AECOM

Hong Kong Housing Authority

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Consultancy for Environmental Design Studies for Public Housing Development at Wang Chau Phase 1 Site B, Yuen Long

Air Ventilation Assessment – Initial Study (AVA-IS)

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1 INTRODUCTION

Background

1.1 AECOM Asia Co. Ltd. has been commissioned by the Hong Kong Housing Authority (HKHA) to undertake an Air Ventilation Assessment (AVA) Study – Initial Study (IS) for the Public Housing Development located at Wang Chau Phase 1 Site B (the "Site), Yuen Long to examine the air ventilation impact of the proposed building design quantitatively and formulate effective and practicable measures enhancing the air ventilation as part of the continuous design improvement process.

Objectives

1.2 The purpose of this study is to fulfill the requirement in the planning brief that a quantitative Air Ventilation Assessment (AVA) - Initial Study to be conducted at the detailed design stage. The AVA Study for the proposed public housing development at the Site has been conducted in accordance with the methodology outlined in the Technical Guide for AVA for Developments in Hong Kong (the Technical Guide) annexed in HPLB and ETWB TC No. 1/06. The main purposes of this AVA Study, echoing the Technical Guide, are:

- To assess the characteristics of the wind availability (V_∞) of the Site;
- To give a general pattern and a rough quantitative estimate of wind performance at the pedestrian level reported using Wind Velocity Ratio (VR);
- To quantitatively assess the air ventilation performance in the neighbourhood of the Proposed Development; and
- To compare two studied schemes in terms of air ventilation performance aspect.

Content of This Report

1.3 Section 1 is the introduction section. The remainder of the report is organized as follows:

- Section 2 on site characteristics;
- Section 3 on assessment methodology;
- Section 4 on assessment criteria;
- Section 5 on key findings of AVA study;
- Section 6 on directional analysis; and
- Section 7 with a summary and conclusion.

2 SITE CHARACTERISTICS

Site and Its Surrounding Area

2.1 Wang Chau Phase 1 (WCP1) was rezoned from "Green Belt" (“GB”) to "Residential (Group A) 4" (“R(A)4”) in 2014. The proposed development site consisted of 2 public housing sites (i.e. Site A and Site B), a social welfare block, a school site and a new public road. The current study location, namely Wang Chau Phase 1 Site B is bounded by the School Site to the east, Umah International Primary School to the south, Wing Ning Tsuen to the west, and the hilly terrain to the north.

2.2 In 2015, a major revision of the new public road alignment was made by the Government. The configuration of Site B was changed. After a review of the site constraints, the development site (the "Study Area") was revised. The public housing development at Site B ("the Site"), with a gross site area of about 2.02 ha, is bounded by Wing Ning Village to the west, West Rail Line viaduct to the southwest, Kai Shan hillside to the north, Umah International Primary School and a school site to the east. A new public road will be constructed at the east to link up the Site to the existing Long Ping Road.

2.3 According to the “Approved Ping Shan Outline Zoning Plan No. S/YL-PS/20”, the Site currently falls within an area zoned “Residential (Group A)4” (“R(A)4”) with a maximum plot ratio (PR) of 6 and a building height restriction (BHR) of +135mPD. The potential public housing development at the eastern portion of the Study Area (i.e. Wang Chau Phase 1 Site A) is zoned “R(A)4” and is subject to the Plot Ratio and Building Height Restriction same as those for the Site. In April 2021, the site of Wang Chau Remaining Phases (WCRP) was rezoned from "GB" and "OS" to "Residential (Group A)5" ("R(A)5") for high-density public housing development. The WCRP site is subject to a maximum PR of 6.5 and a building height restriction (BHR) of 135mPD. In March 2023, TPB approved the S16 Application submitted by HKHA on proposed minor relaxation of BHR for permitted public housing developments at the Site from +135 to +145mPD.

2.4 The Site is currently under site formation works by CEDD after completion of land resumption and clearance in April 2021. The surrounding areas of the Site are characterized by a mixture of various land uses. To the east of the Site across Long Ping Road is the high-rise residential Long Ping Estate (63-102mPD) in “R(A)”. To the immediate south of the Site are low-rise village houses of the Green Hills and Umah International Primary School (26mPD) in “Green Belt” (“GB”). Wing Ning Tsuen in zone “GB” in the west comprises rural residential dwellings, temporary structures and open storages. To the north are small knolls (50mPD) in “Conservation Area” (“CA”) which consists of natural landscapes, burial grounds and graves.

2.5 The topography is generally flat. Natural slopes to the north of the Site are from mild gradient to hilly where approaching Kai Shan (121mPD) in the northwest.

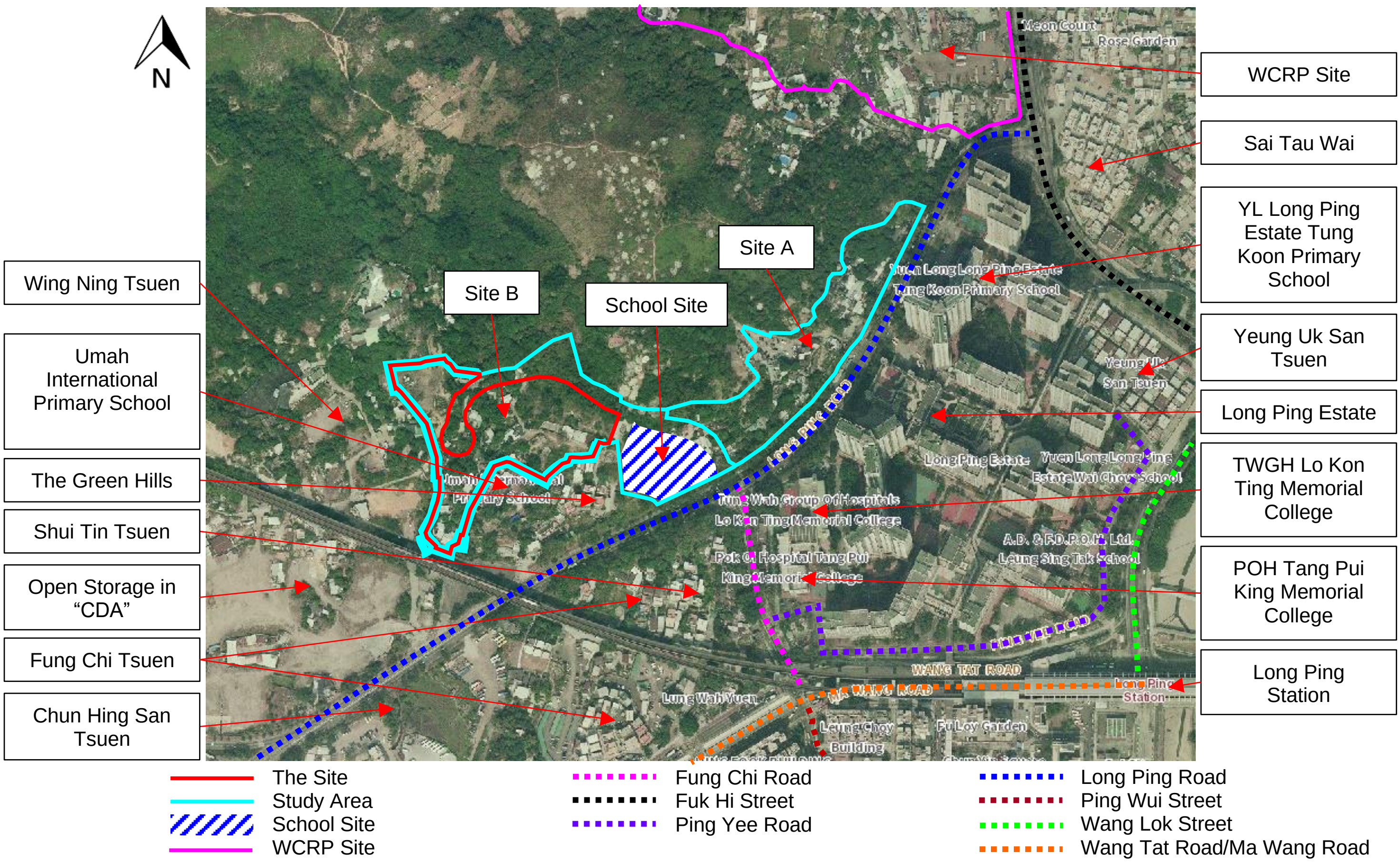


Figure 2.1 Overview of the Site and its Surroundings (Source: GeoInfo Map)

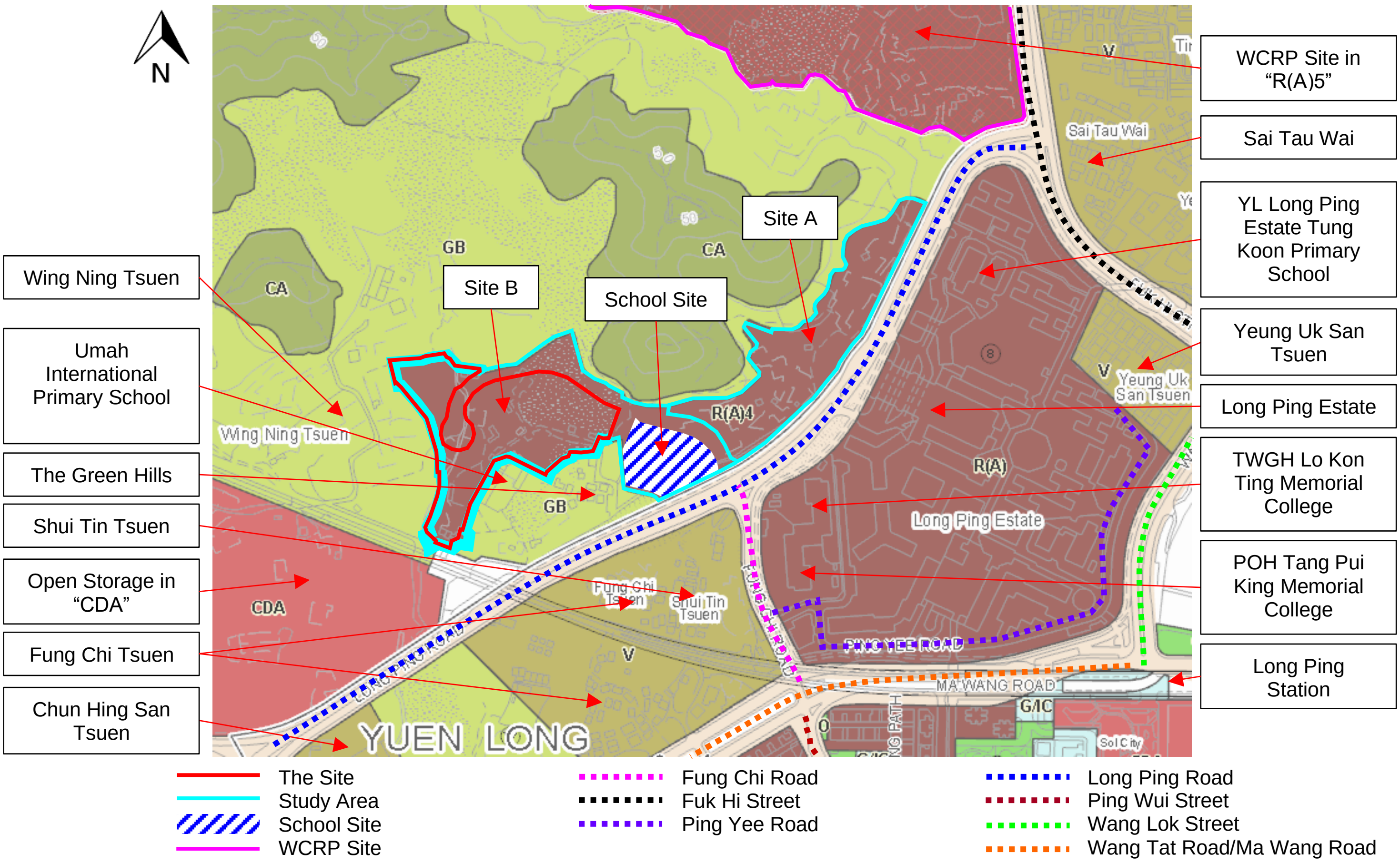


Figure 2.2 Land Use of the Site and its Surroundings in Draft OZP (Source: Statutory Planning Portal 2)

3 ASSESSMENT METHODOLOGY

3.1 This AVA study was carried out in accordance with the guidelines stipulated in the Technical Guide for AVA for Developments in Hong Kong with regard to Computational Fluid Dynamics (CFD) modelling. Reference was also made to the "Recommendations on the use of CFD in Predicting Pedestrian Wind Environment" issued by a working group of the COST action C14 "Impact of Wind and Storms on City Life and Built Environment" (COST stands for the European Cooperation in the field of Scientific and Technical Research). COST action C14 is developed by European Laboratories/Institutes dealing with wind and/or structural engineering, whose cumulative skills, expertise and facilities have an internationally leading position. Thus, it is considered that the COST action C14 is a valid and good reference for CFD modelling in the AVA study.

Modelling Tool and Model Setup

3.2 Assessment was conducted by means of a 3-dimensional CFD model. The well-recognised commercial CFD package FLUENT was used in this exercise. The FLUENT model has been widely applied for various AVA research and studies worldwide. The accuracy level of the FLUENT model was very much accepted by the industry for AVA applications.

Computational Domain

3.3 A 3D CFD model including major topographical features and building morphology which would likely affect the wind flow was constructed. The methodology described in the Technical Guide was adopted for this assessment. According to the Technical Guide, the Assessment Area should include the project's surroundings up to a perpendicular distance of 1H while the Surrounding Area (marked in blue) should at least include the project's surroundings up to a perpendicular distance of 2H calculated from the project boundary, H being the height of the tallest building within Surrounding Area. In this study, the value of H being 140 meters with the computational domain size of around 2500m x 2500m x 1000m. In addition, the grid expansion ratio and the blockage ratio should not exceed 1.3 and 3% respectively. The ground of the computational domain should include topography.

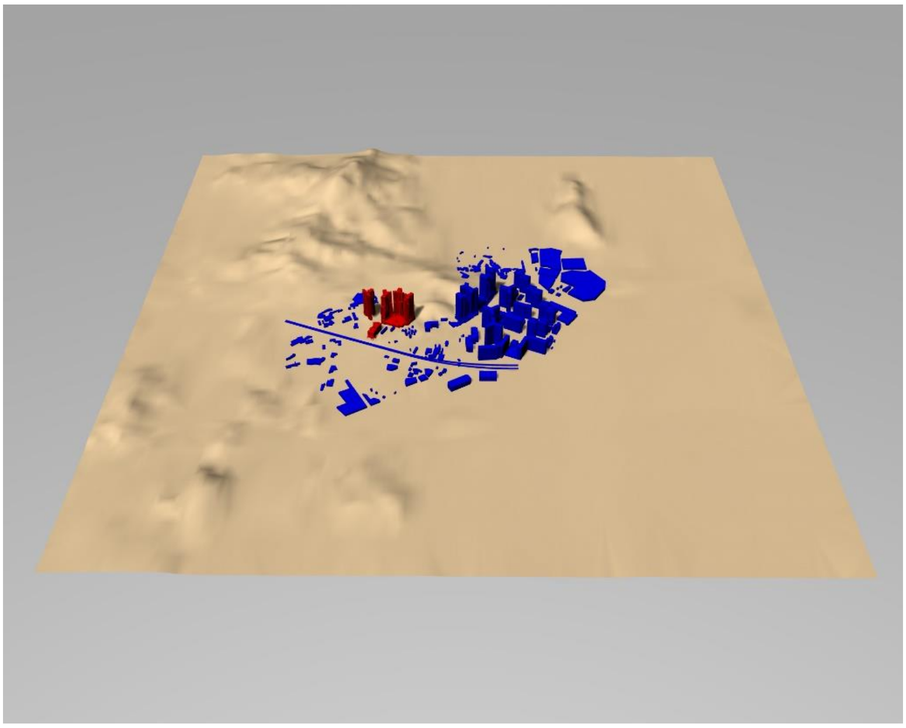


Figure 3.1 Geometry of Computational Model

Assessment and Surrounding Areas

3.4 Both the Baseline Scheme and Proposed Scheme are assessed under annual and summer wind conditions. A 3D model will be built according to the GIS information obtained from the Lands Department to include all existing, planned and committed development, if any, within the Surrounding Area. All other major elevated structures including the elevated railway tracks, and noise barriers, if any, within the Surrounding Area are also included in the model. The Assessment Area (marked in Green) and Surrounding Area (marked in Blue) have also been incorporated into the simulation model for Air Ventilation Assessment as shown in **Figure 3.2**.

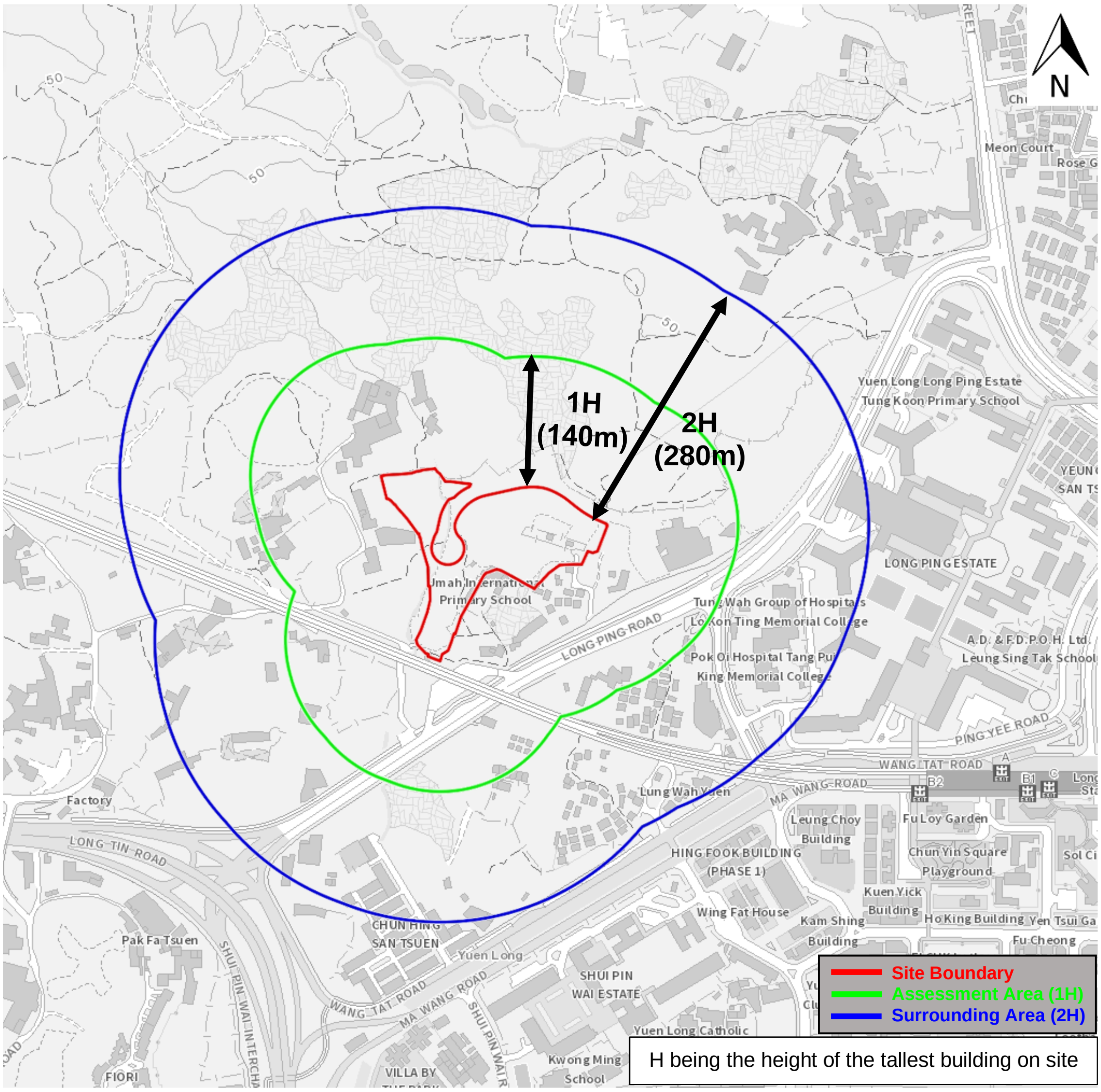


Figure 3.2 **Boundaries of the Site, Assessment Area and Surrounding Area**

Studied Schemes

3.5 **Figure 3.9** and **Figure 3.10** demonstrated the model geometry of the Baseline Scheme and the Proposed Scheme in the simulation.

3.6 In 2015, a major revision of the new public road alignment was made by the government in 2015. Site B was then divided by the new access road into two separate sites. The housing design for Site A and Site B was revamped after a review of the site constraints.

Baseline Scheme

3.7 The Baseline Scheme adopt the indicative layout used for the Section 16 submission for the potential public housing development at the Site. The maximum permitted overall Plot Ratio of the Site is 6.0 (as land designated "R(A)4").

3.8 The Baseline Scheme comprises 4 domestic blocks with maximum building heights of 137-141mPD on 1 to 2-storey non-domestic podiums and 1-storey podium garden. The social welfare block (42mPD) is included within the Site boundary.

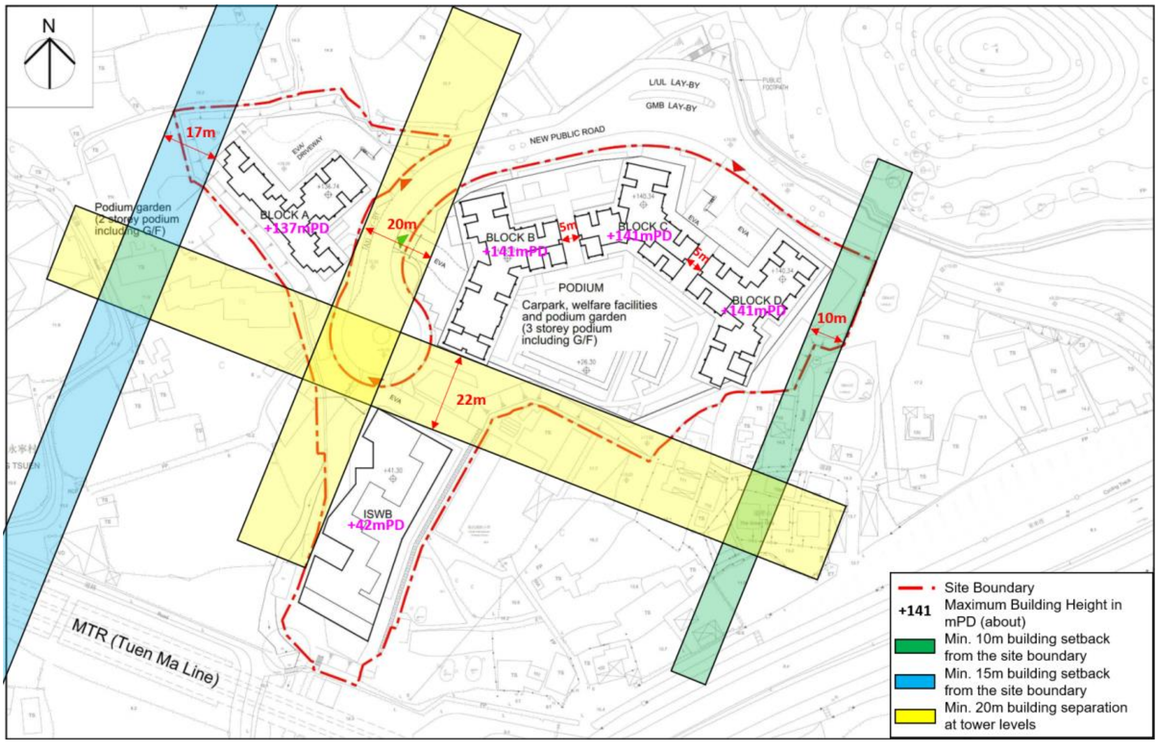


Figure 3.3 **Indicative Plan of Baseline Scheme (Master Layout)**

Proposed Scheme

3.9 The Proposed Scheme comprises 4 domestic blocks with maximum building heights of 135-140mPD on 1 to 2-storey non-domestic podiums and 1-storey podium gardens. The social welfare block (42mPD) is included within the Site boundary. Empty bays under domestic blocks and at podium levels could enhance the wind permeability. A minimum of 20m building setback from the site boundary, a minimum of 15m building setback from the site boundary near the school site and a minimum of 20m building separations at tower levels are incorporated in the Proposed Scheme to facilitate the air circulation as illustrated in **Figure 3.4**.

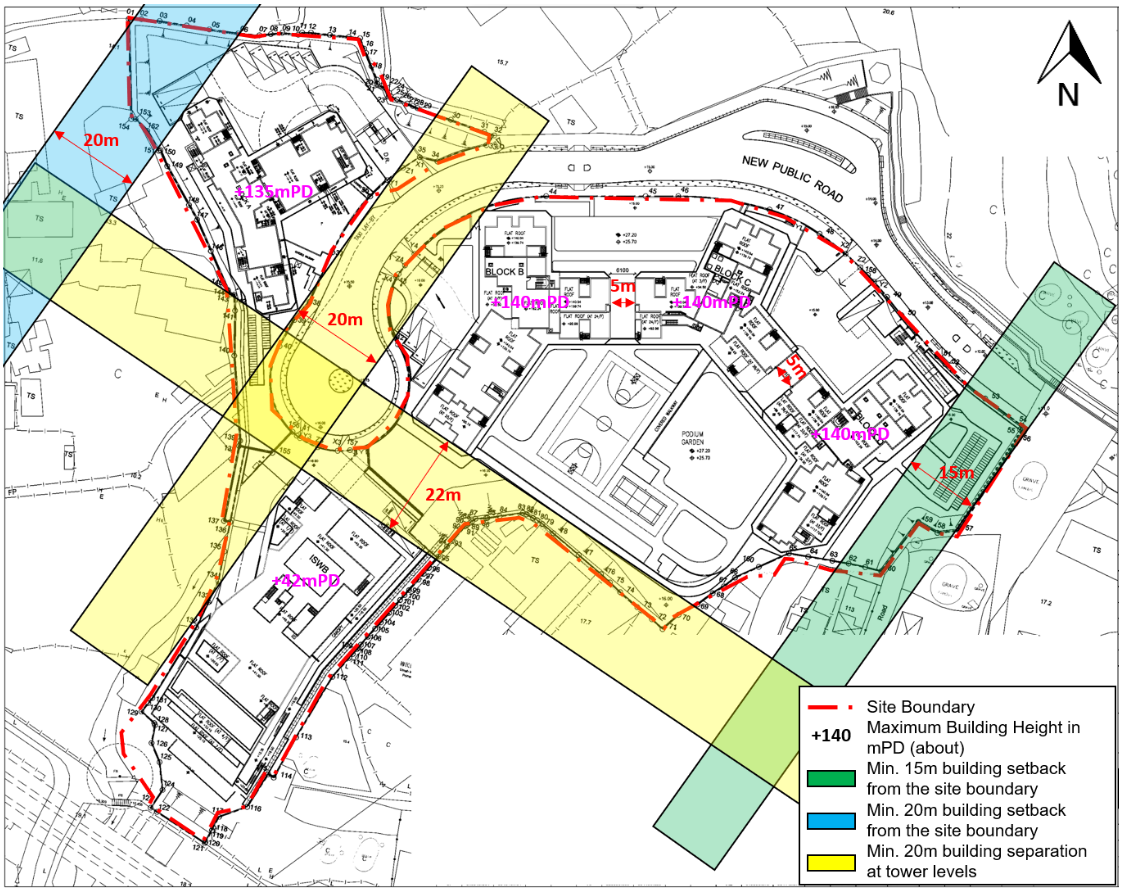
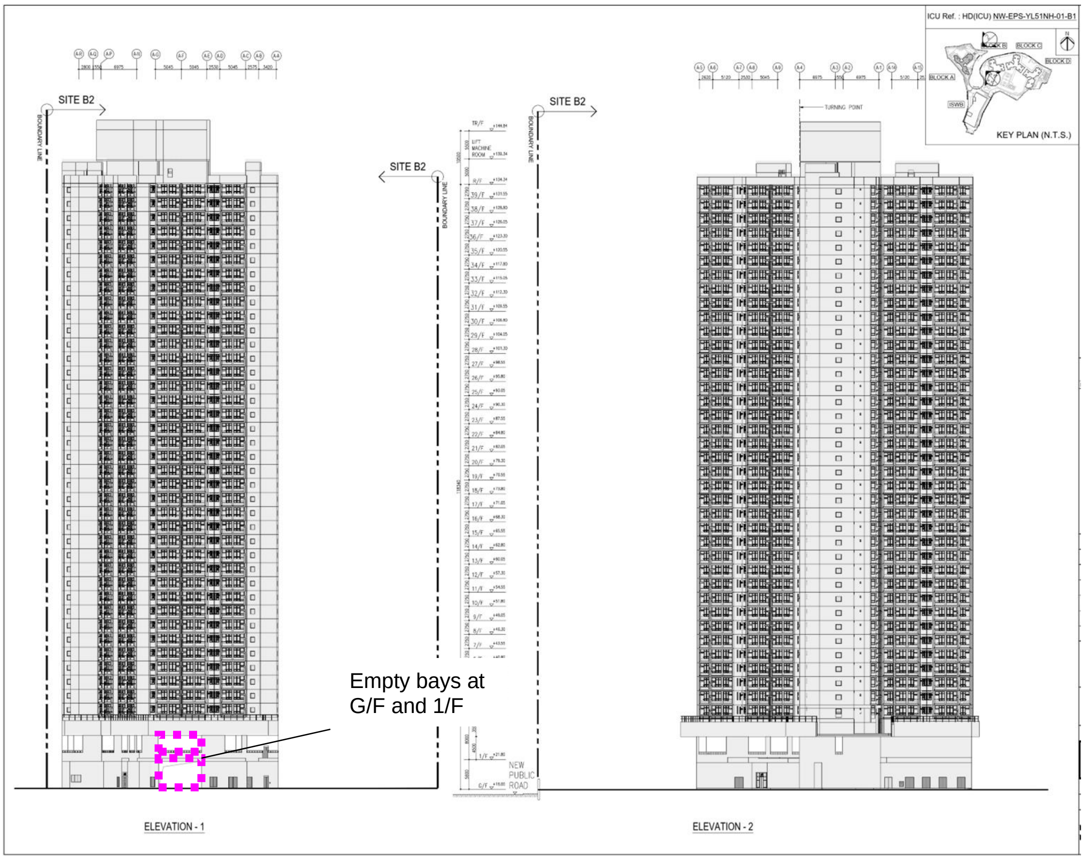


Figure 3.4 Layout Plan of Proposed Scheme at Site B (Master Layout)



