Issue No : 4
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AIR VENTILATION ASSESSMENT FOR THE PROPOSED DEVELOPMENT OF PUBLIC RENTAL HOUSING AT EX-SAN PO KONG FLATTED FACTORY SITE

INITIAL STUDY

Report Prepared by :
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EXECUTIVE SUMMARY

Allied Environmental Consultants Limited (AEC) was commissioned by the Hong Kong Housing Authority to undertake an Air Ventilation Assessment (AVA) Initial Study for the proposed public rental housing development at Ex-San Po Kong Flatted Factory Site.

The AVA initial study is to assess air ventilation performance of the building design and its impacts to the surrounding pedestrian accessible locations. Computational Fluid Dynamic (CFD) modelling is used for quantitative ventilation performance evaluation. There are two design schemes being reviewed in this Initial AVA Study including:

1. Scheme 1 Scenario: evaluating ventilation performance within 450m of the subject site after the proposed developments Scheme 1 (original design) is in place.
2. Scheme 2 Scenario: evaluating ventilation performance within 450m of the subject site after the proposed developments Scheme 2 (recommended design) is in place.

The Public Rental Housing project gross site area of approximately 0.68 hectares will comprise of a 100mPD housing blocks with flat production of about 860, a supported hostel for mentally handicapped persons, retail shops and an existing underground sewage pumping station. This proposed development was evaluated in this AVA-IS. To address the improvement measures suggested in the Expert Evaluation Report, the design was proposed to be revised. The air ventilation performance based on this revised design was evaluated as the Scheme 2.

Based on the result of the wind rose analysis, the wind directions for the Subject Site and the surrounding area representative of the prevailing situations are determined to be mainly ENE, E, NE, ESE NNE, SSW, SE and SW. These 8 out of the 16 wind directions which occur for about 79.7% of time in a year are adopted in the Initial Study.

According to the CFD modelling results, the following conclusion can be drawn:

The slightly higher values in SVRw for Scheme 2 demonstrate a slight improvement of air ventilation performance to the immediate surroundings. The slightly lower values in LVRw for scheme 2 demonstrates that the proposed building openings in Scheme 2 will slightly decrease the wind availability of the surroundings.

The higher SVRw than LVRw in Scheme 2 indicates a slight improvement air ventilation on pedestrian level in the vicinity.

In terms of Wind availability within the assessment area, the areas around the proposed development of Scheme 1 or Scheme 2 are comparable where no particular stagnant and wind gust problem has been observed.

Result shows that with provision of the proposed good design features, the development shall cause insignificant impact to the local wind environment as there is no particular wind gust or stagnant area observed both in terms of contour and vector plot and individual VR values.

1. INTRODUCTION

1.1. PROJECT BACKGROUND

Hong Kong Housing Authority (HKHA) proposes to develop the Development of Public Rental Housing at Ex-San Po Kong flatted factory site (the Project). The project site area is approximately 0.68 hectares. The development will comprise of a 100mPD housing block with flat production of about 860, a supported hostel for mentally handicapped persons, retail shops and an existing underground sewage pumping station.

Allied Environmental Consultants Limited (AEC) was commissioned by HKHA to carry out an Initial Study on Air Ventilation Assessment (AVA-IS) to refine and substantiate the Expert Evaluation. The AVA-IS was carried out according to the air ventilation assessment framework as set out in *Technical Circular No. 1/06* and its *Annex A - Technical Guide for Air Ventilation Assessment for Development in Hong Kong* issued jointly by Housing, Planning and Lands Bureau and Environment, Transport and Work Bureau (Technical Guide).

1.2. SCOPE OF STUDY

The objective of this study is to evaluate the wind performance of the development using the methodology of Air Ventilation Assessment (AVA), based on the Technical Circular No.1/06 jointly issued by the Housing Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB) in July 2006.

The Initial Study will refine and substantiate the Expert Evaluation. The following tasks will be achieved with the Initial Study:

- Further refinement of the understanding (good design features and problem areas) of the Expert Evaluation;
- Giving a general pattern and a rough quantitative estimate of wind performance at the pedestrian level reported using Wind Velocity Ratio (VR);
- Refine of the project design and/or design options by applying wind velocity ratio as indicator of wind performance for the Air Ventilation Assessment, and reporting all VR of test points;
- Further defines the “focuses”, wind flow around the different options of block layouts should be simulated using computer model. Consideration of opening in the building mass (e.g. open vent bays at ground level of domestic blocks) should be taken into consideration.

1.3. PROJECT DETAILS

There are two public housing design schemes to be investigated in this Initial Study Scheme 1and Scheme 2

Both Scheme 1 and Scheme 2 have been examined in the Expert Evaluation Report[1], in which mitigation measures and enhancement design features have been adopted to enhance the wind performance:

1. Podium free design
2. Set back distance facing Prince Edward Road East prevent possible blockage of wind channel to industrial area located at the western side of subject site
3. Reduce non-permeability building structures to improve air permeability at the pedestrian level for Scheme 2

The details of the building block in these two schemes are shown in ***Figure 1*** and ***Figure 2*** and the design layout for the enhancement feature is shown in ***Appendix B.***

Due to site constrains of the Subject Site, the space is limited for an alternative site layout plan to improve the wind performance to a larger extent. With the above mentioned mitigations features applied in Scheme 1, it is reasonable to use the Scheme 1 design as a reasonable basis for comparison with the proposed design.

The composition of the Latest Design Scheme of the Project is summarized in ***Table 1.*** The surrounding area of the project site is shown in ***Figure 3.***

According PNAP 152, the permeability for both schemes is the same due to the reason that the permeable elements are not recognizable when looking on both projection planes:

- Projection A (view from south-western):Middle and high zone = 51%, low zone = 45%
- Projection B (view from south-eastern): Middle and high zone = 43%, low zone= 43%

[1] AIR VENTILATION ASSESSMENT FOR THE PROPOSED DEVELOPMENT OF PUBLIC RENTAL HOUSING AT SAN PO KONG-EXPERT EVAULATION, 2012

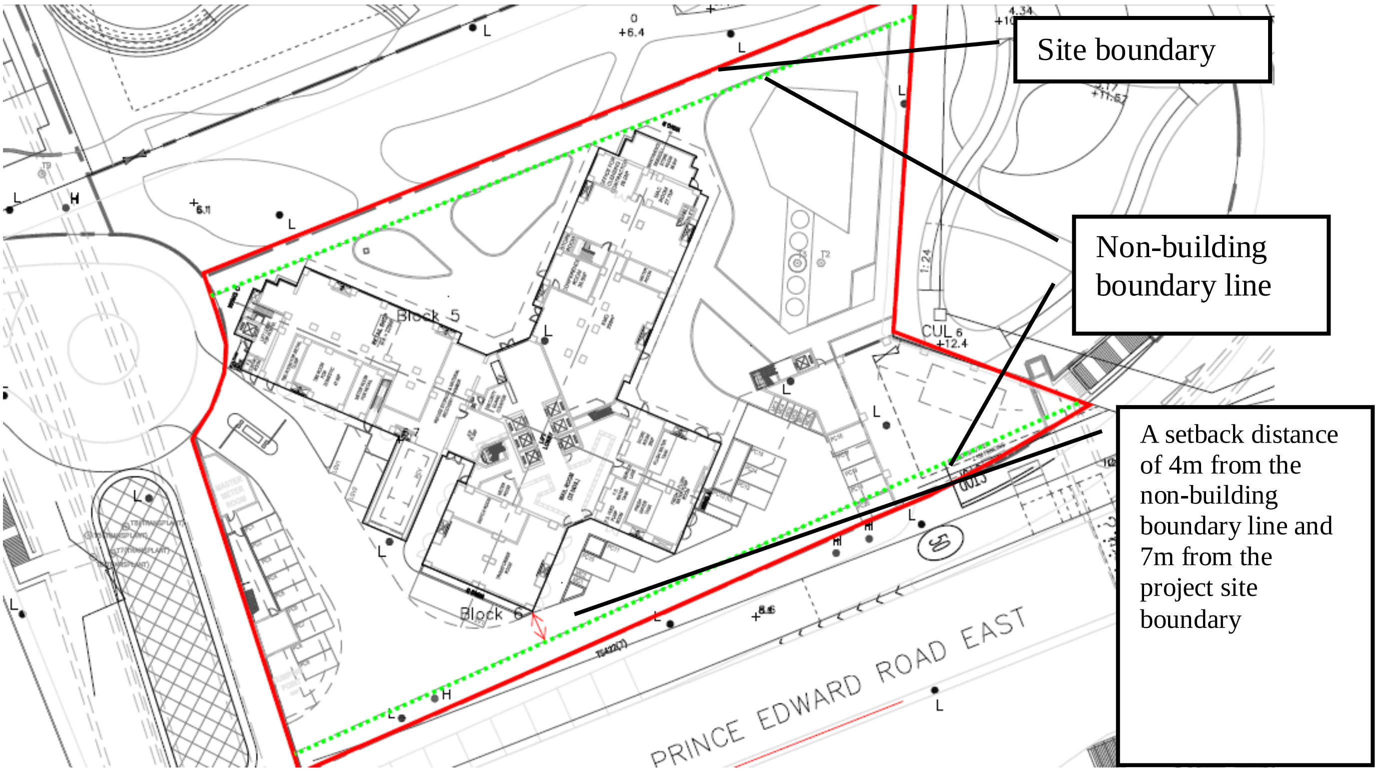


Figure 1 Setback distance from project site boundary and non-building boundary line

