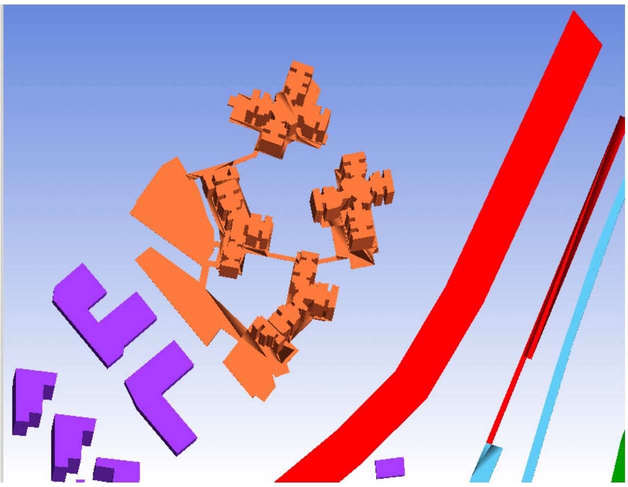
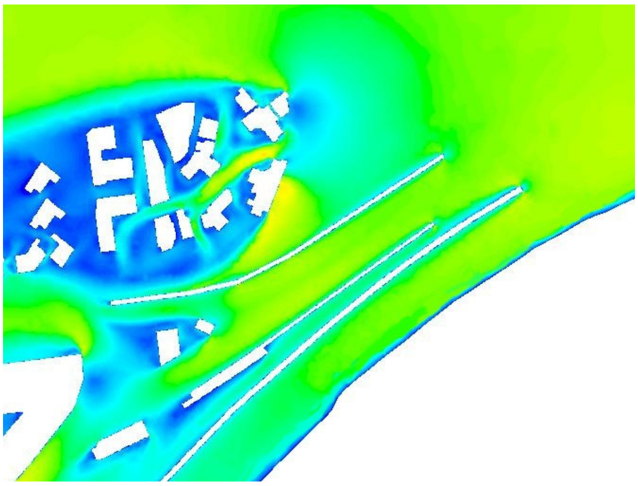
Hong Kong Housing Authority

Proposed Public Housing Development at Tung Chung Area 56

Air Ventilation Assessment (AVA) Initial Study Report





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Air Ventilation Assessment (AVA) Initial Study Report

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Report No	EB000532/TC56/AVA/R002
Date	25 October 2013

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Executive Summary

In April 2009, Hyder Consulting Ltd. (HCL) was commissioned by the Hong Kong Housing Authority to undertake an Air Ventilation Assessment (AVA) Initial Study for the Tung Chung Area 56 (TC56) Public Housing Development, to assess air ventilation performance of the building design and its impacts to the surrounding pedestrian accessible locations. Finding from the AVA Initial Study undertaken are documented in this report and summarised in the following section. Computational Fluid Dynamics (CFD) simulation was employed as the assessment tool for quantitative ventilation performance in the study.

Local AVA simulated results (LVR) computed by analysing the group of overall test points and perimeter test points, and Site AVA simulated results (SVR) evaluated by considering perimeter test points only are summarised in the tables below:

Table 1 Summary of Local Velocity Ratios for Tung Chung Area 56 Public Housing Development under Prevailing Wind Directions

Local Air Ventilation Assessment Results (LVR)			
Prevailing Wind Direction	*Prior to Construction of TC56 Public Housing Development*	*Subsequent to Construction of TC56 Public Housing Development*	*VR Change*
NNE (22.5º)	0.414	0.408	-0.006
NE (45º)	0.426	0.376	-0.050
ENE (67.5º)	0.362	0.325	-0.038
E (90º)	0.385	0.328	-0.056
ESE (112.5º)	0.372	0.259	-0.113
SE (135º)	0.347	0.239	-0.108
SSE (157.5 º)	0.374	0.314	-0.060
SSW (202.5º)	0.316	0.255	-0.062
Overall (weighted)	**0.380**	**0.323**	**-0.057**

Table 2 Summary of Site Velocity Ratios for Tung Chung Area 56 Public Housing Development under Prevailing Wind Directions

Site Air Ventilation Assessment Results (SVR)			
Prevailing Wind Direction	*Prior to Construction of TC56 Public Housing Development*	*Subsequent to Construction of TC56 Public Housing Development*	*VR Change*
NNE (22.5º)	0.451	0.420	-0.031
NE (45º)	0.478	0.380	-0.099
ENE (67.5º)	0.360	0.329	-0.031
E (90º)	0.399	0.308	-0.091
ESE (112.5º)	0.363	0.220	-0.143
SE (135º)	0.374	0.273	-0.101
SSE (157.5 º)	0.434	0.312	-0.122
SSW (202.5º)	0.348	0.238	-0.110
Overall (weighted)	**0.403**	**0.319**	**-0.084**

Local Air Ventilation Assessment (LVR)

The overall weighted VR change in the Local Air Ventilation Assessment from the construction of Tung Chung Area 56 Public Housing Development is not substantial (less than 0.06 which is equivalent to 0.5 m/s wind velocity reduction) and its impact upon ventilation performance of potential areas is deemed to be insignificant. Therefore, it can be concluded that the design and erection of Tung Chung Area 56 Public Housing Development is unlikely to have a significant adverse wind impact on pedestrian level ventilation performance of the surrounding community.

Site Air Ventilation Assessment (SVR)

The construction of the Tung Chung Area 56 Public Housing Development involves erection of vertical structures which would ultimately lead to reduced wind permeability at pedestrian levels within the project site area (originally entirely exposed). Therefore, as shown by the velocity ratios in the table above, the TC56 Public Housing Development would generally have some impact upon the wind availability of these test points, as expected. However, in terms of overall ventilation performance of site perimeter areas with respect to impact from construction of TC56 Public Housing Development, a SVR reduction of 0.087 (equivalent to 0.7m/s reduction in wind velocity) for the subject assessment can be considered as relatively insignificant and acceptable.

Conclusion

The AVA study findings reveal that the construction of the Tung Chung Area 56 Public Housing Development is unlikely to have an adverse ventilation performance impact upon pedestrian areas at nearby sensitive communities and within the site. The design and erection of the public housing development leads to ventilation performance results of LVR change = 0.057 (equivalent to less than 0.5 m/s wind speed reduction) and SVR change = 0.084 (equivalent to 0.7 m/s wind speed reduction), all of which are deemed to be insignificant and acceptable.

1 Introduction

1.1 Background

The Planning Department (PD) completed a Feasibility Study for Establishment of Air Ventilation Assessment System (AVAS) for Hong Kong in 2005. As a way forward from the study, the Housing, Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB) jointly issued the Technical Circular No. 1/06 – Air Ventilation Assessments (AVA). This technical circular provides guidelines on undertaking AVA for developments in Hong Kong with the core objective of assessing impacts on pedestrian wind environment. Technical Circular No. 1/06 – AVA is provided in *Appendix A* for reference

In April 2009, Hyder Consulting Ltd. (HCL) was commissioned by the Hong Kong Housing Authority to undertake Consultancy for Environmental Design Study of Public Housing Development Projects in Batch C2 (Agreement No: CB20090005). As a part of the consultancy assignment, an Air Ventilation Assessment (AVA) Initial Study is required for the Tung Chung Area 56 (TC56) Development to assess air ventilation performance of the building design and its impacts to the surrounding pedestrian accessible locations.

1.2 Objectives and Report Structure

Using methodology outlined in the Technical Guide for AVA for Developments in Hong Kong (Technical Guide) annexed in HPLB and ETWB TC No. 1/06 as a basis, the impacts of the proposed Tung Chung Area 56 (TC56) Public Housing Development on pedestrian level wind environment were analysed and investigated. Computational Fluid Dynamics (CFD) simulation was employed as the assessment tool for quantitative ventilation performance evaluation in the study. In essence, the main purposes of this assignment, echoing the technical guide include:

- to assess characteristics of the wind availability (V_∞) of the site;
- to give a general pattern of the proposed design and a quantitative estimates of wind performance at pedestrian levels (at street level) reported using Wind Velocity Ratio (VR); and
- to identify ventilation performance of the proposed design and areas of concerns in the neighbourhood.

This report describes the AVA Initial Study undertaken for the proposed design of the TC56 Public Housing Development and the remainder of the report is sectionalised as follows:

Section 2: Site Wind Conditions and Expert Evaluation, Site Environs

Section 3: Site Wind Availability

Section 4: General Prevailing Wind Condition and Expert Evaluation

Section5: Results and Analysis

2 Site Wind Conditions and Expert Evaluation

2.1 Site Environs

The subject site for the proposed TC56 public housing development is located at the northeast region of the Tung Chung district, as shown in Figure 1. The site is bounded at the south by the North Lantau Highway and sea area to the immediate north and east. High-rise residential buildings (Caribbean Coast) are found in the southwest region of the site. Currently, a vacant area is located at the west of the subject site.

However, it is envisaged that upon completion of the Tung Chung Area 56 Public Housing Development, part of these areas will be built up with buildings and a noise barrier will be erected to the south of the site (indicated in the figure below). Therefore, for the purpose of this study, air ventilation performance influence of the TC56 public housing development to these future buildings will also be investigated.

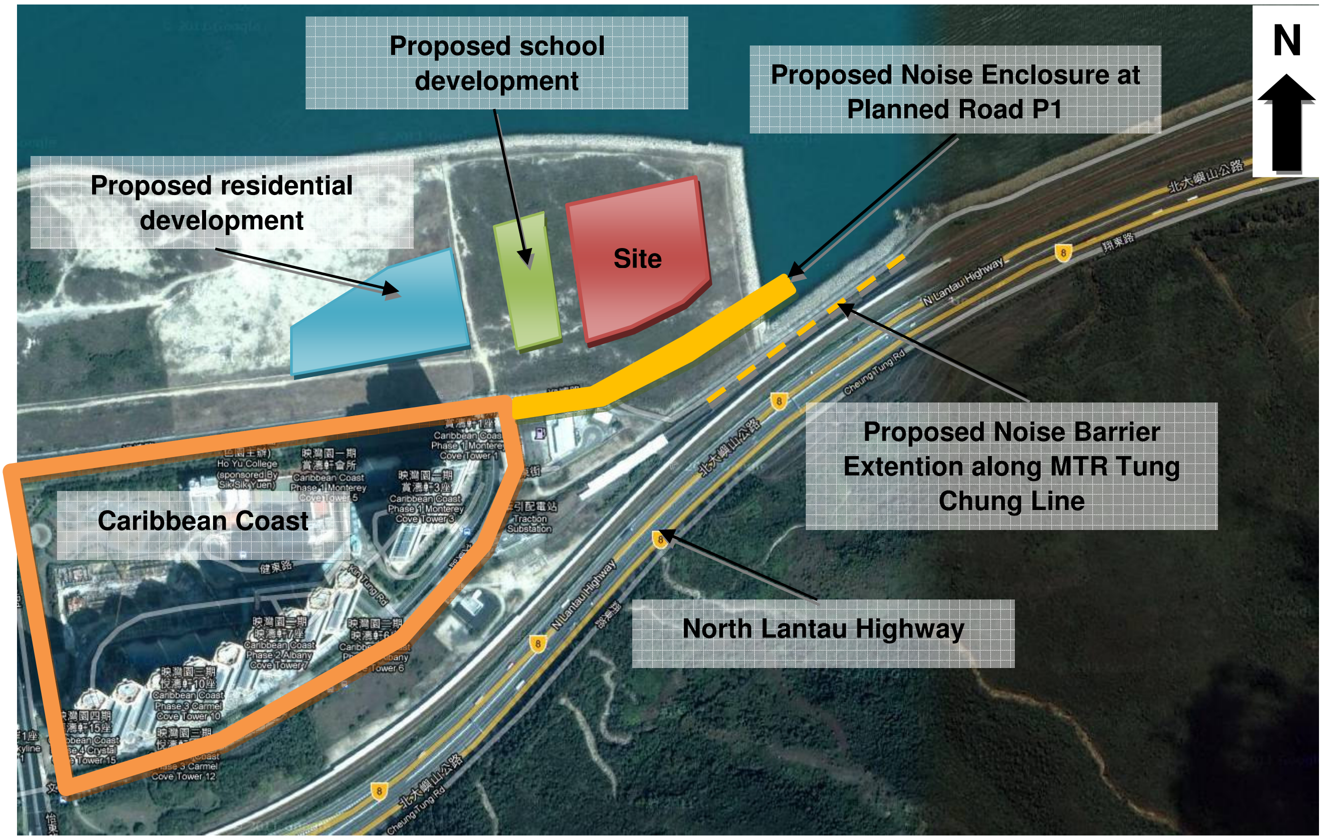

Figure 1 Location of The TC56 in Red Highlighted Area

The proposed design of the TC56 public housing development consists of the following buildings and facilities:

- 4 site specific domestic blocks with varying height from 36 to 40 storeys
- Retail provision in the form of street front shops and a wet market
- Social welfare and government facilities
- Estate Management accommodations and associated recreational facilities

2.2 Project Area and Assessment Area Boundary and Surrounding Area Boundary

The project area is defined by project site boundaries including all open areas for which pedestrian are likely to access. For the purpose of this study, the project area is therefore equivalent to the project site area as illustrated (encoded by green boundary line) overleaf.

According to the Technical Circular No. 1/06 – AVA, the assessment area (encoded by blue boundary line) includes the site's surrounding environment up to a perpendicular distance of H (where H is the height of the tallest building within the project site) as shown overleaf. For the project site, H is 125 meters.

The surrounding area should normally be up to a perpendicular distance of 2H from the project site boundary, which is 250 meters for this study. However, since there is hilly terrain immediate outside the assessment area regions, the surrounding area for this AVA study has been enlarged as shown below and these are modeled in the CFD simulation described in Section 4. Project site area, assessment area and surrounding area boundaries are all shown as below.

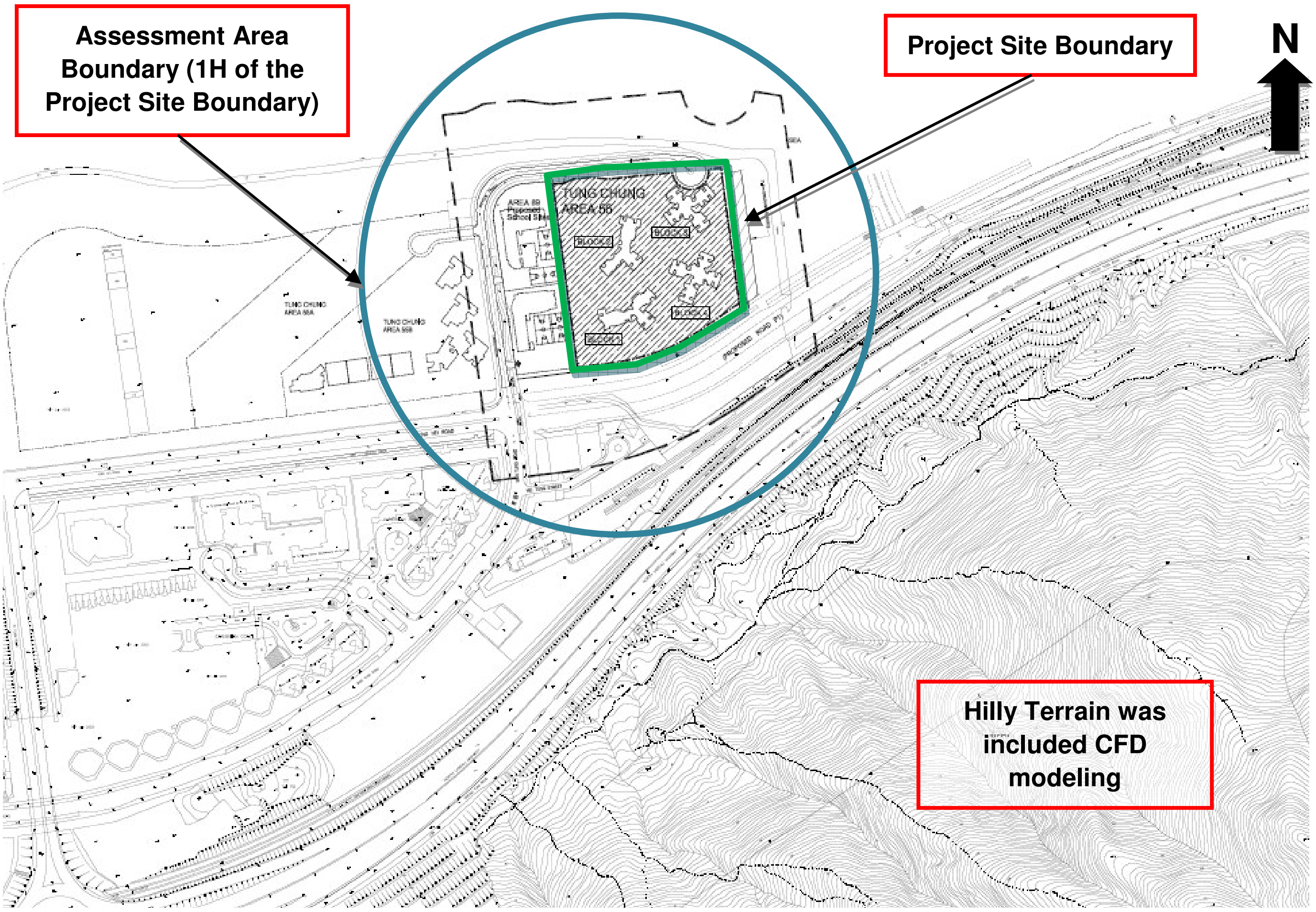

Figure 2 Project Site Boundary and Assessment Area Boundary

2.3 General Prevailing Wind Conditions and Expert Evaluation

Air ventilation assessments would generally be affected by wind availability under all wind directions and frequency of occurrence of individual wind directions, and in particular predominated by prevailing wind flows. With regards to the project site, based on the site wind availability data provided by the Planning Department for the immediate vicinity of the project site in Tung Chung region (see Section 3 below), north-north-easterly to south-south-westerly winds occurrence exceed 75% of the time throughout the year.

The overall wind performance of the project site should be acceptable since there is no obstruction and building blocks to the north and east of the TC56 development (open sea area). As mentioned above (and evaluated in Section 3), up to 50% annual winds are originated from the north-north-easterly to eastern direction. A hilly terrain (Lantau Island) is found at southeastern direction to the site. However, there is unlikely to be significant ventilation impacts under these directions since there are no immediate developments that are adjoining to the subject site. Finally, there is a potential wind corridor available along the North Lantau Highway (shown by yellow arrows below) under the southwestern wind direction.

