat-head development.

2.6.2 Land Use Proposals

2.6.2.1 With the proposed refinement of the PH site boundary, types of land use remain unchanged. These include residential with local open space and parking spaces, retail, schools, integrated social welfare building (ISWB), PTI, roads, amenity greening and slope.

2.6.2.2 The PH site can be roughly divided into three portions. The southwestern portion of the PH site consists of the area around residential blocks 1 to 10 (Phase 1), the middle portion consists of the area around residential blocks 11 to 17 (Phase 2), and the northern portion consists of the area around buildings 18 to 24 (Phase 3). The middle and northern portions are bisected by the proposed northern access road.

2.6.2.3 **The Southwestern Portion**: The southwestern portion occupies an area of about 5.5ha. It consists of 10 residential buildings, two underground parking structures, a 2-storey commercial area, a social welfare building, i.e. ISWB, one school, and complementary recreational functions. All residential buildings in this portion will be of either 31 or 36 storeys. Single-aspect buildings have been utilized in all of the residential buildings, except Block 3, in order to minimize any potential conflicts from traffic noise issues. A two-storey retail facility has been placed strategically along Long Ping Road to allow street-front retail as well as serve the residents within the proposed new residential housing estate. A footbridge tentatively linking the pedestrian walkway system of Long Ping Estate would land at the same level as the podium level. The ISWB at the southwestern tip of

this portion will provide a minimum net operating floor area of approximately 6000 m^2 for various social welfare facilities. A site of a primary school is reserved and proposed with a maximum building height of 8 storeys. Areas for two children playgrounds, two badminton courts, and one basketball court have also been reserved to serve the future residents. An existing shrine exists adjacent to the ISWB. Minimal disturbance has been taken into consideration with site formation in order to preserve this shrine.

2.6.2.4 **The Middle Portion**: It has an area of about 5.8ha. It consists of 7 residential buildings, a commercial area, one underground parking area, and other complementary recreational functions as well as a new road. The residential buildings in this portion taper from tallest (41 storeys) to the west to lowest (31 storeys) to the east. A pedestrian corridor with retail facilities on both sides is proposed. This design will minimize the adverse interface conflict between pedestrians and vehicles. In terms of complementary recreational functions, areas for four children playgrounds, three badminton courts, and two basketball courts have been served. An existing well currently situated between the proposed Blocks 12 and 13 is proposed to be preserved and beautified to give the area more character.

2.6.2.5 **The Northern Portion**: This portion occupies an area of about 7.5ha. It consists of 7 residential buildings, a commercial area, a semi-covered PTI, a non-buildable area, one underground parking area, two schools and complementary recreational functions. The residential buildings taper from tallest to the west (41 storeys) to lowest to the east (31 storeys). This tapering is of similar nature as to the buildings tapering in the middle portion. The commercial area in this portion is placed in the vicinity of the PTI, and creates a gateway to the pedestrian street found in the middle portion with the intention that it would serve both the PH site as well as the YLIEE site. In order to minimize the adverse interface conflicts generated between the YLIEE and the PH sites, a 50-metre buffer has been created between these two distinct zones. The buffer area would comprise of open space, a football pitch, badminton courts, and two playgrounds. Due to the shape of the 50-metre buffer area, this area is also most suitable for an underground parking area. Two schools have been placed strategically at the end of the proposed road, in order to further expand the frame of vision toward Kai Shan, as well as to provide a visual buffer from the high-density developments of the middle and northern portions. Apart from the recreational functions found along the 50-metre buffer, areas for two additional children playgrounds and two basketball courts have been reserved.

2.6.3 Development Schemes with Parameters

2.6.3.1 In the refined development scheme, the PH site has a site area of 18.81 ha. While the total site area is 18.81 ha, the total residential site area is of a total of 14. 49ha which excludes 30-degree cut slope areas,

local roads, and non residential structures, like the PTI, the ISWB, and the three school sites, based on the abovementioned land use proposals. Taking the opportunities to further optimize housing supply in response to the territorial need for housing by visiting various factors with a plot ratio (PR) of 6.0 (i.e. 5.86 domestic and 0.14 non-domestic) and maximum building height of 41 storeys, a total of a domestic GFA of 848,750 m^2 and retail GFA of 19,760 m^2. will be accommodated (**Table 2.6.1**). The proposed development option could then provide a total of 16,975 flats to cater for around 52,113 populations (**Table 2.6.2**). The breakdown of the GFA of each portion is as follows:

Table 2.6.1: Domestic and Retail GFA of the Three Portions

	Domestic GFA (m^2)	Retail GFA (m^2)
Southwestern Portion	213,750	6,784
Middle Portion	324,000	8,589
Northern Portion	311,000	4,383
Total	**848,750**	**19,756**

Remarks: It is assumed that the social welfare facilities, PTI, underground parking areas, schools and recreational functions are not accountable for GFA.

Table 2.6.2: The Estimation and Number of Flats of the Three Portions

	Area of Residential Site (ha)	Number of Flats^	Population*
Southwestern Portion	3.83	4,275	13,124
Middle Portion	5.00	6,480	19,894
Northern Portion	5.68	6,220	19,095
Total	**14.49#**	**16,975**	**52,113**

An adjustment of 0.02ha has been applied and subtracted from the total site area to avoid overprovision of domestic GFA.
^ It is also assumed that 50% of the flats will be for PRH and 50% will be for HOS.
* It is assumed that the person per flat is 3.07.

2.6.3.2 A summary of the key planning parameters for the PH development is given in **Table 2.6.3** below.

Table 2.6.3: Summary of Key Planning Parameters for PH development

Development Parameters	Units
Residential Site Area	14.49 ha
Domestic Plot Ratio	5.86
Domestic GFA	848,750 m^2
Estimates No. of Flats	16,975
Estimated Population	52,113
Non-domestic Plot Ratio	0.14
Non-domestic GFA	19,760 m^2
Maximum Building Height (in storeys) (Ground floor included)	31 / 36 / 41
Maximum Building Height (in metres)	87.1m / 100.85m / 114.6m
Maximum Number of Residential Storeys	30 / 35 / 40
Assumed No. of Units Per Storey	11 - 29 units
No. of Towers	24

2.7 Proposed Development of the YLIEE Site

2.7.1 Guiding Planning & Design Principles for the YLIEE Site

2.7.1.1 There are four planning & design principles that should be considered:

- Optimising the development potential by partitioning the individual site with an optimal plot size between 0.65 and 0.75 ha as advised by HKSTPC.
- Minimising disturbance to existing woodland and providing an on-site woodland compensation area to minimise the need for off-site woodland compensation.
- Providing sufficient local open space for the enjoyment of local employees.
- Providing a pedestrian connection from the existing YLIE to the proposed YLIEE site.

2.7.2 Land Use Proposal

2.7.2.1 With the proposed refinement of the YLIEE site boundary, the major types of land use remain unchanged. These include industrial, local open space, car parking space, road and slope area. While chances have been taken to further bring forward capitalization on existing natural resources within the YLIEE site, it is proposed to allow more on-site woodland compensation and ecological conservation area.

2.7.2.2 The YLIEE site has an area of 14.65ha. It consists of 16 individual plots, connected by a local road that terminates at a roundabout. Adequate Local Open Space (LOS) and parking areas have also been provided within the site. The LOS is currently occupied by woodland which will be preserved on-site. One on-site ecological compensation area has been proposed to the west of development plot VIII, and a woodland compensation area to the west of development plot VII has also been proposed.

2.7.3 Development Schemes with Parameters

2.7.3.1 In the refined preferred option, the total area for YLIEE site is 14.65 ha with 11.66 ha reserved for industrial use. A PR ratio of 2.5 and a maximum building height of 8 storeys for the industrial lots are proposed to remain unchanged. Chances were also taken to optimize industrial GFA provision and as a result, a maximum GFA of 291,545 m^2 will be provided to accommodate about 3,887 workers. A summary of the key planning parameters for the YLIEE development is given in **Table 2.7.1** below.

Table 2.7.1: Summary of key planning parameters for YLIEE development

Development Parameters	Units
Industrial Site Area	11.66 ha
Plot Ratio	2.5
Maximum GFA	291,545 m^2
Estimated No. of Worker*	About 3,887
Maximum Building Height (in storeys)	8 storeys
Maximum Building Height (in metres)	32m

* It is assumed that a worker density is 75 workers/ m^2.

2.7.3.2 In terms of the distribution of industrial lots, a summary is given in **Table 2.7.2** below.

Table 2.7.2: Summary of industrial lot sizes

Industrial lot size	Number of lots
1.10 ha -1.19 ha	1
1.00 ha - 1.09 ha	0
0.90 ha - 0.99 ha	0
0.80 ha - 0.89 ha	2
0.70 ha - 0.79 ha	4
0.60 ha - 0.69 ha	8
0.50 ha - 0.59 ha	1
Total number of lots	16

2.8 Tentative Implementation Programme

2.8.1.1 The PH site would be implemented in three phases and the YLIEE site would be developed in a single phase. The following summarises the tentative commissioning dates for both the PH and the YLIEE sites:

- Year 2022: Granting of YLIEE's land starting from 2022 which will take about 4 years to complete
- Year 2024: Population intake of PH Site Phase 1
- Year 2026: Population intake of PH Site Phases 2 & 3

3 DESK STUDY AND SITE RECONNAISSANCE

3.1 General

3.1.1.1 This section presents details of the various desk study sources and site reconnaissance undertaken to assist in the development of a ground model for the PH and YLIEE sites.

3.2 Topographic Maps

3.2.1.1 Digital Topographical Map B5000 (1:5,000) and B10000 (1:10,000) from Lands Department were used as a basis for plans, maps and other analysis.

3.3 Aerial Photography

3.3.1.1 Aerial Photograph Interpretation (API) using aerial photographs from the Aerial Photography Library of the GEO has been undertaken to determine the site development history, landslide history and geomorphological condition of the slopes adjacent to the PH and YLIEE sites (**Appendix A**).

3.3.1.2 A list of aerial photographs used for the API is provided in **Table 3.2.2**, below.

Table 3.2.2: List of aerial photographs examined

Year	Photograph No.	Altitude (feet)
1924	Y00158-Y00159	-
1945	Y00815-Y00816	20,000
1945	Y00770-Y00771	20,000
1949	Y02263-Y02266	8,000
1949	Y02339-Y02342	8,000
1954	Y02819-Y02820	29,200
1963	Y09582-Y09584	3,900
1963	Y09624-Y09626	3,900
1964	Y13043-Y13044	12,500
1973	7818-7819	12,500
1976	16445-16446	12,500
1977	18868-18869	4,000
1978	24538-24539	12,500
1979	28474-28475	10,000
1984	55747-55748	4,000
1988	CN2020-CN2021	6,000
1994	A38216-A38217	5,000
1994	A38360-A38361	5,000
1999	CN24509-CN24510	3,500
2005	CW68659-CW68660	8,000

Year	Photograph No.	Altitude (feet)
2005	CW68790-CW68791	8,000
2010	CW88011-CW88012	3,500

3.4 Published Geological Literature

3.4.1.1 The following geological maps have been reviewed to provide information on the anticipated geological conditions at the PH and YLIEE sites:

- Frost, D.V. (1992). Sheet Report No. 1 Geology of Yuen Long. Hong Kong: Geotechnical Engineering Office. 69p;
- Fyfe, J.A., Shaw, R., Campbell, S.D.G., Lai, K.W. and Kirk, P.A. (2000). Quaternary Geology of Hong Kong. Hong Kong. Hong Kong Geological Survey. 210p;
- GCO (1988). North West New Territories. Geotechnical Area Studies Programme. GASP Report IV. Geotechnical Control Office, Civil Engineering Services Department, Hong Kong;
- GEO, (1988).1:20,000 Geological Map Sheet 6 (Yuen Long), Hong Kong Geological Survey;
- Langford, R.L., Lai, K.W., Arthurton, R.S., and Shaw, R. (1989). Geological Memoir No. 3 Geology of the Western New Territories, Hong Kong Geological Survey. 140 p;
- Sewell et al, (2000). 1:5,000 Geological Map Sheet 6-NW-B, Hong Kong Geological Survey;
- Sewell, R.J., Campbell, S.D.G., Fletcher, C.J.N., Lai, K.W. & Kirk, P.A. (2000). The Pre-Quaternary Geology of Hong Kong. Hong Kong Geological Survey, Geotechnical Engineering Office, Hong Kong, 181p.

3.4.1.2 Extracts from the Hong Kong Geological Survey 1:20,000 map and 1:5,000 map are provided in **Figures 3.4.1** and **3.4.2**.

3.5 Archival Ground Investigation and Laboratory Testing Data

3.5.1.1 3 No. drillholes formed within the PH and YLIEE sites have been identified within the GIU archive. A further 60 No. drillholes formed within 100m of the PH and YLIEE sites have been identified within the GIU archive. The locations of these drillholes are shown in **Figure 3.5.1**, with further details provided in Table B1 in **Appendix B**. Field and laboratory testing data obtained from GIU archive has been reviewed and incorporated into the ground model and geotechnical assessment.

3.6 Slope Records

3.6.1 Records of Past Instability

3.6.1.1 Historical data relating to any previously recorded landslides within the Study Area was collected through a review of the GEO Historical Landslide Catchments, Landslide Incident Records; Landslide Mapping Reports; the Enhanced Natural Terrain Landslide Inventory (ENTLI); and the Large Landslide Dataset. The Boulder Field Inventory has also been consulted to help assess the potential for boulder fall hazard. The locations of all previously recorded landslides within the Study Area are presented with the Boulder Field Inventory in **Figure 3.6.1**.

3.6.2 Registered Man-made Slope Features

3.6.2.1 Registered man-made features recorded within or in close proximity to the PH and YLIEE sites have been identified within the Slope Information System (SIS) and the Landslide Prevention and Mitigation Slope Information System (LPMIS). The locations of these registered features are shown in **Figure 3.6.2**. Summary tables of these features for the PH and YLIEE sites, including the registration number and responsible maintenance party are provided in Section 8.3 of this report.

3.7 Land Use

3.7.1.1 Information on existing land use has been obtained from the Ping Shan Outline Zoning Plan (OZP) No. S/YL-PS/14 and Yuen Long OZP No. S/YL-21. An extract of this plan is provided in **Figure 3.7.1**.

