AECOM

Hong Kong Housing Authority

Construction of Housing Authority Public Housing Development at Kai Tak Site 1A and 1B

Air Ventilation Assessment Detailed Study Report

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1 INTRODUCTION

1.1 Background of the Study

1.1.1 A Feasibility Study for Establishment of Air Ventilation Assessment (AVA) System has been completed by the Planning Department in 2005. Since then, the Technical Circular No. 1/06 – AVA (the Technical Circular) was jointly issued by the Housing, Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB). The Technical Guide for AVA annexed in the Technical Circular detailed the AVA methodology.

1.1.2 In response to this Technical Circular which provides guidance for applying AVA to major government projects, the Hong Kong Housing Authority commissioned an AVA study to assess the air ventilation performance at the pedestrian level of the proposed housing development at Kai Tak Site 1A and 1B.

1.2 Objectives

1.2.1 AECOM is commissioned by the Housing Authority to conduct an AVA detailed study for the public housing development at Kai Tak Site 1A and 1B 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 and objectives of the AVA study, echoing the Technical Guide, are:

- To assess the characteristics of the wind availability (V_∞) of the site in detail;
- To give a general pattern and quantitative estimate of wind performance at the pedestrian level reported using Wind Velocity Ratio (VR); both Site VR (SVR), Local VR (LVR) and wind gust problems are reported where appropriate; and
- To provide a summary of how the identified problem areas, if any, have been resolved.

1.3 Structure of this Report

1.3.1 The remainder of the report is organized as follows:

- Section 2 on expert evaluation and site wind availability;
- Section 3 on assessment methodology;
- Section 4 on key findings of AVA detailed study; and
- Section 5 with summary and conclusions.

1.3.2 This AVA study is conducted in two stages using Computational Fluid Dynamic (CFD) model. The first stage covers the Expert Evaluation and the Initial Study which examined the ventilation performance under the 8 most prevailing wind directions (with the percentage of occurrence of the 8 wind directions exceed 75% of time in a typical year). The second stage namely the Detailed Study examined the ventilation performance under all the 16 wind directions. This AVA Report summarizes the findings of the Detailed Study of the AVA study.

2 EXPERT EVALUATION

2.1 Site Environs

2.1.1 The proposed development is located in the southeastern part of Kowloon Peninsula at the northeastern end of the former Kai Tak Airport. The Subject Sites namely public housing development Kai Tak Sites 1A and 1B are presently an open area within the former Kai Tak Airport North Apron with a total site area of around 9 hectare. It adjoins Road L2, Eastern Road and Kwun Tong Bypass to the east. The location and the environs of the Subject Sites are shown in **Figure 2.1**.

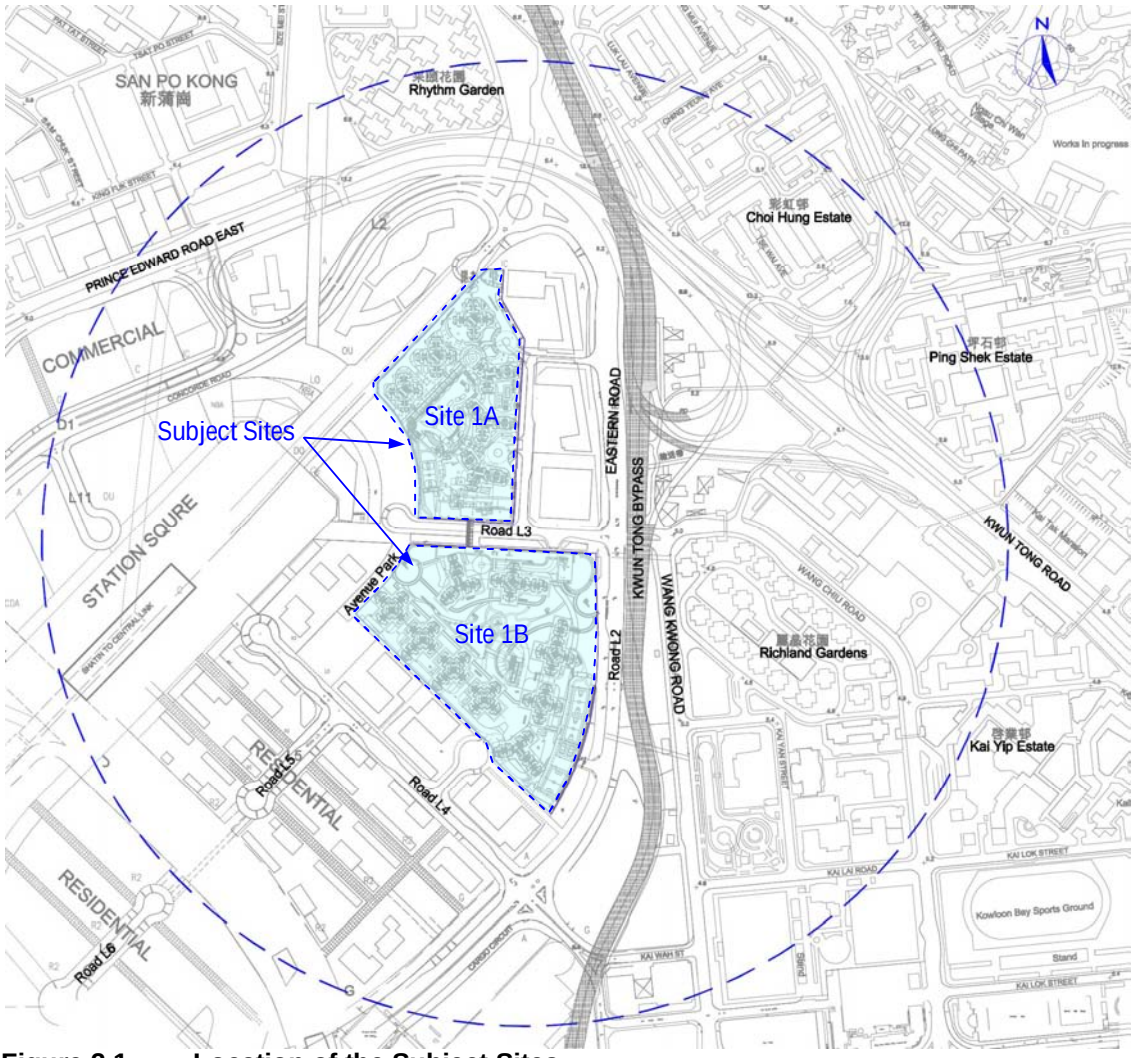


Figure 2.1 Location of the Subject Sites

2.1.2 As shown in **Figure 2.1**, to the north of the Subject Sites is the Rhythm Garden, which is a cluster of residential buildings of about 22 to 30 storeys. Further to the north and northwest of Site 1A and Site 1B is mostly characterised by clusters of medium- to high-rise residential and commercial buildings in the San Po Kong area.

2.1.3 To the northeast of the Subject Sites are slip roads connecting Kwun Tong Bypass, Prince Edward Road East and Kwun Tong Road. Further northeast of these slip roads are the medium-rise residential buildings in the Choi Hung area.

2.1.4 A cluster of residential buildings namely Richland Gardens of about 36-storey high is located along Kwun Tong Bypass to the east of Site 1B together with some adjacent low- to medium-rise buildings of commercial, educational and leisure uses. To the southeast of the Subject Sites are the Kowloon Bay district characterised with clusters of medium-rise commercial and industrial buildings.

2.1.5 Proposed educational-use buildings will be standing immediately to the east of Site 1A as well as to the southwest of Site 1B. Further to the south and southwest is now an open area which will be developed into residential sites with building height at about 100 mPD.

2.1.6 To the west of the Subject Sites are the planned railway station and Station Square of the Shatin to Central Link. Clusters of mixed-use high-rise buildings are proposed around the Station Square further to the west and northwest.

2.2 Site Wind Environment

2.2.1 The Subject Sites are located in the south-eastern part of Kowloon Peninsula. As shown in the aerial photo (**Figure 2.2**), the terrain surrounding the Subject Sites is relatively flat with only slightly raised terrain in San Po Kong area to its north and Kowloon Bay area to its southeast. Influence of local topography to the wind flow pattern at the Subject Sites should be minimal.

2.2.2 With regards to the local wind condition of the Subject Sites, lower level (16m above mean sea level) wind data are available from the Kai Tak Automatic Weather Station operated by the Hong Kong Observatory. The Kai Tak Automatic Weather Station is located above the roof of the former Kai Tak Airport Fire Station situated at the tip of the ex-Kai Tak Runway.

2.2.3 In accordance with the five years (2004 to 2008) annual wind rose from the Kai Tak Automatic Weather Station as shown in **Figure 2.3**, the prevailing winds for years 2004 to 2008 at the lower level of the area are predominantly easterly and southeasterly winds. The annual prevailing winds of the Subject Sites are mainly from the east to southerly east, whereas the summer prevailing winds are mainly coming from the southeast and the southwest quarters (see **Figure 2.8** under **Section 2.3**).

2.2.4 Although the influence of local topography to the wind flow pattern around the Subject Sites is minimal, the Subject Sites are surrounded by a number of existing and planned developments in almost all directions. The wind flow pattern at the Subject Sites would be significantly influenced by this surrounding built environment. The annual prevailing winds from the east to southerly east and summer prevailing winds from southerly east towards the Subject Sites would be blocked by the existing medium- to high-rise developments in the Kowloon Bay area. Whereas prevailing summer wind from the southwest towards the Subject Sites is currently unobstructed, but it might be blocked by the future Kai Tak Development. The noise enclosure on Kwun Tong Bypass will also have localised effect on pedestrian level wind speeds.

2.2.5 The Subject Sites have to rely on the existing and planned road networks surrounding the Sites as the major breezeways. These include Road L4 running in the southeast-northwest orientation, Road L3 and Kai Yan Street running in the east-west orientation, Prince Edward Road East and Kwun Tong Road running at the north of the Subject Sites and Road L2, Eastern Road, and Kwun Tong Bypass running in the south-north orientation. In addition, open spaces in the proposed Kai Tak Development, such as the North Apron District Park and the Station Square, would also serve as relatively unobstructed air paths for the Subject Sites.

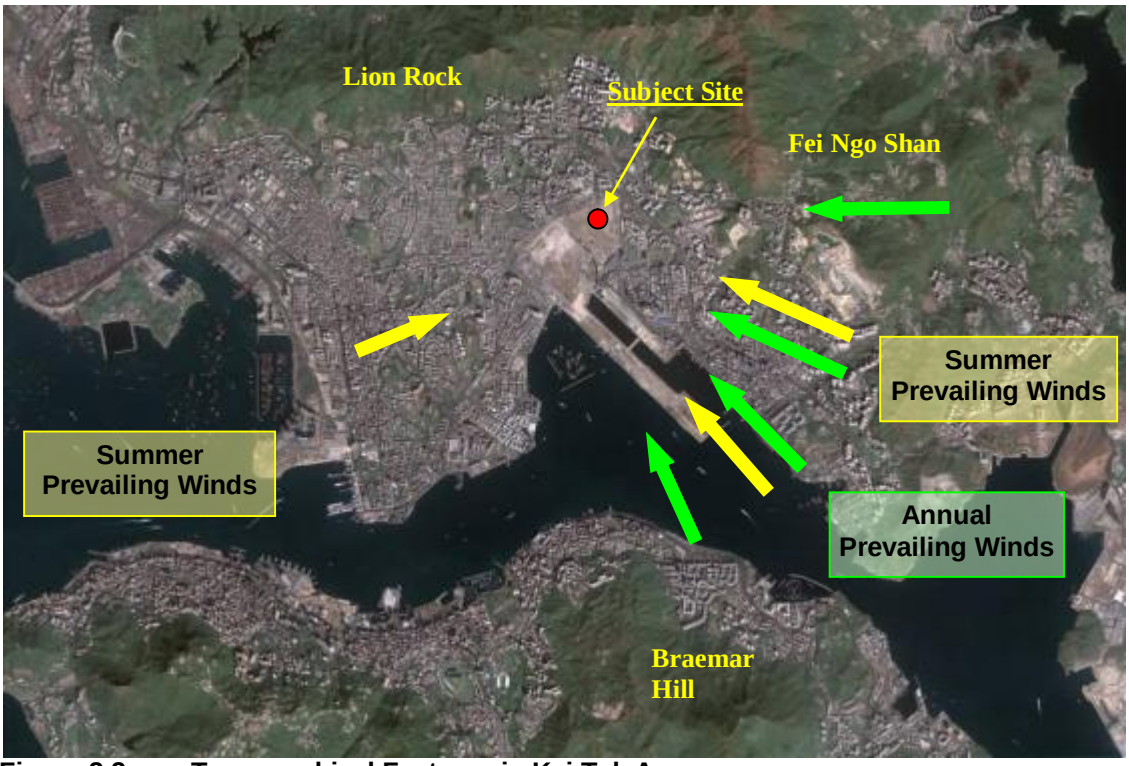


Figure 2.2 Topographical Features in Kai Tak Area

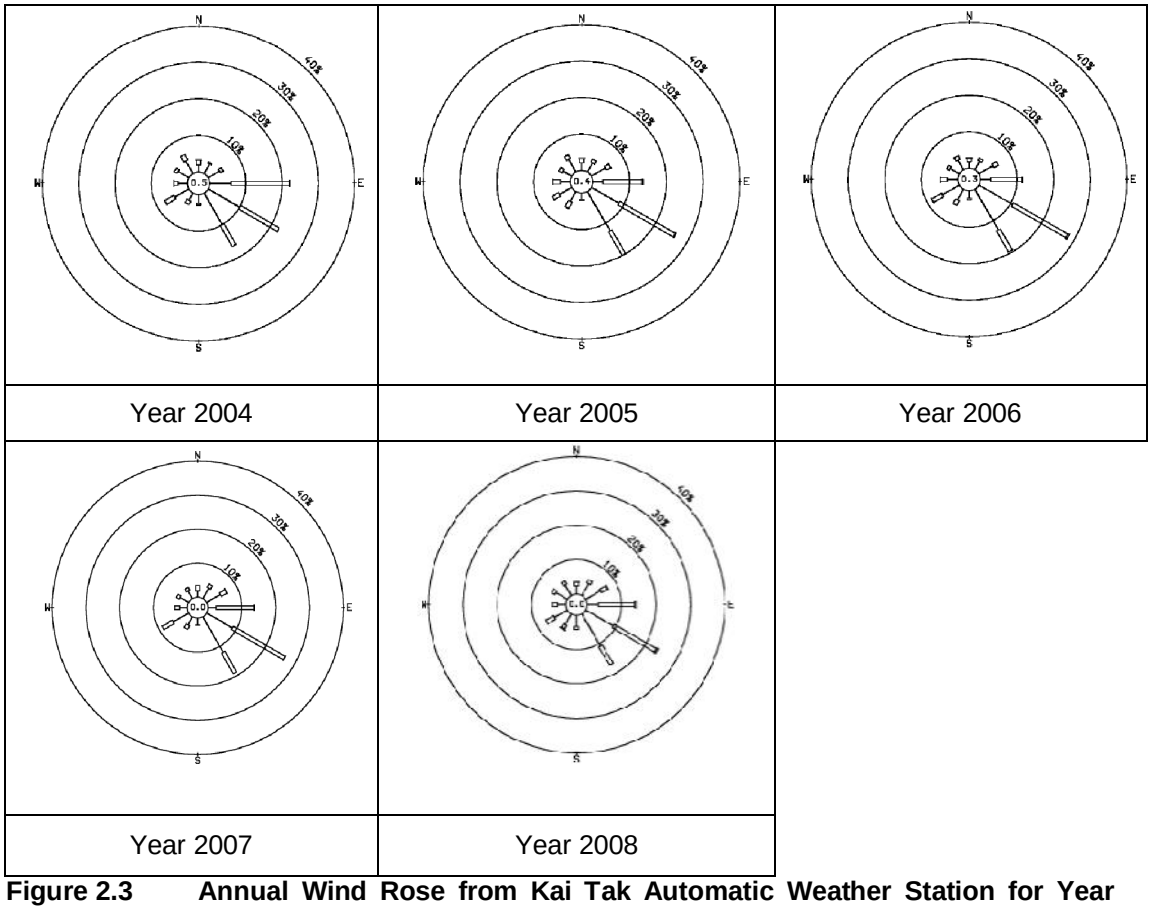


Figure 2.3 Annual Wind Rose from Kai Tak Automatic Weather Station for Year 2004 to 2008

2.3 Site Wind Availability

2.3.1 With reference to the "*Experimental Site Wind Availability Study for the Proposed Kai Tak Development, Hong Kong - Investigation Report WWTF013-2009*", Kai Tak Site 1A and Site 1B fall within Study Area B of the Kai Tak Development AVA Study. The wind availability data determined using large scale topographical model (1:2000) tested in a boundary layer wind tunnel under the Kai Tak Development AVA Study for Study Area B were therefore adopted for this AVA detailed study for Kai Tak Site 1A and 1B. The coverage of Study Area B and the relevant wind availability data are extracted and shown in **Appendix A**.

2.3.2 The wind tunnel testing techniques used for the site wind availability study satisfied the quality assurance requirements stipulated in the Australasian Wind Engineering Society Quality Assurance Manual, AWES-QAM-1-2001 (2001) and the American Society of Civil Engineers Manual and Report on Engineering Practice No. 67 for Wind Tunnel Studies of Buildings and Structures (1999). The site wind availability study was also conducted in accordance with the recommendations of Planning Department's Feasibility Study for Establishment of Air Ventilation Assessment System – Final Report (2005) and Technical Guide for Air Ventilation Assessment for Developments in Hong Kong (2006).

2.3.3 The site wind availability study was conducted using a 1:2000 scale topographical model to determine the effects of surrounding topography and urban environment on mean wind speeds and turbulence intensities above the Study Area B.

2.3.4 The wind tunnel testing results were subsequently combined with a statistical model of the Kai Tak non-typhoon wind climate, based on wind speed measurements taken at the Kai Tak Automatic Weather Station to determine directional wind characteristics and availability for the Kai Tak Area.

2.3.5 Photographs of the 1:2000 scale topographical model of the proposed Kai Tak Development in the low speed test section for Study Area B under north, east, south and west directions are shown in **Figure 2.4** to **Figure 2.7** for reference.

2.3.6 Based on the findings of the site wind availability study, the annual prevailing non-typhoon winds at Kai Tak are mainly coming from the south-east quadrant while from south-east and south-west quadrants during summer months (June to August). The site wind availability study also pointed out that significant reductions in the magnitudes of wind speed were measured at elevations below 150 mPD for N, NNE, NE, ENE and E wind directions caused by the mountains to the north and north-east of the Kai Tak Area. Besides, the mountains located on Hong Kong Island would reduce wind speeds from the south and south-westerly directions. Winds approaching from the south-east were the least affected due to the relatively open water of the Victoria Harbour and Lei Yue Mun.

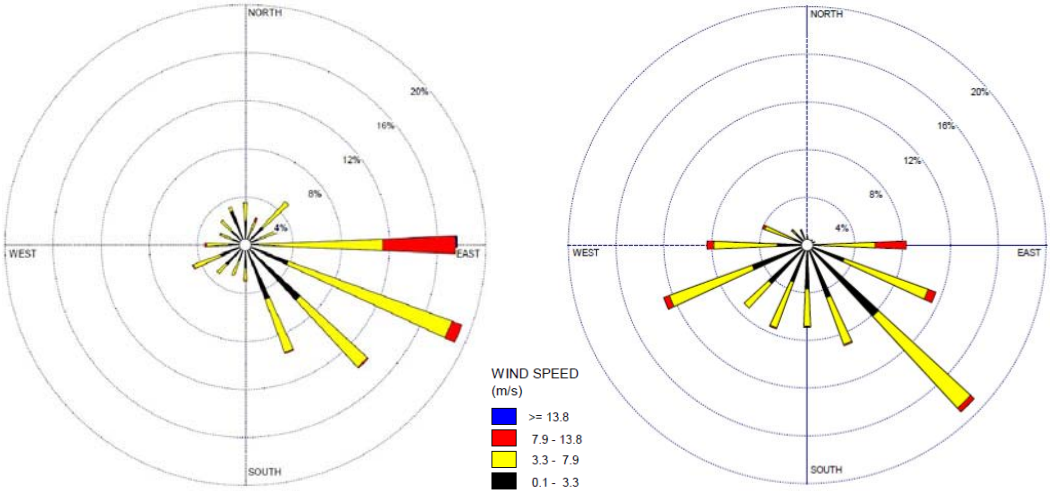
2.3.7 The annual and summer wind roses at 150 mPD based on the results of the site wind availability study are shown in **Figure 2.8**. The wind rose result indicates the dominance of each of the 16 wind directions and distribution of the wind speed at 150m above terrain. The percentage of annual and summer season occurrence of a particular wind direction at level 150 mPD is also presented in **Table 2.1**.

Figure 2.4 1:2000 scale topographical model of the proposed Kai Tak Development in the low speed test section, Study Area B, (North wind direction, 360˚)

Figure 2.5 1:2000 scale topographical model of the proposed Kai Tak Development in the low speed test section, Study Area B, (East wind direction, 90˚)

Figure 2.6 1:2000 scale topographical model of the proposed Kai Tak Development in the low speed test section, Study Area B, (south wind direction, 180˚)

Figure 2.7 1:2000 scale topographical model of the proposed Kai Tak Development in the low speed test section, Study Area B, (west wind direction, 270˚)



(a) Annual **(b) Summer**

Figure 2.8 **Wind Roses for Annual and Summer, non-typhoon winds for Kai Tak, corrected to 150mPD at Site 1A & 1B, 1998 - 2009**

Table 2.1 **Frequency of Annual and Summer Season Occurrence of Individual Wind Directions at 150mPD**

Wind Direction	% of Annual Occurrence	% of Summer Season Occurrence
0º (N)	3.5%	0.8%
22.5º (NNE)	2.4%	0.3%
45º (NE)	5.0%	0.6%
67.5º (ENE)	3.5%	0.8%
90º (E)	17.5%	8.3%
112.5º (ESE)	19.2%	11.4%
135º (SE)	13.9%	19.0%
157.5º (SSE)	9.6%	8.9%
180º (S)	3.0%	6.9%
202.5º (SSW)	2.8%	7.6%
225º (SW)	3.2%	7.2%
247.5º (WSW)	4.6%	12.7%
270º (W)	3.4%	8.4%
292.5º (WNW)	2.3%	4.0%
315º (NW)	2.8%	1.7%
337.5º (NNW)	3.4%	1.4%

3 ASSESSMENT METHODOLOGY AND CRITERIA

3.1 General

3.1.1 This 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 CFD modelling. Reference is 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 the 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 AVA study.

3.2 Modelling Tool and Assumptions

3.2.1 Assessment was conducted by means of 3-dimensional CFD model and using wind profile information obtained from the site wind availability study discussed in **Section 2.3** above.

3.2.2 The well-recognised commercial CFD package FLUENT was used in this exercise. FLUENT model had 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 application.

3.2.3 Wind Directions: In the CFD model, all 16 wind directions together with their respective % of occurrence determined for the Subject Sites were adopted for simulation of air ventilation performance (see **Table 2.1**)

3.2.4 Vertical Wind Profile: Wind environment under different wind directions was defined in the CFD environment. The wind profiles for the 16 wind directions follow those determined from the site wind availability study as extracted in **Appendix A**.

3.2.5 Turbulence Model: As recommended in COST action C14, realizable K-epsilon turbulence model was adopted in the CFD model to simulate the real life problem. Common computational fluid dynamics equations are adopted in the analysis.

3.2.6 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 viscous fluid turbulence model. Solutions were obtained by iterations.

3.2.7 Computational Domain: The 3-dimensional CFD model was constructed to capture all major components such as topographical features and buildings within and in the vicinity of the Subject Sites that would likely affect the wind flow. The methodology described in the Technical Guide was adopted for this assessment. According to the Technical Guide, the surrounding area up to a perpendicular distance of 2 times of the maximum building height within the Subject Sites (2H) is included in the CFD model. The maximum height of building block for the proposed Site 1A and Site 1B developments is around 120mPD. Therefore, a study area covering not less than 240m from the Subject Sites boundary was included in the formulation of the CFD model and is further extended to include some prominent buildings just outside 240m of the Subject Sites boundary. The size of the CFD model for this Study is approximately 4,700 m (L) x 3,500 m (W) x 720 m (H) and contains about 6,500,000 cells. **Figure 3.1** shows the boundaries of the Project Area, Assessment Area and Surrounding Area examined in this AVA whereas **Figure 3.2** shows the extent of the computational domain adopted in the CFD model. An example cross-sectional wind velocity ratio vector plot across the computational domain under one wind direction is shown in **Figure 3.3** and **Figure 3.4** shows some images of the general setup in the CFD model.

3.2.8 Given the large computational domain adopted in this assessment and the physical limitation on the computational resources of the CFD model, the horizontal grid size employed in the CFD model in the vicinity of the Project Area was taken as a global general minimum size of about 3m (smaller grid size was also employed for specific fine details including elevated road, proposed car park, etc) and increased for the grid cells further away from the Project Area. Besides, prism cells (each layer of not more than 0.5m thick) were employed above the terrain so that the pedestrian level test points (located at 2m above ground level) were located at least the third cell away from the terrain to ensure a better resolution of flow close to the ground as per the recommendation of COST action C14. **Figure 3.5** shows the images of the grid cell setup in the CFD model.