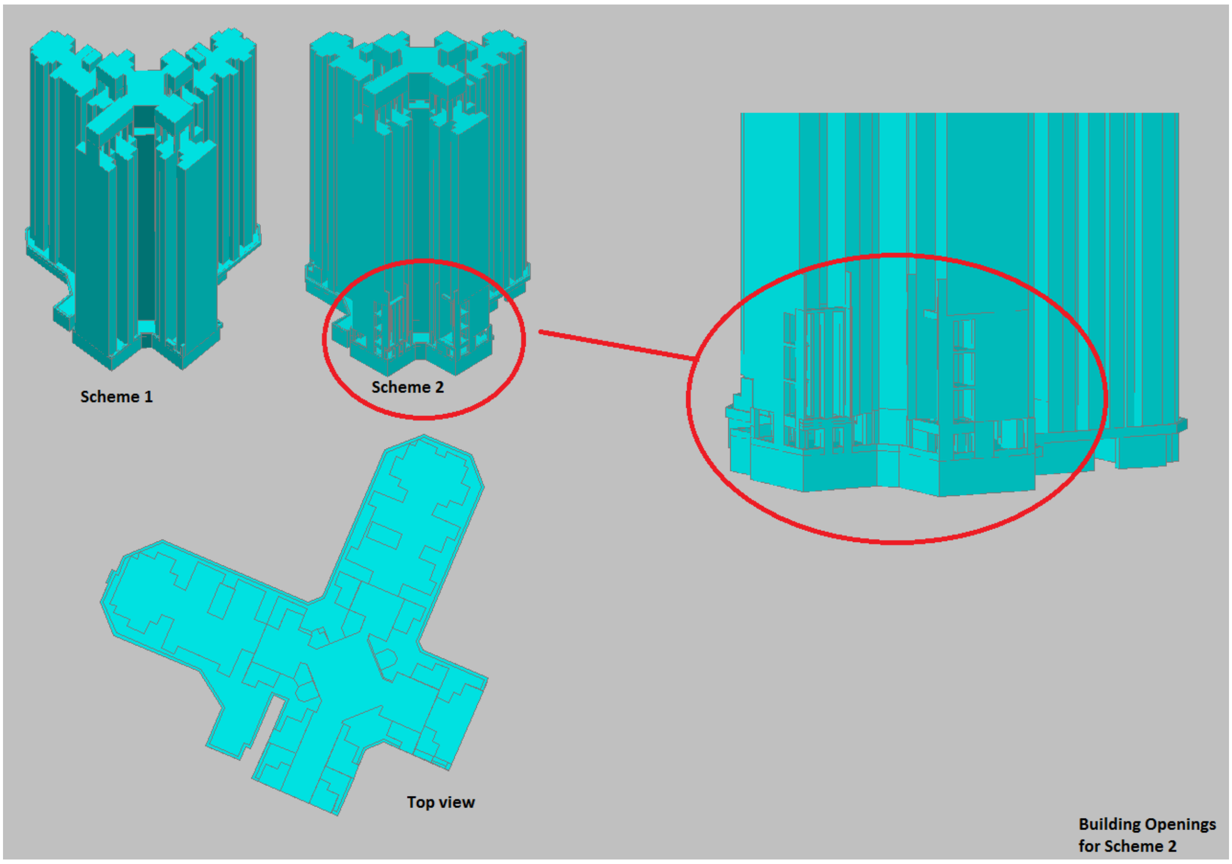


Figure 2 Comparison of Scheme 1 and Scheme 2

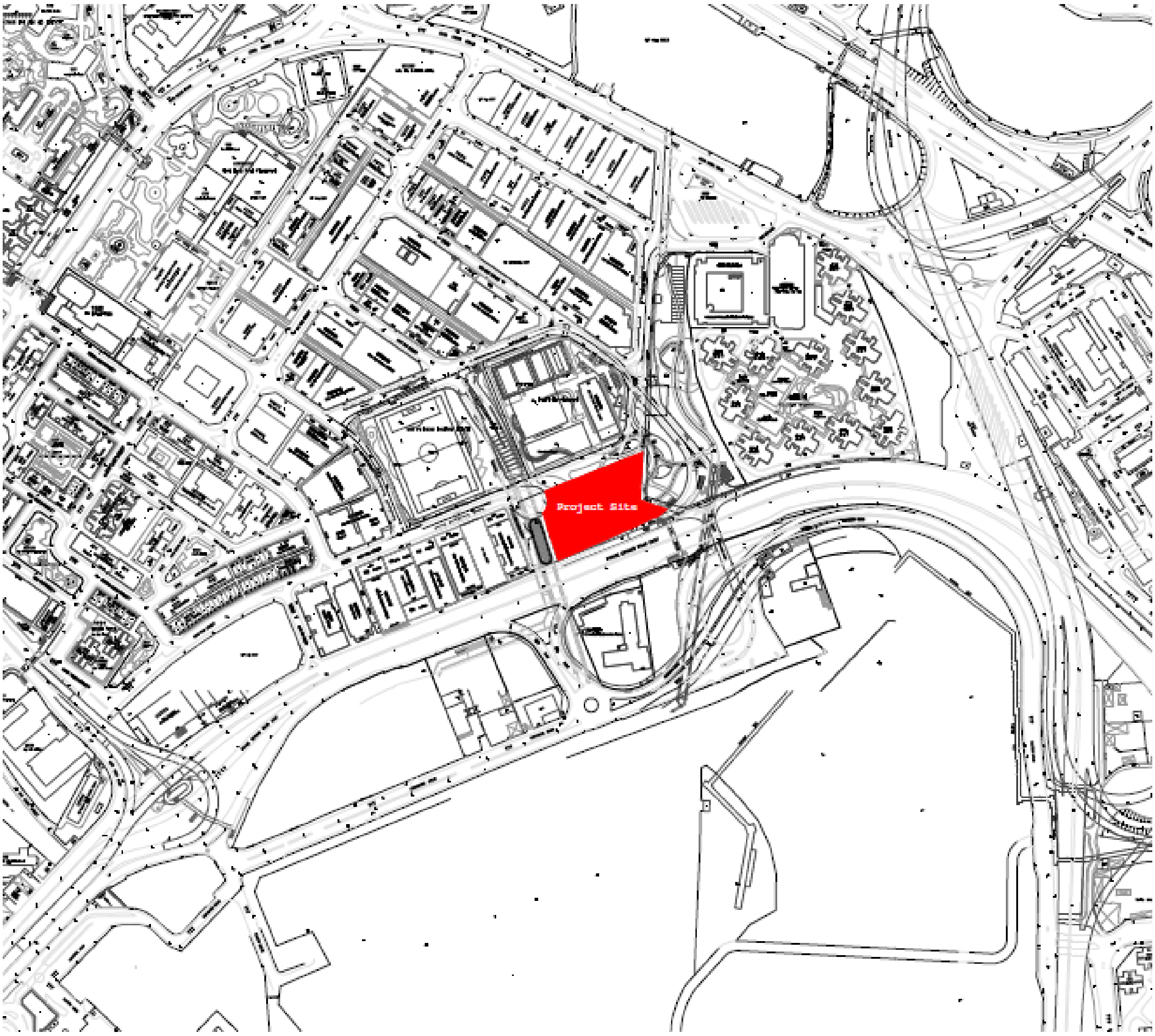


Figure 3 Layout Plan for the Project

	Proposed Development
Site Area	Around 0.68 hectares
No of Residential Blocks	1
No of flats	Around 860 units
Building Height	100mPD
Other Facilities	A supported hostel for mental handicapped persons, retail shops and a existing underground sewage pumping station

Table 1 Scope of the Project

2. WIND AVAILABILITY

The wind data from Hong Kong Observatory (HKO) and Mesoscale Model (MM5) published by Planning Department were adopted in this AVA-IS. The HKO wind data represents the lower level wind availability where the wind direction is influenced by local topography in the surrounding environment while the MM5 wind data represents the wind availability at boundary layer (i.e. 596mPD).

The occurrences of winds from different direction are referred to MM5 wind data while local wind conditions for different seasons (annual and summer periods) are referred to HKO wind data due to MM5's limitation.

2.1. WIND DATA FROM HONG KONG OBSERVATORY

There is a HKO automatic weather station located in the vicinity of the subject site, Kai Tak (KT) which is approximately 3.7km on the south-east away from the subject site as shown in ***Figure 2***. However, as there are not sufficient data available at the closest Kai Tak weather station, the wind data of Hong Kong Observatory (HKO) weather station are obtained to identify wind availabilities during annual and summer periods as this seasonal information are not available in MM5 data.

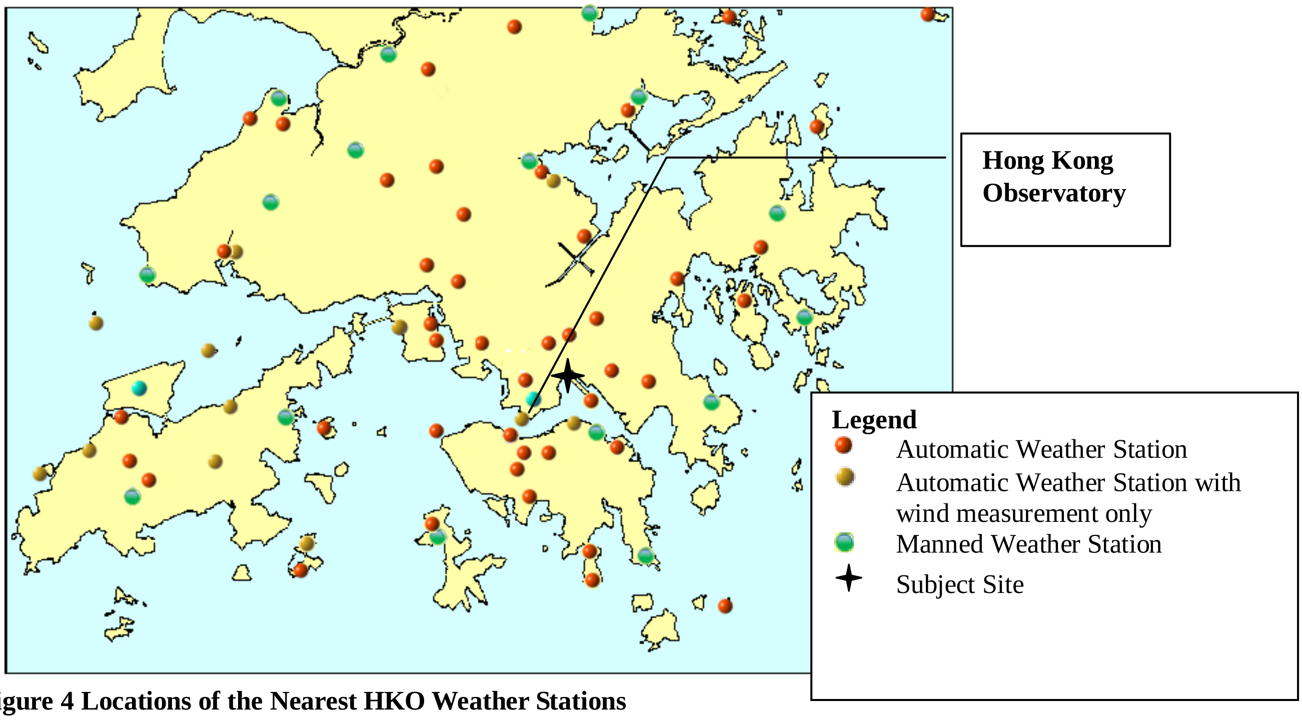
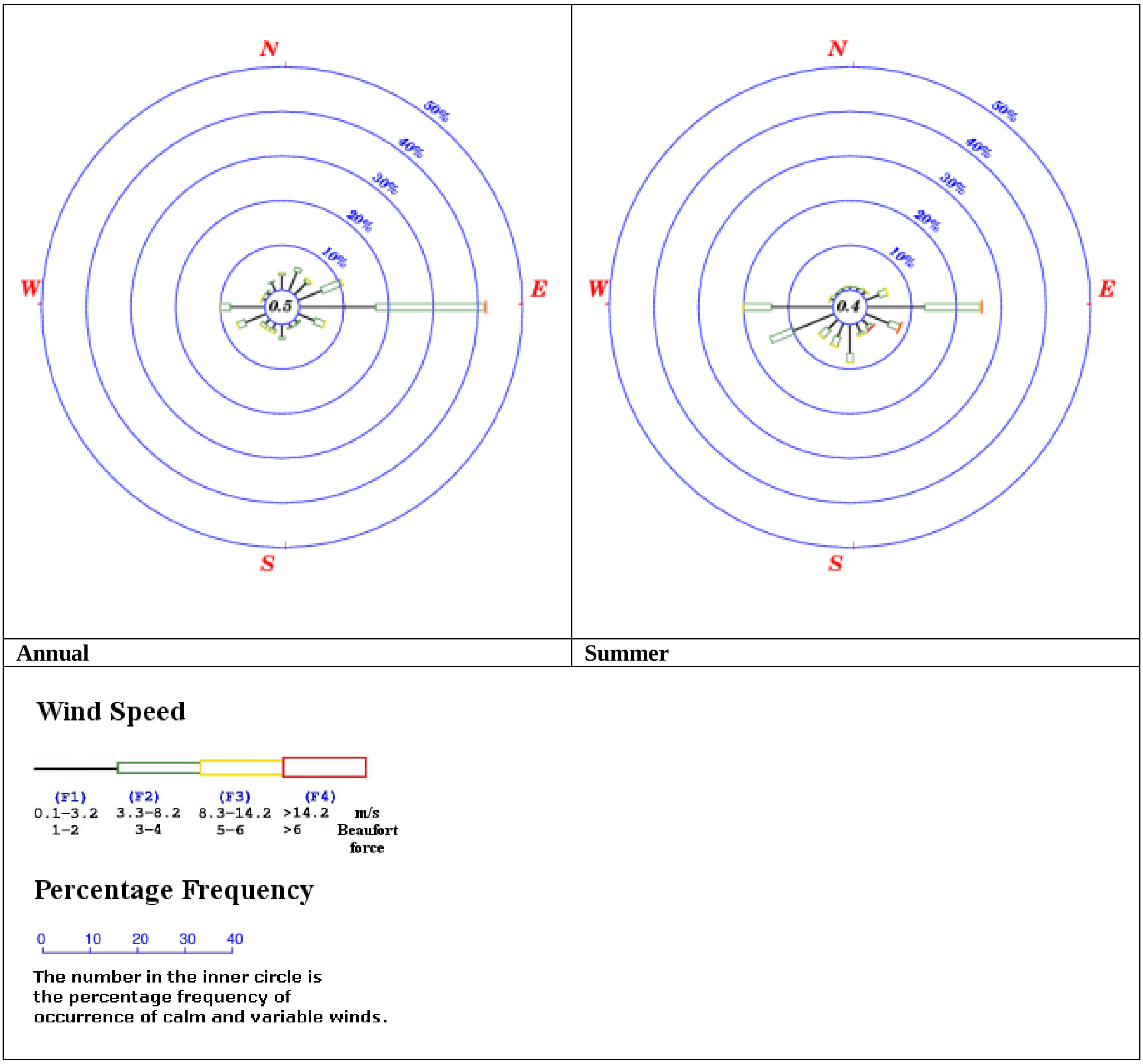


Figure 4 Locations of the Nearest HKO Weather Stations

2.1.1. Hong Kong Observatory Weather Station

The recorded annual mean wind speed measured at anemometer of HKO automatic weather station was 3.1 m/s (11km/hr) from 1981-2010. ***Figure 5*** shows the season wind roses for HKO station from 2010. The monthly prevailing wind direction and wind speed of year 2010 are tabulated in ***Table 2***. It is found that wind mainly comes from east, and south-west direction in summer period, while wind from east (E) dominates annually.

Figure 5 HKO Wind Rose (1981-2010)



Month	**Monthly Prevailing Direction (Degrees)**	**Wind Speed (m/s)**
January	90	2.94
February	90	3.25
March	90	3.33
April	90	3.19
May	90	2.97
June	90	2.94
July	260	2.97
August	90	2.83
September	90	3.17
October	90	3.36
November	90	3.06
December	90	2.78

Table 2 Wind Availability Data of HKO 1981-2010

2.1.2. Wind Data from MM5

The wind availability to the subject site is evaluated with reference to the "Site Wind Availability Data" simulated by the Fifth-Generation NCAR/Penn State MM5 at the height of 596m above ground (Boundary Layer). The subject site is located within grid (29, 28) and its wind rose is shown in ***Figure 6***.The wind velocity ranges from 0 to 24m/s from 16 wind directions and the mean wind velocity is 5.73m/s. It is found that east (E) and east-northeast (ENE) winds dominate the annual wind frequency.

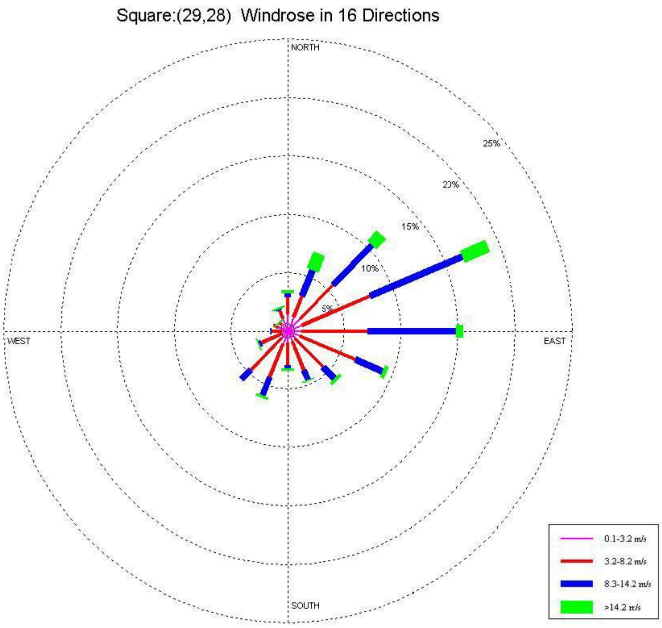


Figure 6 Wind Rose of Grid (29,28), MM5

Power law is used to convert the MM5 data at 596m above ground level to pedestrian level at 2m above ground level by taking consideration of the effect of topography/built-up area in the vicinity of the subject site on site wind availability.

2.1.3. Findings of Wind Availability

Based on the wind data from HKO and MM5, it is concluded that winds come from E are dominant annual and wind from E and SW direction dominates during summer.

3. EXPERT EVALUATION

This AVA-IS quantitatively evaluates the ventilation performance in the site environment within project and its surroundings. The study area of air ventilation assessment is approximately 500m from the subject site boundary. The conditions under annual and summer are considered. Building heights, street/road orientation and patterns, and open spaces have also been taken into account for evaluating the characteristics of wind environment.

3.1. EXISTING CONDITION

The subject site is currently a flatted factory site as shown in ***Figure 7***. The existing conditions of subject site (i.e. without the Project) are summarized as the follows.

- Building Heights

The subject site is located in the southern end of San Po Kong industrial and commercial area, the existing land uses in the vicinity of the subject site includes residential, commercial, industrial and recreational areas. The building heights of the existing buildings located within the study area are shown in ***Figure 7.***

The height of majority of the existing commercial and industrial buildings located to the west and north of the subject site are ranged from 45mPD to 133mPD. These buildings would not cause significant impediments to the dominant E wind during annual and summer period but would have an effect on the SW wind during summer period to penetrate to the street level.