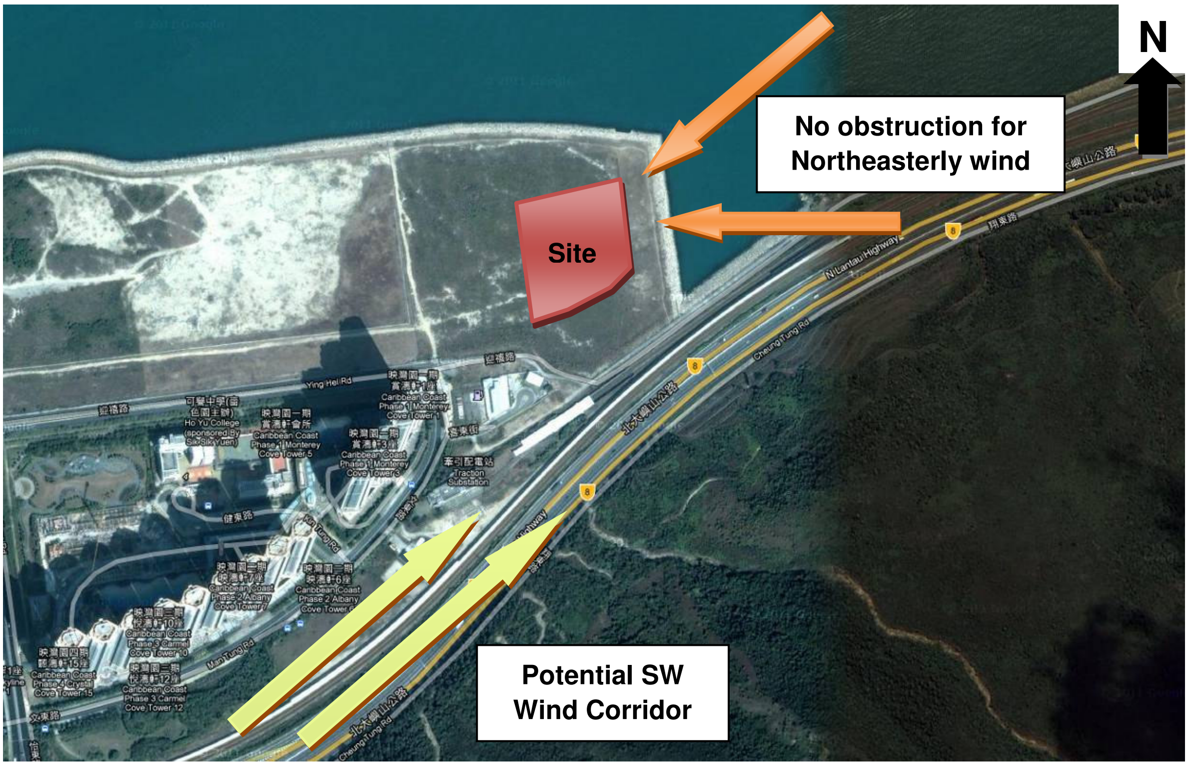

Figure 3 Wind Corridor Directing Air Circulation toward Project Site

Good Design Features and Problem Areas

The erection of the proposed TC56 public housing development on site could potentially block north-north-easterly prevailing wind directions to pedestrian areas within close vicinity. In order to reduce the air ventilation impact upon building completion, building separation was maximized with the presence of two 15 meters wide wind corridor along the four domestic blocks proposed on site.

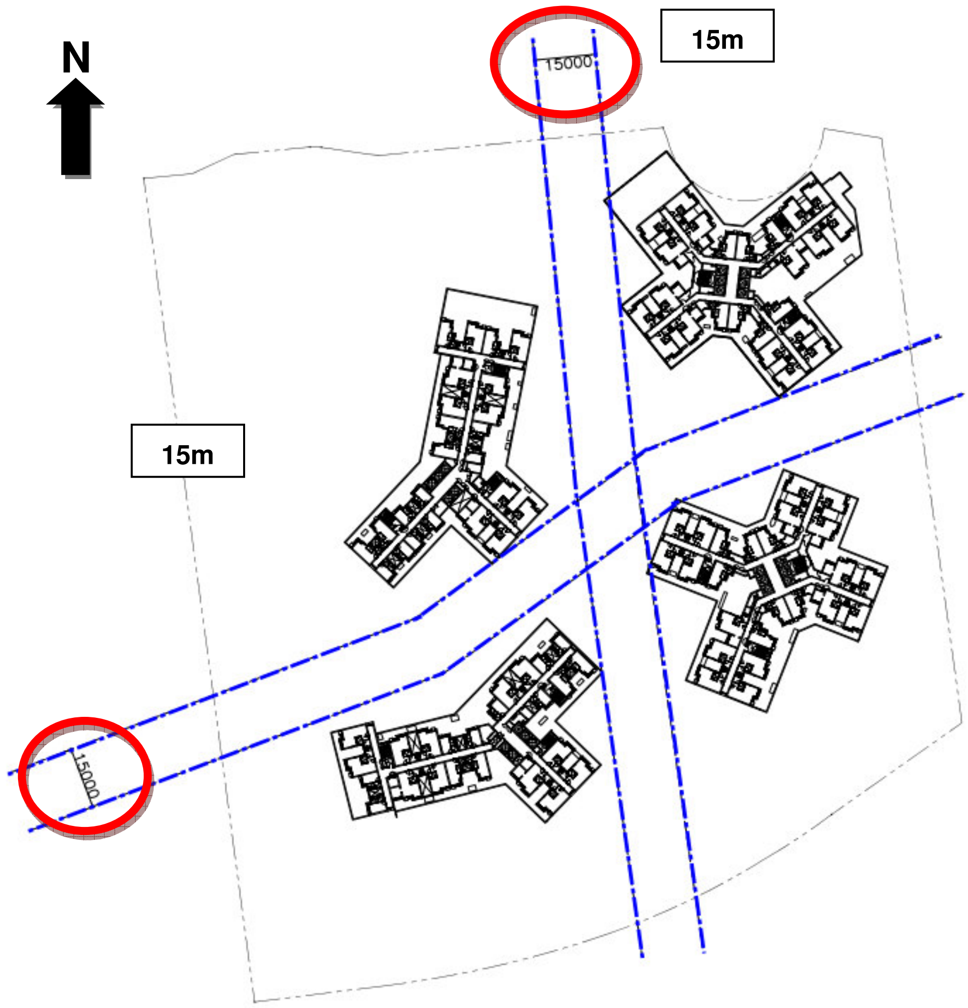

Figure 4 Two Blocks of "Y" Shape and Two Blocks of "X" Shape Domestic Blocks Situated on Top of the Common Podium Level

The presence of wind passages between domestic blocks in east-northeast to west-southwest direction (15m wide) and in north-northwest to south-southeast direction (15m wide) diverts these prevailing winds through the site onto future the P1 road[1]. These wind corridors minimize ventilation impact upon neighbourhood buildings, and potential adverse ventilation performance effects within the assessment area (at a distance of 125 m from the site boundary as per AVA standard) should be insignificant and acceptable.

[1] This future road will be connected to existing Man Tung Road and future L16 road which will be connected to Ying Hei Road

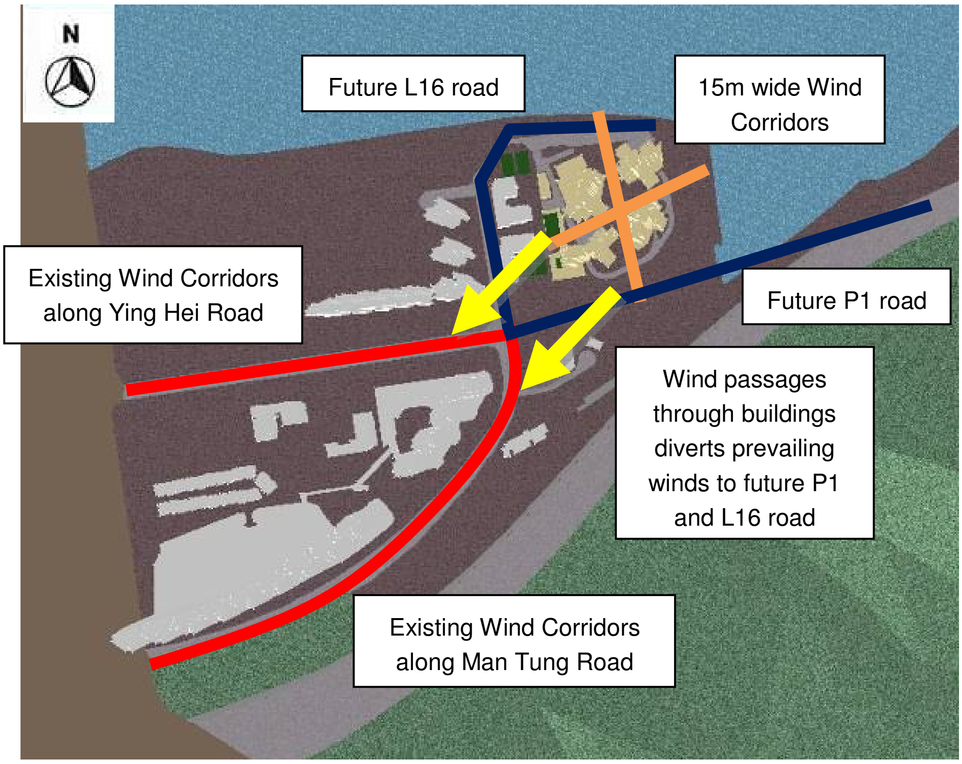

Figure 5 Wind Passages within Site Diverting Prevailing Winds onto nearby pedestrian level

As mentioned in Section 2.1, two noise barriers[2] are proposed at the southern direction of the site. Winds from the southeast quadrant are likely to be sheltered which may result in relatively low wind speed at pedestrian levels.

Using CFD simulation as the assessment tool, quantitative ventilation performance evaluation of proposed design of TC56 public housing development and its surrounding community was undertaken, with methodology adopted described in Section 4 and results explained in Section 5.

2.4 Focus

Wind availability of individual areas within the site and close proximity are verified in the study as detailed below:

- Whether the building height and disposition design of the Tung Chung Area 56 Public Housing Development has significant impact on surrounding areas; and
- Whether air ventilation performance will deteriorate after construction of the development.

Specifically, the ventilation performance of pedestrian areas within close proximity to the project is the main focus of this AVA study.

[2] In order to fulfil EPD's noise compliance of domestic units within the TC56 public housing development, a 7m high semi-enclosure noise barrier is proposed to be erected along future planned road P1 and 7m high noise barrier extension is proposed along the existing MTR Tung Chung Line railway at the southern portion of the site to further mitigate traffic noise. The virtual 3-Dimensional Model constructed for this AVA study has incorporated this proposed noise barrier to comprehensively investigate ventilation impacts resulting from the construction of the TC56 Public Housing development.

3 Site Wind Availability

3.1 Simulated Site Wind Data

Site Wind Availability Data for Hong Kong obtained from the Planning Department website was used for the AVA study in this report. The simulated wind data were made available by Planning Department (PD) using simulation model - 5th Generation NCAR /Penn State Mesoscale Model (MM5).

One set of wind data representing the immediate vicinity of the project site (Tung Chung District, labeled in red) was extracted for the study as shown below.

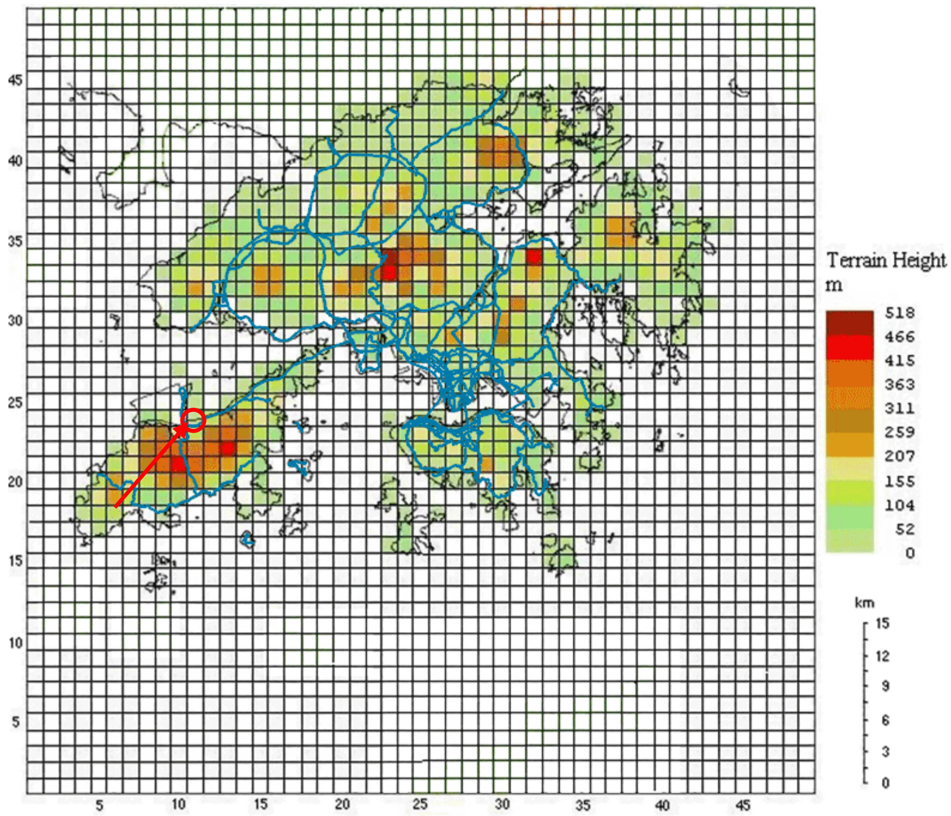

Figure 6 Site Wind Availability Data for Hong Kong and Location of Project Site

3.2 Wind Rose and Probability in 16 directions

Relevant wind rose and wind probability table were also obtained from the Planning Department (PD) website (http://www.pland.gov.hk/pland_en/misc/MM5/1124.html). The wind rose result indicates dominance of each of the 16 wind directions and distribution of wind speed. The figure below shows relevant wind rose for the assessment area. The wind probability table showing simulated wind speed of the selected region at infinity (596m above the terrain) shown in *Appendix B*. Individual wind direction occurrence is directly extracted from the wind probability table. The 16-wind direction occurrences in percentage for the project site and assessment area are also shown in the table overleaf.

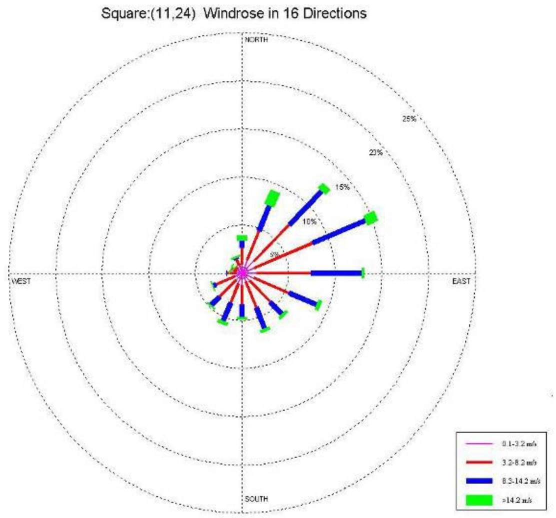

Figure 7 Relevant Wind Rose for Tung Chung District

3.3 Simplification of Wind Data for the Study

According to the Technical Circular No. 1/06 – AVA, probability of wind coming from a reduced set of directions exceeding 75% of time would normally be considered adequate. The eight most frequent wind directions with accumulative occurrence percentage of approximately 75.0% are shown overleaf. The table overleaf shows the selected wind direction with corresponding average speed at infinity height, 596m.

(Using raw data extracted from Planning Department website: http://www.pland.gov.hk/pland_en/misc/MM5/1124.html).

Table 3 Wind Data for Tung Chung District

Angle	Wind Direction	Wind Speed at infinity, 596m (m/s)	Probability	
67.50	ENE	8.34	15.4%	>75%
90.00	E	7.47	13.0%	
45.00	NE	7.52	12.7%	
22.50	NNE	8.32	9.1%	
112.50	ESE	7.27	8.9%	
157.50	SSE	6.97	6.5%	
135.00	SE	6.84	6.2%	
202.50	SSW	7.39	5.7%	
180.00	S	5.88	4.8%	
225.00	SW	6.28	4.8%	
0.00	N	6.91	3.9%	
247.50	WSW	4.82	3.4%	
337.50	NNW	3.14	1.8%	
270.00	W	3.65	1.7%	
292.50	WNW	3.65	1.3%	
315.00	NW	1.85	1.0%	

4 Assessment Methodology and Criteria

4.1 CFD Software

The numerical simulation undertaken for the study involved complex 3-dimensional turbulence flow for the assessment area. The CFD software employed for this assignment is the ANSYS Fluent 13.0.

4.1.1 Assessment Methodology and Assumption

Wind environment within the assessment area prior to and subsequent to construction of TC56 public housing development on the project site was simulated using ANSYS Fluent 13.0 under the impact of the eight selected wind directions (i.e. NNE, NE, ENE, E, ESE, SE, SSE, SSW). The methodology as stipulated in Technical Circular No.1/06 – AVA was adopted, with the assessment and surrounding areas as previously described, and there were modeled and analysed using ANSYS Fluent 13.0.

3-Dimensional Modelling

In this study, 3-Dimensional models[3] within the surrounding and assessment area were built in order to conduct CFD simulation as shown below.

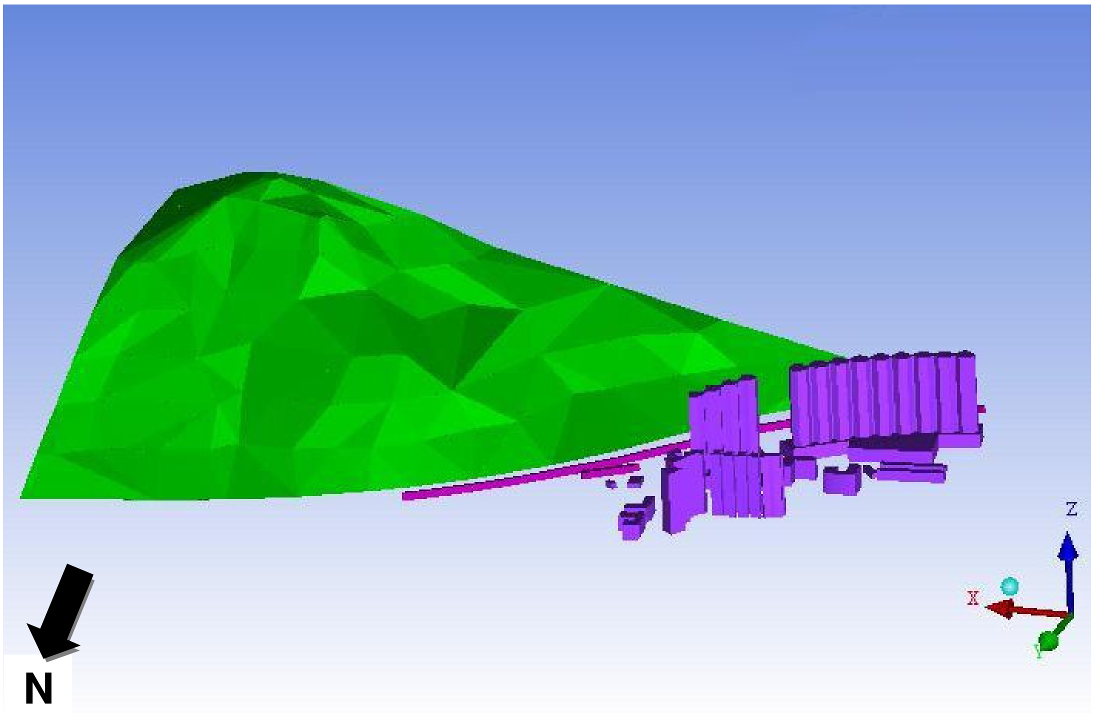

Figure 8 3-Dimensional Virtual Model Prior to Construction of the Tung Chung Area 56 Public Housing Development

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[3] Currently, some of the surrounding areas to the subject site are vacant land. However, it is envisaged that upon completion of the Tung Chung Area 56 Public Housing Development, part of these areas will be built up with buildings. Therefore, for the purpose of this study, form, massing and height designs of these future new buildings were provided by the Hong Kong Housing Authority for constructing the 3-Dimensional model of the surrounding areas. These "virtual" new buildings are encircled in the image overleaf.