3.8 Site Reconnaissance

3.8.1.1 In addition to the desk study, walkover surveys of the PH and YLIEE sites were carried out between September 2012 and August 2013. The purpose of these surveys was to investigate some of the findings of the desk study, and to determine the proposed locations of ground investigation works. Photographic records from these surveys are provided in **Appendix C**. Findings have been incorporated during development of the ground model.

3.8.1.2 In addition to the site reconnaissance, field mapping of the natural terrain areas adjacent to the PH and YLIEE sites was undertaken during April and May 2013. Further details are provided in TR-3C, the Natural Terrain Hazard Study report.

4 SITE DESCRIPTION

4.1 Site Location

4.1.1.1 The project site, as described in Section 2, is located in Yuen Long, bounded by Fuk Hi Street and Long Ping Road to the east and southeast, and by natural hillslopes to the west as illustrated by **Figure 1.1.1**.

4.2 Topography

4.2.1 Overview

4.2.1.1 The PH and YLIEE sites are located within the western side slopes of the broad Shan Pui alluvial valley. The ground generally slopes from higher sloping ground in the west to flatter low-lying ground in the east in this area. A number of streams starting in the hillside to the west of the site flow west through the site, towards the main river channel. A north-south trending drainage channel is evident to the east of the site, with the stream now contained within a nullah which runs along the eastern YLIEE site boundary.

4.2.2 PH Site

4.2.2.1 Existing ground level within the PH site is highly variable, ranging from +4mPD adjacent to Long Ping Road to the south and Fuk Hi Street to the east, to between +12mPD and +22mPD along the northern and western site boundary, adjacent to the natural terrain hillside. Within the steeper areas along the western boundary of the PH site, the ground is often terraced, with minor cut slopes, to provide flatter platforms for agriculture and the existing housing.

4.2.3 YLIEE Site

4.2.3.1 Existing ground level within the YLIEE site is highly variable, ranging from between +3mPD and +5mPD adjacent to the nullah and Fuk Hi Street to the east, to between +16mPD and +20mPD along the western site boundary, adjacent to the natural terrain hillside. The steeper ground within the central/ western portion of the site is terraced, with a number of existing minor cut and fill slopes.

4.3 Site Development History

4.3.1.1 A review of the aerial photographs between the years of 1924 and 2010 provides information on the development of the PH and YLIEE sites. This is summarised below, with further details provided in **Appendix A**:

- In 1924, land use at both sites comprised farmland;

- By 1963, the majority of the land within YLIEE and PH Site was still used for agricultural purposes. Some village houses were observed near the southern portion of the PH Site. Small single storey structures were also observed within the agricultural land;
- By 1984, the southern portion of the YLIEE site has been filled and a significant portion of farmland within the lower hillslopes appears to have been abandoned;
- By 1994, more low-rise buildings were observed to the east of the PH Site. In the northern portion of the PH Site and southern portion of the YLIEE, a significant portion of the former agricultural land has been filled and converted into container storage areas. Man-made feature 6NW-B/C24 and a cut platform were observed in the southern portion of the PH Site.
- By 2010, most of the farmland in YLIEE site and northern portion of the PH Site had been filled and turned into container storage area. Man-made features 6NW-B/F204, 6NW-B/C145, 6NW-B/C146 were built.

4.4 Existing Land Use

4.4.1.1 The PH and YLIEE sites are currently zoned Green Belt (GB) and Open Storage (OS) on the Ping Shan Outline Zoning Plan (OZP) No. S/YL-PS/14 (**Figure 3.7.1**).

4.4.1.2 The YLIEE site is currently occupied by open storage, vehicle parking, farmland, fallow land, grassland; whilst the PH site is currently occupied by rural residential dwellings and temporary structures. Photographs illustrating the current land use taken during the site walkovers are provided in **Appendix C**.

5 GROUND INVESTIGATION AND LABORATORY TESTING UNDER THIS STUDY

5.1 Ground Investigation

5.1.1.1 Two phases of project specific ground investigation have been proposed for this study, comprising a total of total of 38 No. of drillholes, with associated in-situ testing, sampling and monitoring. Further details of the proposed ground investigation including termination criteria, sampling and testing are shown in **Figures 5.1.1** and **5.1.2.**

5.1.1.2 The purpose of this proposed ground investigation is to determine variation in ground conditions across the two sites, to help develop a more detailed ground model and understand the ground-related constraints on the proposed developments.

5.1.1.3 The proposed site specific ground investigation has been postponed due to difficulties gaining access to proposed drillhole locations. As a result no project specific ground investigation data is currently available. The ground investigation shall be completed as part of the detailed design stage following site resumption. It should be noted that site is located within Scheduled Area No. 2, and complex ground conditions are likely to be present beneath the site. Adequate ground investigation is required in order to confirm the proposed site layout and detailed design of foundations.

5.2 Laboratory Testing

5.2.1.1 As the proposed site specific ground investigation has been postponed due to difficulties with land access, no site specific laboratory testing data is currently available. The ground investigation shall be completed as part of the detailed design stage following site resumption.

6 GROUND MODEL

6.1 Published Geology

6.1.1.1 All available published geological information for the site has been reviewed, including the relevant 1:20,000 scale (GEO, 1991) & 1:5,000 scale (Sewell et al, 2000) map sheets published by the Hong Kong Geological Survey (**Figures 3.4.1, 3.4.2a, and 3.4.2b**), the accompanying geological memoir (GEO, 1989) and Sheet Report (GEO, 1992) as well as the relevant reports and the maps prepared for the Geotechnical Area Studies Programme (GASP) (GCO, 1988).

6.1.2 Superficial Geology

6.1.2.1 The 1:20,000 HKGS Geological Map and the 1:5,000 HKGS Geological Map indicate that the Lok Ma Chau formation is overlain locally by Quaternary debris flow deposits (colluvium) comprising unsorted gravelly, clayey silt and sand with cobbles and boulders. These deposits are mapped predominantly in the footslopes of the natural terrain, and can be expected to have accumulated predominantly within open valley areas. The geological maps indicate the presence of Quaternary terraced alluvium comprising well-sorted to semi-sorted gravelly sandy clay and silt. The alluvium is mapped predominantly towards the eastern boundary of the PH and YLIEE sites, and also passing through the PH site corresponding with a drainage line. The maps show fill immediately to the east of the YLIEE site, associated with the existing Yuen Long Industrial Estate.

6.1.3 Solid Geology

6.1.3.1 The site falls within Scheduled Area No. 2, recognised as an area of complex geology where karst features such as an uneven upper surface and dissolution cavities are known to occur within the marble (GEO, 1992).

6.1.3.2 The 1:20,000 HKGS Geological Map (GEO, 1991) and the 1:5,000 HKGS Geological Map (Sewell et al, 2000) indicate that the PH and YLIEE sites are underlain by Carboniferous metasiltstone, and phyllite with metasandstone, of the Lok Ma Chau Formation. The Lok Ma Chau Formation overlies the Yuen Long Formation which comprises Carboniferous marbles and limestones. Indeed, the 1:5,000 HKGS map indicates the presence of marble in boreholes located immediately adjacent to the PH and YLIEE sites, with areas along the eastern YLIEE site boundary shown as being underlain by marble and interbedded marble and siltstone.

6.1.3.3 The boundary between the Lok Ma Chau formation and underlying Yuen Long Formation is gradational in some places and sharp in others. The 1:5,000 HKGS map records areas of ‘undivided’ marble and interbedded marble and siltstone towards the base of the metasiltsones. Conversely, the HKGS Sheet Report No. 1 describes how in the Long Ping Estate area of Yuen Long, 25m to the south east

of the PH site, metasiltstones of the Mai Po Member rest on the dark grey marble of the Long Ping Member, suggesting an unconformity. The missing Ma Tin Member, a massive white marble is reportedly only found within south east of the existing Yuen Long Industrial Estate (HKGS Memoir No. 3).

6.1.3.4 HKGS Sheet Report No. 1 refers to the gravity survey undertaken in the Yuen Long area to assist in the development of the model of marble sub-crop. Positive gravity anomalies correlated well with known areas of marble in south east Yuen Long. However, not all areas of marble sub-crop correlated with positive anomalies: north of Wang Chau, no positive anomaly was recorded where marble is up to 10m thick in a small 'thrust-slice' which does not appear to be sufficient to contribute to the anomaly.

6.1.4 Structural Geology

6.1.4.1 The site is located within the influence zone of the northeast-trending Lo Wu-Tuen Mun fault and fold belt which contains a series of faults, folds and shear zones, including at least four major northeast-trending faults, namely the Lau Fau Shan Fault, Yuen Tau Shan Fault, Ma Tso Lung Fault and the San Tin Fault.

6.1.4.2 HKGS Sheet Report No. 1 describes how this zone is characterised by a series of north east trending dislocations with both normal and reversed throws. The fault pattern is complex, with sub-parallel shear zones containing brecciated and mylonitised rock with evidence of movement which includes slickensided joint surfaces, clay and mica. The dominant elongate, curving faults displaced by a minor set of later north west trending fault structures. Normal fault planes tend to be moderately to steeply dipping between 50 and 70 degrees. The reverse throw, thrust and transcurrent faults are flatter lying and curved in both the vertical and horizontal plane.

6.1.4.3 HKGS Sheet Report No. 1 also describes how the carboniferous strata in this area were affected by intense and complex folding followed by metamorphism which has resulted in a dominant north west dipping foliation. The Yuen Long area is dominated by an anticline structure, with older carbonate rocks of the Yuen Long Formation overlain to the east and west by the younger Lok Ma Chau formation. The sub-crops of Long Ping Member identified below the Long Ping Estate can be interpreted as either isolated thrust-blocks or klippen of the Yuen Long Formation, or the eroded core of the Yuen Long carbonate anticline, unconformably overlain by the Lok Ma Chau formation.

6.1.4.4 The 1:20,000 HKGS Geological Map (GEO, 1991) and the 1:5,000 HKGS Geological Map (Sewell et al, 2000) indicate that several inferred faults pass through and close to the PH and YLIEE sites. These include a northeast-southwest trending inferred thrust fault passing through both sites, which is cross cut by a northwest-southeast trending inferred normal fault which passes through the YLIEE site. A further inferred normal fault passes immediately to the east the PH site.

6.1.4.5 Joints recorded within the hillside to the west of the PH and YLIEE sites on the 1:20,000 HKGS map dip between 34 and 70 degrees to the north west and north-north west.

6.2 Ground Investigation Findings

6.2.1.1 Details of the geological profiles and groundwater levels recorded by the GIU archival logs are provided in **Table B1** of **Appendix B**.

6.2.1.2 As described in Section 5, there is currently no project specific ground investigation data available. It should also be noted that archival records are available for only two drillholes within the PH and one drillhole within the YLIEE site. Records for drillholes located within 100m of the site boundary, the majority located to the south and east of the sites, have also been used to inform the ground model. However, the geomorphological setting and published maps suggest significant variation in ground conditions may be encountered between the areas where ground investigation data is available and conditions within the sites themselves.

6.2.1.3 In addition to the archival borehole records used for the interpretation of the ground conditions, geophysical re-interpretation of the GEO 1988 gravity survey covering the PH and YLIEE sites has been undertaken. The findings of this interpretation are presented in **Appendix F** and have been incorporated into the ground model. This data has been used to better constrain the possible variation in rockhead levels below the sites. It should be noted that the gravity survey data cannot be relied upon to determine engineering rockhead levels. The rockhead determined in the gravity survey report maybe located at the boundary between grade IV/V rock and III rock, however beneath this interpreted boundary it is possible for significant depth of corestones to be present. The anomaly may also represent a difference in the density of horizontally stratified rocks. As noted in the Gravity Survey report (Appendix F), the difference between actual engineering rockhead and rockhead expressed from the gravity survey may be as much as 40%. As a result of this, the rockhead interpreted in the gravity survey report should be deemed indicative only. In the following sections the rockhead interpreted in the gravity survey report will be referred to as 'gravity anomaly boundary'. For further details reference should be made to **Appendix F** of this report.

6.3 Anticipated Ground Conditions

6.3.1 PH

6.3.1.1 The anticipated geological profile below the PH site is illustrated by **Figures 6.3.1 to 6.3.4**, with the locations of the section lines shown in **Figure 3.5.1** and described in further detail below. It should be noted that the lack of ground investigation data within the site itself means there is significant uncertainty in the ground model at present. Ground investigation will be required prior to undertaking preliminary design.

Superficial Geology

6.3.1.2 Although not shown on the published geological maps, developed areas of the proposed PH site are expected to be underlain by a few metres of hard standing and fill, associated with the current land use. This is not expected to be engineered fill and is likely to be highly variable in composition.

6.3.1.3 The 1:5,000 HKGS geological map suggests that superficial deposits are absent from the majority of the narrow southern portion of the PH site, with colluvium expected within topographic depressions at the south western tip and within the central section of this portion of this portion of the site only. The colluvium may be up to 5m thick in this area. The two drillholes located within the southern portion of the PH site (11809/LR10 and LR13) recorded no superficial deposits.

6.3.1.4 The 1:5,000 HKGS geological map suggests that superficial deposits within the northern portion of the PH site comprise colluvium in areas of higher, sloping ground, with terraced alluvium associated with an east-west trending drainage channel which transects this portion of the site, and the main north-south trending alluvial floodplain area to the east. The colluvium may be up to 3m thick. The alluvium may be up to 5m thick, generally increasing in thickness from west to east.

6.3.1.5 The thicknesses of quaternary deposits described above are estimates based on the published maps and limited drillholes located to the east of the site boundary. The ground profile below the site is subject to confirmation by ground investigation within the site.

Solid Geology

6.3.1.6 The PH site is expected to be underlain by meta-siltstones and sandstones of the Lok Ma Chau formation. Such materials were observed within the natural terrain areas to the north and west of the PH site. However, there is a lack of existing ground investigation data to prove the nature of the materials underlying the site itself, particularly within and adjacent to the northern portion of the PH site (as illustrated by **Figure 6.3.1**).