High-rise residential buildings are located on the east side of the subject site. The building heights of these residential buildings range from 70 to 90mPD which cause certain amount of prevailing eastern wind to be obstructed from the east direction.

- Road/Street Pattern

Roads such as Prince Edward Road East and the open area next to Rhythm Garden to the east of the project site are considered as corridors within the study area for both annual and summer prevailing winds.

- Open Spaces

Open spaces and areas are located immediate to the east and north of the project site. The open spaces are currently unoccupied. These open spaces promote air circulation at pedestrian level and increase pedestrian comfort.

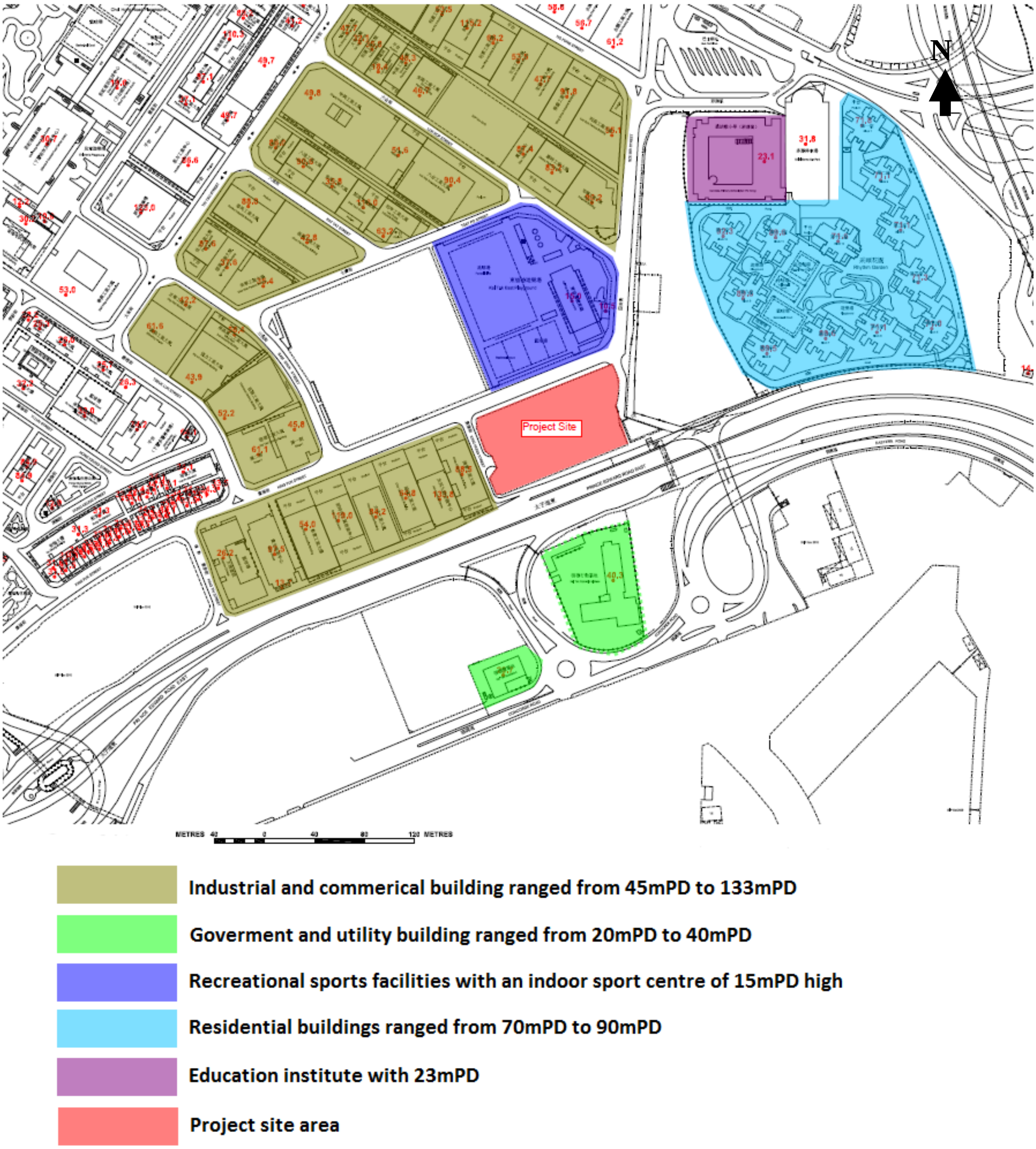


Figure 7 Existing Land use of the Project

3.2. PROJECT AREA, ASSESSMENT AREA BOUNDARY AND SURROUNDING AREA BOUNDARY

The project area is defined by project site boundaries including both housing developments and all open areas for which pedestrian area likely to access. The shaded area as shown in ***Figure 8*** is the project site area.

The assessment area (encoded by blue boundary line) includes the site's surrounding environment up to a perpendicular distance H (where H is the height of the tallest building within the project site) as shown in ***Figure 8***. For this project, H is the height of the AIA Financial Centre, which is 130 m. Therefore the assessment area is determined by offsetting the project site area of 130m.

The surrounding area includes the site surrounding environment p to a perpendicular distance of 2H which is 260m. However there are buildings and obstructive buildings located outside the predefined assessment area regions; thus the surrounding area for this AVA initial Study has been enlarged outside the project boundary to 450m as shown in ***Figure 8*** (encoded by red boundary line).

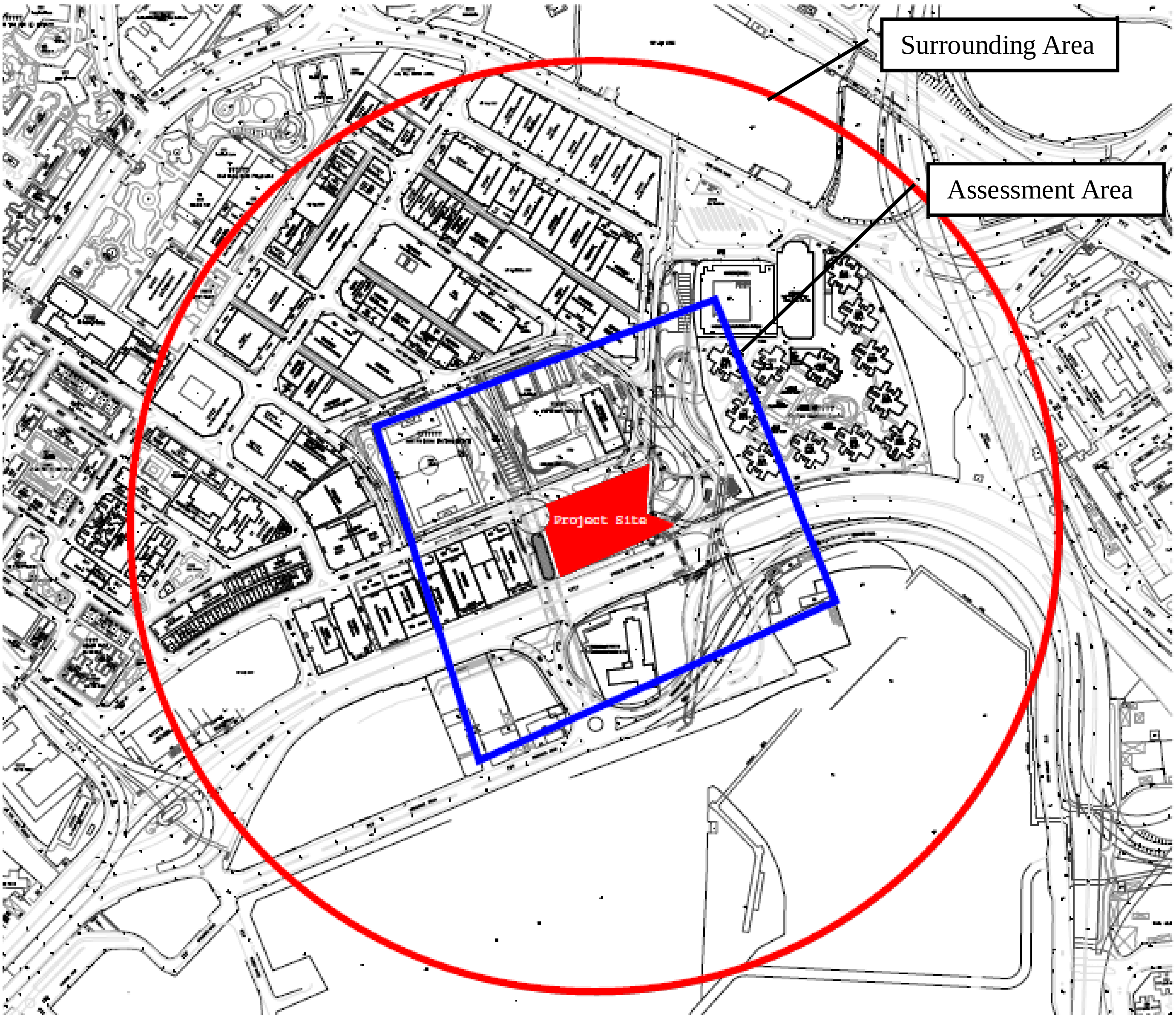


Figure 8 Project site boundary, assessment area boundary and surrounding area boundary

3.3. PREVAILING WIND CONDITION FOR EXISTING ENVIRONMENT

Throughout the year, it is expected that the prevailing winds from E direction flow pass the subject site.

Although some high-rise residential buildings are located to the east of the subject site as shown in ***Figure 9***, the open area in between these buildings acts as a ventilation corridor to allow the prevailing winds reaching to the subject site and the ventilation at pedestrian level is generally maintained.

During the summer period, it is expected that the prevailing winds from E and SW directions flow pass the subject site.

As shown on ***Figure 10,*** the mid to high-rise industrial and commercial buildings are located immediate to the west of the project area. However the open area immediate south and north and in between these buildings also acts as a ventilation corridor to allow the prevailing winds reaching to the subject site.

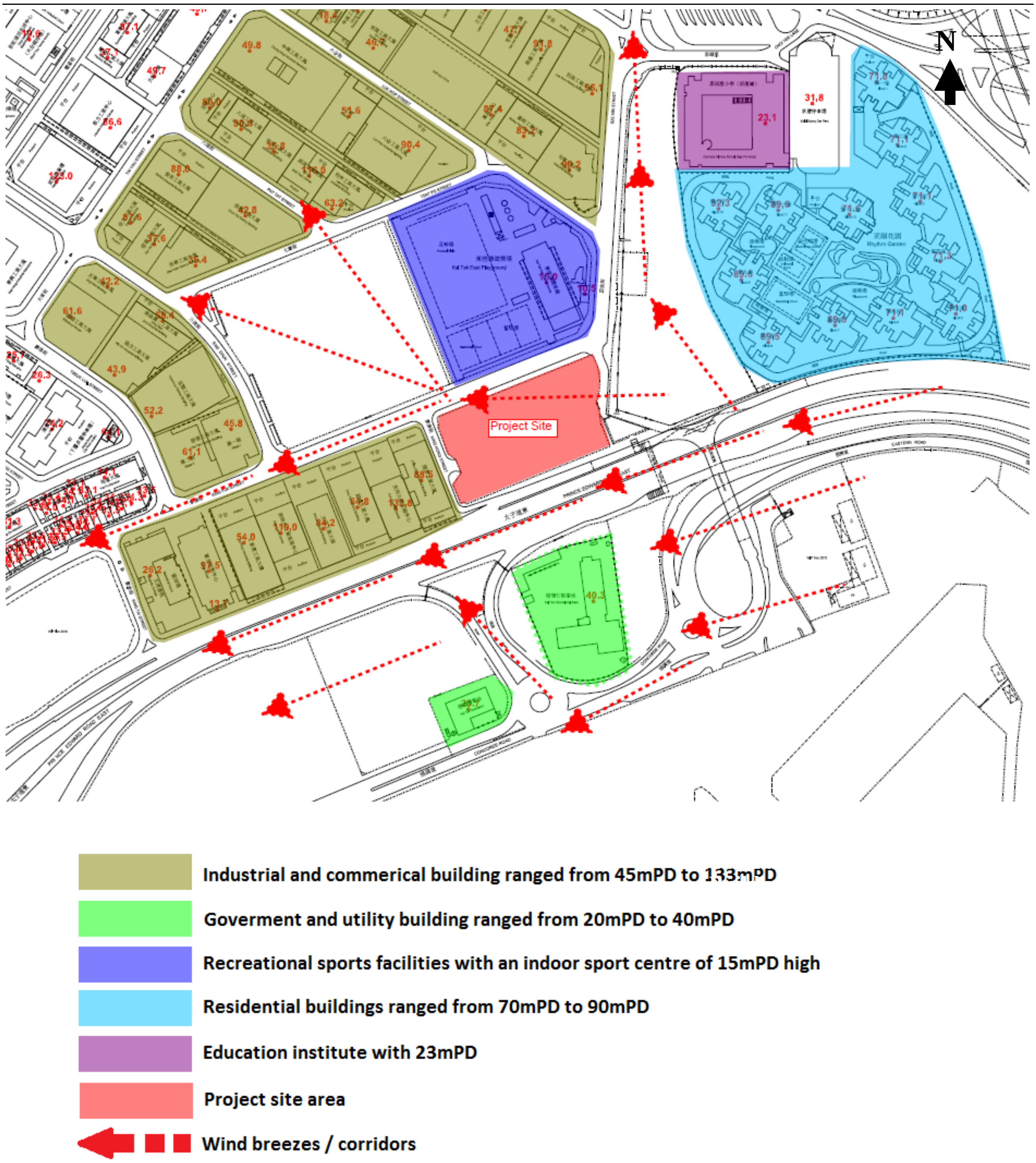


Figure 9 Existing Annual Wind Environment at Subject Site (E Wind)