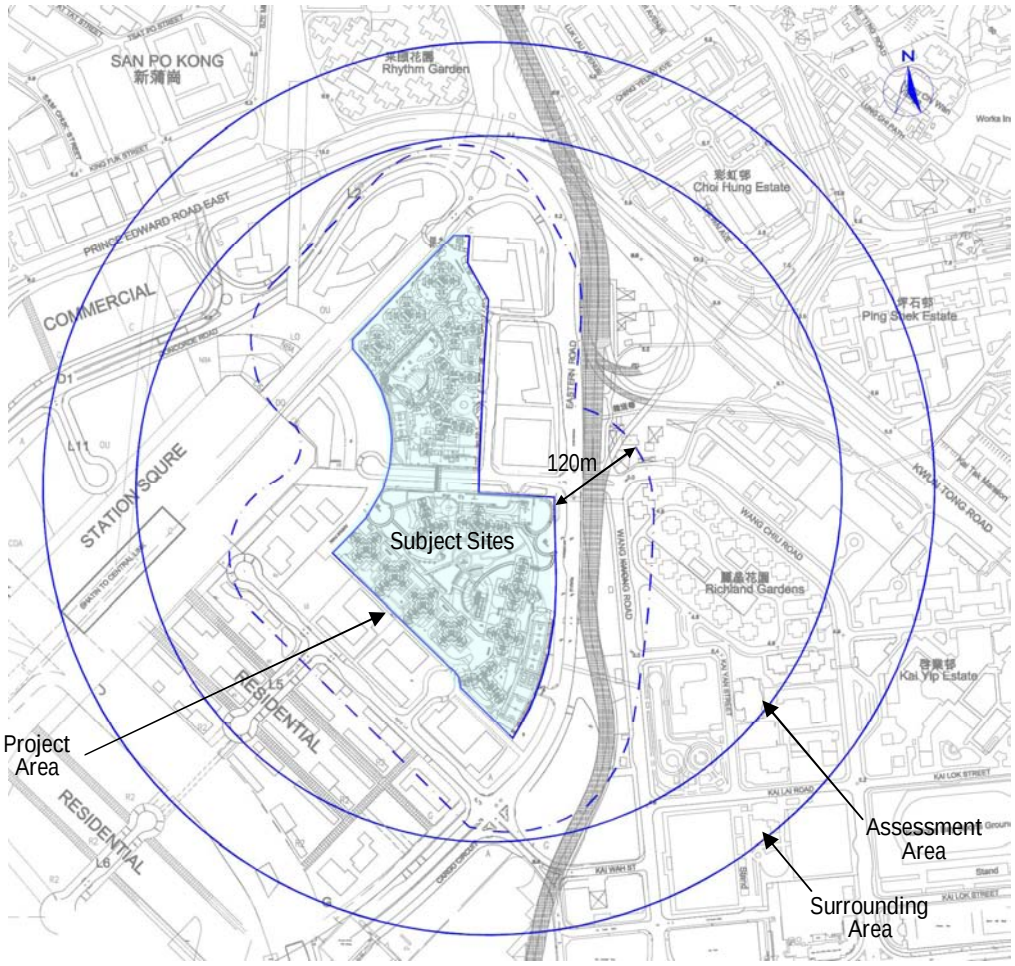


Figure 3.1 Boundaries of Project Area, Assessment Area and Surrounding Area

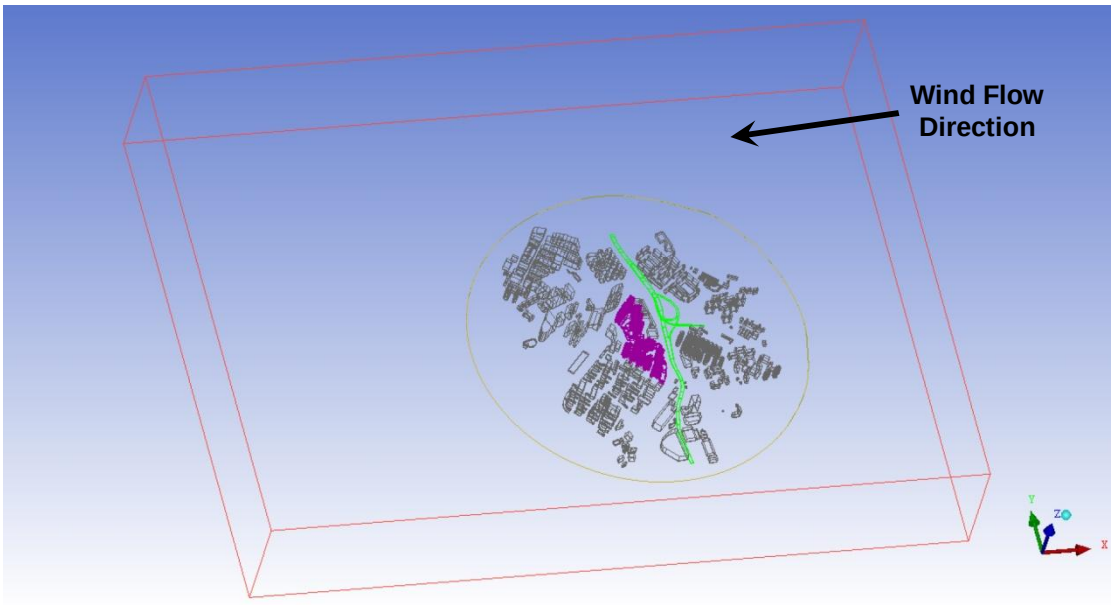


Figure 3.2 Extent of Computational Domain adopted in the CFD Model

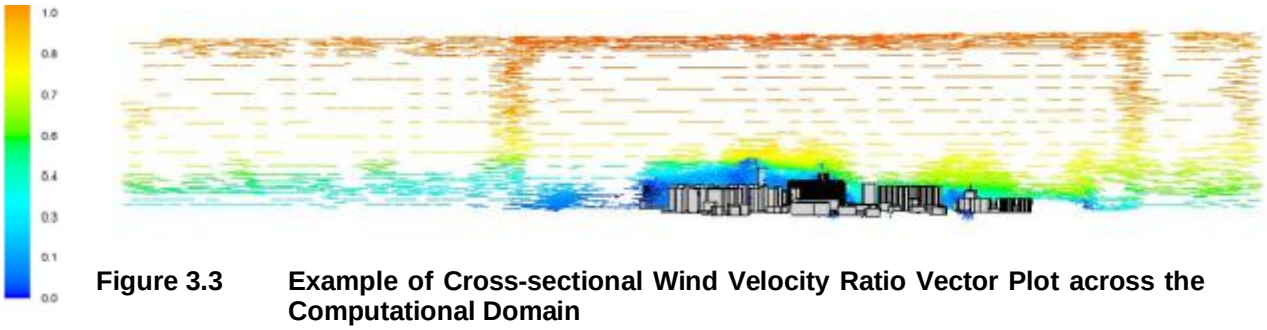
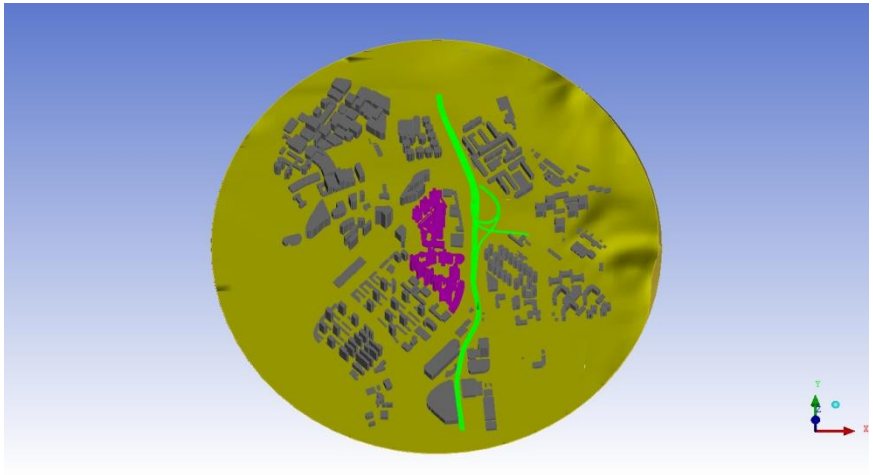
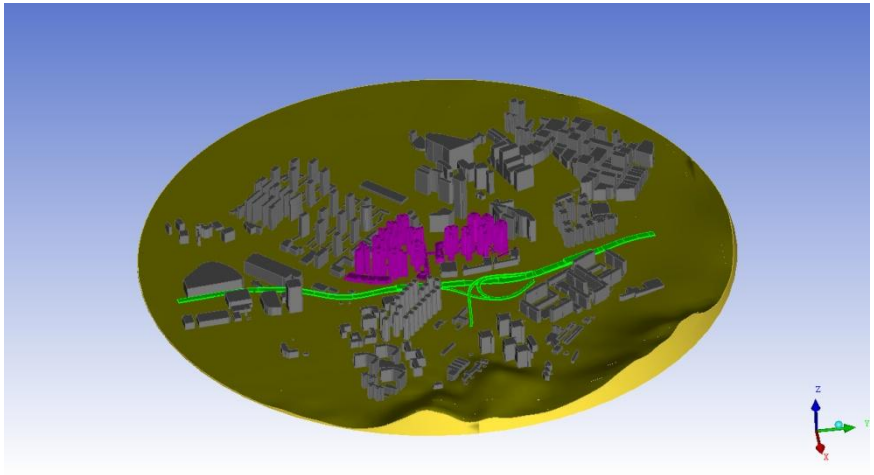


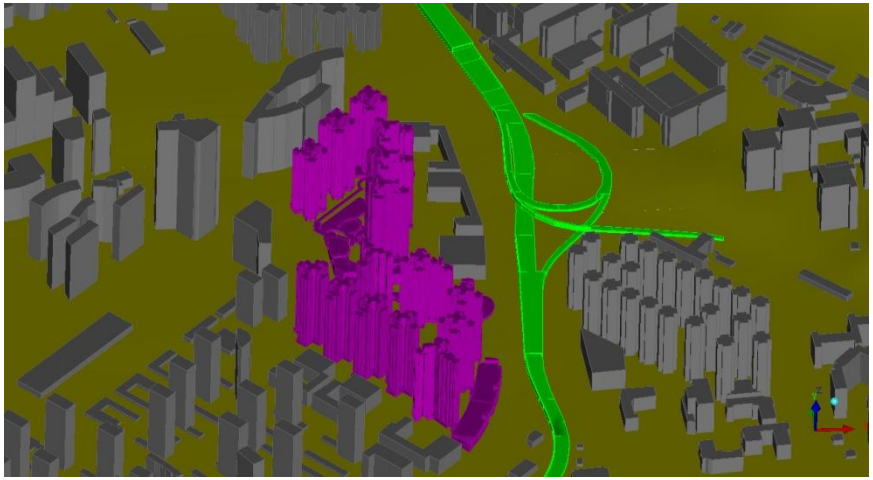
Figure 3.3 Example of Cross-sectional Wind Velocity Ratio Vector Plot across the Computational Domain



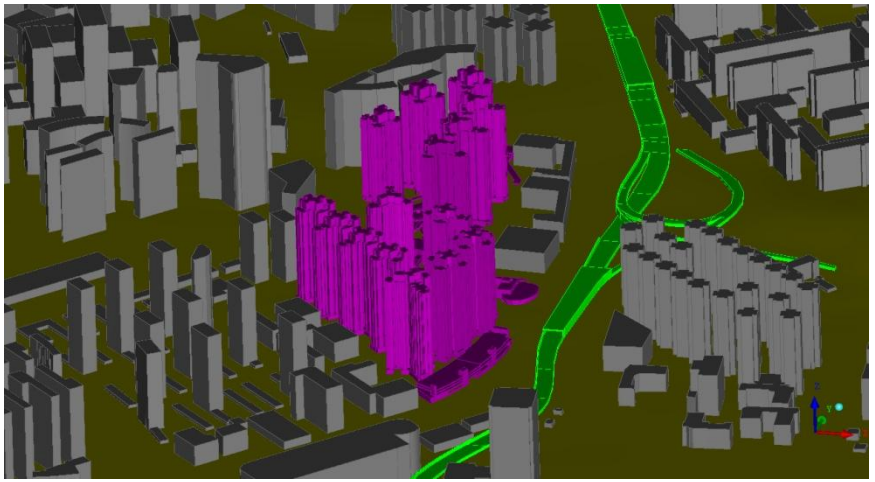
(View 1)



(View 2)

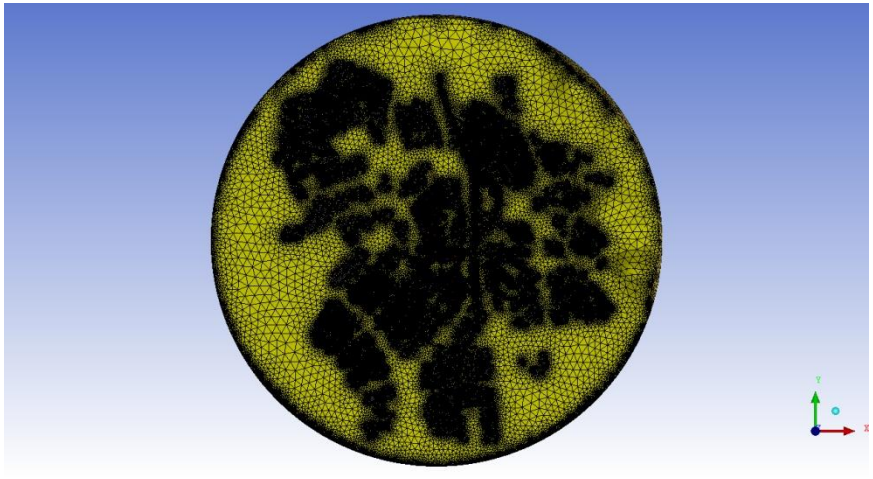


(View 3)



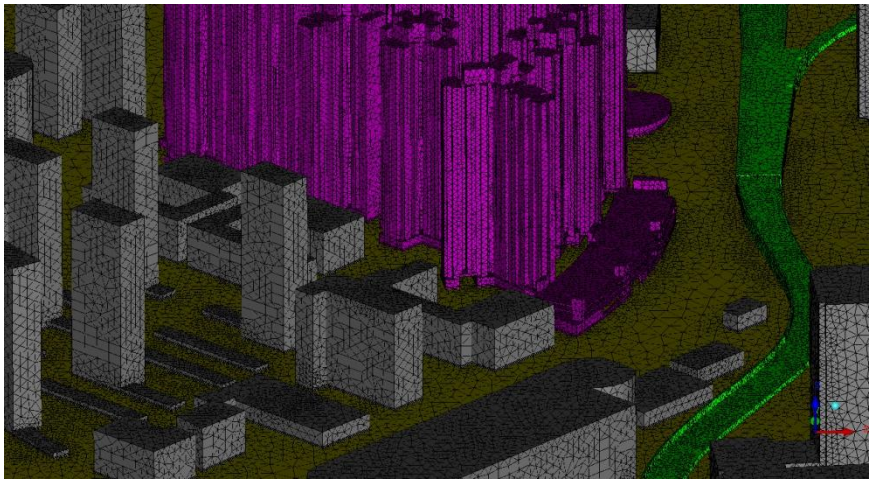
(View 4)

Figure 3.4 Images of General Setup in the CFD Model



(View 1)

(View 2)



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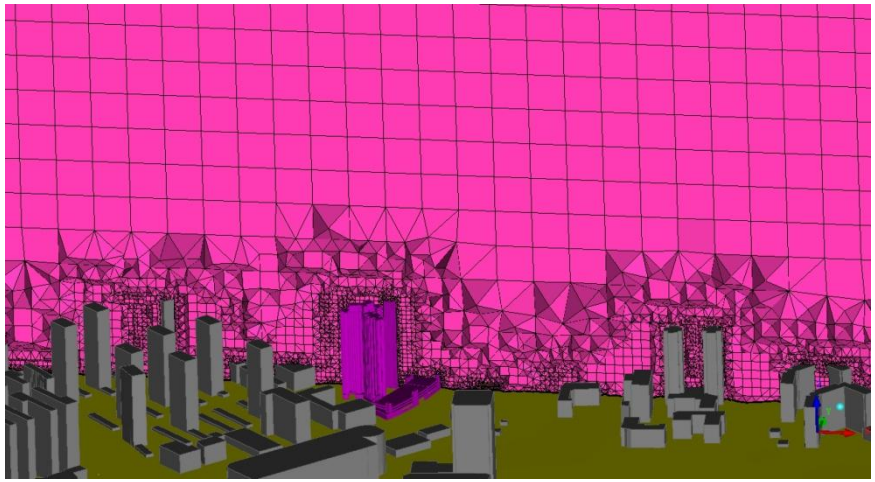


(View 4)

Figure 3.5 Images of Grid Cell Setup in the CFD Model

3.2.9 Test Points: Both perimeter test points and overall test points were selected within the Assessment Area in order to assess the impact on the immediate surroundings and local areas respectively. Perimeter test points were selected along the boundary of the Project Area with separation distance of about 35m. Overall test points were evenly distributed over surrounding open spaces, streets, landscape deck, podium and other parts of the Assessment Area where pedestrian can or will mostly access. All test points are elevated at 2m above ground.

3.2.10 The selected overall test points were grouped based on the land use / sensitive receivers as shown in **Figure 3.6** and summarized in **Table 3.1** for ease of discussion. There are 49 perimeter test points (with prefix "P") and 79 overall test points (with prefix "T") selected for the purpose of this AVA study. For test points along the roads, they are located along the footpath on either side of the road.

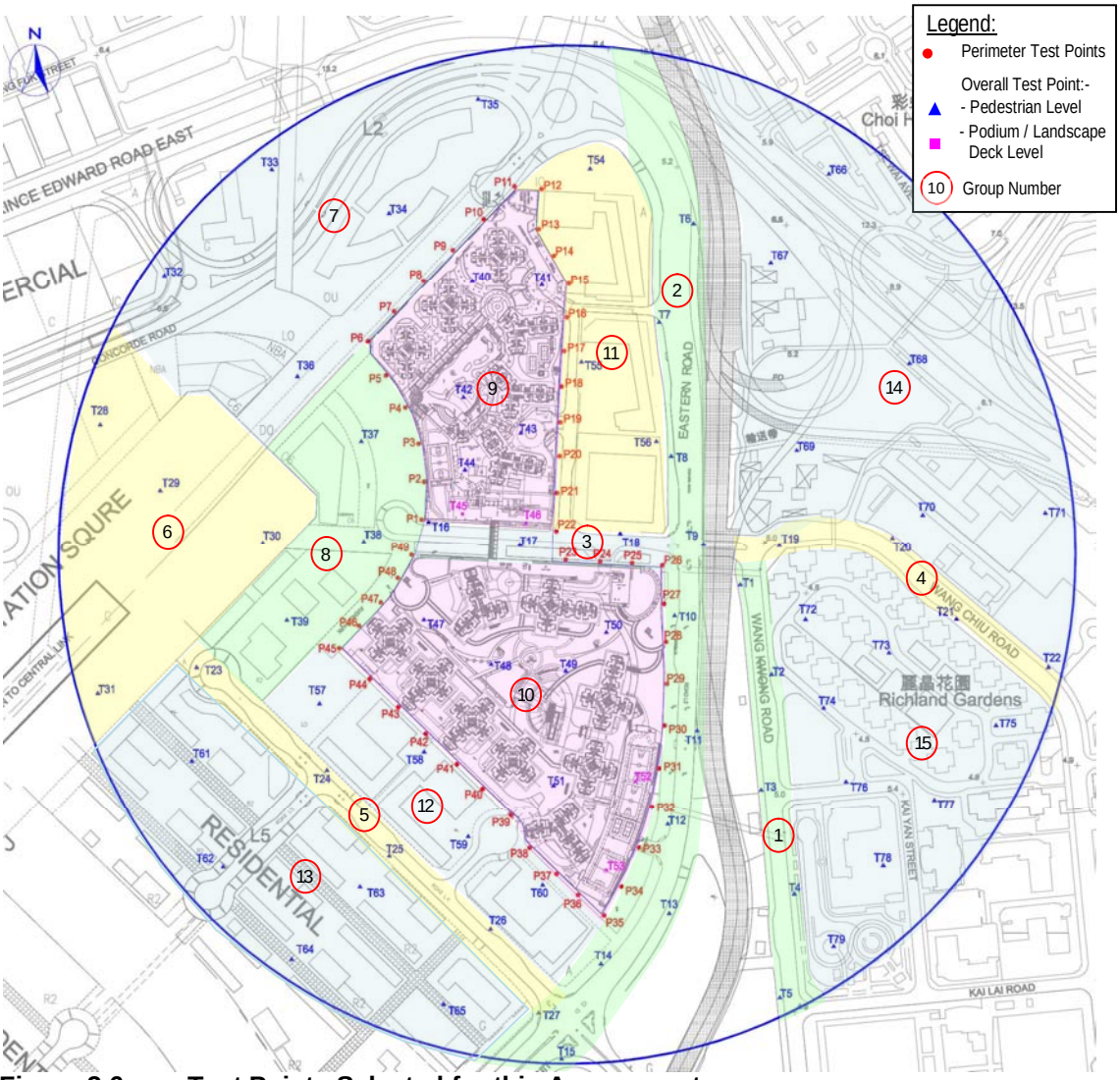


Figure 3.6 Test Points Selected for this Assessment

Table 3.1 Grouping of the Overall Test Points

Group	Description	Test Points
G1	Wang Kwong Road	T1 to T5
G2	Eastern Road, Planned Road L2 and under the Kwun Tong Bypass	T6 to T15 & T27
G3	Corridor along Planned Road L3	T16 – T18
G4	Wang Chiu Road	T19 – T22
G5	Corridor along Planned Road L4	T23 – T27
G6	Planned Shatin to Central Link Station with commercial facility, open space (Station Square) and other specified uses area	T28 to T31
G7	Planned commercial and other specified uses area at Kai Tak Development Area (between Site 1A and Prince Edward Road East)	T32 to T36
G8	Planned commercial and residential development at Kai Tak Development Area 1G	T37 – T39
G9	Open space within Project Area of Site 1A	T40 to T46
G10	Open space within Project Area of Site 1B	T47 to T53
G11	Planned schools between Site 1A and Eastern Road	T54 to T56
G12	Planned schools between Site 1B and Road L4	T57 to T60
G13	Planned residential development at Kai Tak Development Area 1H & 1I	T61 to T65
G14	Open space bounded by Choi Hung Estate, Eastern Road and Wang Chiu Road	T66 to T71
G15	Richland Gardens and the adjacent uses to the east of Site 1B	T72 to T79

3.3 Wind Velocity Ratio

3.3.1 The wind velocity ratio VR_W is the frequency weighted wind velocity ratio calculated based on the frequency of occurrence of the eight wind directions selected in the Initial Study or the 16 wind directions examined in the Detailed Study.

3.3.2 For the Site Air Ventilation Assessment, the Site Spatial Average Wind Velocity Ratio (SVR_W) of all perimeter test points are reported. SVR_W is the average of VR_W of all perimeter test points.

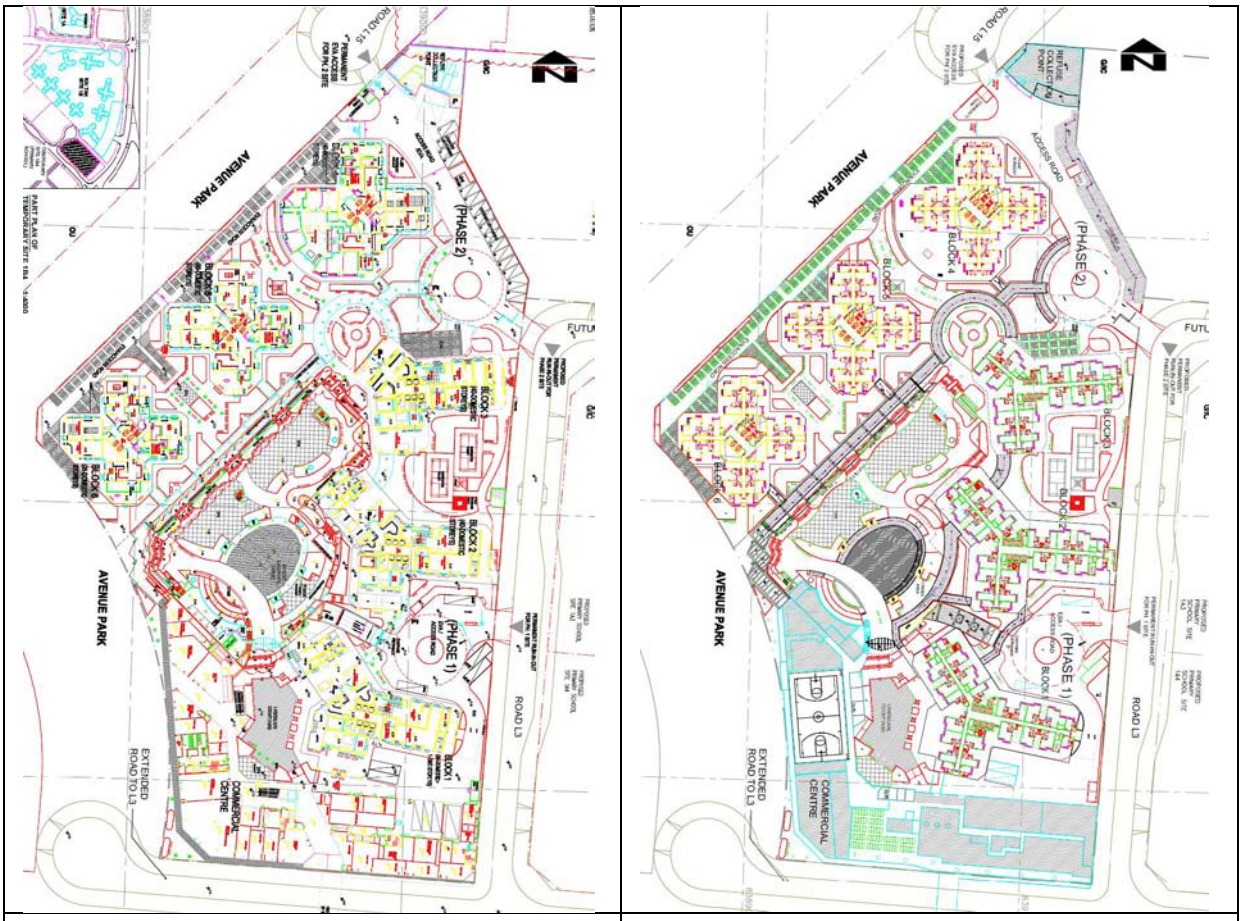
3.3.3 For the Local Air Ventilation Assessment, the Local Spatial Average Wind Velocity Ratio (LVR_W) of all overall test points and perimeter test points, and individual VR_W of the overall test points are reported. LVR_W is the average of all overall test points and perimeter test points.

3.3.4 The SVR_W and LVR_W are worked out so as to understand the overall impact of air ventilation on the immediate and further surroundings of the Project Area due to the proposed development.

3.4 Layout Plan Assessed in this Study

3.4.1 The Subject Sites of this AVA Detailed Study covered both Site 1A and Site 1B with about 9 ha in area consisting commercial block, carport block, kindergarten, ground-level retail shops and necessary supporting facilities.

3.4.2 The layout plan and elevation of Site 1A is shown in **Figure 3.7**and **Figure 3.8** below.



(a) Ground Floor | (b) Typical Floor

Figure 3.7 Master Layout Plan of the Site 1A

Figure 3.8 Elevation View of the Site 1A

3.4.3 The proposed scheme of Site 1B examined in this Detailed Study comprises of nine residential building blocks, commercial facilities, kindergarten and a carport building. The layout plan and elevations are shown in **Figure 3.9** and **Figure 3.10** respectively.

(a) Ground Floor

(b) Typical Floor

Figure 3.9 Master Layout Plan of the Site 1B

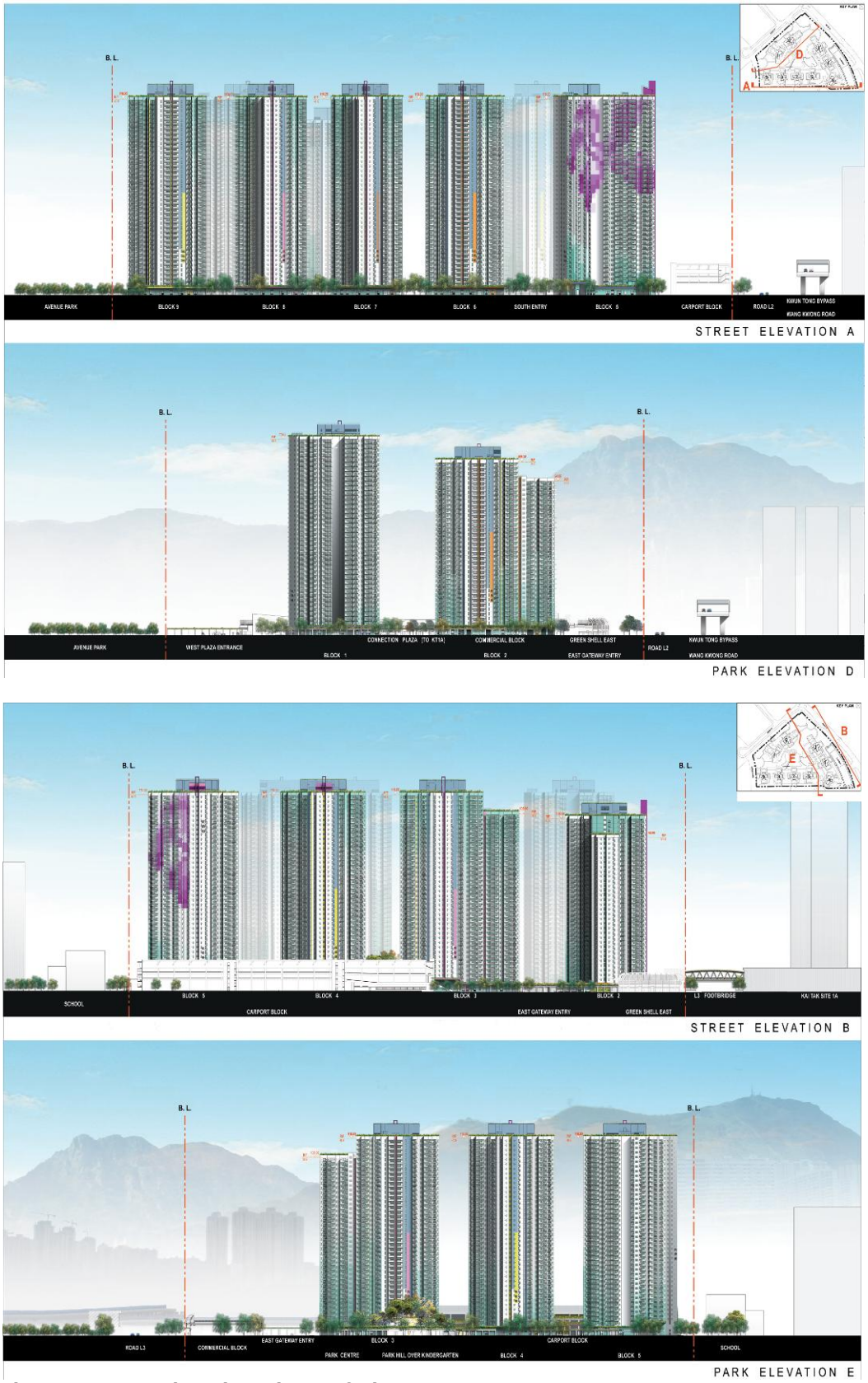


Figure 3.10 Elevation Views of Site 1B

4 KEY FINDINGS OF AVA STUDY

4.1 Local Situation

4.1.1 The local situation including the site environs, site wind environment, and site wind availability of the Subject Sites are described in **Section 2** above.

4.2 Air Ventilation Issues

4.2.1 As discussed in **Section 2** above, the terrain surrounding the Subject Sites is relatively flat and influence of local topography to the wind flow pattern at the Subject Sites should be minimal. However, the Subject Sites will be surrounded by a number of existing and planned developments in almost all directions in future, the wind flow pattern at the Subject Sites would be significantly influenced by this surrounding built environment.

4.2.2 For example, the annual prevailing winds and summer prevailing winds from the east and the east-southerly east towards the Subject Sites would be partially blocked by the existing medium- to high-rise developments in the Kowloon Bay area such as Richland Gardens and Kowloon Bay industrial buildings. Whereas the prevailing summer wind from the west-southerly west towards the Subject Sites is currently unobstructed, but it might be blocked by other developments of the planned Kai Tak Development.

4.2.3 Since the prevailing winds blowing from east to southerly-east covered more than 50% annually, it is important to incorporate wind corridor(s) through and across the Subject Sites along these prevailing wind directions such that acceptable ventilation performance within the Subject Sites could be achieved and at the same time the impact on ventilation to the surrounding existing and planned developments could be minimized.