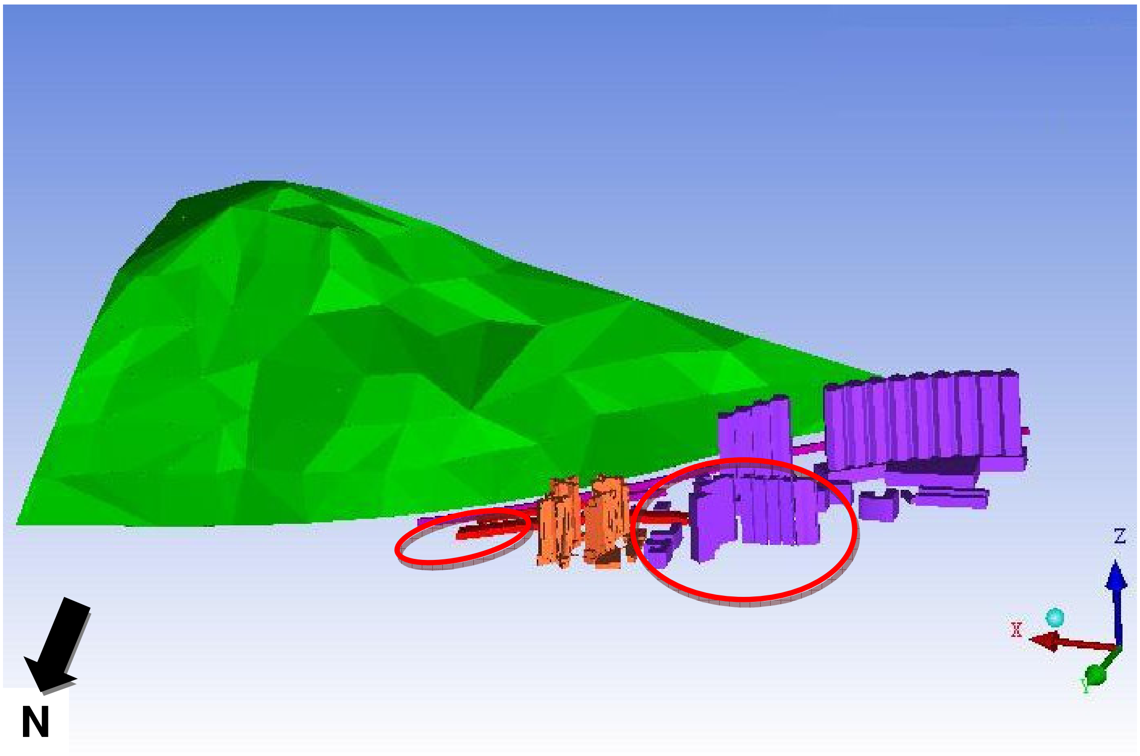


Figure 9 3-Dimensional Virtual Model Subsequent to Construction of the Tung Chung Area 56 Public Housing Development

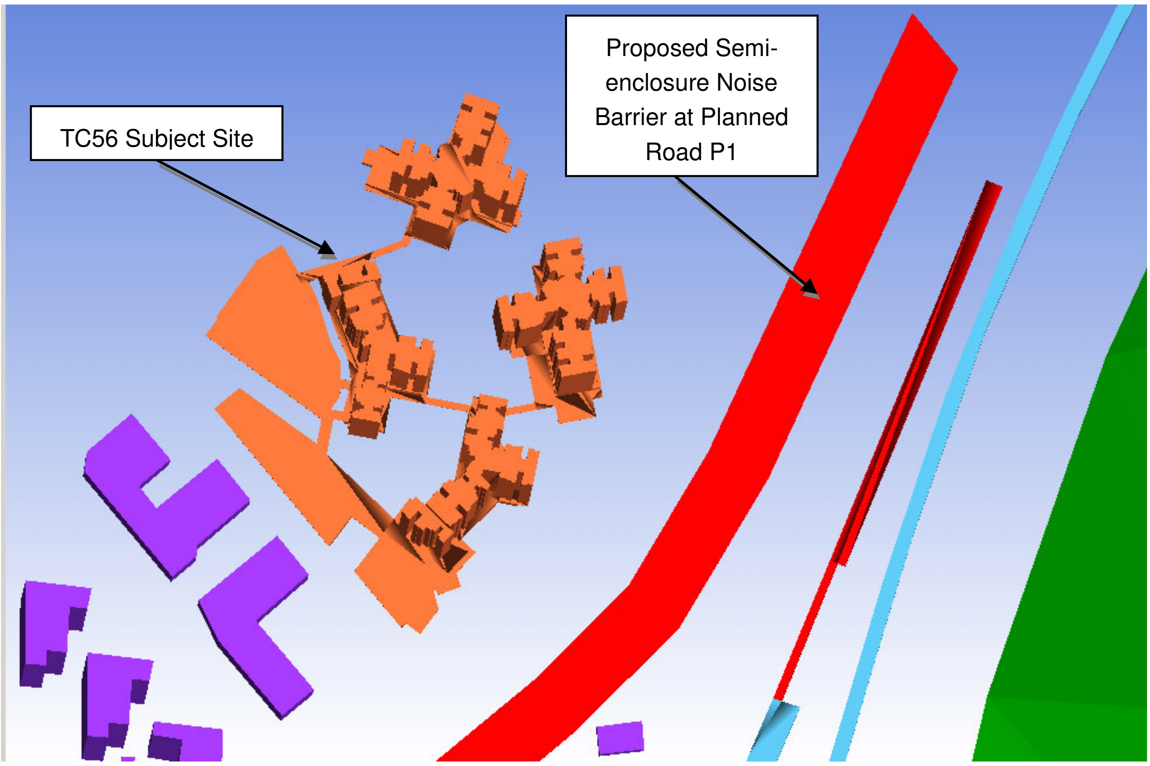


Figure 10 3-Dimensional Virtual Model of the Tung Chung Area 56 Public Housing Development

Computational Fluid Dynamics (CFD) techniques employing Reynolds Averaged Navier-Stokes (RANS) method using turbulence models to solve ensemble-averaged Navier-Stokes equations.

Wind Profile

Although the site wind speed at infinity (terrain height = 596m) were provided, appropriate wind speed were input to the program for our CFD simulation. Vertical wind profile is determined using the Power Law:

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

U_z – wind speed at height **z** from ground
U_G – wind speed at reference height (top of wind boundary layer)
Z_z – height **z** from ground
Z_G – reference height (top of the wind boundary layer)

Where different power law exponents (α) are chosen for the estimation of wind profile of different prevailing direction based on the roughness length of the surrounding area of the subject site. A high value of α implies a high surface roughness of the area that the incoming wind flows through. Base on Figure 11 below (extracted from Feasibility Study for Establishment of Air Ventilation Assessment System conducted by CUHK), Alpha Coefficient (α) in this study is set at 0.15 for NNE, NE, ENE and E prevailing wind directions as the topography in these directions around the project site are open sea area. Alpha coefficient (α) of 0.35 is set for ESE, SE, SSE and SSW prevailing wind because of the suburban terrain nature of developments in these directions.

Terrain crossed by approaching wind	α	Z_G	Z_0
Sea and open space	≈ 0.15	≈ 300	≈ 0.1
Suburban or mid-rise	≈ 0.35	≈ 400	≈ 1
City center or high-rise	≈ 0.50	≈ 500	≈ 3

Figure 11 Alpha Coefficient (α) in Different Topography

Turbulence model

The realizable K-epsilon (κ-ε) Turbulence Model is adopted in the CFD simulation of this AVA study. This is one of the modifications of the standard κ-ε model and is recommended in COST Action C14[4]. The realizable K-epsilon (κ-ε) Turbulence Model mitigates the well known problem associated with the standard κ-ε model and enhance the prediction accuracy for the pedestrian wind analysis.

Calculation Method

2nd order scheme is used for numerical approximations. The convergence criterion is set as 0.001 for the residuals of the corresponding equations.

The boundary wind condition in Table 1 is set as inflow boundary condition. Symmetry boundary condition is adopted in lateral and upper surfaces of computation domain. The downstream boundary is set to a pressure of zero.

[4] COST Action C14 "Impact of Wind and Storms on City Life and Built Environment" Working group 2 CFD techniques – Recommendations on the Use of CFD in Predicting Pedestrian Wind Environment.

Domain Size

Following is the domain dimension employed and graphically illustrated below.

- x-direction = 4,500 m;
- y-direction = 3,500 m; and
- z-direction = 1000 m,

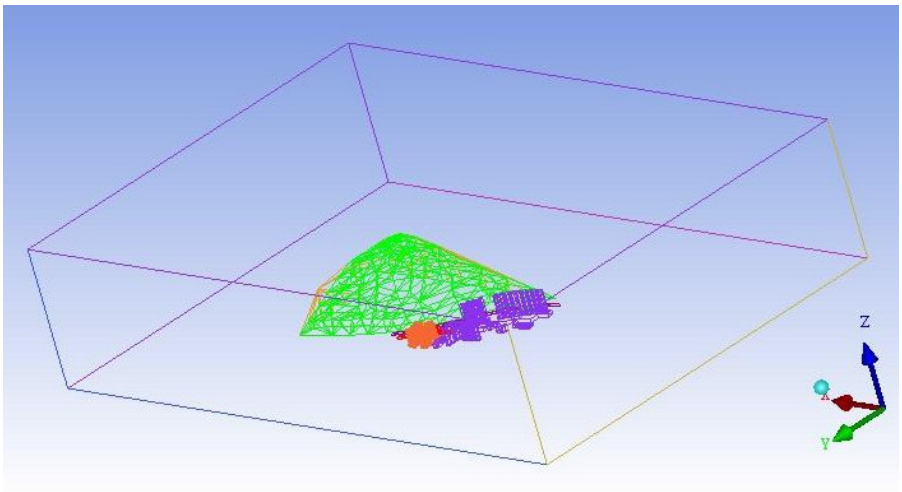


Figure 12 Domain Dimension of the Simulation Model

Simulation Meshing

Unstructured grid technique is adopted to fit and represent the complex geometry of the development and surrounding topography. Finer grid size on the concerned area is set and the grid size is expanded further away from the study area with the expansion ratio of 1.3 for optimizing computational performance and maintaining satisfactory simulation result. Besides, four prism layers with 0.5m thick in each layer are employed above the ground level to further improve the accuracy of the pedestrian wind environment around the buildings. More than 8 million cells is generated and employed in the CFD analysis.

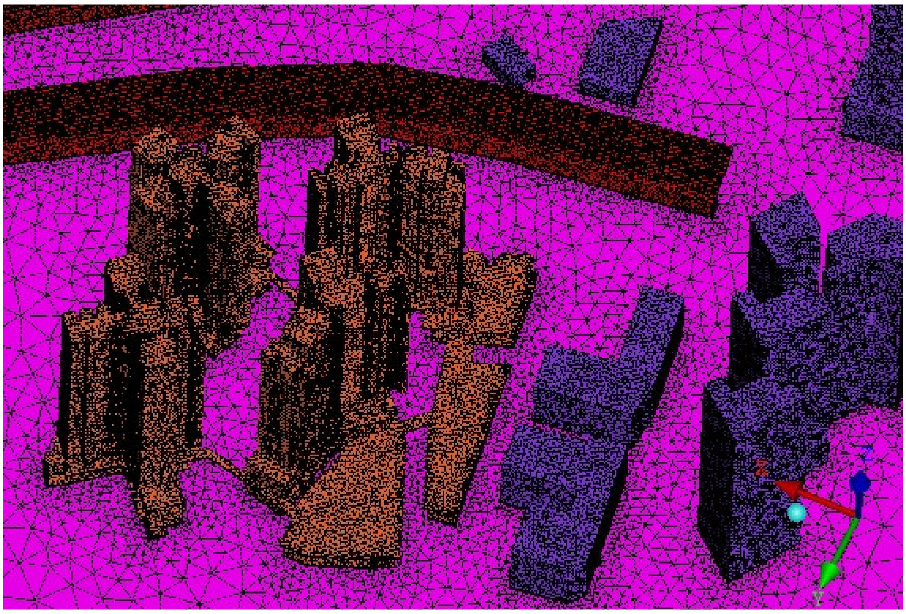


Figure 13 Mesh Arrangement

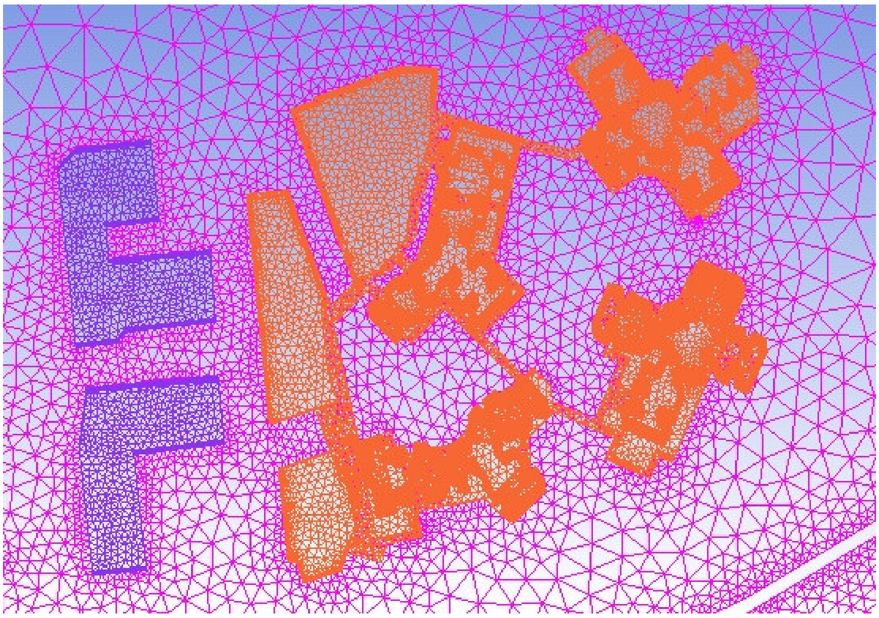


Figure 14 Bird View of Mesh Arrangement

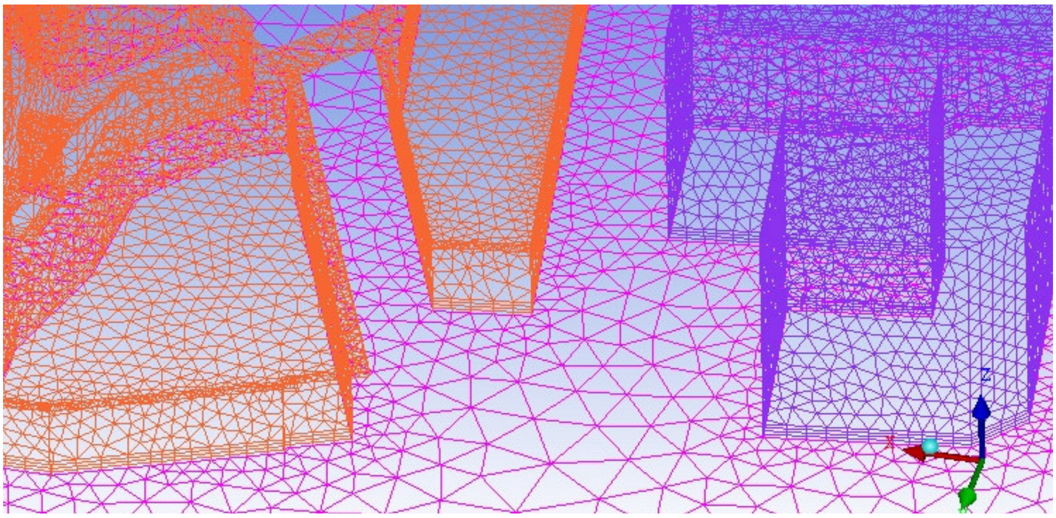


Figure 15 Prism Layer over the Ground Level

4.2 Test Points

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

4.2.1 Perimeter and Overall Test Points

Perimeter Test Points are distributed to areas around perimeters of the project site boundary including open spaces. Test Points in this group are named with prefix 'P' for labelling purposes (i.e. P1, P2...P38) as illustrated below. The distribution is shown in the followings as described in paragraph 27 of the Technical Guide for Air Ventilation Assessment for Developments in *Appendix A*.

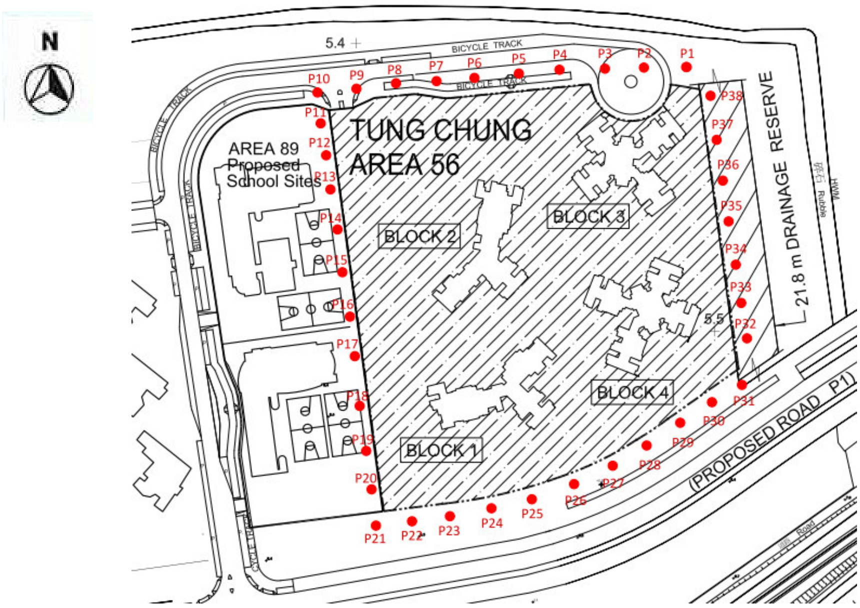


Figure 16 Perimeter Test Points

Overall Test Points are distributed on those potentially pedestrian accessible areas within the assessment area boundary and project site boundary. Overall Test Points are lying within the assessment area boundary and outside project site boundary as illustrated in the figures overleaf. Test Points in this group are named with prefix ‘O’ for labelling purposes (i.e. O1, O2…O32). The requirements of Overall Test Points are stipulated in paragraph 28 of the Technical Guide for Air Ventilation Assessment for Developments in *Appendix A*.