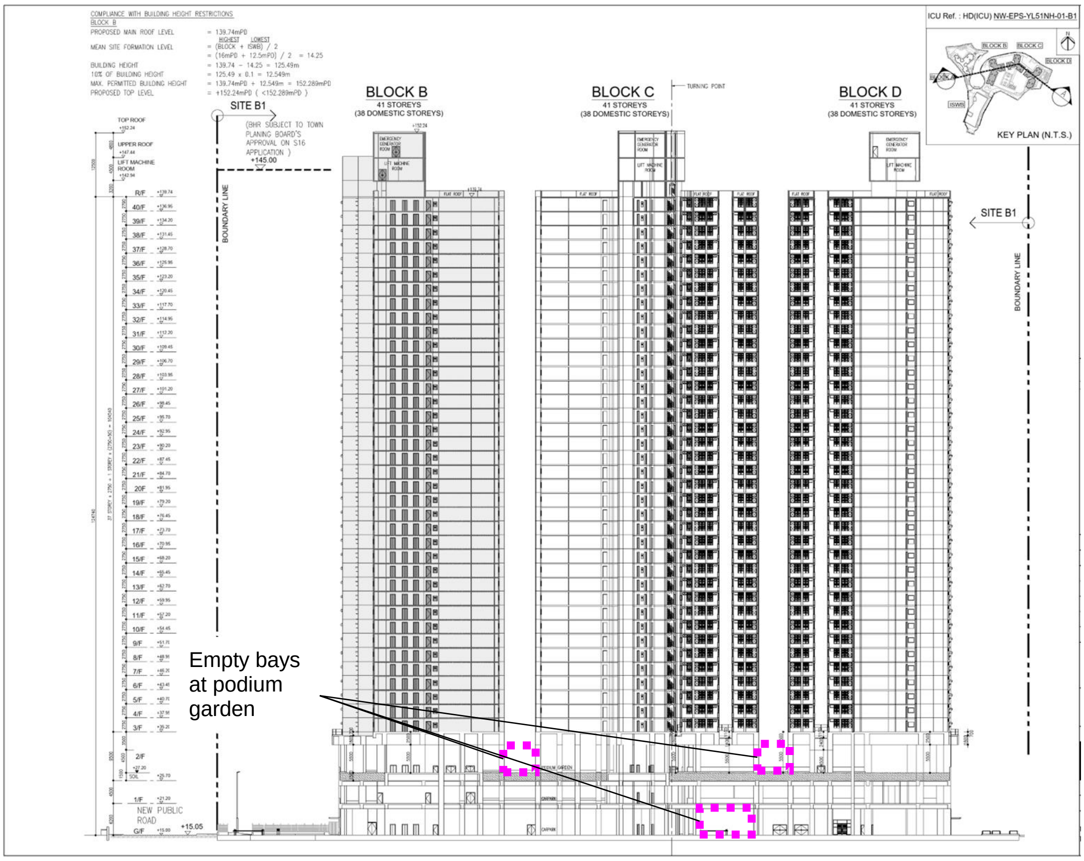


Figure 3.5 Layout Plan of Proposed Scheme at Site B (Section)

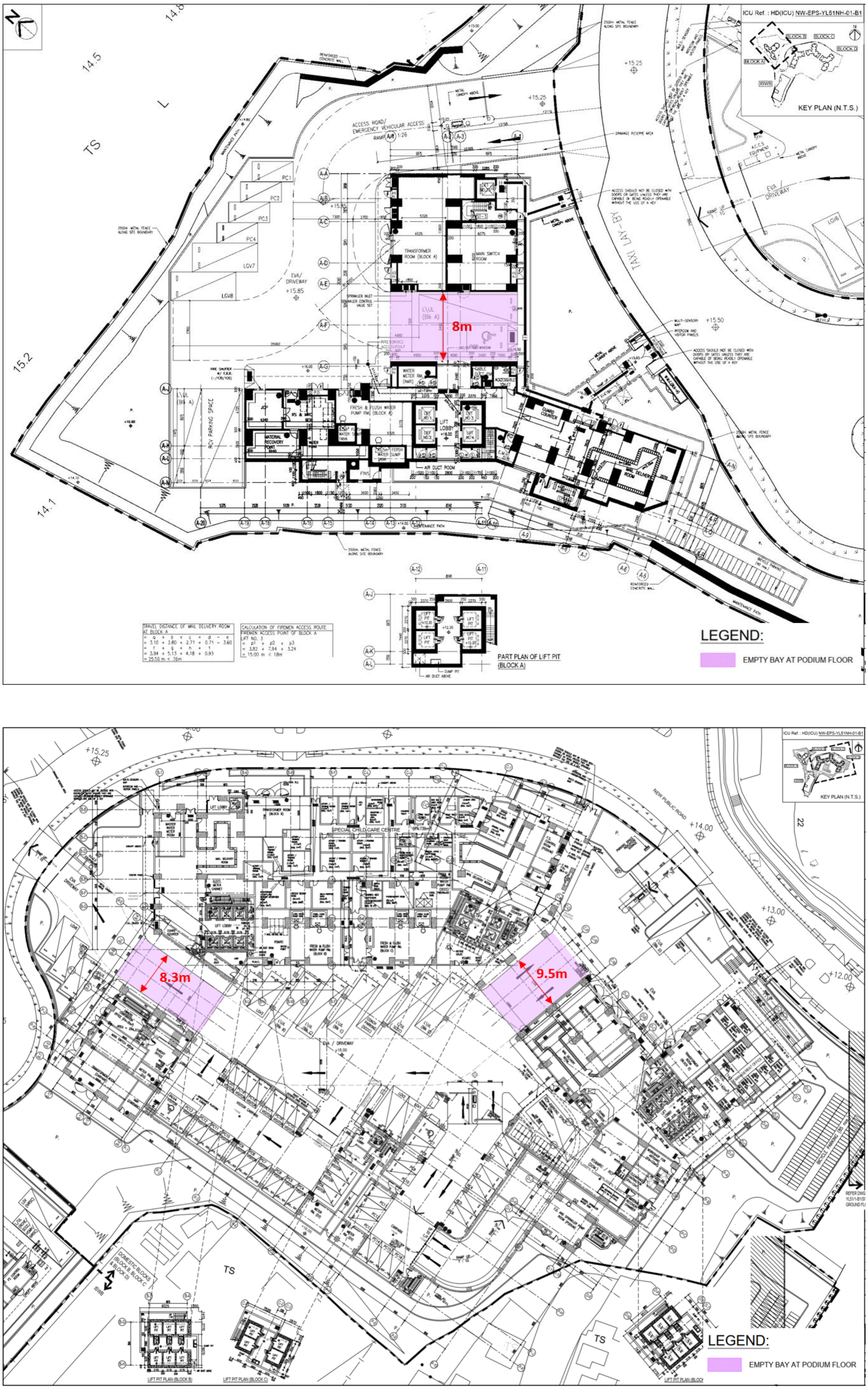


Figure 3.6 Layout Plan of Proposed Scheme at Site B (G/F)

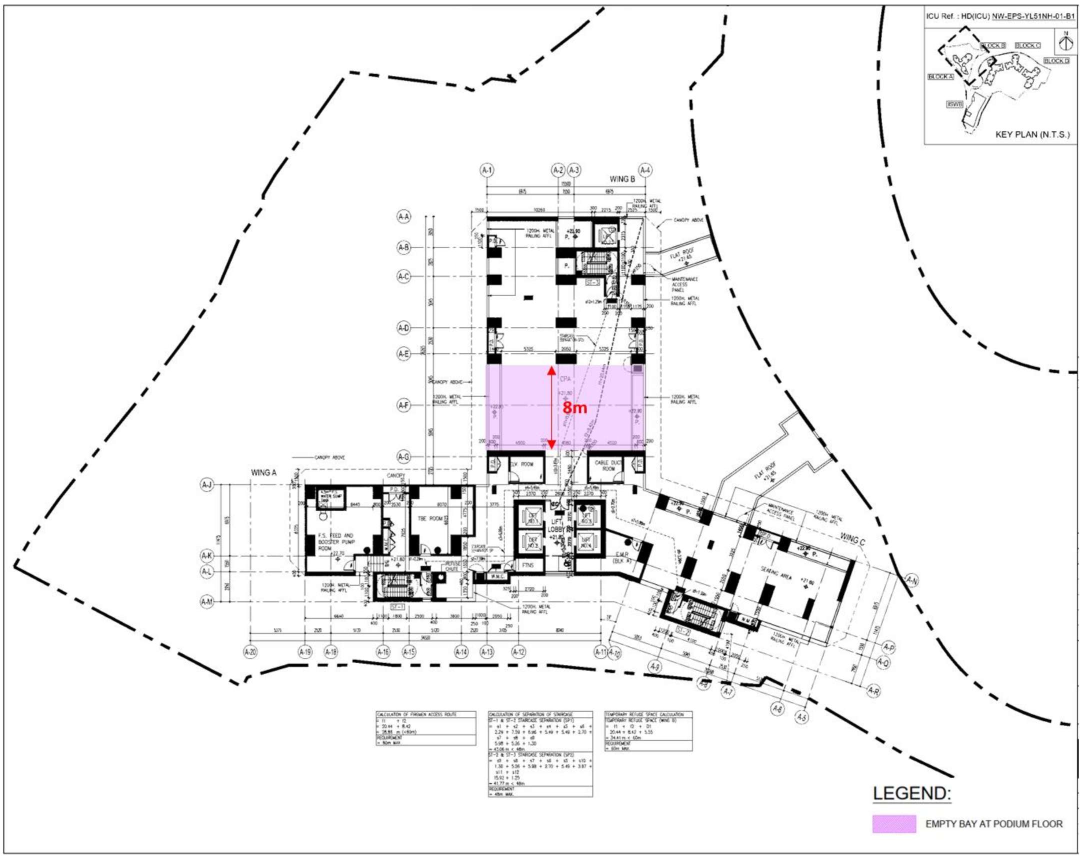
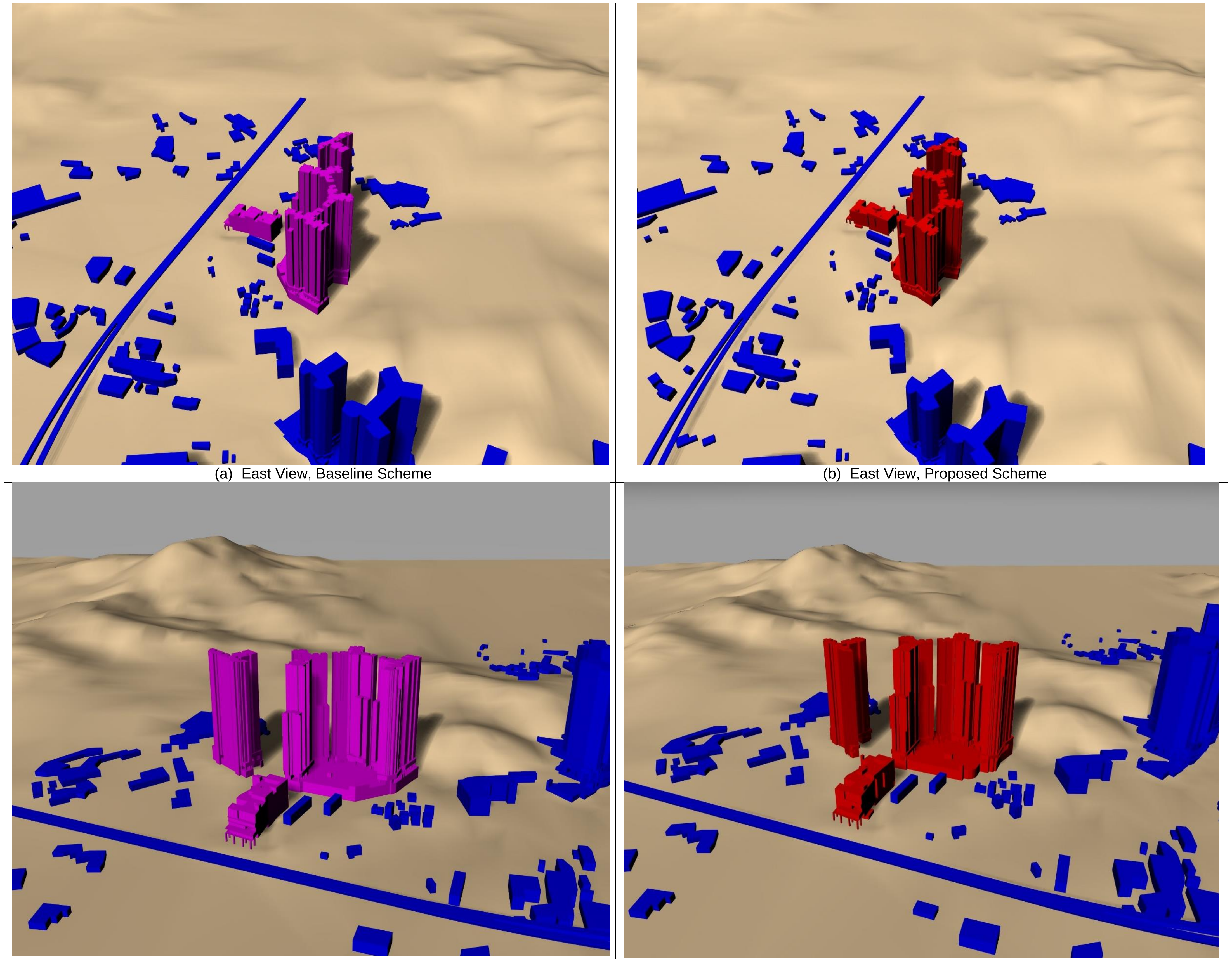


Figure 3.7 Preliminary Layout of Proposed Scheme at Site B (P1/F)

Figure 3.8 Preliminary Layout of Proposed Scheme at Site B (P2/F)



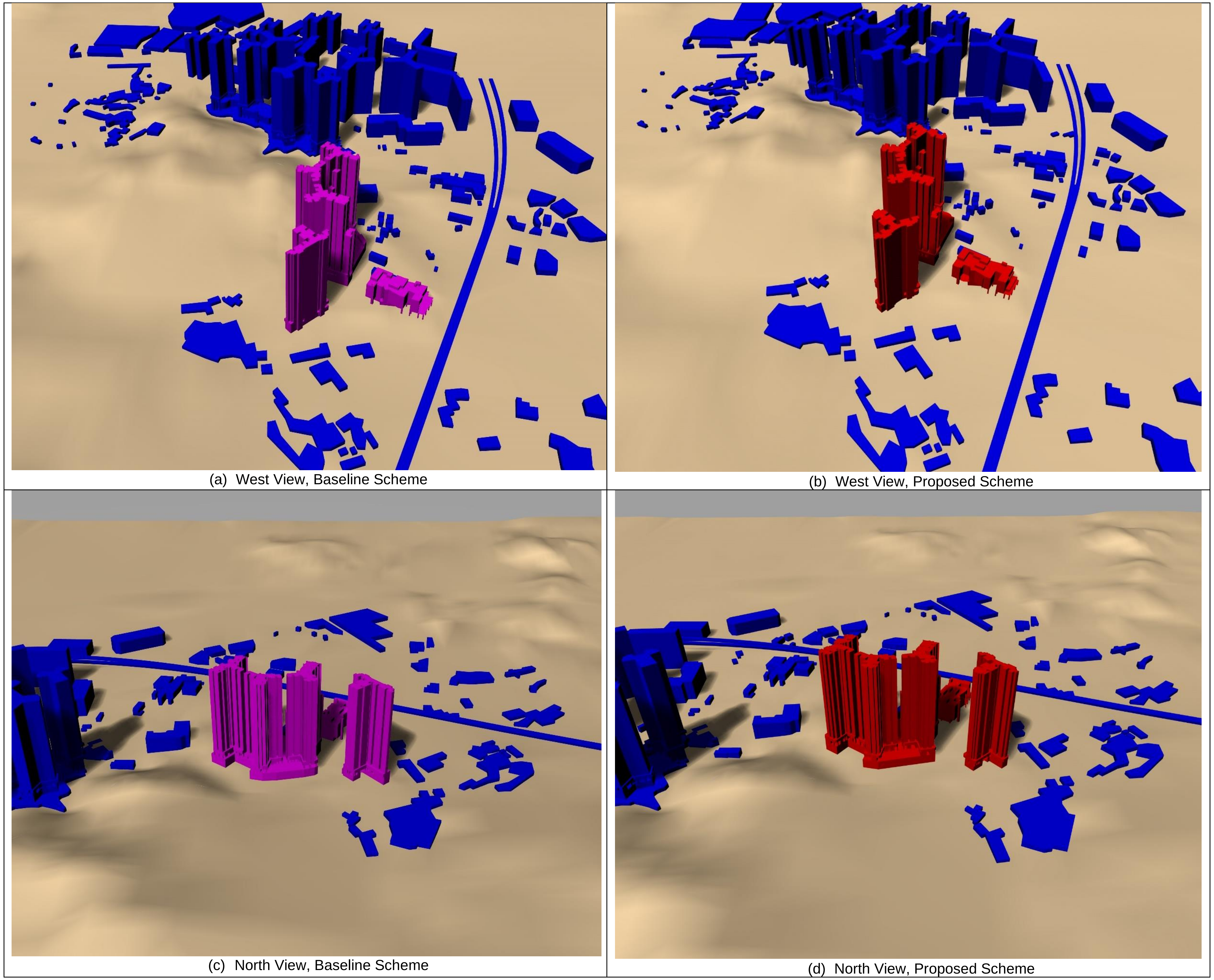
(a) East View, Baseline Scheme

(b) East View, Proposed Scheme

(c) South View, Baseline Scheme

(d) South View, Proposed Scheme

Figure 3.9 Model Geometry under East and South view



(a) West View, Baseline Scheme

(b) West View, Proposed Scheme

(c) North View, Baseline Scheme

(d) North View, Proposed Scheme

Figure 3.10 Model Geometry under West and North views

Wind Environment

3.10 The site wind availability of the Site will be simulated under at least 8 probable prevailing wind directions (which would represent the occurrence of more than 75% of the time) under both annual and summer conditions to illustrate the change in local wind conditions due to the Proposed Development. These prevailing wind directions are determined based on the wind availability simulation result of the Regional Atmospheric Modelling System (RAMS) model published by Planning Department (PlanD from hereafter). **Figure 3.11** shows the location of relevant wind data extraction while the wind roses representing annual and summer winds at the Site of this study are presented in **Figure 3.12** below. Furthermore, the annual prevailing winds at Wang Chau area are from the NNE, NE, ENE, E, ESE, SE, SSE, SE, and SSW directions, whereas the summer prevailing winds are winds from E, ESE, SE, SSE, S, SSW, SW and WSW directions. The summarized chosen prevailing wind directions and their related occurrence probability are listed in **Table 3.1**, arranged in descending order in terms of their occurrence probability. Details of the wind probability table are presented in **Appendix A**.

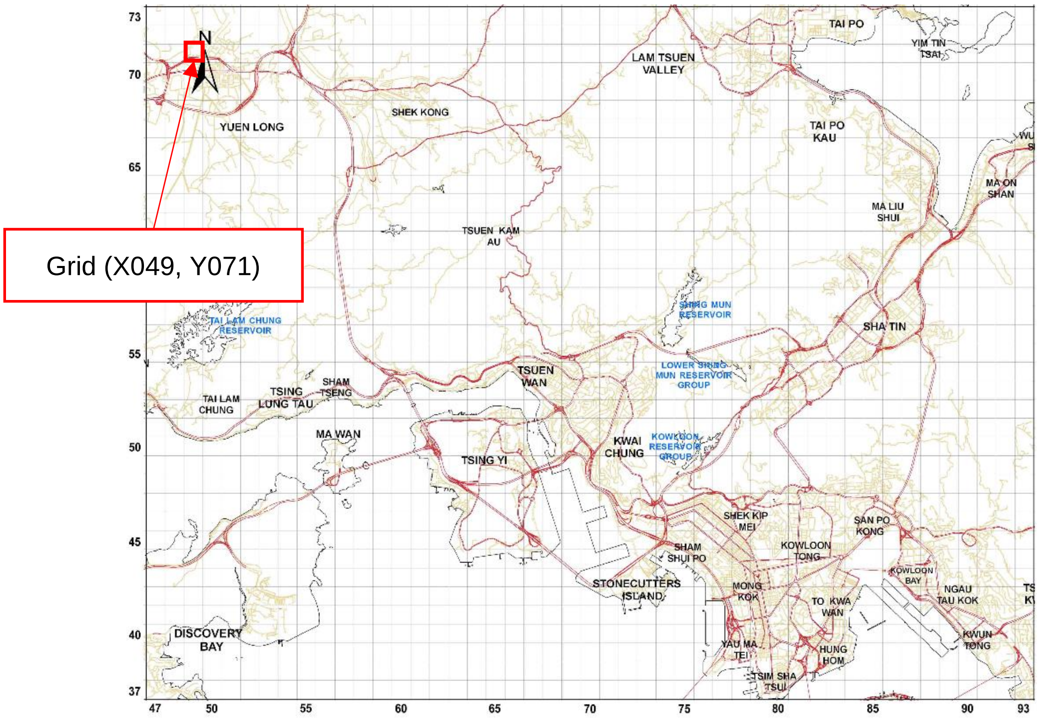
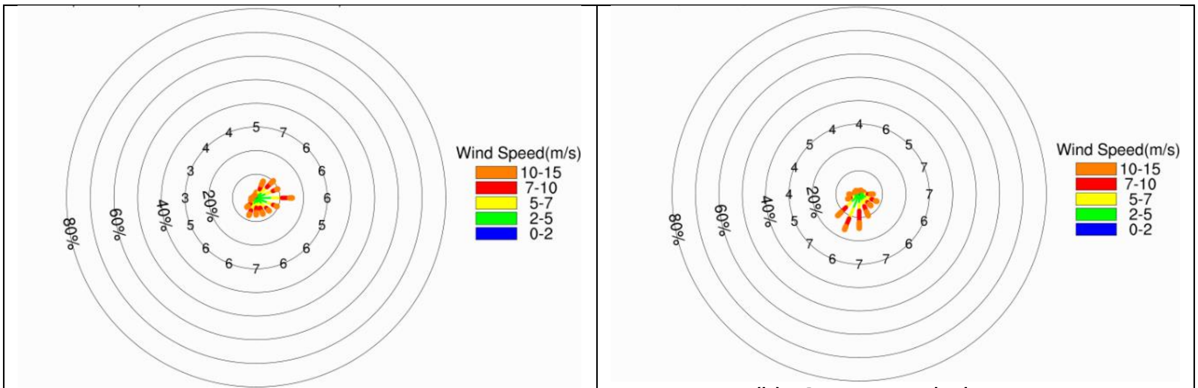


Figure 3.11 Location of data extraction in RAMS model



(a) Annual Wind Rose

(b) Summer Wind Rose

Figure 3.12 Wind Rose at Grid (X049, Y071) (500m height)

Table 3.1 Simulated Wind Directions and their corresponding percentage occurrence, at 500m height

Annual Wind Direction	% of Annual Occurrence	Summer Wind Direction	% of Summer Occurrence
E	15.3%	SSW	16.6%
NE	10.4%	S	15.0%
ENE	9.9%	SW	13.4%
ESE	9.6%	SSE	10.3%
SSW	8.0%	ESE	8.3%
SE	7.9%	SE	7.3%
NNE	7.7%	E	6.2%
SSE	7.5%	WSW	5.4%
Total occurrence	**76.3%**	**Total occurrence**	**82.5%**

Vertical Wind Profiles

3.11 Wind environment under different wind directions will be defined in the CFD environment. According to the Technical Guide (HPLB and ETWB, 2006) per Para 20, the wind profile for the Site could be appropriated from the V∞ data developed from RAMS and with reference to the Power Law or Log Law using coefficients appropriate to the site conditions. In this assessment, vertical wind profile conditions below 20mPD are determined using the Log Law while the wind speed above 20mPD is adopted from the RAMS wind and wind profile on PlanD's website.

3.12 Vertical wind profile and roughness lengths are determined accordingly as follows:

Log Law $$U_z = \frac{u^*}{\sigma}\ln\left(\frac{Z}{Z_0}\right)$$

Where
U_Z : wind speed at height z from ground
u* : friction velocity
σ : von Karman constant = 0.4 for fully rough surface
Z : height z from ground
Z_0 : roughness length.

3.13 The roughness length for determining vertical wind profiles under different wind direction is tabulated in **Table 3.2**. In this study, the land further away from the surrounding area are urban areas with mid to high-rise developments, as a result, a roughness length with Z_0=3 is adopted for the inflow wind profiles.

Table 3.2 Roughness Length for Determining Vertical Wind Profiles under Different Wind Directions

Land Type of Upwind Area(1)	Roughness Length(2), Z_O
Urban area with mid and high-rise developments	3
Sea or open space	0.1

Notes:
(1) The land type refers to the area upwind of the model domain further away from the Surrounding Area
(2) With reference to Feasibility Study for Establishment of Air Ventilation Assessment System (CUHK, 2005)

Mesh Setup

3.14 The total number of cells for this study is about 9,000,000 cells in tetrahedral mesh. Polyhedral mesh cell counts can often be much smaller than comparable tetrahedral meshes with equivalent accuracy as well as improve mesh quality and manner of convergence (Franklyn, 2006). Grids may be converted to polyhedral mesh, if necessary. The horizontal grid size employed in the CFD model in the vicinity of the Site will be taken as a global minimum size of about 2m (a smaller grid size was also employed for specific fine details) and increased for the grid cells further away from the Site. The maximum mesh size within the whole computational domain will be about 200m. Besides, six layers of prism cells (each layer of 0.5m thick) were employed above the terrain. The blockage ratio and grid expansion ratio of this computational model are 1.2 and 3% respectively.

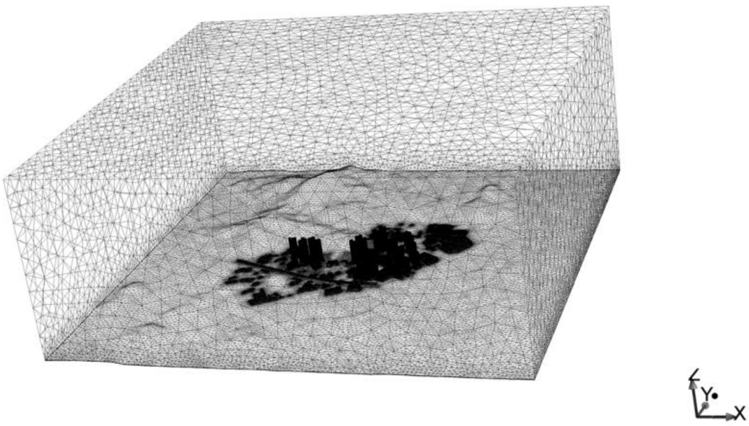


Figure 3.13 Mesh of the simulation domain

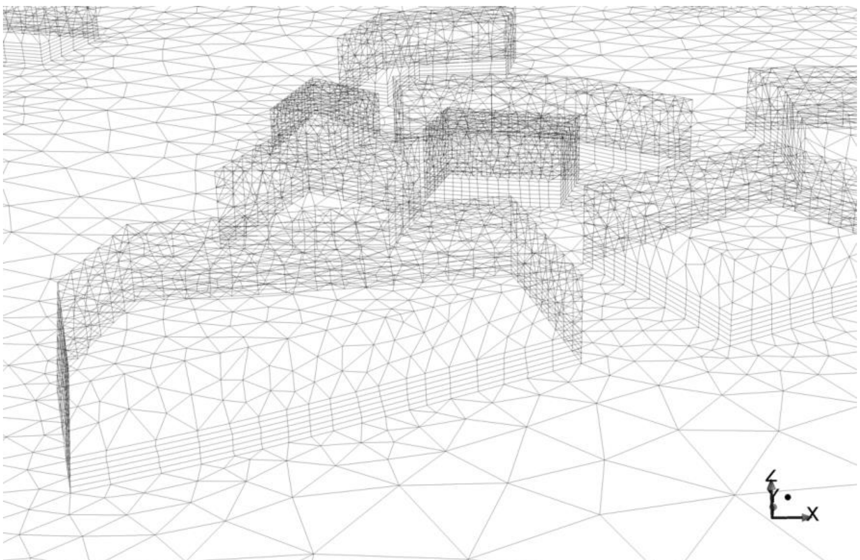


Figure 3.14 Prism layers near ground

Turbulence Model

3.15 As recommended in COST action C14, a realizable K-epsilon turbulence model was adopted in the CFD model to simulate the real life problem. Common computational fluid dynamics equations were adopted in the analysis.

3.16 Variables including fluid velocities and fluid static pressure were calculated throughout the domain. The CFD code captures, simulates and determines the air flow inside the domain under study based on the viscous fluid turbulence model. Solutions were obtained by iterations.

Calculation Method and Boundary Condition

3.17 The advection terms of the momentum and viscous terms are resolved with the second order numerical schemes. The scaled residuals are converged to an order of magnitude of at least 1 x 10^{-4} as recommended in COST action C14.

3.18 The inflow face of the computational domain is set as the velocity inlet condition and the outflow face is set as the zero gradient condition. For the two lateral and top faces, a symmetric boundary condition is used. Lastly for the ground and building walls, no slip condition is employed.

4 ASSESSMENT CRITERIA AND TEST POINTS LOCATION

Wind Velocity Ratio (VR)

4.1 Wind velocity ratio (VR) indicates how much of the wind availability is experienced by pedestrians on the ground which is a relatively simple indicator to reflect the wind environment of the study site. VR is defined as VR = Vp /V_{INF} where V_{INF} is the wind velocity at the top of the wind boundary layer (greater than 500m in height) that would not be affected by the ground roughness and local site features and Vp is the wind velocity at the 2m pedestrian level.

4.2 VRw is the frequency weighted wind velocity ratio calculated based on the frequency of occurrence of 8 selected wind directions for annual and summer respectively for the purpose of comparison.

4.3 For Site Air Ventilation Assessment, the Site Spatial Average Wind Velocity Ratio (SVRw) and individual VR_W of all perimeter test points are reported. SVRw is the average of VRw of all perimeter test points.

4.4 For Local Air Ventilation Assessment, the Local Spatial Average Wind Velocity Ratio (LVRw) of all overall test points and perimeter test points, and individual VRw of the overall test points are reported. LVRw is the average of all overall test points and perimeter test points.

4.5 The SVRw and LVRw are worked out so as to understand the overall impact of air ventilation on the immediate and further surroundings of the Site due to the Proposed Development.

Test Points

4.6 Both perimeter test points and overall test points will be selected within the Assessment Area in order to assess the impact on the immediate surroundings and local areas respectively. Overall test points will be evenly distributed over surrounding open spaces, streets and other parts of the Assessment Area which pedestrians can or will mostly access. There will be 33 Perimeter Test Points, 72 Overall Test Points and 10 Special Test Points. Preliminary locations of perimeter, overall and special test points are illustrated in **Figure 4.1**.