4.2.4 Besides, although northerly and southerly winds are not the prevailing winds in the area. the existing Eastern Road, Kwun Tong Bypass and planned Road L2 serve as the major breezeways for north-south wind movement in the vicinity of the Subject Sites.

4.3 Air Ventilation Improvement Measures

4.3.1 During the development of the design schemes for Site 1A and Site 1B, a number of ventilation improvement measures have been incorporated into the building design to enhance air ventilation performance. The incorporated ventilation improvement measures are summarised below:

Site 1A

a) Provision of openings at ground level of domestic blocks and commercial centre to improved wind flow at pedestrian level;

b) The carpark is half-sunken to reduce obstruction to airflow; and

c) The building separation has been optimized by rotating the wings of the domestic blocks to enhance ait permeability.

Site 1B

a) Reduce the number of residential blocks from 10 blocks to 9 blocks;

b) Building wings at ground floor are strategically opened up to allow wind passage and breezeway at the pedestrian level;

c) The retail shops at ground level along the north boundary of the site are split to allow air passage to/from the courtyard area of the site;

d) Align building blocks along with prevailing wind direction;

e) Streamlined the edge of kindergarten and the north-east corner of retail shops to enhance movement of wind flow; and

f) Maximize wind permeability of carport structure to allow upwind passage.

4.4 Wind Velocity Ratio Results

4.4.1 The annual and summer SVR_W and LVR_W for Site 1A and Site 1B are summarized in **Table 4.1**. The detailed wind velocity ratios at different test points under all 16 wind directions are presented in **Appendix B**.

Table 4.1 Summary of Wind Velocity Ratios for Site 1A and Site 1B as a whole under all Sixteen Wind Directions

	Wind Velocity Ratios	
	Annual	Summer
Perimeter Test Point VR_W	0.063 – 0.314	0.061 – 0.285
Overall Test Point VR_W	0.061 – 0.382	0.068 – 0.371
SVR_W	0.172	0.175
LVR_W	0.183	0.185

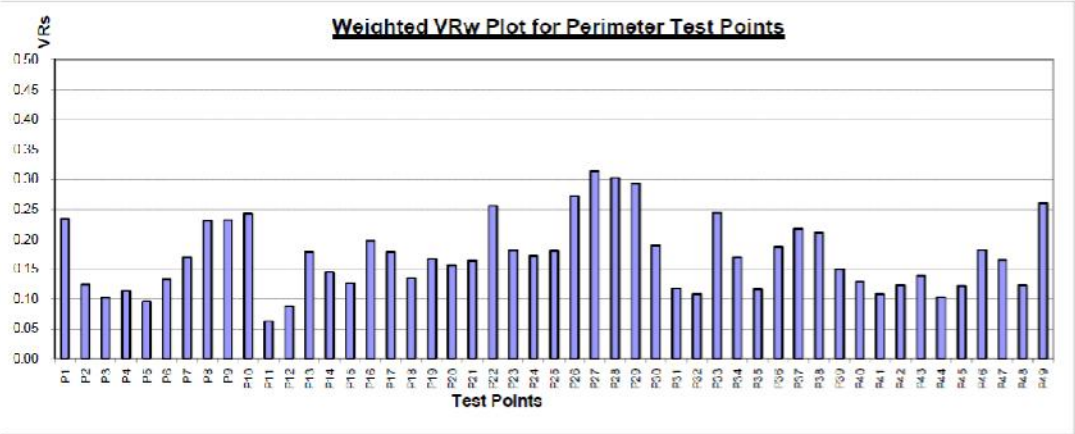
4.4.2 The results of VR_W for different groups of test points are summarized in **Table 4.2**.

Table 4.2 Summary of Wind Velocity Ratio for Different Test Point Groups

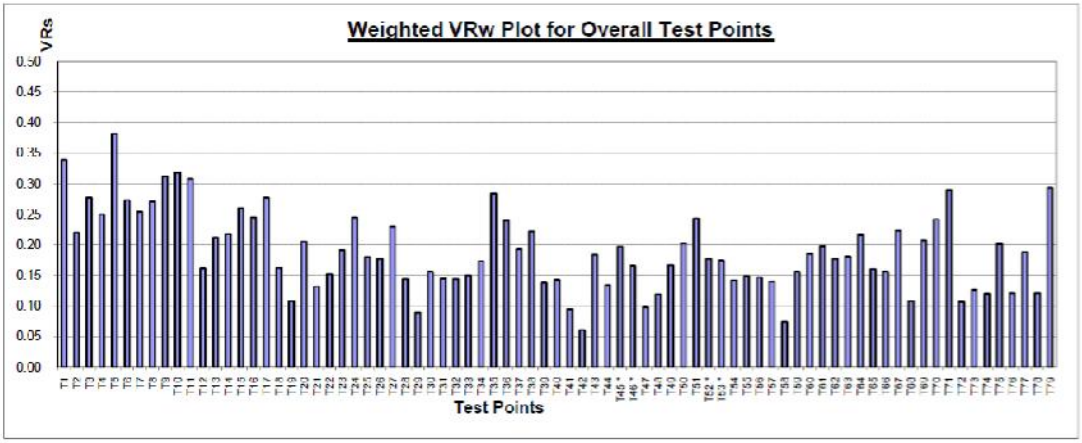
Group	Description	Test Points	Test Points Level	Average VR_w	
				Annual	Summer
G1	Wang Kwong Road	T1 to T5	Pedestrian Level	0.294	0.299
G2	Eastern Road, Planned Road L2 and under the Kwun Tong Bypass	T6 to T15 & T27	Pedestrian Level	0.256	0.245
G3	Corridor along Planned Road L3	T16 – T18	Pedestrian Level	0.228	0.234
G4	Wang Chiu Road	T19 – T22	Pedestrian Level	0.149	0.116
G5	Corridor along Planned Road L4	T23 – T27	Pedestrian Level	0.205	0.201
G6	Planned Shatin Central Link Station with commercial facility, open space (Station Square) and other specified uses area	T28 to T31	Pedestrian Level	0.134	0.161
G7	Planned commercial and other specified uses area at Kai Tak Development Area (between Site 1A and Prince Edward Road East)	T32 to T36	Pedestrian Level	0.198	0.181
G8	Planned commercial and residential development at Kai Tak Development Area 1G	T37 – T39	Pedestrian Level	0.184	0.195
G9	Open space within Project Area of Site 1A	T40 to T44; T45 to T46	Pedestrian Level; Podium Deck	0.140	0.152
G10	Open space within Project Area of Site 1B	T47 to T51; T52 to T53	Pedestrian Level; Podium Deck	0.169	0.166
G11	Planned schools between Site 1A and Eastern Road	T54 to T56	Pedestrian Level	0.146	0.138
G12	Planned schools between Site 1B and Road L4	T57 to T60	Pedestrian Level	0.139	0.157
G13	Planned residential development at Kai Tak Development Area 1H & 1I	T61 to T65	Pedestrian Level	0.186	0.208
G14	Open space bounded by Choi Hung Estate, Eastern Road and Wang Chiu Road	T66 to T71	Pedestrian Level	0.204	0.184
G15	Richland Garden and the adjacent uses to the east of Subject Site 1B	T72 to T79	Pedestrian Level	0.107	0.111

4.4.3 The averaged VR_W result for individual test points and test point groups for annual and the summer season are also presented in the form of bar chart as shown in **Figure 4.1** and **4.2** respectively. The averaged VR_W result for individual test points and test points in the form of bar chart under the sixteen assessed wind directions are shown in **Appendix C**.

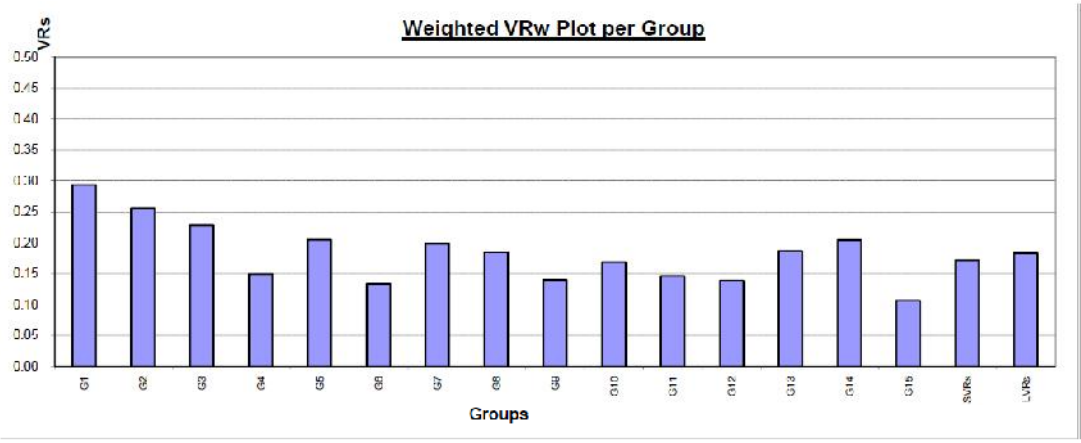
4.4.4 Contour plots of wind velocity ratio at 2m above the pedestrian level of assessment area under the sixteen assessed wind directions are shown in **Appendix D**. The contour plot of the frequency weighted wind velocity ratio at 2m above ground is shown in **Figure 4.3** below.



(a) Perimeter Test Points

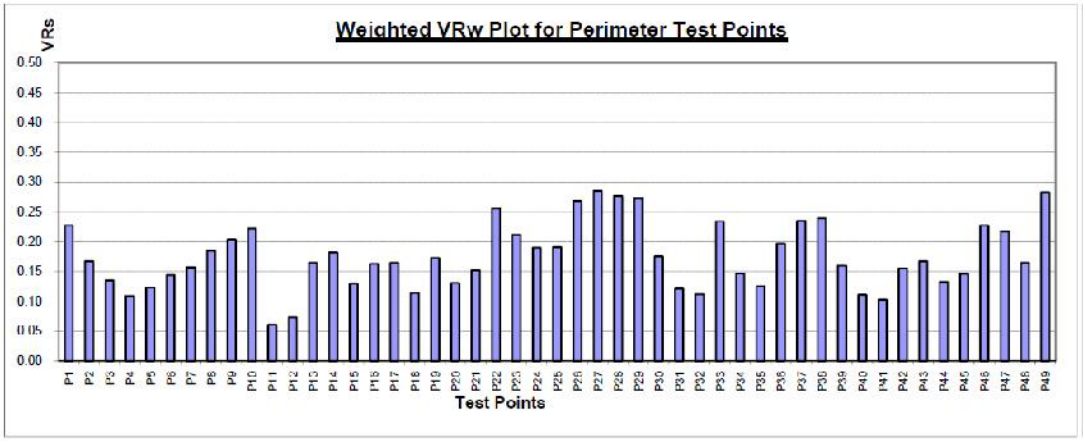


(b) Overall Test Points

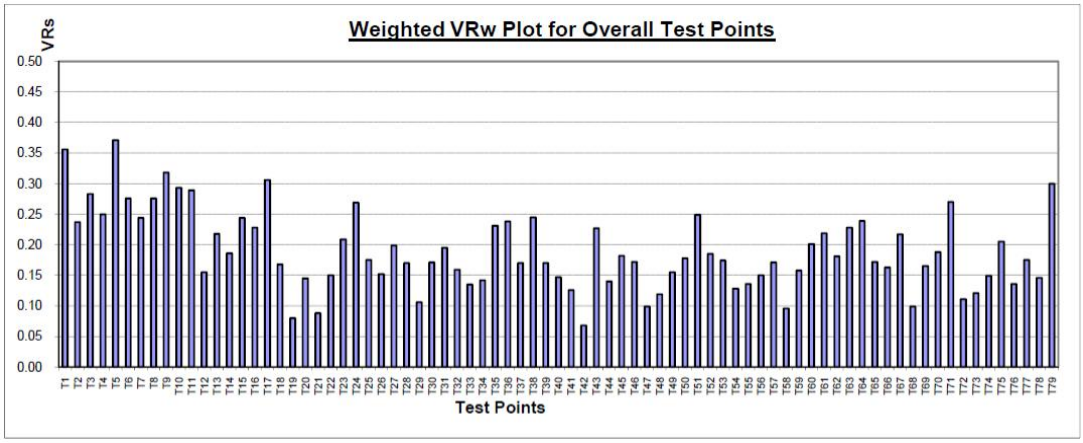


(c) For Different Test Point Groups

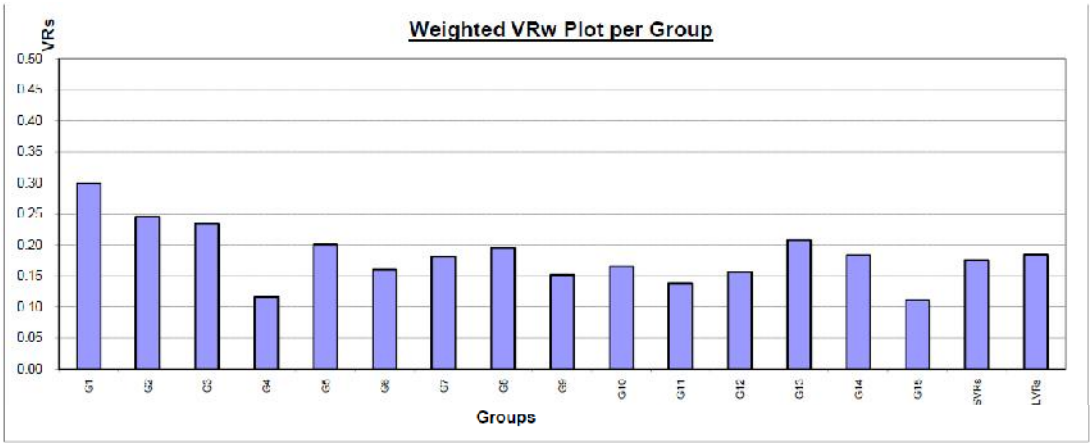
Figure 4.1 Averaged VR_W Result (Annual)



(a) Perimeter Test Points

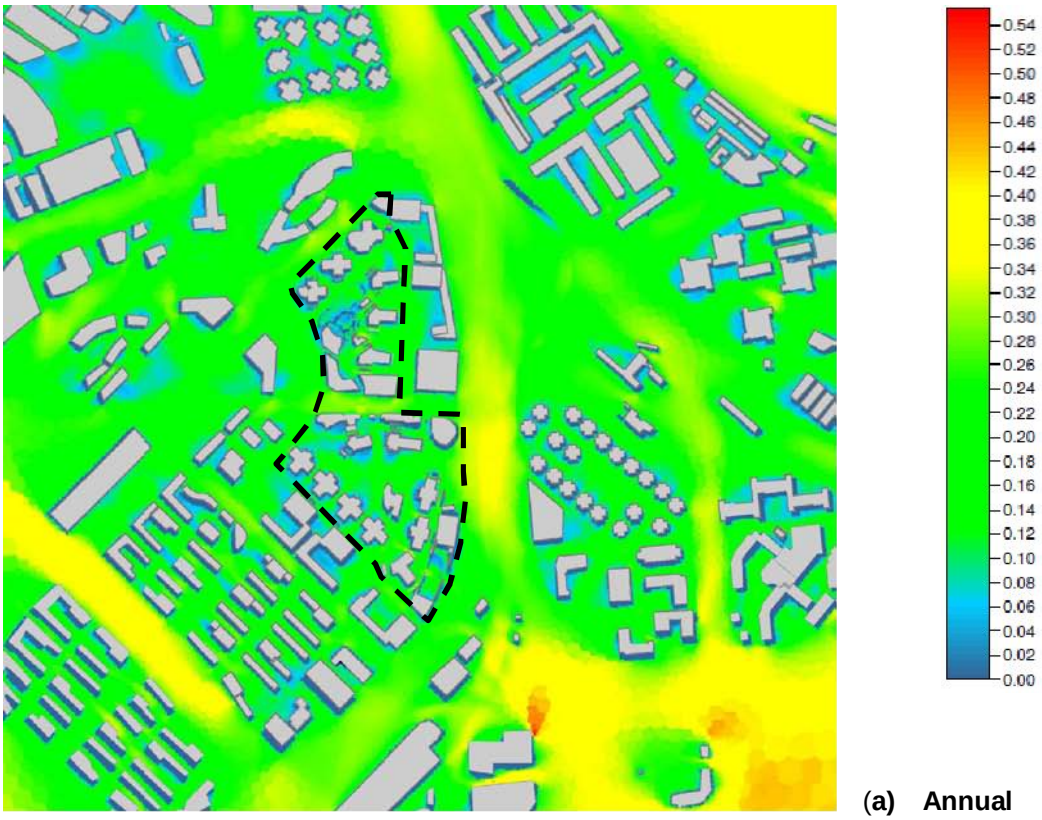


(b) Overall Test Points

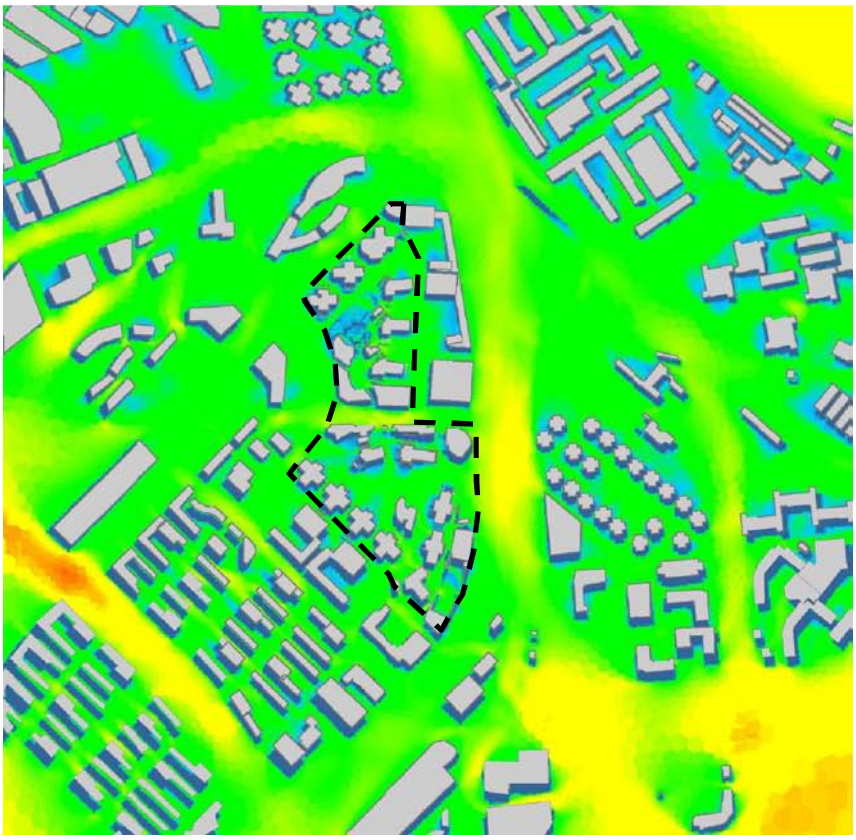


(c) For Different Test Point Groups

Figure 4.2 Averaged VR_W Result (Summer Season)



(a) Annual



(b) Summer

Figure 4.3 Frequency Weighted Wind Velocity Ratio Contour Plot at 2m above Ground

4.5 Site Ventilation Assessment

4.5.1 The predicted annual SVR_W for Site 1A and Site 1B as a whole is 0.172 under all sixteen wind directions. As shown in **Figure 4.1a**, the predicted annual wind velocity ratio of 28 out of 49 perimeter test points exceeds 0.15 whereas 13 out of 49 perimeter test points exceeds 0.20. During summer season, the predicted summer SVR_W is 0.175. As indicated in **Figure 4.2a,** wind velocity ratio of 32 out of 49 and 15 out of 49 perimeters test points exceeds 0.15 and 0.20 respectively during summer season.

4.5.2 The SVR_W indicates how the lower portion of the buildings on the project site may affect the wind environment of its immediate vicinity. As discussed in **Section 4.3** above, both Site 1A and Site 1B have incorporated ventilation improvement design into the lower portion of the development including the provision of openings at ground level of domestic blocks and to optimize building separation by rotating the wings of the domestic blocks, etc.

4.5.3 Besides, the wind velocity ratio contour plots shown in **Figure 4.3** and **Appendix D** do not indicate any spot within Site 1A and Site 1B which are subject to high wind velocity gradient, wind gust problem within Site 1A and Site 1B is therefore not expected.

4.6 Local Air Ventilation Assessment

4.6.1 The averaged LVR_W for Site 1A and Site 1B under annual and summer winds are 0.183 and 0.185 respectively. As shown in **Figure 4.1c** and **Figure 4.2c**, the averaged VR_W for most test points groups are close to or above 0.15 except Group 15 for annual wind probability data and Group 4 and Group 15 for summer season.

4.6.2 Test points for Group 4 and Group 15 are at Wang Chiu Road, Richland Gardens and some existing schools. The reason for the lower averaged VR_W at these two Groups in both annual and summer season is due to the sheltering effect by its own building structure as well as the prevailing southeasterly wind is obstructed by the massive buildings of the adjacent Kai Yip Estate. This can be illustrated by the relatively higher VR_W at Point T79 in the same area which is not obstructed by Kai Yip Estate.

5 SUMMARY AND CONCLUSIONS

5.1.1 This AVA Study Report aims at assessing 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 different wind directions.

5.1.2 The ventilation improvement designs that have been incorporated into Site 1A and Site 1B to improve the penetration of wind across the developments include the introduction of building openings at ground level of domestic blocks for Site 1A and Site 1B, streamlined north-east edge of retail shops and kindergarten of Site 1B, deletion of one domestic block at Site 1B, half-sunken design of carpark at Site 1A and reduction of footprint for the carport at Site 1B.

5.1.3 To conclude, the air ventilation performance of Site 1A and Site 1B as a whole is considered as acceptable after examined the frequency weighted site and local spatial average wind velocity ratios based on the wind profile and frequencies of all sixteen incoming wind directions.

APPENDICES

Appendix A

Information extracted from "Experimental Site Wind Availability Study for the Proposed Kai Tak Development, Hong Kong - Investigation Report WWTF013-2009"

--Appendix A Information extracted from "*Experimental Site Wind Availability Study for the Proposed Kai Tak Development, Hong Kong - Investigation Report WWTF013-2009*"

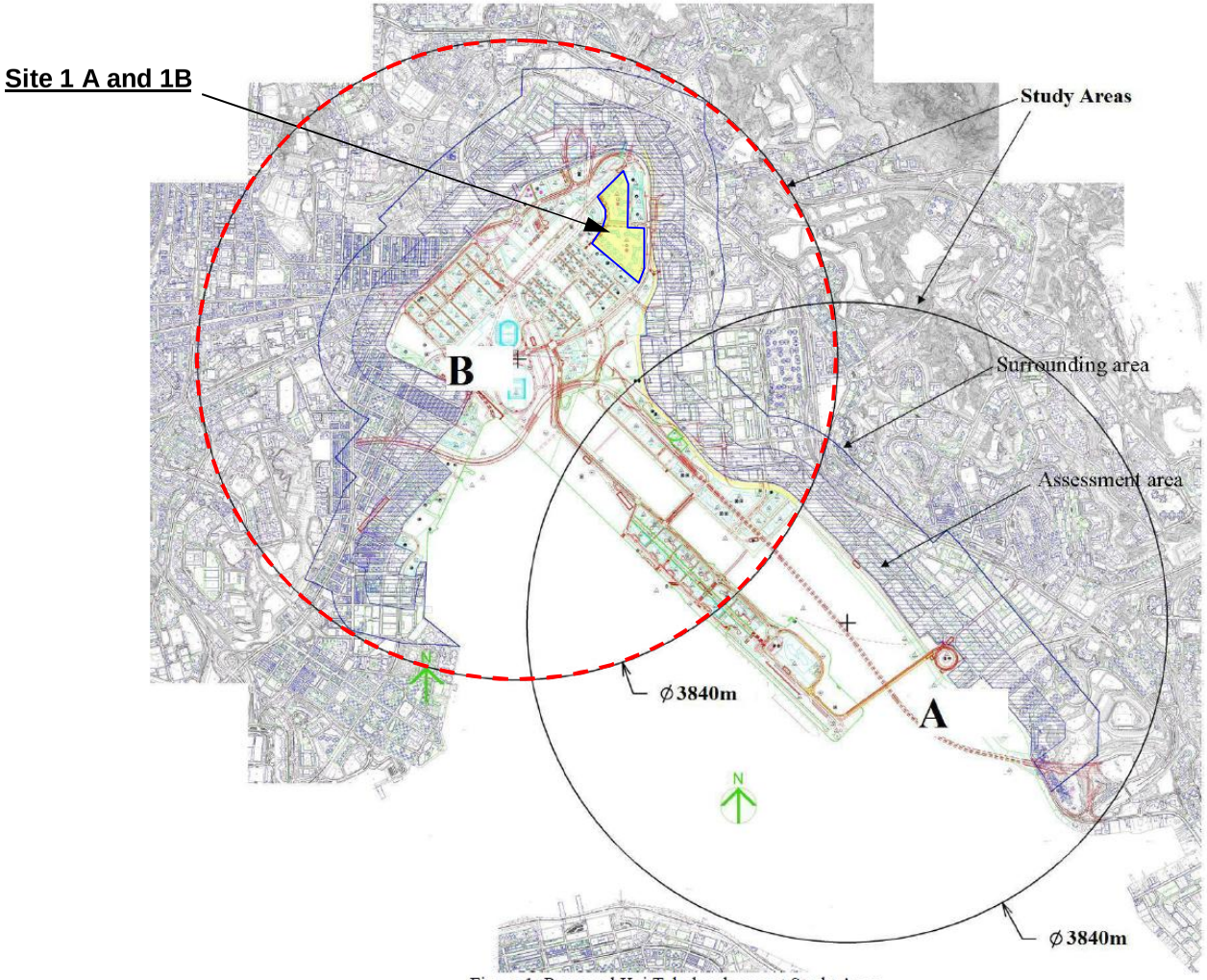


Figure 1: Proposed Kai Tak development Study Areas

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APPENDIX B

TABULATED RESULTS FOR KAI TAK-STUDY AREA B

Table B1: Site wind characteristics of Study Area B, 22.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.47	22.1%
50	0.51	21.6%
75	0.53	21.7%
100	0.56	21.3%
150	0.61	20.4%
200	0.64	19.6%
300	0.72	17.5%
400	0.82	14.2%
500	0.90	10.6%

Table B2: Site wind characteristics of Study Area B, 45°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.49	24.0%
50	0.53	22.9%
75	0.55	23.5%
100	0.56	23.7%
150	0.54	26.4%
200	0.51	28.5%
300	0.45	32.4%
400	0.45	35.1%
500	0.49	34.6%

Table B3: Site wind characteristics of Study Area B, 67.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.38	25.6%
50	0.41	25.1%
75	0.43	25.0%
100	0.45	24.9%
150	0.49	23.8%
200	0.54	22.6%
300	0.62	18.9%
400	0.68	17.0%
500	0.76	14.2%

Table B4: Site wind characteristics of Study Area B, 90°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.45	20.8%
50	0.47	21.4%
75	0.49	22.1%
100	0.51	22.1%
150	0.57	21.1%
200	0.63	19.7%
300	0.75	14.1%
400	0.84	10.1%
500	0.89	6.9%

Table B5: Site wind characteristics of Study Area B, 112.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.49	19.9%
50	0.51	19.7%
75	0.53	20.0%
100	0.54	20.6%
150	0.57	21.0%
200	0.60	20.0%
300	0.68	18.0%
400	0.76	15.2%
500	0.83	12.0%

Table B6: Site wind characteristics of Study Area B, 135°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.60	11.8%
50	0.64	11.4%
75	0.67	10.9%
100	0.71	10.4%
150	0.76	9.5%
200	0.79	8.7%
300	0.85	7.4%
400	0.89	6.1%
500	0.92	5.2%

Table B7: Site wind characteristics of Study Area B, 157.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.60	15.4%
50	0.63	15.7%
75	0.67	15.3%
100	0.68	15.5%
150	0.70	16.0%
200	0.71	16.4%
300	0.70	16.9%
400	0.69	17.2%
500	0.71	17.2%

Table B8: Site wind characteristics of Study Area B, 180°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.50	17.1%
50	0.54	16.8%
75	0.55	16.7%
100	0.57	16.6%
150	0.60	16.5%
200	0.63	16.8%
300	0.71	15.0%
400	0.78	12.9%
500	0.86	10.0%

Table B9: Site wind characteristics of Study Area B, 202.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.35	25.5%
50	0.39	25.9%
75	0.40	25.5%
100	0.43	25.4%
150	0.46	25.9%
200	0.49	24.7%
300	0.56	23.3%
400	0.60	21.9%
500	0.66	20.3%

Table B10: Site wind characteristics of Study Area B, 225°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.42	24.4%
50	0.46	24.0%
75	0.48	23.9%
100	0.51	23.6%
150	0.54	23.3%
200	0.61	21.1%
300	0.70	17.8%
400	0.80	13.9%
500	0.87	10.9%

Table B11: Site wind characteristics of Study Area B, 247.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.40	21.9%
50	0.43	22.1%
75	0.46	22.3%
100	0.49	22.5%
150	0.57	20.9%
200	0.66	17.4%
300	0.79	11.2%
400	0.85	7.2%
500	0.88	5.8%