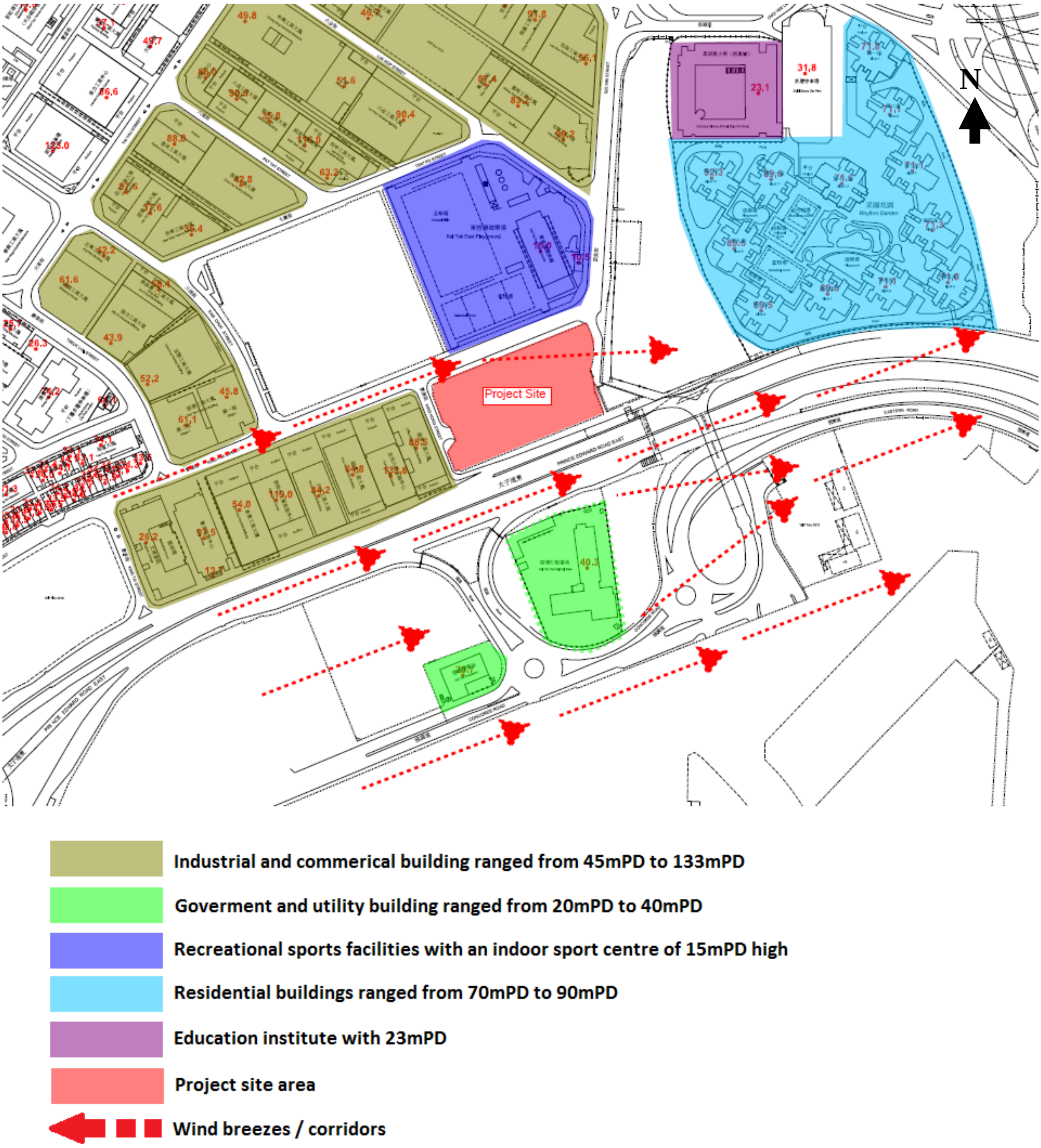


Figure 10 Existing Summer Wind Environment at Subject Site (SW Wind)

3.4. PROPOSED DEVELOPMENT

The proposed site layout of scheme 1 as shown in ***Figure 11*** comprises one residential building with a building height of 100mPD. The main building block is an X-shaped housing block where short edges are located at the southern side of the block. The subject building locates about 30m north east of the closest industrial building Chiap King Industrial Building.

A setback distance of 7meters from Prince Edward Road East is provided reduce the impediment of upcoming prevailing wind across Prince Edward Road East.

Scheme 2 design is similar to Scheme 1 but with building openings located at the 2/F to 8/F at the southern side of the building block where the short edges of the X-shape. An open area of 210m^2 is located at 2/F to 3/F and an area of 30m2 at 4/F to 8/F. is as shown in ***Figure 12*** and *Error! Reference source not found.* **.**

The extent of these impacts was quantitatively investigated by CFD simulation and details of methodology are given in ***Section 4***.

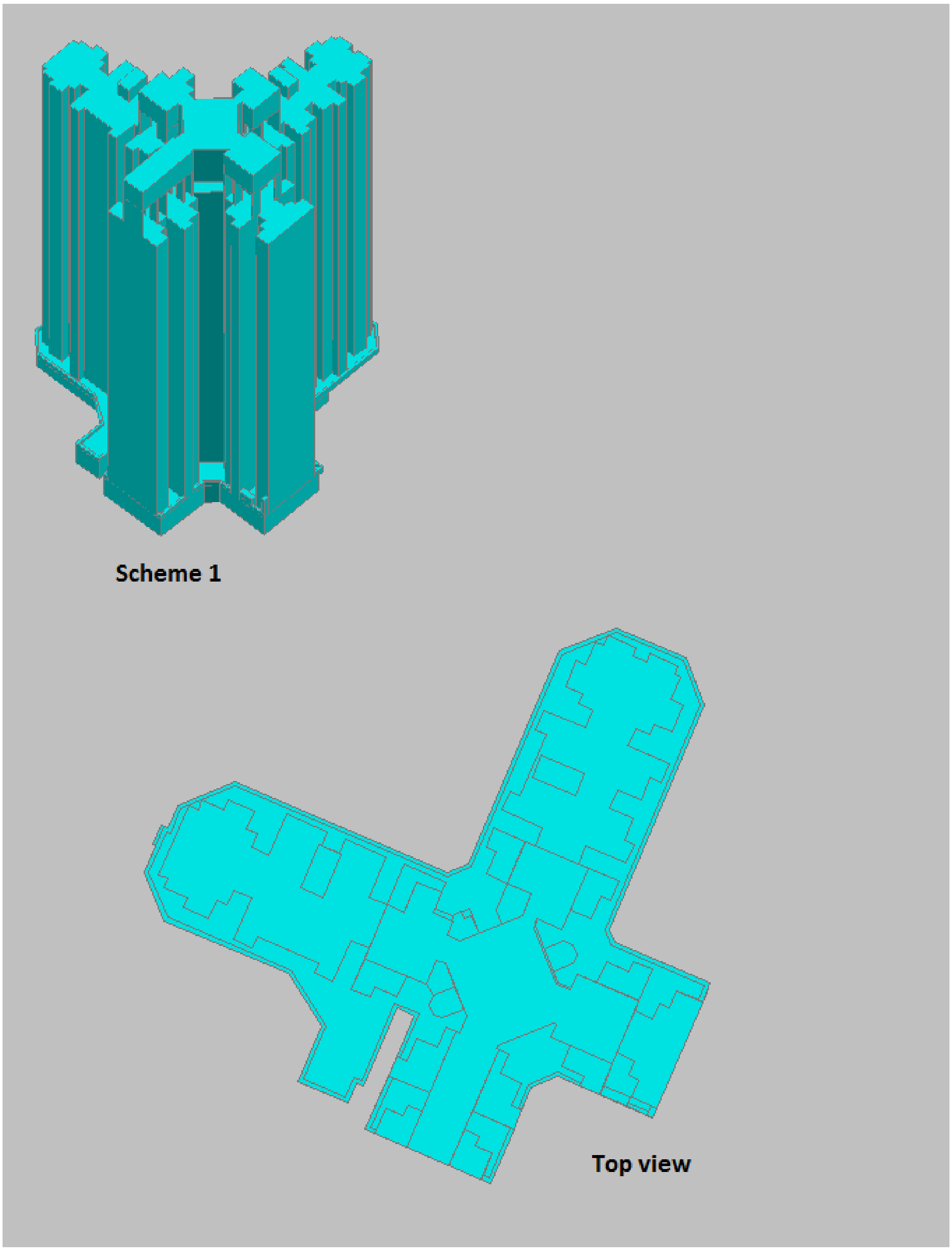


Figure 11 Scheme 1 design layout

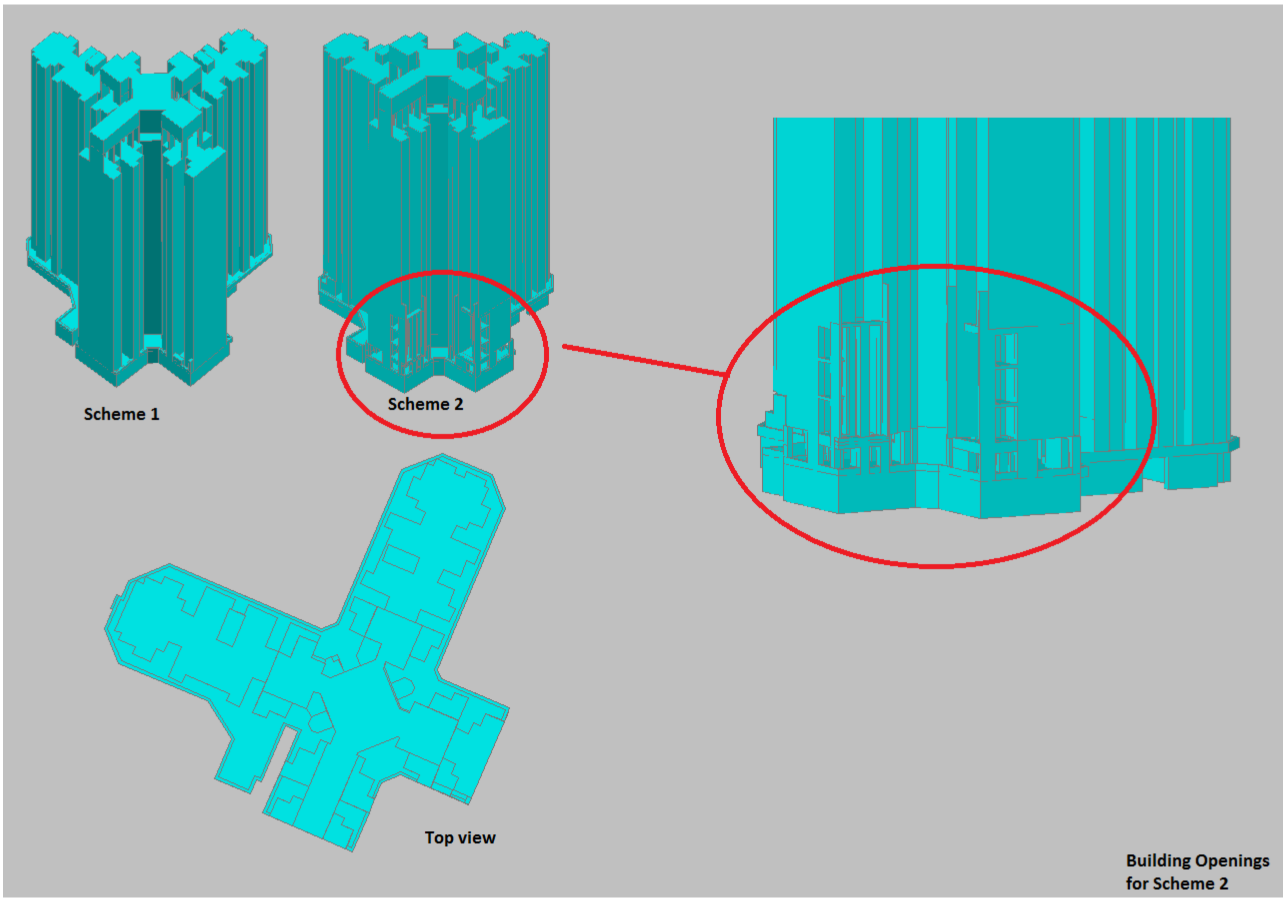


Figure 12 Scheme 2 design layout

4. ASSESSMENT APPROACH AND METHODOLOGY

4.1. MODELLING TOOL

The AVA study is carried out in accordance with the guidelines stipulated in the Technical guide for AVA for developments in Hong Kong with regards to a computational fluid dynamics (CFD) computer simulation model, ANSYS FLUENT.

The CFD model solves algebraic equations resulting from the application of the conservation laws of physics to finite volumes of space and time to simulate wind flow.

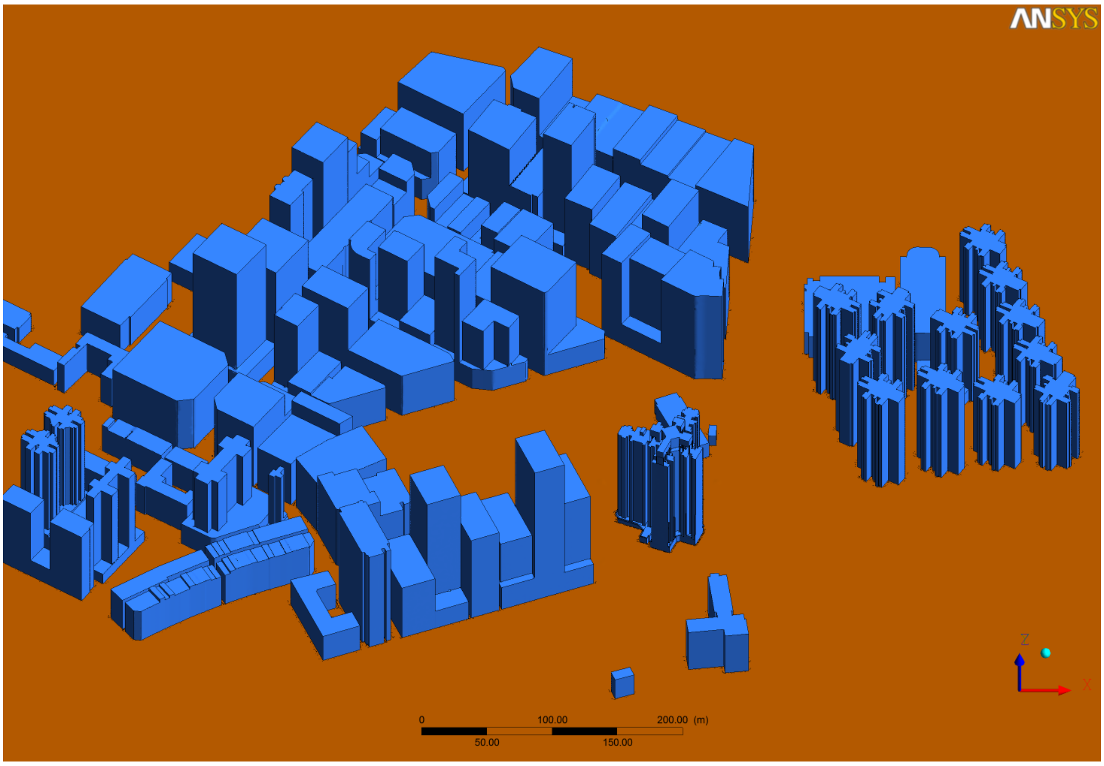
There are two Scenarios being assessed by CFD modelling in this Initial AVA Study.