4.7 The Test Points are further divided into 9 groups in order to analyse the respective localized wind environment performances. The coverage of the Test Points Groups is shown in **Figure 4.1** while the description of the major covering regions of each group is summarized in **Table 4.1.**

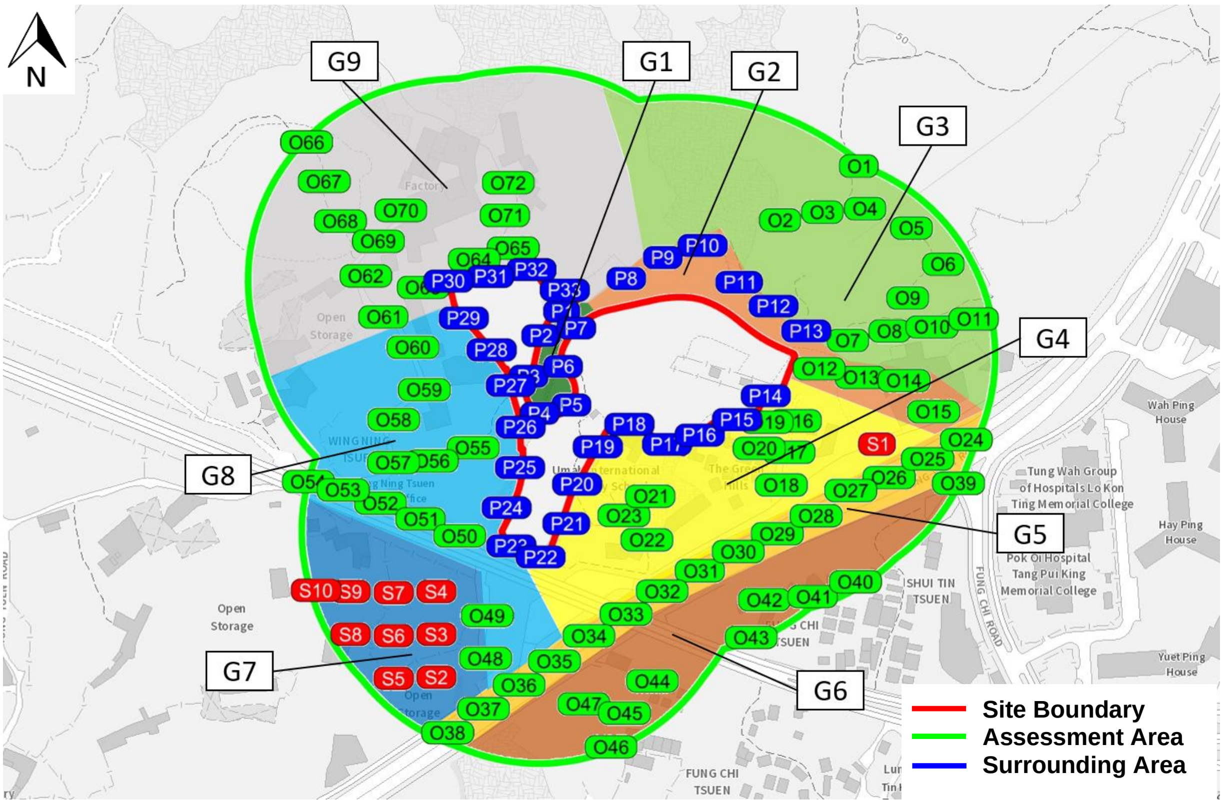


Figure 4.1 Distribution of Test Points

Table 4.1 Test Point Groups and respective represented locations

Test Point Groups	Test Point Numbers	Major location covered
G1	P1 – P7	New Public Road (western section)
G2	P8 – P13, O12 – O15	New Public Road (eastern section)
G3	O1 – O11	Wang Chau Natural Landscapes, Burial Grounds and Graves
G4	P14 – P22, O16 – O23, S1	The Green Hills and Umah International Primary School
G5	O24 – O39	Long Ping Road
G6	O40 – O47	Fung Chi Tsuen and Shui Tin Tsuen
G7	S2 - S10	Open Storage in the SW
G8	P23 – P29, O48 – O60	Wing Ning Tsuen (southern portion)
G9	P30 – P33, O61 – O72	Wing Ning Tsuen (northern portion)

5 KEY FINDINGS OF AVA STUDY

Good design features

5.1 The Proposed Development consists of 4 residential blocks on 1 to 2-storey non-domestic podiums and 1-storey podium garden in the studied schemes for Home Ownership Scheme (HOS) in Site B as well as a social welfare block. There is a 20m-wide building gap aligning in about SW-NE direction between Block A and Block B, while Block B to Block D are relatively compact. Another 22m-wide building gap aligns the WNW-ESE direction between Block B and the social welfare block.

5.2 The Baseline Scheme has reserved a building setback of about 17m to the west of Block A and a building setback of about 10m to the eastern site boundary next to the school site. Empty bays are designed at podium levels of the residential blocks. In the Proposed Scheme, the building setback to the west of Block A is increased to 20m-wide and the building setback to the eastern site boundary is increased to 15m-wide for better air circulation. About 3m to 9.5m-wide empty bays at G/F and P2/F in Site B of the Proposed Scheme are reserved to promote air movement at the pedestrian level. Additionally, the building morphology of Block A in the Proposed Scheme is modified to minimize the building frontage, which could mitigate the air ventilation impact.

5.3 To sum up, good design features inherited from the Baseline Scheme (for Site B) include:

- Building gaps to break the bulkiness of the potential development
- Building setback of about 17m to the west of Block A
- Building setback of about 10m from the eastern site boundary
- About 22m-wide building separation between Block B and the social welfare block
- 20m-wide building separation between Block A and Block B
- Empty bays designed at podium levels of the residential blocks

5.4 Additional good design features for improving the air ventilation performance of the Proposed Scheme (for Site B) include:

- Widening of building setback to the west of Block A from about 17m to about 20m
- Widening of building setback to the eastern site boundary from about 10m to about 15m
- Modifying the building morphology of Block A to minimize the building frontage

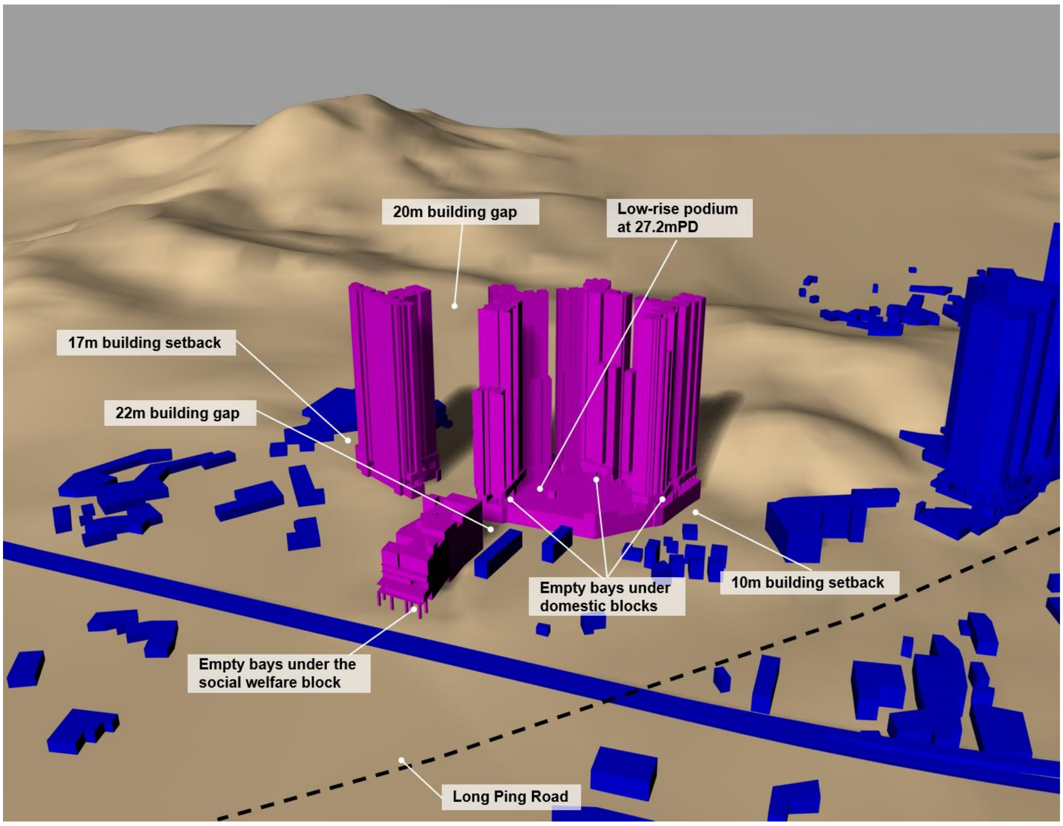


Figure 5.1 Good Design Features in Baseline Scheme

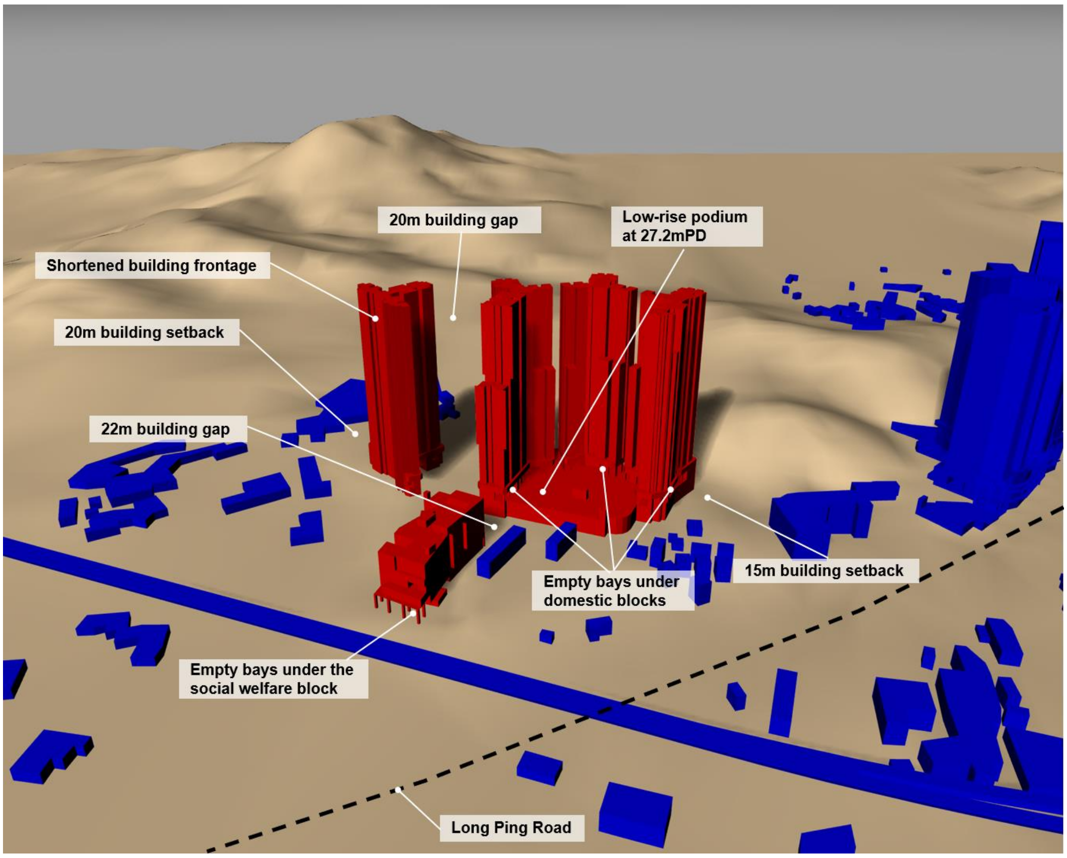


Figure 5.2 Good Design Features in Proposed Scheme

Wind Velocity Ratio Results

5.5 A summary of the predicted wind velocity ratios for the Perimeter Test Points and the Overall Test Points i.e. SVR_W and LVR_W under both annual and summer prevailing winds are presented in **Table 5.1** below. Details of the predicted wind velocity ratios are presented in **Appendix B**.

Table 5.1 Summary of Wind Velocity Ratio

	Annual Winds		Summer Winds	
	Baseline Scheme	Proposed Scheme	Baseline Scheme	Proposed Scheme
SVR_W	0.18	0.19	0.26	0.26
LVR_W	0.18	0.19	0.25	0.25

5.6 The results of VRw for different groups of test points are summarized in **Table 5.2** below.

Table 5.2 Summary of Wind Velocity Ratio for Different Test Point Groups

Group	Description	Test Points	Average VR_w (Annual Winds)		Average VR_w (Summer Winds)	
			Baseline Scheme	Proposed Scheme	Baseline Scheme	Proposed Scheme
G1	New Public Road (western section)	P1 – P7	0.23	0.25	0.34	0.36
G2	New Public Road (eastern section)	P8 – P13, O12 – O15	0.24	0.22	0.26	0.27
G3	Wang Chau Natural Landscapes, Burial Grounds and Graves	O1 – O11	0.24	0.25	0.35	0.34
G4	The Green Hills and Umah International Primary School	P14 – P22, O16 – O23, S1	0.15	0.16	0.19	0.19
G5	Long Ping Road	O24 – O39	0.17	0.18	0.22	0.23
G6	Fung Chi Tsuen and Shui Tin Tsuen	O40 – O47	0.13	0.13	0.16	0.18
G7	Open Storage in the SW	S2 - S10	0.18	0.18	0.21	0.22
G8	Wing Ning Tsuen (southern portion)	P23 – P29, O48 – O60	0.15	0.15	0.22	0.23
G9	Wing Ning Tsuen (northern portion)	P30 – P33, O61 – O72	0.19	0.20	0.27	0.28

5.7 Contour plots of wind velocity ratio at 2m above the pedestrian level of assessment area under prevailing wind directions are shown in directional analysis in Section 6.

Site Air Ventilation Assessment

5.8 The layouts of the Proposed Scheme consist of 4 slightly lower residential blocks and podiums for carpark, retail and auxiliary facilities, while the Baseline Scheme comprises 4 slightly taller residential blocks with podiums. Both the Proposed Scheme and Baseline Scheme have incorporated permeable spaces at the podium level. In the Proposed Scheme, with the widened building setback to the eastern and western site boundary as well as the shortened building frontage of Block A, the air ventilation impact at its site perimeter by the Proposed Scheme could be minimized when compared to the Baseline Scheme.

5.9 The SVRw indicates how the lower portion of the buildings within the Site affects the wind environment of its immediate vicinity. Under annual winds, the average of predicted SVRw over these prevailing winds Proposed Scheme is increased from 0.18 in the Baseline Scheme to 0.19, indicating the Proposed Scheme has slightly better air ventilation due to the widened building setback and shortened building frontage of Block A. In summer, the SVRw is 0.26 for both the Baseline Scheme and the Proposed Scheme. The result indicates that the air ventilation performance for both schemes is similar.

Local Air Ventilation Assessment

5.10 The LVRw indicates the overall wind environment within the Assessment Area of the two schemes under the annual and summer winds. The LVRw for the Proposed Scheme is increased from 0.18 to 0.19 compared to the Baseline Scheme under the annual prevailing winds. While during the summer seasons, the LVRw is 0.25 for both schemes. The results indicate that the Proposed Scheme would have a slight improvement on the pedestrian wind environment compared to the Baseline Scheme at the Site boundary and throughout the Assessment Area.

5.11 The averaged wind velocity ratio of Group 1 test points reflects the wind environment along the western section of the New Public Road. The Proposed Scheme has a positive impact on the wind environment within the Group 1 area compared to that of the Baseline Scheme under annual and summer winds, since averaged VRw in Group 1 Test Points increased from 0.23 to 0.25 annually, while from 0.34 to 0.36 in summer for the Baseline Scheme and the Proposed Scheme respectively. It is observed that the shortened frontage of Block A in the Proposed Scheme could effectively mitigate the wind influence along this Assessment Area.

5.12 Group 2 Test Points cover the eastern section of the New Public Road within the Assessment Area. It is observed that the Proposed Scheme would have worse air ventilation than the Baseline with VRw decreasing from 0.24 to 0.22 but increased from 0.26 to 0.27 during annual and summer conditions respectively.

5.13 Group 3 Test Points located at Wang Chau Natural Landscapes, Burial Grounds and Graves to the northeast of the Site, and the VRw obtained indicated the pedestrian wind environment there. The annual VRw are 0.24 and 0.25 for the Baseline Scheme and Proposed Scheme respectively. Whereas summer VRw is slightly decreased from 0.35 to 0.34 for the Proposed Scheme compared to the Baseline Scheme. Nonetheless, the velocity ratio in this area is still relatively high.

5.14 The VRw values of Group 4 Test Points indicate the air ventilation performance of The Green Hills and Umah International Primary School to the southeast of the Site. The results indicate a slightly better wind environment annually for the Proposed Scheme compared to the Baseline Scheme. Under the annual wind, the VRw is slightly increased from 0.15 to 0.16. For summer, the VRw value is 0.19 for both the Baseline Scheme and the Proposed Scheme.

5.15 Group 5 Test Points are equally spaced along Long Ping Road to the south of the Site. The results show a slightly improved wind environment between the Baseline and the Proposed Scheme. Under annual conditions, the VRw is slightly increased from 0.17 to 0.18 for the Proposed Scheme compared to the Baseline Scheme. For summer conditions, the VRw is also slightly increased from 0.22 to 0.23. This implies that the incoming wind could flow freely along this major pathway.

5.16 The ventilation performance of Fung Chi Tsuen and Shui Tin Tsuen to the south of the Site is assessed by Group 6 Test Points. There is a slight ventilation enhancement in this monitoring region in summer. The VRw is 0.13 for both schemes under annual conditions and increases from 0.16 to 0.18 for the summer seasons for the Proposed Scheme compared to the Baseline Scheme.

5.17 Special Test Points in Group 7 are located within open storage in the SW. The result of annual VRw is 0.18 for both schemes, while summer VRw slightly increased from 0.21 to 0.22 for the Proposed Scheme compared to the Baseline Scheme, which indicates a slight improvement of air ventilation during summer but similar ventilation performance annually for the Proposed Scheme.

5.18 Group 8 Test Points are evenly distributed at the footpath of Wing Ning Tsuen (southern portion) to the west of the Site, where the VRw is 0.15 for both the Baseline Scheme and the Proposed Scheme under annual winds, while VRw is slightly increased from 0.22 to 0.23 during summer wind condition, indicating a similar ventilation performance annually and slightly improved ventilation performance during the summer season.

5.19 Group 9 Test Points monitor footpaths of Wing Ning Tsuen (northern portion) in the northwest of the Site. Under annual wind, the VRw of this area is increased from 0.19 to 0.20 for the Proposed Scheme compared to the Baseline Scheme. Under summer wind, the air ventilation performance is also improved, and the VRw is increased from 0.27 to 0.28. This illustrates that the shortened frontage in Block A and the widened building setback could benefit the wind environment in this Assessment Area.

6 DIRECTIONAL ANALYSIS

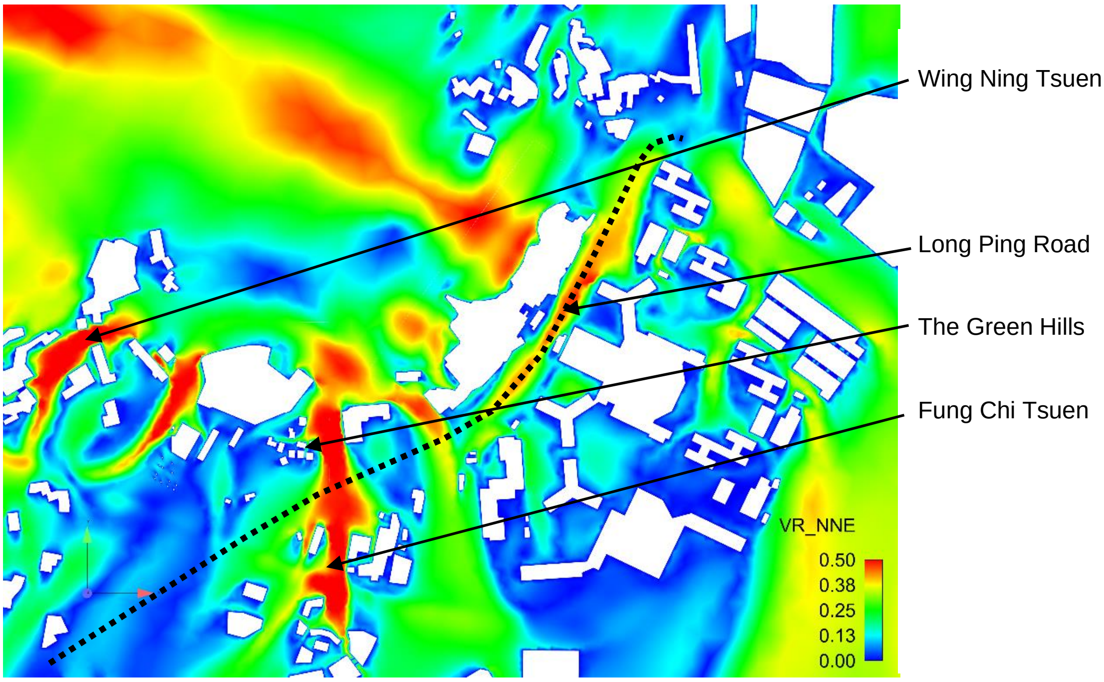
NNE: (Annual: 7.7%)

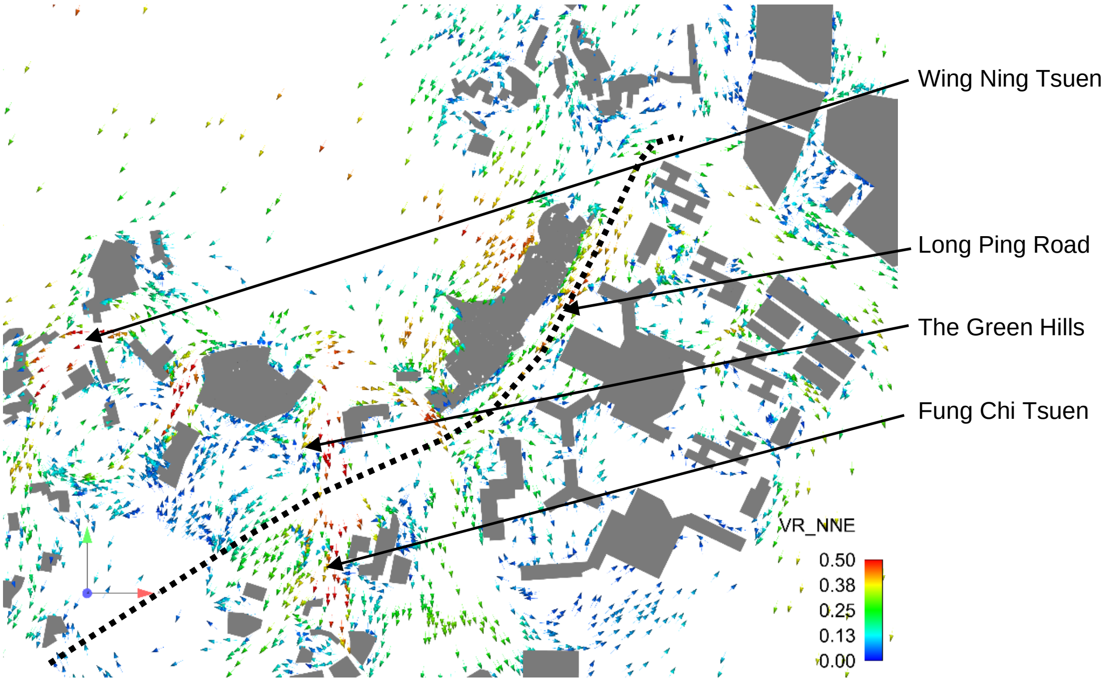
6.1 Under NNE wind, major air paths mainly follow Long Ping Road and flow over the hilly region of Kai Shan. A portion of the wind would diffuse through the building gaps and flow over the buffer zone of natural landscapes to reach the Site. Site wind availability of the Site mainly relies on a free flow of winds over the natural landscapes of Kai Shan in the north and northeast.

6.2 In the Baseline Scheme, the unobstructed wind from natural landscapes enters Site B freely and flushes each building gap. It is observed that the proposed developments (137-141mPD) would generate localized air ventilation impact at the leeward side of residential blocks. The proposed residential Block A and Block B, C & D with the podium are found to slightly obstruct the incoming wind from reaching the downwind region in the south-southeast of the Site, affecting some wind sensitive areas such as the southern portion of Wing Ning Tsuen, Umah International Primary School, and the Green Hills. However, as Block B, C & D are closely packed, a large building separation between Block A and B (20m in width) is provided, reducing the influencing zone at the downwind region to the southwest of the Site. It is observed that the incoming wind could travel freely along the building gap between Block A and B, providing satisfactory air ventilation performance in the social welfare block and the open storage in SW. In addition, it is also observed that the incoming wind would pass through the 10m-wide building setback from the eastern site boundary, which reduces the wind influence on the immediate downstream, it is found that the incoming wind could reach Fung Chi Tsuen through the building setback. Moreover, empty bays under Block B to D at the podium garden level allow near ground wind to skim over and penetrate through the podium to reach the pedestrian level at the leeward side to alleviate the wind influence.

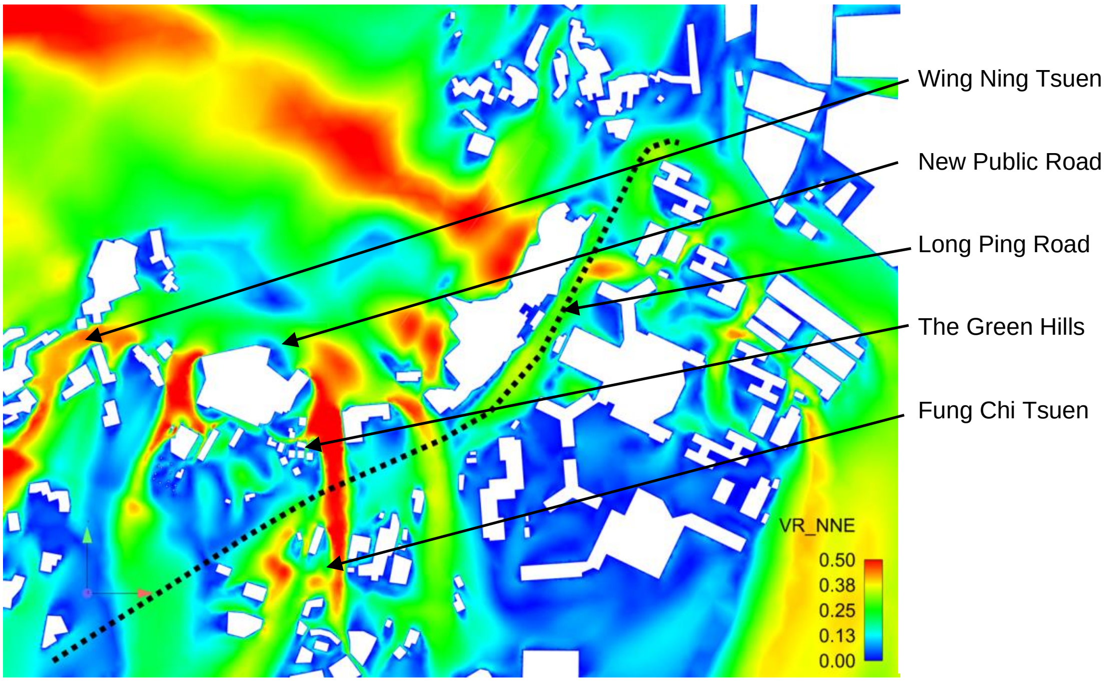
6.3 In the Proposed Scheme, a similar wind flow pattern could be observed. However, the proposed residential developments (135-140mPD) are expected to cause less air ventilation impact to the immediate downstream of Block A compared to the Baseline Scheme. Due to the modified building morphology of Block A, the building frontage is slightly reduced, such that the obstruction against the incoming wind is reduced. It is found that the wind velocity in the immediate downstream of Block A is slightly increased, benefiting the air ventilation performance of the southern portion of Wing Ning Tsuen.

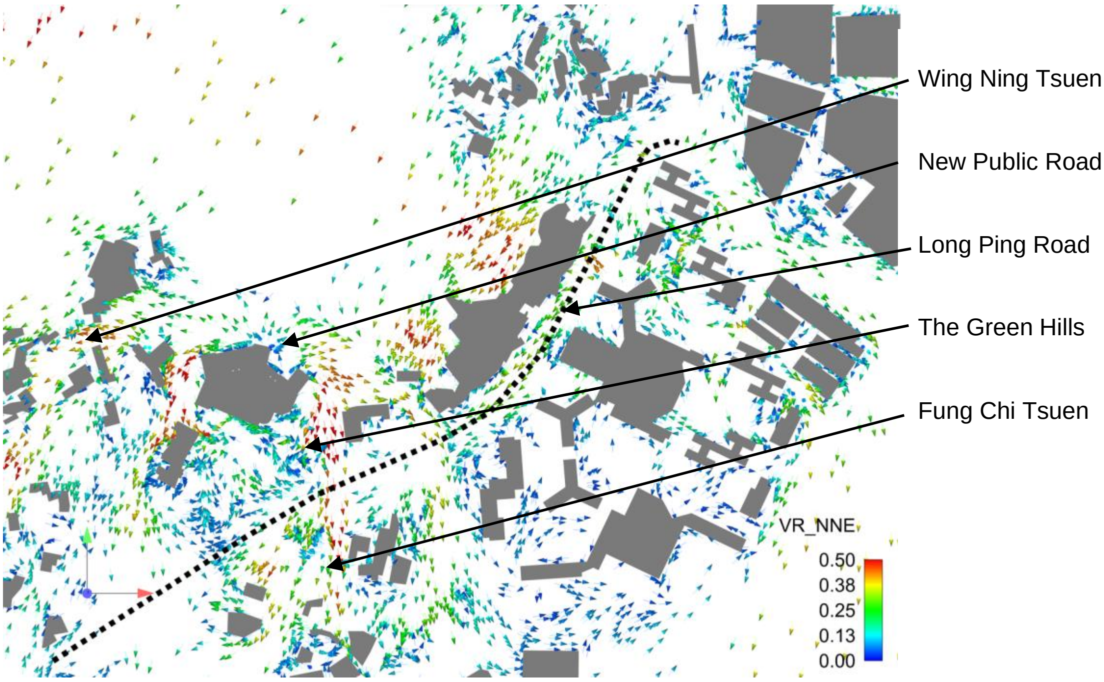
Baseline Scheme





Proposed Scheme





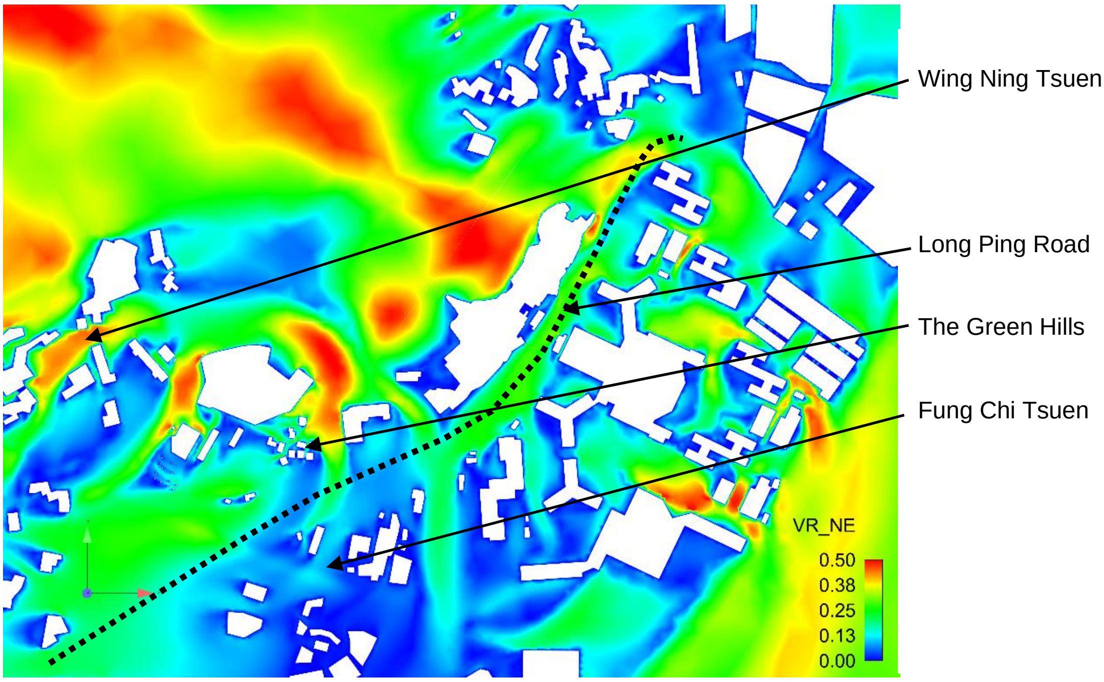
NE: (Annual: 10.4%)

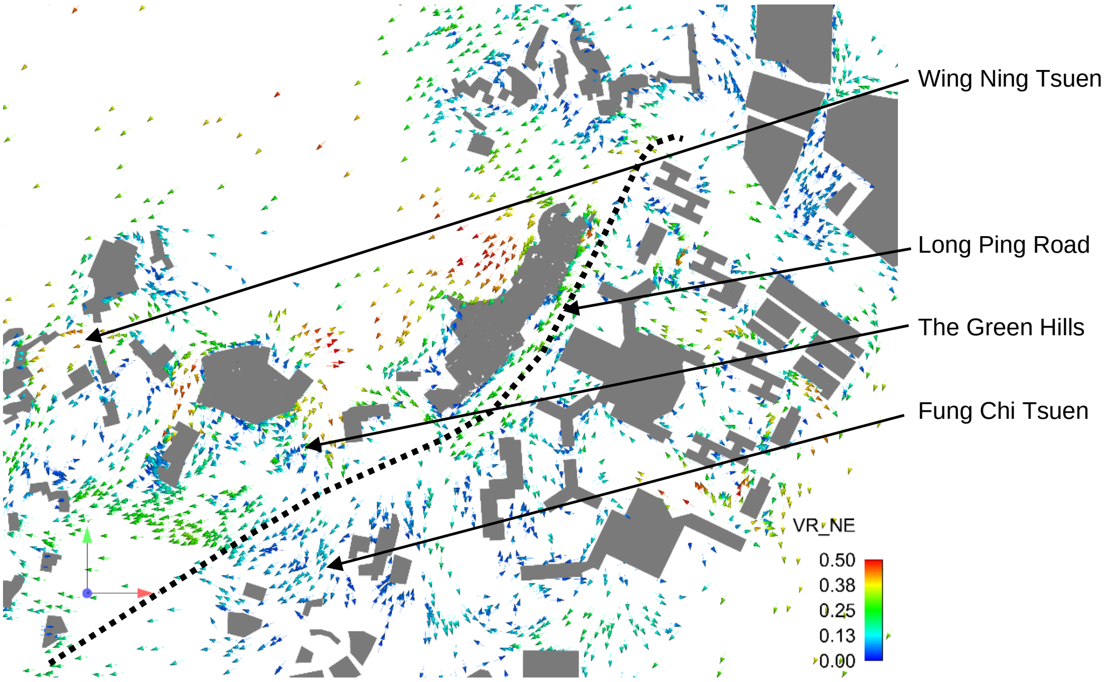
6.4 Similar to NNE wind, under NE wind, major air paths mainly follow Long Ping Road and flow over the hilly region of Kai Shan. A portion of the wind would diffuse through the building gaps and flow over the buffer zone of natural landscapes to reach the Site. Site wind availability of the Site mainly relies on the free flow of winds over the natural landscapes of Kai Shan in the north and northeast.