Table B12: Site wind characteristics of Study Area B, 270°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.43	19.7%
50	0.47	19.5%
75	0.49	19.9%
100	0.53	19.6%
150	0.60	17.9%
200	0.66	16.1%
300	0.79	11.0%
400	0.87	7.1%
500	0.91	5.2%

Table B13: Site wind characteristics of Study Area B, 292.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.48	15.9%
50	0.52	16.0%
75	0.55	16.0%
100	0.57	16.3%
150	0.61	15.9%
200	0.66	14.7%
300	0.74	12.7%
400	0.82	10.6%
500	0.87	8.9%

Table B14: Site wind characteristics of Study Area B, 315°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.57	17.7%
50	0.61	17.4%
75	0.64	17.3%
100	0.67	16.7%
150	0.73	15.0%
200	0.78	13.8%
300	0.84	12.0%
400	0.89	9.8%
500	0.93	7.3%

Table B15: Site wind characteristics of Study Area B, 337.5°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.35	30.6%
50	0.37	31.3%
75	0.39	31.9%
100	0.40	32.5%
150	0.41	32.8%
200	0.43	33.3%
300	0.48	33.6%
400	0.51	32.7%
500	0.58	30.3%

Table B16: Site wind characteristics of Study Area B, 360°

Prototype scale elevation (mPD)	Normalised mean wind speed	Turbulence intensity (%)
25	0.43	21.9%
50	0.47	22.2%
75	0.50	22.3%
100	0.51	22.5%
150	0.57	21.8%
200	0.60	21.0%
300	0.71	16.9%
400	0.80	12.7%
500	0.87	10.1%

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Table B17: Percentage occurrence for annual, non-typhoon directional winds at Study Area B at 150 m

Wind Angle	Percentage occurrence for wind speed ranges:				
	0 < u ≤ 3.3 m/s	3.3 < u ≤ 7.9 m/s	7.9 < u ≤ 13.8 m/s	u > 13.8 m/s	Total
0°	2.0%	1.5%	0.0%	0.0%	3.5%
22.5°	0.6%	1.5%	0.3%	0.0%	2.4%
45°	2.0%	2.9%	0.0%	0.0%	5.0%
67.5°	1.1%	2.4%	0.1%	0.0%	3.5%
90°	1.1%	10.3%	6.1%	0.1%	17.5%
112.5°	3.8%	14.5%	0.9%	0.0%	19.2%
135°	6.2%	7.6%	0.1%	0.0%	13.9%
157.5°	4.8%	4.7%	0.1%	0.0%	9.6%
180°	1.9%	1.0%	0.1%	0.0%	3.0%
202.5°	1.4%	1.3%	0.0%	0.0%	2.8%
225°	2.2%	1.0%	0.0%	0.0%	3.2%
247.5°	2.2%	2.4%	0.1%	0.0%	4.6%
270°	1.4%	1.8%	0.2%	0.0%	3.4%
292.5°	1.1%	1.1%	0.1%	0.0%	2.3%
315°	1.6%	1.2%	0.0%	0.0%	2.8%
337.5°	3.0%	0.4%	0.0%	0.0%	3.4%

Table B18: Percentage occurrence for summer, non-typhoon directional winds at Study Area B at 150 m

Wind Angle	Percentage occurrence for wind speed ranges:				
	0 < u ≤ 3.3 m/s	3.3 < u ≤ 7.9 m/s	7.9 < u ≤ 13.8 m/s	u > 13.8 m/s	Total
0°	0.7%	0.1%	0.0%	0.0%	0.8%
22.5°	0.2%	0.1%	0.0%	0.0%	0.3%
45°	0.4%	0.2%	0.0%	0.0%	0.6%
67.5°	0.3%	0.4%	0.0%	0.0%	0.8%
90°	0.7%	5.0%	2.6%	0.0%	8.3%
112.5°	3.3%	7.5%	0.7%	0.0%	11.4%
135°	8.1%	10.5%	0.4%	0.0%	19.0%
157.5°	4.7%	4.2%	0.1%	0.0%	8.9%
180°	3.7%	3.1%	0.1%	0.0%	6.9%
202.5°	3.3%	4.1%	0.1%	0.0%	7.6%
225°	4.4%	2.8%	0.0%	0.0%	7.2%
247.5°	4.9%	7.4%	0.5%	0.0%	12.7%
270°	2.5%	5.3%	0.6%	0.0%	8.4%
292.5°	1.1%	2.7%	0.2%	0.0%	4.0%
315°	0.9%	0.8%	0.1%	0.0%	1.7%
337.5°	1.4%	0.0%	0.0%	0.0%	1.4%

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Appendix B

Details of Predicted Wind Velocity Ratios (VR_W)

Appendix B Details of Predicted Wind Velocity Ratios (VR_W)

"Annual Wind"

		Wind Velocity Ratio - Annual																VR_W for Total
	Test Point	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	16 Wind Directions
	Wind probability	0.035	0.024	0.05	0.035	0.175	0.192	0.139	0.096	0.03	0.028	0.032	0.046	0.034	0.023	0.028	0.034	1
Site 1A	P1	0.069	0.300	0.289	0.301	0.237	0.274	0.307	0.111	0.093	0.145	0.284	0.262	0.249	0.099	0.217	0.222	0.234
	P2	0.042	0.059	0.105	0.052	0.073	0.091	0.204	0.020	0.180	0.127	0.297	0.249	0.276	0.107	0.180	0.196	0.124
	P3	0.060	0.021	0.110	0.033	0.055	0.061	0.173	0.054	0.198	0.066	0.218	0.142	0.276	0.088	0.133	0.181	0.102
	P4	0.050	0.166	0.091	0.215	0.180	0.044	0.115	0.087	0.198	0.122	0.098	0.040	0.164	0.046	0.181	0.164	0.114
	P5	0.038	0.041	0.018	0.019	0.037	0.048	0.215	0.147	0.154	0.157	0.231	0.017	0.127	0.071	0.207	0.112	0.096
	P6	0.057	0.156	0.092	0.087	0.053	0.055	0.288	0.339	0.247	0.175	0.025	0.022	0.055	0.051	0.137	0.191	0.133
	P7	0.040	0.142	0.140	0.200	0.221	0.166	0.106	0.308	0.274	0.108	0.249	0.056	0.077	0.150	0.183	0.122	0.170
	P8	0.064	0.301	0.283	0.293	0.332	0.275	0.033	0.316	0.327	0.153	0.133	0.075	0.164	0.241	0.281	0.331	0.231
	P9	0.029	0.273	0.351	0.207	0.290	0.274	0.147	0.320	0.377	0.181	0.211	0.086	0.138	0.134	0.148	0.179	0.232
	P10	0.078	0.236	0.335	0.266	0.260	0.261	0.257	0.244	0.401	0.146	0.258	0.080	0.126	0.208	0.199	0.344	0.243
	P11	0.097	0.151	0.147	0.040	0.045	0.042	0.047	0.098	0.207	0.018	0.102	0.018	0.041	0.056	0.030	0.049	0.063
	P12	0.097	0.187	0.185	0.081	0.029	0.129	0.132	0.062	0.042	0.024	0.032	0.076	0.029	0.004	0.006	0.177	0.088
	P13	0.174	0.256	0.279	0.101	0.107	0.176	0.411	0.241	0.037	0.061	0.079	0.051	0.078	0.088	0.079	0.056	0.179
	P14	0.125	0.221	0.231	0.090	0.049	0.037	0.352	0.151	0.097	0.224	0.273	0.119	0.244	0.197	0.133	0.045	0.145
	P15	0.063	0.122	0.140	0.069	0.068	0.127	0.316	0.187	0.027	0.080	0.177	0.036	0.033	0.028	0.051	0.021	0.127
	P16	0.229	0.325	0.393	0.092	0.136	0.188	0.439	0.255	0.014	0.025	0.057	0.037	0.039	0.017	0.043	0.153	0.197
	P17	0.247	0.333	0.404	0.135	0.141	0.184	0.246	0.102	0.063	0.160	0.228	0.097	0.193	0.130	0.061	0.131	0.179
	P18	0.204	0.280	0.310	0.190	0.112	0.127	0.252	0.053	0.024	0.046	0.085	0.087	0.086	0.035	0.028	0.059	0.135
	P19	0.184	0.290	0.354	0.204	0.158	0.054	0.274	0.158	0.055	0.118	0.222	0.165	0.271	0.148	0.145	0.053	0.167
	P20	0.137	0.229	0.397	0.278	0.246	0.033	0.190	0.173	0.061	0.049	0.151	0.038	0.210	0.149	0.072	0.052	0.156
	P21	0.053	0.089	0.294	0.238	0.226	0.163	0.228	0.104	0.079	0.070	0.080	0.238	0.084	0.054	0.044	0.037	0.164
	P22	0.068	0.092	0.301	0.255	0.238	0.224	0.387	0.426	0.146	0.175	0.269	0.205	0.174	0.132	0.192	0.190	0.256
Site 1B	P23	0.042	0.077	0.075	0.090	0.089	0.202	0.331	0.213	0.024	0.093	0.236	0.238	0.327	0.210	0.255	0.153	0.181
	P24	0.118	0.167	0.189	0.111	0.089	0.132	0.266	0.271	0.090	0.074	0.243	0.169	0.274	0.226	0.256	0.144	0.172
	P25	0.105	0.048	0.109	0.102	0.146	0.171	0.272	0.312	0.182	0.158	0.051	0.105	0.262	0.216	0.261	0.091	0.180
	P26	0.328	0.300	0.387	0.222	0.036	0.295	0.398	0.565	0.354	0.361	0.110	0.053	0.190	0.189	0.241	0.274	0.272
	P27	0.418	0.373	0.470	0.283	0.138	0.364	0.434	0.554	0.362	0.351	0.138	0.069	0.104	0.112	0.108	0.374	0.314
	P28	0.399	0.354	0.386	0.203	0.177	0.344	0.397	0.527	0.347	0.353	0.204	0.049	0.107	0.130	0.110	0.373	0.303
	P29	0.427	0.403	0.405	0.203	0.183	0.306	0.343	0.488	0.350	0.378	0.249	0.143	0.081	0.054	0.094	0.392	0.293
	P30	0.407	0.436	0.475	0.261	0.090	0.077	0.140	0.377	0.324	0.367	0.172	0.066	0.143	0.037	0.028	0.322	0.189
	P31	0.023	0.032	0.124	0.091	0.116	0.120	0.099	0.272	0.189	0.260	0.118	0.030	0.051	0.057	0.013	0.067	0.118
	P32	0.087	0.050	0.076	0.038	0.115	0.122	0.121	0.159	0.164	0.195	0.099	0.050	0.078	0.039	0.061	0.053	0.108
	P33	0.035	0.119	0.214	0.171	0.298	0.370	0.448	0.080	0.144	0.157	0.127	0.149	0.212	0.083	0.023	0.016	0.244
	P34	0.024	0.192	0.228	0.123	0.174	0.319	0.249	0.033	0.124	0.089	0.136	0.040	0.094	0.079	0.042	0.043	0.170
	P35	0.012	0.137	0.183	0.110	0.111	0.140	0.163	0.025	0.182	0.152	0.125	0.091	0.171	0.086	0.067	0.016	0.116
	P36	0.022	0.060	0.301	0.185	0.211	0.281	0.190	0.039	0.160	0.252	0.152	0.268	0.269	0.137	0.038	0.008	0.187
	P37	0.036	0.024	0.285	0.181	0.240	0.289	0.225	0.172	0.281	0.398	0.172	0.227	0.268	0.145	0.076	0.027	0.218
	P38	0.046	0.043	0.120	0.097	0.180	0.236	0.264	0.352	0.378	0.338	0.052	0.188	0.240	0.277	0.099	0.104	0.211
	P39	0.122	0.159	0.267	0.177	0.062	0.108	0.232	0.248	0.191	0.124	0.082	0.129	0.233	0.109	0.124	0.102	0.150
	P40	0.031	0.067	0.196	0.079	0.194	0.166	0.077	0.169	0.121	0.186	0.095	0.054	0.043	0.054	0.066	0.060	0.129
	P41	0.072	0.102	0.190	0.121	0.160	0.044	0.065	0.146	0.178	0.135	0.088	0.080	0.086	0.147	0.139	0.107	0.108
	P42	0.047	0.047	0.163	0.089	0.094	0.082	0.052	0.158	0.254	0.190	0.170	0.267	0.207	0.255	0.173	0.179	0.123
	P43	0.017	0.032	0.290	0.139	0.102	0.064	0.005	0.286	0.293	0.090	0.223	0.330	0.236	0.258	0.184	0.205	0.139
	P44	0.051	0.022	0.210	0.068	0.058	0.070	0.050	0.181	0.228	0.341	0.197	0.157	0.103	0.146	0.026	0.083	0.103
	P45	0.059	0.098	0.100	0.073	0.081	0.077	0.166	0.190	0.171	0.118	0.238	0.179	0.136	0.085	0.143	0.160	0.122
	P46	0.107	0.143	0.218	0.148	0.142	0.138	0.117	0.234	0.216	0.209	0.263	0.417	0.426	0.250	0.078	0.180	0.182
	P47	0.141	0.090	0.173	0.090	0.064	0.072	0.225	0.290	0.282	0.268	0.334	0.352	0.178	0.079	0.118	0.238	0.165
	P48	0.054	0.064	0.134	0.085	0.063	0.105	0.078	0.180	0.213	0.255	0.212	0.333	0.188	0.094	0.139	0.071	0.123
	P49	0.066	0.272	0.339	0.279	0.246	0.311	0.349	0.109	0.189	0.327	0.342	0.414	0.282	0.078	0.137	0.089	0.260
	Average SVR	0.112	0.167	0.236	0.148	0.142	0.164	0.222	0.216	0.190	0.176	0.171	0.140	0.166	0.120	0.119	0.143	0.172
	P_{Min}	0.012	0.021	0.018	0.019	0.029	0.033	0.005	0.020	0.014	0.018	0.025	0.017	0.029	0.004	0.006	0.008	0.063
	P_{Max}	0.427	0.436	0.475	0.301	0.332	0.370	0.448	0.565	0.401	0.398	0.342	0.417	0.426	0.277	0.281	0.392	0.314

		Wind Velocity Ratio - Annual																VR_W for Total
	Test Point	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	16 Wind Directions
	Wind probability	0.035	0.024	0.05	0.035	0.175	0.192	0.139	0.096	0.03	0.028	0.032	0.046	0.034	0.023	0.028	0.034	1
	T1	0.346	0.384	0.470	0.246	0.115	0.265	0.512	0.718	0.454	0.474	0.330	0.204	0.208	0.080	0.124	0.470	0.339
	T2	0.275	0.245	0.124	0.023	0.115	0.222	0.366	0.294	0.245	0.268	0.197	0.146	0.221	0.173	0.152	0.355	0.220
Group 1	T3	0.334	0.296	0.282	0.089	0.130	0.184	0.381	0.717	0.263	0.236	0.262	0.203	0.132	0.182	0.198	0.453	0.277
	T4	0.285	0.177	0.139	0.072	0.110	0.173	0.463	0.728	0.159	0.181	0.187	0.070	0.102	0.020	0.085	0.417	0.250
	T5	0.267	0.129	0.115	0.304	0.374	0.453	0.586	0.664	0.142	0.378	0.360	0.185	0.154	0.138	0.058	0.315	0.382
	T6	0.380	0.212	0.234	0.133	0.166	0.258	0.406	0.511	0.381	0.347	0.164	0.137	0.136	0.082	0.112	0.366	0.273
	T7	0.384	0.279	0.376	0.052	0.129	0.239	0.365	0.570	0.312	0.343	0.187	0.072	0.055	0.033	0.021	0.245	0.254
	T8	0.398	0.321	0.428	0.141	0.124	0.201	0.385	0.597	0.357	0.398	0.234	0.151	0.134	0.041	0.014	0.297	0.271
	T9	0.367	0.265	0.411	0.306	0.075	0.302	0.419	0.742	0.428	0.408	0.230	0.205	0.107	0.083	0.210	0.261	0.312
Group 2	T10	0.425	0.370	0.438	0.248	0.145	0.351	0.418	0.608	0.417	0.359	0.174	0.066	0.117	0.112	0.131	0.393	0.318
	T11	0.478	0.468	0.480	0.266	0.178	0.294	0.316	0.508	0.387	0.311	0.278	0.224	0.132	0.170	0.145	0.441	0.308
	T12	0.114	0.339	0.366	0.153	0.071	0.156	0.179	0.222	0.286	0.255	0.142	0.102	0.046	0.038	0.110	0.179	0.161
	T13	0.260	0.412	0.389	0.164	0.128	0.174	0.366	0.165	0.397	0.233	0.190	0.195	0.052	0.108	0.110	0.151	0.212
	T14	0.018	0.328	0.427	0.265	0.257	0.374	0.120	0.039	0.454	0.167	0.165	0.130	0.100	0.148	0.142	0.033	0.218
	T15	0.143	0.319	0.476	0.406	0.363	0.186	0.201	0.300	0.490	0.361	0.283	0.148	0.121	0.150	0.114	0.061	0.260
	T16	0.085	0.319	0.349	0.323	0.249	0.293	0.330	0.118	0.092	0.139	0.276	0.231	0.222	0.077	0.215	0.213	0.245
Group 3	T17	0.085	0.206	0.302	0.256	0.164	0.318	0.419	0.302	0.045	0.269	0.366	0.382	0.361	0.240	0.224	0.184	0.277
	T18	0.113	0.153	0.181	0.120	0.078	0.129	0.243	0.347	0.172	0.082	0.269	0.112	0.083	0.061	0.212	0.124	0.162
	T19	0.217	0.306	0.450	0.292	0.072	0.027	0.072	0.082	0.076	0.080	0.081	0.023	0.185	0.079	0.035	0.218	0.108
Group 4	T20	0.120	0.094	0.273	0.382	0.351	0.289	0.088	0.054	0.023	0.024	0.056	0.100	0.259	0.140	0.170	0.391	0.205
	T21	0.159	0.193	0.142	0.238	0.200	0.142	0.034	0.105	0.026	0.053	0.084	0.038	0.080	0.076	0.173	0.386	0.132
	T22	0.303	0.329	0.099	0.090	0.040	0.043	0.328	0.261	0.091	0.120	0.088	0.045	0.100	0.108	0.237	0.487	0.152
	T23	0.018	0.021	0.125	0.028	0.161	0.287	0.235	0.242	0.182	0.148	0.163	0.244	0.224	0.186	0.126	0.062	0.191
	T24	0.059	0.009	0.044	0.085	0.255	0.317	0.278	0.366	0.355	0.292	0.018	0.257	0.275	0.410	0.149	0.134	0.245
Group 5	T25	0.050	0.046	0.121	0.093	0.259	0.250	0.192	0.140	0.168	0.152	0.037	0.114	0.255	0.251	0.060	0.087	0.180
	T26	0.031	0.029	0.254	0.213	0.247	0.238	0.143	0.135	0.211	0.213	0.078	0.079	0.048	0.165	0.163	0.129	0.177
Group 2 & 5	T27	0.086	0.264	0.424	0.306	0.269	0.325	0.166	0.203	0.433	0.168	0.150	0.084	0.189	0.070	0.033	0.033	0.230
	T28	0.056	0.054	0.061	0.038	0.095	0.151	0.286	0.195	0.157	0.069	0.102	0.148	0.271	0.154	0.030	0.062	0.144
Group 6	T29	0.038	0.074	0.081	0.127	0.033	0.055	0.218	0.056	0.059	0.111	0.157	0.049	0.145	0.085	0.115	0.099	0.089
	T30	0.042	0.204	0.201	0.218	0.219	0.111	0.070	0.104	0.087	0.074	0.286	0.340	0.334	0.168	0.094	0.153	0.156
	T31	0.019	0.114	0.285	0.063	0.050	0.116	0.103	0.204	0.146	0.083	0.413	0.411	0.334	0.211	0.101	0.075	0.145
	T32	0.069	0.094	0.149	0.198	0.157	0.045	0.182	0.242	0.152	0.146	0.245	0.164	0.124	0.178	0.191	0.071	0.144
	T33	0.083	0.113	0.197	0.222	0.238	0.091	0.068	0.311	0.339	0.112	0.084	0.065	0.086	0.126	0.056	0.073	0.150
Group 7	T34	0.166	0.078	0.123	0.205	0.249	0.258	0.204	0.074	0.200	0.081	0.079	0.050	0.026	0.115	0.118	0.112	0.173
	T35	0.138	0.206	0.436	0.411	0.407	0.322	0.254	0.246	0.074	0.025	0.093	0.295	0.199	0.186	0.166	0.335	0.284
	T36	0.267	0.328	0.398	0.227	0.151	0.167	0.249	0.373	0.316	0.267	0.443	0.108	0.177	0.126	0.285	0.397	0.240
	T37	0.119	0.146	0.095	0.075	0.197	0.292	0.325	0.039	0.069	0.127	0.112	0.080	0.087	0.048	0.275	0.404	0.193
Group 8	T38	0.082	0.275	0.264	0.278	0.238	0.222	0.214	0.102	0.083	0.150	0.417	0.486	0.326	0.093	0.150	0.177	0.222
	T39	0.074	0.073	0.259	0.044	0.017	0.059	0.284	0.248	0.219	0.129	0.195	0.198	0.142	0.051	0.167	0.161	0.138
	T40	0.031	0.246	0.093	0.262	0.145	0.129	0.190	0.144	0.205	0.175	0.243	0.077	0.121	0.018	0.115	0.044	0.143
	T41	0.042	0.091	0.119	0.031	0.022	0.043	0.177	0.167	0.069	0.190	0.221	0.113	0.148	0.133	0.082	0.050	0.095
	T42	0.023	0.061	0.082	0.046	0.058	0.031	0.124	0.051	0.055	0.035	0.115	0.040	0.100	0.025	0.047	0.037	0.061
Group 9	T43	0.049	0.175	0.190	0.154	0.086	0.153	0.361	0.173	0.099	0.233	0.288	0.265	0.285	0.219	0.163	0.046	0.184
	T44	0.038	0.060	0.136	0.124	0.152	0.138	0.229	0.101	0.045	0.110	0.149	0.105	0.202	0.071	0.076	0.041	0.134
	T45 *	0.067	0.206	0.259	0.249	0.227	0.259	0.272	0.054	0.019	0.092	0.221	0.205	0.162	0.109	0.149	0.119	0.197
	T46 *	0.046	0.148	0.205	0.179	0.198	0.171	0.218	0.061	0.057	0.142	0.227	0.192	0.236	0.172	0.144	0.099	0.166
	T47	0.011	0.054	0.170	0.200	0.107	0.113	0.028	0.033	0.093	0.135	0.089	0.071	0.245	0.242	0.124	0.109	0.098
	T48	0.060	0.149	0.190	0.114	0.071	0.170	0.049	0.077	0.155	0.223	0.099	0.114	0.152	0.183	0.168	0.210	0.119
	T49	0.232	0.310	0.378	0.250	0.058	0.165	0.255	0.159	0.137	0.171	0.088	0.137	0.102	0.092	0.064	0.186	0.167
Group 10	T50	0.227	0.306	0.403	0.265	0.157	0.264	0.252	0.101	0.124	0.174	0.086	0.155	0.152	0.154	0.111	0.139	0.202
	T51	0.148	0.202	0.239	0.149	0.211	0.338	0.361	0.177	0.301	0.195	0.095	0.211	0.291	0.182	0.078	0.108	0.243
	T52 *	0.154	0.299	0.322	0.146	0.121	0.114	0.224	0.339	0.450	0.379	0.085	0.074	0.046	0.093	0.032	0.043	0.177
	T53 *	0.038	0.124	0.287	0.169	0.168	0.245	0.206	0.088	0.325	0.283	0.178	0.083	0.124	0.050	0.060	0.041	0.174
	T54	0.171	0.157	0.091	0.132	0.177	0.122	0.227	0.203	0.114	0.053	0.057	0.051	0.106	0.041	0.043	0.090	0.142
Group 11	T55	0.187	0.242	0.379	0.182	0.142	0.123	0.210	0.057	0.027	0.142	0.217	0.088	0.161	0.092	0.029	0.125	0.149
	T56	0.163	0.190	0.269	0.085	0.141	0.092	0.148	0.226	0.111	0.198	0.168	0.132	0.216	0.094	0.023	0.146	0.147
	T57	0.112	0.100	0.247	0.051	0.029	0.103	0.241	0.190	0.175	0.059	0.115	0.302	0.159	0.265	0.128	0.097	0.140
Group 12	T58	0.055	0.060	0.061	0.082	0.026	0.059	0.066	0.143	0.137	0.123	0.042	0.167	0.140	0.115	0.033	0.038	0.074
	T59	0.056	0.061	0.110	0.053	0.177	0.218	0.182	0.196	0.286	0.175	0.077	0.104	0.105	0.077	0.050	0.019	0.156
	T60	0.021	0.012	0.220	0.151	0.189	0.261	0.178	0.178	0.313	0.416	0.127	0.189	0.148	0.079	0.055	0.023	0.185

	Test Point	Wind Velocity Ratio - Annual																VR_w for Total
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	16 Wind Directions
	Wind probability	0.035	0.024	0.05	0.035	0.175	0.192	0.139	0.096	0.03	0.028	0.032	0.046	0.034	0.023	0.028	0.034	1
Group 13	T61	0.043	0.034	0.065	0.046	0.141	0.252	0.239	0.439	0.309	0.199	0.115	0.191	0.167	0.173	0.113	0.063	0.198
	T62	0.058	0.038	0.187	0.098	0.148	0.228	0.159	0.350	0.165	0.208	0.058	0.141	0.266	0.105	0.060	0.116	0.177
	T63	0.105	0.072	0.219	0.054	0.110	0.106	0.087	0.409	0.407	0.381	0.045	0.285	0.402	0.384	0.200	0.183	0.181
	T64	0.089	0.072	0.240	0.098	0.142	0.192	0.149	0.488	0.314	0.413	0.054	0.176	0.315	0.414	0.287	0.222	0.216
	T65	0.010	0.107	0.212	0.180	0.181	0.156	0.047	0.158	0.247	0.210	0.129	0.256	0.220	0.345	0.202	0.188	0.160
Group 4	T66	0.064	0.084	0.087	0.077	0.135	0.062	0.256	0.500	0.076	0.129	0.155	0.064	0.106	0.088	0.124	0.072	0.156
	T67	0.159	0.166	0.186	0.145	0.149	0.268	0.292	0.242	0.209	0.321	0.221	0.032	0.154	0.261	0.215	0.505	0.223
	T68	0.065	0.060	0.056	0.060	0.062	0.147	0.136	0.209	0.140	0.019	0.035	0.024	0.062	0.094	0.172	0.162	0.108
	T69	0.169	0.167	0.240	0.260	0.298	0.271	0.072	0.199	0.210	0.252	0.221	0.026	0.102	0.118	0.072	0.373	0.207
	T70	0.118	0.104	0.229	0.315	0.318	0.367	0.295	0.072	0.089	0.070	0.023	0.067	0.169	0.166	0.241	0.429	0.242
	T71	0.241	0.190	0.103	0.224	0.207	0.329	0.397	0.660	0.228	0.190	0.149	0.093	0.096	0.179	0.234	0.326	0.290
Group 15	T72	0.124	0.120	0.122	0.082	0.054	0.088	0.104	0.191	0.111	0.089	0.044	0.143	0.168	0.053	0.112	0.227	0.107
	T73	0.226	0.233	0.238	0.140	0.108	0.070	0.173	0.112	0.104	0.187	0.149	0.133	0.029	0.020	0.065	0.217	0.127
	T74	0.026	0.066	0.082	0.024	0.047	0.065	0.157	0.295	0.312	0.117	0.139	0.156	0.121	0.138	0.158	0.175	0.120
	T75	0.106	0.073	0.334	0.225	0.194	0.163	0.173	0.360	0.340	0.343	0.290	0.118	0.116	0.037	0.076	0.179	0.201
	T76	0.063	0.008	0.101	0.109	0.119	0.096	0.177	0.164	0.112	0.123	0.150	0.142	0.150	0.092	0.082	0.072	0.121
	T77	0.103	0.061	0.345	0.297	0.259	0.179	0.213	0.128	0.098	0.236	0.264	0.126	0.125	0.091	0.029	0.089	0.188
	T78	0.065	0.099	0.066	0.058	0.082	0.092	0.157	0.255	0.374	0.228	0.204	0.039	0.107	0.035	0.020	0.057	0.121
	T79	0.192	0.095	0.072	0.188	0.178	0.314	0.471	0.696	0.239	0.262	0.307	0.139	0.127	0.032	0.054	0.374	0.293
	Average LVR	0.128	0.168	0.232	0.160	0.152	0.181	0.229	0.245	0.200	0.189	0.170	0.144	0.163	0.126	0.120	0.171	0.183
	T_{Min}	0.010	0.008	0.044	0.023	0.017	0.027	0.028	0.033	0.019	0.019	0.018	0.023	0.026	0.018	0.014	0.019	0.061
	T_{Max}	0.478	0.468	0.480	0.411	0.407	0.453	0.586	0.742	0.490	0.474	0.443	0.486	0.402	0.414	0.287	0.505	0.382

Remarks:
Test Point T45, T46, T52 and T53 are located at 2m above the top of the commerical centre or carport.