1. Scheme 1 Scenario: evaluating ventilation performance within 450m of the subject site after the proposed developments Scheme 1 (original design) is in place.
2. Scheme 2 Scenario: evaluating ventilation performance within 450m of the subject site after the proposed developments Scheme 2 (recommended design) is in place.

4.2. GEOMETRY AND DOMAIN SETTING

Geometry and simulation options for the subject developments and surrounding environment have been set up to calculate the wind speed around the developments and in the surrounding ambient. Related wind speeds around the developments were assessed by setting up a geometry model of the developments with surrounding building structures. Computational Fluid Dynamics (CFD) simulation software FLUENT ANSYS shall be used in the Initial Study.

In this study, 3-dimensional models within the surrounding and assessment area were built in order to conduct CFD simulation. The 3D models for both schemes are shown in ***Figure 13&Figure 14.***



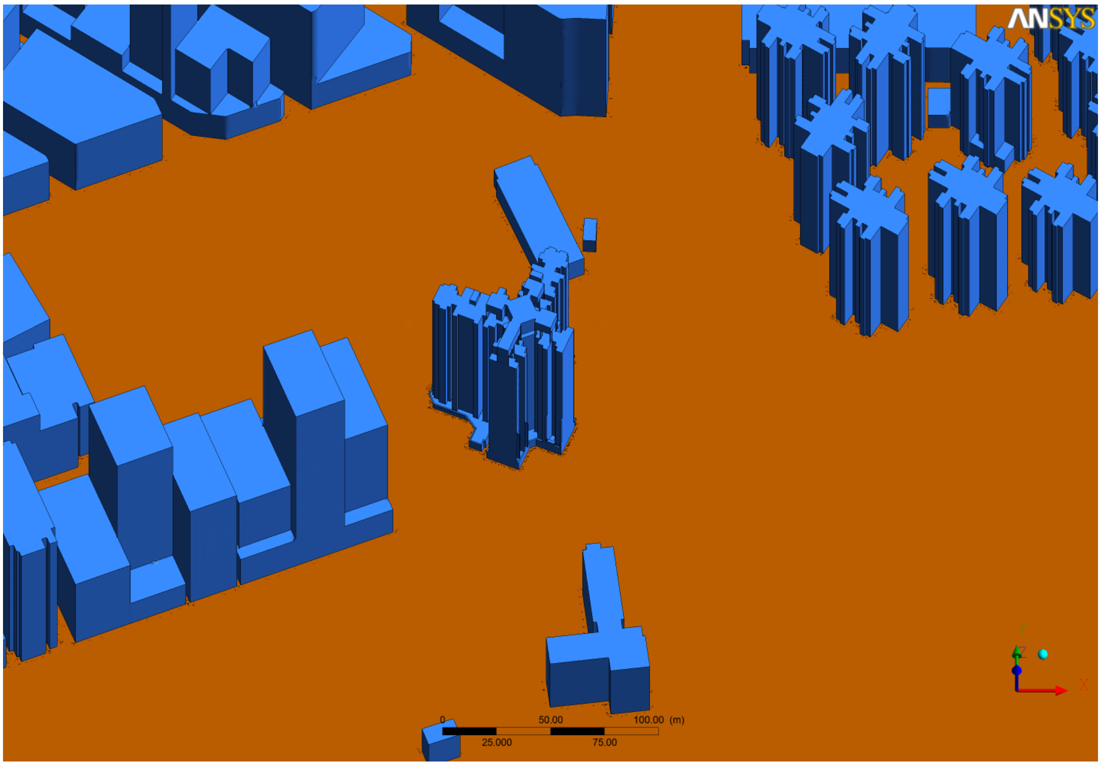
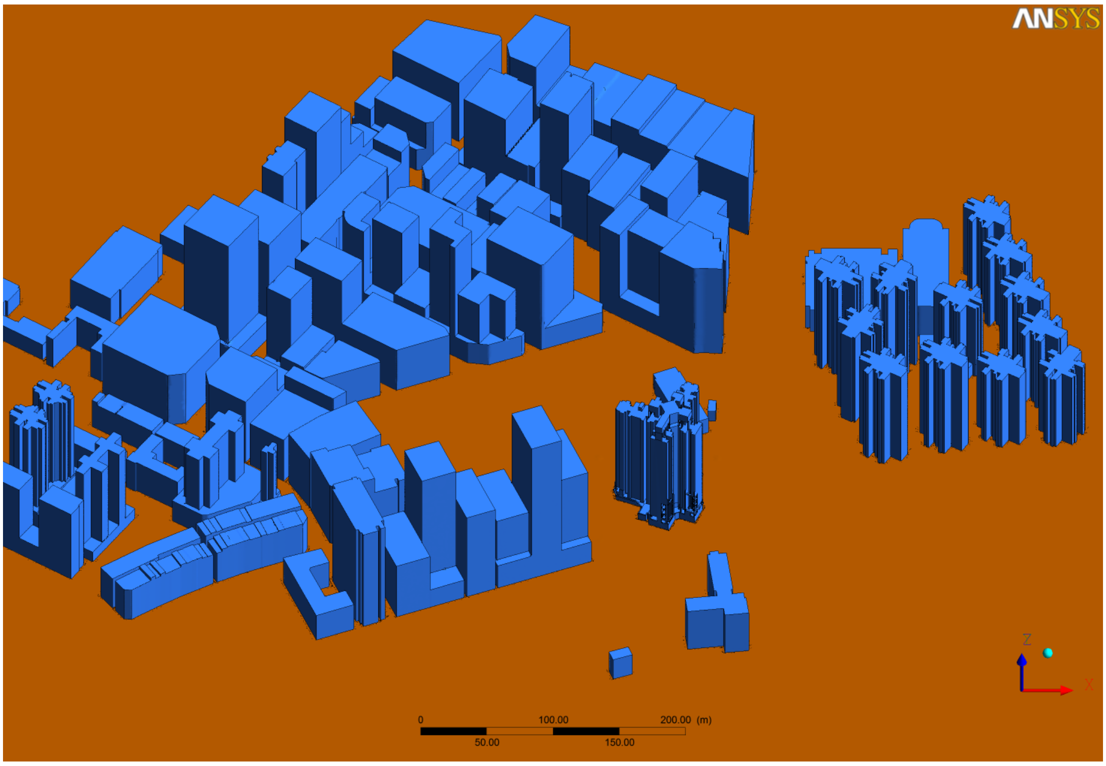


Figure 13 Dimensional Virtual Model of Scheme 1



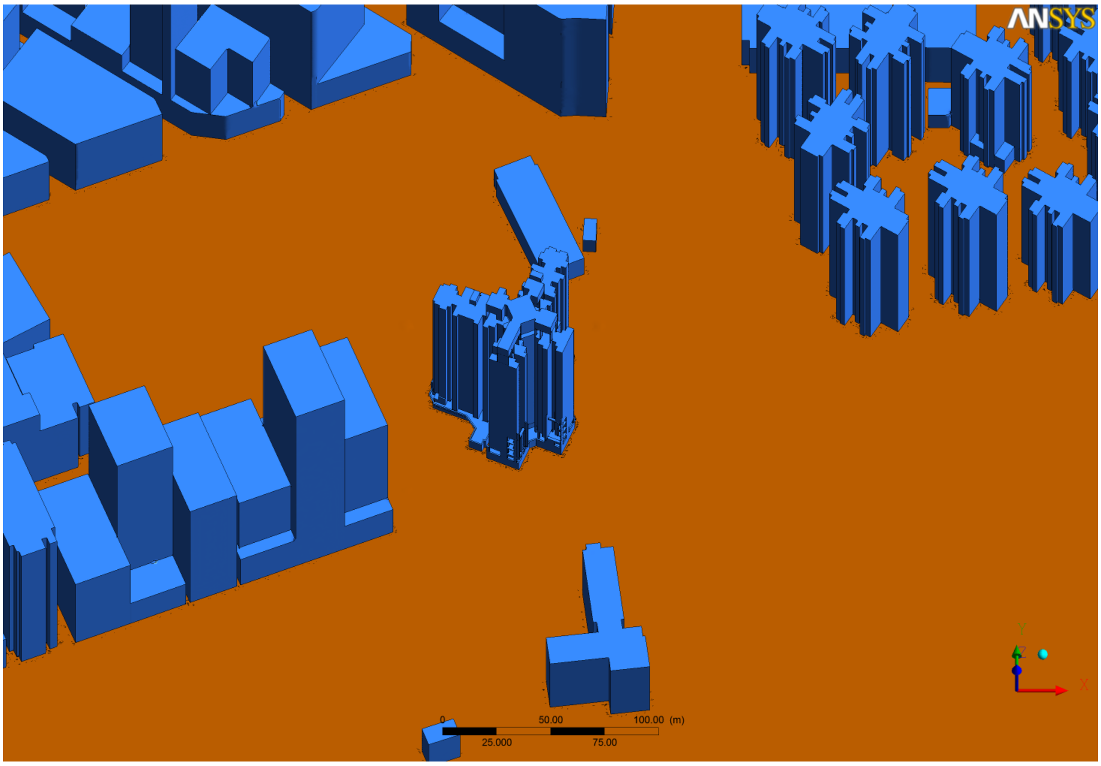


Figure 14 Dimensional Virtual Model of Scheme 2

The following assumption and inputs are adopted for CFD simulation:

Convergence	0.001
Numerical Scheme	Second order
Blockage Ratio	3.3%
Setting of boundary condition	Refer to ***Appendix F***
Grid expansion ratio	1.2
Grid type	Tetrahedral
Prismatic mesh	4 layers of 0.5m
Total number of mesh[2]	Scheme 1 : 15818496
	Scheme 2: 15860429

Table 3 CFD Model Assumption and Simulation

*[1]The blockage ratio is higher than the 3% as recommended by COST Action 14 (2004). However as the site is relatively flatted throughout the model area, no boundary effect from the model is observed as shown in **Figure 15& Figure 16** for information*

*[2]Please refer to **Appendix G** for graphically illustration of meshing details*

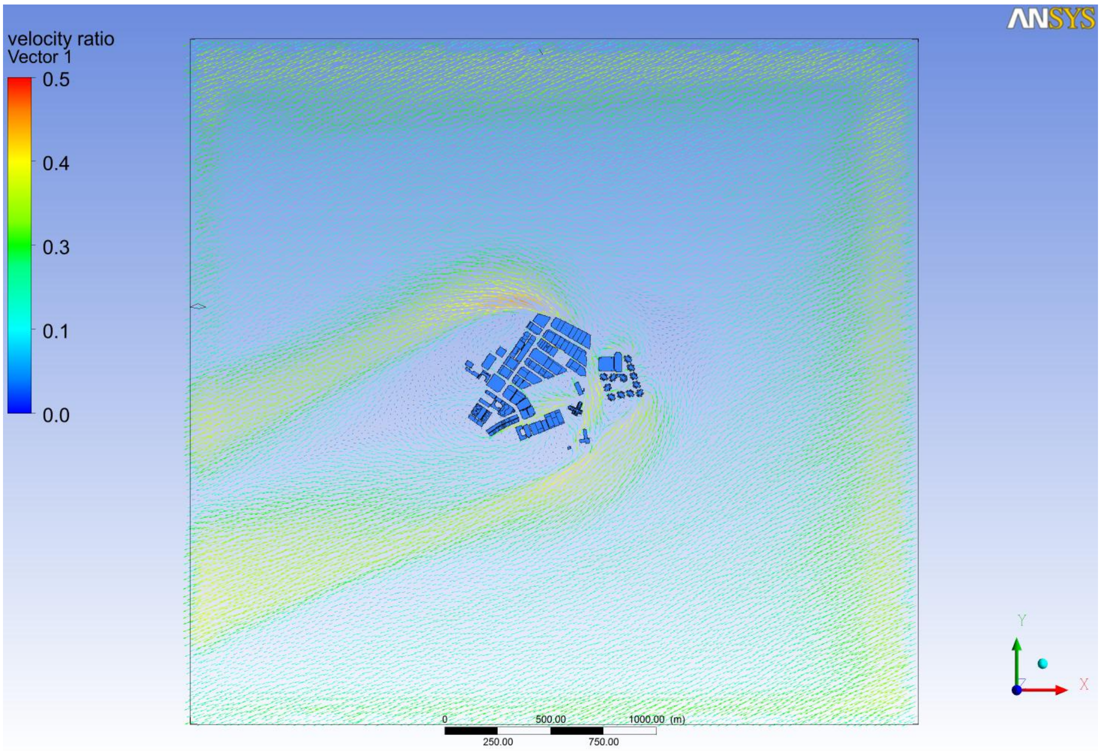


Figure 15 Contour and vector for ENE wind direction

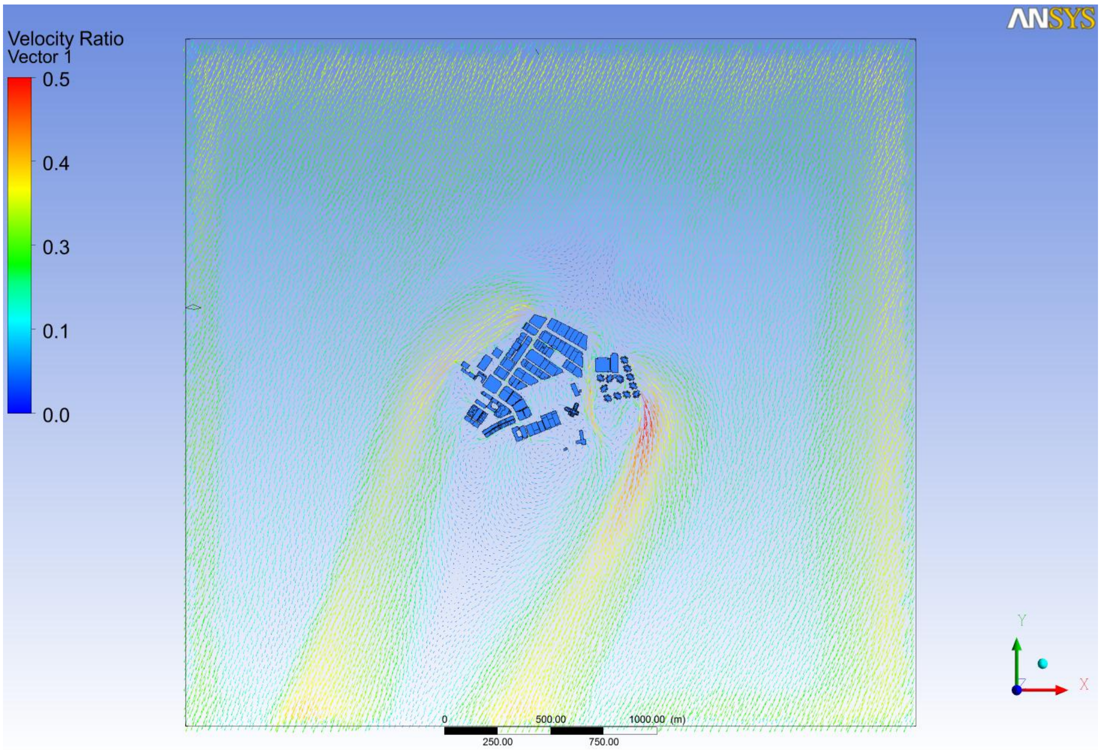


Figure 16 Contour and vector for NNE wind direction

4.3. WIND PROFILE

Wind data used in CFD simulation should be referred to MM5 data published by Planning Department as recommended in the Technical Guide.