6.5 In the Baseline Scheme, the unobstructed wind from natural landscapes enters Site B freely and flushes each building gap. It is observed that the proposed developments (137-141mPD) would generate localized air ventilation impact at the leeward side of residential blocks. The proposed residential Block A and Block B, C & D with the podium are found to slightly obstruct the incoming wind to reach the sensitive areas such as the southern portion of Wing Ning Tsuen, Umah International Primary School, and the Green Hills. However, as Block B, C & D are closely packed, a large building separation between Block A and B (20m in width) is provided, reducing the influencing zone at the downwind region to the southwest of the Site. It is observed that the incoming wind could travel freely along the building gap between Block A and B, providing satisfactory air ventilation performance in the social welfare block and the open storage in SW. In addition, it is also observed that the incoming wind would pass through the 10m-wide building setback from the eastern site boundary, which reduces the wind influence on the immediate downstream, it is found that the incoming wind could reach Fung Chi Tsuen through the building setback. Moreover, empty bays under Block B to D at the podium garden level allow near ground wind to skim over and penetrate through the podium to reach the pedestrian level at the leeward side to alleviate the wind influence. It is also found that the empty bays in the social welfare block may also facilitate wind penetration, an increased VR is observed in the downstream of the social welfare block.

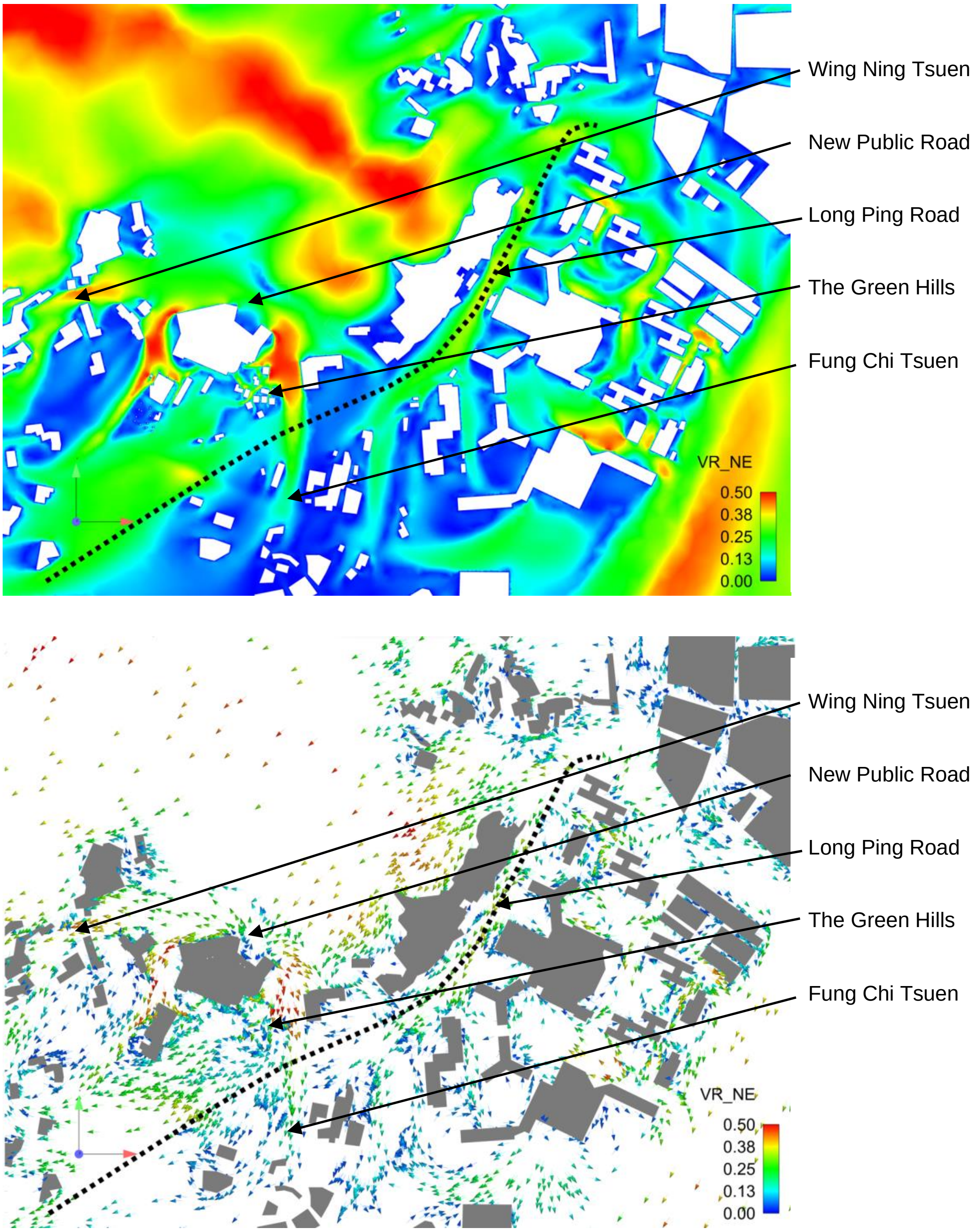
6.6 In the Proposed Scheme, a similar wind flow pattern could be observed. However, the proposed residential developments (135-140mPD) are expected to cause less air ventilation impact to the immediate downstream than the Baseline Scheme. With the reduced building frontage of Block A, the obstruction against the incoming wind is slightly reduced. On the other hand, it is observed that the widened building setbacks to the west of Block A as well as the eastern site boundary could increase the velocity ratio to the immediate downstream. The incoming wind is able to penetrate the Site more effectively, such that the air ventilation performance of the open storage in SW, Umah International Primary School, and the Green Hills is slightly improved.

Baseline Scheme





Proposed Scheme



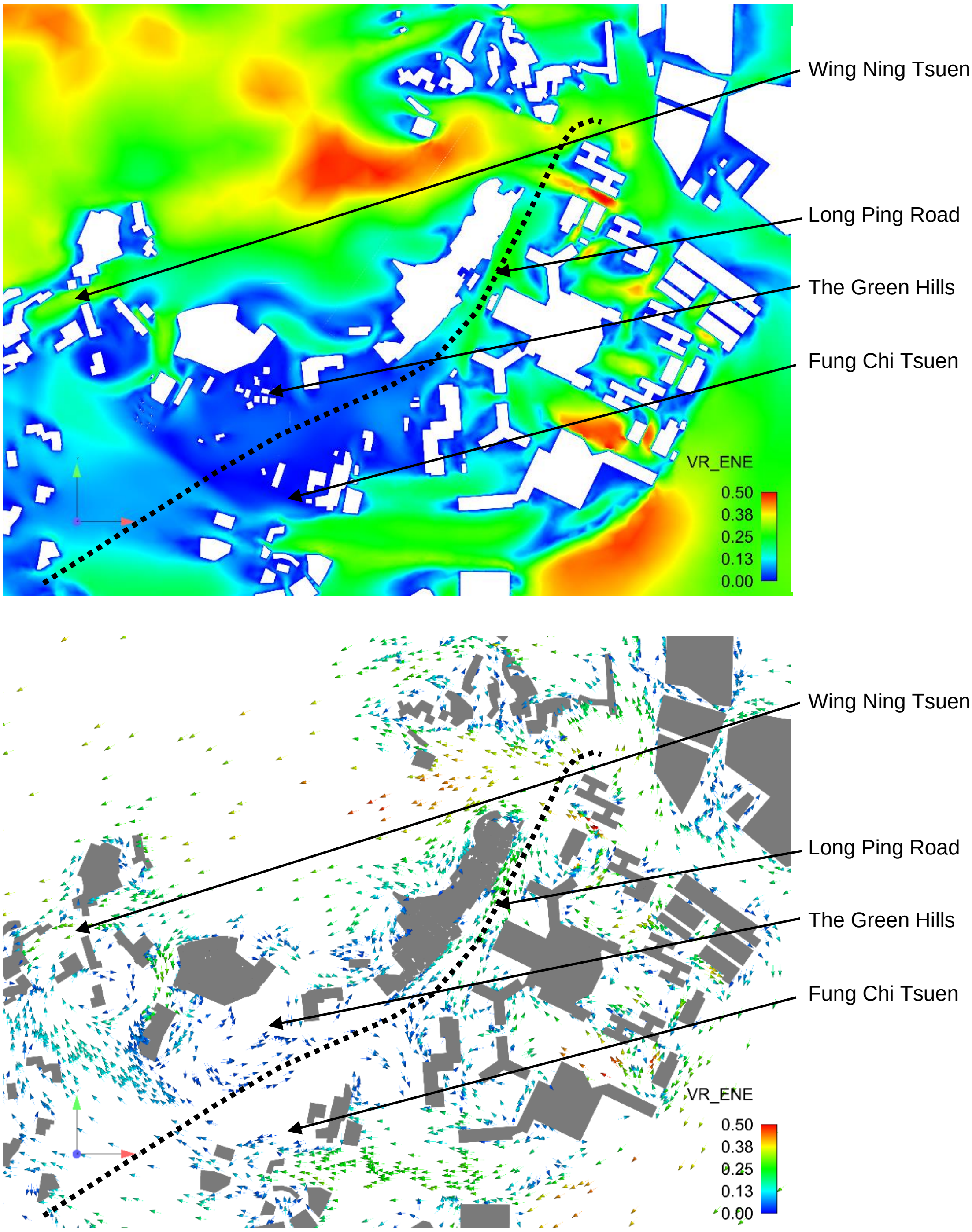
ENE: (Annual: 9.9%)

6.7 ENE winds skim over the low-rise village houses above the pedestrian level, located to the east of Fuk Hi Street, freely to reach the natural landscapes in the northeast of the Site, through the junction of Long Ping Road and Fuk Hi Street. Another stream of wind skims over the low-rise villages in Yuen Long Kau Hui and then passes through the Yuen Long Town along Yuen Long On Lok Road/Long Yip Street and Wang Tat Road/Ma Wang Road. Due to a lack of effective air path aligning with the prevailing winds, Long Ping Estate and proposed development in Site A at the upstream would obstruct the ENE winds from penetrating into the Site. The incoming wind could flow along the northern perimeter of the Site, while the site wind availability of the Site is generally weak, mainly relies on redirected wind from natural landscapes, diffused wind from Site A, the low-rise zones and building gaps at Long Ping Estate.

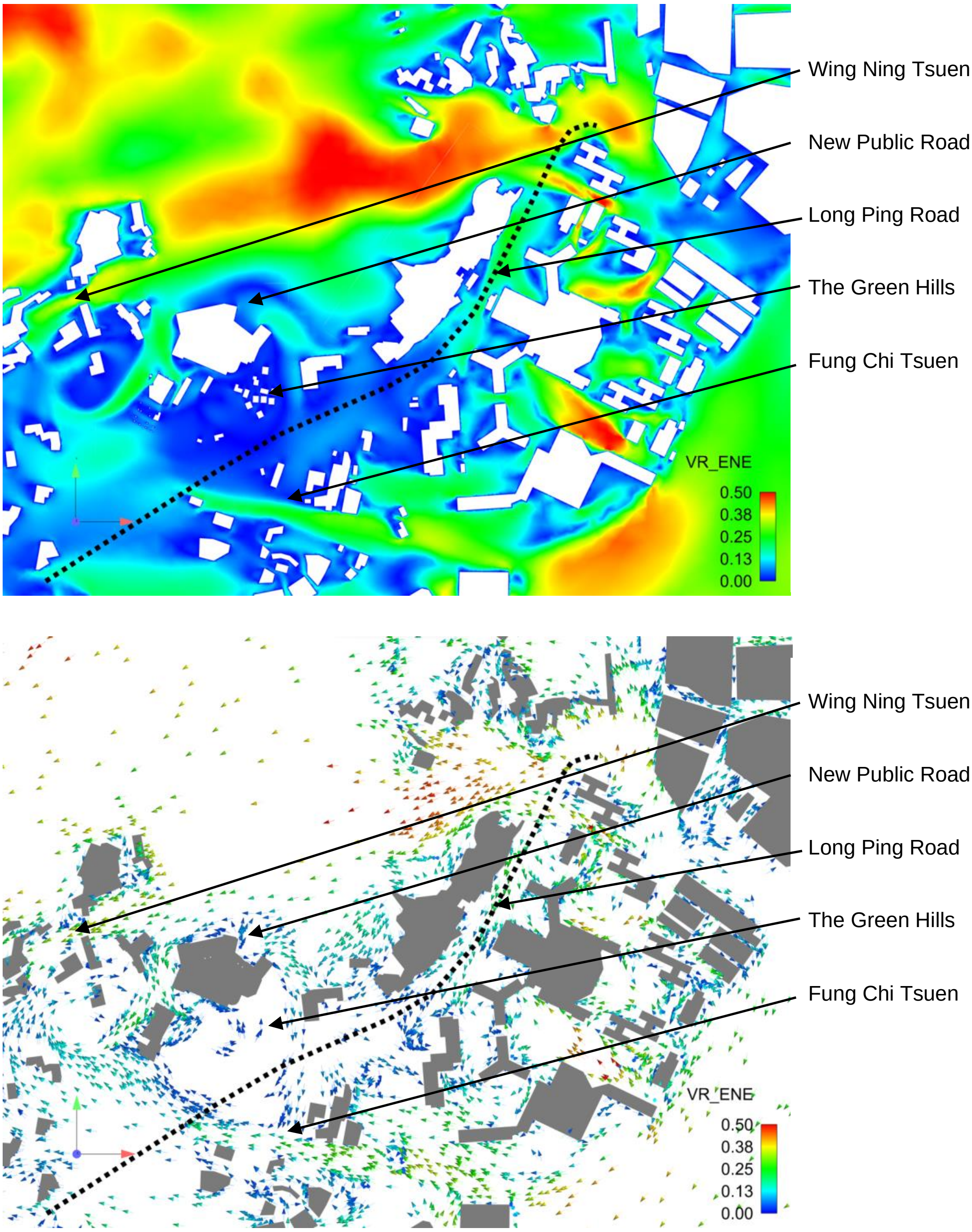
6.8 In the Baseline Scheme, the weakened incoming wind is observed to enter the Site through the 20m-wide building gap between Block 1 and 2. It is found that the proposed developments (137-141mPD) would generate localized air ventilation impact at the leeward side of residential blocks. Given that the wind availability is relatively low before interacting with the Site, the downstream area of the Site such as the southern portion of Wing Ning Tsuen is found to receive a relatively low velocity ratio. In addition, it is found that the empty bays in the social welfare block may also facilitate wind penetration, air movement is observed in the permeable space of the social welfare block.

6.9 In the Proposed Scheme, the building morphology of the proposed development Block 1 (135mPD), in addition to the widened building setbacks to the eastern site boundary slightly reduces the wind influence towards immediate downstream compared to the Baseline Scheme, including the southern portion of Wing Ning Tsuen and the Open Storage in the SW. A slightly improved air ventilation performance is observed among these areas.

Baseline Scheme



Proposed Scheme



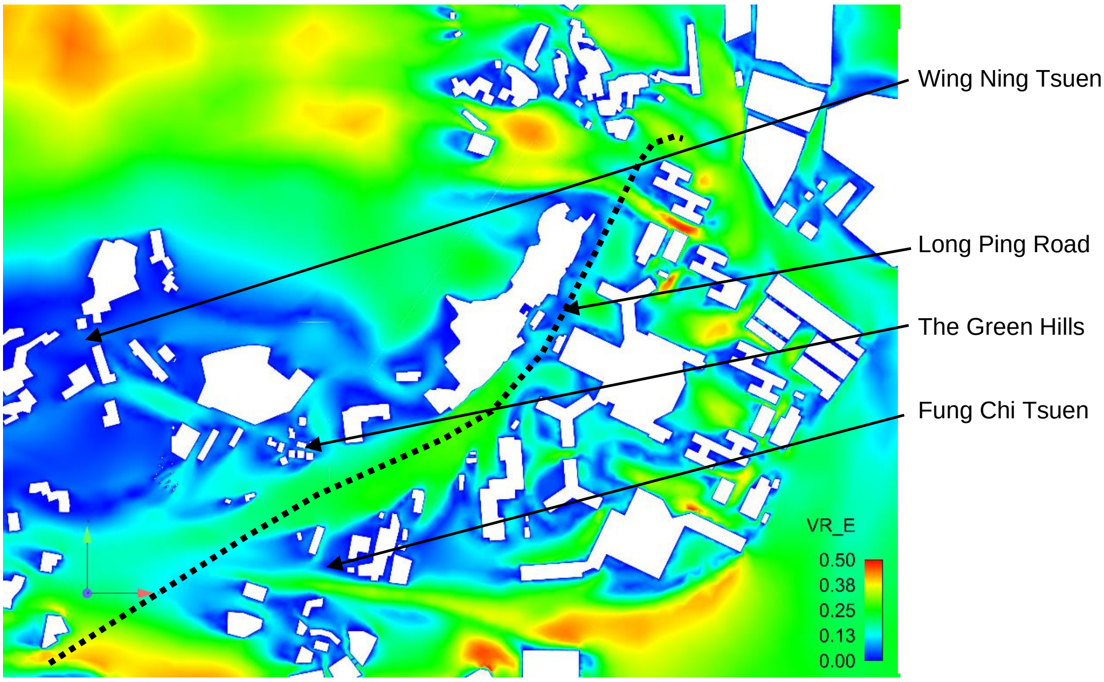
E: (Annual: 15.3%, Summer: 6.2%)

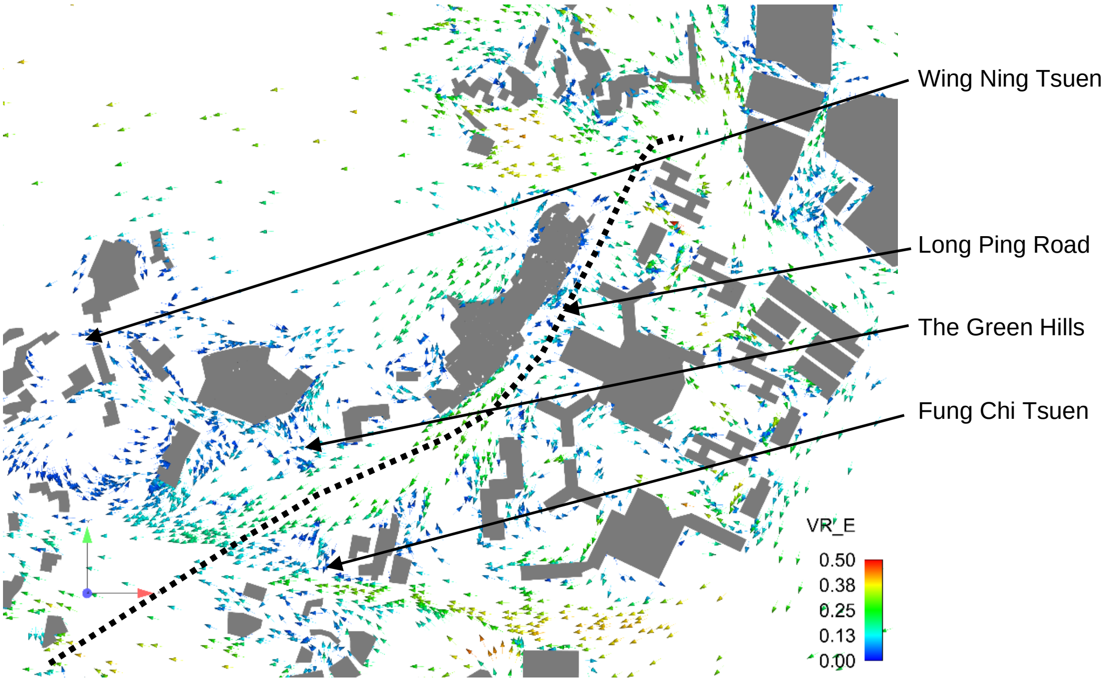
6.10 Similar to the ENE wind, E winds skim over the low-rise village houses above the pedestrian level, located to the east of Fuk Hi Street, freely to reach the natural landscapes in the northeast of the Site, through the junction of Long Ping Road and Fuk Hi Street. Another stream of wind skims over the low-rise villages in Yuen Long Kau Hui and then passes through the Yuen Long Town along Yuen Long On Lok Road/Long Yip Street and Wang Tat Road/Ma Wang Road. Due to a lack of effective air paths aligning with the prevailing winds, Long Ping Estate and the proposed development in Site A at the upstream would obstruct the E winds from penetrating into the Site, creating a relatively large wind stagnant zone that extends to the Site. The site wind availability of the Site is generally weak, mainly relies on redirected wind from natural landscapes, diffused wind from Site A, the low-rise zones and building gaps at Long Ping Estate.

6.11 In the Baseline Scheme, the weakened incoming wind is observed to enter the Site and obstructed by Block A and the closely packed Block B, C & D with the podium bulk (137-141mPD). However, the building gap between the social welfare block and Block B is found to facilitate wind penetration. It is noticed that the wind availability is relatively low before interacting with the Site, the incoming wind could penetrate the Site and reach the downstream area including the southern portion of Wing Ning Tsuen. Another portion of the incoming wind is found to be obstructed by the social welfare block and diverted to Long Ping Road. Yet, the empty bays in the social welfare block may facilitate wind penetration at the pedestrian level and reduce the wind impact towards the downstream area.

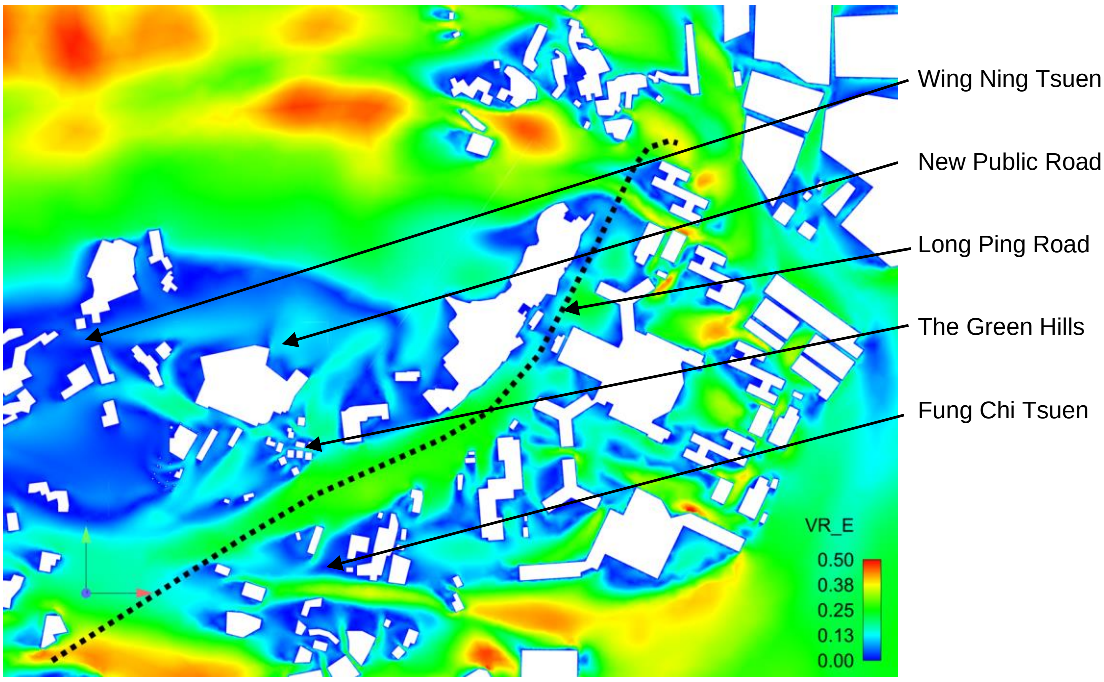
6.12 In the Proposed Scheme, the proposed residential developments (135-140mPD) are expected to cause less air ventilation impact to the immediate downstream than the Baseline Scheme. It is observed that the widened building setbacks to the eastern site boundary are able to facilitate a larger portion of the incoming wind then enter the Site. Moreover, the building morphology in Block A is observed to promote a better air ventilation performance to Wing Ning Tsuen due to less hindrance to the incoming wind from the building frontage of Block A. It also benefits the recirculation wind to ventilate the Site and the natural landscapes to the north of the Site.