Appendix B Details of Predicted Wind Velocity Ratios (VR_W)

"Summer Season"

		Wind Velocity Ratio - Summer Season																VR_W for Total
	Test Point	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	16 Wind Directions
	Wind probability	0.008	0.003	0.006	0.008	0.083	0.114	0.19	0.089	0.069	0.076	0.072	0.127	0.084	0.04	0.017	0.014	1
Group 1	T1	0.346	0.384	0.470	0.246	0.115	0.265	0.512	0.718	0.454	0.474	0.330	0.204	0.208	0.080	0.124	0.470	0.356
	T2	0.275	0.245	0.124	0.023	0.115	0.222	0.366	0.294	0.245	0.268	0.197	0.146	0.221	0.173	0.152	0.355	0.237
	T3	0.334	0.296	0.282	0.089	0.130	0.184	0.381	0.717	0.263	0.236	0.262	0.203	0.132	0.182	0.198	0.453	0.283
	T4	0.285	0.177	0.139	0.072	0.110	0.173	0.463	0.728	0.159	0.181	0.187	0.070	0.102	0.020	0.085	0.417	0.250
	T5	0.267	0.129	0.115	0.304	0.374	0.453	0.586	0.664	0.142	0.378	0.360	0.185	0.154	0.138	0.058	0.315	0.371
Group 2	T6	0.380	0.212	0.234	0.133	0.166	0.258	0.406	0.511	0.381	0.347	0.164	0.137	0.136	0.082	0.112	0.366	0.276
	T7	0.384	0.279	0.376	0.052	0.129	0.239	0.365	0.570	0.312	0.343	0.187	0.072	0.055	0.033	0.021	0.245	0.244
	T8	0.398	0.321	0.428	0.141	0.124	0.201	0.385	0.597	0.357	0.398	0.234	0.151	0.134	0.041	0.014	0.297	0.276
	T9	0.367	0.265	0.411	0.306	0.075	0.302	0.419	0.742	0.428	0.408	0.230	0.205	0.107	0.083	0.210	0.261	0.318
	T10	0.425	0.370	0.438	0.248	0.145	0.351	0.418	0.608	0.417	0.359	0.174	0.066	0.117	0.112	0.131	0.393	0.293
	T11	0.478	0.468	0.480	0.266	0.178	0.294	0.316	0.508	0.387	0.311	0.278	0.224	0.132	0.170	0.145	0.441	0.289
	T12	0.114	0.339	0.366	0.153	0.071	0.156	0.179	0.222	0.286	0.255	0.142	0.102	0.046	0.038	0.110	0.179	0.155
	T13	0.260	0.412	0.389	0.164	0.128	0.174	0.366	0.165	0.397	0.233	0.190	0.195	0.052	0.108	0.110	0.151	0.218
	T14	0.018	0.328	0.427	0.265	0.257	0.374	0.120	0.039	0.454	0.167	0.165	0.130	0.100	0.148	0.142	0.033	0.186
	T15	0.143	0.319	0.476	0.406	0.363	0.186	0.201	0.300	0.490	0.361	0.283	0.148	0.121	0.150	0.114	0.061	0.244
Group 3	T16	0.085	0.319	0.349	0.323	0.249	0.293	0.330	0.118	0.092	0.139	0.276	0.231	0.222	0.077	0.215	0.213	0.228
	T17	0.085	0.206	0.302	0.256	0.164	0.318	0.419	0.302	0.045	0.269	0.366	0.382	0.361	0.240	0.224	0.184	0.306
	T18	0.113	0.153	0.181	0.120	0.078	0.129	0.243	0.347	0.172	0.082	0.269	0.112	0.083	0.061	0.212	0.124	0.168
Group 4	T19	0.217	0.306	0.450	0.292	0.072	0.027	0.072	0.082	0.076	0.080	0.081	0.023	0.185	0.079	0.035	0.218	0.080
	T20	0.120	0.094	0.273	0.382	0.351	0.289	0.088	0.054	0.023	0.024	0.056	0.100	0.259	0.140	0.170	0.391	0.145
	T21	0.159	0.193	0.142	0.238	0.200	0.142	0.034	0.105	0.026	0.053	0.084	0.038	0.080	0.076	0.173	0.386	0.088
	T22	0.303	0.329	0.099	0.090	0.040	0.043	0.328	0.261	0.091	0.120	0.088	0.045	0.100	0.108	0.237	0.487	0.150
Group 5	T23	0.018	0.021	0.125	0.028	0.161	0.287	0.235	0.242	0.182	0.148	0.163	0.244	0.224	0.186	0.126	0.062	0.209
	T24	0.059	0.009	0.044	0.085	0.255	0.317	0.278	0.366	0.355	0.292	0.018	0.257	0.275	0.410	0.149	0.134	0.269
	T25	0.050	0.046	0.121	0.093	0.259	0.250	0.192	0.140	0.168	0.152	0.037	0.114	0.255	0.251	0.060	0.087	0.175
	T26	0.031	0.029	0.254	0.213	0.247	0.238	0.143	0.135	0.211	0.213	0.078	0.079	0.048	0.165	0.163	0.129	0.152
Group 2 & 5	T27	0.086	0.264	0.424	0.306	0.269	0.325	0.166	0.203	0.433	0.168	0.150	0.084	0.189	0.070	0.033	0.033	0.199
Group 6	T28	0.056	0.054	0.061	0.038	0.095	0.151	0.286	0.195	0.157	0.069	0.102	0.148	0.271	0.154	0.030	0.062	0.170
	T29	0.038	0.074	0.081	0.127	0.033	0.055	0.218	0.056	0.059	0.111	0.157	0.049	0.145	0.085	0.115	0.099	0.106
	T30	0.042	0.204	0.201	0.218	0.219	0.111	0.070	0.104	0.087	0.074	0.286	0.340	0.334	0.168	0.094	0.153	0.171
	T31	0.019	0.114	0.285	0.063	0.050	0.116	0.103	0.204	0.146	0.083	0.413	0.411	0.334	0.211	0.101	0.075	0.195
Group 7	T32	0.069	0.094	0.149	0.198	0.157	0.045	0.182	0.242	0.152	0.146	0.245	0.164	0.124	0.178	0.191	0.071	0.159
	T33	0.083	0.113	0.197	0.222	0.238	0.091	0.068	0.311	0.339	0.112	0.084	0.065	0.086	0.126	0.056	0.073	0.135
	T34	0.166	0.078	0.123	0.205	0.249	0.258	0.204	0.074	0.200	0.081	0.079	0.050	0.026	0.115	0.118	0.112	0.142
	T35	0.138	0.206	0.436	0.411	0.407	0.322	0.254	0.246	0.074	0.025	0.093	0.295	0.199	0.186	0.166	0.335	0.231
	T36	0.267	0.328	0.398	0.227	0.151	0.167	0.249	0.373	0.316	0.267	0.443	0.108	0.177	0.126	0.285	0.397	0.238
Group 8	T37	0.119	0.146	0.095	0.075	0.197	0.292	0.325	0.039	0.069	0.127	0.112	0.080	0.087	0.048	0.275	0.404	0.170
	T38	0.082	0.275	0.264	0.278	0.238	0.222	0.214	0.102	0.083	0.150	0.417	0.486	0.326	0.093	0.150	0.177	0.245
	T39	0.074	0.073	0.259	0.044	0.017	0.059	0.284	0.248	0.219	0.129	0.195	0.198	0.142	0.051	0.167	0.161	0.170
Group 9	T40	0.031	0.246	0.093	0.262	0.145	0.129	0.190	0.144	0.205	0.175	0.243	0.077	0.121	0.018	0.115	0.044	0.147
	T41	0.042	0.091	0.119	0.031	0.022	0.043	0.177	0.167	0.069	0.190	0.221	0.113	0.148	0.133	0.082	0.050	0.126
	T42	0.023	0.061	0.082	0.046	0.058	0.031	0.124	0.051	0.055	0.035	0.115	0.040	0.100	0.025	0.047	0.037	0.068
	T43	0.049	0.175	0.190	0.154	0.086	0.153	0.361	0.173	0.099	0.233	0.288	0.265	0.285	0.219	0.163	0.046	0.227
	T44	0.038	0.060	0.136	0.124	0.152	0.138	0.229	0.101	0.045	0.110	0.149	0.105	0.202	0.071	0.076	0.041	0.140
	T45	0.067	0.206	0.259	0.249	0.227	0.259	0.272	0.054	0.019	0.092	0.221	0.205	0.162	0.109	0.149	0.119	0.182
	T46	0.046	0.148	0.205	0.179	0.198	0.171	0.218	0.061	0.057	0.142	0.227	0.192	0.236	0.172	0.144	0.099	0.172
Group 10	T47	0.011	0.054	0.170	0.200	0.107	0.113	0.028	0.033	0.093	0.135	0.089	0.071	0.245	0.242	0.124	0.109	0.099
	T48	0.060	0.149	0.190	0.114	0.071	0.170	0.049	0.077	0.155	0.223	0.099	0.114	0.152	0.183	0.168	0.210	0.119
	T49	0.232	0.310	0.378	0.250	0.058	0.165	0.255	0.159	0.137	0.171	0.088	0.137	0.102	0.092	0.064	0.186	0.155
	T50	0.227	0.306	0.403	0.265	0.157	0.264	0.252	0.101	0.124	0.174	0.086	0.155	0.152	0.154	0.111	0.139	0.178
	T51	0.148	0.202	0.239	0.149	0.211	0.338	0.361	0.177	0.301	0.195	0.095	0.211	0.291	0.182	0.078	0.108	0.249
	T52	0.154	0.299	0.322	0.146	0.121	0.114	0.224	0.339	0.450	0.379	0.085	0.074	0.046	0.093	0.032	0.043	0.185
	T53	0.038	0.124	0.287	0.169	0.168	0.245	0.206	0.088	0.325	0.283	0.178	0.083	0.124	0.050	0.060	0.041	0.174
Group 11	T54	0.171	0.157	0.091	0.132	0.177	0.122	0.227	0.203	0.114	0.053	0.057	0.051	0.106	0.041	0.043	0.090	0.128
	T55	0.187	0.242	0.379	0.182	0.142	0.123	0.210	0.057	0.027	0.142	0.217	0.088	0.161	0.092	0.029	0.125	0.136
	T56	0.163	0.190	0.269	0.085	0.141	0.092	0.148	0.226	0.111	0.198	0.168	0.132	0.216	0.094	0.023	0.146	0.150
Group 12	T57	0.112	0.100	0.247	0.051	0.029	0.103	0.241	0.190	0.175	0.059	0.115	0.302	0.159	0.265	0.128	0.097	0.171
	T58	0.055	0.060	0.061	0.082	0.026	0.059	0.066	0.143	0.137	0.123	0.042	0.167	0.140	0.115	0.033	0.038	0.096
	T59	0.056	0.061	0.110	0.053	0.177	0.218	0.182	0.196	0.286	0.175	0.077	0.104	0.105	0.077	0.050	0.019	0.158
	T60	0.021	0.012	0.220	0.151	0.189	0.261	0.178	0.178	0.313	0.416	0.127	0.189	0.148	0.079	0.055	0.023	0.201

		Wind Velocity Ratio - Summer Season																VR_W for Total
	Test Point	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	16 Wind Directions
	Wind probability	0.008	0.003	0.006	0.008	0.083	0.114	0.19	0.089	0.069	0.076	0.072	0.127	0.084	0.04	0.017	0.014	1
	T1	0.346	0.384	0.470	0.246	0.115	0.265	0.512	0.718	0.454	0.474	0.330	0.204	0.208	0.080	0.124	0.470	0.356
	T2	0.275	0.245	0.124	0.023	0.115	0.222	0.366	0.294	0.245	0.268	0.197	0.146	0.221	0.173	0.152	0.355	0.237
Group 1	T3	0.334	0.296	0.282	0.089	0.130	0.184	0.381	0.717	0.263	0.236	0.262	0.203	0.132	0.182	0.198	0.453	0.283
	T4	0.285	0.177	0.139	0.072	0.110	0.173	0.463	0.728	0.159	0.181	0.187	0.070	0.102	0.020	0.085	0.417	0.250
	T5	0.267	0.129	0.115	0.304	0.374	0.453	0.586	0.664	0.142	0.378	0.360	0.185	0.154	0.138	0.058	0.315	0.371
	T6	0.380	0.212	0.234	0.133	0.166	0.258	0.406	0.511	0.381	0.347	0.164	0.137	0.136	0.082	0.112	0.366	0.276
	T7	0.384	0.279	0.376	0.052	0.129	0.239	0.365	0.570	0.312	0.343	0.187	0.072	0.055	0.033	0.021	0.245	0.244
	T8	0.398	0.321	0.428	0.141	0.124	0.201	0.385	0.597	0.357	0.398	0.234	0.151	0.134	0.041	0.014	0.297	0.276
	T9	0.367	0.265	0.411	0.306	0.075	0.302	0.419	0.742	0.428	0.408	0.230	0.205	0.107	0.083	0.210	0.261	0.318
Group 2	T10	0.425	0.370	0.438	0.248	0.145	0.351	0.418	0.608	0.417	0.359	0.174	0.066	0.117	0.112	0.131	0.393	0.293
	T11	0.478	0.468	0.480	0.266	0.178	0.294	0.316	0.508	0.387	0.311	0.278	0.224	0.132	0.170	0.145	0.441	0.289
	T12	0.114	0.339	0.366	0.153	0.071	0.156	0.179	0.222	0.286	0.255	0.142	0.102	0.046	0.038	0.110	0.179	0.155
	T13	0.260	0.412	0.389	0.164	0.128	0.174	0.366	0.165	0.397	0.233	0.190	0.195	0.052	0.108	0.110	0.151	0.218
	T14	0.018	0.328	0.427	0.265	0.257	0.374	0.120	0.039	0.454	0.167	0.165	0.130	0.100	0.148	0.142	0.033	0.186
	T15	0.143	0.319	0.476	0.406	0.363	0.186	0.201	0.300	0.490	0.361	0.283	0.148	0.121	0.150	0.114	0.061	0.244
	T16	0.085	0.319	0.349	0.323	0.249	0.293	0.330	0.118	0.092	0.139	0.276	0.231	0.222	0.077	0.215	0.213	0.228
Group 3	T17	0.085	0.206	0.302	0.256	0.164	0.318	0.419	0.302	0.045	0.269	0.366	0.382	0.361	0.240	0.224	0.184	0.306
	T18	0.113	0.153	0.181	0.120	0.078	0.129	0.243	0.347	0.172	0.082	0.269	0.112	0.083	0.061	0.212	0.124	0.168
	T19	0.217	0.306	0.450	0.292	0.072	0.027	0.072	0.082	0.076	0.080	0.081	0.023	0.185	0.079	0.035	0.218	0.080
Group 4	T20	0.120	0.094	0.273	0.382	0.351	0.289	0.088	0.054	0.023	0.024	0.056	0.100	0.259	0.140	0.170	0.391	0.145
	T21	0.159	0.193	0.142	0.238	0.200	0.142	0.034	0.105	0.026	0.053	0.084	0.038	0.080	0.076	0.173	0.386	0.088
	T22	0.303	0.329	0.099	0.090	0.040	0.043	0.328	0.261	0.091	0.120	0.088	0.045	0.100	0.108	0.237	0.487	0.150
	T23	0.018	0.021	0.125	0.028	0.161	0.287	0.235	0.242	0.182	0.148	0.163	0.244	0.224	0.186	0.126	0.062	0.209
	T24	0.059	0.009	0.044	0.085	0.255	0.317	0.278	0.366	0.355	0.292	0.018	0.257	0.275	0.410	0.149	0.134	0.269
Group 5	T25	0.050	0.046	0.121	0.093	0.259	0.250	0.192	0.140	0.168	0.152	0.037	0.114	0.255	0.251	0.060	0.087	0.175
	T26	0.031	0.029	0.254	0.213	0.247	0.238	0.143	0.135	0.211	0.213	0.078	0.079	0.048	0.165	0.163	0.129	0.152
Group 2 & 5	T27	0.086	0.264	0.424	0.306	0.269	0.325	0.166	0.203	0.433	0.168	0.150	0.084	0.189	0.070	0.033	0.033	0.199
	T28	0.056	0.054	0.061	0.038	0.095	0.151	0.286	0.195	0.157	0.069	0.102	0.148	0.271	0.154	0.030	0.062	0.170
Group 6	T29	0.038	0.074	0.081	0.127	0.033	0.055	0.218	0.056	0.059	0.111	0.157	0.049	0.145	0.085	0.115	0.099	0.106
	T30	0.042	0.204	0.201	0.218	0.219	0.111	0.070	0.104	0.087	0.074	0.286	0.340	0.334	0.168	0.094	0.153	0.171
	T31	0.019	0.114	0.285	0.063	0.050	0.116	0.103	0.204	0.146	0.083	0.413	0.411	0.334	0.211	0.101	0.075	0.195
	T32	0.069	0.094	0.149	0.198	0.157	0.045	0.182	0.242	0.152	0.146	0.245	0.164	0.124	0.178	0.191	0.071	0.159
	T33	0.083	0.113	0.197	0.222	0.238	0.091	0.068	0.311	0.339	0.112	0.084	0.065	0.086	0.126	0.056	0.073	0.135
Group 7	T34	0.166	0.078	0.123	0.205	0.249	0.258	0.204	0.074	0.200	0.081	0.079	0.050	0.026	0.115	0.118	0.112	0.142
	T35	0.138	0.206	0.436	0.411	0.407	0.322	0.254	0.246	0.074	0.025	0.093	0.295	0.199	0.186	0.166	0.335	0.231
	T36	0.267	0.328	0.398	0.227	0.151	0.167	0.249	0.373	0.316	0.267	0.443	0.108	0.177	0.126	0.285	0.397	0.238
	T37	0.119	0.146	0.095	0.075	0.197	0.292	0.325	0.039	0.069	0.127	0.112	0.080	0.087	0.048	0.275	0.404	0.170
Group 8	T38	0.082	0.275	0.264	0.278	0.238	0.222	0.214	0.102	0.083	0.150	0.417	0.486	0.326	0.093	0.150	0.177	0.245
	T39	0.074	0.073	0.259	0.044	0.017	0.059	0.284	0.248	0.219	0.129	0.195	0.198	0.142	0.051	0.167	0.161	0.170
	T40	0.031	0.246	0.093	0.262	0.145	0.129	0.190	0.144	0.205	0.175	0.243	0.077	0.121	0.018	0.115	0.044	0.147
	T41	0.042	0.091	0.119	0.031	0.022	0.043	0.177	0.167	0.069	0.190	0.221	0.113	0.148	0.133	0.082	0.050	0.126
	T42	0.023	0.061	0.082	0.046	0.058	0.031	0.124	0.051	0.055	0.035	0.115	0.040	0.100	0.025	0.047	0.037	0.068
Group 9	T43	0.049	0.175	0.190	0.154	0.086	0.153	0.361	0.173	0.099	0.233	0.288	0.265	0.285	0.219	0.163	0.046	0.227
	T44	0.038	0.060	0.136	0.124	0.152	0.138	0.229	0.101	0.045	0.110	0.149	0.105	0.202	0.071	0.076	0.041	0.140
	T45	0.067	0.206	0.259	0.249	0.227	0.259	0.272	0.054	0.019	0.092	0.221	0.205	0.162	0.109	0.149	0.119	0.182
	T46	0.046	0.148	0.205	0.179	0.198	0.171	0.218	0.061	0.057	0.142	0.227	0.192	0.236	0.172	0.144	0.099	0.172
	T47	0.011	0.054	0.170	0.200	0.107	0.113	0.028	0.033	0.093	0.135	0.089	0.071	0.245	0.242	0.124	0.109	0.099
	T48	0.060	0.149	0.190	0.114	0.071	0.170	0.049	0.077	0.155	0.223	0.099	0.114	0.152	0.183	0.168	0.210	0.119
	T49	0.232	0.310	0.378	0.250	0.058	0.165	0.255	0.159	0.137	0.171	0.088	0.137	0.102	0.092	0.064	0.186	0.155
Group 10	T50	0.227	0.306	0.403	0.265	0.157	0.264	0.252	0.101	0.124	0.174	0.086	0.155	0.152	0.154	0.111	0.139	0.178
	T51	0.148	0.202	0.239	0.149	0.211	0.338	0.361	0.177	0.301	0.195	0.095	0.211	0.291	0.182	0.078	0.108	0.249
	T52	0.154	0.299	0.322	0.146	0.121	0.114	0.224	0.339	0.450	0.379	0.085	0.074	0.046	0.093	0.032	0.043	0.185
	T53	0.038	0.124	0.287	0.169	0.168	0.245	0.206	0.088	0.325	0.283	0.178	0.083	0.124	0.050	0.060	0.041	0.174
	T54	0.171	0.157	0.091	0.132	0.177	0.122	0.227	0.203	0.114	0.053	0.057	0.051	0.106	0.041	0.043	0.090	0.128
Group 11	T55	0.187	0.242	0.379	0.182	0.142	0.123	0.210	0.057	0.027	0.142	0.217	0.088	0.161	0.092	0.029	0.125	0.136
	T56	0.163	0.190	0.269	0.085	0.141	0.092	0.148	0.226	0.111	0.198	0.168	0.132	0.216	0.094	0.023	0.146	0.150
	T57	0.112	0.100	0.247	0.051	0.029	0.103	0.241	0.190	0.175	0.059	0.115	0.302	0.159	0.265	0.128	0.097	0.171
Group 12	T58	0.055	0.060	0.061	0.082	0.026	0.059	0.066	0.143	0.137	0.123	0.042	0.167	0.140	0.115	0.033	0.038	0.096
	T59	0.056	0.061	0.110	0.053	0.177	0.218	0.182	0.196	0.286	0.175	0.077	0.104	0.105	0.077	0.050	0.019	0.158
	T60	0.021	0.012	0.220	0.151	0.189	0.261	0.178	0.178	0.313	0.416	0.127	0.189	0.148	0.079	0.055	0.023	0.201

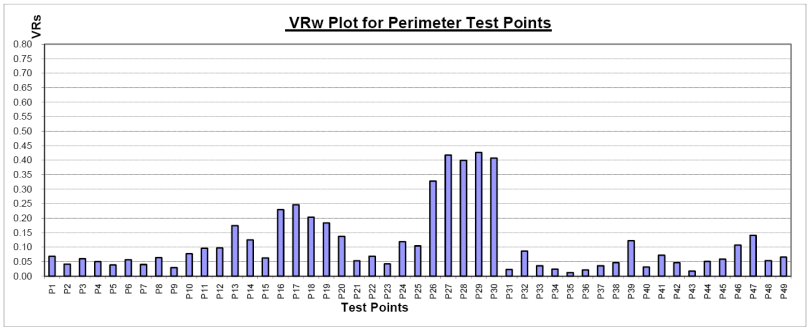
	Test Point	Wind Velocity Ratio - Summer Season																VR_W for Total
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	16 Wind Directions
	Wind probability	0.008	0.003	0.006	0.008	0.083	0.114	0.19	0.089	0.069	0.076	0.072	0.127	0.084	0.04	0.017	0.014	1
Group 13	T61	0.043	0.034	0.065	0.046	0.141	0.252	0.239	0.439	0.309	0.199	0.115	0.191	0.167	0.173	0.113	0.063	0.219
	T62	0.058	0.038	0.187	0.098	0.148	0.228	0.159	0.350	0.165	0.208	0.058	0.141	0.266	0.105	0.060	0.116	0.181
	T63	0.105	0.072	0.219	0.054	0.110	0.106	0.087	0.409	0.407	0.381	0.045	0.285	0.402	0.384	0.200	0.183	0.228
	T64	0.089	0.072	0.240	0.098	0.142	0.192	0.149	0.488	0.314	0.413	0.054	0.176	0.315	0.414	0.287	0.222	0.239
	T65	0.010	0.107	0.212	0.180	0.181	0.156	0.047	0.158	0.247	0.210	0.129	0.256	0.220	0.345	0.202	0.188	0.172
Group 4	T66	0.064	0.084	0.087	0.077	0.135	0.062	0.256	0.500	0.076	0.129	0.155	0.064	0.106	0.088	0.124	0.072	0.163
	T67	0.159	0.166	0.186	0.145	0.149	0.268	0.292	0.242	0.209	0.321	0.221	0.032	0.154	0.261	0.215	0.505	0.217
	T68	0.065	0.060	0.056	0.060	0.062	0.147	0.136	0.209	0.140	0.019	0.035	0.024	0.062	0.094	0.172	0.162	0.099
	T69	0.169	0.167	0.240	0.260	0.298	0.271	0.072	0.199	0.210	0.252	0.221	0.026	0.102	0.118	0.072	0.373	0.165
	T70	0.118	0.104	0.229	0.315	0.318	0.367	0.295	0.072	0.089	0.070	0.023	0.067	0.169	0.166	0.241	0.429	0.188
	T71	0.241	0.190	0.103	0.224	0.207	0.329	0.397	0.660	0.228	0.190	0.149	0.093	0.096	0.179	0.234	0.326	0.270
Group 15	T72	0.124	0.120	0.122	0.082	0.054	0.088	0.104	0.191	0.111	0.089	0.044	0.143	0.168	0.053	0.112	0.227	0.111
	T73	0.226	0.233	0.238	0.140	0.108	0.070	0.173	0.112	0.104	0.187	0.149	0.133	0.029	0.020	0.065	0.217	0.121
	T74	0.026	0.066	0.082	0.024	0.047	0.065	0.157	0.295	0.312	0.117	0.139	0.156	0.121	0.138	0.158	0.175	0.149
	T75	0.106	0.073	0.334	0.225	0.194	0.163	0.173	0.360	0.340	0.343	0.290	0.118	0.116	0.037	0.076	0.179	0.205
	T76	0.063	0.008	0.101	0.109	0.119	0.096	0.177	0.164	0.112	0.123	0.150	0.142	0.150	0.092	0.082	0.072	0.136
	T77	0.103	0.061	0.345	0.297	0.259	0.179	0.213	0.128	0.098	0.236	0.264	0.126	0.125	0.091	0.029	0.089	0.175
	T78	0.065	0.099	0.066	0.058	0.082	0.092	0.157	0.255	0.374	0.228	0.204	0.039	0.107	0.035	0.020	0.057	0.146
	T79	0.192	0.095	0.072	0.188	0.178	0.314	0.471	0.696	0.239	0.262	0.307	0.139	0.127	0.032	0.054	0.374	0.300
	Average LVR	0.128	0.168	0.232	0.160	0.152	0.181	0.229	0.245	0.200	0.189	0.170	0.144	0.163	0.126	0.120	0.171	0.185
	T_{Min}	0.010	0.008	0.044	0.023	0.017	0.027	0.028	0.033	0.019	0.019	0.018	0.023	0.026	0.018	0.014	0.019	0.068
	T_{Max}	0.478	0.468	0.480	0.411	0.407	0.453	0.586	0.742	0.490	0.474	0.443	0.486	0.402	0.414	0.287	0.505	0.371

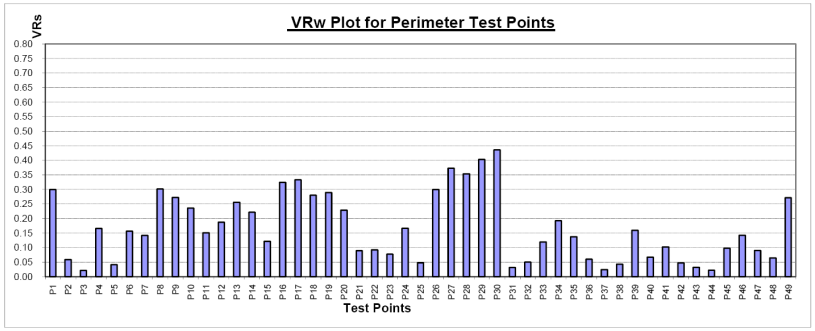
Test Point T45, T46, T52 and T53 are located at 2m above the top of the commerical centre or carport.