The occurrence of winds which exceed 75% of a reference year includes ENE, NE, E, NNE, ESE, SW, SE and SSW winds. As MM5 data indicates wind availability at 596m above ground level, in order to evaluate wind availability at pedestrian level (2m above ground level), the wind velocities of the eight probable winds obtained from MM5 are converted to pedestrian level. Wind profiles of different prevailing direction are determined using the Power Law:

$$\frac{U_z}{U_G} = \left(\frac{Z_Z}{Z_G}\right)^{\alpha}$$

Where U_Z is the wind speed at height z from ground;

U_G is the wind speed at reference height (top of wind boundary layer);

Z_Z is the height z from ground;

Z_G is the reference height (top of wind boundary layer); and

α is the power law exponent.

The power law exponent (α) is based on the roughness length of the approaching area outside the modeled area. With reference to the power law exponent suggested by Poreh and Paciuk (1980)[2], the power law exponent is 0.28 for city centres. Wind profile for the 79.7% of wind occurrence and the calculation of wind speed at height 596m for each direction is illustrated in ***Appendix D.***

4.4. TEST POINTS

Test Points are the locations where Wind Velocity Ratio (VRs) at 2m above ground level is reported. Based on the VR of the test points, the resultant wind environment of the project can be assessed. Perimeter Test Points and Local Test Points are distributed around the project site.

Perimeter Test Points are distributed to areas around perimeters of the project site boundary which are likely to be frequently accessed by pedestrians. Test Points in this group are named with prefix “P” (i.e. P1, P2…). There is a total of 20 Perimeter Test Points distributed at an approximate 10m interval along the perimeter of the subject site. This group of perimeter test points provides data for the Site Air Ventilation Assessment.

Local Test Points are distributed on areas within the assessment area boundary and project site boundary, which are frequently accessed by pedestrians. Test points in this group are named

[2] city centers, buildings of medium to high density, typical building height 30 meters (10 storeys), Poreh and Paciuk (1980)

with prefix “O” (i.e. O1, O2…). There is a total of 77 Overall Test Points evenly distributed on the streets, open space and places. This group of overall test points, together with the 20 perimeter test points provides data for the Local Air Ventilation Assessment.

Special Test Points are positioned at the podium of proposed development, where these areas are likely to be frequently accessed by pedestrians. Test points in this group are name with prefix “S” (i.e. S1, S2…). There is a total of 11 special test points.

Locations of the perimeter test points, overall test points and special test points are shown in ***Figure 17*** and ***Figure 18*** and coordinates of these test points are tabulated in ***Table 4***.

Test Point	Location	Description	X	Y	Z
P01	Site Perimeter	Pedestrian Walkway	8728.21	-8242.24	2.25
P02	Site Perimeter	Pedestrian Walkway	8737.43	-8244.55	2.25
P03	Site Perimeter	Pedestrian Walkway	8723.60	-8245.99	2.25
P04	Site Perimeter	Pedestrian Walkway	8706.32	-8251.46	2.25
P05	Site Perimeter	Pedestrian Walkway	8690.19	-8253.48	2.25
P06	Site Perimeter	Pedestrian Walkway	8679.24	-8255.49	2.25
P07	Site Perimeter	Pedestrian Walkway	8669.45	-8245.99	2.25
P08	Site Perimeter	Pedestrian Walkway	8659.94	-8239.07	2.25
P09	Site Perimeter	Pedestrian Walkway	8653.31	-8223.80	2.25
P10	Site Perimeter	Pedestrian Walkway	8655.04	-8215.16	2.25
P11	Site Perimeter	Pedestrian Walkway	8660.80	-8198.45	2.25
P12	Site Perimeter	Pedestrian Walkway	8676.36	-8192.40	2.25
P13	Site Perimeter	Pedestrian Walkway	8689.61	-8187.22	2.25
P14	Site Perimeter	Pedestrian Walkway	8705.75	-8179.44	2.25
P15	Site Perimeter	Pedestrian Walkway	8722.46	-8175.12	2.25
P16	Site Perimeter	Pedestrian Walkway	8735.13	-8172.24	2.25
P17	Site Perimeter	Pedestrian Walkway	8739.16	-8190.10	2.25
P18	Site Perimeter	Pedestrian Walkway	8731.39	-8212.86	2.25
P19	Site Perimeter	Pedestrian Walkway	8723.32	-8221.21	2.25
P20	Site Perimeter	Pedestrian Walkway	8734.55	-8232.73	2.25
S01	Proposed Development	Pedestrian Walkway	8727.35	-8239.36	2.25
S02	Proposed Development	Pedestrian Walkway	8731.39	-8224.09	2.25
S03	Proposed Development	Pedestrian Walkway	8728.22	-8207.09	2.25
S04	Proposed Development	Pedestrian Walkway	8731.39	-8195.86	2.25
S05	Proposed Development	Pedestrian Walkway	8715.83	-8216.89	2.25
S06	Proposed Development	Pedestrian Walkway	8720.73	-8205.65	2.25
S07	Proposed Development	Pedestrian Walkway	8726.78	-8190.10	2.25
S08	Proposed Development	Pedestrian Walkway	8684.43	-8201.62	2.25
S09	Proposed Development	Pedestrian Walkway	8673.48	-8241.95	2.25
S10	Proposed Development	Pedestrian Walkway	8671.75	-8230.72	2.25
S11	Proposed Development	Pedestrian Walkway	8661.67	-8220.92	2.25

O01	Kai Tak East Playground	Pedestrian Walkway	8509.61	-8120.50	2.25
O02	Kai Tak East Playground	Pedestrian Walkway	8579.45	-8095.16	2.25
O03	Kai Tak East Playground	Pedestrian Walkway	8543.75	-8108.09	2.25
O04	Kai Tak East Playground	Pedestrian Walkway	8620.83	-8080.67	2.25
O05	Kai Tak East Playground	Pedestrian Walkway	8660.66	-8065.15	2.25
O06	Sze Mei Street	Pedestrian Walkway	8781.20	-8018.08	2.25
O07	Sze Mei Street	Pedestrian Walkway	8744.47	-8033.08	2.25
O08	Kai Tak East Playground	Pedestrian Walkway	8521.51	-8156.20	2.25
O09	Kai Tak East Playground	Pedestrian Walkway	8557.20	-8144.81	2.25
O10	Kai Tak East Playground	Pedestrian Walkway	8584.62	-8117.92	2.25
O11	Kai Tak East Playground	Pedestrian Walkway	8630.66	-8113.26	2.25
O12	Kai Tak East Playground	Pedestrian Walkway	8669.97	-8098.26	2.25
O13	Kai Tak East Playground	Pedestrian Walkway	8716.53	-8083.77	2.25
O14	Sze Mei Street	Pedestrian Walkway	8755.85	-8066.19	2.25
O15	Sze Mei Street	Pedestrian Walkway	8794.13	-8052.22	2.25
O16	Rhythm Garden	Pedestrian Walkway	8829.82	-8042.39	2.25
O17	Kai Tak East Playground	Pedestrian Walkway	8501.85	-8210.51	2.25
O18	Kai Tak East Playground	Pedestrian Walkway	8537.54	-8196.55	2.25
O19	Kai Tak East Playground	Pedestrian Walkway	8572.20	-8184.13	2.25
O20	Kai Tak East Playground	Pedestrian Walkway	8606.86	-8169.65	2.25
O21	Kai Tak East Playground	Pedestrian Walkway	8647.73	-8153.61	2.25
O22	Kai Tak East Playground	Pedestrian Walkway	8683.94	-8136.02	2.25
O23	Kai Tak East Playground	Pedestrian Walkway	8729.46	-8114.81	2.25
O24	Sze Mei Street	Pedestrian Walkway	8766.71	-8103.95	2.25
O25	Rhythm Garden	Pedestrian Walkway	8804.47	-8091.02	2.25
O26	Rhythm Garden	Pedestrian Walkway	8848.96	-8083.77	2.25
O27	King Fuk Street	Pedestrian Walkway	8515.30	-8246.21	2.25
O28	King Fuk Street	Pedestrian Walkway	8551.00	-8232.76	2.25
O29	King Fuk Street	Pedestrian Walkway	8582.03	-8218.27	2.25
O30	King Fuk Street	Pedestrian Walkway	8619.28	-8206.38	2.25
O31	King Fuk Street	Pedestrian Walkway	8659.63	-8192.41	2.25
O32	King Fuk Street	Pedestrian Walkway	8698.43	-8176.89	2.25
O33	King Fuk Street	Pedestrian Walkway	8745.50	-8160.34	2.25
O34	Sze Mei Street	Pedestrian Walkway	8785.85	-8144.82	2.25
O35	Rhythm Garden	Pedestrian Walkway	8822.58	-8136.02	2.25
O36	Rhythm Garden	Pedestrian Walkway	8864.48	-8126.71	2.25
O37	Proposed Development	Pedestrian Walkway	8724.29	-8216.72	2.25
O38	Sze Mei Street	Pedestrian Walkway	8762.57	-8199.65	2.25
O39	Sze Mei Street	Pedestrian Walkway	8802.92	-8186.20	2.25
O40	Rhythm Garden	Pedestrian Walkway	8837.06	-8176.89	2.25
O41	Prince Edward Road East	Pedestrian Walkway	8548.41	-8332.60	2.25
O42	Prince Edward Road East	Pedestrian Walkway	8579.45	-8317.08	2.25

O43	Prince Edward Road East	Pedestrian Walkway	8617.73	-8302.59	2.25
O44	Prince Edward Road East	Pedestrian Walkway	8652.39	-8288.11	2.25
O45	Prince Edward Road East	Pedestrian Walkway	8692.74	-8275.18	2.25
O46	Prince Edward Road East	Pedestrian Walkway	8733.60	-8260.69	2.25
O47	Prince Edward Road East	Pedestrian Walkway	8778.09	-8242.59	2.25
O48	Prince Edward Road East	Pedestrian Walkway	8817.41	-8227.07	2.25
O49	Prince Edward Road East	Pedestrian Walkway	8854.65	-8213.62	2.25
O50	Prince Edward Road East	Pedestrian Walkway	8892.93	-8198.10	2.25
O51	Prince Edward Road East	Pedestrian Walkway	8561.09	-8367.98	2.25
O52	Prince Edward Road East	Pedestrian Walkway	8597.68	-8358.43	2.25
O53	Prince Edward Road East	Pedestrian Walkway	8634.27	-8343.58	2.25
O54	Prince Edward Road East	Pedestrian Walkway	8671.91	-8328.74	2.25
O55	Prince Edward Road East	Pedestrian Walkway	8706.38	-8311.24	2.25
O56	Prince Edward Road East	Pedestrian Walkway	8748.80	-8296.92	2.25
O57	Prince Edward Road East	Pedestrian Walkway	8795.46	-8277.30	2.25
O58	Prince Edward Road East	Pedestrian Walkway	8835.23	-8265.64	2.25
O59	Prince Edward Road East	Pedestrian Walkway	8870.75	-8249.73	2.25
O60	Prince Edward Road East	Pedestrian Walkway	8911.05	-8232.23	2.25
O61	Outdoor carpark next to Concorde Road	Pedestrian Walkway	8575.41	-8405.62	2.25
O62	Outdoor carpark next to Concorde Road	Pedestrian Walkway	8613.59	-8394.49	2.25
O63	Prince Edward Road East	Pedestrian Walkway	8648.58	-8381.23	2.25
O64	Prince Edward Road East	Pedestrian Walkway	8685.70	-8363.73	2.25
O65	Kai Tak Operational Base	Pedestrian Walkway	8723.35	-8348.36	2.25
O66	Kai Tak Operational Base	Pedestrian Walkway	8766.30	-8335.10	2.25
O67	Concorde Road	Pedestrian Walkway	8810.31	-8319.19	2.25
O68	Concorde Road	Pedestrian Walkway	8851.67	-8300.64	2.25
O69	Concorde Road	Pedestrian Walkway	8892.49	-8288.44	2.25
O70	Concorde Road	Pedestrian Walkway	8931.73	-8270.94	2.25
O71	Concorde Road	Pedestrian Walkway	8588.67	-8443.80	2.25
O72	Concorde Road	Pedestrian Walkway	8628.43	-8432.13	2.25
O73	Concorde Road	Pedestrian Walkway	8663.43	-8420.47	2.25
O74	Concorde Road	Pedestrian Walkway	8704.26	-8406.15	2.25
O75	Concorde Road	Pedestrian Walkway	8738.72	-8390.78	2.25
O76	Concorde Road	Pedestrian Walkway	8778.49	-8373.81	2.25
O77	Concorde Road	Pedestrian Walkway	8824.62	-8354.19	2.25