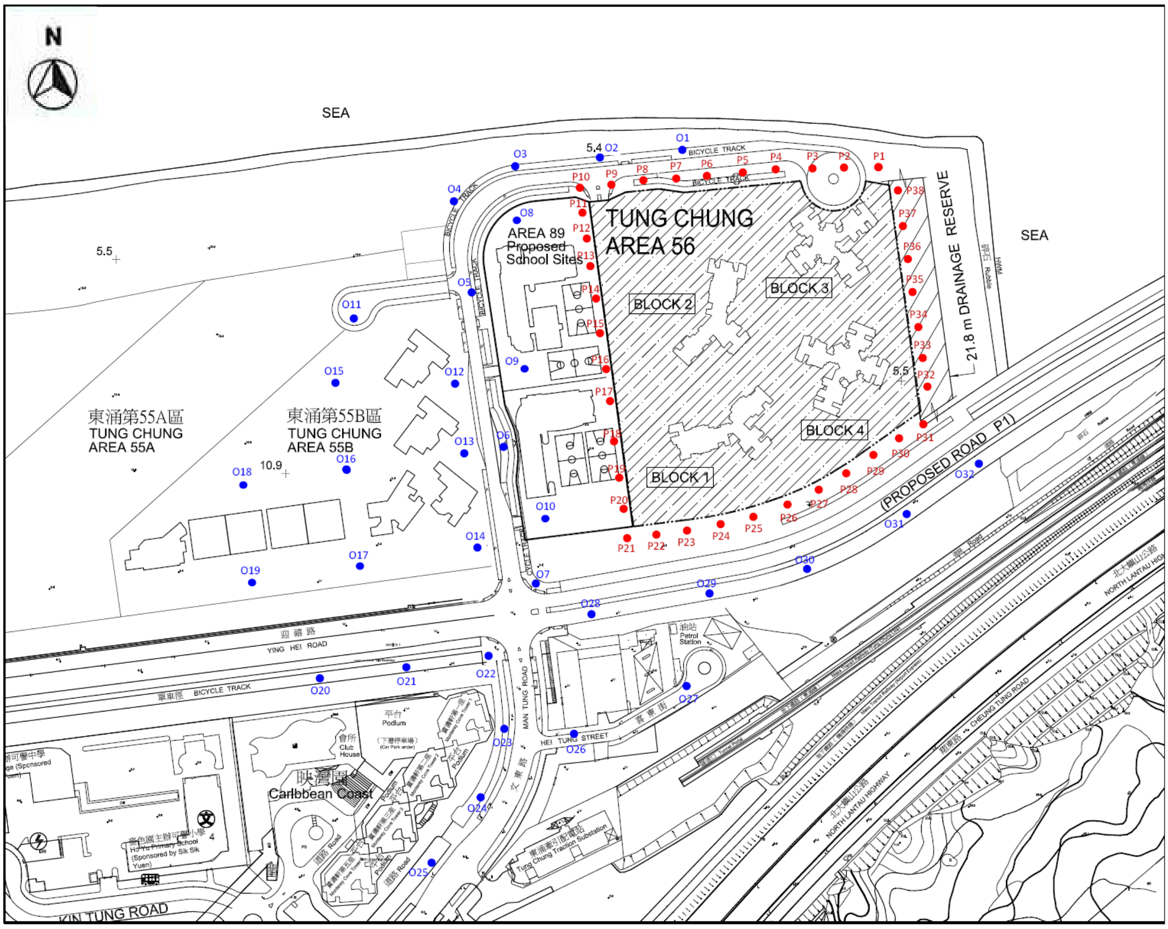


Figure 17 Overall Test Points

4.2.2 Special Test Points

Special Test Points are positioned at the pedestrian area within the site where these areas are likely to be frequently accessed by pedestrians as illustrated below. Test Points in this group are named with prefix 'S' for labelling purposes (i.e. S1, S2…S10). The distribution is shown in the followings as described in paragraph 29 of the Technical Guide for Air Ventilation Assessment for Developments in *Appendix A*.

Figure 18 Special Test Points

4.3 Wind Velocity Ratio

Wind velocity ratio (VR) is defined as V_p/V_∞ (velocity at pedestrian level/velocity at infinity) and is adopted as the indicator of wind performance enjoyed by pedestrians at particular levels, taking into account of surrounding buildings, topography and the project site. In addition, VR can also be used for the purpose of objective comparison between ventilation performances of various building-massing scenarios. VR for all test points reported in this AVA are taken at 2 meters above ground level.

V∞ captures the wind velocity at the top of the wind boundary layer and is taken as the wind availability of the site. MM5 Data from Planning Department website are used to determine velocity at infinity level for the project site. Vp captures the wind velocity at pedestrian level and is taken from CFD simulation results.

Adopting this ratio method for analysing CFD results will determine the extent to which the new proposed development impact upon the wind environment of its immediately vicinity and local areas. In general, a higher VR means the proposed building design provides a better ventilation performance to the site and its surrounding environments. The higher the value of VR is, the lesser the impact of the proposed design to the wind availability of the site and its macro wind environment. However in some instances, too high VRs and uneven VR distribution could be a cause of concern and our analysis will address these issues as necessary.

5 Results and Analysis

AVA study and CFD simulation results for the assignment are provided in *Appendix C and D*. Pedestrian level velocity ratios and plots described in Section 4.3, prior to and subsequent to construction of the Tung Chung Area 56 Public Housing Development, for each of the eight prevailing wind directions are also tabulated in the *Appendix C*. Wind probability weighted VR for each test point is provided in *Appendix D*. The following sections provide a summary and discussions upon study findings.

Local AVA simulated results (LVR) computed by analysing the group of overall test points and perimeter test points, and Site AVA simulated results (SVR) evaluated by considering perimeter test points only are summarised in the tables below:

Table 4 Summary of Local Velocity Ratios for Tung Chung Area 56 Public Housing Development under Prevailing Wind Directions

Local Air Ventilation Assessment Results (LVR)			
Prevailing Wind Direction	*Prior to Construction of TC56 Public Housing Development*	*Subsequent to Construction of TC56 Public Housing Development*	*VR Change*
NNE (22.5º)	0.414	0.408	-0.006
NE (45º)	0.426	0.376	-0.050
ENE (67.5º)	0.362	0.325	-0.038
E (90º)	0.385	0.328	-0.056
ESE (112.5º)	0.372	0.259	-0.113
SE (135º)	0.347	0.239	-0.108
SSE (157.5 º)	0.374	0.314	-0.060
SSW (202.5º)	0.316	0.255	-0.062
Overall (weighted)	**0.380**	**0.323**	**-0.057**

Table 5 Summary of Site Velocity Ratios for Tung Chung Area 56 Public Housing Development under Prevailing Wind Directions

Site Air Ventilation Assessment Results (SVR)			
Prevailing Wind Direction	*Prior to Construction of TC56 Public Housing Development*	*Subsequent to Construction of TC56 Public Housing Development*	*VR Change*
NNE (22.5º)	0.451	0.420	-0.031
NE (45º)	0.478	0.380	-0.099
ENE (67.5º)	0.360	0.329	-0.031
E (90º)	0.399	0.308	-0.091
ESE (112.5º)	0.363	0.220	-0.143
SE (135º)	0.374	0.273	-0.101
SSE (157.5 º)	0.434	0.312	-0.122
SSW (202.5º)	0.348	0.238	-0.110
Overall (weighted)	**0.403**	**0.319**	**-0.084**

5.1 Local Air Ventilation Assessment Findings

CFD simulation results of the LVR from above reveal that ventilation performance of adjacent pedestrian access areas within the vicinity of the site will be predominately unaffected by the construction of Tung Chung Area 56 Public Housing Development. The change in weighted LVR is 0.06 and this is equivalent to a speed reduction of less than 0.5 m/s at pedestrian level which is deemed to be insignificant and acceptable.

Due to the open sea topography at the northeast quadrant of the site and suburban terrain at the southeast and southwest quadrant, wind availability of the project site and its surrounding community is inherently good with a LVR of 0.32 which is equivalent to wind speeds of around 2.5 m/s at nearby pedestrian areas and thus the overall performance can be considered as satisfactory.

Under the northeast quadrant of prevailing wind directions (NNE, NE, ENE and E), the reduction of LVR is relatively low (0.006 – 0.056). As predicted from the qualitative ventilation performance evaluation in Section 2.3, the presence of two 15m wide building separation with winds prevailing from east-northeast to the west-southwest direction, strategically reduces the ventilation impact of the erection of TC56 development and diverts the upcoming wind to the vicinity of the site, as shown below.

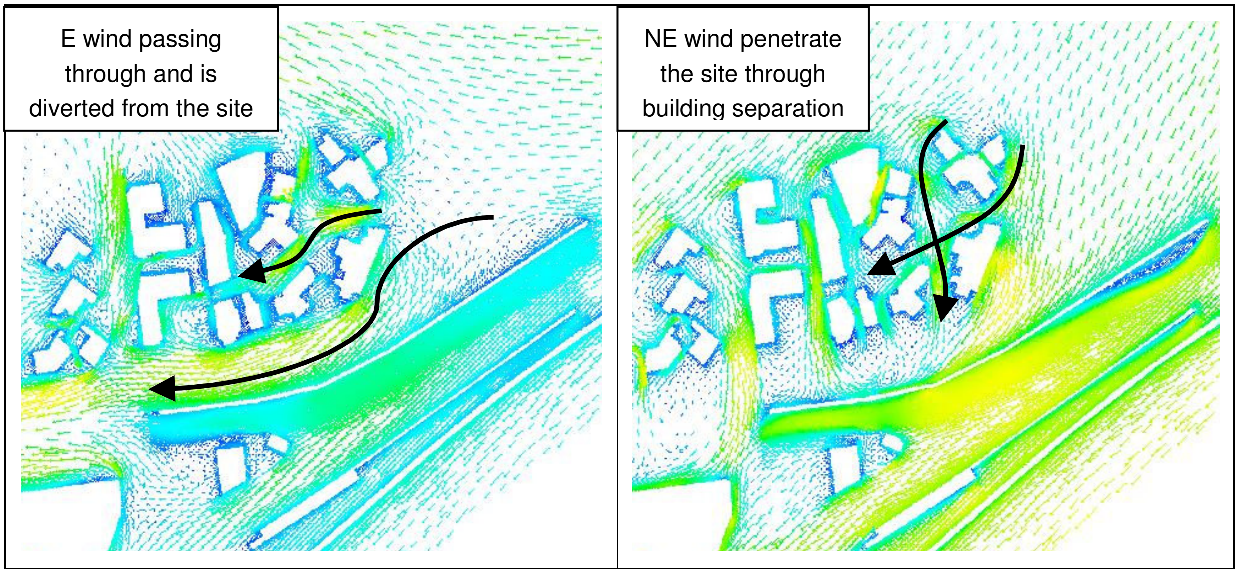


Figure 19 East (Left) and North East (Right) Prevailing Wind Path between TC56 Development and Surrounding Topography

As mentioned in Section 2.3, the reduction in VR should be predominately found in the southern quadrant of prevailing wind directions (ESE, SE, SSE) as obstructive noise barriers (describe in Section 2.3) are erected at the southern part of the site. The construction of the TC56 development and its associated noise barriers induces a barrier effect with LVR reductions ranging from 0.06 and 0.11 for ESE, SE and SSE prevailing winds, but in absolute terms, the associated velocity reduction is less than 0.7m/s.

In summary, the overall weighted VR change in the Local Air Ventilation Assessment from the construction of Tung Chung Area 56 Public Housing Development is not substantial (less than 0.06 which is equivalent to 0.5 m/s wind velocity reduction) and its impact upon ventilation performance of potential areas is deemed to be insignificant. Therefore, it can be concluded that the design and erection of Tung Chung Area 56 Public Housing Development is unlikely to have a significant adverse wind impact on pedestrian level ventilation performance of the surrounding community.

5.2 Site Air Ventilation Assessment Findings

The ventilation performance of the site perimeter as a result of Tung Chung Area 56 Public Housing Development construction is summarised in the table below (Site Perimeter Velocity Ratio for each prevailing wind direction is summarised in Session 5). Using the same CFD simulation data, local and site velocity assessments finds are also summarised below:

Table 6 Summary of Local Velocity Ratio and Site Velocity Ratio for TC56 Public Housing Development under Prevailing Wind Directions

	Before Development	After Development
LVR (Overall Test Points)	0.380	0.323
SVR (Perimeter Test Point)	0.403	0.319

The construction of the Tung Chung Area 56 Public Housing Development involves erection of vertical structures which would ultimately lead to reduced wind permeability at pedestrian levels within the project site area (originally entirely exposed). Therefore, as shown by the velocity ratios in the table above, the TC56 Public Housing Development would generally have some impact upon the wind availability of these test points, as expected.

The Site Perimeter Velocity Ratio for each prevailing wind direction is summarised in the SVR results in Table 3. With reference to these simulated results, a similar ventilation performance trend to LVR is apparent. As a result of wind corridors created from east-northeast to the west-southwest direction, the erection of the TC56 Public Housing Development will have least ventilation impacts under NNE, NE, ENE and E directions with SVR reductions of less than 0.1. Wind availability impacts under ESE, SE, SSE and SSW directions are more adverse with up to 0.14 SVR reductions. The major cause of these ventilation performance reductions is attributable to the erection of noise barrier at the southern side of the subject site as previously mentioned in LVR findings.

In essence, in terms of overall ventilation performance of site perimeter areas with respect to impact from construction of TC56 Public Housing Development, a SVR reduction of 0.087 (equivalent to 0.7m/s reduction in wind velocity) for the subject assessment can be considered as relatively insignificant and acceptable.

5.3 Air Ventilation Performance of Special Test Points

The ventilation performance of special test points within Tung Chung Area 56 Public Housing Development as extracted from CFD simulation results are tabulated below.

Table 7 Summary of Special Velocity Ratios under Prevailing Wind Directions

Special Air Ventilation Assessment Results			
Prevailing Wind Direction	*Prior to Construction of TC56 Public Housing Development*	*Subsequent to Construction of TC56 Public Housing Development*	*VR Change*
NNE (22.5º)	0.464	0.274	-0.190
NE (45º)	0.519	0.276	-0.243
ENE (67.5º)	0.356	0.266	-0.090
E (90º)	0.424	0.222	-0.202
ESE (112.5º)	0.404	0.222	-0.182
SE (135º)	0.355	0.192	-0.164
SSE (157.5 º)	0.431	0.191	-0.240
SSW (202.5º)	0.408	0.200	-0.207
Overall (weighted)	**0.422**	**0.239**	**-0.183**

The construction of Tung Chung Area 56 Public Housing Development involves erection of buildings with height of 125 meters which would ultimately lead to reduced wind permeability in these areas (originally entirely exposed). Taking into account of annual probability occurrence of prevailing winds, there is a weighted VR reduction of 0.183 but in absolute terms, the resulting velocity change subsequent to construction of Tung Chung Area 56 Public Housing Development is approaching 1.8 m/s, which is deemed as acceptable.

5.4 Overall Conclusion

The AVA study findings reveal that the construction of the Tung Chung Area 56 Public Housing Development is unlikely to have an adverse ventilation performance impact upon pedestrian areas at nearby sensitive communities and within the site. The design and erection of the public housing development leads to ventilation performance results of LVR change = 0.057 (equivalent to less than 0.5 m/s wind speed reduction) and SVR change = 0.084 (equivalent to 0.7 m/s wind speed reduction), all of which are deemed to be insignificant and acceptable.

Appendix A

Technical Guide for Air Ventilation Assessment for development in Hong Kong

1. This Technical Guide assists project proponent to undertake Air Ventilation Assessment (AVA) to assess the impacts of the proposal on the pedestrian wind environment. The assessment should follow this Technical Guide as far as possible and a report should be submitted to the proponent departments / bureau or authorities on the assessment findings.

2. Every site is different. The assessor is strongly advised to approach the assessment intellectually and discretionally taking into account different site conditions. Working with experienced practicing wind engineers throughout the assessment process is strongly recommended.

Indicator

3. Wind Velocity Ratio (VR) should be used as an indicator of wind performance for the AVA. It indicates how much of the wind availability of a location could be experienced and enjoyed by pedestrians on ground taking into account the surrounding buildings and topography and the proposed development. Given the general weak wind conditions in Hong Kong, the higher the wind velocity ratio, the less likely would be the impact of the proposed development on the wind availability.

4. Wind VR is defined as V_p/V_∞ (V pedestrian/V infinity). V_∞ captures the wind velocity at the top of the wind boundary layer (typically assumed to be around 400 m to 600 m above city centre, or at a height wind is unaffected by the urban roughness below). V_∞ is taken as the wind availability of the site. Vp captures the wind velocity at the pedestrian level (2 m above ground) after taking into account the effects of buildings and urban features.

Expert Evaluation / Initial Study / Detailed Study

5. It is always useful and cost effective for the assessor to conduct an early round of **Expert Evaluation**. This provides a qualitative assessment to the design and/or design options and facilitates the identification of problems and issues. The Expert Evaluation is particularly useful for large sites and/or sites with specific and unique wind features, issues, concerns and problems. The following tasks may be achieved with Expert Evaluation:
(a) Identifies good design features.
(b) Identifies obvious problem areas and propose some mitigation measures.
(c) Defines “focuses” and methodologies of the Initial and/or Detailed studies.
(d) Determines if further study should be staged into Initial Study and Detailed Study, or Detailed Study alone.

6. In exercising expert knowledge and experience, the assessor should refer to the “Urban Design Guidelines”, Chapter 11 of the Hong Kong Planning Standards and Guidelines downloadable from the Planning Department’s (PlanD) website at http://www.pland.gov.hk.

7. The Expert Evaluation could lead to an Initial Study or directly to a

Detailed Study depending on the nature of the development. The **Initial Study** will refine and substantiate the Expert Evaluation. The following tasks may be achieved with the Initial Study:
(a) Initially assesses the characteristics of the wind availability (V∞) of the site.
(b) Gives a general pattern and a rough quantitative estimate of wind performance at the pedestrian level reported using Wind VR.
(c) Further refines the understanding (good design features and problem areas) of the Expert Evaluation.
(d) Further defines the "focuses", methodologies and scope of work of the Detailed Study.

8. It is sometimes necessary to reiterate the Initial Study so as to refine the design and/or design options.

9. With or without the Initial Study, the **Detailed Study** concludes the AVA. With the Detailed Study, the assessor could accurately and "quantitatively" compare designs so that a better one could be selected. Detailed Study is essential for more complex sites and developments, and where key air ventilation concerns have been reviewed and identified in the Expert Evaluation / Initial Study. The following tasks may be achieved with the Detailed Study:

(a) To assess the characteristics of the wind availability (V∞) of the site in detail.
(b) To report all VR of test points. To report Site VR (SVR) and Local VR (LVR) when appropriate (as outlined in paras 27 to 30). To report, if any, wind gust problems.
(c) To provide a summary of how the identified problems, if any, have been resolved.

Site Wind Availability Data

10. It is necessary to account for the characteristics of the natural wind availability of the site. As far as possible, the design should utilize and optimize the natural wind.