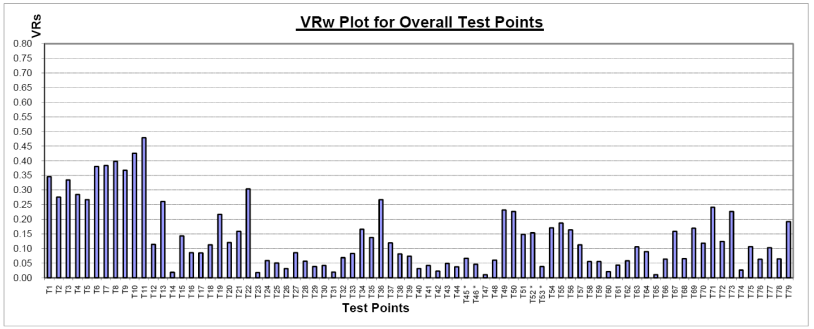
Appendix C

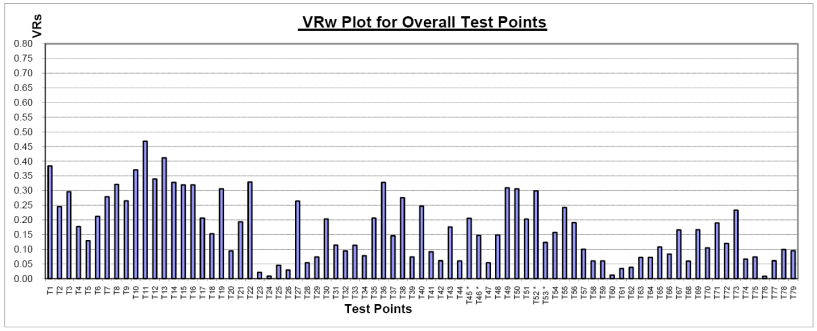
Average VR_W Result for Individual Test Points and Different Test Points Groups under Different Wind Directions

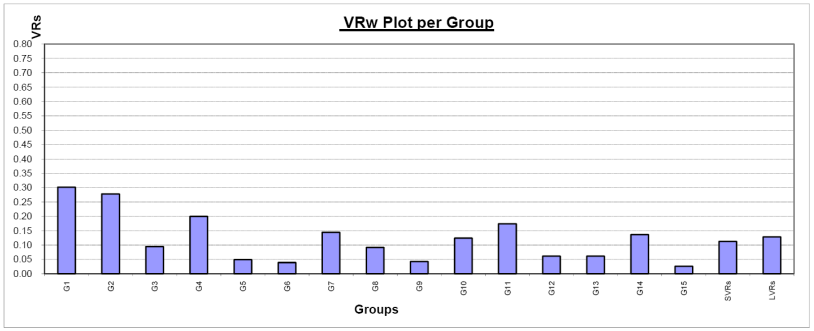
Appendix C Average VR_W Result for Individual Test Points and Different Test Points Groups under Different Wind Directions