Table 4 Coordinates of Perimeter Test Points, Overall Test Points and Special Test Points

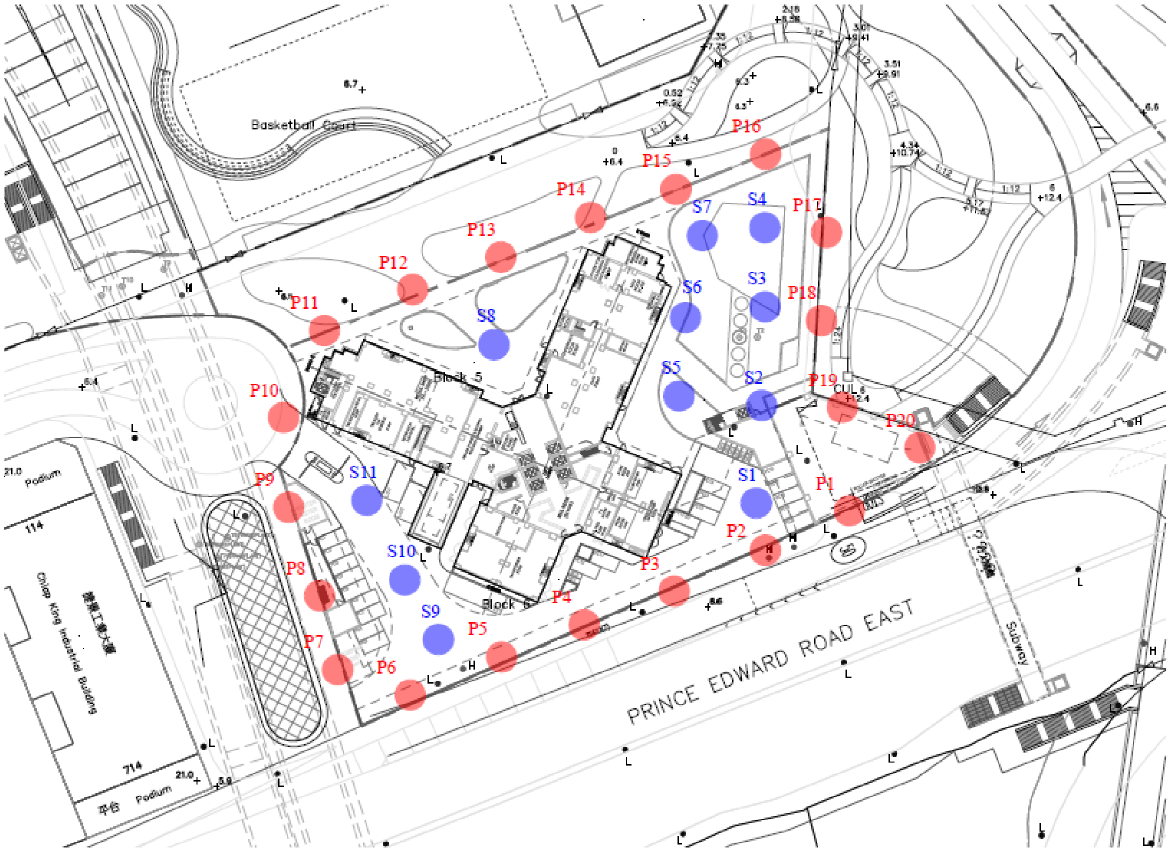


Figure 17 Positions for Perimeter Tests and Special Test Points

Figure 18 Positions for Overall Tests Points

4.5. WIND VELOCITY RATIO

Wind Velocity Ratio (VR) should be used as an indicator of wind performance for the AVA. Wind velocity is assessed at 2m above ground level and podium level of the proposed residential tower. It indicates how much of the wind availability of a location could be experienced and enjoyed by pedestrians. The higher the wind velocity ratio, the less likely would be the impact of the proposed developments on the wind availability.

Wind Velocity Ratio is defined as follows:

$$VR_w = \frac{V_p}{V_\infty}$$

where

Vp is the wind velocity at the pedestrian level (2m above ground) after taking into account the effects of buildings and urban features; and
V_∞ is the wind availability of the site, i.e. wind velocity at the top of the wind boundary layer. MM5 data are used to determine velocity at infinity level for the project site.

The assessment on the overall wind performance of the current situation and the proposed developments were analyzed by comparing the weighted-mean wind velocity ratio (VRw') to account for wind coming from the 8 wind directions. VRw' is the sum of the Wind Velocity Ratio of wind from direction i (VRi) multiplied by the probability (Fi) of wind coming from that direction.

$$VRi = \frac{V_{pi}}{V_{\infty i}} \qquad VR_w = \sum_{i=1}^{16} Fi \times VRi$$

where VRi is the velocity ratio of the location when wind comes from direction i;

V_{pi} is the wind velocity at the pedestrian level (2m above ground) after taking into account the effects of buildings and urban features when wind comes from direction i;

$V_{\infty i}$ is the wind availability of the site when wind comes from direction i, i.e. wind velocity at the top of the wind boundary layer;

Fi is the frequency occurrence of wind from direction i, 16 directions are considered.

The normalized weighting (Fi) for each wind direction is summarized in ***Table 5.***

Wind Direction	Occurrence frequency of the wind direction	Normalized weighting
ENE	18.8%	23.6%
E	15.2%	19.1%
NE	11.5%	14.4%
ESE	9.2%	11.5%
NNE	7.1%	8.9%
SSW	6.1%	7.7%
SE	6.0%	7.5%
SW	5.8%	7.3%
Overall Value	**79.7%**	**100%**

Table 5 Weighted occurrence frequency of the wind directions

5. INITIAL STUDY FINDINGS

5.1. AIR VENTILATION RESULT

The simulation results of velocity ratio demonstrated in terms of contour and arrow plots for all prevailing wind directions are provided in ***Appendix B***.

For the air ventilation assessment of the proposed schemes, 20 perimeter test points and 77 overall test points are assigned at the pedestrian area. The wind velocity ratio (VR) at each test point for all prevailing directions as well as weighted average wind velocity ratio (VRw) at each test point is tabulated in ***Appendix E***

The differences of VRw at each perimeter test point between Scheme 1 and Scheme 2 are presented in ***Figure 19***, while differences of VRw at each overall test point are presented in ***Figure 20*** & ***Figure 21*** and the differences of VRw at each special test point are presented in ***Figure 22.***

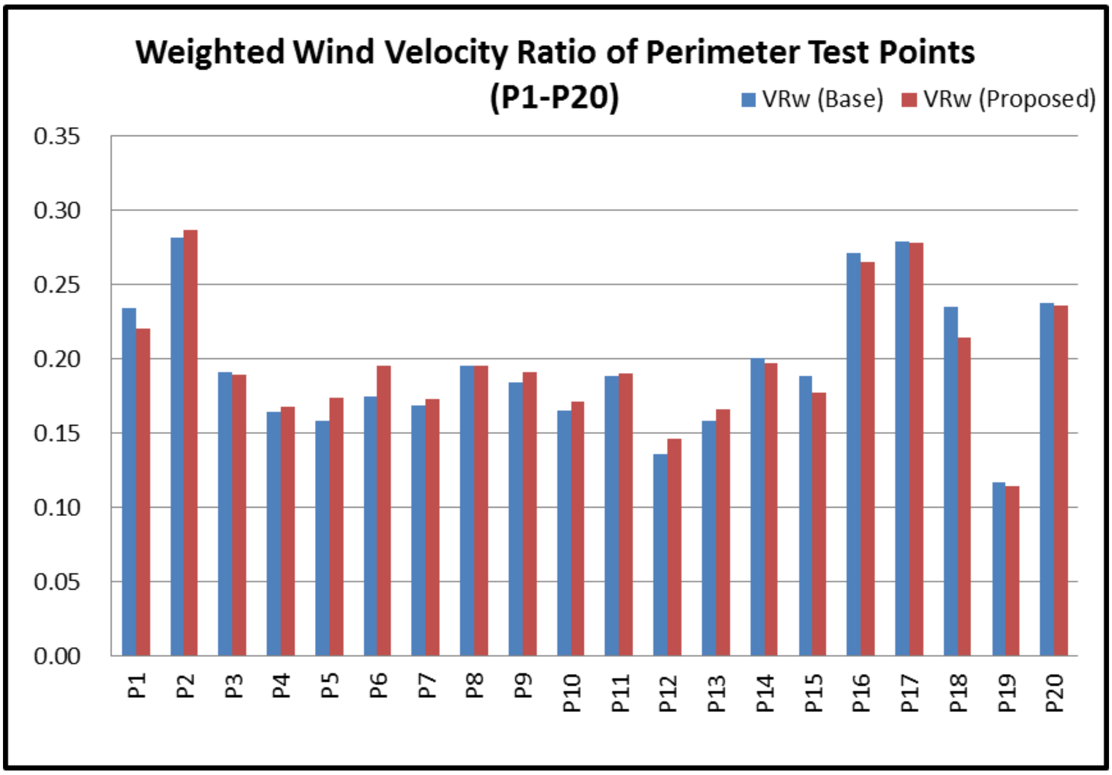


Figure 19 Weighted Wind Velocity Ratio (VRw) of Perimeter Test Points for Scheme 1 and Scheme 2 (P01-P20)

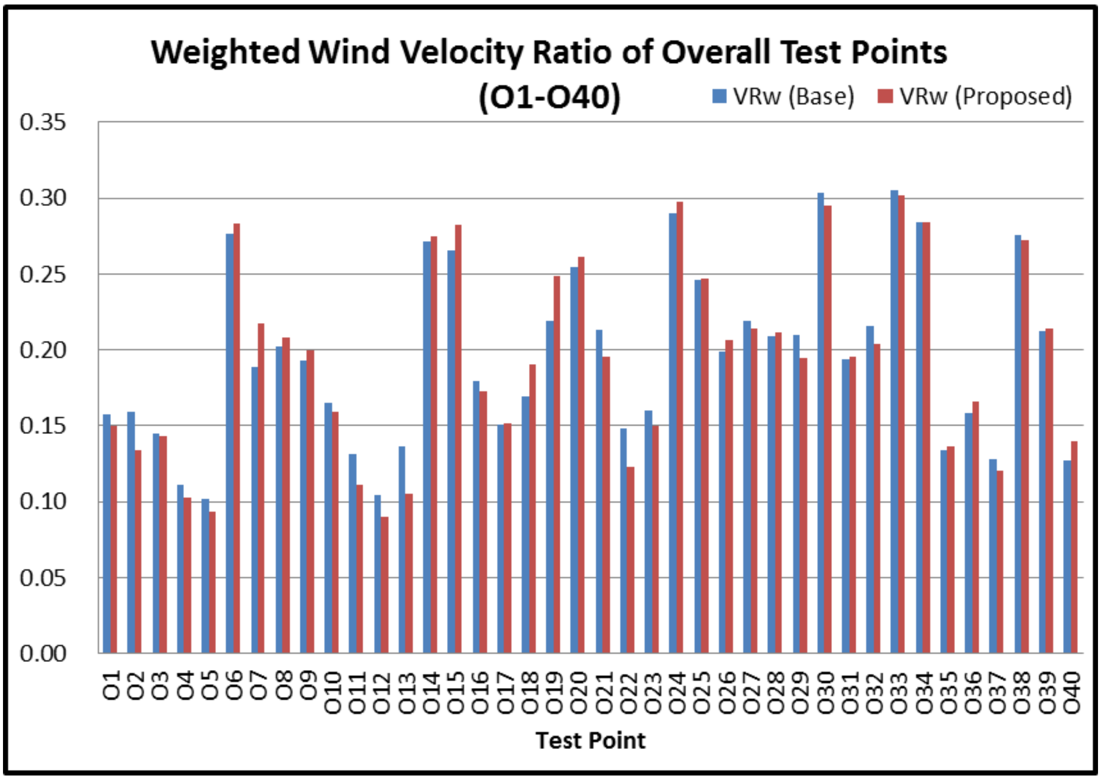


Figure 20 Weighted Wind Velocity Ratio (VRw) of Overall Test Points for Scheme 1 and Scheme 2 (O01-O40)

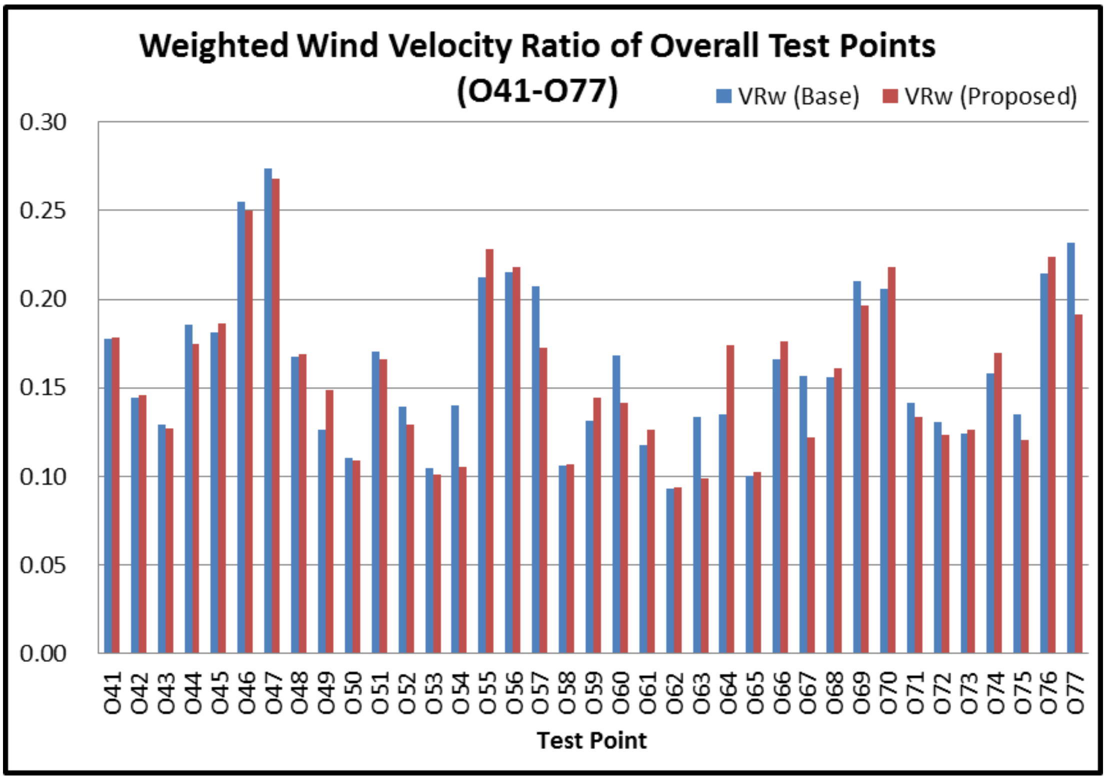


Figure 21 Weighted Wind Velocity Ratio (VRw) of Overall Test Points for Scheme 1 and Scheme 2 (O41-O77)