11. For the Expert Evaluation, it is advisable to make reference to the Hong Kong Observatory Waglan Island wind data, as well as reasonable wind data of nearby weather stations. Expertly interpreted, it is possible to qualitatively estimate the prevailing wind directions and magnitudes of the site necessary for the evaluation.

12. For the Initial Study, it is necessary to be more precise. Either "simulated" site wind data, or "experimental" site wind data, as described in paras. 13 and 15 below, respectively, could be used.

13. Using appropriate mathematical models (e.g. MM5 and CALMET), it is possible to simulate and estimate the site wind availability data (V∞). Typically the site wind rose of V∞ could be obtained[1].

14. For the Detailed Study, it is necessary to be even more precise. “Experimental” site wind data, as described in para 15 below, should be used.

15. Using large scale topographical model (typically 1:2000 to 1:4000) tested in a boundary layer wind tunnel, more precise wind availability and characteristics information in terms of wind rose, wind profile(s) and wind turbulence intensity profile(s) of the site could be obtained. Hong Kong Observatory Waglan Island wind data should be referenced to for the experimental study.

Tools

16. Wind tunnel is recommended for both the Initial and the Detailed Studies, and most particularly for the Detailed Study. The conduct of the wind tunnel test should comply, as far as practicable, with established international best practices, such as, but not be limited to:

(a) Manuals and Reports on Engineering Practice No. 67 : Wind Tunnel Studies of Buildings and Structures, Virginia 1999 issued by American Society of Civil Engineers.

(b) Wind Engineering Studies of Buildings, Quality Assurance Manual on Environment Wind Studies AWES-QAM-1-2001 issued by Australasian Wind Engineering Society.

17. Computational Fluid Dynamics (CFD) may be used with caution, it is more likely admissible for the Initial Studies. There is no internationally recognized guideline or standard for using CFD in outdoor urban scale studies. The onus is on the assessor to demonstrate that the tool used is “fit for the purpose”.

[1] Project proponents may write to PlanD to obtain the MM5 data translated into site wind availability data (V_∞) of the Territory for Expert Evaluation and Initial Study.

18. Should the assessor wish to use other forms of tool for the assessment not described above, the onus is on the proponent to demonstrate that the tool to be employed is “fit for the purpose”. The scientific suitability, as well as the practical merits of the tool to be used must be demonstrated.

Simplification of Wind Data for the Initial Study

19. In general, the characteristics of the site wind availability data should be reported in 16 directions. This is necessary to work out the Wind Velocity Ratio.

20. For the Initial Study, if using CFD, it may be appropriate and cost effective, to reduce the number of directions in the study. This is reasonable especially for sites with only a few incoming prevailing wind directions. The assessor must demonstrate that the probability of wind coming from the reduced set of directions should exceed 75% of the time in a typical reference year. Wind profile(s) for the site could also be appropriated from the V_∞ data developed from simulation models (e.g. MM5 and CALMET) and with reference to the Power Law or Log Law using coefficients appropriate to the site conditions.

21. For the Detailed Study, no simplification is allowed. Wind from all 16 directions and their probability of occurrences must be accounted for, and wind profiles(s) obtained from wind tunnel experiments should be used to conduct the study, and when calculating the Wind Velocity Ratio.

Project, Assessment and Surrounding Areas

22. The testing model for the Initial and the Detailed Studies should cover the Project, the Assessment and the Surrounding Areas.

23. The Project Area is defined by the project site boundaries and includes all open areas within the project that pedestrians are likely to access.

24. A key aim of AVA is to assess a design's impact and effects on its surroundings. The Assessment Area of the project should include the project's surrounding up to a perpendicular distance H from the project boundary, H being the height of the tallest building on site. Occasionally, it may be necessary to include an assessment area larger than that defined above so that special surrounding features and open spaces are not omitted.

25. For the model, it is necessary to include areas surrounding the site. The Surrounding Area is important as it gives a reasonable and representative context to the Assessment Area. It "conditions" the approaching wind profiles appropriately. If the Surrounding Area is not correctly included and modeled, the wind performance of the Assessment Area will likely to be wrongly estimated. The Surrounding Area of up to a perpendicular distance of 2H from the project boundary must be included. Sometimes it may be necessary to enlarge the Surrounding Area if there are prominent features (e.g. tall buildings or large and bulky obstructions) immediately outside the 2H zone. Other than the method recommended, wind engineers can advise alternative extent of the surroundings to be included on a case-by-case basis, especially when there are nearby prominent topographical features.

Test Points

26. Test points are the locations where Wind VRs are reported. Based on the VR of the test points, the resultant wind environment of the project can be assessed. As each site is unique, it is impossible to be specific about the number and distribution of the required test points; but they must be carefully and strategically located. Three types of test points may be specified for assessment: Perimeter, Overall and Special.

27. Perimeter test points are positioned on the project site boundary. They are useful to assess the "immediate" effect of the project to the Assessment Area. Test points at around 10 m to 50 m center to center (or more if larger test site is evaluated) may be located around the perimeters of the project site boundary.

Test points are normally not necessary at perimeter(s) where there is no major air ventilation issues e.g. waterfront area with ample sea breeze, inaccessible land such as green belt. Tests points must be located at the junctions of all roads leading to the project site, at main entrances to the project, and at corners of the project site. This group of perimeter test points will provide data for the **Site Air Ventilation Assessment**. Typically about 30 to 50 perimeter test points well spaced out and located will suffice.

28. Overall test points are evenly distributed and positioned in the open spaces, on the streets and places of the project and Assessment Areas where pedestrians frequently access. This group of overall test points, together with the perimeter test points, will provide data for the **Local Air Ventilation Assessment**. For practical reasons, around 50 to 80 test points may be adequate for typical development sites.

29. Special test points may be positioned in areas that special localized problems are likely to appear (e.g. wind gust problem for exposed sites). These special test points should not be included in the Site and Local Air Ventilation Assessments, as they may distort the average VRs. They independently may provide additional information to assessors.

Reporting

30. For the purpose of the AVA, Wind Velocity Ratios of all test points should be individually reported. They help to identify problem areas. Two ratios may also be reported, they give a simple quantity to summaries the overall impact on the wind environment for easy comparison:

(a) For the **Site Air Ventilation Assessment**, the Site spatial average Velocity Ratio (SVR) of all perimeter test points (para 27 refers) may be reported. This gives a hint of how the development proposal impacts the wind environment of its immediate vicinity.

(b) For the **Local Air Ventilation Assessment**, the Local spatial average velocity ratio (LVR) of all perimeter and overall test points (paras 27 and 28, respectively refer) may be reported. This gives a hint of how the development proposal impacts the wind environment of the local area.

The local air ventilation considerations should always take precedence over the site specific air ventilation considerations. For exposed sites, concerns of wind gust should be reported.

31. The AVA report should contain the following key sections. The technical merit, as well as the results of the AVA of the project must be demonstrated:

(a) An introductory section of the details of the project.

(b) A section on results of the **Expert Evaluation**. Concerns and potential problems should be identified. Focuses and methodologies of further studies should be defined.

(c) A section on the characteristics of the **Site Wind Availability** to be used for Initial Studies and Detail Studies. Methodologies used to obtain the information must be explained in detail.

(d) A section on the **Methodology of the Initial Study**. The tool used for the studies must be explained in detail. It is important for the assessor to demonstrate and to justify that the tool and work process used is technically “fit for the purpose”.

(e) A section on results and **key findings of the Initial Study**.

(f) A section on **Methodology of the Detailed Study**. The tool used for the studies must be explained in detail. It is important for the assessor to demonstrate and to justify that the tool and work process used is technically "fit for the purpose".

(g) A section on results and **key findings of the Detailed Study**.

(h) A section on Evaluation and **Assessment**. Summarize findings, highlight problems and outline mitigation measures, if any.

32. Based on the reported VR, the assessor would compare the merits and demerits of different design options. The following considerations on the reporting of SVR and LVR may be useful to note:

(a) In the general weak wind conditions in Hong Kong, for the AVA, the higher the values of the spatial average VR, the better the design. Comparing performances of design options using the spatial average VR (both SVR and LVR) is recommended (para 30 refers).

(b) The **Site Air Ventilation Assessment** (SVR) gives an idea of how the lower portion of the buildings on the project site may affect the immediate surroundings. When problems are detected, it is likely that design changes may be needed for the lower portion of the development (e.g. the coverage of the podium) (para 30(a) refers).

(c) The **Local Air Ventilation Assessment** (LVR) gives an idea of how the upper portion of the buildings on the project site may affect the surroundings. When problems are detected, it is likely that design changes may be needed for the upper portion of the development (e.g. re-orientation of blocks and adjustment to the extent of the towers) (para 30(b) refers).

(d) For very large sites, or for sites with elongated or odd geometry, it may be necessary to work out the SVR and LVR to suit the size or geometry. For example, say for an elongated site, it might be useful to sub-divide the site into smaller sub-sections to work out the spatial averages. It is possible that the development may have a high VR at one end and a low VR at the other end.

(e) It is necessary to examine VR of the individual test points of SVR and/or LVR to ensure that none is way below the spatial average. When this happens, it indicates possible stagnant zones to be avoided.

(f) On the other hand, no individual VR should be obviously above the spatial average SVR and/or LVR. When this happens, it indicates wind amplification, and the possibility of wind gust and pedestrian safety concerns. Further assessments and mitigation measures may be required.

(g) Where large differentials in individual VRs are reported, the spatial average SVR and/or LVR should be interpreted more carefully to avoid overlooking problem areas due to averaging of the individual VRs.

(h) In addition to SVR and LVR, and beyond the key focus of AVA in this Technical Guide, VR of special test points, if positioned, may be analyzed. The results from these additional test points will identify potential wind problems in areas of special concerns.

Appendix B

MM5 Wind Speed/Probability Data

Square (11,24)	Wind direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
V infinity (m/s)	Sum	0.039	0.091	0.127	0.154	0.13	0.089	0.062	0.065	0.048	0.057	0.048	0.034	0.017	0.013	0.01	0.018
0_to_1	0.03	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.003	0.002	0.002	0.001	0.001	0.002	0.002
1_to_2	0.064	0.004	0.005	0.006	0.004	0.005	0.005	0.004	0.004	0.005	0.004	0.003	0.002	0.003	0.003	0.002	0.004
2_to_3	0.063	0.003	0.005	0.007	0.006	0.007	0.004	0.004	0.003	0.005	0.004	0.004	0.003	0.002	0.002	0.003	0.003
3_to_4	0.086	0.005	0.008	0.011	0.01	0.007	0.007	0.004	0.005	0.003	0.004	0.005	0.007	0.003	0.002	0.002	0.003
4_to_5	0.094	0.003	0.007	0.012	0.013	0.013	0.007	0.006	0.008	0.003	0.003	0.006	0.006	0.002	0.001	0	0.002
5_to_6	0.087	0.004	0.007	0.01	0.014	0.01	0.008	0.004	0.005	0.004	0.005	0.005	0.004	0.002	0.001	0	0.002
6_to_7	0.085	0.003	0.005	0.009	0.014	0.012	0.008	0.008	0.005	0.004	0.005	0.005	0.003	0.001	0.002	0	0
7_to_8	0.088	0.001	0.004	0.01	0.014	0.013	0.009	0.01	0.006	0.005	0.005	0.005	0.003	0.002	0.001	0	0
8_to_9	0.085	0.002	0.007	0.012	0.012	0.015	0.009	0.005	0.008	0.005	0.005	0.005	0.002	0	0	0	0
9_to_10	0.078	0.002	0.007	0.013	0.013	0.009	0.009	0.004	0.006	0.005	0.005	0.003	0.001	0	0	0	0
10_to_11	0.061	0.002	0.007	0.009	0.011	0.01	0.006	0.003	0.004	0.002	0.005	0.002	0.001	0	0	0	0
11_to_12	0.052	0.001	0.005	0.007	0.012	0.009	0.006	0.002	0.003	0.001	0.002	0.001	0	0	0	0	0.001
12_to_13	0.038	0.001	0.002	0.005	0.011	0.008	0.004	0.002	0.003	0.001	0.002	0.001	0	0	0	0	0
13_to_14	0.026	0.001	0.003	0.004	0.005	0.006	0.001	0.002	0.002	0	0.002	0.001	0	0	0	0	0
14_to_15	0.021	0.001	0.005	0.003	0.004	0.002	0.001	0.001	0.001	0	0.002	0.001	0	0	0	0	0
15_to_16	0.012	0.001	0.004	0.001	0.003	0	0	0.001	0	0	0.001	0	0	0	0	0	0
16_to_17	0.01	0.002	0.004	0.001	0.001	0	0.001	0	0	0.001	0.001	0	0	0	0	0	0
17_to_18	0.009	0.001	0.003	0.002	0.002	0	0	0	0	0	0	0	0	0	0	0	0
18_to_19	0.004	0	0	0.001	0.002	0	0	0	0	0	0	0	0	0	0	0	0
19_to_20	0.002	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0
20_to_21	0.002	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0
21_to_22	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22_to_23	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23_to_24	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24_to_25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25_to_26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26_to_27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Probability and Wind Profiles

Using Tung Chung region raw MM5 data for the subject site, wind speed and probability under prevailing direction are computed as follows:

Angle (°)	Wind Direction	Wind speed at infinity(m/s)	Probability	
67.50	ENE	8.34	15.4%	>75.0%
90.00	E	7.47	13.0%	
45.00	NE	7.52	12.7%	
22.50	NNE	8.32	9.1%	
112.50	ESE	7.27	8.9%	
157.50	SSE	6.97	6.5%	
135.00	SE	6.84	6.2%	
202.50	SSW	7.39	5.7%	
180.00	S	5.88	4.8%	
225.00	SW	6.28	4.8%	
0.00	N	6.91	3.9%	
247.50	WSW	4.82	3.4%	
337.50	NNW	3.14	1.8%	
270.00	W	3.65	1.7%	
292.50	WNW	3.65	1.3%	
315.00	NW	1.85	1.0%	

Using infinity wind speed (terrain height = 596m) from above, vertical wind profiles were evaluated at each prevailing direction through adoption of the Power Law:

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

U_z – wind speed at height **z** from ground
U_G – wind speed at reference height (top of wind boundary layer)
Z_z – height **z** from ground
Z_G – reference height (top of the wind boundary layer)

Terrain crossed by approaching wind	α	Z_G	Z_0
Sea and open space	≈ 0.15	≈ 300	≈ 0.1
Suburban or mid-rise	≈ 0.35	≈ 400	≈ 1
City center or high-rise	≈ 0.50	≈ 500	≈ 3

Where different power law exponents (α) are chosen for the estimation of wind profile of different prevailing direction based on the roughness length of the surrounding area of the subject site. A high value of α implies a high surface roughness of the area that the incoming wind flows through. Alpha Coefficient (α) in this study is set at 0.15 for NNE, NE, ENE and E prevailing wind directions as the topography in these directions around the project site are open sea area. Alpha coefficient (α) of 0.35 is set for ESE, SE, SSE and SSW prevailing wind because of suburban terrain in these directions.