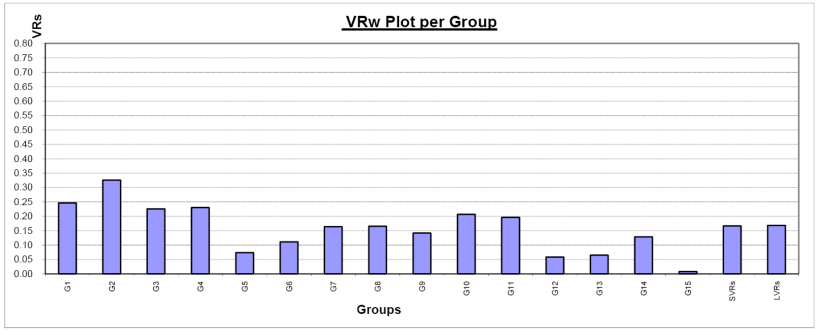




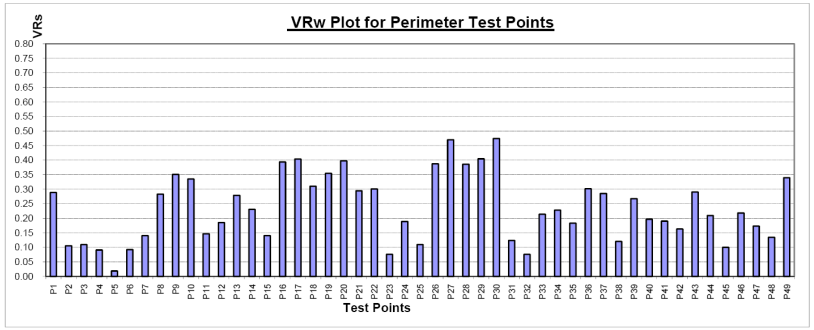


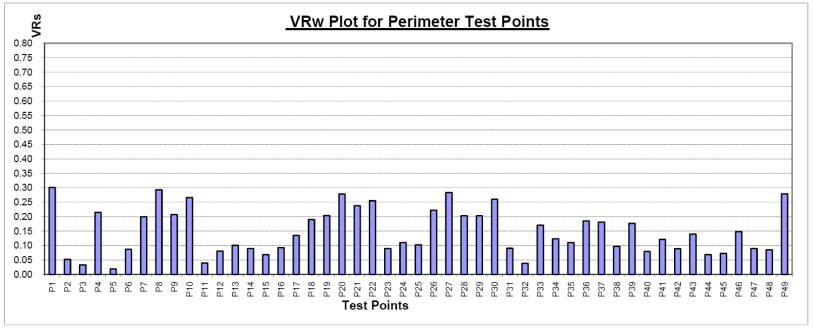


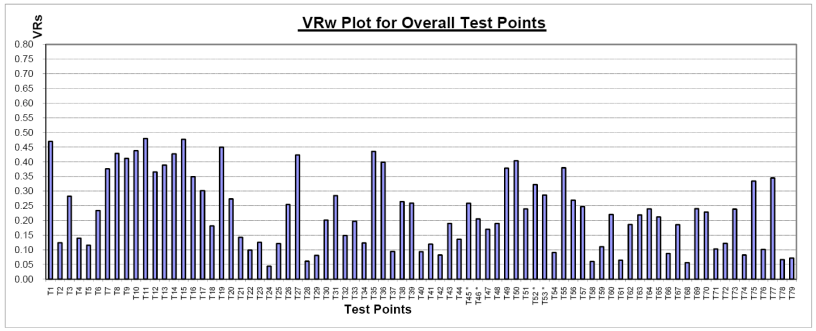
VR_W Result under N Wind Direction

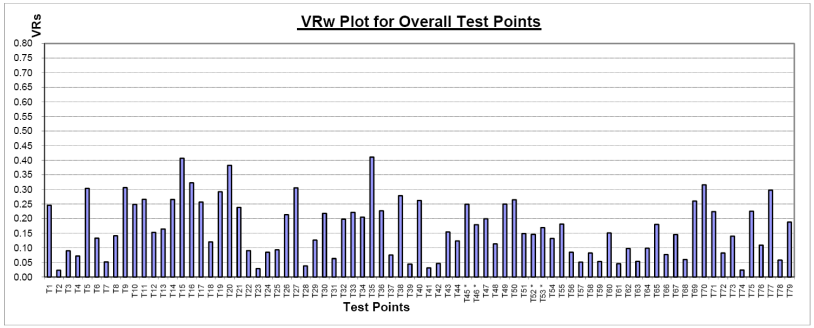


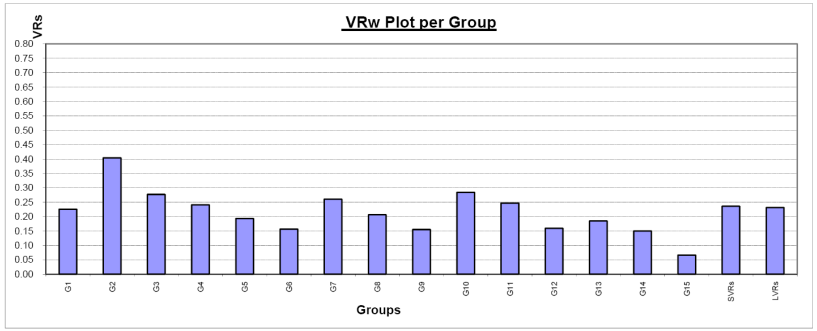
VR_W Result under NNE Wind Direction



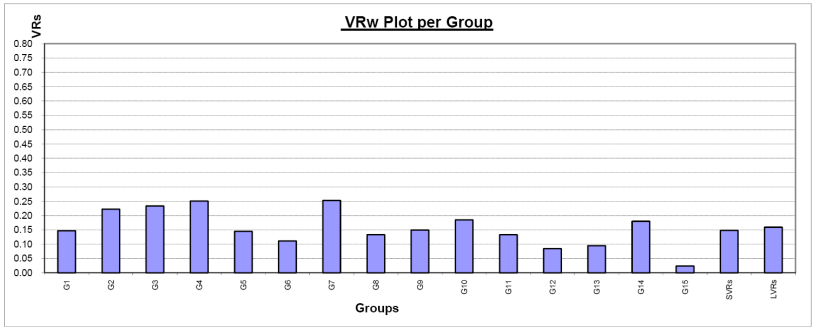




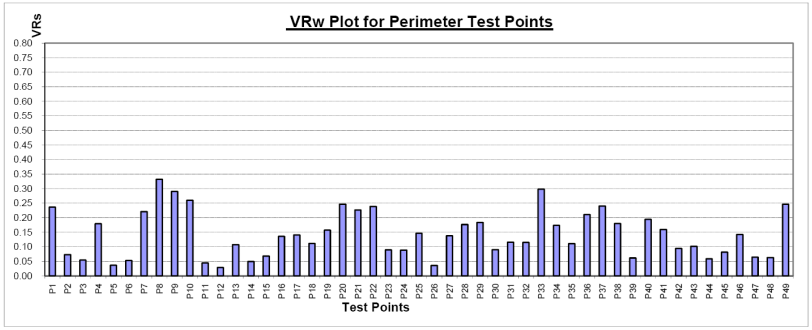


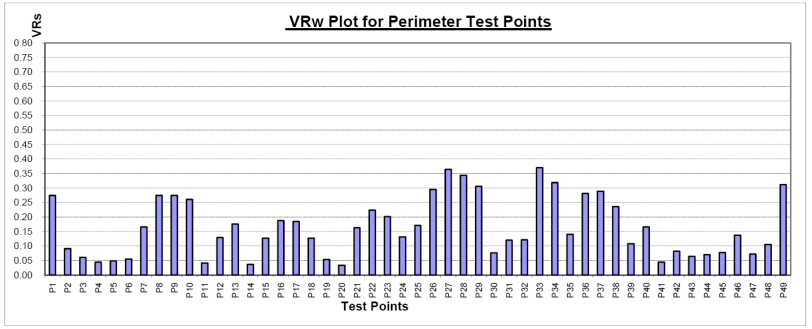


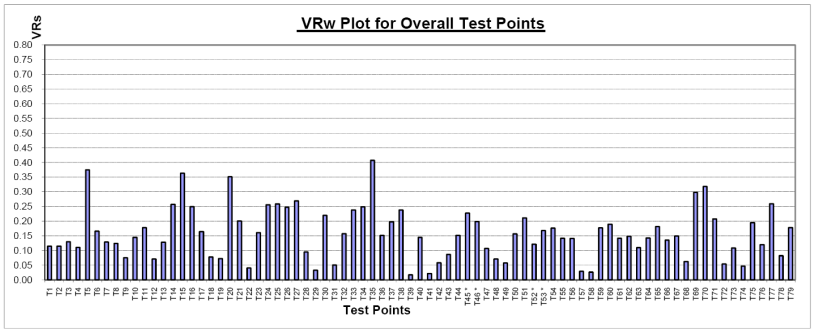
VR_w Result under NE Wind Direction

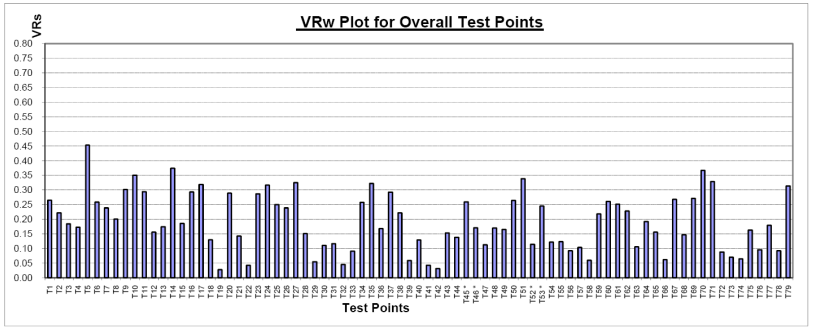


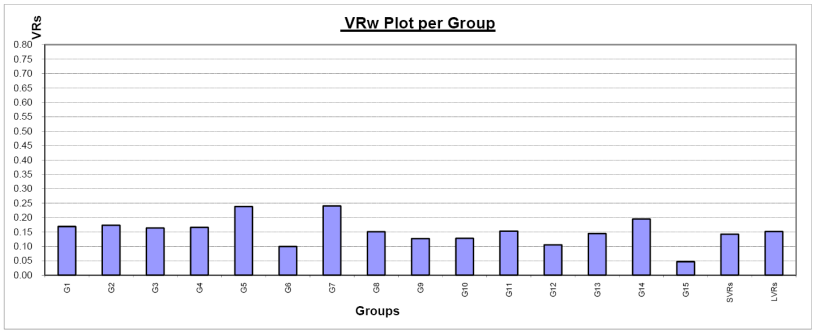
VR_w Result under ENE Wind Direction



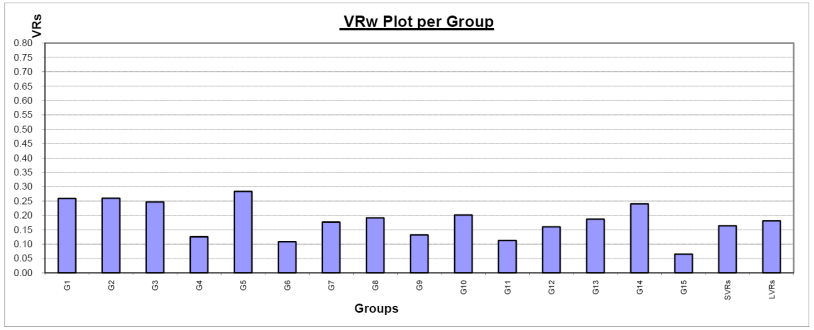




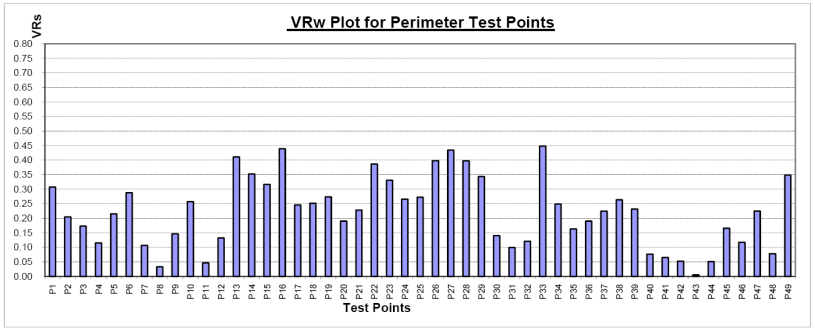


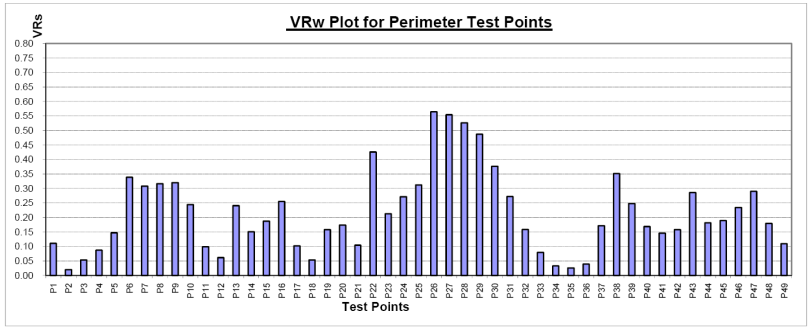


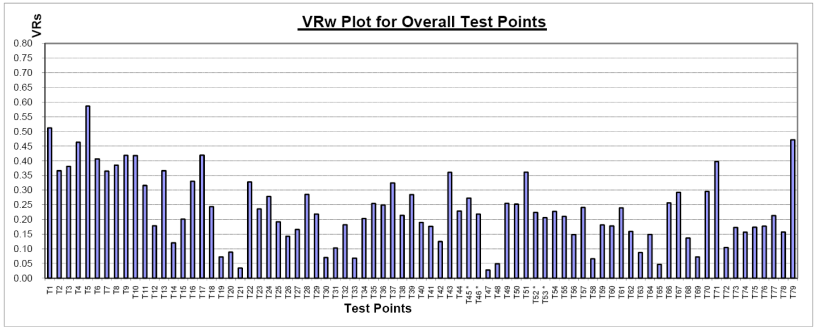
VR_w Result under E Wind Direction

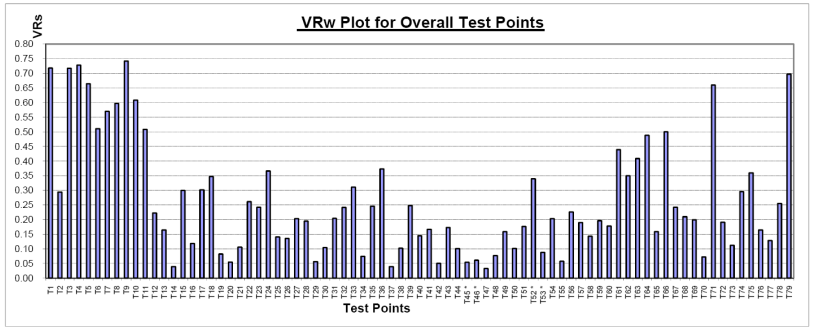


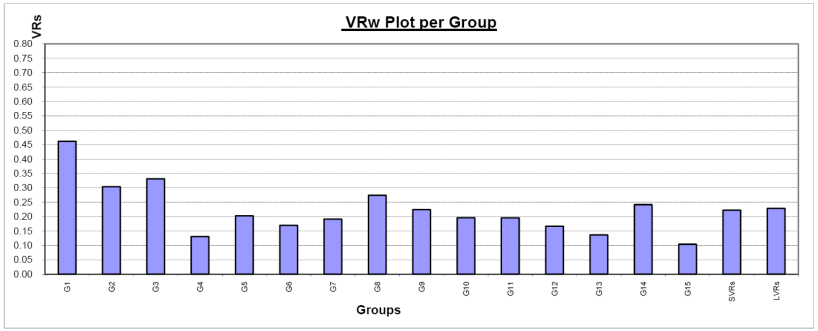
VR_w Result under ESE Wind Direction



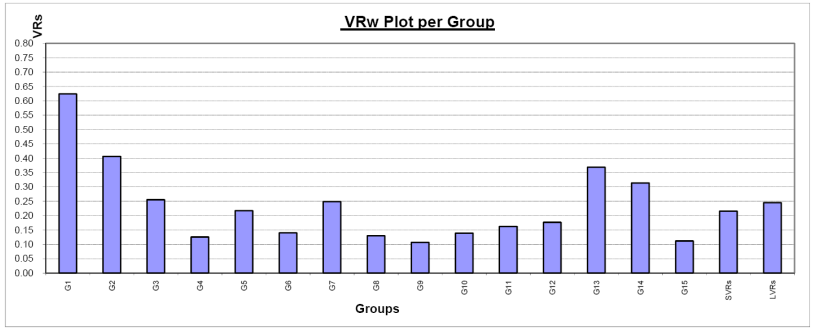




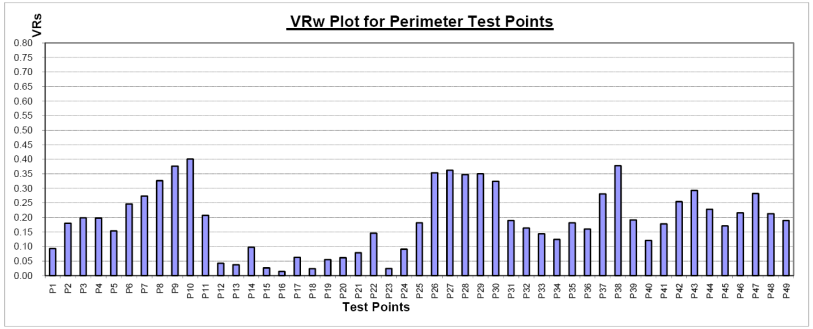


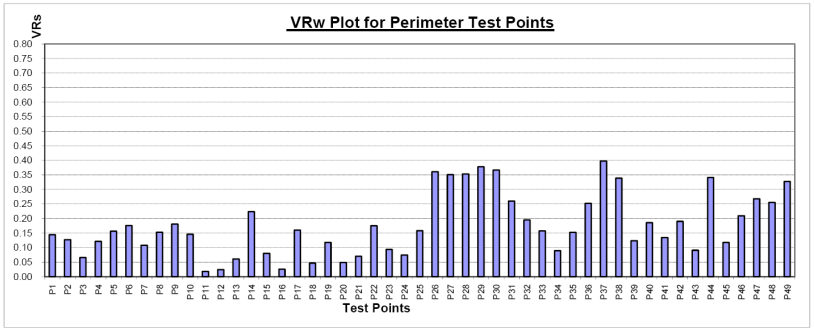


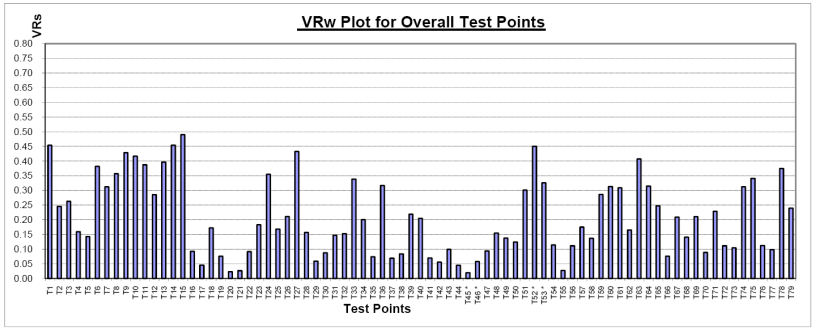
VR_w Result under SE Wind Direction

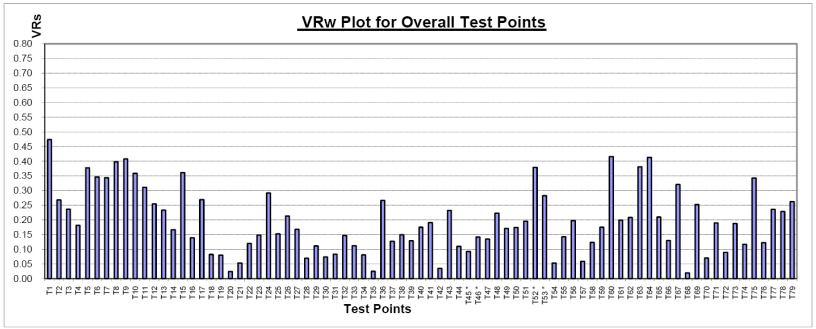


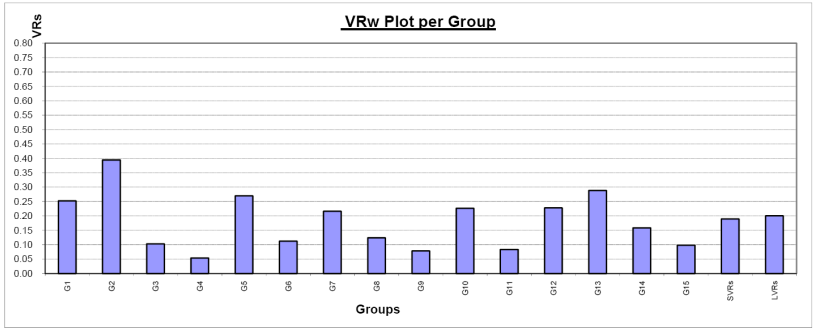
VR_w Result under SSE Wind Direction



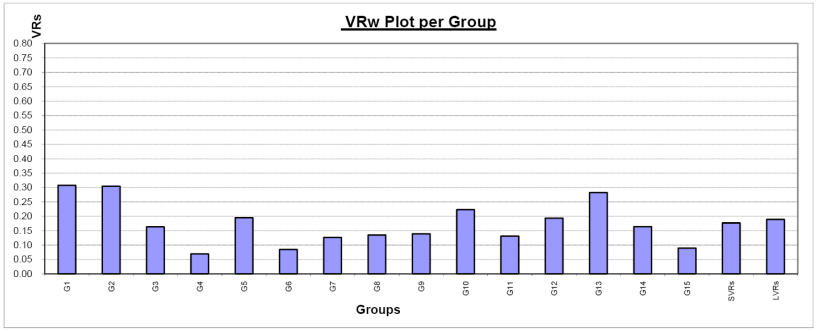




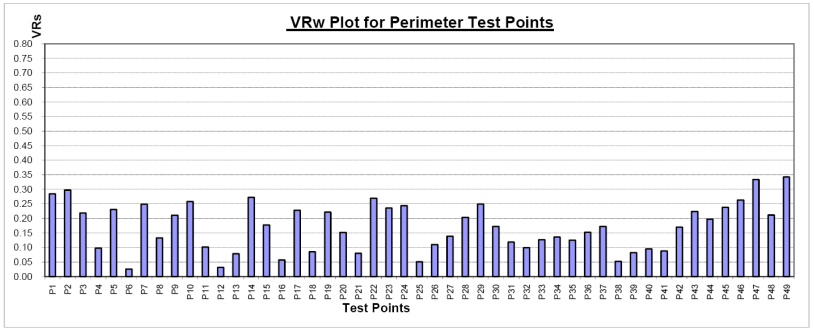


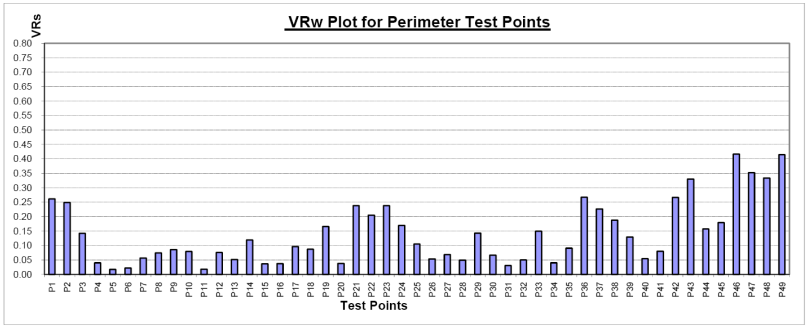


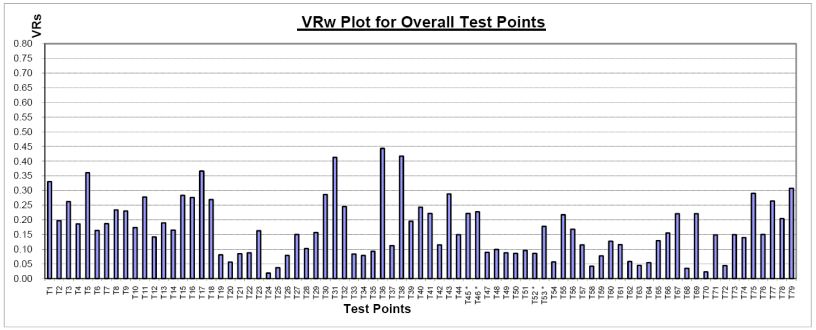
VRw Result under S Wind Direction

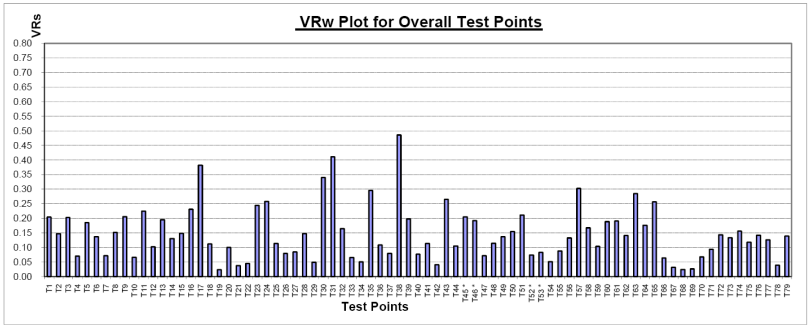


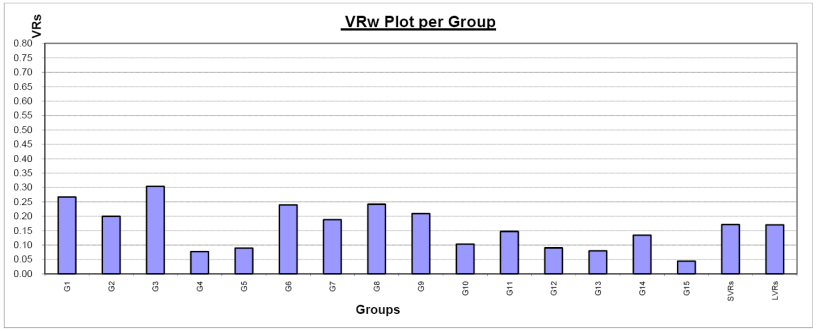
VRw Result under SSW Wind Direction



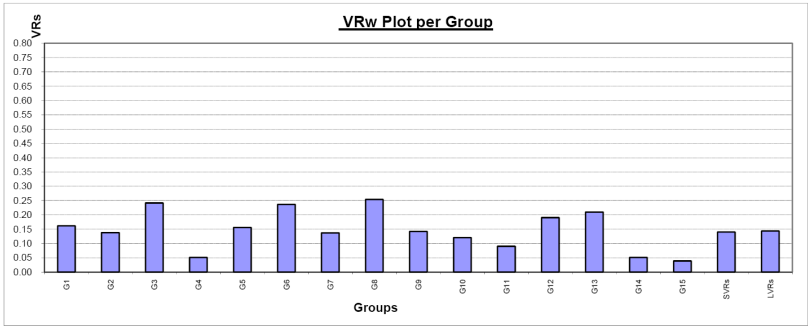




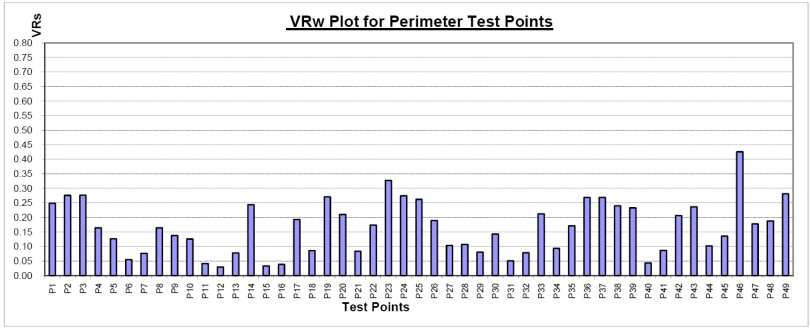


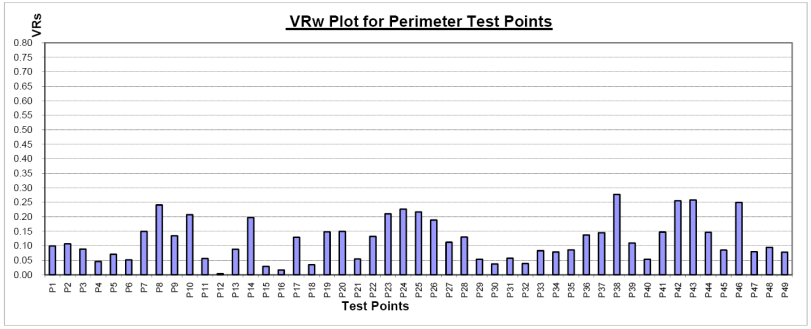


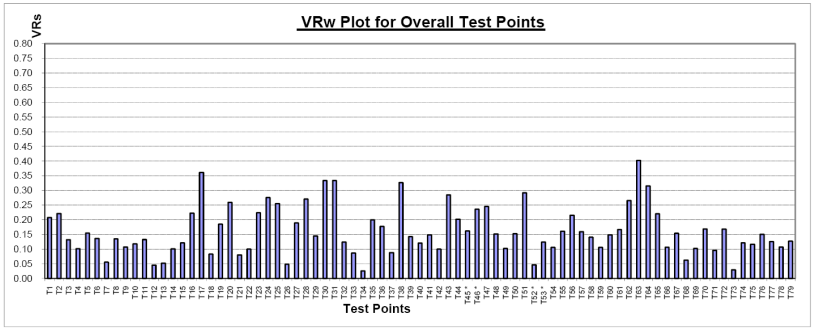
VRw Result under SW Wind Direction

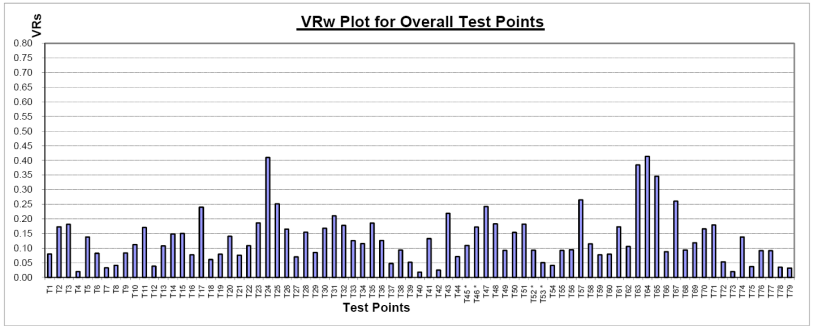


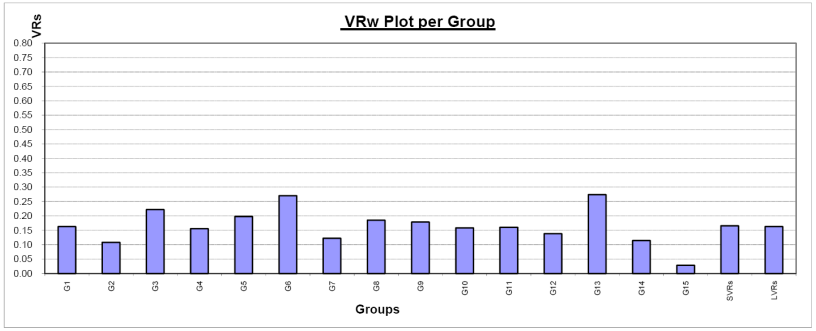
VRw Result under WSW Wind Direction



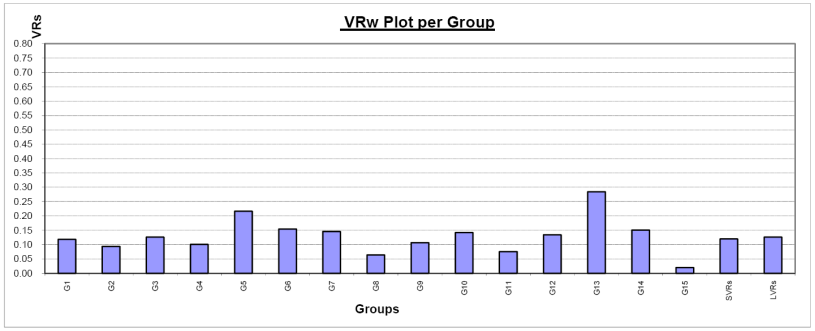




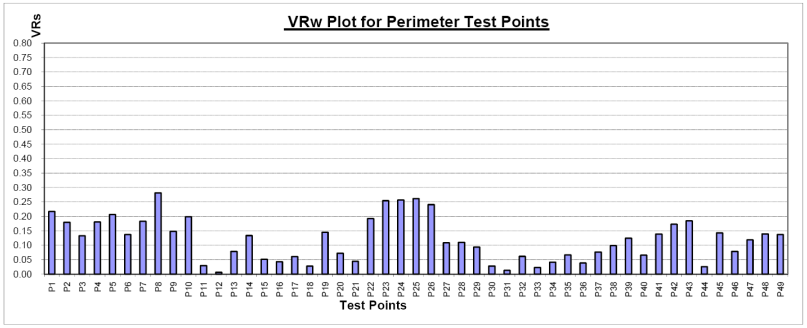


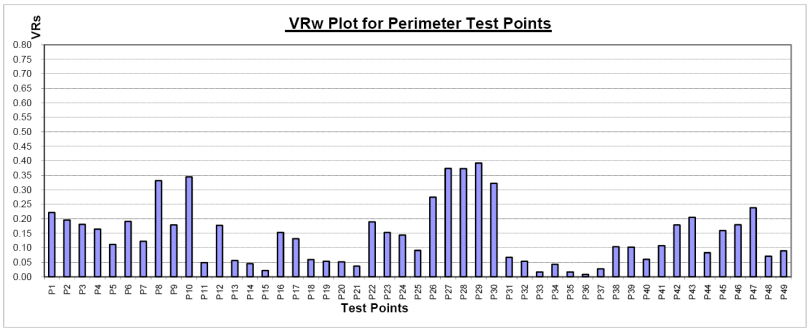


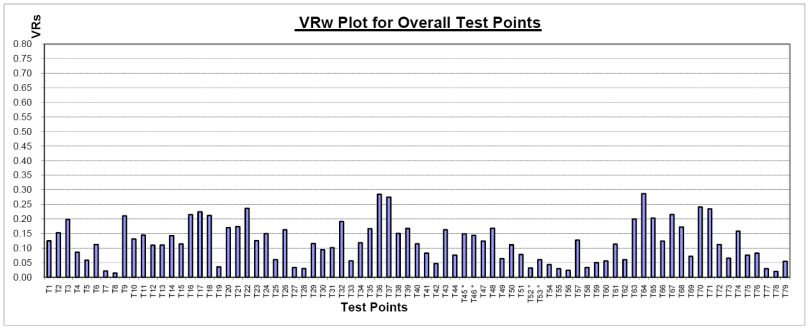
VRw Result under W Wind Direction

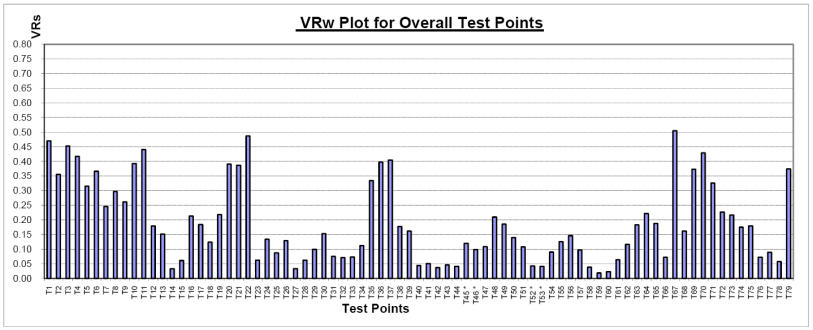


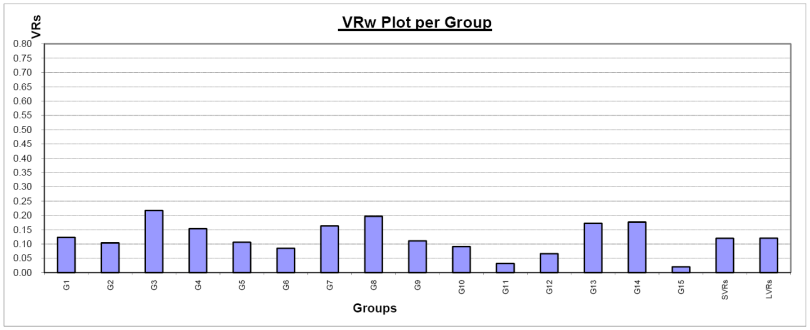
VRw Result under WNW Wind Direction



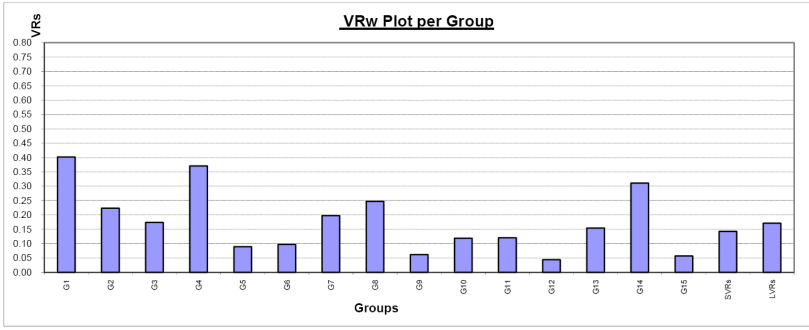








VRw Result under NW Wind Direction



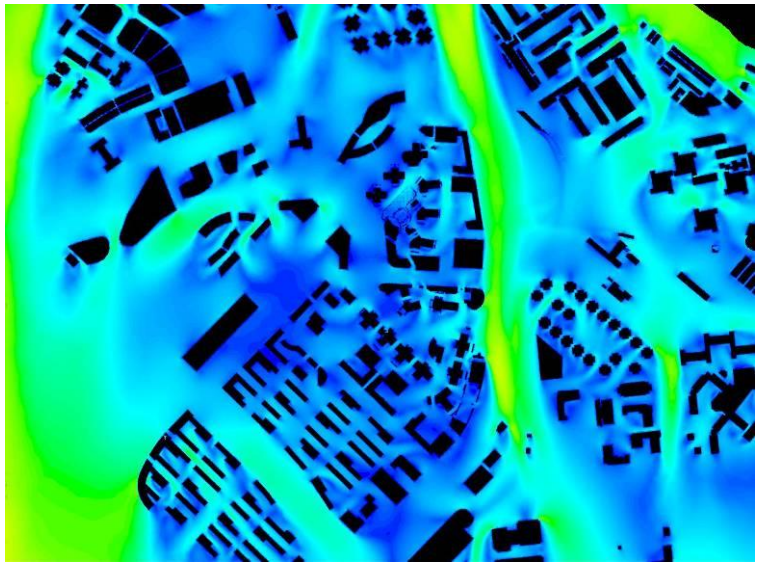
VRw Result under NNW Wind Direction

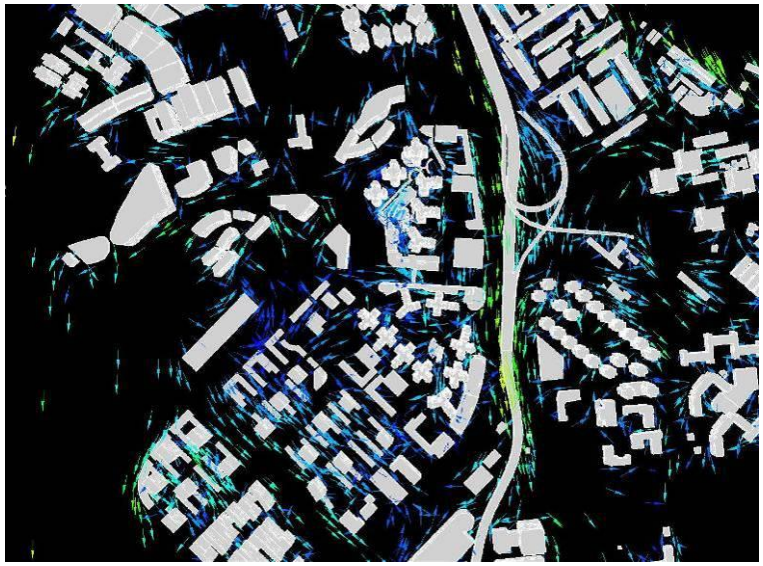
Appendix D

Wind Velocity Ratio Contour and Vector Plots at 2m above Ground under Different Wind Directions

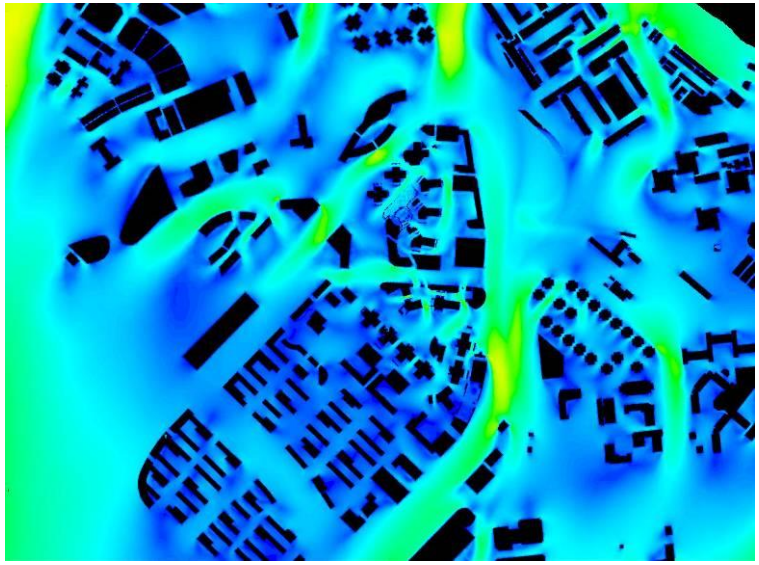
Appendix D Wind Velocity Ratio Contour and Vector Plots at 2m above Ground under Different Wind Directions

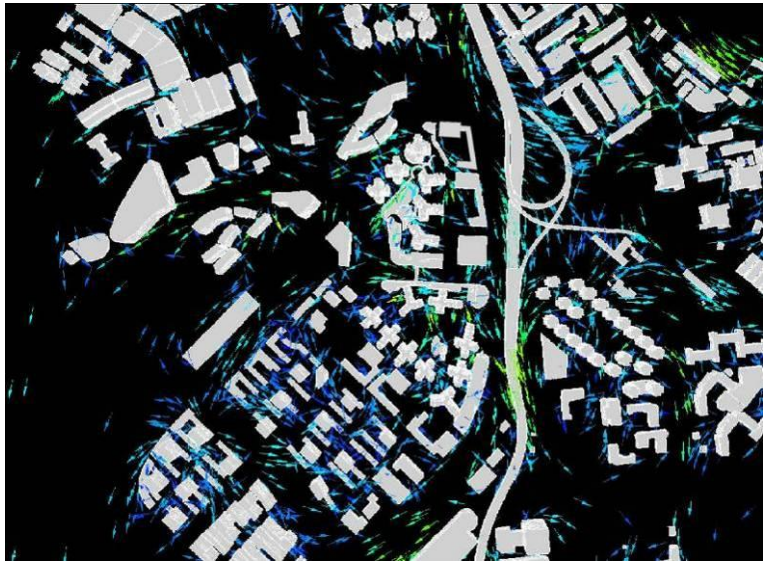
"N"





"NNE"

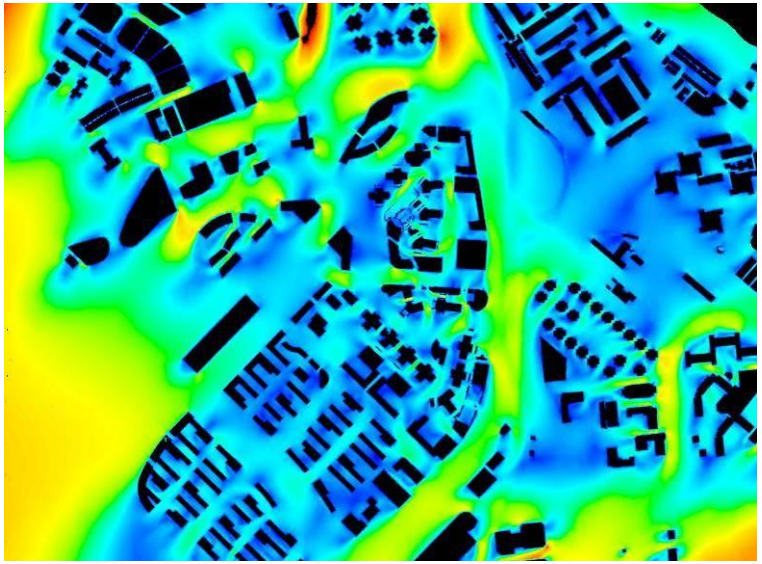


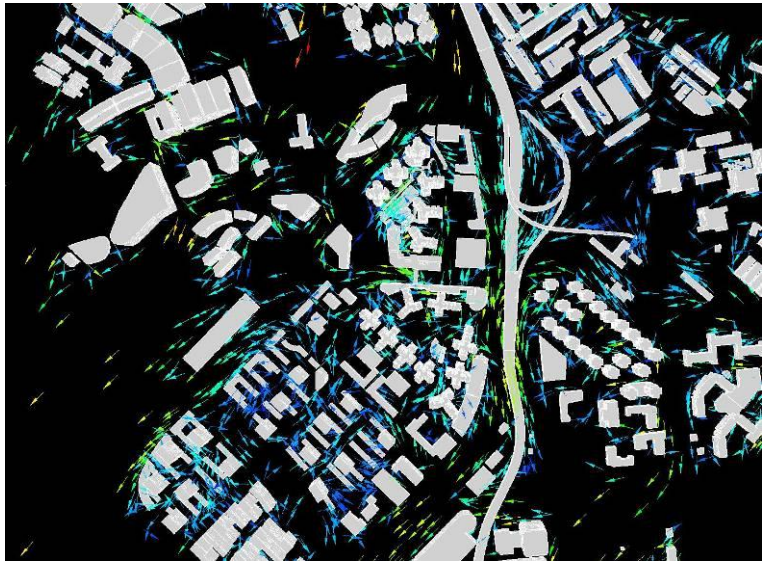


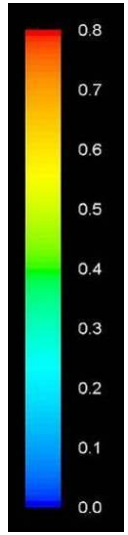
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

"NE"







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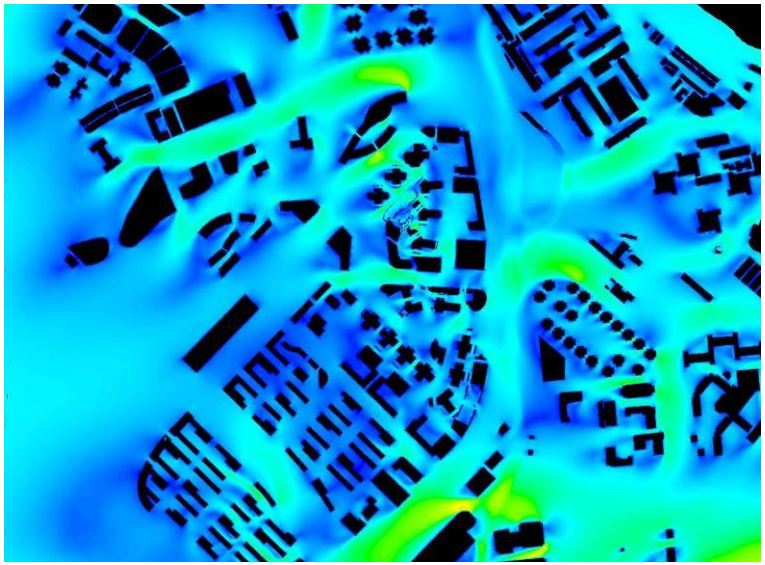
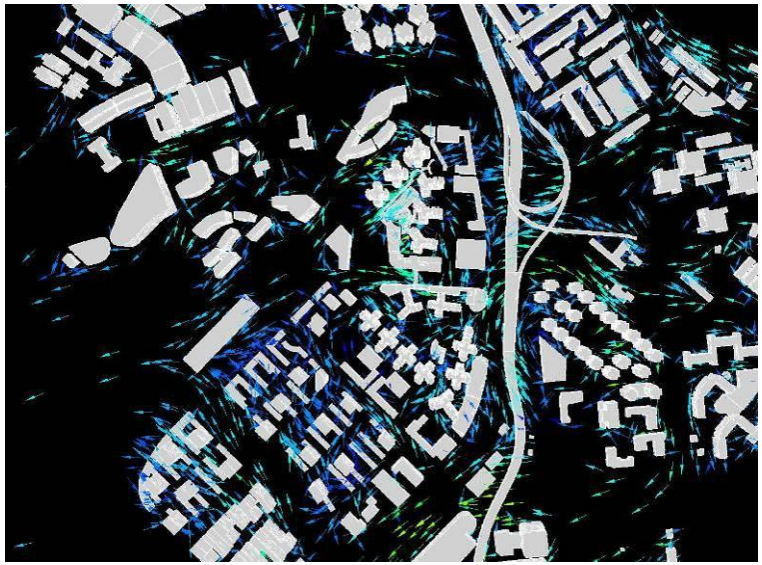
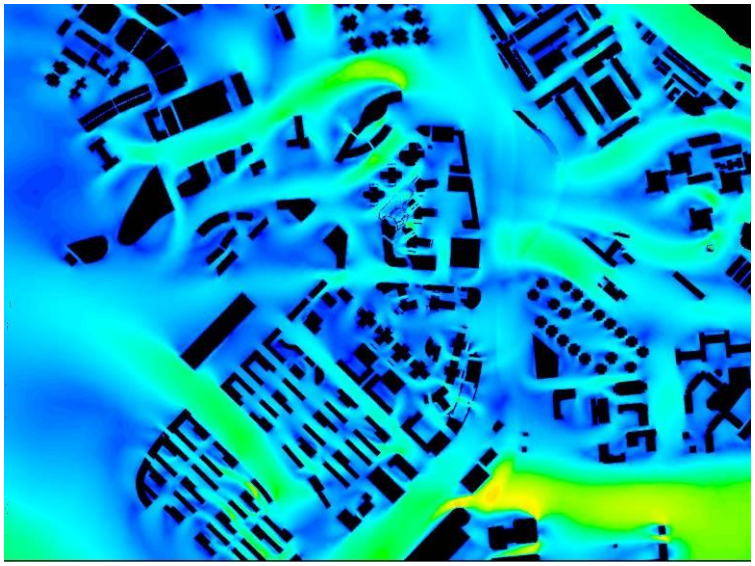


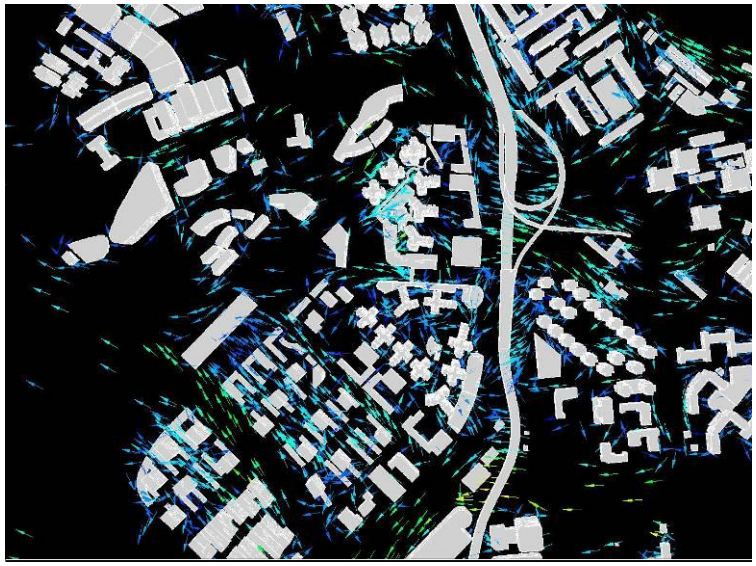


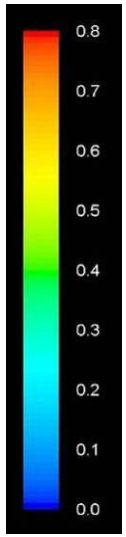
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

"E"







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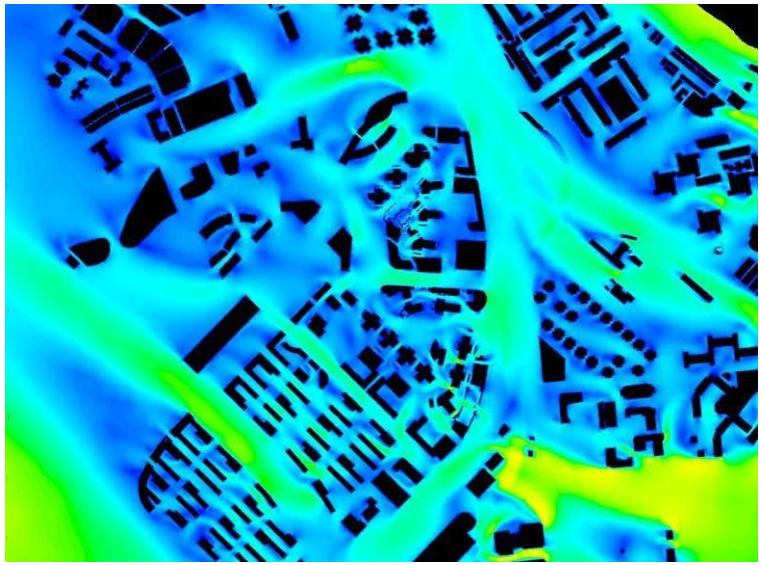
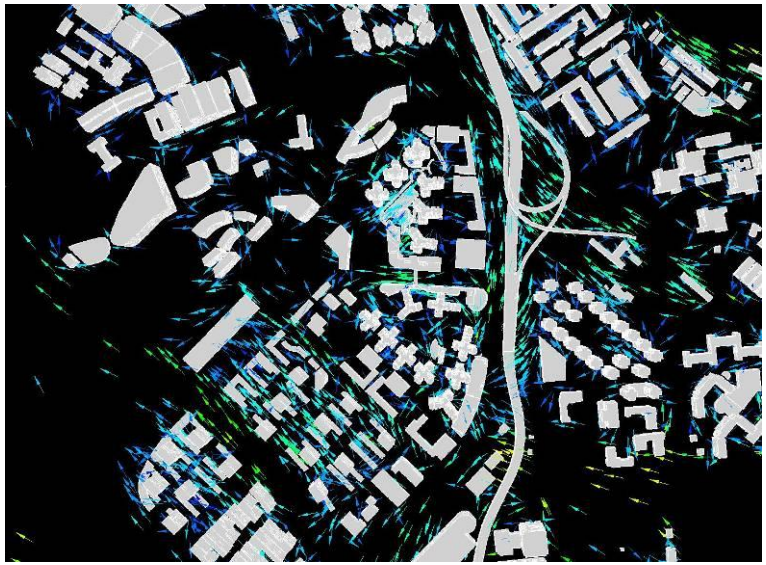
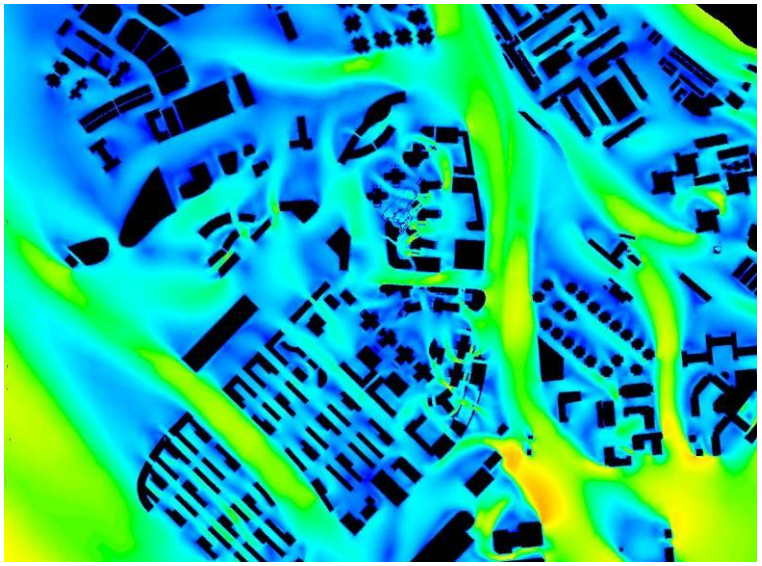