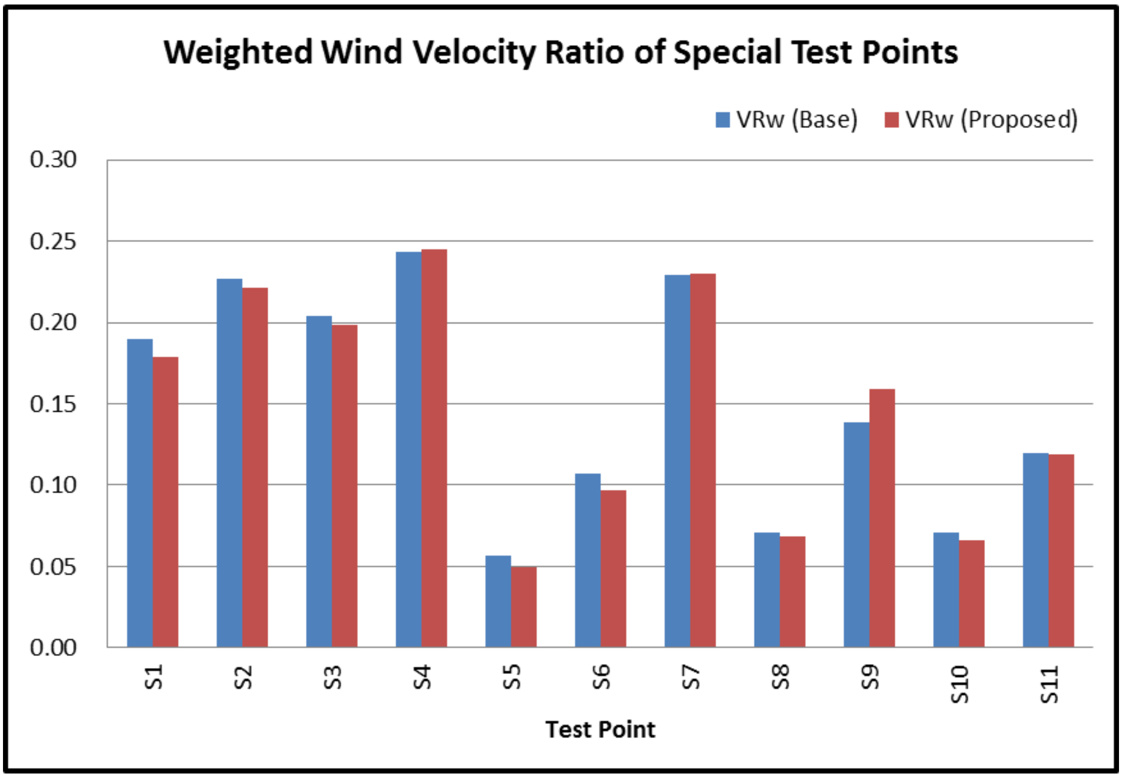


Figure 22 Weighted Wind Velocity Ratio (VRw) of Special Test Points for Scheme 1 and Scheme 2 (S01-S11)

The site AVA results, site velocity ratio (SVR), evaluated by considering perimeter test points (20 test points) are tabulated in ***Table 6;*** while the Local AVA results, local velocity ratio (LVR) evaluated by considering both perimeter test points (20 test points) and overall test points (77 test points) are tabulated in ***Table 7.*** And the results for special points (11 test points) are tabulated in ***Table 8.***

Wind Directions	**$VR_{average}$ (Scheme 1)**	**$VR_{average}$ (Scheme 2)**	**$VR_{average}$ Change**	**% $VR_{average}$ Change**
ENE	0.207	0.201	-0.005	-2.7%
NE	0.167	0.171	0.004	2.3%
E	0.245	0.223	-0.022	-9.9%
NNE	0.098	0.124	0.026	21.1%
ESE	0.257	0.268	0.011	4.2%
SSW	0.196	0.211	0.015	6.9%
SW	0.196	0.198	0.003	1.5%
SE	0.224	0.216	-0.009	-4.1%
SVRw	**0.1962**	**0.1972**	0.001	0.5%

Table 6 Summary of Weighted Site Velocity Ratios (SVRw)

Wind Directions	$VR_{average}$ (Scheme 1)	$VR_{average}$ (Scheme 2)	$VR_{average}$ Change	% $VR_{average}$ Change
ENE	0.183	0.176	-0.006	-3.6%
NE	0.170	0.168	-0.002	-1.1%
E	0.209	0.198	-0.011	-5.6%
NNE	0.121	0.129	0.007	5.8%
ESE	0.205	0.204	-0.000	-0.1%
SSW	0.208	0.217	0.009	4.0%
SW	0.193	0.194	0.001	0.7%
SE	0.194	0.195	0.001	0.3%
LVRw	**0.1824**	**0.1806**	-0.002	-1.0%

Table 7 Summary of Weighted Local Velocity Ratios (LVRw)

Wind Directions	**$VR_{average}$ (Scheme 1)**	**$VR_{average}$ (Scheme 2)**	**$VR_{average}$ Change**	**% $VR_{average}$ Change**
ENE	0.170	0.165	-0.005	-2.9%
NE	0.121	0.120	-0.001	-0.7%
E	0.209	0.191	-0.017	-9.0%
NNE	0.057	0.071	0.014	19.6%
ESE	0.199	0.206	0.007	3.6%
SSW	0.125	0.121	-0.004	-3.6%
SW	0.135	0.117	-0.017	-14.8%
SE	0.183	0.195	0.012	6.3%
	0.1506	**0.1483**	-0.002	-1.5%

Table 8 Summary of Weighted Special Point Velocity Ratios (SPVRw)

5.2. AIR VENTILATION ASSESSMENT

For perimeter test points, as shown on ***Table 6***, SVRw of Scheme 2 varies from that of Scheme 1 by ranging from -9.9% to 21.1% for various wind directions and the weighted average change of SVRw is 0.5%. For both perimeter and overall test points, as shown on ***Table 7***, LVRw of Scheme 2 varies from that of Scheme 1 by -5.6% to 5.8% and the weighted average change of SVRw is -1.0%.

As compared with Scheme 1 which possessed a SVRw of 0.1962 and LVRw of 0.1824 Scheme 2 has a SVRw of 0.1972 and LVRw of 0.1806. The overall changes in SVRw and LVRw from Scheme 1 to Scheme 2 are 0.5% and -1.0% respectively.

For the Special Test Points where positioned at the ground level of proposed development, the weighted average wind velocity ratio (SPVRw) at different special test pointed are determined and ranged from -14.8% to 19.6%. Comparing the Scheme 2 with the Scheme 1, a weighted average of 1.5% decrease is observed. Moreover, a 19.6% increase in VR average is observed under NNE wind condition where the wind availability (0.057 to 0.071) at the vicinity of the site is relatively low.

The increase in SVRw means that the lower part of Scheme 2 enhances the wind environment of the immediate surroundings as compared to Scheme 1. Hence the building openings are shown to benefits the immediate surroundings; although only an overall of 0.5% increase is achieved, the VR average under NNE wind increased 21.1% from 0.098 to 0.124 where the VR average of NNE is lowest among the 8 wind directions. In general, an increase in %VR averages are observed under the wind directions that are relatively low in average VR i.e. weaker in wind availability.

The LVR gives an idea of how the upper portion of the buildings on the project site may affect the surroundings and a reduction of LVRw is observed. However, the model was set up that there were no changes in the upper portions of the two schemes. Therefore it is expected that the building openings located at 2/F to 8/F of Scheme 2 would reduce the local air ventilation at pedestrian level. Moreover a significant increase in average VR of NNE is also observed.

With the current good design features for both schemes, i.e. podium free, maximizing setback distance from Prince Edward Road East, optimum orientation to maximize separation distance from the adjoining industrial building and Sport Centre and enhancing permeable structures (building openings) maintaining a reasonable permeability; the wind environment is generally enhanced in different wind directions.

Under E wind condition, it is observed that the VR for test points O41 to O45 which is located at the downstream area of Prince Edward Road East have VR ranged from 0.25 to 0.37 with an average VR of 0.3. With both the SVRw and LVRw below 0.2, it is suggest that the proposed development cause no significant impact on the Prince Edward Road East which is an important wind corridor for the district.

On the other hand, the large separation between the proposed development and the adjoining Chiap King Industrial Building enhances the wind penetration from Prince Edward Road East to the Kai Tak East Playground through King Hong Street. This is particular effective under E, ESE, SE, SSW and SW wind condition. Whereas the building separation from Kai Tak East Sport Centre also provides an adequate space for air ventilation while the average VRw of test points P11 to P16 for both schemes is 0.19. From the contour and vector plot, it is observed these separations provide a reasonable wind corridor to facilitate air ventilation to the Kai Tak East playground and inner San Po Kong industrial area especially under ESE and SW wind condition.

Moreover the increase in permeable structure at the southern side of the proposed domestic building will possibly enhance the wind penetration through Prince Edward Road East to King Hong Street. In terms of weight velocity ratio (VRw) under all wind directions, test points P7 to P10 are located at King Hong Street where the average VRw P7 to P10 for Scheme 1 and Scheme 2 are 0.178 and 0.182 respectively.

Under NE, NNE and ENE wind condition, the deposition of the proposed development minimized the impediment to the upcoming wind from the wind corridor at Sze Mei Street and the open area located to the north-east of the project site.

5.2.1. Problem Area

In terms of contour, vector plots and individual VR, no particular test points are way below or above the SVR and LVR which indicate that there is no major stagnant zone of wind gust problem within the assessment area.

5.2.2. Focus area

Within the assessment area, there are different areas that may raise concern after the development of the proposed building. The surrounding development has been divided into 5 different focus areas; the test points for each focus area are shown in ***Figure 23*** and the VRw for each focus area is tabulated in ***Table 9*** and the summary of VRw for each focus area is shown in ***Appendix E.***

Figure 23 Focus area test points

Focus Area	VR_w (Scheme 1)	VR_w (Scheme 2)	VR_w Change	% VRw Change
Focus Area 1	0.164	0.160	-0.004	-2.4%
Focus Area 2	0.182	0.179	-0.003	-1.6%
Focus Area 3	0.218	0.225	0.007	3.1%
Focus Area 4	0.175	0.176	0.001	0.3%
Focus Area 5	0.156	0.151	-0.005	-3.4%

Table 9 Focus area weighted average velocity ratio

In terms of VRw for all wind direction, reductions in VRw for Scheme 2 are observed in Focus Area 1, 2 and 5 where enhancement in VRw is observed for Scheme 2 in Focus Area 3 and 4. However, None of VRw is significantly lower than the LVRw and SVRw within the assessment area.

In terms annual prevailing E wind, as shown in ***Table 10***, it is observed that the average VR for all focus areas ranged from 0.178 to 0.236. The relatively high average VR of Focus Area 4 which is Prince Edward Road East further indicates that the proposed development with the proposed setback distance from the Prince Edward Road East would cause insignificant impact to the important wind corridor in San Po Kong Area.

Under summer prevailing SW wind, as shown in ***Table 11***, it is observed that the average VR for all focus areas ranged from 0.136-0.293. The relatively high average VR of Focus Area 4 also indicates the preservation of the important wind corridor at Prince Edward Road East. However, Focus Area 1 has an average VR of 0.136 which suggest that the wind availability is at Kai Tak East Playground is expected to be relatively low. Moreover, due to the current merits of both schemes taken into account of adequate building separations for air ventilation to the leeward Kai Tak East Playground, it is expected that the relatively low average VR is contributed by the `surrounding exiting developments especially the industrial buildings location west of the project development.

Focus Area	VRaverage (Scheme 2 Under E Wind)
Focus Area 1	0.187
Focus Area 2	0.224
Focus Area 3	0.179
Focus Area 4	0.236
Focus Area 5	0.178

Table 10 Focus area weighted average velocity ratio for Scheme 2 under annual prevailing E wind

Focus Area	VRaverage (Scheme 2 Under SW Wind)
Focus Area 1	0.136
Focus Area 2	0.293
Focus Area 3	0.165
Focus Area 4	0.268
Focus Area 5	0.216

Table 11 Focus area weighted average velocity ratio for Scheme 2 under summer prevailing SW wind

6. CONCLUSION

In this AVA Initial Study, two scenarios, Scheme 1 and Scheme 2 for the subject development were being assessed by CFD modeling. Due to site constraint, there is no alternative site layout plan to improve the wind performance to a larger extent. Both schemes adopted podium free design and includes a setback distance on the southern side of the building which air ventilation in Scheme 1(previous design) and Scheme 2 (building permeable openings in 2nd to 8th floor) are investigated in this Initial Study.

Based on the result of the wind rose analysis, the wind directions for the Subject Site and the surrounding area representative of the prevailing situations are determined to be mainly ENE, E, NE, ESE NNE, SSW, SE and SW. These 8 out of the 16 wind directions which occur for about 79.7% of time in a year are adopted in the Initial Study.

According to the CFD modelling results, the following conclusion can be drawn:

The slightly higher values in SVRw for Scheme 2 demonstrate a slight improvement of air ventilation performance to the immediate surroundings. The slightly lower values in LVRw for scheme 2 demonstrates that the proposed building openings in Scheme 2 will slightly decrease the wind availability of the surroundings.

The higher SVRw than LVRw in Scheme 2 indicates a slight improvement air ventilation on pedestrian level in the vicinity.

In terms of Wind availability within the assessment area, the areas around the proposed development of Scheme 1 or Scheme 2 are comparable where no particular stagnant and wind gust problem has been observed.

Result shows that with provision of the proposed good design features, the development shall cause insignificant impact to the local wind environment as there is no particular wind gust or stagnant area observed both in terms of contour and vector plot and individual VR values.