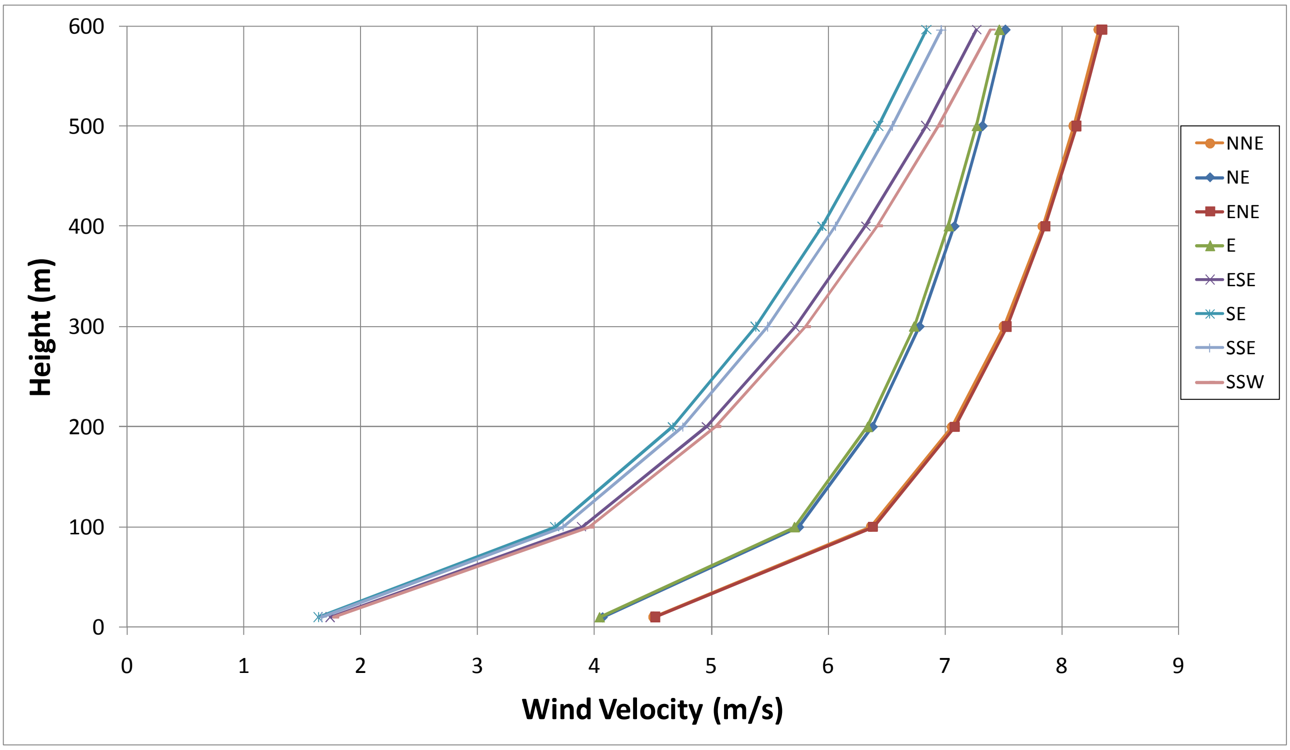
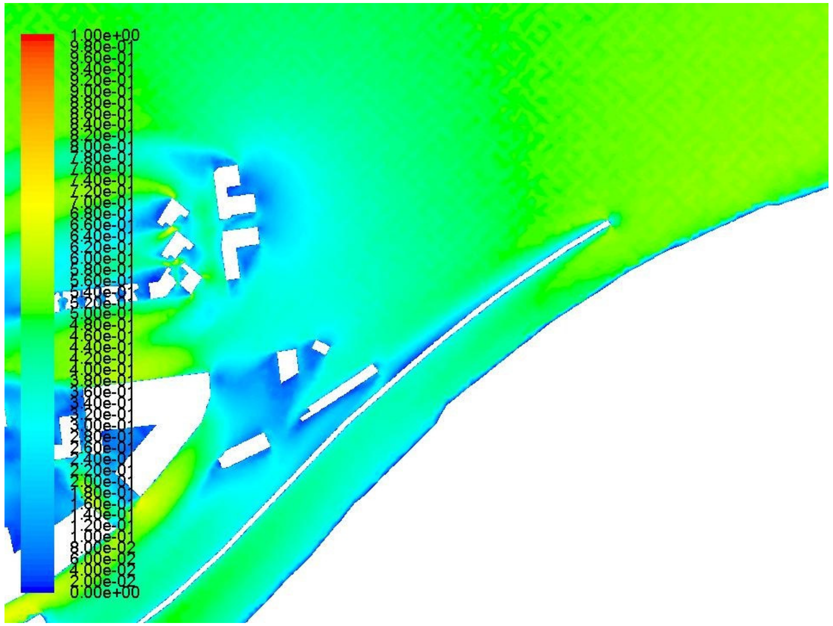
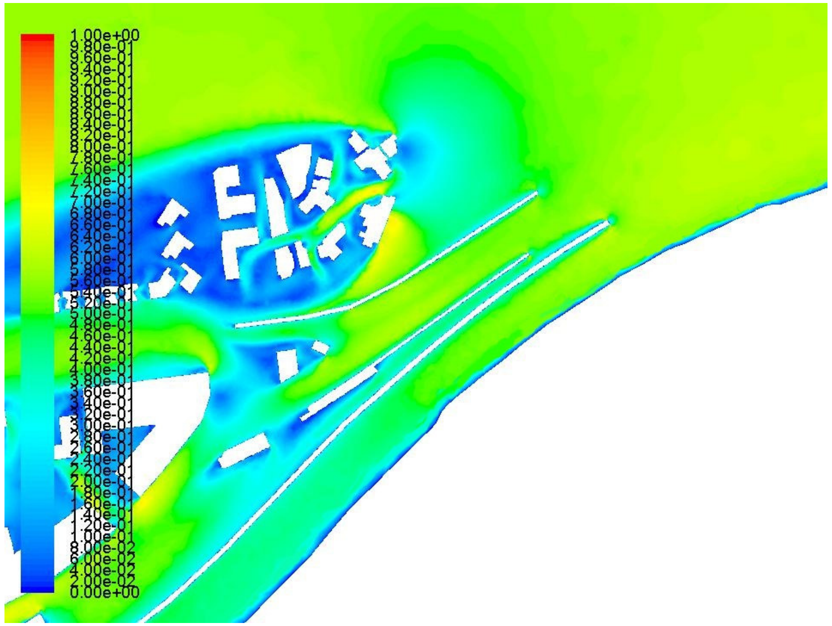
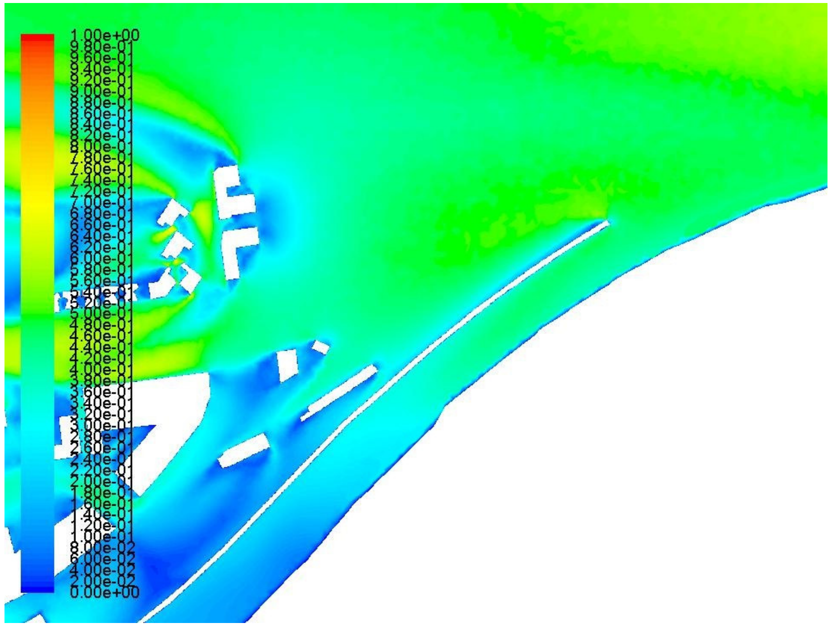
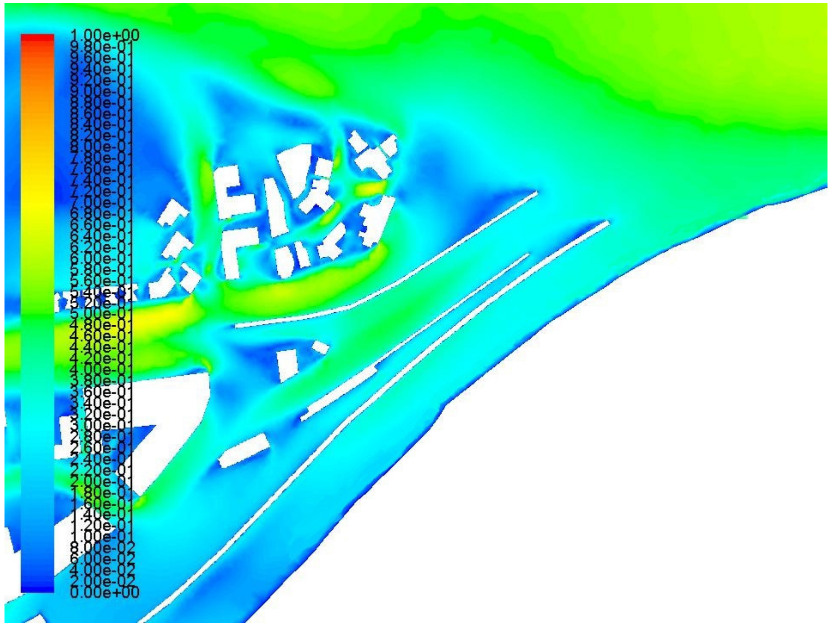
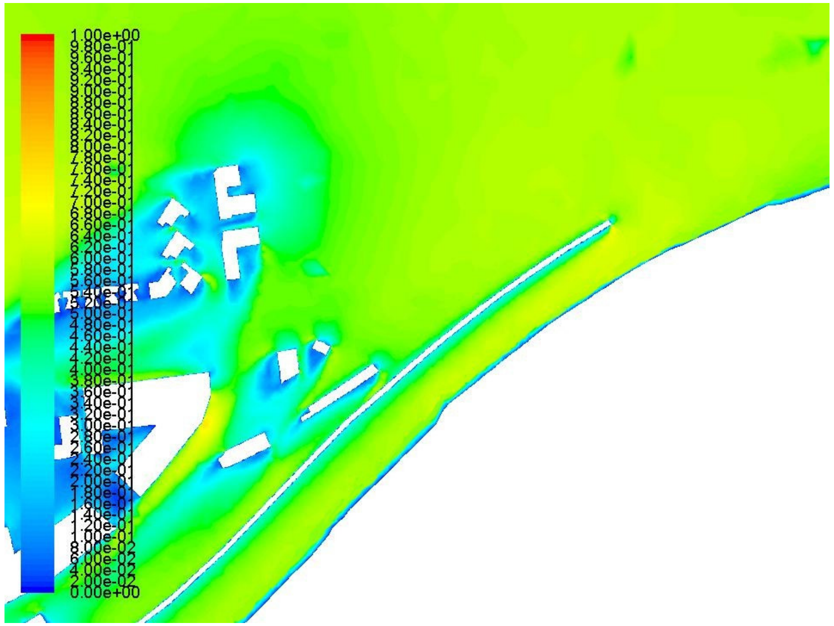
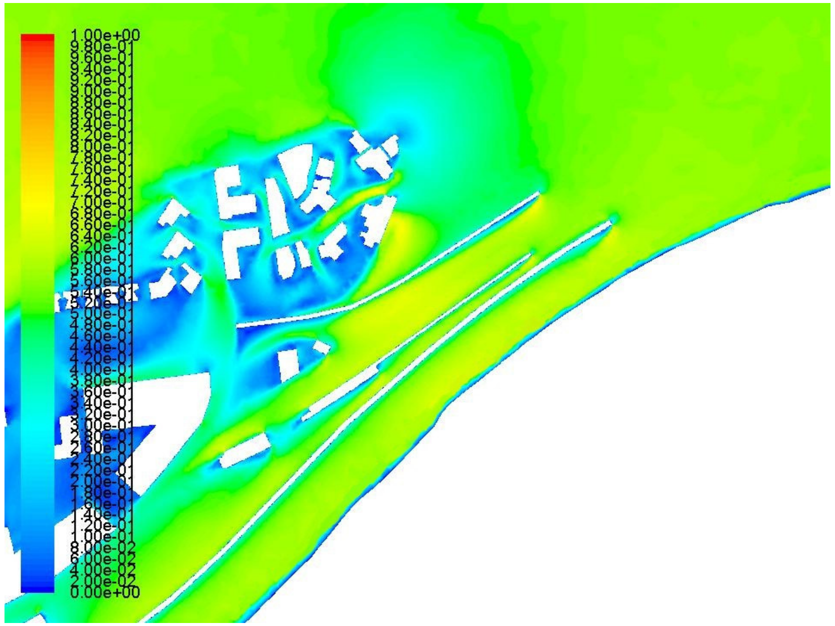
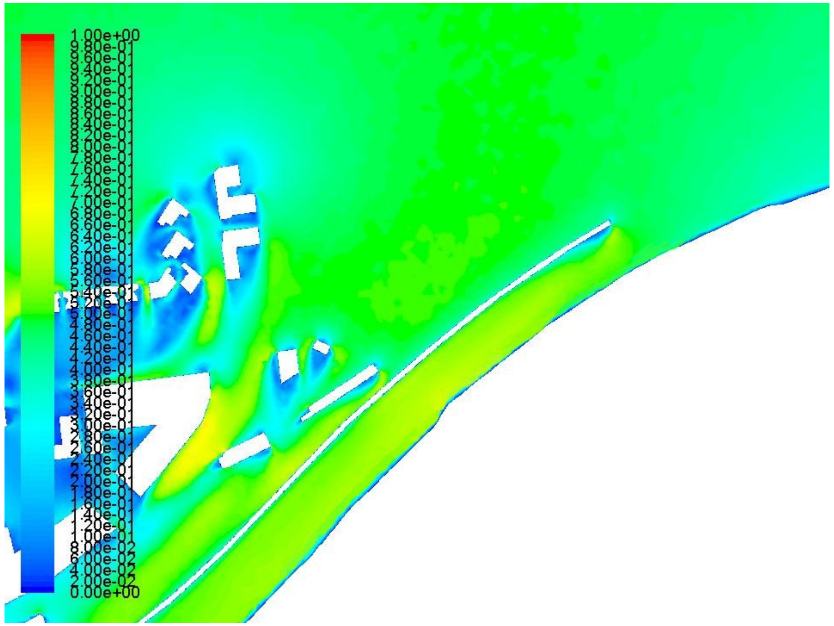
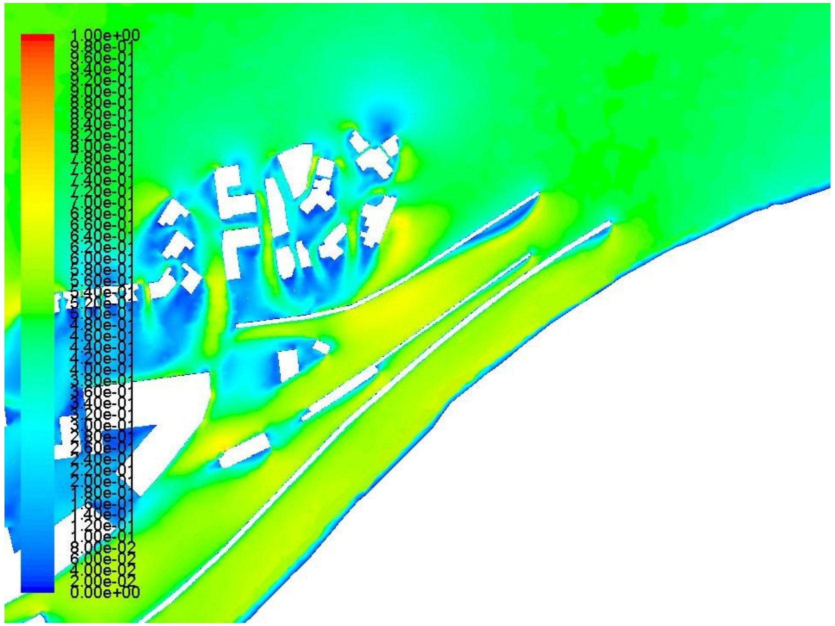


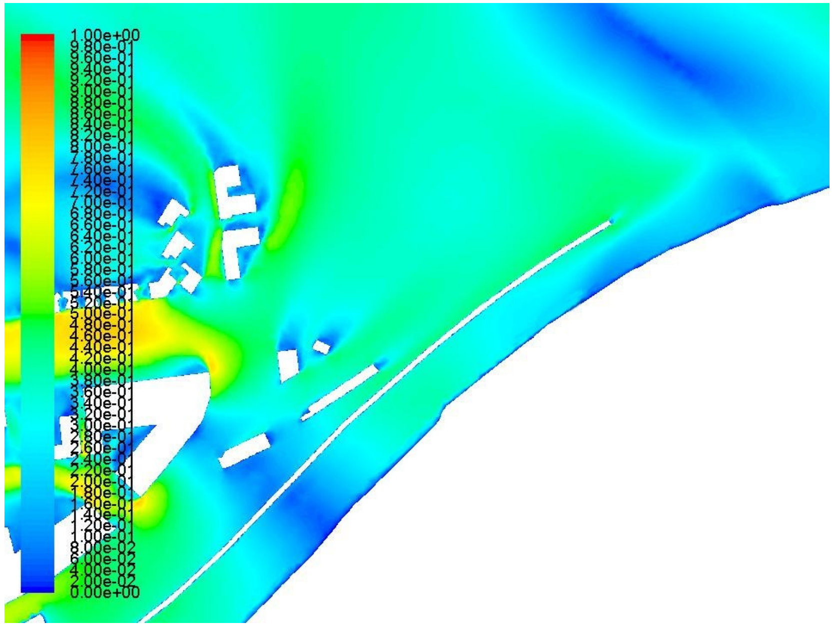
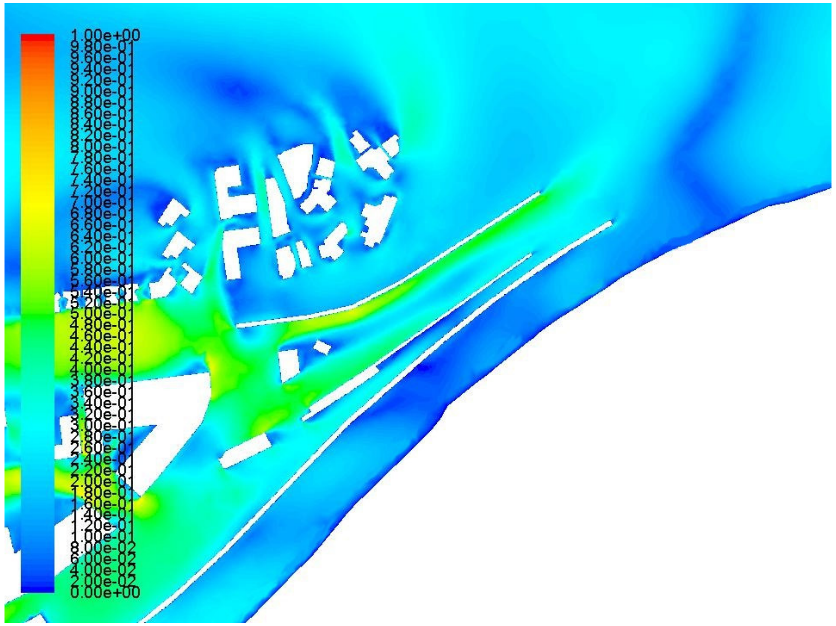
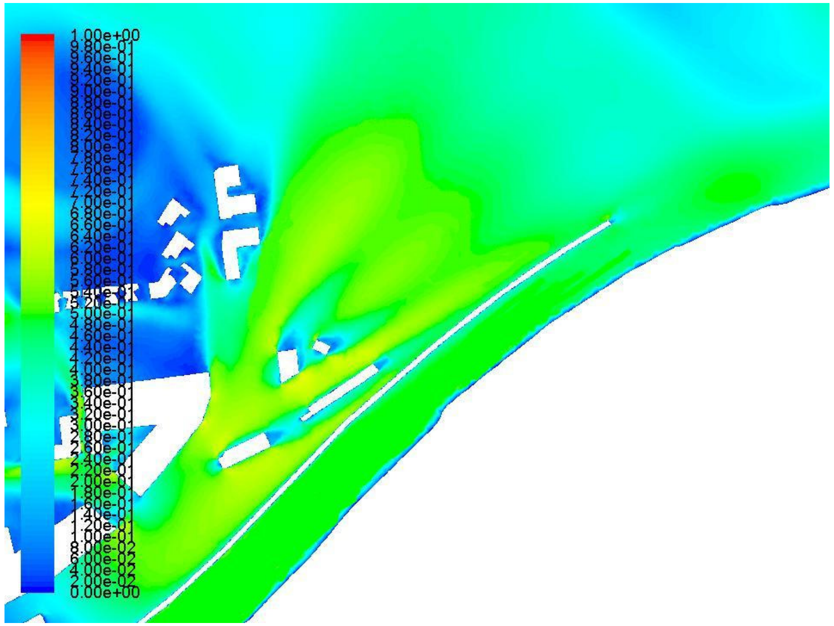
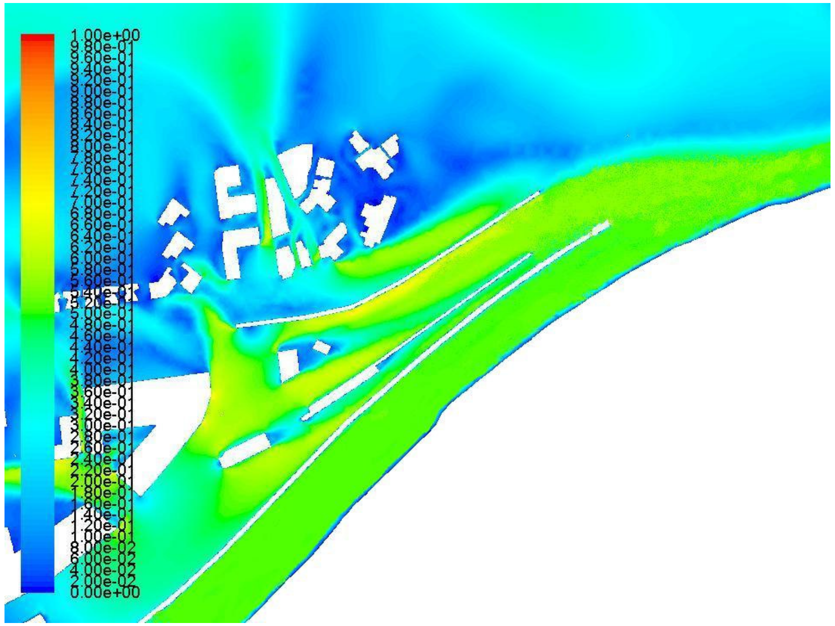
Fig. 1 Wind Profiles of Prevailing Winds