6.3.1.7 The gravity survey data covering the site, and the limited available drillholes within and immediately adjacent to the site have been used to determine the likely variability of the top of Grade III rock below the site, and hence determine likely thickness of Grade V and IV material above.

6.3.1.8 The gravity survey data suggests that in the southern portion of the PH site corresponding with phase 1, gravity anomaly boundary varies between approximately 0mPD and -30mPD, dipping to the south and east. This suggests the thickness of the overlying Grade V and IV meta-sandstones and siltstones may vary between 20m and 40m. Within this zone, corestones of IV and III rock may be present. The two drillholes located within the southern portion of the PH site (11809/LR10 and LR13) recorded 3m and 10m of V siltstone and sandstone over 2m and 27m of mixed IV and III sandstone and siltstone.

6.3.1.9 The gravity survey data suggests that for the central and northern portions of the PH site (corresponding with phase 1 and 2 of the PH site) the gravity anomaly boundary varies between approximately -5mPD and beyond -50mPD. The gravity anomaly boundary is generally dipping to the east, with two low features (where the gravity anomaly boundary is deeper than -40mPD) interpreted adjacent to the northern and eastern boundaries of this portion of the site. This suggests the thickness of the overlying Grade V and IV meta-sandstones and siltstones may vary from 20m to beyond 55m. However, there is no drillhole data within the areas where lower rockhead is predicted to confirm the depth and nature of these features. There is a possibility they relate to areas underlain by marble, however histograms presented as Figures 4a and 4b in **Appendix F** showing distribution of marble and other rocks against the gravity anomaly boundary depth do not show that deep a gravity anomaly boundary is exclusively related to marble and frequently occurs in areas where marble has not been identified in existing boreholes. There is no existing ground investigation data within or adjacent to the northern portion of the PH site to confirm variation in rockhead level, rock type or thickness of the overlying V/IV saprolitic soils.

6.3.1.10 It should be noted that the 'gravity anomaly boundary' referred to above has been derived from interpretation of the gravity data. Whilst it provides a general model for the interface between Grade III rock or corestone zone and V/IV saprolitic soil, it may or may not correspond with an 'engineering rockhead'. 'Engineering rockhead' is defined in terms of specific criteria required for foundation design. This requires drillhole data to determine core recovery, core length and confirm decomposition grade across the site.

Structural Geology

6.3.1.11 The 1:5,000 HKGS map shows a west-dipping thrust fault crossing through both the northern and southern portions of the PH site. The rock may be foliated as a result of movement along this fault. However, there is no existing ground investigation to confirm any such fabric within the rock mass.

6.3.1.12 Further evidence of a possible fault running along the eastern boundary of the narrow central portion of the PH site includes a lineation identified from the gravity survey data. Drillholes located immediately to the east of the boundary also record an alternating soil and rock or corestone sequence with the weaker zones comprising breccia and kaolin seams, and described locally as a 'shear zone'.

6.3.2 YLIEE

6.3.2.1 The anticipated geological profile below the YLIEE site is illustrated by **Figures 6.3.5 to 6.3.7**, with the section lines illustrated by **Figure 3.5.1** and described in further detail below. It should be noted that the lack of ground investigation data within the site itself means there is significant uncertainty in the ground model at present. Ground

investigation will be required prior to undertaking any preliminary design.

Superficial Geology

6.3.2.2 Although not recorded on the published geological maps, much of the YLIEE site is expected to be underlain by a few metres of hard standing and fill, associated with the current land use. This is not expected to be engineered fill and is likely to be highly variable in composition. An unregistered fill slope was observed close to the western boundary of the central portion of the YLIEE site during site reconnaissance, as recorded in Appendix C. Fill is likely to be absent from areas where the current land use is still agricultural, as shown in **Figure 6.3.5**.

6.3.2.3 The 1:5,000 HKGS geological map suggests that superficial deposits within the YLIEE site comprise colluvium in areas of higher, sloping ground within the western portion of the site, with terraced alluvium associated with the lower-lying north west-south east trending alluvial floodplain area within the eastern portion.

6.3.2.4 The 1:20,000 scale HKGS map suggests that marine deposits of the Hang Hau formation are present more than 30m to the east of the eastern YLIEE site boundary. However, drillholes located immediately to the east of the site boundary suggest these deposits may extend further to the west than shown on the map. Marine deposits up to 4m thick may be encountered along the eastern site boundary of the YLIEE site, potentially extending below the eastern portion of the site. Ground investigation within the YLIEE site itself will be required to determine the lateral extent, thickness and properties of these deposits below the site itself.

6.3.2.5 The colluvium may be up to 3m thick. The alluvium may be up to 10m thick, generally increasing in thickness to from west to east. Based on the drillholes located just outside of the eastern site boundary, the alluvium is expected to comprise interbedded very loose to medium dense sands, and soft to stiff silty clays and clayey silts.

6.3.2.6 The thicknesses of quaternary deposits described above are estimates based on the published maps and limited drillholes located to the east of the site boundary. The only existing drillhole located within the site (55968/BH41) recorded 1.5m of fill above residual soil. The ground profile below the site is subject to confirmation by ground investigation within the site.

Solid Geology

6.3.2.7 The YLIEE site is expected to be underlain by meta-siltsones and sandstones of the Lok Ma Chau formation. Such materials were observed within the natural terrain areas to the west of, and within cut slopes along the western boundary of the YLIEE site. However, there is a lack of existing ground investigation data to prove the nature of the materials underlying the site itself.

6.3.2.8 The gravity survey data covering the site, and the limited available drillholes within and immediately adjacent to the site have been used to determine the likely variability of the top of Grade III rock below the site, and hence determine likely thickness of Grade V and IV material above.

6.3.2.9 The gravity survey data suggests that the gravity anomaly boundary varies between approximately 0mPD and -45mPD, dipping to the east and south east below the majority of the YLIEE site. This suggests the thickness of the overlying Grade V and IV meta-sandstones and siltstones may vary between 20m and 40m. Within this zone, corestones of IV and III rock may be present above rockhead. Drillhole 55968/BH41 located in the south west of the YLIEE site recorded 3m of residual soil over and 4.5m of V meta-siltstone over mixed VI and III meta-siltstone with some core loss, which may be related to a possible fault or shear zone close to the western boundary of the site (see **Figure 6.3.7**).

6.3.2.10 Within the south eastern portion of YLIEE site an area of deeper gravity anomaly boundary (below -40mPD) has been interpreted from the gravity survey. This part of the site may be underlain by marble. Indeed, marble has been identified in drillholes just outside of the site boundary in this area, to the east of the thrust fault shown on the 1:5,000 HKGS map.

6.3.2.11 Rockhead is expected to be closer to ground level (around +15mPD to +20mPD) at the western-most portion of the site, where Grade III rock was observed within cut slopes. In this area, the thickness of V and VI is expected to be much thinner, potentially absent, or there may be a corestone bearing profile underlying the colluvium.

6.3.2.12 It should be noted that the 'gravity anomaly boundary' referred to above has been largely derived from interpretation of the gravity data. Whilst it provides a general model for the interface between Grade III rock and V/IV saprolitic soil, it may not correspond with an 'engineering rockhead'. 'Engineering rockhead' is defined in terms of specific criteria required for foundation design. This requires drillhole data to determine core recovery, core length and confirm decomposition grade across the site.

Structural Geology

6.3.2.13 The 1:5,000 HKGS map shows a west-dipping thrust fault crossing through south eastern portion of the YLIEE site. The rock may be foliated as a result of movement along this fault. However, there is evidence of foliation from the existing drillholes located close to this feature.

6.3.2.14 The 1:5,000 HKGS map also shows a north-east dipping normal fault crossing the north eastern portion of the YLIEE site.

6.3.2.15 A persistent linear trough in the gravity anomaly boundary has also been interpreted by the geophysical data and is indicated in **Figure 2** of **Appendix F**. This feature is indicated as trending in a north-

northwest direction and is located immediately to the east of the YLIEE site boundary, tapering away from the PH site boundary.

6.4 Anticipated Groundwater Conditions

6.4.1.1 Due to the lack of existing ground investigation within the proposed site and at locations of proposed retaining walls and slopes, it is not possible to confirm ground water levels at this time. Ground investigation including ground water monitoring will be carried out during the detailed design stage of investigation following land resumption, and ground water observations considered during detailed design. Groundwater monitoring is further discussed in **Sections 9.3.5 and 10.2**.

6.4.2 PH

6.4.2.1 A summary of the available groundwater monitoring data is provided in Table B6, **Appendix B**. 8 No. 7-day groundwater monitoring records are available for monitoring installations within or close to site. These record groundwater levels varying between +1.6mPD and +9.3mPD for the 7 days immediately post-installation. Long term groundwater monitoring data is not available from archival data.

6.4.3 YLIEE

6.4.3.1 A summary of the available groundwater monitoring data is provided in Table B6, **Appendix B**. 5 No. 7-day groundwater monitoring records are available for monitoring installations located to the east of the site. These record groundwater levels varying between -2.9mPD and +0.5mPD for the 7 days immediately post-installation. Long term groundwater monitoring data is not available.

7 GEOTECHNICAL PROPERTIES OF MATERIALS

7.1 General

7.1.1.1 The engineering properties of soils and rocks within, and within 100m of the YLIEE and PH Site have been assessed using field and laboratory test data from the GIU archive investigations. The test results for each soil or rock type are presented in tabular and/or graphical format and discussed in the following sections.

7.1.1.2 There is only a small amount of testing data available for each of the different materials. As there is only a small volume of data, and none is project-specific at this stage, recommended design parameters are not proposed. Recommendations for geotechnical design parameters shall be derived during detailed design stage from project specific ground investigation and laboratory testing data interpretation to be obtained after site resumption Geotechnical Parameter Plots derived from archived ground investigation data obtained from the GIU are included in **Appendix G**.

7.2 Soils

7.2.1 Classification and Index Properties

7.2.1.1 A summary of the bulk density, dry density, moisture content, Atterberg limits and Plasticity Index test results for the various soils anticipated within the PH and YLIEE sites is provided in **Table 7.2.1** and **Table 7.2.2**.

Table 7.2.1 Summary of Soil Index Testing Data (Bulk Density and Natural Moisture Content)

Soil Stratum	Bulk Density (Mgm^{-3})				Natural Moisture Content (%)				Particle Size Distribution
	No. Tests	Max	Min	Ave	No. Tests	Max	Min	Ave	
Fill	4	2.12	1.68	1.91	5	45.0	15.7	33.4	G1.1
Marine Deposits	4	1.97	1.64	1.85	4	35.5	24.6	29.4	G1.2
Alluvium (Clay/Silt)	3	2.20	1.79	1.94	3	40.1	16.3	28.5	G1.3
Alluvium (Sand/ Gravel)	5	2.16	2.04	2.08	6	23.0	17.7	20.8	G1.4
V/IV meta-siltstone/ sandstone	21	1.40	2.24	1.92	31	70.8	8.5	27.2	G1.5

Table 7.2.2 Summary of Soil Index Testing Data

Soil Stratum	Liquid Limit (%)				Plastic Limit (%)				Plasticity Index			
	No. Tests	Max	Min	Ave	No. Tests	Max	Min	Ave	No. Tests	Max	Min	Ave
Fill	3	88	37	60	3	31	29	30	3	59	8	31
Marine Deposits	2	33	28	31	2	17	16	17	2	17	11	14
Alluvium (Clay/Silt)	2	49			2	25			2	24		
V/IV meta-siltstone/ sand-stone	9	69	35	49	9	35	24	29	9	34	11	21

7.2.2 Shear Strength

Undrained Shear Strength

7.2.2.1 There is no in-situ or UU Triaxial Testing from which s_u-depth design lines can be derived for either the Marine Deposits or Alluvium.

7.2.2.2 Undrained shear strength of overconsolidated clays can be estimated from SPT N value, factored according to the Plasticity Index of the soil using the plots provided by Stroud and Butler (1975) and relationship proposed by Stroud (1989). These suggest that Su typically varies between s_u = 4.5N for overconsolidated, high plasticity clays to s_u = 5.5N for overconsolidated, low plasticity clays.

7.2.2.3 This relationship is not relevant to the marine deposits which may not be overconsolidated, and for which SPT data is not considered a reliable measure of undrained shear strength due to their typically low strength.

7.2.2.4 Although expected to be overconsolidated, there is insufficient plasticity testing data to determine a typical plasticity index for the Alluvial clays and Silts. On this basis, only a very approximate range of possible s_u values can be determined for the Alluvial clays and silts. Using the relationships proposed by Stroud (1989), undrained shear strength of the Alluvial clays and silts may range from 10kPa to 120kPa.

Drained Shear Strength

7.2.2.5 The drained shear strength of the fill, alluvium, V/IV and V/IV meta-siltstone/sandstone has been determined from Consolidated Undrained

Triaxial (CU) testing and Consolidated Undrained Multi-stage (CUM) triaxial testing.

7.2.2.6 s'-t plots showing the results of this testing and interpreted lines presented in **Figures G1.5** to **G1.8 of Appendix G**. The derived cohesion (c') and the friction angles (φ') are summarised in **Table 7.2.3**. There is insufficient data to have an interpreted line for fill.

Table 7.2.3 Summary of Drained Soil Shear Strength Data

Soil Stratum	No. of Test	Cohesion from CUT (kPa)	Recommended cohesion in Geoguide 1	Friction angle from CUT (deg.)	Recommended friction angle in Geoguide 1 (deg.)
Fill	3	-	0-5 *	-	35-38 *
Alluvium (Clay/Silt)	6	0	-	28	-
Alluvium (Sand/Gravel)	6	0	-	34	-
V/IV Meta-Siltsone/Sandstone	16	6	-	33	-

* for compacted granular fill only

7.2.3 Stiffness

7.2.3.1 The Standard Penetration Test (SPT) data can be used to estimate soil stiffness from empirical correlation. SPT data is plotted with depth in **Figures G1.9 to G1.13 of Appendix G** for YLIEE and PH Site.

7.2.3.2 According to GEO (2006), stiffness can be estimated from the SPT N value according to the relationship: E' = 1 x N (MPa) when there is only limited data at the investigation stage.

7.2.3.3 The lower ranges and upper ranges for SPT N with depth are shown in **Figures G1.5** to **G1.8 of Appendix G** for YLIEE and PH sites. Based on these design lines, the range in stiffness can be determined from relationships provided in **Table 7.2.4**.