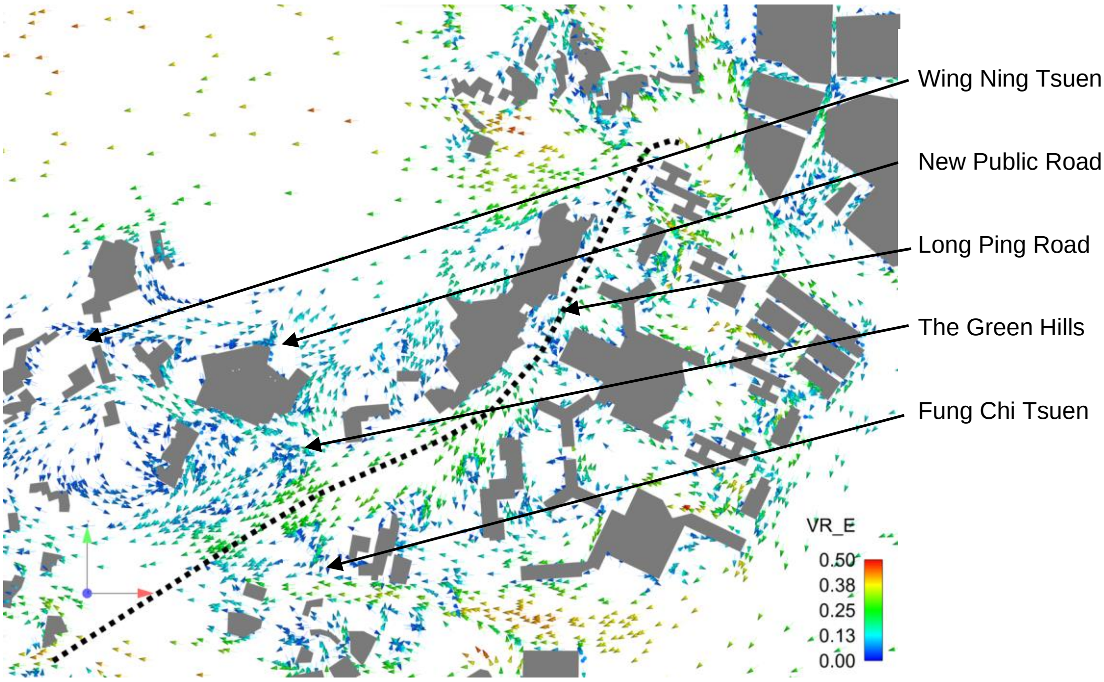
Baseline Scheme





Proposed Scheme





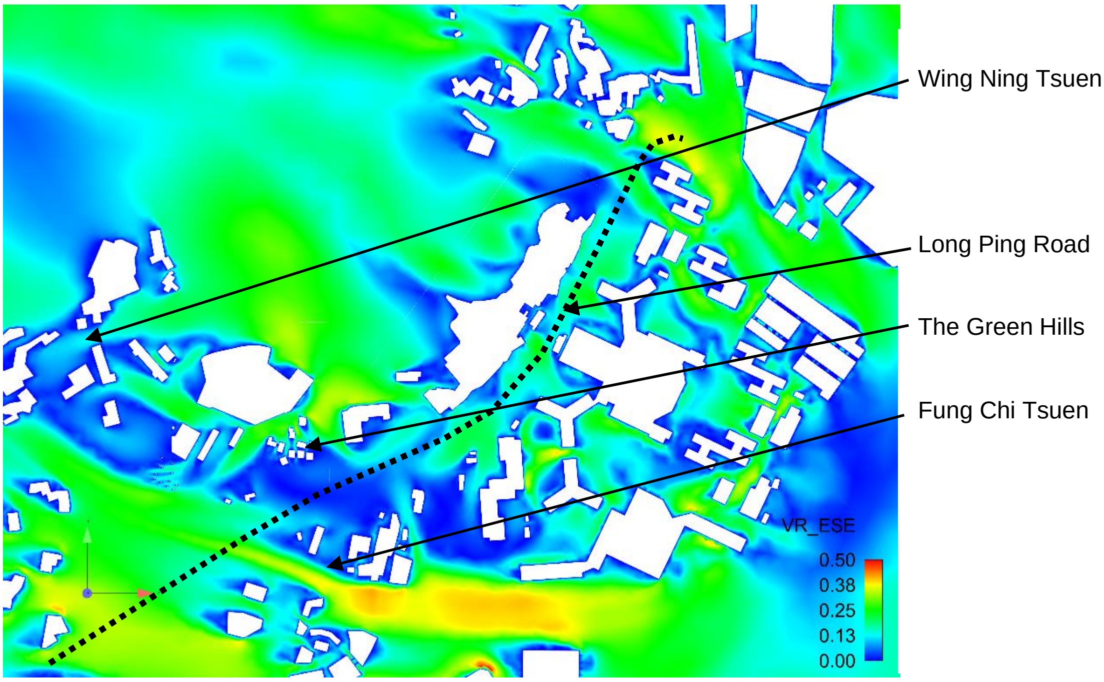
ESE: (Annual: 9.6%, Summer: 8.3%)

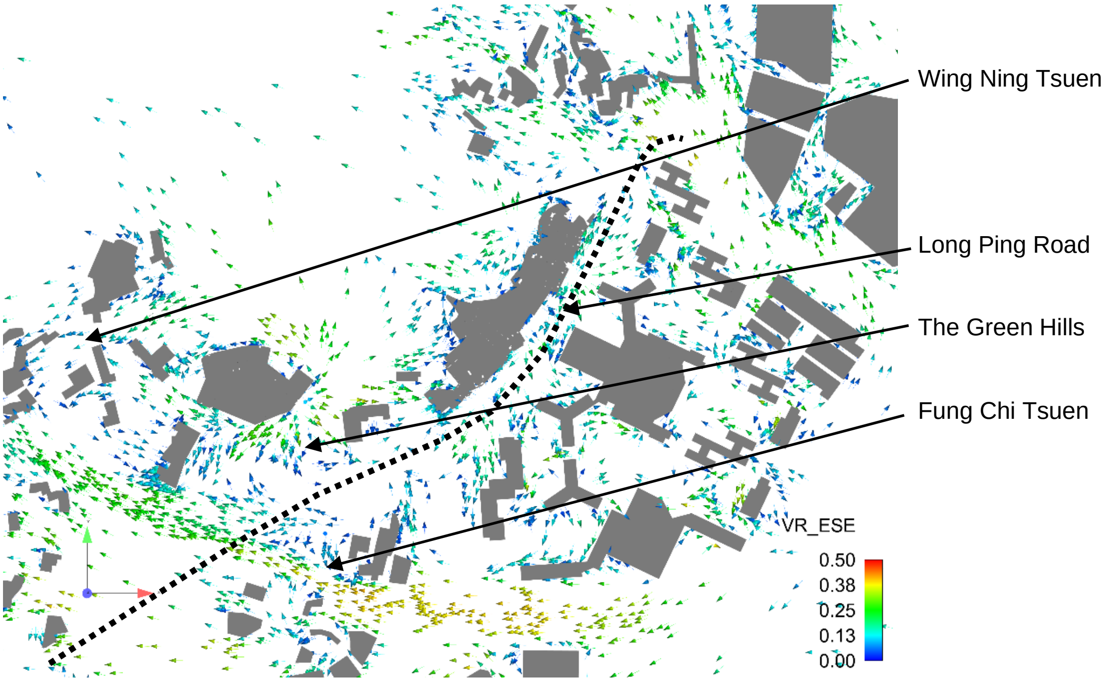
6.13 ESE wind adopts Yuen Long On Lok Road/Long Yip Street and Wang Tat Road/Ma Wang Road as major air paths through the Yuen Long Town and then follow the viaduct of Tuen-Ma Line Railway to ventilate the area in the south. A stream of wind would enter Fuk Hi Street from the nullah of Shan Pui River. Incoming ESE wind is partially obstructed by Long Ping Estate and proposed development in Site A from penetrating into downstream areas such as the hilly region of Kai Shan, creating a large extent of shadow zone to the Site. Site wind availability of the Site is weak, while mainly relies on redirected wind from Long Ping Road, low-rise zones and building gaps at Long Ping Estate.

6.14 In the Baseline Scheme. The air ventilation performance of the Site is satisfactory. The incoming wind is observed to be slightly blocked by the proposed developments (137-141mPD). The ESE wind is observed to flow along New Public Road and natural landscapes in the north, along with the reserved building gap between Block B and the social welfare block, the incoming wind is observed to penetrate the Site effectively to reach the downstream area such as Wing Ning Tsuen. On the other hand, being adjacent to the ESE wind, the social welfare block is found to create a wind stagnant in the immediate downstream at the pedestrian level, reducing the velocity ratio of the open storage in SW. However, the empty bays under the social welfare block are found to slightly reduce the wind stagnant.

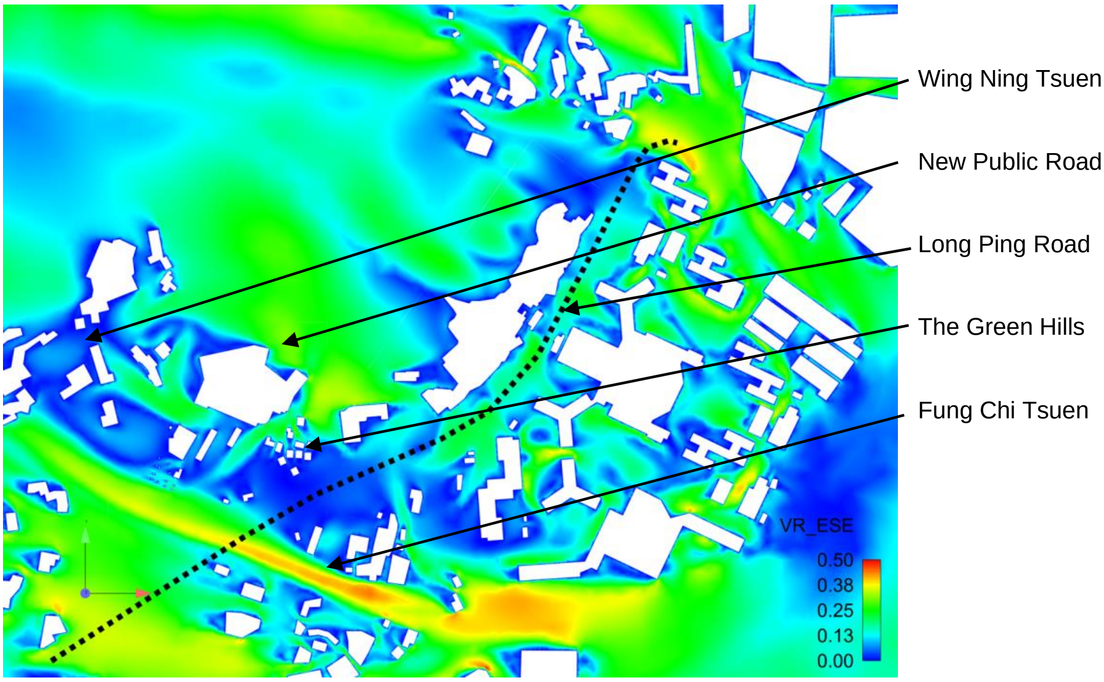
6.15 In the Proposed Scheme, similar air ventilation performance is observed. The proposed developments (135-140mPD) are found not to create adverse impacts on the surrounding developments. Compared to the Baseline Scheme, the modified building morphology of Block A would allow more recirculation wind to pass through the building gap between Block 1 and Block 2 to ventilate New Public Road, slightly improving the air ventilation performance of this area.

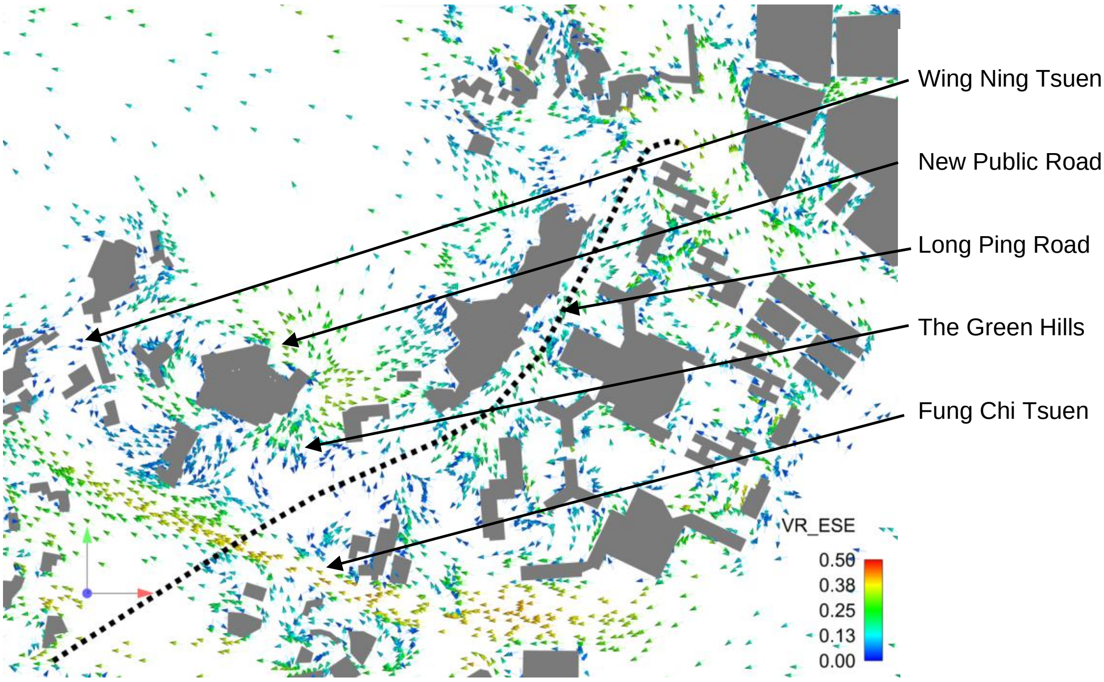
Baseline Scheme





Proposed Scheme





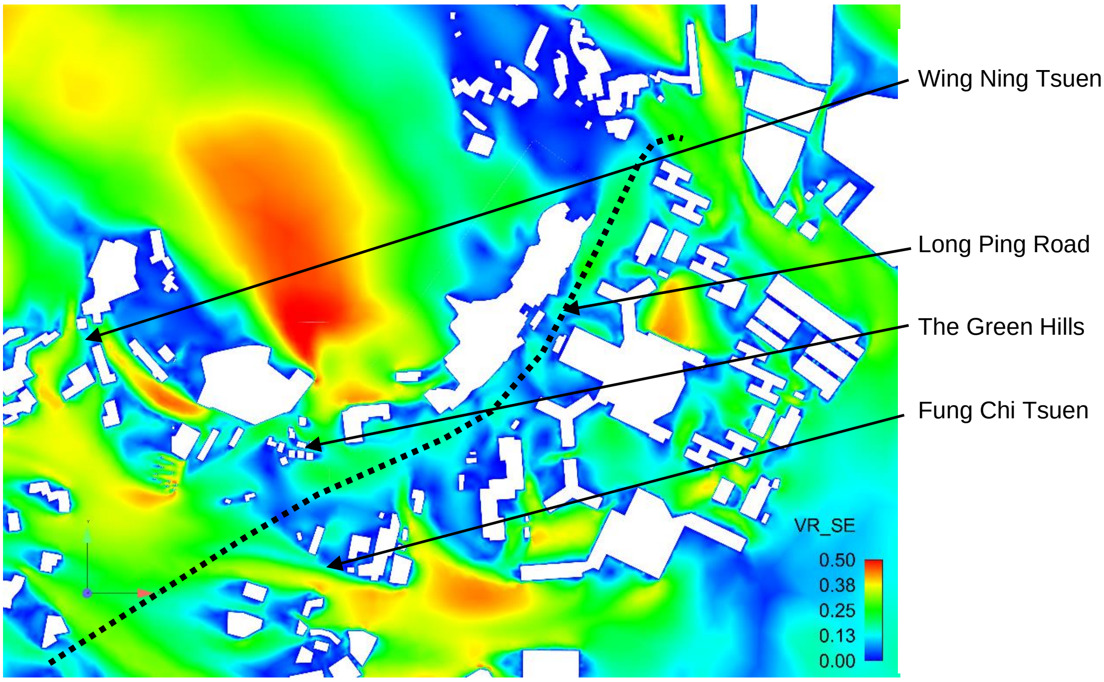
SE: (Annual: 7.9%, Summer: 7.3%)

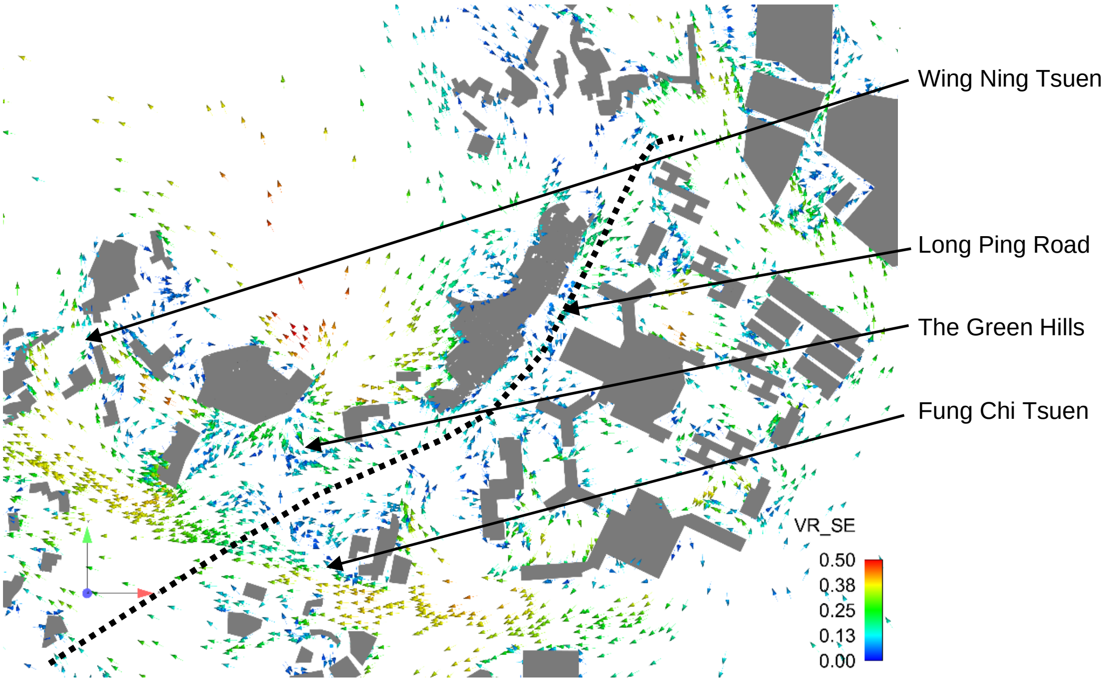
6.16 SE wind flows from building gaps and open space of Yuen Long Town to the upstream of Wang Tai Road / Ma Wang Road would pass through Chun Hing San Tsuen and the GB zone, the existing open storage area and the Yick Shun car park freely to reach Wing Ning Tsuen to the west of the Site. However, the prevailing winds would not be able to penetrate through the building gaps of Shui Pin Wai Estate, limiting the site wind availability at the Site. Another stream of SE wind travels along Fung Chi Road, which is aligned in SE direction, reaches the building gap between the proposed school and proposed developments in Site A, a good wind environment is observed between this large gap, promoting air movement to the eastern perimeter of the Site. The site wind availability of the Site relies on a portion of incoming wind that would reattach at Fung Chi Tsuen and Shui Tin Tsuen, and then reach the Green Hills and Umah International Primary School in the upstream of the Site.

6.17 In the Baseline Scheme. The air ventilation performance of the immediate downstream is impacted by the proposed development Block A and the closely packed Block B, C & D (137-141mPD), a wind stagnant zone in the immediate downstream is observed, affecting wind sensitive areas including the northern portion of Wing Ning Tsuen. However, the building separation between Block B and the social welfare block is aligned with the SE wind, the incoming wind is found to flow along this wind corridor effectively, along with the empty bays under the social welfare block and the residential blocks, the wind impact in Wing Ning Tsuen is alleviated. Moreover, an observable wind acceleration toward natural landscapes in the northeast is found when the incoming wind is diverted from high level and splits at Block D.

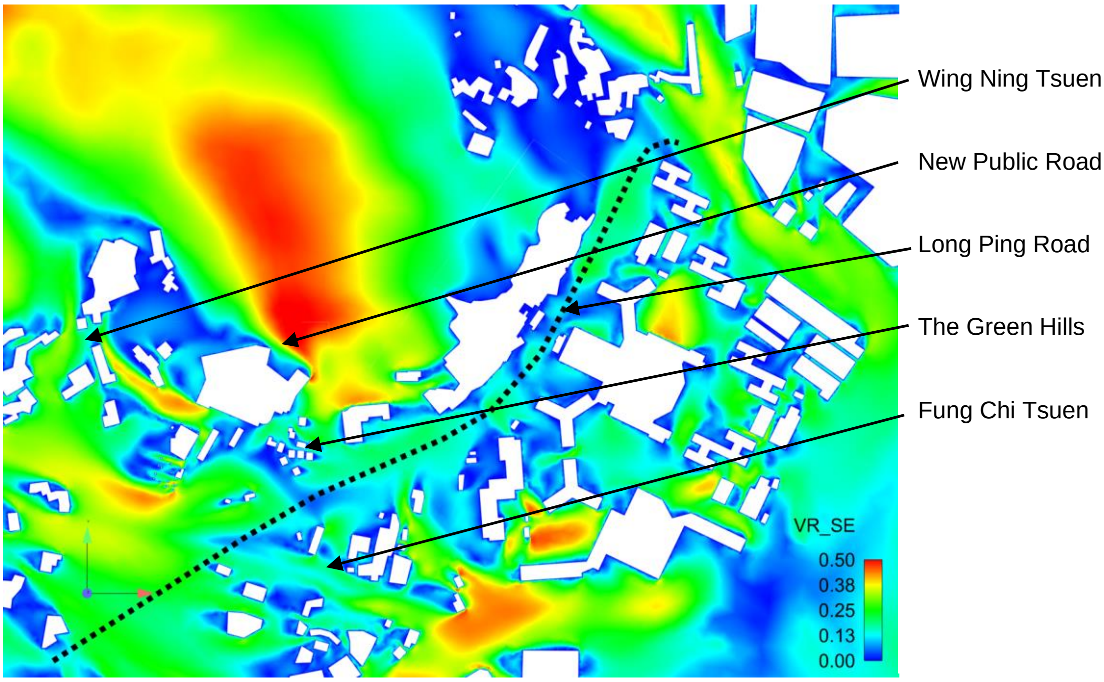
6.18 In the Proposed Scheme, there is a slight improvement in air ventilation performance in the New Public Road and natural landscapes in the northeast. The building morphology of the proposed development Block A (135mPD) is modified. It is found that Block A could divert a portion of the recirculation wind to New Public Road and natural landscapes in the northeast through the building gap between Block 1 and Block 2, leading to a higher velocity ratio in this area.

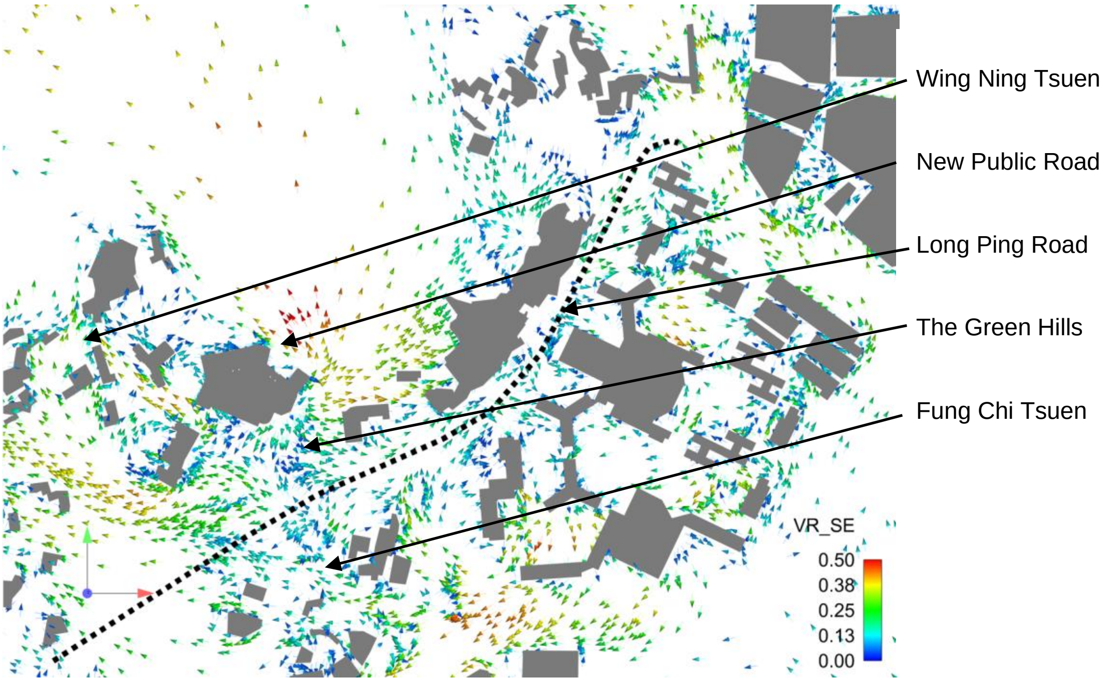
Baseline Scheme





Proposed Scheme





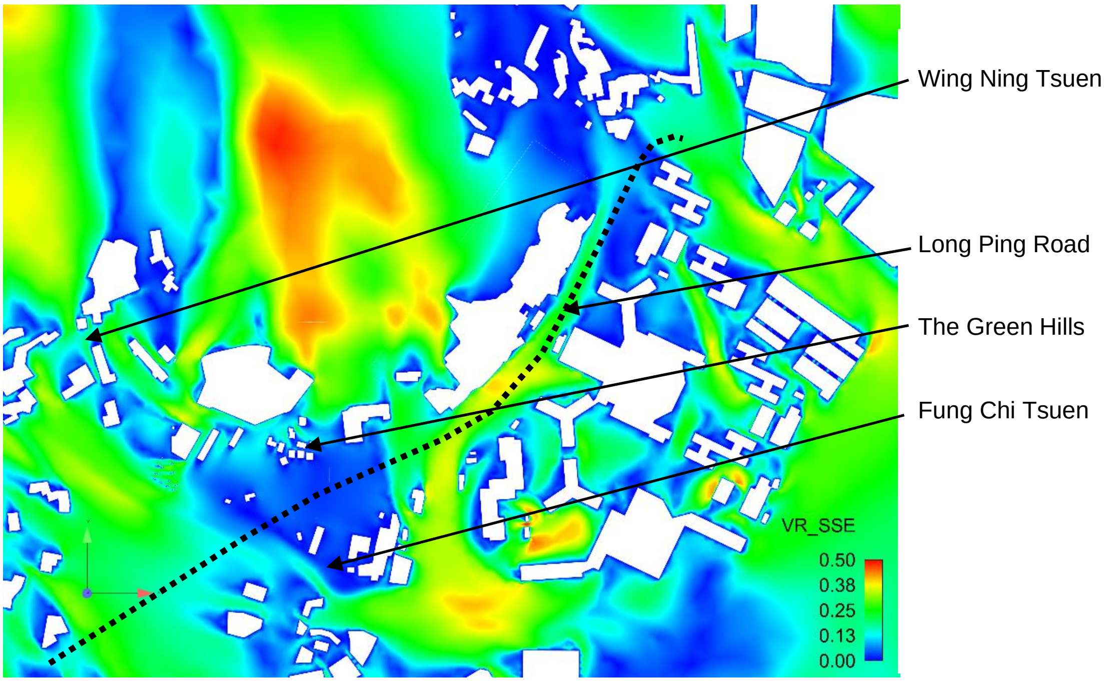
SSE: (Annual: 7.5%, Summer: 10.3%)

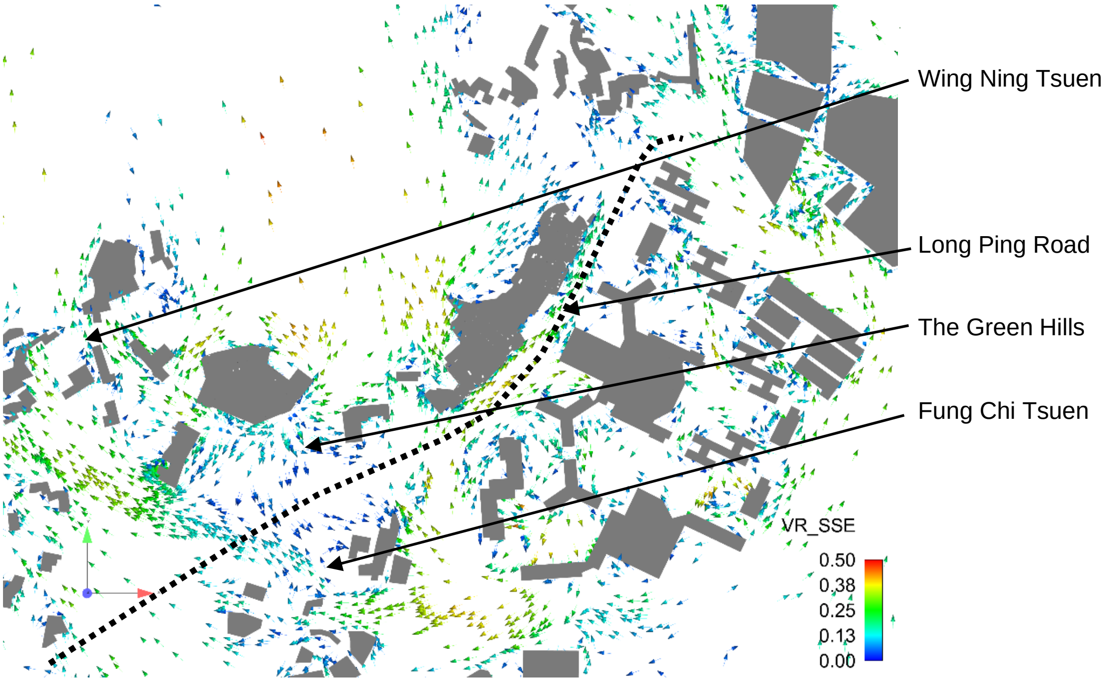
6.19 Similar to SE wind, SSE wind flows from building gaps and open space of Yuen Long Town to the upstream of Wang Tai Road / Ma Wang Road would pass through Chun Hing San Tsuen and the GB zone, the existing open storage area and the Yick Shun car park freely to reach Wing Ning Tsuen to the west of the Site. However, the prevailing winds would not be able to penetrate through the building gaps of Shui Pin Wai Estate, limiting the site wind availability at the Site. Another stream of SSE wind travels along Fung Chi Road, which is aligned in SSE direction, reaches the building gap between the proposed school and proposed developments in Site A, a good wind environment is observed between this large gap, promoting air movement to the eastern perimeter of the Site. The site wind availability of the Site relies on a portion of incoming wind that would reattach at Fung Chi Tsuen and Shui Tin Tsuen, and then reach the Green Hills and Umah International Primary School in the upstream of the Site.

6.20 In the Baseline Scheme, the incoming wind reaching the Site is partially obstructed by the low-rise village houses. It is observed that a wind influencing zone could also be observed to the immediate downstream of the proposed development Block A (137mPD). However, the incoming wind could still flow along the 22m-wide building gap between Block B and the social welfare block. A portion of the incoming wind is found to flow along this wind corridor to reduce the wind impact in Wing Ning Tsuen. Another portion of the incoming wind is observed to split by Block A and flow towards the 20m-wide building gap between Block A and Block B to ventilate New Public Road and the natural landscapes in the northeast. Additionally, the empty bays under Block A allow near ground wind to skim over and penetrate through the podium to reach pedestrian level at the leeward side to alleviate the wind influence. Also, an observable wind acceleration toward natural landscapes in the northeast is found when the incoming wind is diverted from high level and splits at Block D, the velocity ratio in this region is relatively higher.

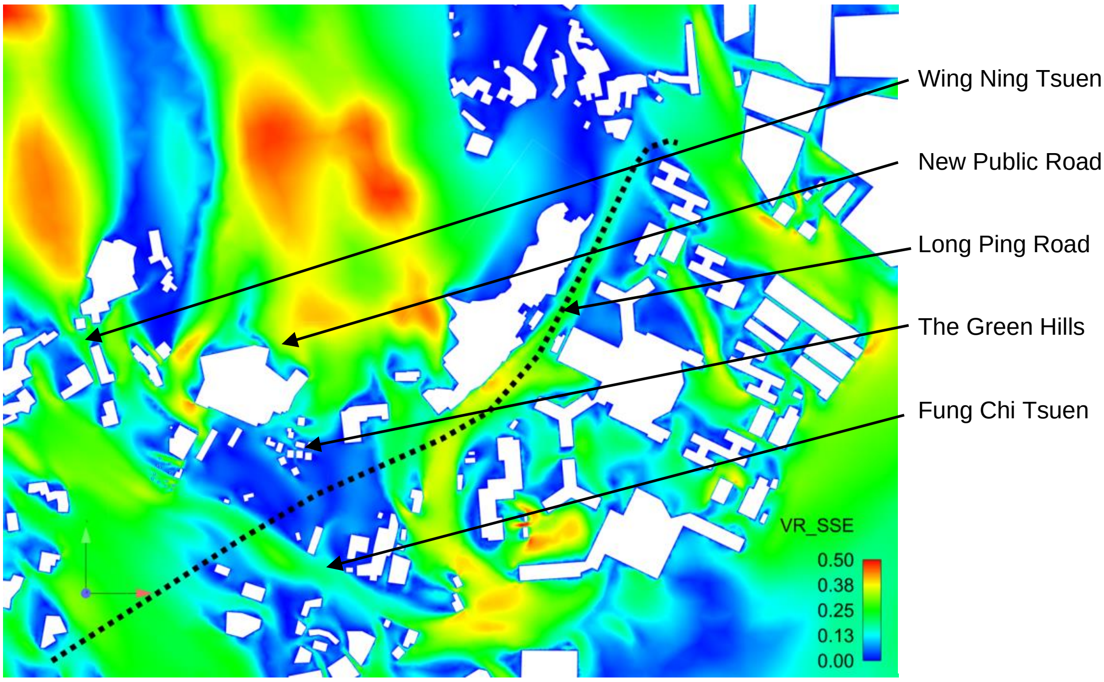
6.21 In the Proposed Scheme, a similar wind flow pattern is found compared to the Baseline Scheme. A slight enhancement in the air ventilation performance is that the incoming wind could reach the natural landscapes in the northeast more effectively due to the modified building morphology of the proposed development Block A (135mPD), such that the air ventilation performance along the New Public Road is improved.