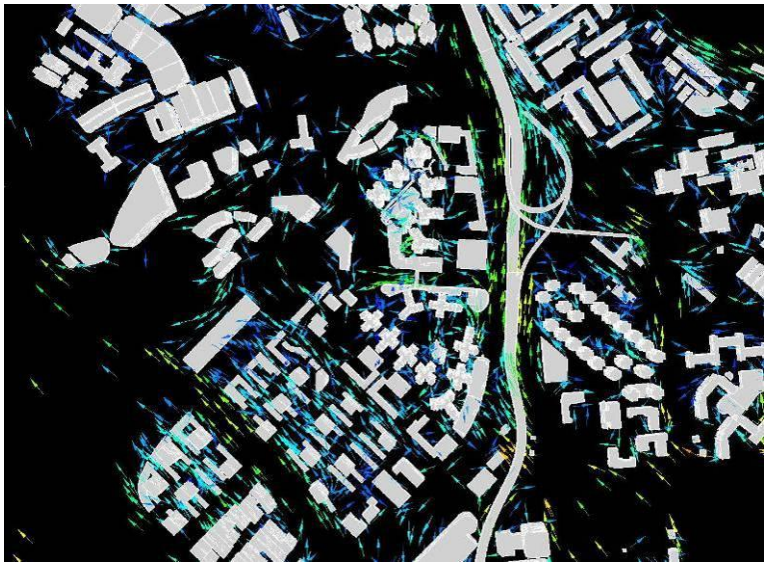


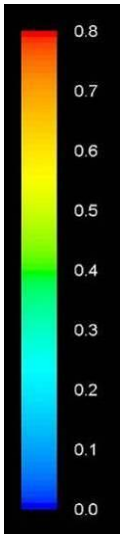
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

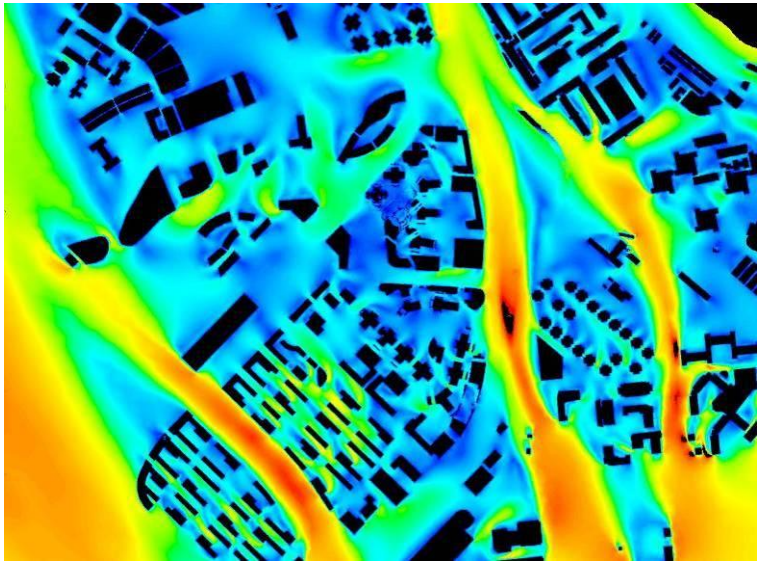
"SE"

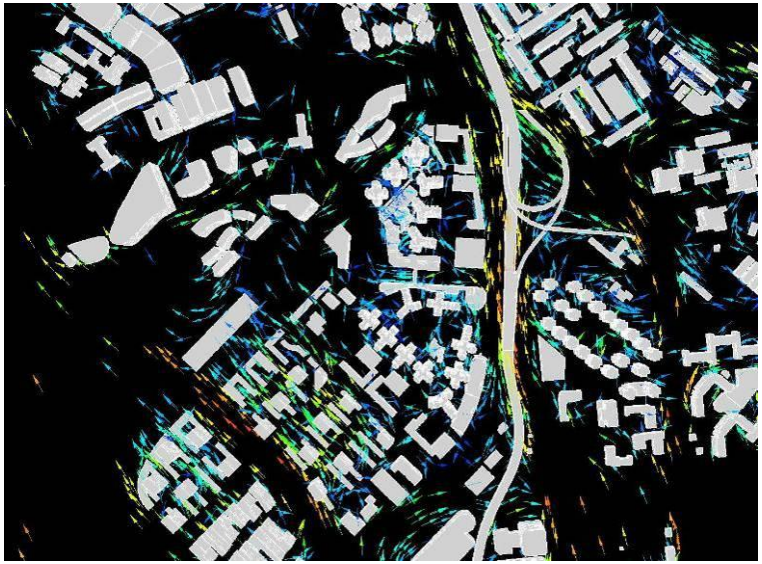






"SSE"

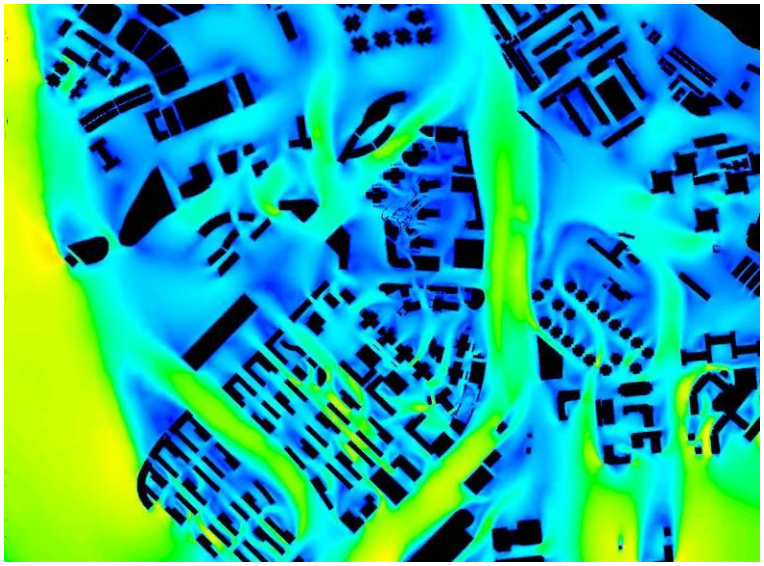


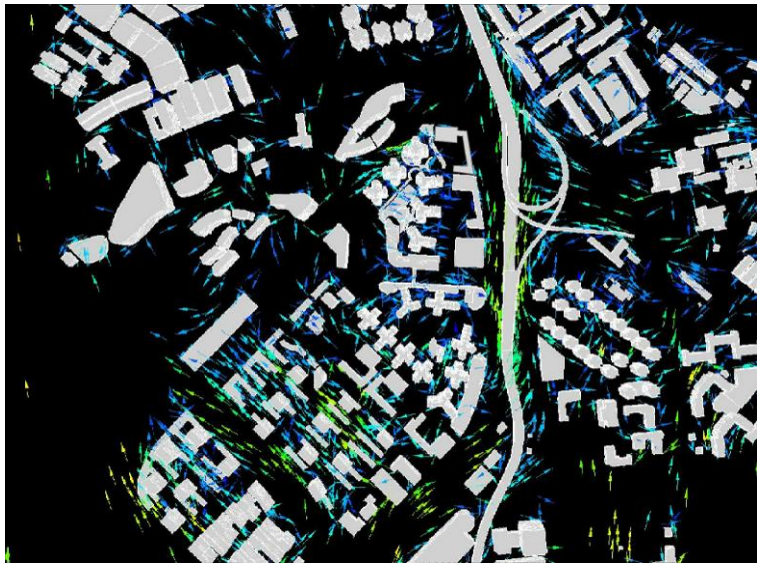


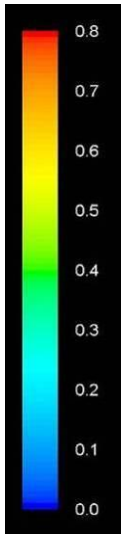
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

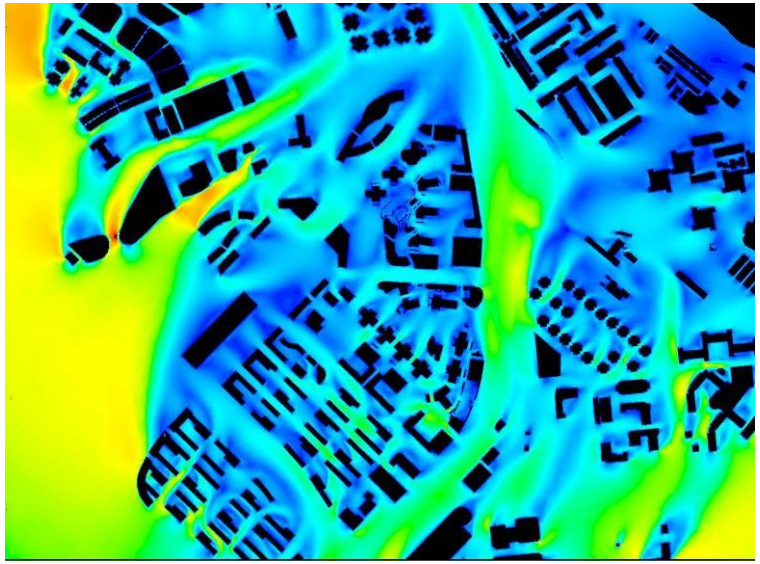
"S"

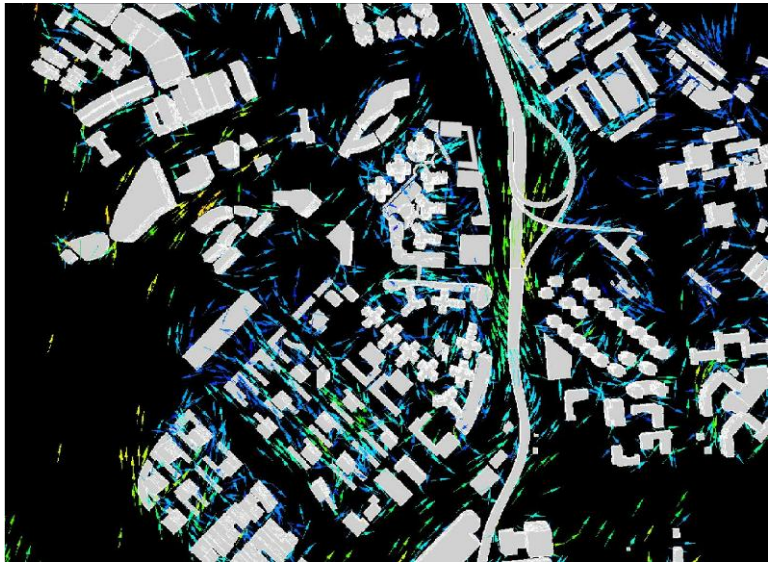






"SSW"

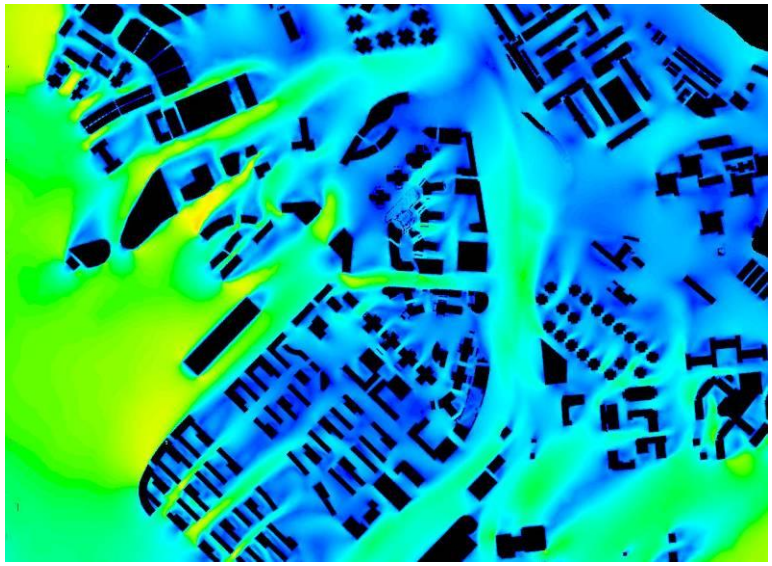


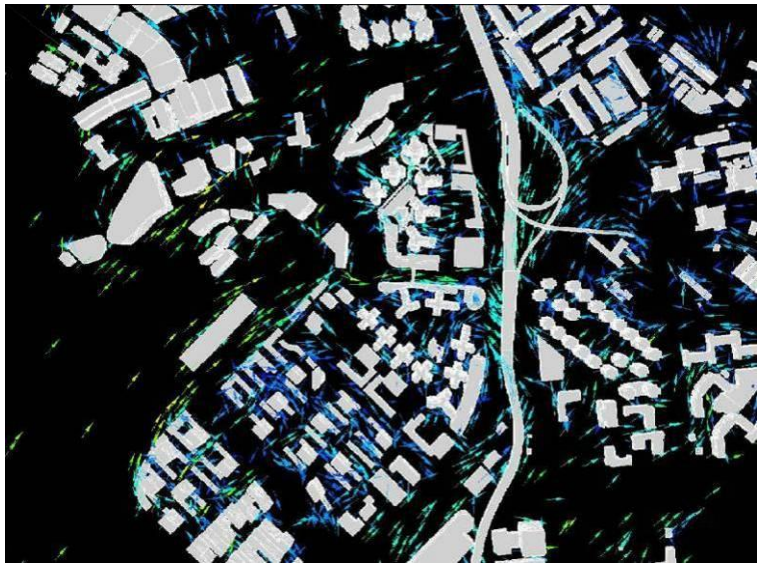


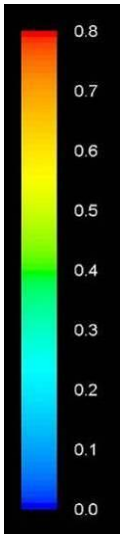
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

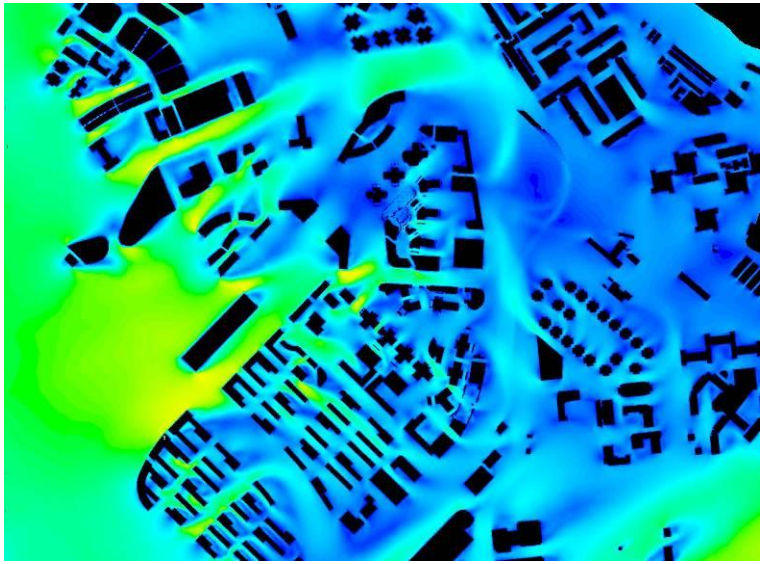
"SW"

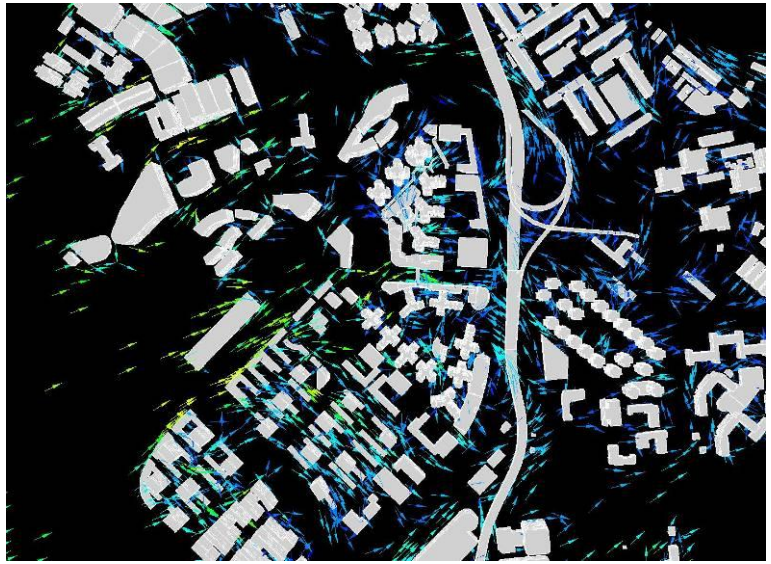






"WSW"

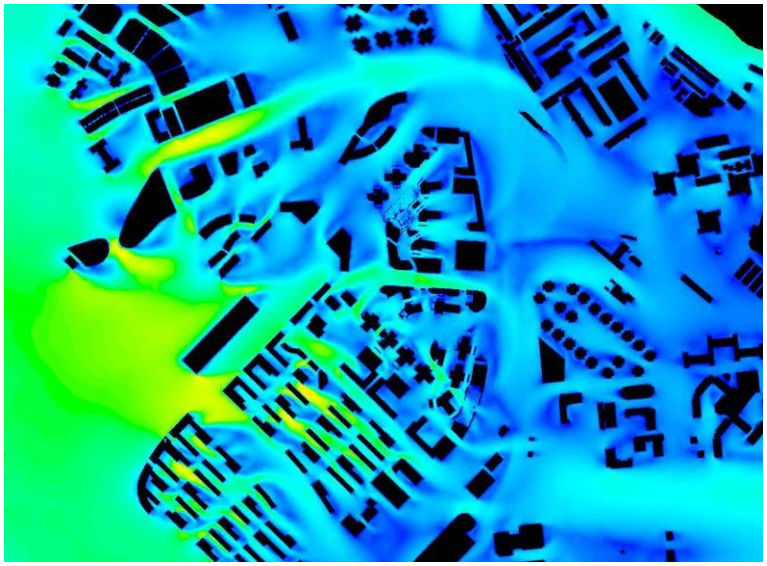


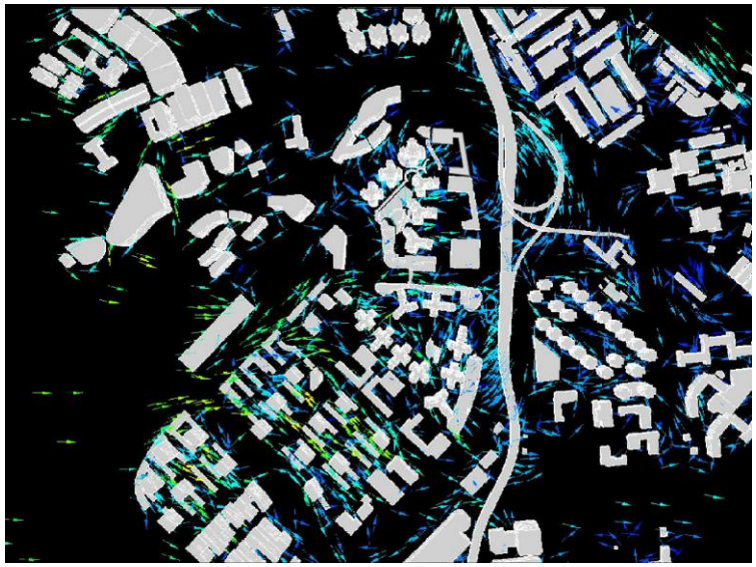


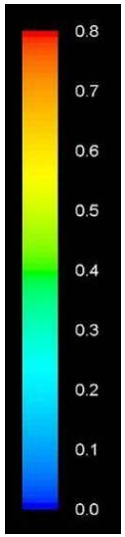
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

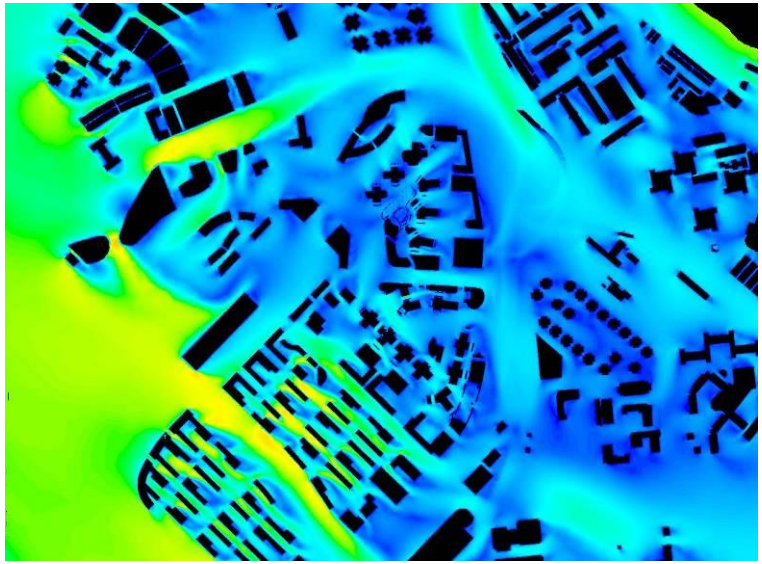
"W"

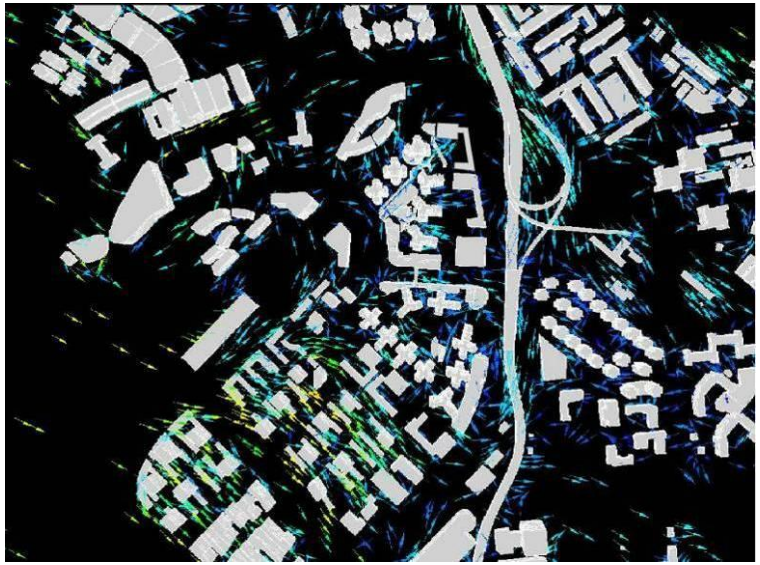






"WNW"

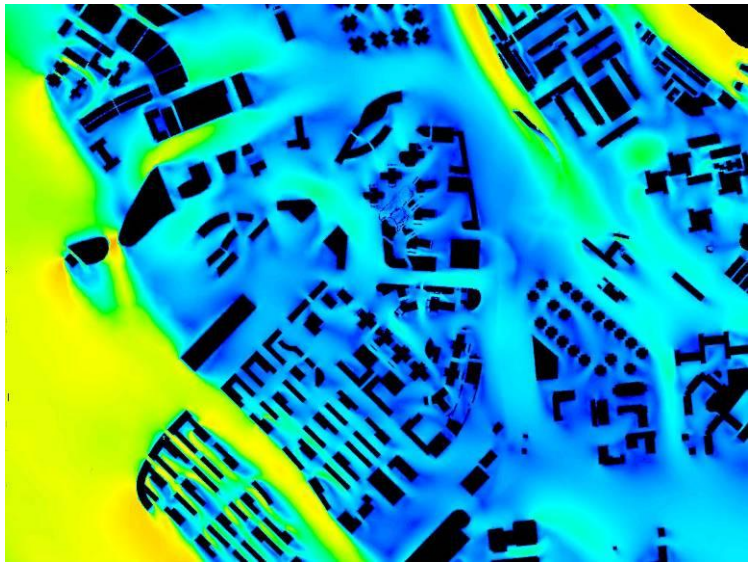


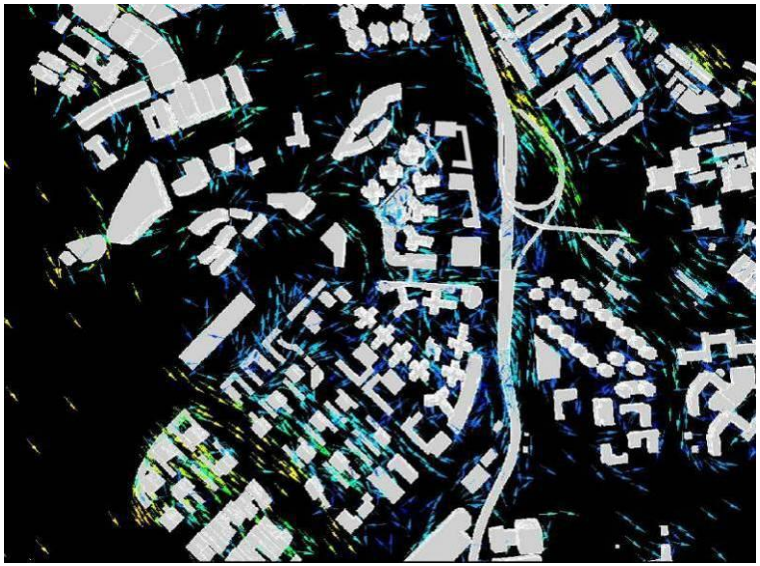


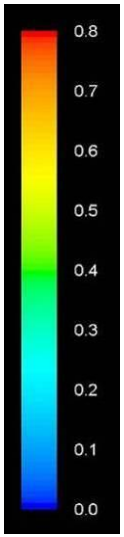
Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground

"NW"







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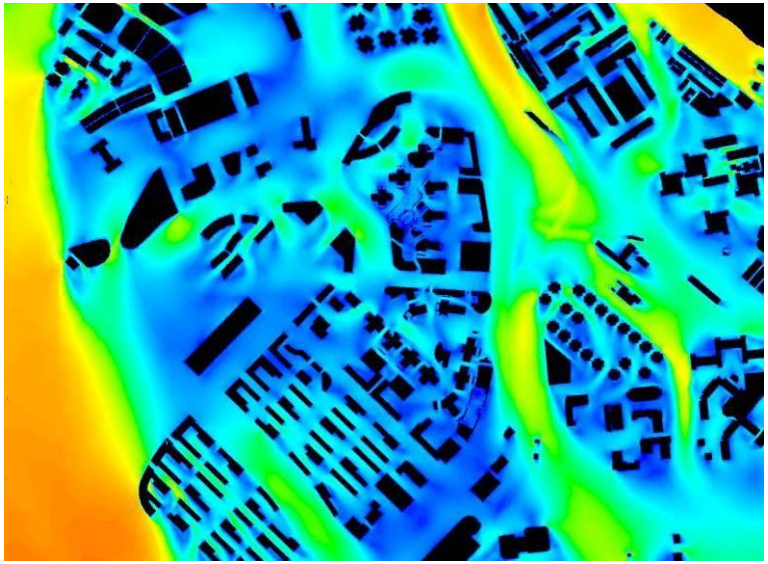

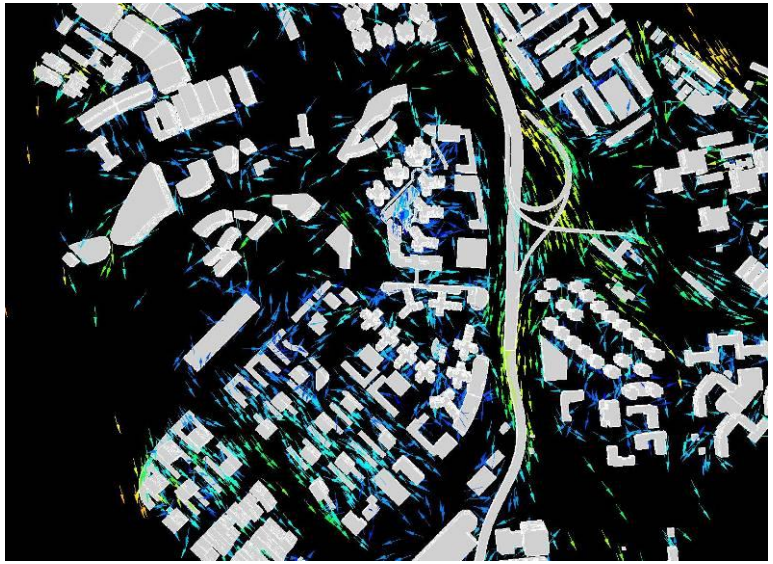

Wind Velocity Ratio Contour Plat at 2m above Ground

Wind Velocity Vector Plat at 2m above Ground