Table 7.2.4 Summary of Soil Stiffness design lines

Soil Stratum	Stiffness E' (MPa)	
	Lower Range	Upper Range
Fill	2	19
Marine Deposits	1	18
Alluvium (Clay/Silt)	0.2z + 1.6	1.9z + 4.4
Alluvium (Sand/Gravel)	0.7z + 0.7	6.7z + 6.7
V/IV Meta-siltstone/sandstone	0.4z	2.1z + 34.7

Note: 'z' refers to mbGL

7.3 Rock

7.3.1.1 The compressive strength of intact rock and marble has been determined from Uniaxial Compressive Strength (UCS) and Point

Load Index (PLI) testing. The point load test is an index test for indirect measurement of compressive strength of rock and the test results are to be correlated with the Uniaxial Compressive Strength. There is insufficient data to develop a reliable correlation between UCS and PLI. A summary of the UCS and PLI for the different rock materials is provided in **Table 7.3.1**.

Table 7.3.1 Summary of Rock Compressive Strength

Rock Stratum	Test	No. of Tests	Max	Min	Average
III/II Meta- siltstone/sandstone (MPa)	UCS	1	32.7		
III/II Marble (MPa)	PLI	4	3.3	0.5	2.1
III/II Marble (MPa)	UCS	4	1.6	0.3	0.9

7.3.1.2 There is insufficient data to determine the allowable bearing pressure for foundation design based on Table 2.1 from BD (2004). The allowable bearing pressure shall be determined during the detailed design stage following completion of the ground investigation and laboratory testing.

7.4 Aggressivity

7.4.1.1 There is no chemical testing available for samples from drillholes within 100m of the YLIEE and PH site. The parameters for aggressivity shall be determined during the detailed design stage following completion of the ground investigation and laboratory testing.

7.5 Contamination

7.5.1.1 There is no contamination testing found within and within 100m offset of the YLIEE and PH site from the archival data. The parameters for contamination shall be determined during the detailed design stage following completion of the ground investigation and laboratory testing. Further details of contamination can be found in separate TR-3G on EIA report.

.

8 GEOTECHNICAL ASSESSMENT

8.1 Foundations

8.1.1.1 A key consideration for foundation design for the PH and YLIEE sites is the potential complexity of the geology.

8.1.1.2 As described in Section 6.1.3, the sites falls within Scheduled Area No. 2, recognised as an area of complex geology where karst features such as an uneven upper surface and dissolution cavities are known to occur within the marble (GEO, 1992). The requirements set out in ETWB TC(W) No. 4/2004 for the geotechnical control for foundation works in Scheduled Area No. 2 shall be followed during foundation design and construction.

8.1.1.3 The site is also located within the influence zone of the northeast-trending Lo Wu-Tuen Mun fault and fold belt which contains a series of faults, folds and shear zones.

8.1.1.4 There is currently insufficient ground investigation data to confirm the complexity of ground conditions below the site or to determine the variation in 'engineering' rockhead levels for foundation design. In order to determine foundation levels which meet the BD (2004) requirements for assumed bearing pressure, drillholes recording decomposition grade, Total Core Recovery (TCR) and Unconfined Compressive Strength (UCS) testing will be required.

8.1.1.5 Existing ground investigation to the south and east of the PH and YLIEE eastern site boundaries have proven marble. The gravity anomaly boundary interpreted from the gravity data suggests low rockhead features within the northern portion of the PH site and south eastern portion of the YLIEE site which may be associated with marble. However, there is insufficient drillhole data within the sites themselves to either confirm or preclude the existence of marble below the sites.

8.1.1.6 If marble is present, it may have been subject to dissolution, and resulting palaokarst conditions may pose significant problems for foundation design and construction. Such problems previously experienced in the Yuen Long area include an anomalously deep rockhead, with rock locally in excess of 150m below ground level.

8.1.1.7 A steeply inclined and irregular rockhead profile makes the construction of conventional end-bearing piles very difficult. In addition, cavities formed within the marble may be infilled with weak and highly compressible material at considerable depth. The on-going dissolution and collapse of the marble rock mass results in thick superficial deposits comprising collapse material and weak cavity-fill. Such conditions are problematic for driven pile construction as piles have to penetrate very deep to pass through the cavities and weak material.

8.1.1.8 The faults which affect this area may also give rise to localised variations in rockhead level, which will impact on foundation design. The ground model will be further developed to identify variations in rockhead and potentially problematic ground conditions once the project specific ground investigation has been completed during detailed design stage.

8.1.1.9 Pleistocene alluvial silts and clays may be present locally within the PH site. Holocene marine deposits may be present along the eastern boundary of the YLIEE site. Pleistocene alluvial silts and clays are also anticipated across a large proportion of the YLIEE site. There is currently insufficient existing GI data to confirm the distribution both laterally and vertically of any such materials across the sites.

8.1.1.10 Although the consolidation of compressible soils should have been completed due to their long formation history within the area, further consolidation may be triggered if there are additional surcharges. Additional surcharges may be due to site formation, building structures bearing on ground, or possible groundwater drawdown around the area. If this was to happen, the consolidation of significant thicknesses of compressible soils could cause negative skin friction on piles which will need to be considered for any pile design. Piles could be sleeved or designed to take the negative skin friction into account.

8.1.1.11 Significant thicknesses of alluvial and marine deposits may also impact on the lateral displacement and capacity of the piles. This would result in additional cost of pile construction.

8.1.1.12 Whilst there is insufficient data to confirm the foundation requirements for the various proposed structures at the PH and YLIEE sites, a discussion of the potential constraints and solutions is provided in the following sections. A summary of the possible foundation options for both sites is provided in **Table 8.1.1**.

8.1.1.13 It should be noted that the gravity survey data discussed below cannot be relied upon to determine engineering rockhead levels. The rockhead determined in the gravity survey report maybe located at the boundary between grade IV/V rock and III rock, however beneath this interpreted boundary it is possible for significant depth of corestones to be present. The anomaly may also represent a difference in the density of horizontally stratified rock. As noted in the Gravity Survey Report (Appendix F), the difference between actual engineering rockhead and rockhead expressed from the gravity survey may be as much as 40%. As a result of this, the rockhead interpreted in the gravity survey report expressed in the following sections should be deemed indicative only. In the following sections the rockhead interpreted in the gravity survey report will be referred to as 'gravity anomaly boundary'. For further details reference should be made to **Appendix F** of this report.

8.1.1.14 Options for foundation requirements shall be reviewed upon completion of the site specific ground investigation, and further refined with subsequent phases of ground investigation and pre-drilling.

8.1.2 PH

8.1.2.1 The PH site comprises both residential and non-residential buildings. The residential towers will be a maximum of 41 storeys, whilst the non-residential buildings e.g. schools and community buildings will be a maximum of 8 storeys.

Residential Towers

8.1.2.2 Given the large load applied by the residential towers through their foundations, piled foundations are considered to be the most appropriate foundation type for the residential towers. The preferred pile option would be end bearing bored piles, socketed into competent rock (5 metres continuous Grade III or better with a minimum core recovery of 85%). However, if a very deep weathering profile or karst features are proven below these structures, end bearing bored piles may not be feasible.

8.1.2.3 The gravity survey interpretation suggests that for phase 1 of the PH site, the gravity anomaly boundary varies between -5 and -20mPD beneath the locations of tower Nos. 1 to 10. If this boundary is proven to be consistent with engineering rockhead during the ground investigation carried out as part of the detailed design, end bearing bored piles will be appropriate for this area.

8.1.2.4 The gravity survey interpretation suggests that for phase 2 of the PH site, the gravity anomaly boundary will varies between -5 and -30mPD beneath the locations of tower Nos. 11, 12, 13, 16 and 17. If this boundary is proven to be consistent with engineering rockhead during the ground investigation carried out as part of the detailed design, end bearing bored piles will be appropriate for this area. The gravity survey interpretation suggests that rockhead may be deeper at the location of tower Nos. 14 and 15, and so there is an increased potential that adverse geological conditions may be present at these locations, particularly at the location of tower No. 14.

8.1.2.5 The gravity survey interpretation suggests that for phase 3 of the PH site, the gravity anomaly boundary varies between -15 and -35mPD beneath the locations of tower Nos. 23 and 24. If this boundary is proven to be consistent with engineering rockhead during the ground investigation carried out as part of the detailed design, end bearing bored piles will be appropriate for this area. The gravity survey interpretation suggests that rockhead may be deeper at the location of tower Nos. 18, 19, 20, 21, 22, 23, and 24, and so there is an increased potential that adverse geological conditions may be present at these locations, particularly at the location of tower Nos. 18 and 19.

8.1.2.6 Where adverse geological conditions are proven at structure locations, particularly deep rockhead (i.e. greater than 100mbgl) and/or karst/cavities are encountered three possible solutions include:

- Relocation of the affected tower in order to avoid localised deep weathering;
- An engineering solution such as friction piles;

- Ground treatment to infill cavities

8.1.2.7 With these solutions there are potential restrictions and implications. If marble formation is encountered at shallow depth and extended beyond the practical construction limit of conventional end bearing bored piles, it may be desirable to exchange the location of an affected residential tower with one of the proposed low rise buildings. Ground improvement by infilling the cavities with cement grout could be a possible solution. However there can be inherent difficulties with identifying the extent of the cavities and possible leakage of grout through joints. Therefore this option is considered to be a last resort.

8.1.2.8 Small to medium rise buildings are preferable particularly on marble formation with cavities at which the increase in vertical effective stress is limited according to GEO Publication No.1/2006. Depending on the extent and/or number of areas identified where rockhead exceeds 100mbgl, moving towers may not always be feasible, and an alternative foundation solution for the residential towers may be sought.

8.1.2.9 If particularly deep rockhead is encountered, friction piles (including driven steel H-piles, bored piles and barrettes) may be adopted. Friction piles generally provide a lower bearing capacity compared to piles bearing on rock. The frictional capacity of bored piles and barrettes can be enhanced by post-construction grout (i.e. shaft-grouting), which is capable of providing a greater pile capacity compared with a non-grouted friction pile.

Non-Residential Buildings

8.1.2.10 For those buildings which are expected to be 8 storeys or less, the loading will be much lower than for the residential towers. For these buildings, pre-bored H-piles and mini-piles socketed into rock are considered to be most appropriate deep foundation solution. These types of foundation also provide more flexibility on the piling arrangement to suit the building layout. However, the practical construction limit for these piles is around 50 to 70m depth below ground level.

8.1.2.11 The gravity survey interpretation suggests that for phase 1 of the PH site, the gravity anomaly boundary is at approximately -10mPD beneath the locations of School 3, and between -15 and -30mPD at the location of G/IC building. If this boundary is proven to be consistent with engineering rockhead during the ground investigation carried out as part of the detailed design, pre-bored H-piles or mini-piles socketed into rock will be appropriate for these structures.

8.1.2.12 The gravity survey interpretation suggests that for phase 2 of the PH site, the gravity anomaly boundary varies between approximately -10 and -35mPD beneath the locations of School 1 and School 2. If this boundary is proven to be consistent with engineering rockhead during the ground investigation carried out as part of the detailed design, pre-bored H-piles or mini-piles socketed into rock will be appropriate for these structures. The gravity survey interpretation suggests that rockhead is dipping to the northeast at the location of School 2, and so

there is an increased potential that adverse geological conditions may be present at this location.

8.1.2.13 As with the residential towers, where adverse geological conditions are proven at structure locations, particularly deep rockhead (i.e. greater than 50 to 70mbgl in the case of pre-bored H-piles or mini-piles) and/or karst/cavities are encountered an alternative engineering solution may be sought. This may comprise friction piles rather than piles bearing on rock. Alternatively, if limits are imposed on vertical effective stress due to presence of marble or cavities over a large area (GEO Publication No.1/2006.), a buoyancy raft foundation may be a viable option. The buoyancy raft takes the concept of balancing the loading of the building with the weight of the excavated soil such that the incremental stress in marble affected by different degrees of dissolution features would be minimized and would not adversely affect the performance of the raft. The bearing capacity of the buoyancy raft is therefore restricted/limited by the depth of the raft, the strength and stiffness of the bearing stratum, the marble site class and the top level of karst features/marble bedrock. The differential settlement and long term consolidation of underlying soil may also limit the loading of the building. Because of the limited bearing capacity and serviceability concern, buoyancy raft is considered to be suitable for low to medium rise buildings.

8.1.2.14 As with the residential towers, ground improvement by infilling the cavities with cement grout can be considered as a last resort.

8.1.3 YLIEE

8.1.3.1 Buildings within the proposed YLIEE are expected to be a maximum of 8 storeys. Considering the building height, loading condition and column grid, pre-bored H-piles socketed into rock and end bearing bored piles are considered to be most appropriate deep foundation solution. Pre-bored H-piles provide more flexibility on piling arrangement to suit the building layout due to their relatively smaller working capacity.

8.1.3.2 The gravity survey interpretation suggests that for the YLIEE site, the gravity anomaly boundary varies between approximately -5 and -40mPD beneath the locations of buildings I to XI, and XIV. If this boundary is proven to be consistent with engineering rockhead during the ground investigation carried out as part of the detailed design, pre-bored H piles and end bearing bored piles will be appropriate for these buildings. The gravity survey interpretation suggests that rockhead is dipping to the east with particular areas of low rockhead at the locations of buildings XII, XIII, XV, and XVI, and so there is an increased potential that adverse geological conditions may be present at these location.

8.1.3.3 As with the PH site, if adverse geological conditions such as deep rockhead and/or karst/cavities are encountered, an alternative engineering solution may be sought. This may comprise friction piles rather than piles bearing on rock. Alternatively, if limits are imposed

on vertical effective stress due to presence of marble or cavities over a large area (GEO Publication No.1/2006), a buoyancy raft foundation may be a viable option.