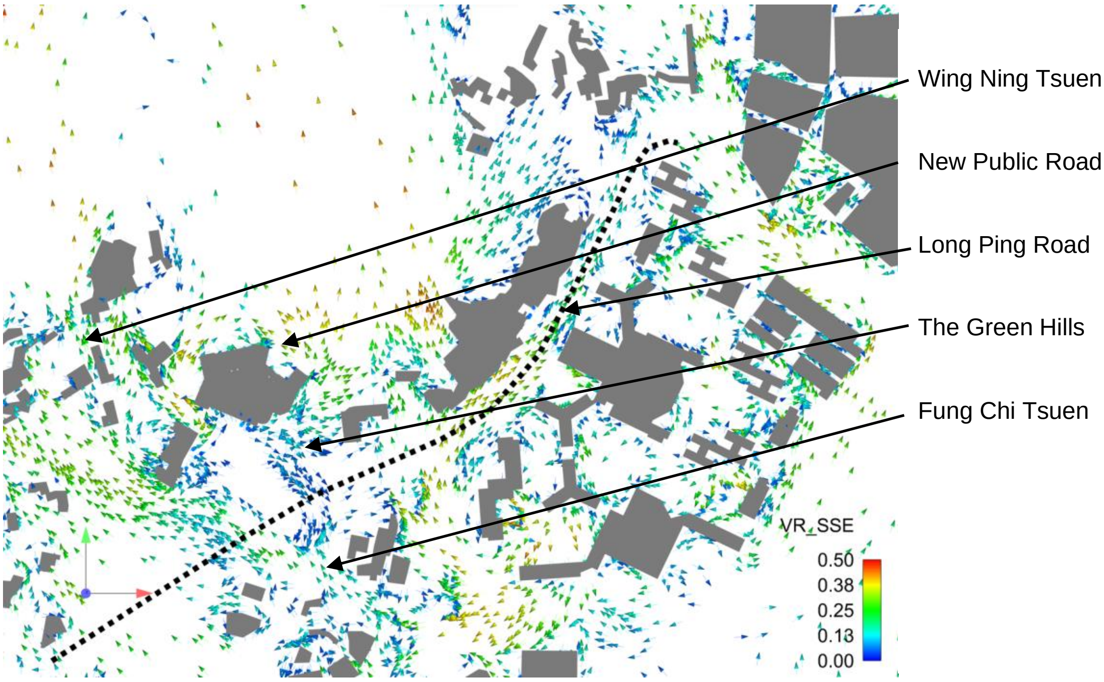
Baseline Scheme





Proposed Scheme





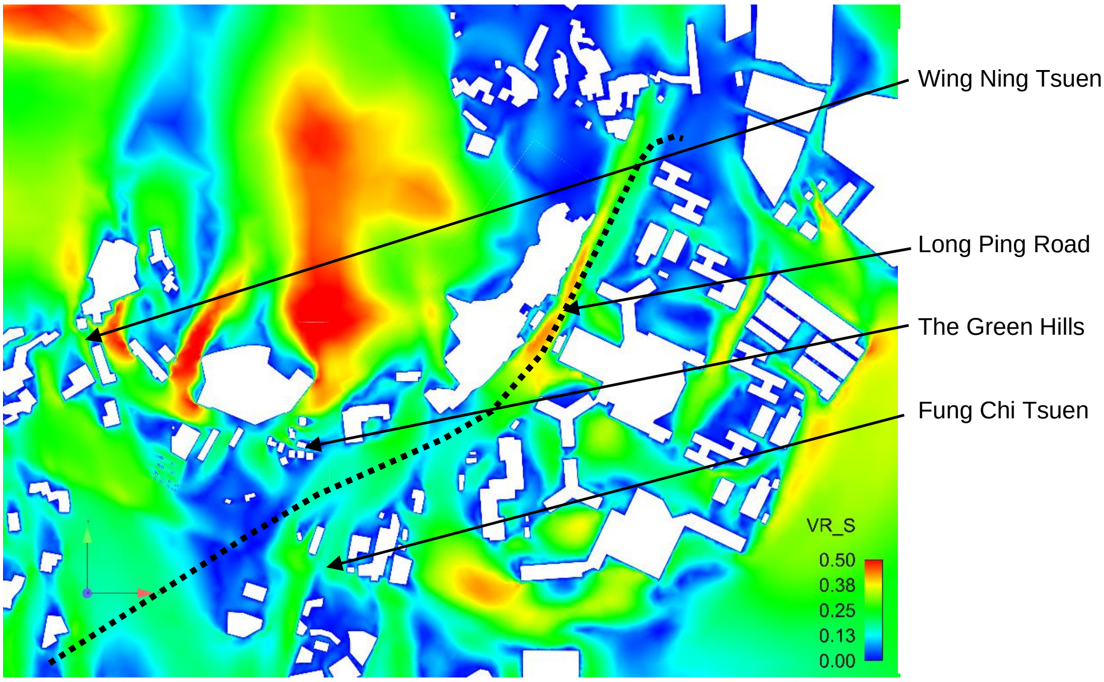
S: (Summer: 15.0%)

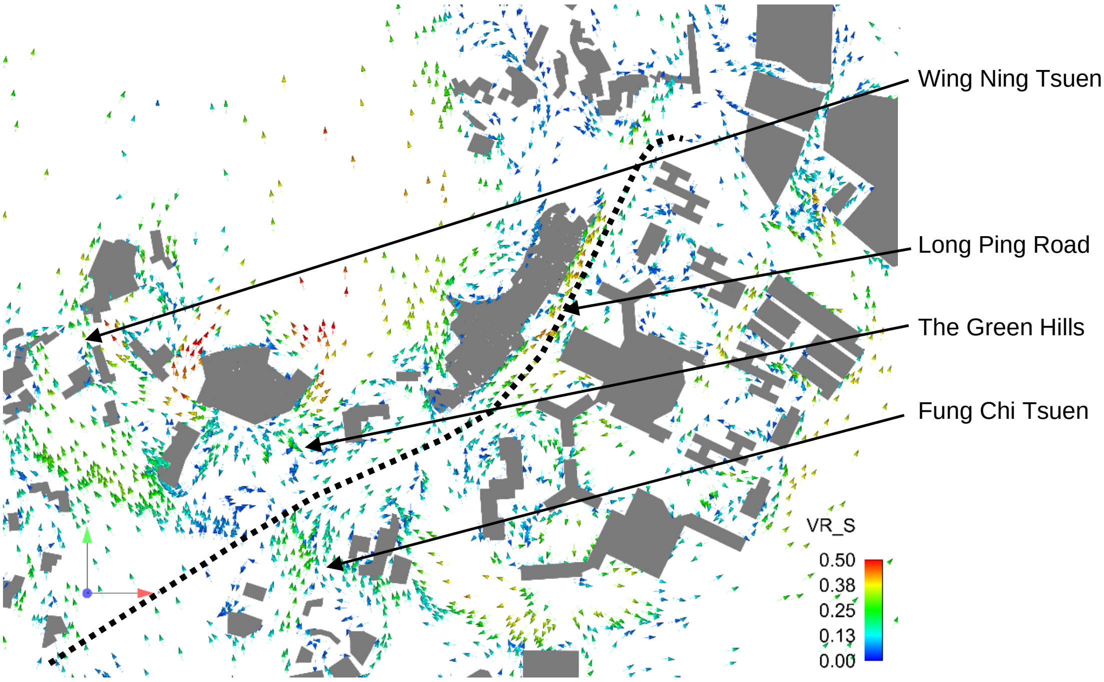
6.22 S wind travels along Long Tin Road freely without much hindrance from low-rise village houses of Choi Hong San Tsuen to reach the Green Hills and the Site after reattachment of wind from Yuen Long Park via low-rise zones. The site wind availability is satisfactory.

6.23 In the Baseline Scheme, the unobstructed wind from the low-rise zone is found to flush both the lateral sides of the social welfare block (42mPD) at its short frontage with empty bays which enhanced the wind penetration. Then, the incoming wind flushes the 20m-wide building gap between the proposed development Block B (141mPD), ventilating the natural landscapes in the north of the Site. Another portion of the incoming wind is found to be diverted by Block D, an observable wind acceleration toward natural landscapes in the north and northeast is found. It is found that the proposed developments create wind influencing zones in its immediate downstream. However, empty bays under each residential block at the podium garden level allow near ground wind to skim over and penetrate through the podium to reach the pedestrian level at the leeward side to alleviate the wind influence.

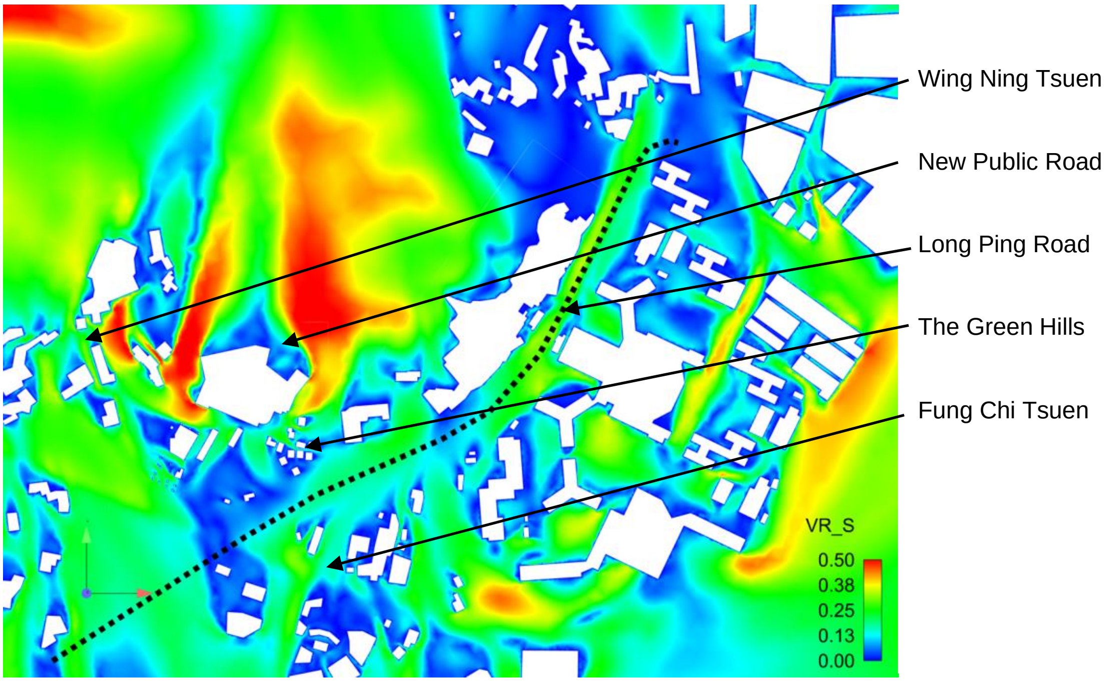
6.24 In the Proposed Scheme, similarly, the proposed developments (135-140mPD) are found not to induce adverse wind impact to the surrounding area. Moreover, less air ventilation impact to the immediate downstream than the Baseline Scheme is observed. With the reduced building frontage of Block A, the obstruction against the incoming wind is slightly reduced. On the other hand, it is observed that the widened building setbacks to the west of Block A as well as the eastern site boundary could increase the velocity ratio to the immediate downstream. The incoming wind is able to penetrate the Site more effectively, such that the air ventilation performance of the northern portion of Wing Ning Tsuen, New Public Road, and the natural landscapes in the north is observed to have a slightly higher velocity ratio.

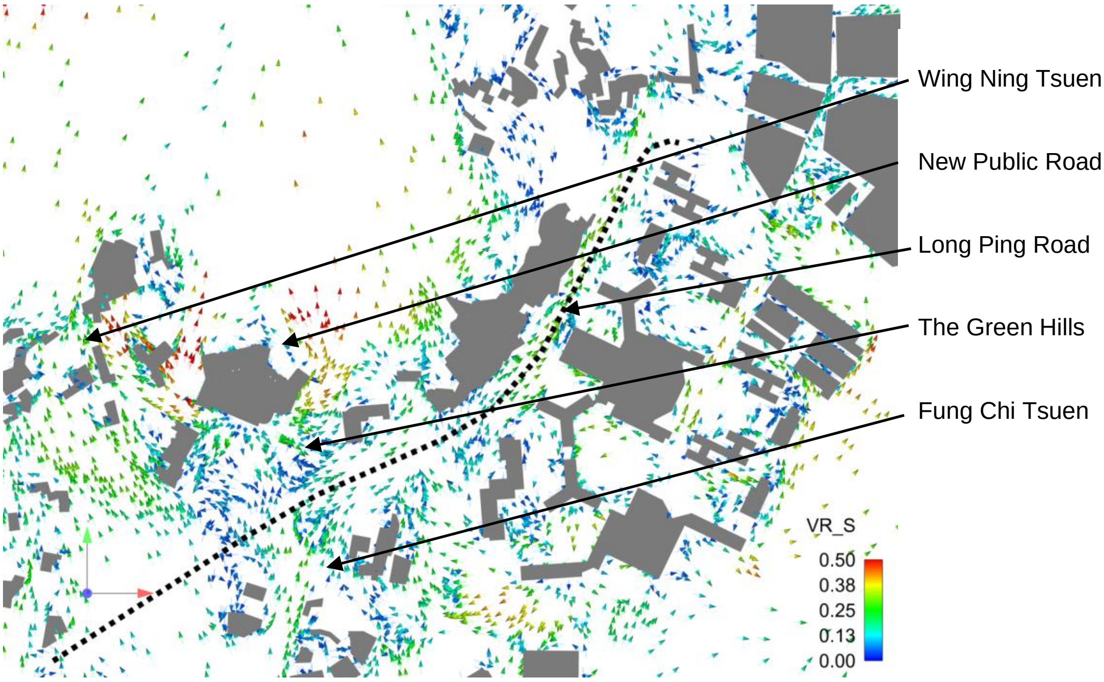
Baseline Scheme





Proposed Scheme





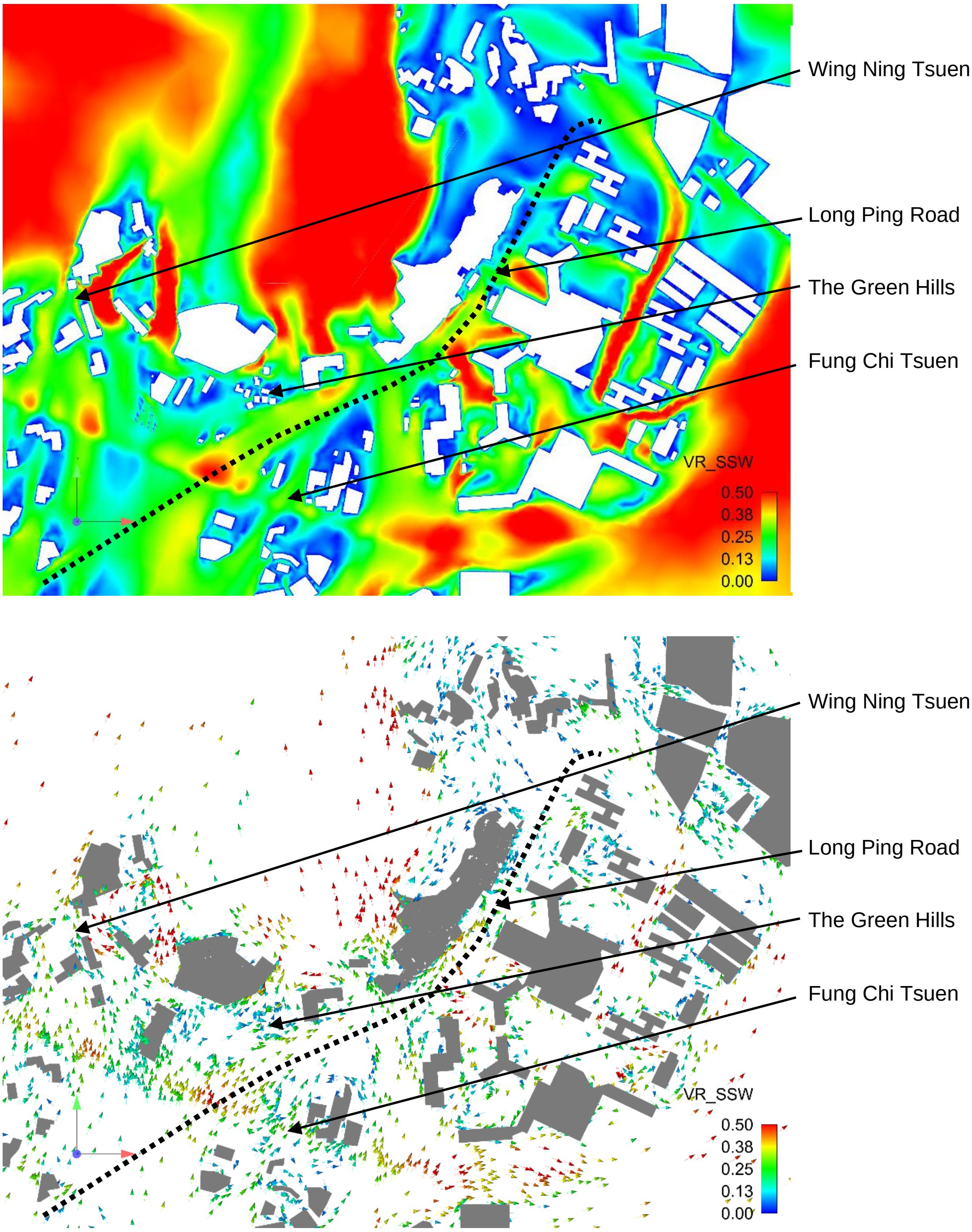
SSW: (Annual: 8.0%, Summer: 16.6%)

6.25 Similar to S wind, SSW wind travels along Long Tin Road freely without much hindering from low-rise village houses of Choi Hong San Tsuen to reach the Green Hills and the Site after reattachment of wind from Yuen Long Park via low-rise zones. The site wind availability is satisfactory.

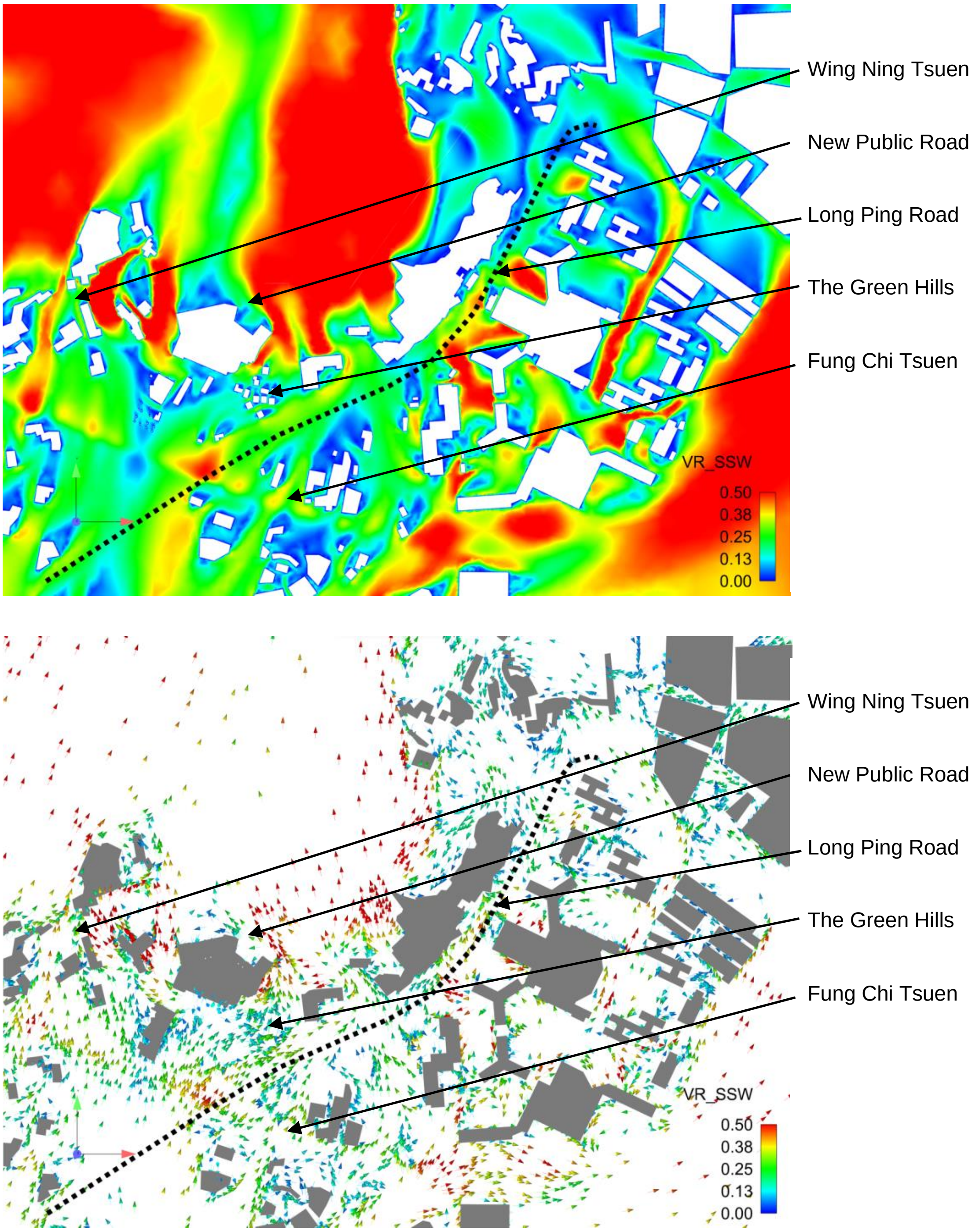
6.26 In the Baseline Scheme, the SSW wind flushes both the lateral sides of the social welfare block (42mPD) at its short frontage with empty bays which facilitated the wind penetration. The incoming wind is observed to flush between the 20m-wide building gap of Block A and B, where it is aligned with SSW wind direction, an observable wind acceleration toward the northern portion of Wing Ning Tsuen and the natural landscapes in the north is found. Moreover, it is also observed that the incoming wind would pass through the 10m-wide building setback from the eastern site boundary and the 17m-wide building setback to the west of Block A, in addition to the empty bays under the proposed residential blocks, it further reducing the wind influence on the immediate downstream.

6.27 In the Proposed Scheme, comparable to the Baseline Scheme, the building gaps between the proposed residential developments (135-140mPD) are aligned to the wind direction, the wind velocity ratio of the Site and the surrounding developments are relatively high. Given that the building morphology of Block A is modified, the obstruction against the incoming wind is then minimized, it is found that a portion of the incoming wind could penetrate the air permeable space under Block A to ventilate the downstream area. Besides, the widened building setbacks to the west of Block A and the eastern site boundary could slightly enhance the air ventilation performance to the immediate downstream, such as the northern portion of Wing Ning Tsuen, New Public Road, and the natural landscapes in the north.

Baseline Scheme



Proposed Scheme



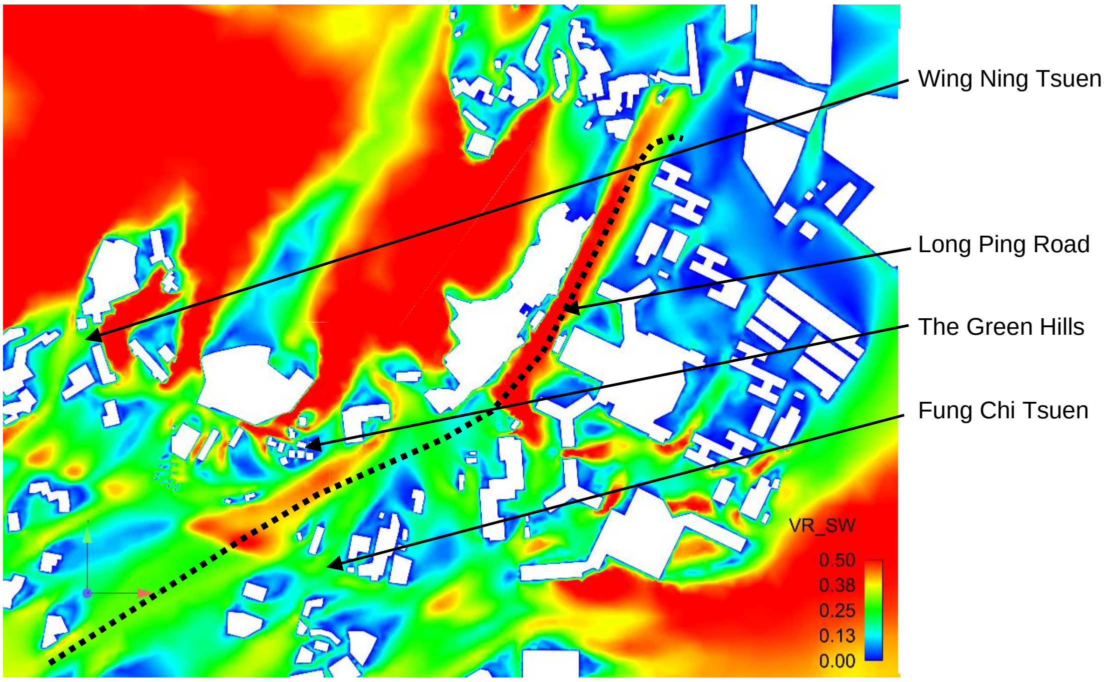
SW: (Summer: 13.4%)

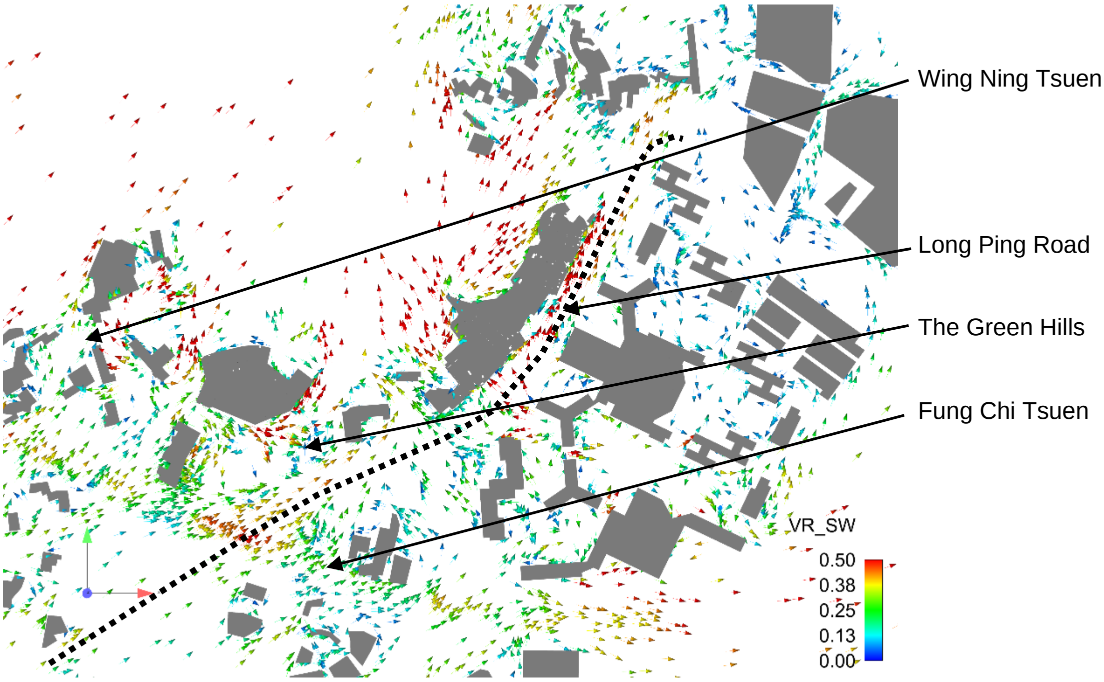
6.28 Incoming SW wind over the low-rise clusters, the open space at Wing Ning Tsuen, and the open storage sites is unobstructed to reach the Site freely. A stream of wind adopts Long Ping Road as a major air path. The site wind availability is satisfactory.

6.29 In the Baseline Scheme, the unobstructed wind from the low-rise zone is found to flush between the building gap of Block A and B (20m in width) freely as it is aligned with the wind direction, ventilating the natural landscapes in the north of the Site. A relatively lower velocity ratio is observed in the immediate downstream of the proposed developments (137-141mPD). Notwithstanding, empty bays under each residential block at the podium garden level could foster wind penetration and alleviate the wind influence on the downstream area. Additionally, it is also observed that the incoming wind would pass through the 10m-wide building setback from the eastern site boundary and the 17m-wide building setback to the west of Block A. As a result, a significant wind acceleration along these building gaps and setbacks is found.

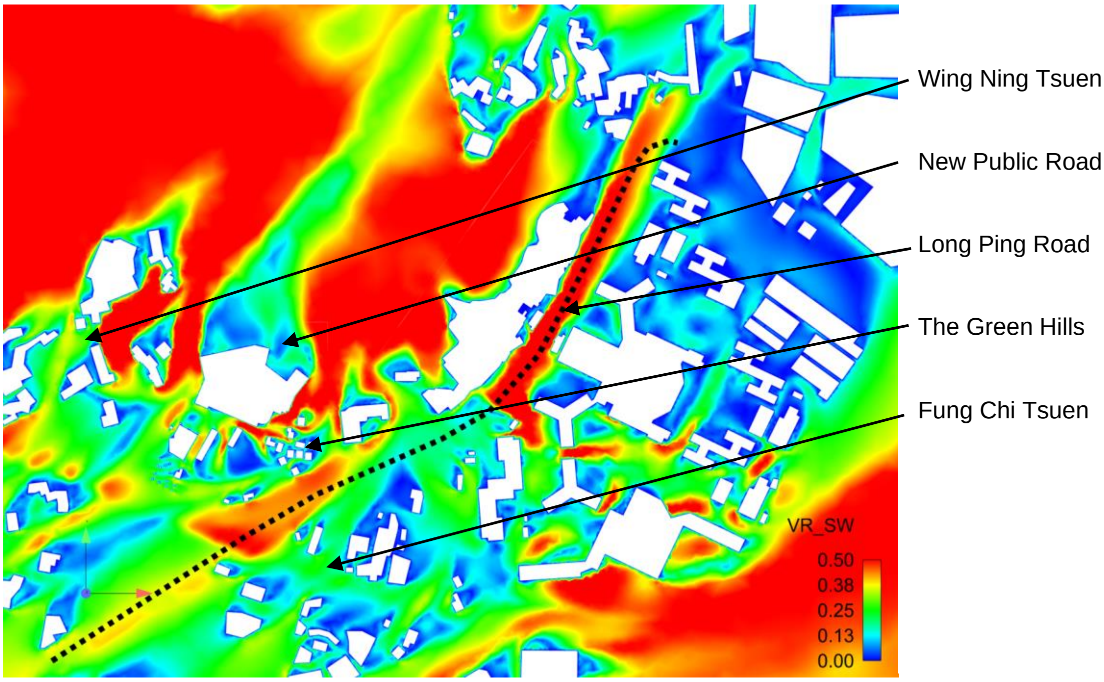
6.30 In the Proposed Scheme, it is found that the proposed residential developments (135-140mPD) create a shorter wind influencing zone at the downwind area compared to the Baseline Scheme. the modified building morphology as well as the widened building setbacks to the west of Block A and the eastern site boundary is observed to minimize the wind influencing zone to the immediate downstream of the Site, which favours the air ventilation performance of the natural landscapes in the north.