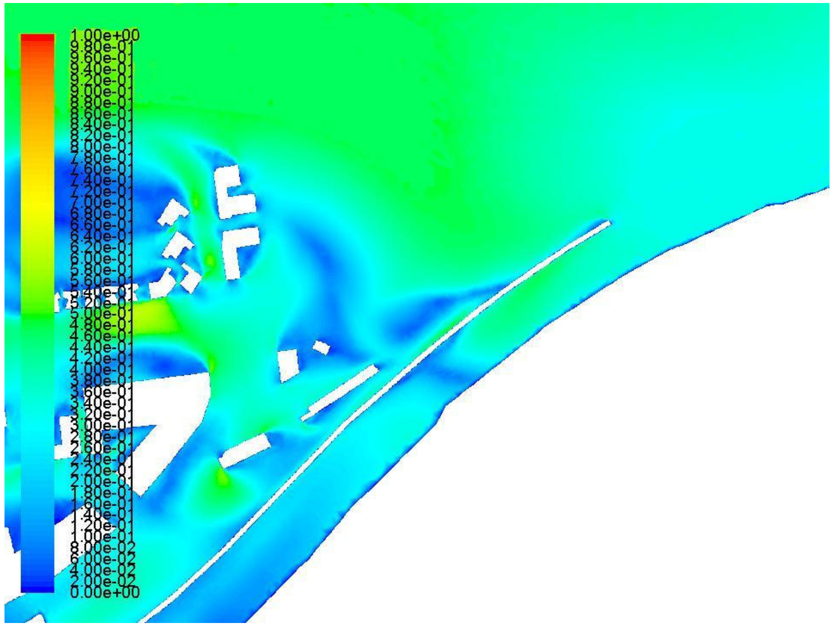
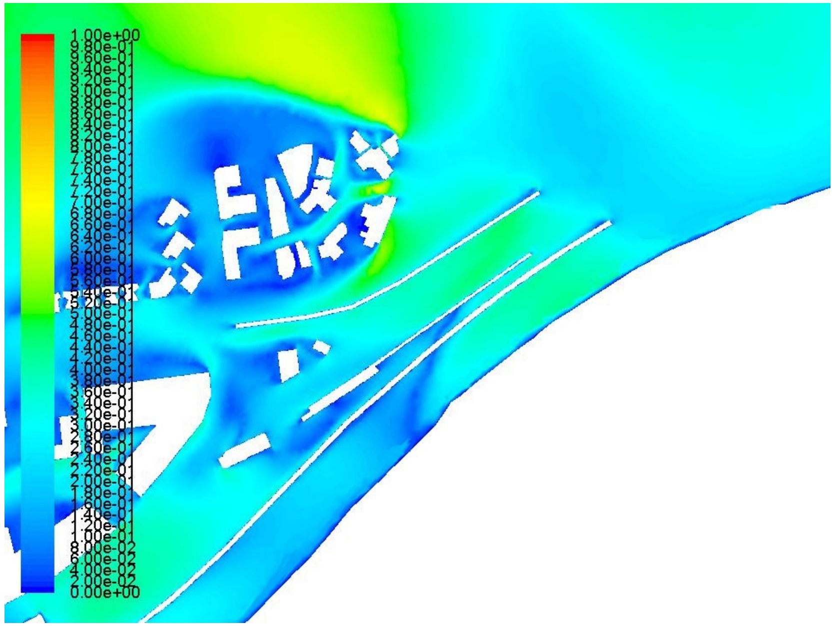
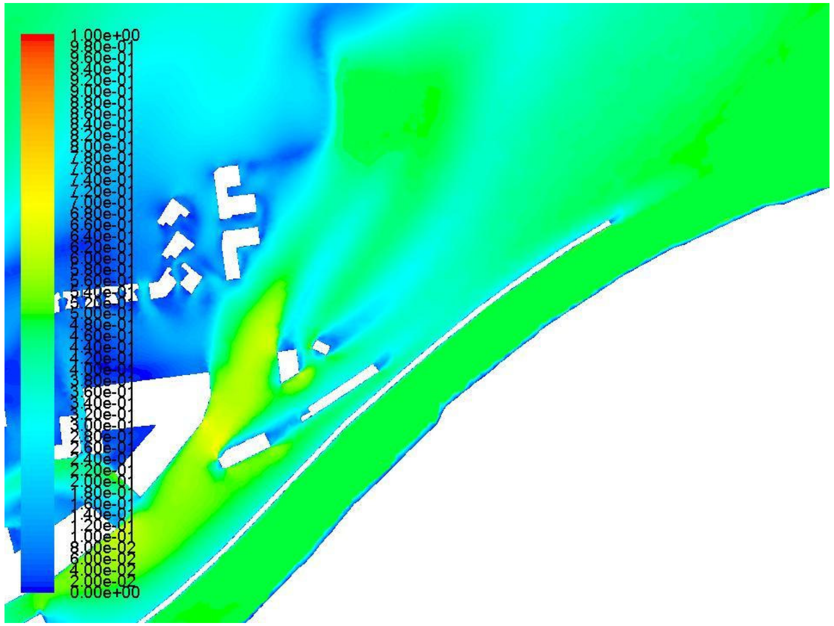
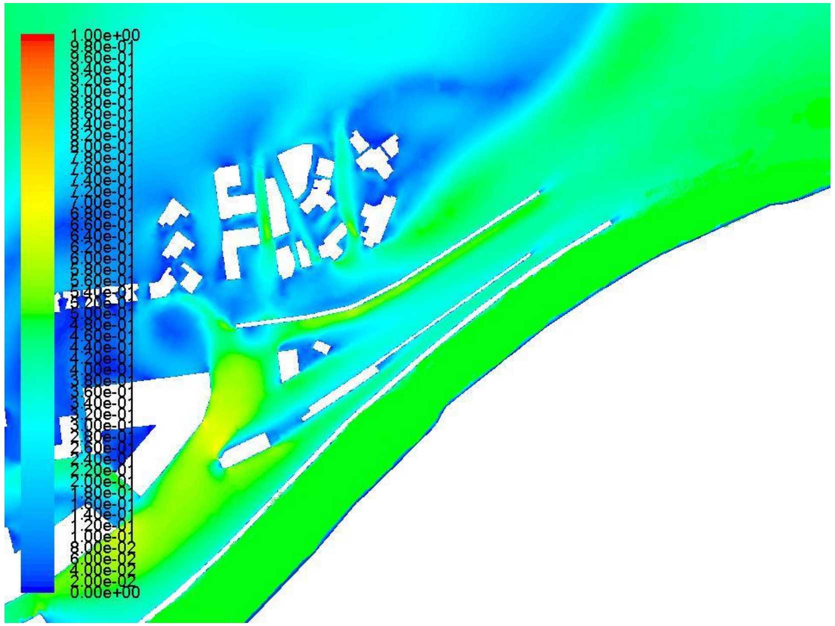
Appendix C

Velocity Contours of CFD Simulation

Prevailing Winds	Prior to Construction of Tung Chung Areas 56 (Velocity Ratio VR)	Subsequent to Construction of Tung Chung Areas 56 (Velocity Ratio VR)
ENE **(15.4%)**		
E **(13%)**		

Prevailing Winds	Prior to Construction of Tung Chung Areas 56 (Velocity Ratio VR)	Subsequent to Construction of Tung Chung Areas 56 (Velocity Ratio VR)
NE **(12.7%)**		
NNE **(9.1%)**		

Prevailing Winds	Prior to Construction of Tung Chung Areas 56 (Velocity Ratio VR)	Subsequent to Construction of Tung Chung Areas 56 (Velocity Ratio VR)
ESE **(8.9%)**		
SSE **(6.5%)**		

Prevailing Winds	Prior to Construction of Tung Chung Areas 56 (Velocity Ratio VR)	Subsequent to Construction of Tung Chung Areas 56 (Velocity Ratio VR)
SE **(6.2%)**		
SSW **(5.7%)**		

Appendix D

Summary of Velocity Ratio (VR) at Different Test Points

Wind Velocity Ratio of Perimeter Test Points in ENE Direction

ENE Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.46	0.48	0.02
P2	0.44	0.52	0.08
P3	0.43	0.55	0.12
P4	0.39	0.51	0.12
P5	0.42	0.41	-0.01
P6	0.41	0.42	0.01
P7	0.39	0.49	0.10
P8	0.39	0.50	0.11
P9	0.33	0.47	0.14
P10	0.39	0.54	0.15
P11	0.34	0.48	0.14
P12	0.30	0.09	-0.21
P13	0.19	0.14	-0.05
P14	0.16	0.16	0.00
P15	0.08	0.22	0.14
P16	0.18	0.26	0.08
P17	0.16	0.15	-0.01
P18	0.28	0.05	-0.23
P19	0.32	0.09	-0.23
P20	0.34	0.15	-0.19
P21	0.31	0.06	-0.25
P22	0.34	0.06	-0.28
P23	0.35	0.08	-0.27
P24	0.35	0.07	-0.28
P25	0.36	0.13	-0.23
P26	0.38	0.53	0.15
P27	0.39	0.59	0.20
P28	0.40	0.56	0.16
P29	0.41	0.55	0.14
P30	0.43	0.52	0.09
P31	0.44	0.53	0.09
P32	0.44	0.52	0.08
P33	0.44	0.43	-0.01
P34	0.44	0.32	-0.12
P35	0.44	0.28	-0.16
P36	0.45	0.17	-0.28
P37	0.45	0.10	-0.35
P38	0.45	0.32	-0.13
Average	**0.36**	**0.33**	**-0.03**
Max	0.46	0.59	
Min	0.08	0.05	

Wind Velocity Ratio of Local Test Points in ENE Direction

ENE Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.41	0.54	0.13
O2	0.40	0.51	0.11
O3	0.39	0.55	0.16
O4	0.43	0.55	0.12
O5	0.23	0.11	-0.12
O6	0.39	0.09	-0.30
O7	0.37	0.29	-0.08
O8	0.44	0.36	-0.09
O9	0.31	0.12	-0.19
O10	0.17	0.06	-0.11
O11	0.44	0.07	-0.37
O12	0.27	0.03	-0.23
O13	0.15	0.03	-0.12
O14	0.31	0.19	-0.12
O15	0.15	0.07	-0.08
O16	0.44	0.10	-0.34
O17	0.46	0.45	-0.02
O18	0.38	0.11	-0.27
O19	0.50	0.48	-0.02
O20	0.59	0.41	-0.19
O21	0.57	0.36	-0.22
O22	0.39	0.54	0.15
O23	0.27	0.08	-0.20
O24	0.46	0.43	-0.03
O25	0.53	0.54	0.01
O26	0.17	0.34	0.17
O27	0.14	0.46	0.31
O28	0.31	0.41	0.10
O29	0.33	0.48	0.14
O30	0.41	0.50	0.09
O31	0.44	0.50	0.06
O32	0.41	0.47	0.06
Average	**0.37**	**0.32**	**-0.05**
Max	0.59	0.55	
Min	0.14	0.03	

Wind Velocity Ratio of Special Test Points in ENE Direction

ENE Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.37	0.18	-0.19
S2	0.37	0.18	-0.19
S3	0.36	0.27	-0.09
S4	0.33	0.44	0.11
Average	**0.36**	**0.27**	**-0.09**
Max	0.37	0.44	
Min	0.33	0.18	

Wind Velocity Ratio of Perimeter Test Points in E Direction

E Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.43	0.43	0.01
P2	0.42	0.40	-0.02
P3	0.41	0.30	-0.12
P4	0.45	0.21	-0.24
P5	0.40	0.35	-0.05
P6	0.40	0.19	-0.21
P7	0.39	0.11	-0.28
P8	0.43	0.20	-0.24
P9	0.40	0.22	-0.18
P10	0.43	0.21	-0.22
P11	0.42	0.26	-0.16
P12	0.41	0.25	-0.17
P13	0.32	0.20	-0.12
P14	0.30	0.14	-0.16
P15	0.15	0.08	-0.08
P16	0.16	0.05	-0.10
P17	0.08	0.09	0.01
P18	0.28	0.11	-0.17
P19	0.32	0.10	-0.23
P20	0.38	0.55	0.17
P21	0.43	0.56	0.13
P22	0.39	0.58	0.18
P23	0.43	0.57	0.13
P24	0.41	0.55	0.14
P25	0.42	0.55	0.13
P26	0.44	0.50	0.06
P27	0.48	0.50	0.02
P28	0.46	0.48	0.02
P29	0.44	0.46	0.02
P30	0.49	0.37	-0.11
P31	0.53	0.33	-0.20
P32	0.48	0.28	-0.21
P33	0.48	0.26	-0.22
P34	0.47	0.18	-0.29
P35	0.51	0.28	-0.23
P36	0.45	0.15	-0.30
P37	0.44	0.29	-0.15
P38	0.39	0.38	-0.01
Average	**0.40**	**0.31**	**-0.09**
Max	0.53	0.58	
Min	0.08	0.05	

Wind Velocity Ratio of Local Test Points in E Direction

E Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.40	0.26	-0.14
O2	0.42	0.21	-0.21
O3	0.49	0.20	-0.29
O4	0.17	0.39	0.22
O5	0.32	0.50	0.18
O6	0.45	0.42	-0.03
O7	0.47	0.45	-0.02
O8	0.48	0.18	-0.29
O9	0.38	0.40	0.02
O10	0.21	0.51	0.30
O11	0.37	0.11	-0.26
O12	0.22	0.15	-0.08
O13	0.16	0.12	-0.05
O14	0.21	0.50	0.29
O15	0.24	0.32	0.08
O16	0.38	0.32	-0.06
O17	0.52	0.65	0.13
O18	0.33	0.27	-0.05
O19	0.52	0.51	0.00
O20	0.60	0.50	-0.10
O21	0.60	0.52	-0.09
O22	0.44	0.47	0.03
O23	0.25	0.15	-0.10
O24	0.29	0.38	0.09
O25	0.31	0.42	0.10
O26	0.14	0.22	0.09
O27	0.16	0.40	0.24
O28	0.42	0.27	-0.16
O29	0.40	0.35	-0.05
O30	0.45	0.44	-0.02
O31	0.48	0.40	-0.08
O32	0.50	0.32	-0.18
Average	**0.37**	**0.35**	**-0.02**
Max	0.60	0.65	
Min	0.14	0.11	

Wind Velocity Ratio of Special Test Points in E Direction

E Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.43	0.18	-0.26
S2	0.50	0.24	-0.25
S3	0.40	0.18	-0.22
S4	0.37	0.28	-0.09
Average	**0.42**	**0.22**	**-0.20**
Max	0.50	0.28	
Min	0.37	0.18	

Wind Velocity Ratio of Perimeter Test Points in ESE Direction

ESE Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.43	0.26	-0.16
P2	0.42	0.07	-0.35
P3	0.41	0.10	-0.31
P4	0.45	0.04	-0.41
P5	0.40	0.34	-0.06
P6	0.40	0.07	-0.32
P7	0.39	0.15	-0.24
P8	0.43	0.17	-0.27
P9	0.40	0.12	-0.28
P10	0.43	0.16	-0.27
P11	0.42	0.24	-0.19
P12	0.41	0.29	-0.13
P13	0.32	0.33	0.01
P14	0.30	0.38	0.08
P15	0.15	0.38	0.23
P16	0.16	0.33	0.17
P17	0.08	0.30	0.22
P18	0.28	0.20	-0.08
P19	0.32	0.20	-0.13
P20	0.38	0.18	-0.19
P21	0.43	0.11	-0.32
P22	0.39	0.14	-0.25
P23	0.43	0.17	-0.26
P24	0.41	0.19	-0.22
P25	0.42	0.22	-0.20
P26	0.44	0.21	-0.22
P27	0.48	0.22	-0.26
P28	0.46	0.22	-0.24
P29	0.44	0.28	-0.16
P30	0.49	0.19	-0.30
P31	0.53	0.25	-0.28
P32	0.48	0.21	-0.27
P33	0.48	0.21	-0.27
P34	0.47	0.23	-0.24
P35	0.51	0.21	-0.30
P36	0.45	0.23	-0.22
P37	0.44	0.35	-0.09
P38	0.39	0.36	-0.03
Average	**0.40**	**0.22**	**-0.18**
Max	0.53	0.38	
Min	0.08	0.04	

Wind Velocity Ratio of Local Test Points in ESE Direction

ESE Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.46	0.08	-0.39
O2	0.36	0.09	-0.27
O3	0.36	0.10	-0.26
O4	0.40	0.15	-0.25
O5	0.48	0.17	-0.30
O6	0.56	0.42	-0.13
O7	0.44	0.16	-0.28
O8	0.19	0.11	-0.09
O9	0.52	0.39	-0.12
O10	0.30	0.03	-0.27
O11	0.08	0.08	0.00
O12	0.17	0.17	0.01
O13	0.14	0.22	0.08
O14	0.34	0.43	0.08
O15	0.24	0.15	-0.09
O16	0.36	0.28	-0.08
O17	0.66	0.55	-0.11
O18	0.30	0.19	-0.11
O19	0.72	0.61	-0.11
O20	0.51	0.53	0.02
O21	0.46	0.45	-0.01
O22	0.69	0.54	-0.15
O23	0.48	0.49	0.01
O24	0.09	0.16	0.07
O25	0.27	0.19	-0.09
O26	0.38	0.48	0.10
O27	0.42	0.41	-0.01
O28	0.46	0.35	-0.10
O29	0.21	0.47	0.27
O30	0.41	0.41	0.00
O31	0.39	0.45	0.05
O32	0.37	0.44	0.07
Average	**0.38**	**0.31**	**-0.08**
Max	0.72	0.61	
Min	0.08	0.03	

Wind Velocity Ratio of Special Test Points in ESE Direction

ESE Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.39	0.24	-0.15
S2	0.38	0.18	-0.21
S3	0.43	0.23	-0.19
S4	0.42	0.24	-0.18
Average	**0.40**	**0.22**	**-0.15**
Max	0.43	0.24	
Min	0.38	0.18	

Wind Velocity Ratio of Perimeter Test Points in NE Direction

NE Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.50	0.27	-0.24
P2	0.53	0.29	-0.24
P3	0.53	0.37	-0.16
P4	0.51	0.54	0.03
P5	0.51	0.58	0.06
P6	0.53	0.54	0.02
P7	0.46	0.54	0.08
P8	0.46	0.55	0.09
P9	0.48	0.52	0.03
P10	0.45	0.50	0.05
P11	0.38	0.48	0.09
P12	0.30	0.42	0.12
P13	0.25	0.16	-0.09
P14	0.25	0.21	-0.04
P15	0.33	0.36	0.03
P16	0.36	0.20	-0.16
P17	0.39	0.31	-0.08
P18	0.51	0.44	-0.07
P19	0.47	0.21	-0.26
P20	0.47	0.14	-0.33
P21	0.50	0.18	-0.32
P22	0.50	0.29	-0.21
P23	0.50	0.21	-0.29
P24	0.49	0.13	-0.35
P25	0.47	0.22	-0.26
P26	0.47	0.11	-0.36
P27	0.58	0.55	-0.03
P28	0.54	0.61	0.07
P29	0.55	0.62	0.07
P30	0.55	0.58	0.03
P31	0.57	0.56	-0.01
P32	0.56	0.55	-0.01
P33	0.56	0.49	-0.07
P34	0.53	0.41	-0.12
P35	0.56	0.40	-0.16
P36	0.50	0.38	-0.12
P37	0.54	0.31	-0.23
P38	0.54	0.20	-0.34
Average	**0.48**	**0.38**	**-0.10**
Max	0.58	0.62	
Min	0.25	0.11	