8.1.3.4 Ground improvement by infilling the cavities with cement grout can be considered as a last resort.

Table 8.1.1 Summary of foundation options for PH and YLIEE sites

Foundation Type		Details	PH		YLIEE
			Residential Towers (max. 41 storeys)	Non-Residential Buildings (max. 8 storeys)	(max 8 storeys)
Piles bearing on Rock	Cast In-situ Bored Piles	Ideal where competent rockhead is present. Not suitable where excessively deep rockhead is encountered (i.e. in excess of 100m).	✓	✓	✓
	Pre-bored H-Piles socketed into rock	Provides more flexibility on the piling arrangement to suit the building layout. Practical construction limit for these piles is around 50 to 70m.		✓	✓
	Pre-bored Mini Piles socketed into rock	Provides more flexibility on the piling arrangement to suit the building layout. Practical construction limit for these piles is around 50 to 70m.		✓	✓
Friction Piles	Driven Steel H-Piles	Friction is obtained from contact between the pile and surrounding soil.	✓	✓	✓
	Cast in-situ Bored Piles	Friction is obtained from contact between the pile and surrounding soil. Generally provide a lower bearing capacity compared to end bearing bored piles	✓	✓	✓
	Barrettes	Friction is obtained from contact between the pile and surrounding soil. Generally provide a lower bearing capacity compared to end bearing bored piles	✓	✓	✓
	Shaft Grouted Piles	Shaft is grouted to increase the pressure between the pile and surrounding soil. Less suitable in stiff soils, as the pressure gained by shaft grouting is relatively low compared to softer soils.	✓	✓	✓
Raft	Buoyancy Raft	Shallow raft foundations may be used where load applied to the ground is restricted, e.g. where 'honeycombed' marble or cavities are present over a large area. Allowable building load is typically less than that which can be applied to large pile foundations.		✓	✓

8.1.4 Programme for Foundation Construction

8.1.4.1 It is currently anticipated that foundation construction for the PH development will be undertaken in three phases, in line with the three site formation phases discussed in **Section 9.2.2**. In addition, the foundation construction will be carried out after the completion of the site formation works. The preliminary programme is provided in Table 8.1.2, below and is based on the assumption that cast in-situ bored piles will be used for the residential towers, whilst pre-bored H-piles or mini piles will be used for the non-residential buildings. It should be noted that through progression to detailed design, any changes to the proposed foundations are likely to impact on the programme for foundation construction as the foundation programme is closely related to the type of foundation being constructed.

Table 8.1.2: Proposed PH Foundation Construction Programme

PH Site Formation Phase	Anticipated Date
Phase 1	Sept 2020 – Aug 2021
Phase 2	Jun 2023 – May 2024
Phase 3	Jun 2023 – May 2024

8.1.4.2 There is currently no anticipated programme for foundation construction for the YLIEE site. This will be subject to the requirements of the future tenants.

8.2 Natural Terrain Hazards

8.2.1.1 The extent of the natural terrain hillside requiring Natural Terrain Hazard Study (NTHS) has been determined based on the identification of the proposed facilities that satisfy the Inclusion Guidelines defined within Section 1.5 of GEO Report No. 138. According to this report sites/facilities that are located beyond the influence zone that landslide debris may reach would not be subject to natural terrain hazards even if landslides occur on the hillside. Such areas may therefore be excluded from further screening NTHS

8.2.1.2 Screening of the natural terrain hillside adjacent to the PH and YLIEE sites determined that 17 of the 31 No. catchments required NTHS. The potential for landslide hazards and boulder or rock fall hazards to impact on the proposed developments was considered.

8.2.1.3 Following detailed API and field mapping, modelling undertaken in accordance with GEO Report No. 138 indicated the possibility of Open Hillslope Landslides (OHLs) entering the proposed development from Catchments S and H only. Modelling discounted the potential for boulder or rock fall hazards.

8.2.1.4 Modelling of landslide hazards at Catchments S and H concluded that the total volume of material expected to enter the proposed site was 0.1m^3 and 6.0m^3 respectively.

8.2.1.5 Due to the very small volumes of material expected to enter the proposed development site in the event of OHLs, the construction of mitigation measures is not considered necessary.

8.2.1.6 Full details of the analysis undertaken are provided in TR-3C, the Natural Terrain Hazard Study report.

8.3 Existing Registered Geotechnical Features

8.3.1 General

8.3.1.1 In accordance with ETWB TC(W) No. 29/2002, investigation and study of existing man-made slopes and retaining walls within or in the vicinity of the site is required of such slopes or retaining walls could affect or be affected by the proposed development, or if their failure could affect lives and property within or outside the site.

8.3.1.2 A desk-based review of the registered man-made geotechnical features within and immediately adjacent to the PH and YLIEE sites has been carried out under this study. Both the potential for slope failure to impact on the proposed development and impact of the proposed development on existing features have been considered.

8.3.1.3 The assessment determined that some features will be removed completely during site formation and do not need further assessment. Others will require modification as they encroach partially on the site formation works areas. The remaining slopes will be retained, but may require upgrading.

8.3.1.4 Those features which will be modified during site formation and those which will be retained but may require upgrading will require further assessment to determine their stability and the extent of any modification and/or upgrading works required. This assessment should include a detailed site inspection and slope stability analysis.

8.3.1.5 The findings of this review are summarised in Sections 8.3.2 (PH site) and 8.3.3 (YLIEE site), below.

8.3.1.6 In addition to the registered features, a number of unregistered slope features were noted during the site reconnaissance. Detailed inspection and analysis of any such features should be undertaken at detailed design stage to determine if they might have any adverse impact on the proposed development, and whether upgrading and/or registration is required.

8.3.2 PH

8.3.2.1 Details of the registered features located within or in the vicinity of the PH site are provided in **Table 8.3.1** below.

8.3.2.2 As shown in **Figure 8.3.1**, of the 9 No. features within or adjacent to the PH site, 4 No. are to be removed; 3 No. are to be modified during site formation and 2 No. will be retained, or are unaffected by the proposed site formation works.

8.3.2.3 All preliminary analyses have been carried out under the consideration of the anticipated facilities, and Consequence-to-Life following completion of the PH site development. Preliminary analysis suggests that those slopes which are to be retained (6NW-B/C024 and 6NW-B/C103) should not pose a significant risk to the proposed facilities. In accordance with GEO TGN No. 15, soil debris volumes for these slopes are expected to be less than $300m^3$ for 6NW-B/C103 and a maximum of $50m^3$ for 6NW-B/C024. Volumes up to $50m^3$, are unlikely to cause severe damage to substantial structures. In addition, proposed facilities within the expected travel distance of any landslide debris are expected to comprise open space. Further assessment of the condition and stability of these slopes should be undertaken at detailed design stage, to determine if they require upgrading.

8.3.3 YLIEE

8.3.3.1 Details of the registered features located within or in the vicinity of the PH site are provided in **Table 8.3.2**, below.

8.3.3.2 As shown in **Figure 8.3.2**, of the 7 No. features within or adjacent to the YLIEE site, 2 No. are to be removed; 3 No. are to be modified during site formation, and 2 No. will be retained, or are unaffected by the proposed site formation works.

8.3.3.3 All preliminary analyses have been carried out under the consideration of the anticipated facilities, and Consequence-to-Life following completion of the YLIEE site development. Preliminary analysis suggests that those slopes which are to be retained (6NW-B/C107 and 6NW-B/C108) should not pose a significant risk to the proposed facilities. In accordance with GEO TGN No. 15, soil debris volumes for these slopes are expected to be a maximum of $50m^3$, and are unlikely to cause severe damage to substantial structures. Proposed facilities within the expected travel distance of any landslide debris are expected to comprise open space and a proposed 30 degree cut slope. Further assessment of the condition and stability of these slopes should be undertaken at detailed design stage, to determine if they require upgrading.

8.4 Blasting Requirements

8.4.1.1 The current ground model suggests that extensive rock excavation will not be required at either site. As such, it is not anticipated that blasting will be required.

Table 8.3.1: Summary of Registered Geotechnical Features- PH Site

Feature Type	Registration No.	Maintenance Responsibility	Date GIU data last updated	Slope Material	Slope/ Wall Height (m)	Slope/ Wall Length (m)	Slope/ Wall Angle (degrees)	Feature to be retained, modified or removed[1]	Facilities at toe[2]	Facilities at crest[3]	Current Consequence to Life Category	Post Development Consequence to Life Category	Further assessment required
Cut slope	6NW-B/C016	HyD	07/01/2011	Soil	14.0	325.0	35.0	Modified	Existing Long Ping Road	Existing village housing	1	1	Yes
Cut slope	6NW-B/C023	HyD	14/02/2011	Soil	3.0	125.0	30.0	Removed	N/A	N/A	2	N/A	No
Cut slope	6NW-B/C103	Private DD122 Lot1144 & 1143/ Gov. Dept. Lands D	11/06/2003	Not recorded	5.0	50.0	60.0	Retained	Open space	Existing Graves	3	3	Yes
Cut slope	6NW-B/C104	Lands D	11/06/2003	Not recorded	4.0	25.0	40.0	Modified	Open space/ School	Existing Graves	3	2	Yes
Cut slope	6NW-B/C105	Private DD126 Lot603/ Gov. Dept. Lands D	11/06/2003	Not recorded	4.0	85.0	40.0	Modified	Open space	Existing Graves	3	3	Yes
Cut slope	6NW-B/C122	Private DD122 Lot1201/ Gov. Dept. Lands D	13/06/2001	Soil	4.0	25.0	46.0	Removed	N/A	N/A	1	N/A	No
Cut slope	6NW-B/C154	DSD	18/05/2010	Soil	3.0	7.0	40.0	Removed	N/A	N/A	1	N/A	No
Cut slope	6NW-B/C024	Private DD122 Lot1236/ Gov. Dept. Lands D	11/06/2003	Not recorded	3.0	14.0	55.0	Retained	Open Space	Existing Graves	3	3	Yes
Retaining Wall	6NW-B/R088	HyD	13/02/2003	Soil	4.00	25.00	90.00	Removed	N/A	N/A	2	N/A	No

Notes: 1. Features to be retained, modified or removed as a result of the proposed site formation works

2 & 3. Facilities at toe and facilities crest are those that will be present following the proposed development of the site and any required modification of slopes.

Table 8.3.2: Summary of Registered Geotechnical Features- YLIEE Site

Feature Type	Registration No.	Maintenance Responsibility	Date GIU data last updated	Slope Material	Slope/ Wall Height (m)	Slope/ Wall Length (m)	Slope/ Wall Angle (degrees)	Feature to be retained, modified or removed[1]	Facilities at toe[2]	Facilities at crest[3]	Current Consequence to Life Category	Post Development Consequence to Life Category	Further assessment required
Cut slope	6NW-B/C099	Lands D	12/01/2011	Soil	3.0	100.0	40.0	Removed	N/A	N/A	3	N/A	No
Cut slope	6NW-B/C107	Lands D	20/08/2001	Soil	3.0	20.0	30.0	Retained	Open Space	Existing Graves	3	3	Yes
Cut slope	6NW-B/C108	Lands D	23/08/2001	Soil	3.0	23.0	35.0	Retained	Proposed cut slope	Existing Graves	3	3	Yes
Cut slope	6NW-B/C109	Private DD126 Lot581G Gov. Dept. Lands D	05/10/2001	Soil	3.0	20.0	60.0	Removed	N/A	N/A	3	N/A	No
Cut slope	6NW-B/C145	Private DD126 Lots 268A, 5472B, 573, 574. Gov. Dept. Lands D	08/10/2007	Soil	5.0	75.0	35.0	Modified	Proposed 30° cut slope over open storage	Existing Graves	3	3	Yes
Cut slope	6NW-B/C146	Private DD126 Lot568A & Lot569 Gov. Dept. Lands D	30/11/2002	Soil (Colluvium)	4.0	90.0	40.0	Modified	Proposed 30° cut slope over open storage	Existing Graves	3	3	Yes
Fill slope	6NW-B/F204	Private DD126 Lots 565, 581G, 563, 557. Gov. Dept. Lands D	08/10/2007	Soil	5.0	95.0	35.0	Modified	Proposed retaining wall/cut slope	Proposed retaining wall in non-crowded built-up facility	2	2	Yes

Notes: 1. Features to be retained, modified or removed as a result of the proposed site formation works

2 & 3. Facilities at toe and facilities crest are those that will be present following the proposed development of the site and any required modification of slopes.

9 SITE FORMATION ASSESSMENT

9.1 Design Considerations

9.1.1.1 In addition to the assumptions and constraints related to the ground model developed for the PH and YLIEE sites, the following have been considered when developing the proposal for site formation as presented in this report:

- Requirements of the proposed land-use;
- Maximisation of the developable area whilst keeping the site formation works within the site boundary and hence minimising impact on the adjacent natural hillside and existing infrastructure;
- Balancing the volumes of cut and fill material as far as possible to maximise re-use of site-won spoil, and minimise the export of spoil and/or import of fill;
- Traffic requirements, including Emergency Vehicle Access (EVA);
- Potential environmental impacts, including minimisation of impact on existing graves, mature trees, natural vegetation and stream courses;
- Drainage and sewerage system requirements, including maintenance or enhancement of the natural drainage system and protecting water quality;
- Integration with existing infrastructure adjacent to the PH and YLIEE sites, including roads, utilities and the MTR West Rail Line;
- Anticipated programme and timeframe allowed for site formation works.

9.1.1.2 Overall, the proposed site formation layout aims to minimise the site formation works and impact on existing landscape as much as possible, taking into account the various constraints listed above.

9.2 Proposed Site Formation

9.2.1.1 The proposed site formation configuration and formation levels are presented in **Figures 9.2.1 to 9.2.4**. Whilst the extent of site formation works has been minimised as far as possible, the formation of fill platforms, cut and fill slopes and retaining structures is required to meet the following constraints:

- Formation of a platform or platforms on sloping ground, particularly adjacent to the hillside along the western periphery of the sites;

- Requirement to minimise slope gradient across each platform such that there is a maximum level difference of 0.5m across 100m (gradient of 1:200);
- Road profile design;
- Requirements to retain existing features or structures, such as graves and existing infrastructure, and access to these.

9.2.1.2 The current ground model suggests that all cut slopes will be excavated within soil (principally Colluvium and Completely Decomposed Meta-siltstone and sandstone, overlain by a thin layer of Fill). Within the proposed site formation design, cut slope angles have therefore been kept to a maximum of 30 degrees to avoid stabilisation measures. Slopes constructed at 30 degrees or less can also be planted with vegetation to minimise visual impact.