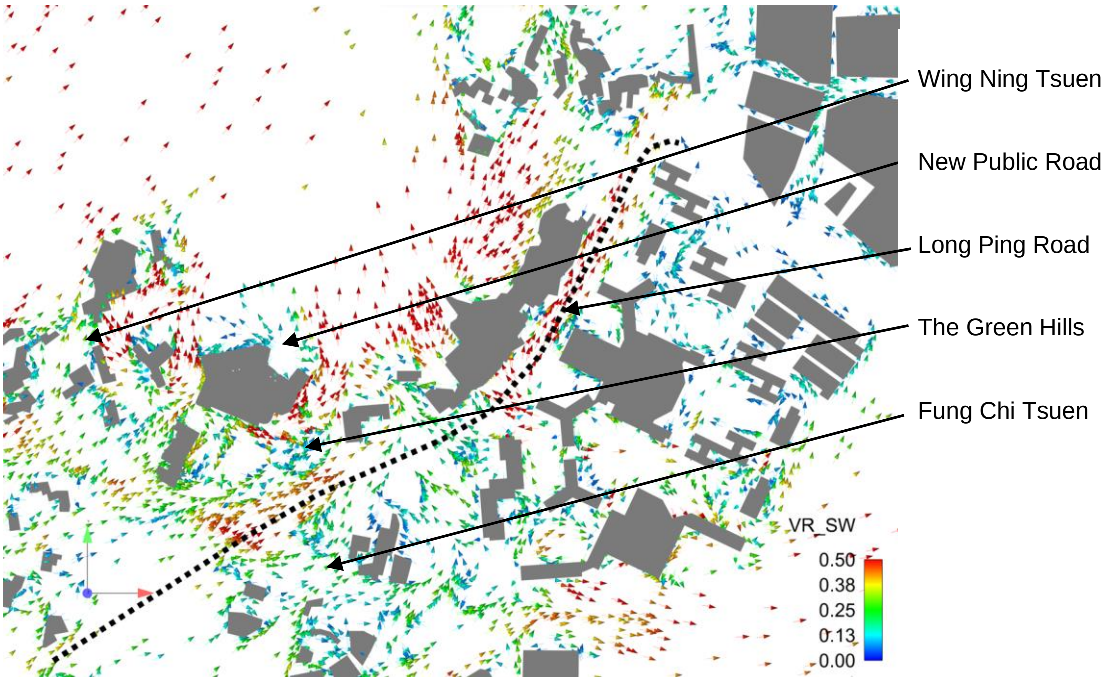
Baseline Scheme





Proposed Scheme





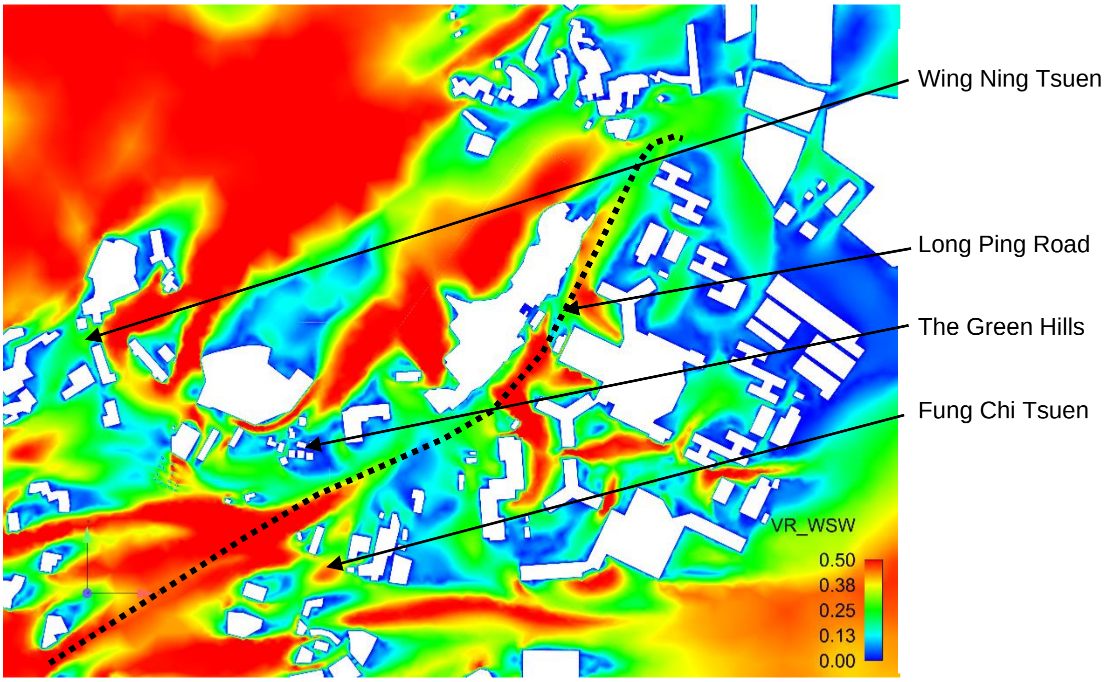
WSW: (Summer: 5.4%)

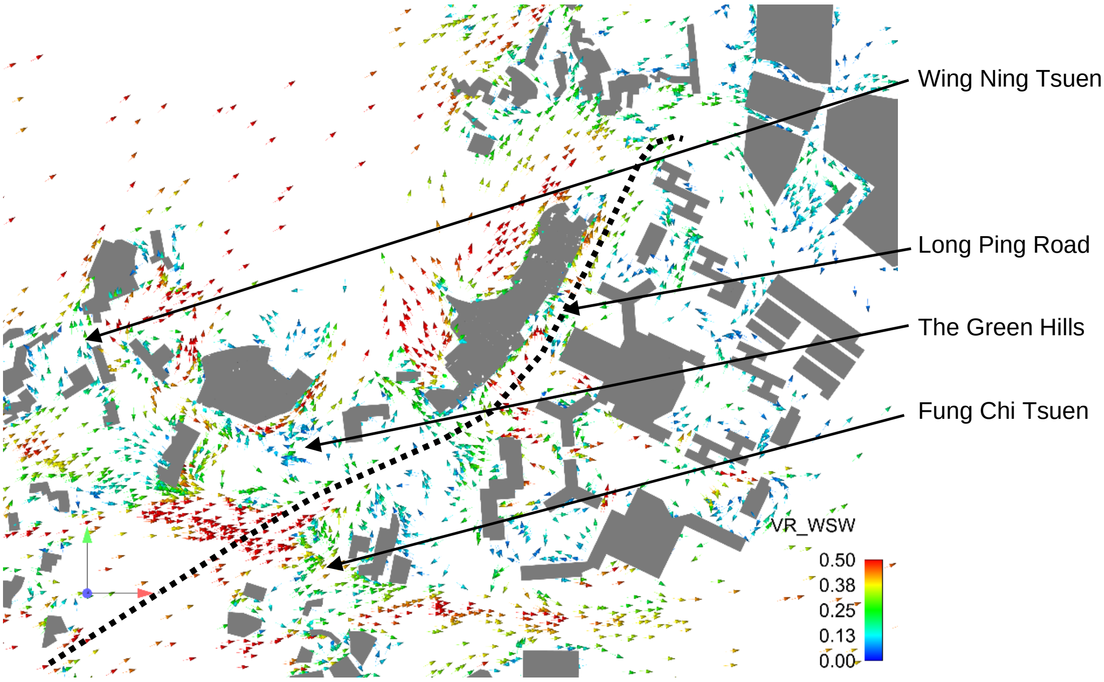
6.31 Incoming WSW wind over the low-rise clusters, the open space at Wing Ning Tsuen, and the open storage sites is unobstructed to reach the Site freely. A stream of wind adopts Long Ping Road as a major air path. The site wind availability is satisfactory.

6.32 In the Baseline Scheme, the unobstructed wind is found to split northward and southward along the proposed residential developments (137-141mPD), including the social welfare block, Block A and the podium bulk under Block B to D, which is generating a small, localized air ventilation impact at the leeward side of residential blocks. Despite the wind corridors reserved at the Site being less effective under WSW wind, the incoming wind, the incoming wind is observed to penetrate through the building gaps and empty bays under the proposed residential blocks, such that the air ventilation performance of the surrounding developments remains satisfactory.

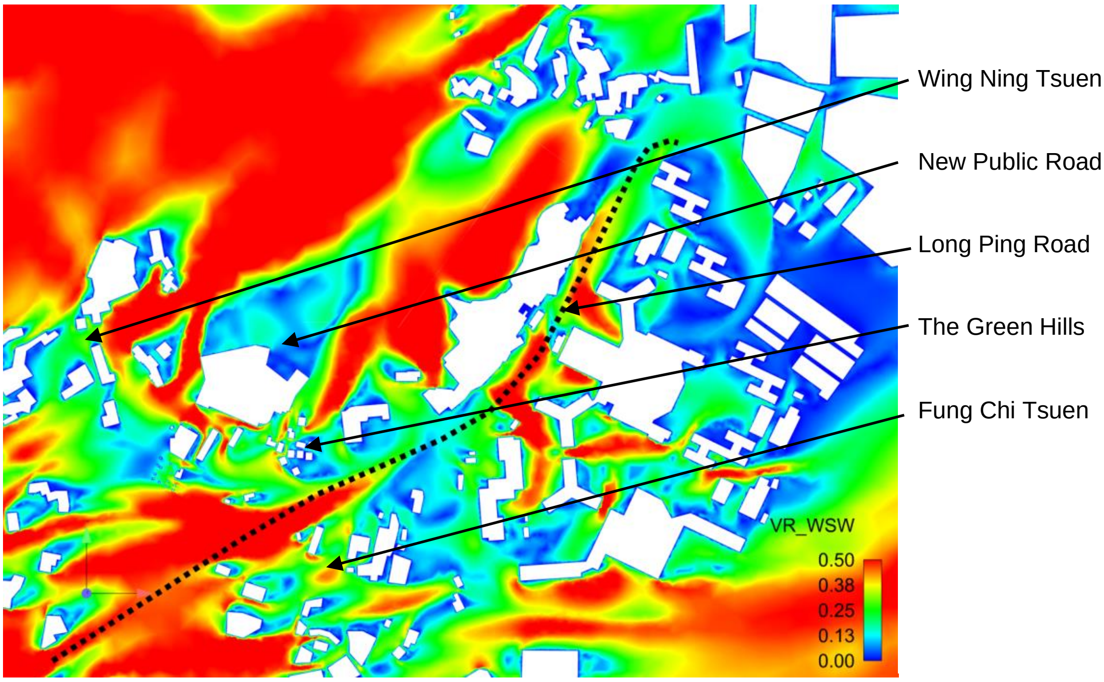
6.33 In the Proposed Scheme, similar to the Baseline Scheme, the air ventilation performance of the Site and the surrounding developments is satisfactory. The modification of the building morphology of the proposed development Block A (135mPD) and the widened building setbacks would lead to a less significant enhancement in the air ventilation performance of the wind sensitive area under WSW wind.

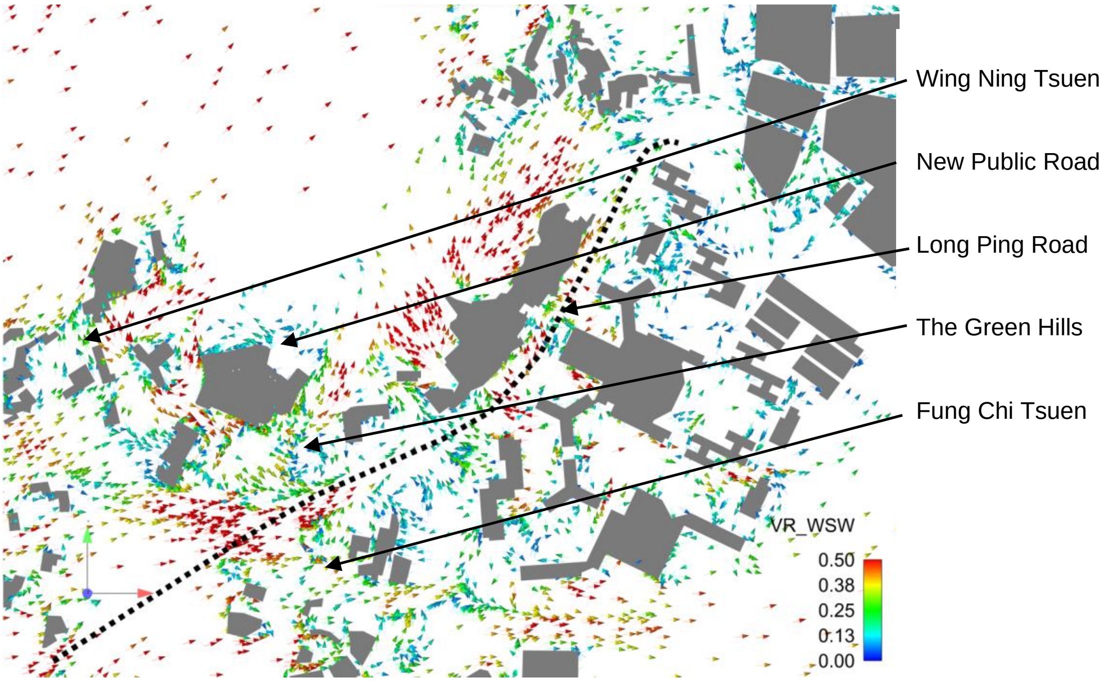
Baseline Scheme





Proposed Scheme

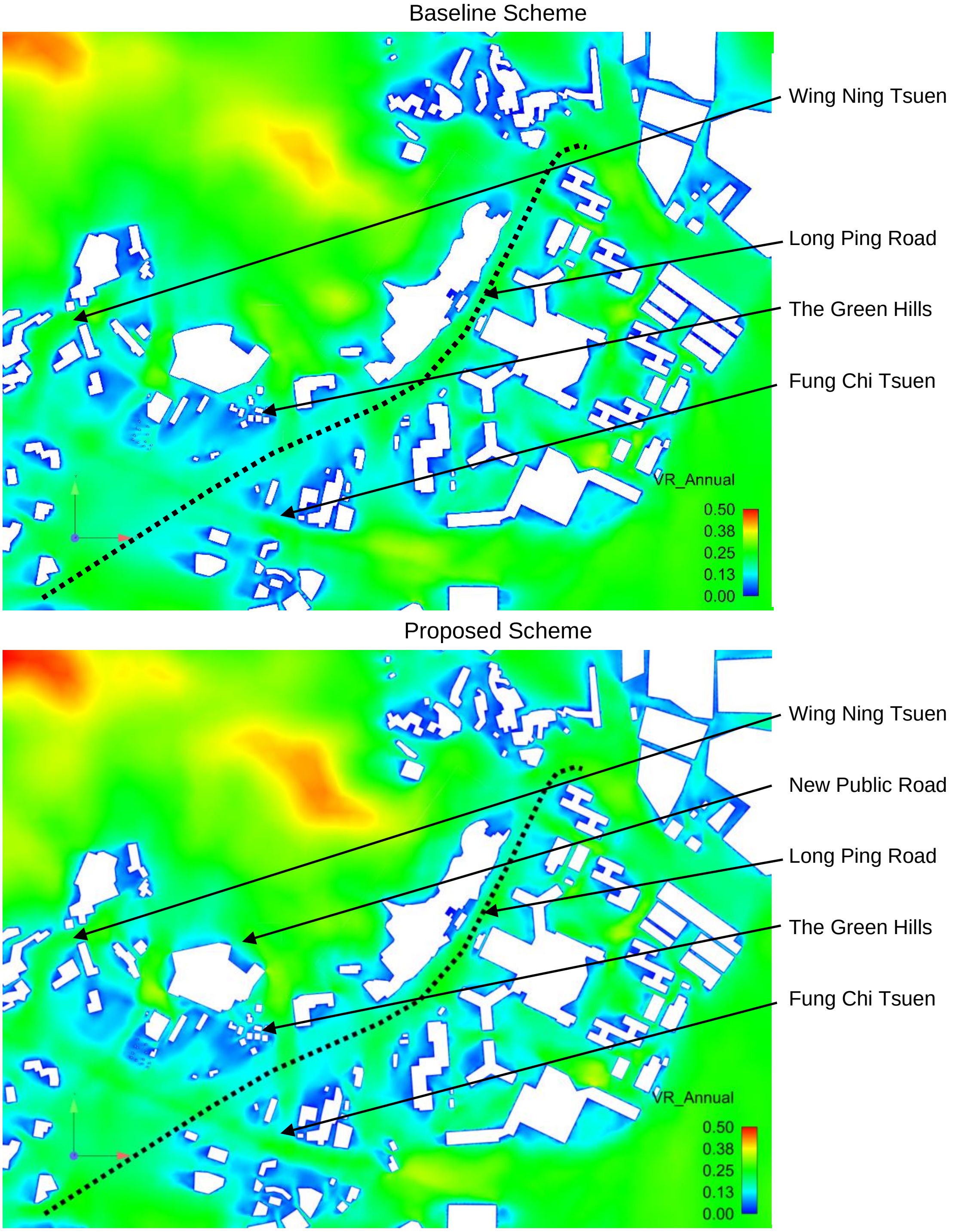




Overall Annual Frequency Weighted VR (76.3%)

6.34 According to the overall annual frequency weighted VR plot, observable air ventilation enhancements and drawbacks are summarized as follows:

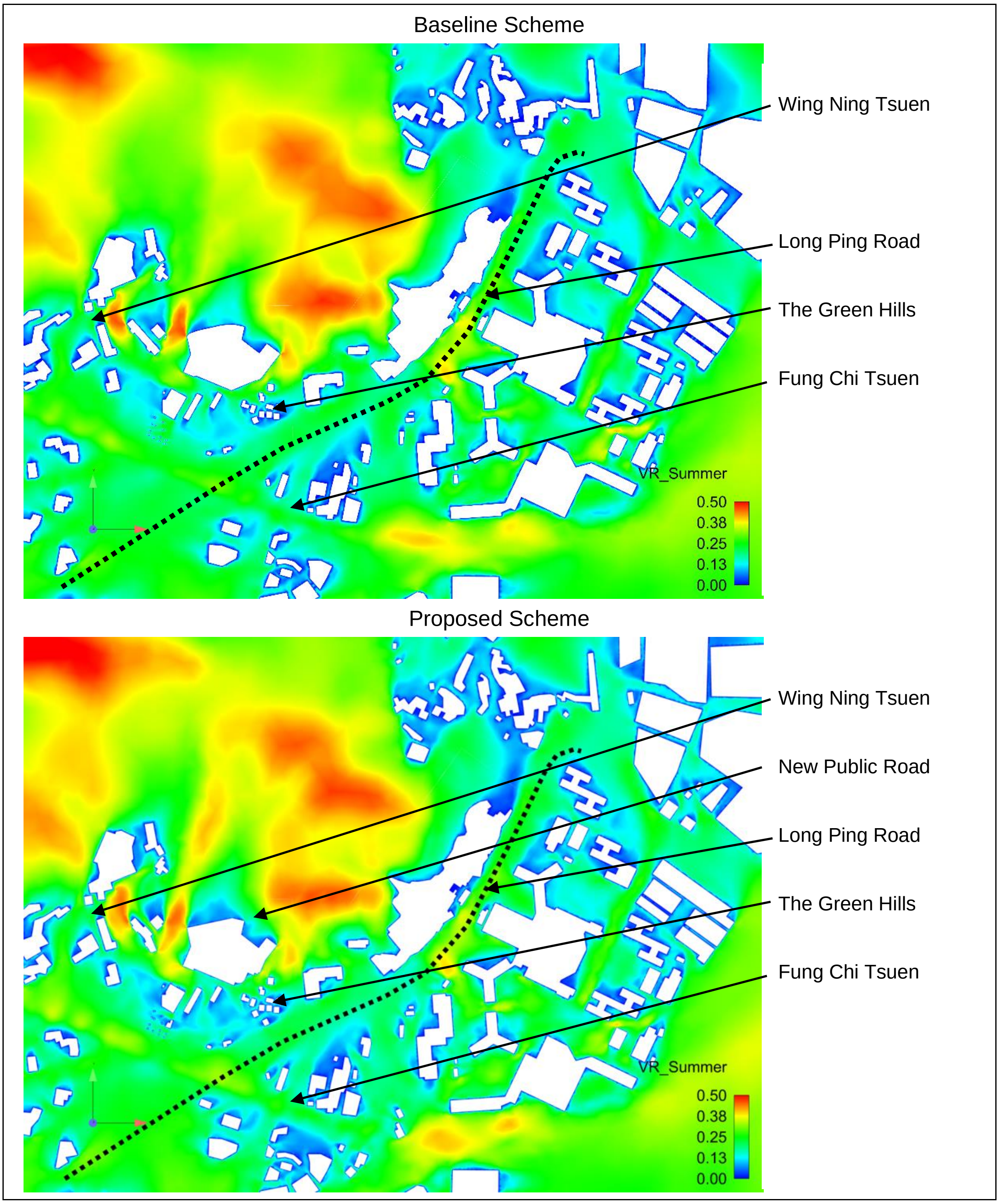
- An observable improvement in air ventilation performance in natural landscapes
- A slightly smaller wind stagnant zone in the north of the Site
- A slightly better wind environment at Wing Ning Tsuen



Overall Summer Frequency Weighted VR (82.5%)

6.35 According to the overall summer frequency weighted VR plot, observable air ventilation enhancements and drawbacks are summarized as follows:

- An observable improvement in air ventilation performance in natural landscapes
- A slightly better wind environment at Wing Ning Tsuen



7 SUMMARY AND CONCLUSIONS

7.1 The Wang Chau Phase 1 Site B of this study is situated at Wang Chau, Yuen Long in the New Territories. It is noticed that the Wang Chau area is generally flat except for natural slopes from mild gradient to hilly towards Kai Shan (121mPD) in the northwest.

7.2 Based on the wind data from the RAMS model, the annual prevailing winds at Wang Chau area are from the NNE, NE, ENE, E, ESE, SE, SSE, SE, and SSW directions, whereas the summer prevailing winds are winds from E, ESE, SE, SSE, S, SSW, SW and WSW directions.

7.3 The existing developments in the vicinity of the Site are residential, village and open storage buildings varying in building height and density, which will cause observable impact upon the wind environment under different prevailing winds.

7.4 There are abundant low-rise buildings that allow prevailing winds to skim over in the vicinity of the Site. These air paths contribute to maintaining the air ventilation performance within the Site and their surrounding areas.

7.5 Wang Chau Phase 1 Site B is located at the north of Long Ping Road, near a large area of natural landscapes. The indicative layout used for Section 16 submission of Wang Chau Phase 1 Site B (i.e. the Baseline Scheme) incorporated building gaps and air permeable spaces at the podium garden levels which would allow winds from the southeast quadrant winds to reach the natural landscapes, thus alleviating the possible wind influence.

7.6 This AVA Study Report aims to assess the characteristics of the wind availability of the Site, providing a general pattern and a quantitative estimate of wind performance at the pedestrian level under the annual and summer wind directions with the highest occurrence and investigating the ventilation impacts for the indicative layout used for Section 16 submission (the Baseline Scheme). During the detail design stage, the Proposed Scheme has incorporated good design features and mitigation measures for the housing development.

7.7 To mitigate the potential air ventilation impact on site perimeter by the Proposed Development, several good design features were considered in the Proposed Scheme, such as widened building setbacks and modified building morphology of Block A to minimize the building frontage and to enhance the wind environment in the immediate vicinity. The effectiveness of wind enhancement features is assessed.

7.8 From the finding of this AVA Initial Study, the SVRw for both the Baseline Scheme and the Proposed Scheme is slightly increased from 0.18 to 0.19 under the annual prevailing wind from NNE, NE, ENE, E, ESE, SE, SSE, SE, and SSW directions which amount to about 76.3% of the whole time in a year. Thus, an improvement in air ventilation performance is observed in the vicinity of the Proposed Scheme under annual prevailing winds.

7.9 The LVRw for the Proposed Scheme is increased from 0.18 to 0.19 compared to the Baseline Scheme under the annual wind directions stated above. It can be concluded that the Proposed Scheme would have a better air ventilation performance compared to the Baseline Scheme under the major annual winds.

7.10 From the finding of this AVA Initial Study, the SVRw for both the Baseline Scheme and the Proposed Scheme is 0.26 under the summer prevailing wind from E, ESE, SE, SSE, S, SSW, SW and WSW directions which amounts to about 82.5% of the whole time in a year, which implies that both schemes would have similar air ventilation performance.

7.11 The LVRw for the Baseline Scheme and the Proposed Scheme has remained 0.25 under summer wind conditions. It can be concluded that the Proposed Scheme would have a comparable wind environment when compared to the Baseline Scheme for Section 16 submission.

7.12 In addition to the good design features identified, the following are some general recommendations that would be adopted as far as practical in the detailed design stage of the Proposed Development to facilitate wind penetration:

- Adopt building permeability equivalent to 20% to 33.3% whenever possible with reference to PNAP APP-152.
- Avoid long continuous façades and face shorter frontages to the prevailing wind directions; and
- Reference to the recommendations of design measures in the Sustainable Building Design Guideline (SBDG) and Hong Kong Planning Standards and Guidelines (HKPSG).

7.13 To conclude, according to the simulation results in **Table 5.1**, improved LVR and SVR are achieved by the Proposed Scheme when compared with the Baseline Scheme under annual wind conditions. Similar LVR and SVR are obtained in both schemes. No significant impact is anticipated on the surrounding pedestrian wind environment due to the Proposed Scheme.

Appendix A

Wind Probability Table

Tabulated Results – Percentage Occurrence of Directional Winds
Annual – 500m

e_00097	Wind direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
V infinity (m/s)	Sum	0.023	0.077	0.104	0.099	0.153	0.096	0.079	0.075	0.073	0.080	0.056	0.025	0.021	0.012	0.013	0.013
00_to_01	0.024	0.001	0.001	0.001	0.001	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.001
01_to_02	0.061	0.003	0.003	0.004	0.005	0.008	0.006	0.005	0.004	0.004	0.004	0.003	0.003	0.004	0.002	0.002	0.002
02_to_03	0.102	0.003	0.005	0.007	0.009	0.015	0.013	0.009	0.007	0.007	0.008	0.006	0.003	0.004	0.002	0.003	0.003
03_to_04	0.132	0.004	0.007	0.011	0.015	0.019	0.017	0.011	0.008	0.009	0.011	0.006	0.004	0.004	0.002	0.003	0.002
04_to_05	0.136	0.004	0.008	0.013	0.017	0.022	0.017	0.012	0.008	0.007	0.011	0.006	0.003	0.002	0.001	0.001	0.002
05_to_06	0.129	0.002	0.008	0.015	0.016	0.021	0.013	0.012	0.009	0.007	0.012	0.006	0.003	0.001	0.001	0.001	0.001
06_to_07	0.112	0.002	0.008	0.013	0.013	0.018	0.009	0.010	0.009	0.007	0.011	0.007	0.002	0.001	0.001	0.001	0.001
07_to_08	0.089	0.002	0.008	0.011	0.009	0.015	0.007	0.007	0.008	0.008	0.008	0.005	0.002	0.001	0.000	0.000	0.000
08_to_09	0.067	0.001	0.007	0.008	0.006	0.011	0.004	0.004	0.007	0.007	0.006	0.004	0.001	0.000	0.000	0.000	0.000
09_to_10	0.050	0.001	0.006	0.007	0.003	0.007	0.003	0.002	0.006	0.006	0.004	0.003	0.001	0.000	0.000	0.000	0.000
10_to_11	0.034	0.001	0.005	0.004	0.002	0.004	0.002	0.002	0.003	0.004	0.002	0.002	0.001	0.000	0.000	0.000	0.000
11_to_12	0.023	0.000	0.004	0.003	0.001	0.002	0.001	0.001	0.002	0.003	0.001	0.002	0.000	0.000	0.000	0.000	0.000
12_to_13	0.015	0.000	0.004	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
13_to_14	0.010	0.000	0.002	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
14_to_15	0.006	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
15_to_16	0.003	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16_to_17	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17_to_18	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18_to_19	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19_to_20	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20_to_21	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21_to_22	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22_to_23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23_to_24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Tabulated Results – Percentage Occurrence of Directional Winds Summer – 500m

e_00097	Wind direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
V infinity (m/s)	Sum	0.014	0.018	0.016	0.023	0.062	0.083	0.073	0.103	0.150	0.166	0.134	0.054	0.044	0.022	0.021	0.015
00_to_01	0.025	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.003	0.001	0.001	0.001
01_to_02	0.060	0.003	0.002	0.002	0.003	0.004	0.004	0.004	0.004	0.006	0.006	0.005	0.004	0.007	0.002	0.002	0.002
02_to_03	0.104	0.002	0.003	0.002	0.003	0.006	0.007	0.009	0.009	0.011	0.014	0.012	0.008	0.009	0.004	0.003	0.003
03_to_04	0.127	0.002	0.002	0.002	0.002	0.007	0.012	0.009	0.010	0.014	0.025	0.017	0.008	0.007	0.004	0.004	0.002
04_to_05	0.113	0.001	0.002	0.002	0.002	0.006	0.013	0.009	0.009	0.012	0.023	0.015	0.008	0.005	0.003	0.002	0.002
05_to_06	0.109	0.001	0.002	0.001	0.001	0.005	0.011	0.009	0.011	0.013	0.024	0.015	0.006	0.003	0.003	0.003	0.002
06_to_07	0.101	0.001	0.001	0.001	0.002	0.005	0.009	0.007	0.011	0.014	0.021	0.015	0.006	0.002	0.002	0.002	0.002
07_to_08	0.088	0.001	0.001	0.001	0.002	0.005	0.009	0.005	0.009	0.018	0.017	0.012	0.004	0.001	0.001	0.001	0.001
08_to_09	0.072	0.000	0.001	0.001	0.001	0.004	0.006	0.004	0.008	0.017	0.012	0.010	0.002	0.002	0.001	0.001	0.000
09_to_10	0.059	0.000	0.001	0.001	0.001	0.003	0.004	0.003	0.009	0.016	0.008	0.008	0.002	0.001	0.000	0.001	0.000
10_to_11	0.044	0.000	0.001	0.000	0.001	0.003	0.003	0.003	0.007	0.011	0.005	0.007	0.002	0.001	0.001	0.000	0.000
11_to_12	0.029	0.000	0.000	0.001	0.001	0.002	0.001	0.002	0.003	0.007	0.004	0.005	0.001	0.001	0.000	0.000	0.000
12_to_13	0.022	0.000	0.001	0.000	0.001	0.002	0.001	0.002	0.003	0.004	0.002	0.004	0.001	0.001	0.000	0.000	0.000
13_to_14	0.014	0.000	0.000	0.000	0.001	0.002	0.001	0.001	0.003	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000
14_to_15	0.010	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000
15_to_16	0.006	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.000	0.000	0.000	0.000	0.000
16_to_17	0.004	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
17_to_18	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
18_to_19	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19_to_20	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20_to_21	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21_to_22	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22_to_23	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23_to_24	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix B