Wind Velocity Ratio of Local Test Points in NE Direction

NE Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.48	0.56	0.08
O2	0.45	0.54	0.09
O3	0.49	0.50	0.01
O4	0.49	0.50	0.01
O5	0.10	0.22	0.12
O6	0.31	0.35	0.03
O7	0.39	0.30	-0.10
O8	0.43	0.49	0.06
O9	0.13	0.34	0.22
O10	0.13	0.16	0.04
O11	0.52	0.50	-0.01
O12	0.07	0.15	0.08
O13	0.11	0.12	0.02
O14	0.35	0.19	-0.16
O15	0.35	0.38	0.03
O16	0.31	0.27	-0.04
O17	0.20	0.16	-0.04
O18	0.26	0.38	0.12
O19	0.15	0.22	0.07
O20	0.47	0.32	-0.15
O21	0.40	0.36	-0.05
O22	0.28	0.30	0.01
O23	0.54	0.42	-0.13
O24	0.62	0.45	-0.17
O25	0.53	0.41	-0.13
O26	0.22	0.20	-0.02
O27	0.24	0.52	0.28
O28	0.51	0.37	-0.14
O29	0.48	0.53	0.05
O30	0.51	0.58	0.06
O31	0.52	0.57	0.04
O32	0.58	0.56	-0.02
Average	**0.36**	**0.37**	**0.01**
Max	0.62	0.58	
Min	0.07	0.12	

Wind Velocity Ratio of Special Test Points in NE Direction

NE Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.56	0.17	-0.39
S2	0.52	0.24	-0.28
S3	0.50	0.34	-0.16
S4	0.50	0.35	-0.14
Average	**0.52**	**0.28**	**-0.15**
Max	0.56	0.35	
Min	0.50	0.17	

Wind Velocity Ratio of Perimeter Test Points in NNE Direction

NNE Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.45	0.18	-0.27
P2	0.44	0.14	-0.31
P3	0.48	0.26	-0.22
P4	0.47	0.45	-0.01
P5	0.46	0.45	0.00
P6	0.45	0.44	-0.01
P7	0.44	0.43	0.00
P8	0.42	0.47	0.05
P9	0.40	0.43	0.03
P10	0.33	0.45	0.12
P11	0.32	0.42	0.10
P12	0.31	0.41	0.09
P13	0.29	0.41	0.12
P14	0.26	0.36	0.10
P15	0.42	0.53	0.11
P16	0.38	0.47	0.08
P17	0.43	0.49	0.06
P18	0.53	0.57	0.04
P19	0.53	0.49	-0.04
P20	0.52	0.49	-0.03
P21	0.52	0.51	-0.02
P22	0.51	0.25	-0.26
P23	0.50	0.16	-0.34
P24	0.50	0.14	-0.36
P25	0.51	0.20	-0.31
P26	0.47	0.32	-0.15
P27	0.51	0.41	-0.10
P28	0.51	0.53	0.03
P29	0.47	0.58	0.10
P30	0.48	0.58	0.10
P31	0.47	0.53	0.05
P32	0.47	0.53	0.06
P33	0.46	0.54	0.08
P34	0.50	0.47	-0.04
P35	0.50	0.51	0.01
P36	0.50	0.53	0.03
P37	0.50	0.53	0.03
P38	0.45	0.33	-0.13
Average	**0.45**	**0.42**	**-0.03**
Max	0.53	0.58	
Min	0.26	0.14	

Wind Velocity Ratio of Local Test Points in NNE Direction

NNE Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.43	0.46	0.03
O2	0.40	0.43	0.03
O3	0.34	0.47	0.13
O4	0.38	0.47	0.09
O5	0.36	0.43	0.08
O6	0.44	0.49	0.05
O7	0.32	0.11	-0.21
O8	0.33	0.41	0.08
O9	0.30	0.38	0.08
O10	0.12	0.29	0.17
O11	0.41	0.54	0.12
O12	0.10	0.04	-0.05
O13	0.14	0.14	0.00
O14	0.20	0.30	0.10
O15	0.46	0.53	0.07
O16	0.28	0.26	-0.02
O17	0.46	0.52	0.06
O18	0.21	0.30	0.10
O19	0.12	0.24	0.12
O20	0.26	0.13	-0.13
O21	0.41	0.25	-0.16
O22	0.39	0.50	0.11
O23	0.55	0.45	-0.09
O24	0.56	0.51	-0.04
O25	0.55	0.50	-0.05
O26	0.52	0.38	-0.14
O27	0.33	0.47	0.14
O28	0.52	0.41	-0.11
O29	0.45	0.48	0.04
O30	0.51	0.59	0.08
O31	0.51	0.57	0.06
O32	0.47	0.51	0.04
Average	**0.37**	**0.39**	**0.02**
Max	0.56	0.59	
Min	0.10	0.04	

Wind Velocity Ratio of Special Test Points in NNE Direction

NNE Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.45	0.19	-0.25
S2	0.46	0.23	-0.22
S3	0.47	0.23	-0.24
S4	0.49	0.44	-0.04
Average	**0.46**	**0.27**	**-0.05**
Max	0.49	0.44	
Min	0.45	0.19	

Wind Velocity Ratio of Perimeter Test Points in SE Direction

SE Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.52	0.61	0.08
P2	0.48	0.57	0.10
P3	0.53	0.41	-0.12
P4	0.49	0.28	-0.21
P5	0.49	0.21	-0.28
P6	0.45	0.12	-0.34
P7	0.45	0.14	-0.31
P8	0.44	0.14	-0.30
P9	0.44	0.14	-0.30
P10	0.45	0.13	-0.31
P11	0.41	0.13	-0.28
P12	0.36	0.13	-0.23
P13	0.32	0.14	-0.18
P14	0.28	0.13	-0.15
P15	0.15	0.14	-0.01
P16	0.21	0.13	-0.08
P17	0.22	0.08	-0.15
P18	0.32	0.14	-0.19
P19	0.33	0.12	-0.21
P20	0.30	0.10	-0.20
P21	0.34	0.19	-0.15
P22	0.34	0.18	-0.15
P23	0.26	0.26	0.00
P24	0.17	0.32	0.15
P25	0.10	0.30	0.21
P26	0.18	0.41	0.23
P27	0.23	0.50	0.27
P28	0.32	0.47	0.15
P29	0.37	0.47	0.10
P30	0.41	0.46	0.05
P31	0.44	0.43	-0.01
P32	0.46	0.42	-0.04
P33	0.47	0.37	-0.11
P34	0.48	0.31	-0.17
P35	0.49	0.29	-0.20
P36	0.49	0.24	-0.25
P37	0.52	0.24	-0.28
P38	0.51	0.51	0.00
Average	**0.37**	**0.27**	**-0.10**
Max	0.53	0.61	
Min	0.10	0.08	

Wind Velocity Ratio of Local Test Points in SE Direction

SE Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.51	0.15	-0.35
O2	0.49	0.13	-0.35
O3	0.49	0.12	-0.37
O4	0.35	0.14	-0.21
O5	0.45	0.19	-0.26
O6	0.47	0.16	-0.31
O7	0.37	0.25	-0.12
O8	0.46	0.08	-0.38
O9	0.19	0.19	0.00
O10	0.25	0.10	-0.15
O11	0.11	0.23	0.12
O12	0.27	0.10	-0.17
O13	0.13	0.12	-0.01
O14	0.30	0.16	-0.14
O15	0.17	0.13	-0.04
O16	0.24	0.11	-0.13
O17	0.62	0.32	-0.31
O18	0.21	0.07	-0.14
O19	0.48	0.23	-0.26
O20	0.18	0.12	-0.07
O21	0.08	0.09	0.01
O22	0.52	0.31	-0.21
O23	0.37	0.20	-0.17
O24	0.11	0.29	0.18
O25	0.13	0.26	0.14
O26	0.37	0.12	-0.25
O27	0.27	0.24	-0.04
O28	0.35	0.34	-0.01
O29	0.10	0.31	0.22
O30	0.24	0.36	0.12
O31	0.39	0.38	-0.01
O32	0.46	0.40	-0.06
Average	**0.32**	**0.20**	**-0.12**
Max	0.62	0.40	
Min	0.08	0.07	

Wind Velocity Ratio of Special Test Points in SE Direction

SE Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.47	0.20	-0.27
S2	0.44	0.17	-0.27
S3	0.39	0.23	-0.16
S4	0.12	0.16	0.04
Average	**0.36**	**0.19**	**-0.07**
Max	0.47	0.23	
Min	0.12	0.16	

Wind Velocity Ratio of Perimeter Test Points in SSE Direction

SSE Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.52	0.16	-0.36
P2	0.52	0.16	-0.36
P3	0.49	0.16	-0.33
P4	0.48	0.19	-0.29
P5	0.45	0.20	-0.26
P6	0.44	0.15	-0.29
P7	0.41	0.15	-0.26
P8	0.39	0.31	-0.08
P9	0.33	0.35	0.01
P10	0.33	0.47	0.14
P11	0.30	0.41	0.11
P12	0.27	0.36	0.08
P13	0.25	0.44	0.19
P14	0.16	0.43	0.27
P15	0.09	0.41	0.32
P16	0.13	0.46	0.32
P17	0.16	0.56	0.40
P18	0.48	0.41	-0.07
P19	0.50	0.35	-0.16
P20	0.52	0.24	-0.27
P21	0.54	0.33	-0.21
P22	0.58	0.16	-0.42
P23	0.54	0.18	-0.36
P24	0.44	0.27	-0.17
P25	0.41	0.33	-0.08
P26	0.48	0.44	-0.04
P27	0.54	0.48	-0.06
P28	0.55	0.52	-0.03
P29	0.54	0.55	0.01
P30	0.54	0.57	0.03
P31	0.53	0.57	0.04
P32	0.52	0.29	-0.23
P33	0.51	0.11	-0.40
P34	0.50	0.10	-0.40
P35	0.50	0.11	-0.39
P36	0.51	0.15	-0.36
P37	0.51	0.18	-0.33
P38	0.53	0.16	-0.36
Average	**0.43**	**0.31**	**-0.12**
Max	0.58	0.57	
Min	0.09	0.10	

Wind Velocity Ratio of Local Test Points in SSE Direction

SSE Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.42	0.06	-0.35
O2	0.33	0.49	0.16
O3	0.28	0.26	-0.02
O4	0.13	0.21	0.08
O5	0.11	0.24	0.12
O6	0.23	0.16	-0.08
O7	0.43	0.14	-0.29
O8	0.14	0.12	-0.02
O9	0.08	0.12	0.04
O10	0.36	0.26	-0.09
O11	0.12	0.24	0.12
O12	0.11	0.09	-0.01
O13	0.11	0.19	0.08
O14	0.20	0.49	0.29
O15	0.05	0.19	0.14
O16	0.07	0.10	0.03
O17	0.25	0.23	-0.02
O18	0.09	0.17	0.08
O19	0.16	0.28	0.12
O20	0.09	0.13	0.04
O21	0.08	0.15	0.07
O22	0.44	0.49	0.04
O23	0.53	0.58	0.05
O24	0.59	0.58	-0.02
O25	0.51	0.46	-0.04
O26	0.57	0.55	-0.03
O27	0.59	0.55	-0.04
O28	0.56	0.35	-0.21
O29	0.51	0.49	-0.02
O30	0.50	0.55	0.05
O31	0.51	0.59	0.07
O32	0.50	0.58	0.08
Average	**0.30**	**0.32**	**0.01**
Max	0.59	0.59	
Min	0.05	0.06	

Wind Velocity Ratio of Special Test Points in SSE Direction

SSE Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.43	0.17	-0.27
S2	0.42	0.15	-0.27
S3	0.42	0.20	-0.22
S4	0.45	0.25	-0.20
Average	**0.43**	**0.19**	**-0.12**
Max	0.45	0.25	
Min	0.42	0.15	

Wind Velocity Ratio of Perimeter Test Points in SSW Direction

SSW Perimeter Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
P1	0.51	0.19	-0.32
P2	0.52	0.17	-0.35
P3	0.51	0.12	-0.39
P4	0.50	0.16	-0.34
P5	0.29	0.17	-0.12
P6	0.19	0.12	-0.07
P7	0.19	0.28	0.09
P8	0.18	0.20	0.02
P9	0.22	0.14	-0.08
P10	0.25	0.14	-0.12
P11	0.23	0.10	-0.12
P12	0.16	0.11	-0.05
P13	0.08	0.28	0.19
P14	0.18	0.39	0.21
P15	0.10	0.44	0.34
P16	0.12	0.48	0.36
P17	0.15	0.51	0.36
P18	0.32	0.39	0.07
P19	0.41	0.30	-0.11
P20	0.50	0.18	-0.32
P21	0.56	0.18	-0.38
P22	0.51	0.21	-0.29
P23	0.27	0.20	-0.06
P24	0.28	0.09	-0.19
P25	0.42	0.15	-0.27
P26	0.46	0.26	-0.20
P27	0.42	0.23	-0.20
P28	0.42	0.28	-0.14
P29	0.41	0.36	-0.05
P30	0.37	0.40	0.03
P31	0.37	0.46	0.09
P32	0.36	0.47	0.11
P33	0.41	0.26	-0.15
P34	0.47	0.18	-0.29
P35	0.48	0.15	-0.33
P36	0.44	0.09	-0.35
P37	0.48	0.11	-0.38
P38	0.50	0.11	-0.39
Average	**0.35**	**0.24**	**-0.11**
Max	0.56	0.51	
Min	0.08	0.09	

Wind Velocity Ratio of Local Test Points in SSW Direction

SSW Local Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
O1	0.21	0.29	0.08
O2	0.26	0.12	-0.13
O3	0.28	0.17	-0.11
O4	0.26	0.19	-0.07
O5	0.19	0.18	-0.01
O6	0.12	0.21	0.09
O7	0.45	0.17	-0.28
O8	0.23	0.12	-0.11
O9	0.13	0.14	0.01
O10	0.25	0.16	-0.09
O11	0.12	0.13	0.01
O12	0.09	0.09	-0.01
O13	0.16	0.10	-0.07
O14	0.13	0.39	0.26
O15	0.10	0.13	0.04
O16	0.13	0.16	0.03
O17	0.20	0.22	0.02
O18	0.10	0.19	0.09
O19	0.14	0.08	-0.06
O20	0.06	0.07	0.01
O21	0.10	0.21	0.11
O22	0.23	0.45	0.22
O23	0.60	0.60	0.00
O24	0.62	0.63	0.00
O25	0.55	0.55	0.00
O26	0.60	0.59	-0.01
O27	0.57	0.47	-0.11
O28	0.61	0.31	-0.30
O29	0.36	0.42	0.06
O30	0.31	0.36	0.04
O31	0.31	0.43	0.12
O32	0.40	0.46	0.06
Average	**0.28**	**0.27**	**0.00**
Max	0.62	0.63	
Min	0.06	0.07	

Wind Velocity Ratio of Local Test Points in SSW Direction

SSW Special Test Point			
Test Point	Velocity Ratio		VR Difference
	Before	After	
S1	0.45	0.25	-0.20
S2	0.41	0.13	-0.28
S3	0.41	0.25	-0.16
S4	0.36	0.17	-0.19
Average	**0.41**	**0.20**	**-0.11**
Max	0.45	0.25	
Min	0.36	0.13	

Weighted Velocity of Perimeter Test Point for all 8 Prevailing Wind Directions

Perimeter Test Points	Velocity Ratio		VR Difference
	Before	After	
P1	0.47	0.34	-0.13
P2	0.46	0.31	-0.15
P3	0.47	0.32	-0.15
P4	0.46	0.33	-0.13
P5	0.43	0.37	-0.06
P6	0.42	0.30	-0.12
P7	0.40	0.32	-0.08
P8	0.41	0.35	-0.06
P9	0.38	0.33	-0.05
P10	0.39	0.36	-0.04
P11	0.36	0.35	-0.02
P12	0.33	0.26	-0.07
P13	0.26	0.24	-0.01
P14	0.24	0.25	0.01
P15	0.19	0.30	0.11
P16	0.22	0.27	0.05
P17	0.21	0.28	0.07
P18	0.37	0.26	-0.10
P19	0.39	0.21	-0.18
P20	0.42	0.26	-0.15
P21	0.44	0.26	-0.18
P22	0.43	0.25	-0.19
P23	0.42	0.23	-0.18
P24	0.39	0.22	-0.17
P25	0.40	0.27	-0.14
P26	0.42	0.36	-0.06
P27	0.46	0.46	0.00
P28	0.46	0.48	0.02
P29	0.46	0.50	0.04
P30	0.48	0.46	-0.01
P31	0.49	0.46	-0.03
P32	0.48	0.42	-0.06
P33	0.48	0.35	-0.13
P34	0.48	0.29	-0.19
P35	0.50	0.29	-0.20
P36	0.47	0.25	-0.22
P37	0.48	0.26	-0.21
P38	0.46	0.30	-0.16
Weighted Average	**0.40**	**0.3**	**-0.08**

Weighted Velocity of Local Test Point for all 8 Prevailing Wind Directions

Local Test Points	Velocity Ratio		VR Difference
	Before	After	
O1	0.42	0.34	-0.08
O2	0.40	0.35	-0.05
O3	0.40	0.33	-0.07
O4	0.34	0.37	0.03
O5	0.27	0.26	-0.01
O6	0.39	0.29	-0.09
O7	0.40	0.26	-0.15
O8	0.37	0.27	-0.10
O9	0.27	0.27	0.00
O10	0.21	0.20	0.00
O11	0.32	0.23	-0.09
O12	0.17	0.10	-0.07
O13	0.14	0.12	-0.02
O14	0.27	0.32	0.05
O15	0.23	0.25	0.01
O16	0.31	0.21	-0.10
O17	0.43	0.41	-0.02
O18	0.26	0.22	-0.04
O19	0.37	0.36	-0.01
O20	0.41	0.32	-0.09
O21	0.40	0.33	-0.07
O22	0.42	0.45	0.04
O23	0.42	0.33	-0.10
O24	0.42	0.42	0.00
O25	0.43	0.43	-0.01
O26	0.32	0.34	0.02
O27	0.30	0.44	0.15
O28	0.45	0.36	-0.09
O29	0.37	0.45	0.08
O30	0.43	0.48	0.05
O31	0.46	0.49	0.03
O32	0.47	0.46	0.00
Weighted Average	**0.35**	**0.33**	**-0.02**

Weighted Velocity of Special Test Point for all 8 Prevailing Wind Directions

Special Test Points	Velocity Ratio		VR Difference
	Before	After	
S1	0.44	0.19	-0.25
S2	0.44	0.20	-0.24
S3	0.42	0.25	-0.17
S4	0.39	0.32	-0.07
Weighted Average	**0.42**	**0.24**	**-0.18**