9.2.1.3 Along much of the western boundary of the YLIEE site, there is some space within the site boundary and proposed development to accommodate a maximum 30 degree soil slope. However, the western site boundary is largely constrained by the burial grounds and conservation area (CA) zone within the adjacent hillside. Impact on the burial grounds and CA is to be avoided. Steeper soil slopes, reinforced with soil nails, have also been considered but are not deemed suitable as the soil nails would need to be installed beyond the site boundary. A combination of retaining walls and retaining walls with a maximum 30 degree slope at the top of the retaining walls has therefore been proposed.

9.2.1.4 The type of retaining wall proposed is dependent on the slope height to be retained. Toe walls in the form of mass concrete wall are proposed where the retained height is less than 1.5m. Reinforced concrete (RC) walls are proposed where the retained height is greater than 1.5m. To facilitate the construction of RC wall along the site boundary, a temporary retaining wall with shoring supports is required. The construction cost and time becomes unfavourable when the wall height is increased due to the higher cost of temporary works. For planning purpose, permanent bored pile wall is proposed when the retaining height is greater than 10m with 2m deep utility zone below future ground level (i.e. 8m retaining height above future ground level).

9.2.1.5 Temporary working platforms may be constructed within the site boundary for the purpose of bored pile wall construction and temporary excavation and lateral support works. The working space required for the bored pile wall construction is envisaged to be about 1 to 1.5m to the edge of the bored pile while that for the temporary retaining wall is envisaged to be about 0.5m to the edge of the temporary wall. All works are to be carried out within the site boundary

9.2.1.6 Due to the large difference between existing ground level along the eastern and western boundaries of the PH and YLIEE sites, fill platforms will be required to raise the ground level within eastern portion of the sites to ensure a level platform for the proposed

developments. As such, retaining structures will be required along the southern and eastern site boundaries.

9.2.1.7 Further details of the options for retaining structures that have been considered during development of the site formation proposal are provided in **Table 9.2.1** below.

9.2.1.8 Details of the proposed site formation works, including the proposed slopes and retaining structures are presented for the PH and YLIEE sites in **Figures 9.2.5** to **9.2.10** respectively.

9.2.1.9 In addition to the formation of permanent slopes, temporary slopes will also be required in some areas to facilitate the phasing of the site formation programme. This requires further consideration at detailed design stage. However with regard to the currently proposed temporary slopes, the following points should be noted.

- Temporary slopes have been located in order to reduce excavation requirements during construction of pile foundations, pile caps and underground car parks.
- The layout of temporary slopes may be modified where necessary. This may be required if for example, the building layout or platform levels are modified.
- The temporary slopes are below the proposed final formation level, and therefore shall be incorporated into the platform base.

9.2.1.10 The general arrangement and the detail design of the permanent slope and retaining walls shall be revised and carried out during the detail design stage.

Table 9.2.1: Options for Retaining Structures for the PH and YLIEE sites

Retaining Structure	Details	Suitability	Note
Cantilever Bored Pile Wall	Closely spaced bored piles with concrete lagging between piles. Bored pile diameter, spacing and embedment length shall be subjected to the site specific borehole information.	Suitable where height of soil to be retained is greater than 6 metres above future formation level.	In addition to the retaining height above the future formation level, utility zone shall be allowed beneath the future formation level subject to detailed utility planning. The maximum retaining height of the bored pile wall shall depend on the size and embedment depth of the bored piles, the tolerable ground settlement behind the wall, the existing ground profile, the soil strength and stiffness, the depth of bedrock and other geological factors, which are site specific and location

Retaining Structure	Details	Suitability	Note
			dependent.
L-Shaped Retaining (for soil cutting side)	Strutted temporary wall such as sheet pile or pipe pile wall are required to facilitate the construction of retaining wall along the lot boundary. The wall base of the L-shaped wall faces away from the retaining soil and the wall stem and base may be thickened to provide necessary counter weight against overturning and sliding. Supporting piles may be required, if unfavourable bearing stratum is encountered, subjected to the site specific borehole information.	Suitable where height of soil to be retained is not greater than 8 metres above future formation level.	Utility zone shall be allowed beneath the future formation level and above the wall base subject to detailed utility planning. The width of wall base shall not encroach into future building or basement footprint.
U-Shaped Retaining (for soil cutting side)	Strutted temporary wall such as sheet pile or pipe pile wall are required to facilitate the construction of retaining wall along the lot boundary. The wall base of the U-shaped wall faces away from the retaining soil and the wall stem and base may be thickened to provide necessary counter weight against overturning and sliding.	Suitable where height of soil to be retained is not greater than 8 metres above future formation level, and where soil is to be retained from opposing sides of a cut.	Utility zone shall be allowed beneath the future formation level and above the wall base subject to detailed utility planning.
L-Shaped Retaining (for soil filling side)	L-shaped retaining wall is cast in place, with the wall base facing into the site. Fill material is then placed and compacted to platform level. Supporting piles may be required, if unfavourable bearing stratum is encountered, subjected to the site specific borehole information.	Suitable where height of soil to be retained is not greater than 8 metres above future formation level.	The width of wall base shall not encroach into future building or basement footprint.
Toe Wall	Concrete panels used to retain soil fill material. Panel are tied into compacted soil with steel cables. Can be planted.	Suitable where height of soil to be retained is less than 1.5 metres.	

9.2.2 PH

9.2.2.1 Details of the proposed PH site formation are presented in **Figures 9.2.1** and **9.2.2**. The proposed site formation programme will be undertaken in three phases as given in **Table 9.2.2**, and described in further detail below. Detail of the proposed PH construction sequence are presented in **Figures 9.2.11**

Table 9.2.2: Proposed PH Site Formation Programme

PH Site Formation Phase	Anticipated Date	Proposed Final Platform Levels
Phase 1	Sept 2017 – Aug 2020	+5.0mPD to +15mPD
Phase 2	Jun 2020 – May 2023	+5mPD to +10mPD
Phase 3	Jun 2020 – May 2023	+4.5mPD to +11mPD
Note: Detail Programme will be carried out in the detailed design stage		

9.2.2.2 The proposed site formation programme for phase 2 and phase 3 of PH site is tentative. The programme shall be reviewed and could be shortened in consideration of relatively smaller scale of works comparing to phase 1 of PH site subjected to the study under detail design stage.

PH Phase 1 Site Formation

9.2.2.3 The proposed site formation layout and details of the proposed slopes and retaining structures for PH Phase 1 are provided in **Figure 9.2.1**, and illustrated by cross-sections in **Figures 9.2.5 to 9.2.7.**

9.2.2.4 Existing ground levels within the Phase 1 area range from about +4.9 mPD at Long Ping Road to around +11.0 mPD to +22.0 mPD at the hillside perimeter.

9.2.2.5 The proposed site formation levels will be formed from +5.0 mPD to +14.0 mPD within the northern portion, +13.0 mPD within the central portion and +13.0 mPD to +15.0 mPD within the southern portion.

9.2.2.6 Toe walls, 8 to 10m high bored pile walls and 4 to 7m high L-shaped RC retaining walls are proposed to form the steep cut slopes along the northern/western hillside perimeter. An approximately 30m long U-shaped RC structure is proposed either side of the narrow section of the PH Phase 1 area.

9.2.2.7 Toe walls and 4 to 7m high L-shaped RC retaining walls are proposed to form the edge of the fill platform along the southern/eastern site boundary of the PH Phase 1 area.

PH Phase 2 Site Formation

9.2.2.8 The proposed site formation layout and details of the proposed slopes and retaining structures for PH Phase 2 are provided in **Figure 9.2.2**, and illustrated by cross-sections in **Figure 9.2.7**.

9.2.2.9 Existing ground levels within the Phase 2 area range from about +4.1 mPD at Fuk Hi Street to around +12.0 mPD to +20.0 mPD at the hillside perimeter.

9.2.2.10 The proposed site formation levels will be formed at +7.0 mPD within the eastern portion adjacent to Fuk Hi Street; +5.0 mPD to +9 mPD within the central portion; and +9 mPD to +10 mPD within the western portion, closest to the hillside.

9.2.2.11 Toe walls, 3 to 6m high L-shaped RC retaining walls, and 4m high RC retaining walls with a 30 degree cut slope at their crest are proposed along the western hillside perimeter.

9.2.2.12 A temporary cut slope is proposed to form the edge of the fill platform along the southern/eastern site boundary of the PH Phase 2 area.

PH Phase 3 Site Formation

9.2.2.13 The proposed site formation layout and details of the proposed slopes and retaining structures for PH Phase 3 are provided in **Figure 9.2.2**, and illustrated by cross-sections in **Figure 9.2.8**.

9.2.2.14 Existing ground levels within in the Phase 3 area range from about +4.3 mPD at Fuk Hi Street to around +14.0 mPD to +20.0 mPD at the hillside perimeter.

9.2.2.15 The proposed site formation levels will be formed from +4.5mPD to +7.0 mPD within the eastern portion adjacent to Fuk Hi Street; +6.0 mPD to +9.0 mPD within the central portion; and +10.0 mPD to +11.0 mPD within the western portion, closest to the hillside.

9.2.2.16 Toe walls, 3 to 6m high L-shaped RC retaining walls, and 4m high RC retaining walls with a 30 degree cut slope at their crest are proposed along the western hillside perimeter.

9.2.2.17 3m high L-shaped or inverted T-shaped RC retaining wall is proposed to form the edge of the fill platform along the northern boundary of the PH – phase 3 site.

9.2.2.18 A temporary cut slope is proposed to form the edge of the fill platform along the eastern site boundary of the PH Phase 3 area.

9.2.3 YLIEE

9.2.3.1 The proposed site formation layout and details of the proposed slopes and retaining structures for the YLIEE are provided in **Figure 9.2.3 & Figure 9.2.4**, and illustrated by cross-sections in **Figure 9.2.9 and 9.2.10**, and are described below.

9.2.3.2 The proposed site formation programme of YLIEE site is tentative. The programme shall be reviewed and could be shortened in consideration of relatively smaller scale of works comparing to phase 1 of PH site subjected to the study under detail design stage. The proposed site formation programme is provided in **Table 9.2.3**.

Table 9.2.3: Proposed YLIEE Site Formation Programme

PH Site Formation Phase	Anticipated Date	Proposed Final Platform Levels
YLIEE site formation (Figure 9.2.3)	Sept 2019 – Aug 2022	+6mPD to +8mPD

9.2.3.3 Existing ground levels within the YLIEE site range from between +4.0mPD and +4.5mPD at Fuk Hi Street to between +9.4 mPD to +28.0 mPD at the hillside perimeter.

9.2.3.4 The proposed site formation levels will be formed at +6.0mPD and +6.2 mPD within the eastern portion adjacent to Fuk Hi Street; +7.0 mPD to +8.0 mPD within the western portion, adjacent to the hillside.

9.2.3.5 2 to 7m high L-shaped RC retaining walls, and 5 to 7m high RC retaining walls with a 30 cut degree slope at their crest are proposed along the western hillside perimeter.

9.2.3.6 The retaining wall running along the northern boundary of the YLIEE site needs to cater for the proposed drainage pipe and box culvert. Reserve openings and part of the box culvert will need to be incorporated into the design of this wall.

9.3 Material Suitability

9.3.1.1 An assessment of the suitability of materials underlying the proposed site formation areas has been undertaken for the PH and YLIEE sites, with possible requirements for ground treatment or replacement of unsuitable material identified, as discussed below.

9.3.2 Potentially Unstable Fill and Colluvium

9.3.2.1 Localised areas of unengineered fill have been identified during site reconnaissance and are anticipated from the current land use. This fill may not be stable if encountered during excavation for site formation.

9.3.2.2 Colluvium is also expected to be encountered during excavation. The thickness and in-situ density and other properties of these materials is unknown, making it difficult to predict likely behaviour during excavation.

9.3.2.3 Further ground investigation is required to determine the extent, thickness and nature of the fill and colluvium within the areas where excavation is proposed. It should be noted, however, that these excavated materials are likely to be suitable for reuse as fill, but this will be determined following the ground investigation and laboratory testing carried out under the detailed design phase.

9.3.3 Compressible Soils

9.3.3.1 As discussed in Section 8.1, although there is currently insufficient existing GI data to confirm the distribution both laterally and vertically and nature of such materials across the sites, Pleistocene alluvial silts and clays may be present locally within the PH site, and across a large proportion of the YLIEE site. Holocene marine deposits may also be present along the eastern boundary of the YLIEE site. These materials often exhibit high compressibility.

9.3.3.2 Although the consolidation of compressible soils should have been completed due to their long formation history within the area, further consolidation may be triggered by loading from fill placed during site formation. This may result in long term consolidation settlement after the end of the construction period.

9.3.3.3 Ground investigation is required to determine the lateral extent and vertical thickness of these materials in areas where fill is proposed, as well as their compressibility. Once ground investigation data is available, detailed settlement analysis should be undertaken across the areas where fill is proposed. If analysis shows unacceptable levels or timeframe for settlement a number of engineering measures could be considered:

- Surcharging using vertical drains to accelerate the speed of consolidation,
- Replacement of the compressible material with granular fill;

- Ground improvement using stone columns.

9.3.4 Contamination

9.3.4.1 In accordance with the historical and current land use status, it is anticipated that heavy metals and hydrocarbon contamination may be present at the PH and YLIEE sites. However, there is currently no ground investigation data available to confirm the extent and quantity of contaminated soil.

9.3.4.2 Where practicable on-site treatment and reuse of treated soil would be preferred to minimise off-site disposal.

9.3.4.3 The extent of, and methodology for ground treatment will be determined once the environmental ground investigation has been completed, and the data is available.

9.3.5 Groundwater Levels

9.3.5.1 There is currently insufficient data to determine likely groundwater levels within the areas of excavation. This information is needed to determine slope drainage requirements, both during excavation and for permanent design.

9.3.5.2 Groundwater monitoring is required in the areas where cut slopes are proposed to determine long term groundwater levels and drainage requirements.