Velocity Ratio

Wind Velocity Ratio – Baseline Scheme

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Overall Annual	Overall Summer
Annual	**7.7%**	**10.4%**	**9.9%**	**15.3%**	**9.6%**	**7.9%**	**7.5%**		**8.0%**			**76.3%**	
Summer				**6.2%**	**8.3%**	**7.3%**	**10.3%**	**15.0%**	**16.6%**	**13.4%**	**5.4%**		**82.5%**
O1	0.10	0.30	0.32	0.21	0.10	0.37	0.28	0.35	0.62	0.49	0.07	0.28	0.36
O2	0.12	0.09	0.22	0.10	0.25	0.48	0.41	0.55	0.50	0.45	0.15	0.25	0.41
O3	0.16	0.24	0.25	0.15	0.21	0.44	0.34	0.48	0.55	0.60	0.14	0.27	0.42
O4	0.13	0.36	0.26	0.19	0.13	0.37	0.28	0.36	0.63	0.51	0.21	0.28	0.38
O5	0.29	0.43	0.21	0.20	0.09	0.31	0.35	0.32	0.59	0.59	0.44	0.30	0.40
O6	0.42	0.37	0.20	0.19	0.10	0.31	0.37	0.33	0.54	0.66	0.67	0.29	0.42
O7	0.44	0.27	0.04	0.10	0.24	0.35	0.25	0.35	0.54	0.33	0.54	0.25	0.36
O8	0.20	0.20	0.06	0.06	0.19	0.30	0.19	0.20	0.26	0.15	0.28	0.17	0.21
O9	0.33	0.36	0.15	0.16	0.17	0.35	0.31	0.29	0.51	0.51	0.43	0.27	0.37
O10	0.19	0.14	0.05	0.01	0.18	0.36	0.05	0.14	0.23	0.24	0.38	0.14	0.19
O11	0.39	0.03	0.02	0.08	0.08	0.29	0.32	0.30	0.38	0.48	0.54	0.17	0.32
O12	0.43	0.45	0.18	0.04	0.32	0.38	0.29	0.37	0.34	0.48	0.49	0.28	0.35
O13	0.39	0.24	0.17	0.02	0.30	0.39	0.23	0.05	0.60	0.09	0.06	0.26	0.24
O14	0.40	0.32	0.15	0.11	0.25	0.36	0.21	0.10	0.26	0.39	0.29	0.24	0.24
O15	0.44	0.33	0.03	0.01	0.11	0.02	0.21	0.22	0.26	0.30	0.25	0.16	0.20
O16	0.53	0.45	0.05	0.11	0.31	0.31	0.19	0.19	0.31	0.37	0.26	0.27	0.26
O17	0.53	0.38	0.01	0.14	0.23	0.22	0.09	0.13	0.15	0.13	0.08	0.21	0.15
O18	0.22	0.03	0.02	0.09	0.02	0.07	0.03	0.06	0.12	0.12	0.04	0.07	0.08
O19	0.40	0.35	0.02	0.14	0.35	0.27	0.18	0.19	0.16	0.19	0.30	0.23	0.21
O20	0.38	0.30	0.01	0.05	0.11	0.21	0.12	0.18	0.14	0.28	0.13	0.15	0.16
O21	0.02	0.16	0.03	0.12	0.18	0.12	0.10	0.10	0.14	0.04	0.23	0.11	0.12
O22	0.06	0.27	0.04	0.15	0.03	0.16	0.04	0.05	0.15	0.31	0.20	0.12	0.13
O23	0.16	0.19	0.06	0.14	0.14	0.16	0.06	0.03	0.15	0.24	0.24	0.13	0.14
O24	0.43	0.21	0.03	0.26	0.09	0.17	0.20	0.11	0.26	0.23	0.17	0.20	0.19
O25	0.05	0.11	0.04	0.23	0.13	0.13	0.23	0.23	0.21	0.20	0.21	0.15	0.20
O26	0.18	0.11	0.04	0.20	0.14	0.17	0.09	0.24	0.36	0.25	0.21	0.16	0.23
O27	0.07	0.10	0.04	0.19	0.14	0.21	0.05	0.18	0.36	0.38	0.18	0.15	0.23
O28	0.50	0.21	0.04	0.20	0.05	0.21	0.04	0.16	0.33	0.41	0.18	0.19	0.22
O29	0.35	0.09	0.05	0.21	0.03	0.18	0.03	0.17	0.31	0.45	0.25	0.15	0.22
O30	0.21	0.09	0.05	0.21	0.02	0.10	0.05	0.09	0.29	0.43	0.26	0.13	0.19
O31	0.18	0.14	0.04	0.19	0.12	0.07	0.06	0.04	0.33	0.41	0.38	0.14	0.21
O32	0.15	0.19	0.03	0.18	0.16	0.18	0.04	0.02	0.42	0.41	0.54	0.17	0.24
O33	0.07	0.21	0.01	0.17	0.21	0.24	0.11	0.08	0.46	0.45	0.65	0.18	0.29
O34	0.04	0.22	0.08	0.16	0.24	0.23	0.15	0.03	0.22	0.27	0.57	0.17	0.21
O35	0.06	0.17	0.08	0.13	0.18	0.30	0.17	0.13	0.24	0.26	0.48	0.16	0.22
O36	0.08	0.17	0.09	0.13	0.21	0.26	0.17	0.18	0.21	0.27	0.46	0.16	0.23
O37	0.09	0.19	0.09	0.16	0.27	0.22	0.19	0.18	0.20	0.28	0.42	0.17	0.23
O38	0.10	0.20	0.11	0.24	0.33	0.25	0.22	0.16	0.19	0.29	0.41	0.21	0.24
O39	0.24	0.19	0.07	0.27	0.12	0.13	0.27	0.12	0.24	0.24	0.08	0.19	0.19
O40	0.41	0.09	0.01	0.17	0.02	0.09	0.04	0.13	0.04	0.11	0.16	0.11	0.09
O41	0.50	0.11	0.01	0.18	0.07	0.14	0.05	0.16	0.19	0.27	0.35	0.15	0.17
O42	0.44	0.17	0.02	0.13	0.08	0.10	0.03	0.07	0.08	0.13	0.31	0.13	0.10
O43	0.25	0.07	0.00	0.05	0.03	0.13	0.02	0.27	0.18	0.21	0.27	0.08	0.16
O44	0.22	0.10	0.10	0.20	0.13	0.31	0.10	0.06	0.26	0.29	0.44	0.17	0.21
O45	0.16	0.11	0.08	0.10	0.18	0.12	0.15	0.04	0.36	0.26	0.39	0.15	0.20
O46	0.05	0.05	0.02	0.04	0.05	0.03	0.07	0.05	0.35	0.20	0.28	0.08	0.15
O47	0.07	0.11	0.08	0.10	0.17	0.18	0.15	0.10	0.35	0.29	0.46	0.14	0.23
O48	0.08	0.24	0.09	0.15	0.22	0.30	0.19	0.19	0.13	0.25	0.51	0.18	0.22
O49	0.01	0.27	0.09	0.15	0.23	0.34	0.24	0.19	0.11	0.09	0.38	0.18	0.19
O50	0.11	0.15	0.14	0.06	0.28	0.37	0.29	0.31	0.25	0.38	0.18	0.19	0.28
O51	0.29	0.16	0.15	0.05	0.27	0.36	0.32	0.29	0.45	0.20	0.26	0.23	0.30
O52	0.20	0.05	0.15	0.04	0.26	0.36	0.33	0.29	0.30	0.41	0.34	0.19	0.30
O53	0.09	0.06	0.13	0.03	0.24	0.35	0.29	0.28	0.23	0.36	0.36	0.16	0.27
O54	0.35	0.07	0.10	0.04	0.20	0.33	0.25	0.22	0.42	0.39	0.49	0.19	0.30
O55	0.06	0.10	0.10	0.04	0.08	0.11	0.07	0.21	0.21	0.11	0.14	0.09	0.14

O56	0.02	0.03	0.15	0.03	0.09	0.25	0.24	0.27	0.32	0.20	0.20	0.13	0.22
O57	0.19	0.06	0.15	0.03	0.03	0.36	0.28	0.28	0.29	0.24	0.26	0.15	0.24
O58	0.22	0.11	0.10	0.04	0.07	0.32	0.25	0.28	0.30	0.17	0.27	0.16	0.23
O59	0.21	0.11	0.01	0.06	0.06	0.24	0.07	0.04	0.12	0.17	0.12	0.10	0.11
O60	0.23	0.18	0.02	0.02	0.03	0.12	0.18	0.29	0.31	0.09	0.14	0.12	0.18
O61	0.51	0.40	0.23	0.02	0.09	0.24	0.09	0.12	0.18	0.27	0.21	0.20	0.16
O62	0.16	0.11	0.06	0.03	0.03	0.32	0.25	0.24	0.34	0.33	0.17	0.14	0.24
O63	0.53	0.42	0.32	0.05	0.14	0.31	0.18	0.39	0.55	0.51	0.37	0.29	0.36
O64	0.39	0.34	0.24	0.04	0.18	0.07	0.16	0.18	0.36	0.59	0.55	0.21	0.28
O65	0.21	0.24	0.18	0.05	0.21	0.06	0.01	0.15	0.18	0.44	0.62	0.14	0.21
O66	0.36	0.44	0.35	0.15	0.12	0.24	0.35	0.32	0.55	0.67	0.52	0.30	0.40
O67	0.37	0.41	0.35	0.09	0.14	0.24	0.32	0.29	0.47	0.63	0.48	0.28	0.36
O68	0.36	0.35	0.34	0.03	0.16	0.23	0.27	0.24	0.36	0.47	0.43	0.24	0.29
O69	0.28	0.23	0.17	0.02	0.11	0.30	0.24	0.32	0.42	0.37	0.36	0.20	0.29
O70	0.14	0.10	0.07	0.01	0.05	0.07	0.10	0.20	0.30	0.20	0.25	0.09	0.17
O71	0.20	0.10	0.15	0.03	0.11	0.05	0.04	0.19	0.56	0.67	0.50	0.14	0.31
O72	0.06	0.09	0.04	0.02	0.08	0.04	0.02	0.10	0.07	0.32	0.21	0.05	0.11
P1	0.29	0.24	0.18	0.03	0.08	0.07	0.33	0.48	0.70	0.68	0.68	0.22	0.44
P2	0.26	0.18	0.05	0.02	0.08	0.07	0.20	0.41	0.51	0.57	0.31	0.15	0.33
P3	0.16	0.10	0.04	0.10	0.16	0.39	0.13	0.29	0.24	0.42	0.54	0.15	0.28
P4	0.50	0.38	0.14	0.16	0.24	0.38	0.35	0.36	0.19	0.35	0.33	0.28	0.30
P5	0.37	0.40	0.25	0.14	0.24	0.43	0.32	0.47	0.32	0.28	0.46	0.29	0.34
P6	0.52	0.46	0.31	0.03	0.06	0.03	0.26	0.43	0.47	0.29	0.30	0.25	0.28
P7	0.48	0.43	0.27	0.03	0.16	0.06	0.32	0.50	0.64	0.60	0.63	0.27	0.42
P8	0.25	0.24	0.17	0.08	0.18	0.06	0.25	0.16	0.19	0.12	0.16	0.17	0.16
P9	0.25	0.23	0.17	0.03	0.25	0.18	0.19	0.21	0.14	0.09	0.08	0.17	0.15
P10	0.17	0.21	0.17	0.04	0.30	0.41	0.28	0.20	0.25	0.14	0.12	0.21	0.22
P11	0.29	0.41	0.04	0.08	0.33	0.52	0.41	0.41	0.44	0.35	0.08	0.29	0.36
P12	0.39	0.48	0.08	0.10	0.26	0.44	0.37	0.50	0.44	0.20	0.09	0.30	0.34
P13	0.48	0.50	0.13	0.09	0.25	0.34	0.30	0.39	0.32	0.56	0.44	0.28	0.36
P14	0.27	0.39	0.02	0.12	0.22	0.26	0.20	0.38	0.36	0.59	0.42	0.22	0.35
P15	0.18	0.31	0.01	0.07	0.23	0.14	0.08	0.26	0.45	0.67	0.52	0.17	0.33
P16	0.14	0.12	0.01	0.07	0.27	0.24	0.13	0.11	0.26	0.43	0.49	0.14	0.24
P17	0.04	0.05	0.02	0.09	0.25	0.20	0.10	0.11	0.15	0.47	0.38	0.11	0.21
P18	0.07	0.05	0.04	0.08	0.14	0.15	0.15	0.09	0.17	0.25	0.27	0.10	0.16
P19	0.10	0.20	0.12	0.05	0.04	0.23	0.17	0.14	0.05	0.35	0.26	0.12	0.16
P20	0.06	0.16	0.06	0.11	0.11	0.08	0.13	0.06	0.11	0.43	0.34	0.10	0.17
P21	0.02	0.13	0.05	0.11	0.06	0.18	0.11	0.08	0.19	0.29	0.38	0.11	0.17
P22	0.04	0.21	0.04	0.12	0.26	0.37	0.21	0.17	0.21	0.23	0.45	0.18	0.23
P23	0.03	0.17	0.08	0.07	0.28	0.38	0.28	0.26	0.15	0.24	0.29	0.17	0.24
P24	0.08	0.07	0.05	0.05	0.11	0.22	0.20	0.16	0.17	0.24	0.18	0.11	0.17
P25	0.08	0.14	0.03	0.04	0.05	0.04	0.08	0.13	0.18	0.20	0.08	0.08	0.12
P26	0.52	0.29	0.12	0.03	0.03	0.10	0.12	0.04	0.06	0.27	0.18	0.15	0.10
P27	0.06	0.06	0.03	0.15	0.21	0.43	0.22	0.29	0.15	0.26	0.43	0.16	0.25
P28	0.08	0.05	0.04	0.02	0.09	0.35	0.21	0.23	0.23	0.24	0.30	0.12	0.21
P29	0.15	0.03	0.04	0.06	0.03	0.29	0.28	0.45	0.65	0.55	0.41	0.17	0.40
P30	0.48	0.38	0.30	0.05	0.15	0.17	0.25	0.44	0.67	0.70	0.52	0.28	0.43
P31	0.35	0.26	0.19	0.05	0.16	0.07	0.15	0.13	0.11	0.10	0.55	0.16	0.14
P32	0.17	0.19	0.13	0.07	0.20	0.05	0.02	0.13	0.11	0.06	0.34	0.12	0.11
P33	0.23	0.19	0.15	0.08	0.08	0.05	0.25	0.40	0.72	0.69	0.64	0.20	0.42
S1	0.13	0.11	0.05	0.09	0.04	0.17	0.09	0.08	0.15	0.31	0.11	0.10	0.14
S2	0.05	0.25	0.08	0.16	0.27	0.26	0.21	0.18	0.18	0.20	0.46	0.18	0.22
S3	0.13	0.26	0.09	0.15	0.24	0.32	0.21	0.19	0.18	0.10	0.39	0.20	0.20
S4	0.07	0.25	0.11	0.08	0.24	0.35	0.25	0.21	0.21	0.17	0.48	0.19	0.23
S5	0.19	0.24	0.08	0.16	0.29	0.21	0.21	0.18	0.27	0.17	0.46	0.20	0.23
S6	0.19	0.25	0.09	0.16	0.26	0.30	0.23	0.19	0.28	0.09	0.23	0.21	0.21
S7	0.09	0.22	0.11	0.07	0.23	0.34	0.22	0.19	0.26	0.29	0.48	0.18	0.25
S8	0.08	0.24	0.05	0.17	0.28	0.28	0.10	0.04	0.04	0.06	0.07	0.16	0.11
S9	0.11	0.17	0.11	0.09	0.26	0.35	0.23	0.15	0.09	0.25	0.42	0.17	0.21
S10	0.19	0.15	0.10	0.11	0.25	0.31	0.20	0.14	0.14	0.19	0.16	0.17	0.18

Wind Velocity Ratio – Proposed Scheme

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Overall Annual	Overall Summer
Annual	**7.7%**	**10.4%**	**9.9%**	**15.3%**	**9.6%**	**7.9%**	**7.5%**		**8.0%**			**76.3%**	
Summer				**6.2%**	**8.3%**	**7.3%**	**10.3%**	**15.0%**	**16.6%**	**13.4%**	**5.4%**		**82.5%**
O1	0.14	0.41	0.36	0.21	0.12	0.36	0.31	0.36	0.60	0.49	0.15	0.30	0.37
O2	0.16	0.32	0.21	0.06	0.25	0.47	0.38	0.54	0.50	0.52	0.12	0.27	0.41
O3	0.15	0.39	0.24	0.08	0.20	0.41	0.33	0.43	0.55	0.55	0.13	0.27	0.39
O4	0.21	0.41	0.24	0.15	0.13	0.35	0.31	0.36	0.62	0.52	0.24	0.29	0.38
O5	0.30	0.40	0.18	0.14	0.09	0.30	0.38	0.36	0.52	0.58	0.50	0.27	0.39
O6	0.45	0.39	0.18	0.13	0.10	0.30	0.40	0.31	0.61	0.61	0.65	0.29	0.42
O7	0.38	0.21	0.09	0.07	0.27	0.36	0.24	0.12	0.56	0.37	0.47	0.25	0.32
O8	0.02	0.23	0.11	0.09	0.20	0.31	0.16	0.09	0.25	0.26	0.11	0.16	0.19
O9	0.38	0.36	0.17	0.05	0.16	0.34	0.26	0.31	0.46	0.55	0.56	0.25	0.36
O10	0.23	0.20	0.11	0.12	0.18	0.36	0.13	0.13	0.15	0.19	0.48	0.18	0.19
O11	0.44	0.08	0.10	0.09	0.10	0.28	0.32	0.19	0.39	0.46	0.52	0.20	0.31
O12	0.43	0.36	0.14	0.10	0.33	0.39	0.28	0.32	0.32	0.44	0.56	0.28	0.34
O13	0.34	0.16	0.07	0.04	0.29	0.39	0.09	0.13	0.57	0.42	0.12	0.22	0.29
O14	0.37	0.15	0.06	0.11	0.24	0.36	0.25	0.13	0.28	0.36	0.33	0.21	0.26
O15	0.48	0.17	0.08	0.04	0.13	0.08	0.21	0.23	0.28	0.26	0.27	0.17	0.21
O16	0.58	0.48	0.07	0.16	0.28	0.30	0.18	0.20	0.35	0.34	0.41	0.29	0.28
O17	0.56	0.43	0.04	0.17	0.15	0.22	0.11	0.11	0.20	0.17	0.13	0.23	0.16
O18	0.14	0.08	0.02	0.14	0.04	0.08	0.02	0.08	0.14	0.16	0.12	0.09	0.10
O19	0.47	0.48	0.02	0.18	0.31	0.25	0.15	0.04	0.31	0.16	0.31	0.26	0.20
O20	0.43	0.38	0.02	0.14	0.09	0.21	0.15	0.15	0.15	0.28	0.25	0.19	0.18
O21	0.17	0.17	0.03	0.14	0.12	0.16	0.03	0.02	0.18	0.03	0.26	0.13	0.10
O22	0.19	0.22	0.02	0.12	0.02	0.22	0.00	0.05	0.18	0.28	0.29	0.12	0.14
O23	0.08	0.22	0.02	0.16	0.10	0.25	0.05	0.06	0.21	0.20	0.25	0.14	0.15
O24	0.36	0.09	0.04	0.24	0.07	0.19	0.27	0.11	0.22	0.19	0.13	0.18	0.18
O25	0.18	0.05	0.06	0.22	0.11	0.19	0.20	0.23	0.20	0.18	0.23	0.15	0.20
O26	0.09	0.06	0.04	0.22	0.10	0.20	0.18	0.23	0.27	0.23	0.14	0.15	0.21
O27	0.15	0.07	0.01	0.24	0.08	0.19	0.07	0.20	0.30	0.34	0.17	0.14	0.21
O28	0.47	0.28	0.05	0.26	0.04	0.18	0.05	0.19	0.30	0.40	0.13	0.20	0.21
O29	0.10	0.18	0.01	0.27	0.02	0.13	0.05	0.18	0.30	0.45	0.31	0.14	0.23
O30	0.15	0.13	0.01	0.26	0.02	0.09	0.04	0.10	0.24	0.43	0.29	0.13	0.19
O31	0.12	0.16	0.01	0.23	0.06	0.21	0.01	0.07	0.28	0.43	0.39	0.14	0.21
O32	0.05	0.22	0.03	0.21	0.19	0.23	0.21	0.09	0.42	0.43	0.64	0.19	0.29
O33	0.05	0.29	0.05	0.21	0.36	0.13	0.11	0.02	0.47	0.51	0.75	0.21	0.31
O34	0.05	0.32	0.11	0.22	0.13	0.20	0.13	0.06	0.29	0.29	0.62	0.19	0.22
O35	0.16	0.27	0.12	0.17	0.19	0.27	0.16	0.15	0.28	0.31	0.52	0.20	0.24
O36	0.21	0.25	0.10	0.15	0.22	0.27	0.19	0.19	0.21	0.33	0.47	0.19	0.24
O37	0.22	0.26	0.08	0.16	0.28	0.22	0.23	0.19	0.18	0.34	0.46	0.20	0.25
O38	0.11	0.27	0.07	0.21	0.33	0.21	0.25	0.17	0.22	0.33	0.43	0.21	0.26
O39	0.34	0.13	0.05	0.27	0.11	0.16	0.28	0.13	0.23	0.20	0.07	0.19	0.19
O40	0.16	0.04	0.07	0.18	0.02	0.12	0.06	0.12	0.06	0.12	0.15	0.09	0.10
O41	0.51	0.22	0.07	0.22	0.07	0.22	0.07	0.17	0.25	0.23	0.29	0.20	0.19
O42	0.31	0.14	0.04	0.14	0.04	0.11	0.05	0.08	0.06	0.09	0.36	0.11	0.10
O43	0.18	0.06	0.02	0.07	0.11	0.03	0.12	0.27	0.16	0.21	0.34	0.09	0.17
O44	0.27	0.09	0.20	0.16	0.13	0.18	0.08	0.05	0.29	0.30	0.40	0.17	0.19
O45	0.11	0.06	0.05	0.10	0.19	0.22	0.15	0.06	0.34	0.28	0.43	0.14	0.22
O46	0.07	0.03	0.02	0.04	0.08	0.06	0.06	0.08	0.38	0.20	0.35	0.08	0.17
O47	0.09	0.10	0.08	0.12	0.18	0.22	0.15	0.18	0.38	0.38	0.48	0.16	0.27
O48	0.24	0.27	0.10	0.16	0.24	0.31	0.21	0.20	0.16	0.24	0.52	0.21	0.23
O49	0.26	0.27	0.12	0.12	0.25	0.31	0.23	0.18	0.13	0.12	0.40	0.20	0.20
O50	0.14	0.28	0.12	0.06	0.32	0.40	0.30	0.30	0.31	0.42	0.28	0.22	0.31
O51	0.05	0.05	0.14	0.05	0.32	0.37	0.30	0.29	0.35	0.25	0.21	0.19	0.28
O52	0.17	0.02	0.15	0.04	0.33	0.36	0.30	0.30	0.38	0.40	0.32	0.20	0.32
O53	0.18	0.04	0.10	0.05	0.29	0.35	0.29	0.30	0.30	0.37	0.37	0.18	0.30
O54	0.35	0.18	0.07	0.05	0.20	0.33	0.33	0.22	0.51	0.36	0.49	0.23	0.33
O55	0.12	0.08	0.03	0.05	0.09	0.17	0.13	0.25	0.23	0.08	0.16	0.10	0.16

O56	0.07	0.04	0.03	0.03	0.06	0.20	0.27	0.28	0.27	0.19	0.14	0.11	0.21
O57	0.19	0.04	0.01	0.05	0.11	0.28	0.29	0.27	0.28	0.24	0.25	0.14	0.24
O58	0.20	0.08	0.13	0.06	0.07	0.25	0.25	0.28	0.27	0.21	0.30	0.15	0.22
O59	0.13	0.07	0.08	0.08	0.03	0.20	0.04	0.07	0.09	0.07	0.18	0.09	0.09
O60	0.22	0.10	0.04	0.04	0.03	0.11	0.23	0.31	0.32	0.09	0.17	0.12	0.19
O61	0.36	0.24	0.21	0.01	0.07	0.23	0.10	0.10	0.21	0.28	0.21	0.16	0.16
O62	0.18	0.12	0.04	0.05	0.02	0.29	0.25	0.24	0.38	0.28	0.16	0.15	0.24
O63	0.44	0.41	0.36	0.06	0.05	0.27	0.19	0.37	0.50	0.48	0.38	0.27	0.33
O64	0.32	0.37	0.34	0.05	0.14	0.07	0.21	0.31	0.58	0.71	0.59	0.24	0.38
O65	0.24	0.29	0.31	0.05	0.20	0.07	0.02	0.09	0.15	0.63	0.65	0.16	0.22
O66	0.36	0.43	0.39	0.23	0.16	0.24	0.37	0.32	0.57	0.68	0.51	0.33	0.42
O67	0.34	0.39	0.37	0.16	0.17	0.24	0.33	0.28	0.49	0.62	0.47	0.30	0.37
O68	0.32	0.34	0.37	0.09	0.17	0.21	0.28	0.24	0.38	0.44	0.40	0.26	0.30
O69	0.24	0.24	0.17	0.02	0.09	0.25	0.23	0.30	0.40	0.34	0.38	0.18	0.27
O70	0.12	0.13	0.10	0.03	0.06	0.03	0.20	0.19	0.22	0.24	0.30	0.10	0.17
O71	0.23	0.22	0.13	0.06	0.13	0.03	0.03	0.10	0.47	0.62	0.54	0.15	0.27
O72	0.04	0.06	0.10	0.05	0.08	0.03	0.04	0.05	0.12	0.54	0.37	0.06	0.17
P1	0.35	0.33	0.15	0.06	0.16	0.11	0.40	0.53	0.60	0.67	0.57	0.24	0.44
P2	0.43	0.37	0.13	0.08	0.19	0.09	0.31	0.44	0.56	0.58	0.10	0.25	0.37
P3	0.36	0.34	0.13	0.12	0.16	0.34	0.20	0.28	0.31	0.50	0.68	0.23	0.32
P4	0.45	0.43	0.16	0.17	0.23	0.37	0.22	0.37	0.32	0.42	0.42	0.28	0.32
P5	0.44	0.35	0.22	0.18	0.24	0.41	0.41	0.49	0.38	0.29	0.48	0.31	0.37
P6	0.50	0.40	0.24	0.02	0.09	0.08	0.23	0.44	0.47	0.36	0.48	0.23	0.31
P7	0.46	0.35	0.19	0.03	0.04	0.10	0.29	0.47	0.46	0.62	0.66	0.22	0.37
P8	0.24	0.28	0.12	0.10	0.16	0.04	0.19	0.18	0.09	0.09	0.12	0.15	0.12
P9	0.20	0.26	0.14	0.09	0.25	0.28	0.09	0.12	0.13	0.11	0.13	0.17	0.14
P10	0.05	0.17	0.14	0.08	0.28	0.45	0.30	0.21	0.33	0.19	0.10	0.21	0.25
P11	0.28	0.20	0.05	0.12	0.30	0.52	0.38	0.38	0.51	0.15	0.09	0.27	0.34
P12	0.39	0.26	0.10	0.10	0.23	0.41	0.31	0.45	0.47	0.36	0.04	0.26	0.35
P13	0.47	0.32	0.12	0.14	0.28	0.36	0.30	0.39	0.37	0.51	0.42	0.28	0.37
P14	0.27	0.43	0.02	0.15	0.27	0.28	0.17	0.40	0.36	0.50	0.27	0.24	0.33
P15	0.19	0.34	0.02	0.08	0.19	0.13	0.12	0.29	0.42	0.62	0.30	0.18	0.31
P16	0.06	0.23	0.03	0.13	0.23	0.22	0.14	0.13	0.28	0.37	0.29	0.16	0.23
P17	0.17	0.11	0.02	0.14	0.09	0.06	0.07	0.13	0.09	0.50	0.14	0.10	0.16
P18	0.22	0.20	0.07	0.10	0.07	0.12	0.09	0.13	0.09	0.30	0.48	0.12	0.16
P19	0.22	0.19	0.10	0.05	0.03	0.30	0.30	0.12	0.21	0.35	0.36	0.16	0.22
P20	0.15	0.13	0.07	0.11	0.08	0.14	0.09	0.11	0.03	0.38	0.29	0.10	0.15
P21	0.02	0.16	0.03	0.12	0.04	0.18	0.11	0.03	0.16	0.20	0.11	0.10	0.12
P22	0.06	0.22	0.09	0.12	0.28	0.39	0.26	0.17	0.14	0.28	0.52	0.19	0.24
P23	0.05	0.10	0.12	0.04	0.31	0.37	0.31	0.23	0.13	0.30	0.42	0.16	0.25
P24	0.11	0.04	0.04	0.04	0.11	0.12	0.19	0.16	0.13	0.26	0.09	0.09	0.15
P25	0.30	0.28	0.14	0.03	0.04	0.04	0.04	0.08	0.11	0.25	0.09	0.12	0.10
P26	0.38	0.34	0.21	0.02	0.03	0.06	0.14	0.02	0.03	0.33	0.28	0.14	0.11
P27	0.07	0.05	0.02	0.16	0.23	0.40	0.20	0.29	0.07	0.33	0.49	0.14	0.25
P28	0.06	0.05	0.04	0.02	0.13	0.15	0.24	0.21	0.26	0.21	0.21	0.10	0.20
P29	0.15	0.03	0.03	0.01	0.05	0.06	0.31	0.47	0.68	0.62	0.45	0.14	0.40
P30	0.42	0.41	0.34	0.07	0.05	0.06	0.30	0.49	0.68	0.69	0.51	0.27	0.42
P31	0.30	0.36	0.28	0.08	0.13	0.09	0.15	0.17	0.24	0.54	0.66	0.20	0.26
P32	0.20	0.27	0.23	0.09	0.05	0.07	0.01	0.07	0.08	0.13	0.47	0.13	0.10
P33	0.26	0.27	0.15	0.10	0.14	0.04	0.33	0.53	0.61	0.70	0.59	0.22	0.44
S1	0.07	0.07	0.04	0.07	0.11	0.12	0.14	0.07	0.21	0.28	0.11	0.10	0.15
S2	0.12	0.26	0.09	0.17	0.28	0.26	0.24	0.20	0.21	0.21	0.51	0.20	0.24
S3	0.13	0.26	0.12	0.15	0.27	0.34	0.24	0.19	0.20	0.09	0.42	0.21	0.22
S4	0.13	0.19	0.16	0.04	0.27	0.34	0.24	0.21	0.18	0.22	0.42	0.18	0.23
S5	0.07	0.23	0.10	0.17	0.29	0.23	0.26	0.22	0.23	0.12	0.51	0.19	0.23
S6	0.04	0.23	0.13	0.16	0.28	0.33	0.24	0.23	0.25	0.09	0.26	0.20	0.22
S7	0.11	0.25	0.14	0.05	0.27	0.34	0.25	0.22	0.20	0.36	0.52	0.19	0.26
S8	0.02	0.23	0.13	0.17	0.29	0.32	0.09	0.06	0.07	0.06	0.06	0.17	0.12
S9	0.04	0.07	0.12	0.08	0.29	0.36	0.23	0.18	0.10	0.32	0.46	0.15	0.23
S10	0.03	0.03	0.11	0.10	0.27	0.33	0.23	0.16	0.19	0.20	0.19	0.15	0.20