9.4 Cut and Fill Volumes

Site Clearance

Table 9.4.1: Estimated Areas of affected vegetation, preserved and built-up

Site	Total Site Area (m^2)	Vegetation Area Affected (m^2)	Preserved Area (m^2)	Built-up Area (m^2)
Phase 1	54,800	21,400	0	33,400
Phase 2	58,400	18,000	0	40,400
Phase 3	74,900	7,300	0	67,600
YLIEE	146,500	20,900	2,000	123,600

9.4.1.1 The structural elements on site are mainly temporary structures made-up by metal shed or even metal containers, which could be recycled after decommissioned. From previous experiences, the remaining materials would have the following composition: -

(a) Artificial hard material = 15% by volume
(b) Wood / Timber = 5% by volume

9.4.1.2 Given no detailed investigation and survey were taken within the study area to measure the number of temporary buildings, the following are assumed:

(i) Thickness of hard material (concrete or bitumen) = 0.1m
(ii) Temporary structure coverage = 2.5%
(iii) Height of temporary structures = 3m

Table 9.4.2: Summary of generated and disposal C&D material volumes during site clearance

	Built-up Area (m^2)	Volume of structures[1] (m^3)	Artificial material generated I[2] (m^3)	Inert material generated[3] (m^3)	Non-inert material generated[4] (m^3)	Total disposal Volume[5] (m^3)
Phase 1	33,400	2,505	3,340	375	125	3,840
Phase 2	40,400	3,030	4,040	455	152	4,647
Phase 3	67,600	5,070	6,760	761	254	7,775
YLIEE	123,600	9,270	12,360	1,391	464	14,215
			26,500	2,982	995	30,477

Note:

[1] Volume of structure = Built-up Area X Assumed temporary structure coverage percentage X Assumed Height of temporary structure

[2] Artificial material generated = Built-up Area X Thickness of hard material (concrete or bitumen)

[3] Inert material generated = [1] X assumed Percentage of Artificial hard material (15% by volume)

[4] Non-Inert material generated = [1] X assumed Percentage of Wood / Timber (5% by volume)

[5] Total disposal Volume = [2] + [3] + [4]

9.4.1.3 It is also estimated that there will be about $200m^3$ of vegetation during site clearance.

9.4.1.4 The site clearance works would be undertaken at the early stage of the site formation works. The anticipated disposal programme would be as follows:-

Table 9.4.3: Anticipated disposal volume during site clearance

	Phase 1		YLIEE		Phases 2 & 3	
Year	2017		2019		2020	
	Q3	Q4	Q3	Q4	Q3	Q4
Disposal	50%	50%	50%	50%	50%	50%
Volume (m^3)	1,970	1,970	7,133	7,132	6,236	6,236
Number of trucks	394	394	1427	1426	1247	1247
Number of working days[1]	63	63	63	63	63	63
Number of trucks per day[2]	6	6	23	23	20	20

Note:

[1] Number of working days = 365 (number of calendar days per year) – 52 (number of Sundays per year) – 17 (number of public holidays per year) - 45 (anticipated number of days with inclement weather) = 251 days.

[2] The Volume of truck is $5m^3$

Top Soil

9.4.1.5 No site investigation had been carried out and the thickness of the top soil is yet to be assessed and determined. The existing vegetation area that to be affected by the development are summarized as follows: -

Table 9.4.4: Estimated top soil volume

Location	Affected Vegetation Area (m^2)	Volume of top soil* (m^3)
YLIEE	20,900	4180
PH-Phase 1	21,400	4280
PH-Phase 2	18,000	3600
PH-Phase 3	7,300	1460
Sub-total	67,600	13520

Note: From other major site development works, such as DAR, the top soil is about 200 to 300mm in thickness. In this exercise, a thickness of 300mm is assumed.

9.4.1.6 Given the top soil could be reused in the permanent development works and it is recommended to temporary stored within the site for future use. Temporary stockpile should be identified in each site area for future uses.

9.4.1.7 A typical tree pit will have a plan area of 1.5m x 1.5m and 1.2m depth. The volume of top soil would be $2.7m^3$. The total volume of top soil is $5,925m^3$, which could be fill into about 2,200 number of tree pits within the site.

General Site Formation Works

9.4.1.8 The quantities of fill required and material to be excavated during site formation have been determined. A summary of the estimated cut and fill volumes are provided in Table 9.4 (**Figure 9.4.1**) and **Figures 9.4.2** to **9.4.4** show the cut depth and fill thickness contours in different areas. It shall be noted that the estimated volumes are subject to detailed design work.

Table 9.4.5: Estimated Cut and Fill Quantities for PH and YLIEE sites

Area	Estimated Volume of Excavation (m^3)	Estimated Volume of Filling Works(m^3)
PH Phase 1	133,314	24,513
PH Phase 2	38,639	77,631
PH Phase 3	34,396	67,745
YLIEE	113,336	109,653
Total	**319,685**	**279,542**

9.4.1.9 It is noted that there will be surplus material as a result from the site formation works at Phase 1 and YLIEE development. To prompt a sustainable development, it is recommended to minimise the disposal of surplus excavated material in Phase 1 and YLIEE area but temporary stockpile at Phase 3 and YLIEE areas.

9.4.1.10 The construction programme that Phase 1 will be commenced first and thereafter the YLIEE area. It is feasible that the temporary stockpile could be implemented if land is available.

9.4.1.11 There are structural retaining elements within the site. Additional surplus material should be disposed due to the retaining structure construction works, such as the base slab of the retaining structures. A preliminary estimate shows that the additional excavated volume would be about 10,500m³.

9.4.1.12 The surplus fill volume in Phase 1 area is 103,801m³ (133,314m³ – 24,513m³) whilst the YLIEE area would have a surplus fill volume of 3,683m³ (113,336m³ – 109,653m³).

9.4.1.13 The net volume of fill material required in Phase 2 area and Phase 3 area are 38,992m³ (77,631m³-38,639m³) and 33,349m³ (67,745m³-34,396m³) respectively.

Utilities Works

9.4.1.14 In conjunction with the site formation works within the site, there are utilities installation works outside the development site, including installing new utilities and upgrading existing utilities. The utilities installation works not limited to the drainage and sewer pipes as well as the watermains installation works.

9.4.1.15 According to the latest utilities installation plans, the key elements are the drainage and sewer works. After reviewed the quantities of works, the following are noted: -

Table 9.4.6: Summary of generated and disposal C&D material volumes during utilities works

Area	Estimated C&D soft material Volume of Excavation (m³)	Estimated Volume of Material Reused (m³)	Artificial Hard Material Generated (m³)	Disposal Volume (m³)
External	54,456	31,277	5,343	28,522
PH Phase 1	12,953	10,897	0	2,056
PH Phase 2	5,770	5,770	0	0
PH Phase 3	25,190	25,190	0	0
YLIEE	17,469	17,469	0	0
Total	**115,838**	**90,603**	**5,343**	**30,578**

Disposal Volume for Cut and Fill

9.4.1.16 After considered the total volume of material that to be excavated as well as the volume of material that to be required for backfilling. The disposal volume is as following:

Volume of material to be disposed = (319,685 – 279,542) + 28522 + 10500 +

= 81221 m³

Temporary Stockpiling

9.4.1.17 During the planning of the site formation works at Phase 1 area, sufficient volume of fill material have to be retained for Phases 2 and

3 area. Phases 1 to 3 and YLIEE, equals to 24,513m³ + 38,992m³+33,349m³ - 3,683m³ = 93,171m³.

9.4.1.18 The utilities installation works would also generated a volume of 1,847+6,552+2,649 = 11,048m³ of surplus material during Phase 2, 3 and YLIEE development.

9.4.1.19 Assuming there is a stockpile area that could temporary stock all the fill materials for Phases 2 and 3, i.e. a volume of 68,658m³. After deducting the possible excavated material during the utilities installation works, the stockpile volume could be reduced to 68,658 – 11,048=57,610m³.

9.4.1.20 The volume of material to be disposed is 81,221m³, which mainly from the Phase 1 area. In accordance with the latest construction programme, it is anticipated that the site formation works of the Phase 1 area will commence in September 2017 for completion in August 2020, i.e. 36 months. The commencement date of the construction works will at the mid of the financial year 2017/18. The anticipated disposal volume during the construction period is tabular below: -

Table 9.4.7: Anticipated disposal volume during the construction period

Year	2017		2018			
	Q3	Q4	Q1	Q2	Q3	Q4
Disposal	5%	10%	15%	15%	15%	15%
Volume (m³)	4061	8122	12183	12183	12183	12183
Number of trucks	812	1624	2437	2437	2437	2437
Number of working days	63	63	62	63	63	63
Number of trucks per day	13	26	39	39	39	39

Year	2019			
	Q1	Q2	Q3	Q4
Disposal	10%	7.5%	7.5%	0%
Volume	8122	6092	6092	0
Number of trucks	1624	1218	1218	0
Number of working days	62	63	63	63
Number of trucks per day	26	19	19	0

Note:
1. The volume of truck is 5m³.
2. The number of working days excludes public holidays and days with inclement weather.

9.4.1.21 Form the table above, the average number of trucks movement in disposing the surplus material is 48 numbers. In considering the working hour is 8 hours per day, the number of trucks per hour is about 6 numbers. Given the long construction period for the proposed site formation works, it is reasonable that the throughput of the disposal varies from time to time to take into account the actual progress on site. Assuming a peak factor of 3 to cope with the actual construction progress, the maximum number of truck per hour would be increased to 18 numbers.

Location and Height of Stockpile

9.4.1.22 A temporary stockpile area (32,000m²) has been identified within the development site, where part of it is located in Phase 3 area whilst the

remaining would be within YLIEE site area. The proposed locations of the stockpiling areas are indicated in **Figures 9.4.5** .

9.4.1.23 As per the requirement discussed above, the volume of stockpile is 57,610m³. Taking into account the bulk factor of 1.15 on the excavated material, the height of the stockpile would be 57,610 x 1.15 / 32,000 = 2.07m (say 2.2m). Given the temporary stockpile is quite large and it is costly to provide a temporary retaining structure to contain the temporary stockpile area, it is recommended to provide a temporary barrier in retaining the stockpile. One of the easiest solutions is by stacking one layer of precast concrete blocks, 1.35m in height, at the perimeter of the proposed temporary stockpile area.

9.4.1.24 Apart from that, the following should also be set up as part of the temporary stockpile area:

(a) washing bay : 5m x 12m = 60m²
(b) weight bridge : 5m x 10m = 50m²
(c) office : 6.5m x 2.5m = 16.25m²

The total area required for supporting facilities = 126.25m² (say 150m²). Beside, a temporary access road has to be reserved from the public road to the temporary stockpile area

9.4.1.25 The temporary stockpile will be maintained for couple of year and temporary protective measures have to be incorporated, such as hydroseeding on the surface and proper drainage system to be incorporate at the toe of the temporary stockpile to drainage off the surface water to proper desilting facility before the water is discharge to a designed public discharge point.

Reuse of Material

9.4.1.26 It is anticipated that much of the excavated material will be classified as 'soft inert' and hence be suitable for re-use on site as fill. Re-use of this material will also be subject to it meeting the suitability criteria for general fill in relation to organic content and clay mineralogy. Any rock and artificially hard material will need to be disposed of or processed for re-use off site. The re-use of excavated material is also dependent on the phasing of the site formation works and having sufficient space on site to sort and stockpile any spoil for subsequent phases of filling works.

9.4.1.27 Ground investigation is required to confirm the nature of the materials within the areas to be excavated which will help to confirm the proportion of spoil material that is reusable.

9.4.1.28 To ensure there is sufficient fill for the Phase 2 and Phase 3 of PH site, it would be necessary to stockpile spoil material from the Phase 1 site excavation works. The logistics and contractual arrangements for this need to be considered at detailed design stage.

Disposal of Inert and Non-Inert Materials

9.4.1.29 In summary, the estimated volume of inert and non-inert material that to be disposed off is given in **Table 9.4.8** below:

Table 9.4.8: Summary of materials that to be generated, reused and disposed off

Type of material	Estimated amount of generation (m^3)	Estimated amount to be reused on site (m^3)	Estimated amount to be disposed at public fill (m^3)	Estimated amount to be disposed at landfill (m^3)
Spoil generated during site clearance works	30,677	0	29,482	1195
Spoil generated during site formation works	319,685	279,542	40,143	0
Spoil generated due to retaining wall construction	10,500	0	10,500	0
Spoil generated during utilities installation works	121,181	90,603	25,235	5343
Top soil from vegetation	13,520	13,520	0	0
Total spoil materials generated	**495,563**	**383,665**	**105,360**	**6,538**

9.4.1.30 It is estimated that there will be ~105,360m^3 disposed at public fill and ~6,538m^3 disposed at landfill during site formation works.

9.4.1.31 Assuming that a sufficient volume of the site-won spoil is suitable to meet the fill requirements for all PH and YLIEE phases, and that spoil material from the PH Phase 1 development can be re-used as fill at the PH Phase 2 and 3 and YLIEE site, it is currently anticipated that approximately 329,043m^3 of spoil material will need to be exported off-site for disposal. However, it may be possible to reduce this volume by re-using some of this material for landscaping, subject to the requirements of the detailed design.

9.4.1.32 The preferred location for disposal of the inert spoil material is one of the public fill banks. Given site formation works are not anticipated to commence until 2017, it is too soon for the Public Fill Committee of CEDD (PFC) to confirm capacity to receive material from these sites. As such it is not possible to determine which fill bank the spoil might be sent to.

9.4.1.33 Any non-inert material such as vegetation will most likely need to be disposed at landfill. Currently, the closest landfill is the North East New Territories Landfill.

9.4.1.34 Liaison with the PFC and EPD will be required at detailed design stage to confirm suitable locations for disposal, and hence establish haul routes for exporting waste materials from the PH and YLIEE sites. Liaison with the PFC and EPD will be required at detailed design stage to confirm quantities and programme for spoil disposal.

Sources of Fill

9.4.1.35 As discussed above, if all spoil can be re-used and there is provision within the programme and space on the site for stockpiling and transfer between different phases of site formation for both the PH and YLIEE sites, no fill material would need to be imported to the site for site formation works.

9.4.1.36 If it is not possible to stockpile and transfer spoil between different phases of the PH and YLIEE sites, or if a larger proportion of excavated material is found to be unsuitable for general fill than currently anticipated, general fill material would need to be imported. This will be subject to the findings of ground investigation and laboratory testing to determine the material which will be excavated and its suitability for re-use as general fill.

9.4.1.37 The preferred source of fill to meet any requirements for imported fill is the public fill bank. Given that the import of fill is not currently anticipated and that site formation works are not anticipated to commence until 2017, it is not possible for the Public Fill Committee of CEDD (PFC) to confirm the availability of fill at this stage. From the geophysical location of the site, it is anticipated that the general fill material, if required, would be obtained from the fill bank at Tuen Mun Area 38. If this is the case, a haul route should be established for importing fill to the PH and YLIEE sites at this stage. Liaison with the PFC will be required at detailed design stage to confirm quantities and programme for fill, if required.

9.4.1.38 Alternative potential sources of fill include other concurrent construction projects which are generating sufficient surplus spoil. Again, this will need to be investigated at the detailed design stage.

9.4.1.39 There is no imported fill material for cut and fill activity, however, it is estimated that 5,808 m3 of filter materials will need to be imported for RC retaining structure.

9.5 Impact of Site Formation Process on Drainage, Sewerage and Water Quality

9.5.1 Construction Site Runoff

9.5.1.1 During rainstorm events, construction site runoff would come from all over the works site. The surface runoff might be polluted by:

- Runoff and erosion from site surfaces, earth working areas and stockpiles;
- Wash water from dust suppression sprays and wheel washing facilities; and
- Chemicals spillage such as fuel, oil, solvents and lubricants from maintenance of construction machinery and equipment.

9.5.1.2 Construction runoff may cause physical, biological and chemical effects. The physical effects include potential blockage of drainage channels and increase of suspended solid levels in the Deep Bay WCZ. Runoff containing significant amounts of concrete and cement-derived material may cause primary chemical effects such as increasing turbidity and discoloration, elevation in pH, and accretion of solids. A number of secondary effects may also result in toxic effects to water biota due to elevated pH values, and reduced decay

rates of faecal micro-organisms and photosynthetic rate due to the decreased light penetration.

9.5.1.3 In accordance with the Practice Note for Professional Persons on Construction Site Drainage, Environmental Protection Department, 1994 (ProPECC PN 1/94), best management practices should be implemented on site as far as practicable. For further details of these practices, reference should be made to the relevant section of the EIA prepared under this study.

9.5.1.4 By adopting the best management practices, it is anticipated that the impacts of general site operation will be reduced to satisfactory levels before discharge. Environmental audit of the construction site should be conducted regularly in order to monitor practices.

9.5.2 Sewerage from Workforce

9.5.2.1 Sewage effluents will arise from the sanitary facilities provided for the on-site construction workforce. However, it is anticipated that sewage generation during the construction phase of the Project would not cause any adverse impact on water quality if the following measures are implemented:

- Provision of portable chemical toilets and sewage holding tank;
- Notices posted to remind workers not to discharge any sewage or wastewater into the nearby environment;
- Regular environmental audit of the construction site to provide an effective control of any malpractices.

9.5.2.2 Further details of the specific requirements for these facilities are provided in the relevant section of the EIA prepared under this study

9.5.3 Alternation of Watercourses

9.5.3.1 During construction, all the watercourses within the Project Area will be diverted into either new or upgraded box culverts. During this process, water quality may be adversely impacted by runoff and erosion from site surfaces and earth working areas.

9.5.3.2 To minimise the impact on the watercourses, alternation works should be conducted during dry season when the water flows are low if possible. In addition, the by-pass channels/pipes outside the construction sites should be constructed prior to commencement of site formation works so that the watercourses could be diverted and flow would be separated from the construction sites during site formation works.

9.5.3.3 Water quality monitoring should also be undertaken to ensure the effectiveness of mitigation measures.

9.5.3.4 Further details are provided in the relevant section of the EIA prepared under this study

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Geotechnical and Site Formation Constraints and Solutions

10.1.1.1 In conclusion, a summary of the key geotechnical and site formation related constraints identified by this study is provided in **Table 10.1.1**, below, with solutions to overcome or address these constraints for the proposed developments.

10.1.1.2 Ground investigation is required to better constrain the extent and potential impact of the majority of the key constraints identified. Once this data is available, suitable engineering solutions can be determined to overcome them. As such, it is concluded that the proposed developments at the PH and YLIEE are geotechnically feasible. Site formation works to accommodate the various requirements of the proposed developments are also technically feasible.

Table 10.1.1 Summary of the Geotechnical and Site Formation Constraints and Feasible Solutions for PH and YLIEE Sites

Element Affected	Constraint	Feasible Solution
Foundations	Potential for complex ground conditions including karstic marble and very deep engineering rockhead. Complexity of ground conditions and nature of underlying materials currently poorly constrained due to lack of ground investigation data.	A comprehensive ground investigation shall be carried out to constrain the variation in engineering rockhead level below the proposed developments. Ground investigation is required at each structure and building to determine the ground profile and for the foundation design. If rockhead is found to be very deep in any areas where buildings or other structures are proposed, friction piles may be used as an alternative to end-bearing piles. If 'honeycombed' marble or cavities are present over a large area, buoyancy raft foundations can be considered.
	Bearing capacity of deep foundations penetrating compressible soils (marine deposits and alluvial clays and silts) may be reduced by negative skin friction (NSF). Extent and nature of marine and alluvial deposits currently poorly constrained due to lack of ground investigation data.	Further ground investigation shall be carried out to constrain vertical and lateral extents and consolidation characteristics of compressible soils below buildings. Foundations can be designed to take into account the impact of negative skin friction.
	Insufficient ground investigation and laboratory testing data to confirm parameters for foundation design.	Ground investigation and laboratory testing shall be undertaken for all buildings and other structures.
Natural Terrain Hazard Mitigation	Findings of the NTHS suggest that a very small volume of debris would reach the site in the event of a landslide within the adjacent slopes.	Natural terrain hazard mitigation measures are not required. The volume of landslide debris indicated as entering the proposed development is of a volume too small to require mitigating.

Element Affected	Constraint	Feasible Solution
Existing Registered Slopes and Retaining Walls	Preliminary analysis suggests none of the features within or adjacent to the PH and YLIEE sites will require upgrading, However, 6 No. features (3 No. within the PH site and 3 No. within the YLIEE site) require modification during site formation.	Detailed study of current condition of the slopes and retaining walls to confirm any upgrading/modification works is required. This shall include site inspection and stability analysis, and ground investigation.
Site Formation	The existing topography of the sites means that extensive site formation works are required to form platforms suitable for the proposed developments and access roads.	Site formation works have been optimised to minimise the volume of cut and fill as much as possible, whilst ensuring the developable area is maximised.
	Burial grounds to the north and west of the site boundary and the need to maximise the developable platform area within the site restrict space for slope formation along much of the western and northern site boundary.	Retaining walls or a combination of retaining wall with a maximum 30 degree slope at the crest are proposed to keep the site formation works within the site boundary. Where the difference between the proposed formation level and existing level is greater than 8m, bored pile walls are proposed; where the difference between the proposed formation level and existing level is 1.5m to 8m, RC retaining walls are proposed; where the difference between the proposed formation level and existing level is less than 1.5m toe walls are proposed.
	Potentially unstable fill and colluvium may be encountered during excavation	Ground investigation shall be carried out to constrain vertical and lateral extents and properties of existing fill and colluvium within areas of excavation. Cut slope design and construction methodology shall take into consideration any potentially unstable materials.

Element Affected	Constraint	Feasible Solution
	Compressible marine and alluvial deposits may cause unacceptable levels of settlement when loaded by fill during site formation. Extent and nature of marine and alluvial deposits currently poorly constrained due to lack of ground investigation data.	Ground investigation shall be carried out to constrain vertical and lateral extents and consolidation characteristics of compressible soils below areas of proposed fill. Once ground investigation data is available, detailed settlement analysis shall be undertaken across the areas where fill is proposed. If analysis shows unacceptable levels or timeframe for settlement, a number of engineering measures could be considered, including surcharging, excavation and replacement of compressible material and in-situ ground improvement e.g. stone columns.
	Potentially contaminated soil may pose a health risk to future residents/end-users. Extent and nature of any contamination currently poorly constrained due to lack of ground investigation data.	Environmental ground investigation shall be carried out to constrain extent and nature of any contamination. Once environmental ground investigation data is available, analysis can be undertaken to determine the extent of any contamination and suitable treatment method. To avoid disposal of contaminated spoil off-site, it is anticipated that treatment would be undertaken in-situ or the contaminated soil
	Insufficient ground investigation and laboratory testing data to confirm parameters for slope and retaining wall design.	Ground investigation and laboratory testing shall be undertaken for all earthworks and retaining structures.
	Insufficient data on groundwater levels to determine slope drainage requirements.	Long term groundwater monitoring is required to establish a hydrogeological model for the site, and determine slope drainage requirements.
	The site formation process has potential to impact on Drainage, Sewerage and Water Quality in a number of ways.	Careful planning and monitoring to ensure best environmental practice during site formation works shall ensure any adverse impact is mitigated. Further details are provided in the EIA.

10.2 Recommendations

10.2.1.1 Recommendations for additional studies to be undertaken for detailed design are as follows:

- In addition to the ground investigation and laboratory testing already proposed to develop the general ground model for this stage of study (see Section 5), ground investigation and laboratory testing for specific buildings and structures- for all earthworks, buildings and other facilities prior to detailed design (see below);
- Inspection and stability analysis of registered geotechnical features adjacent to the sites, or those within the sites which require modification as part of the proposed site formation works;
- Detailed settlement analysis for areas where fill is proposed.

10.2.1.2 Given the lack of existing coverage, ground investigation should be undertaken prior to detailed design and comprise the following:

- Drillholes to determine foundation levels for buildings and other structures, and ground profile in areas of excavation, cut slope and retaining wall formation and modification;
- In-situ testing within, and soil sampling from drillholes for laboratory testing, to determine geotechnical parameters for detailed design of foundations and slopes and suitability of excavated material for re-use as fill;
- If rock is encountered above formation level along the western site boundary, in-situ testing and televiewer surveying of Grade III or better rock within and sampling from drillholes for laboratory testing to determine geotechnical parameters for detailed design of slopes;
- Installation of groundwater monitoring wells within drillholes and a comprehensive regime of long-term groundwater monitoring (covering 2 wet seasons as a minimum), including areas of excavation.

10.2.1.3 In relation to the site formation design, the following should be considered at detailed design stage:

- Detailed design of all permanent slopes/retaining walls will need to be submitted to the GEO for checking in accordance with the requirements stipulated in ETWB TC(W) No. 29/2008;
- Programme and practicalities for site formation works to determine if spoil can be stockpiled and transferred between different phases of site formation as required;
- Liaison with the PFC and EPD to confirm spoil disposal arrangements and sources of fill for all phases of site formation.

11 REFERENCES

Building Department. (2004). Code of Practice for Foundations. Hong Kong: Building Department. 57p.

CEDD (2012). Project Administration Handbook for Civil Engineering Works. Hong Kong: CEDD. 64p.

Environmental Protection Department (1994). Practice Note for Professional Persons on Construction Site Drainage, (ProPECC PN 1/94),

Environment, Transport and Works Bureau. (2002). Technical Circular (Works) No. 29/2002. Geotechnical Control for Slopes and Retaining Walls.

Environment, Transport and Works Bureau. (2004). Technical Circular (Works) No. 4/2004. Checking of Foundation Works in the Scheduled Areas of Northwest New Territories and Ma On Shan and the Designated Area of Northshore Lantau. 15p.

Frost, D.V. (1992). Sheet Report No. 1 Geology of Yuen Long. Hong Kong: Geotechnical Engineering Office. 69p;

Fyfe, J.A., Shaw, R., Campbell, S.D.G., Lai, K.W. and Kirk, P.A. (2000). Quaternary Geology of Hong Kong. Hong Kong. Hong Kong Geological Survey. 210p;

GCO (1988). North West New Territories. Geotechnical Area Studies Programme. GASP Report IV. Geotechnical Control Office, Civil Engineering Services Department, Hong Kong;

GCO (1990). GCO Publication No.2/90 Foundation Properties of Marble and Other Rocks in the Yuen Long-Tuen Mun Area. Geotechnical Control office, Civil Engineering Services Departments Hong Kong.

GEO, (1988).1:20,000 Geological Map Sheet 6 (Yuen Long), Hong Kong Geological Survey;

GEO. (1993). Guide to Retaining Wall Design – Geoguide 1. Hong Kong: Geotechnical Engineering Office, Civil Engineering Department.258p.

GEO. (2006) Publication No.1/2006 Foundation Design and Construction. HK: Geotechnical Engineering Office. 376p.

Langford, R.L., Lai, K.W., Arthurton, R.S., and Shaw, R. (1989). Geological Memoir No. 3 Geology of the Western New Territories, Hong Kong Geological Survey. 140 p;

Ng, K.C., Parry, S., King, J.P., Franks, C.A.M. & Shaw, R. (2003). Guidelines for Natural Terrain Hazard Studies – GEO Report No. 138. Hong Kong: Geotechnical Engineering Office, Civil Engineering and Development Department. 138p.

Sewell et al, (2000). 1:5,000 Geological Map Sheet 6-NW-B, Hong Kong Geological Survey;

Sewell, R.J., Campbell, S.D.G., Fletcher, C.J.N., Lai, K.W. & Kirk, P.A. (2000). The Pre-Quaternary Geology of Hong Kong. Hong Kong Geological Survey, Geotechnical Engineering Office, Hong Kong, 181p.

Stroud, M. A. (1989). The standard penetration test—Its application and interpretation. In Institution of Civil Engineering, Penetration Testing, Proceedings of the Geotechnology Conference Organized by the Institution of Civil Engineers and held in Birmingham on 6-8 July 1988.23p.

Stroud, M.A. and Butler, F.G. (1975). The Standard Penetration Test and the engineering properties of glacial materials. Proc. Symo. Enging. Behaviour of Glacial Materials, University of Birmingham, 12p..

Town Planning Board (2010). Ping Shan Outline Zoning Plan (OZP) No. S/YL-PS/14.