Planning Department

Term Consultancies for Air Ventilation Assessment Services

Final Report – Potential Commercial Site at Cheung Shun Street near Lai Chi Kok Road, Cheung Sha Wan

Issue | March 2016

Job number --------

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Document Verification

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Job title	Term Consultancies for Air Ventilation Assessment Services	Job number 246224-00
Document title	Final Report – Potential Commercial Site at Cheung Shun Street near Lai Chi Kok Road, Cheung Sha Wan	File reference
Document ref		

Revision	Date	Filename	20160307_PlanD_LaiChiKok_AVA_v1.docx		
Draft 1	9 Mar 2016	Description	Draft 1		
			Prepared by	Checked by	Approved by
		Name	Kelvin Chow	Henry Au	Sui-Hang Yan
		Signature			
Issue	18 Mar 2016	Filename	20160309_PlanD_LaiChiKok_AVA_v7.3.docx		
		Description	Issue		
			Prepared by	Checked by	Approved by
		Name	Kelvin Chow	Henry Au	Sui-Hang Yan
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
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Contents

1 Introduction

1.1 Background of Study

The Project Site of about 0.423 ha at Cheung Shun Street near Lai Chi Kok Road, Cheung Sha Wan is zoned "Government, Institution or Community" ("G/IC") on the approved Cheung Sha Wan Outline Zoning Plan (OZP) No. S/K5/35, subject to a building height restriction of 13 storeys. To optimize the development opportunity and to allow for more design flexibility, it has been identified as a potential site to be rezoned for commercial use.

A qualitative assessment of the existing wind condition is carried out to familiar the existing wind environment around the project site. Furthermore, a site-specific quantitative assessment on the possible air ventilation impacts is conducted. The report would form part of the rezoning proposal for the Town Planning Board (TPB)'s consideration.

Ove Arup & Partners Hong Kong Ltd. (Arup) was commissioned by Planning Department (PlanD) to carry out an Air Ventilation Assessment (AVA) Computational Fluid Dynamics (CFD) for Potential Commercial Site at Cheung Shun Street near Lai Chi Kok Road, Cheung Sha Wan in accordance with the "*Technical Circular No. 1/06 on Air Ventilation Assessments*" (the Technical Circular) jointly issued by the Housing, Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB) on 19th July 2006.

1.2 Objective of the Study

The objective of the study is to assess the air ventilation impacts of the proposed high-rise development with the stipulated development parameters. It is also the purpose of this study to recommend any design improvements and/or mitigation measures which may be adopted to minimize any adverse air ventilation impact. The findings and recommendations of this study will form an essential basis to substantiate the proposed amendment to the OZP from air ventilation perspective and to incorporate any design requirements for future development on the Project Site for consideration by TPB.

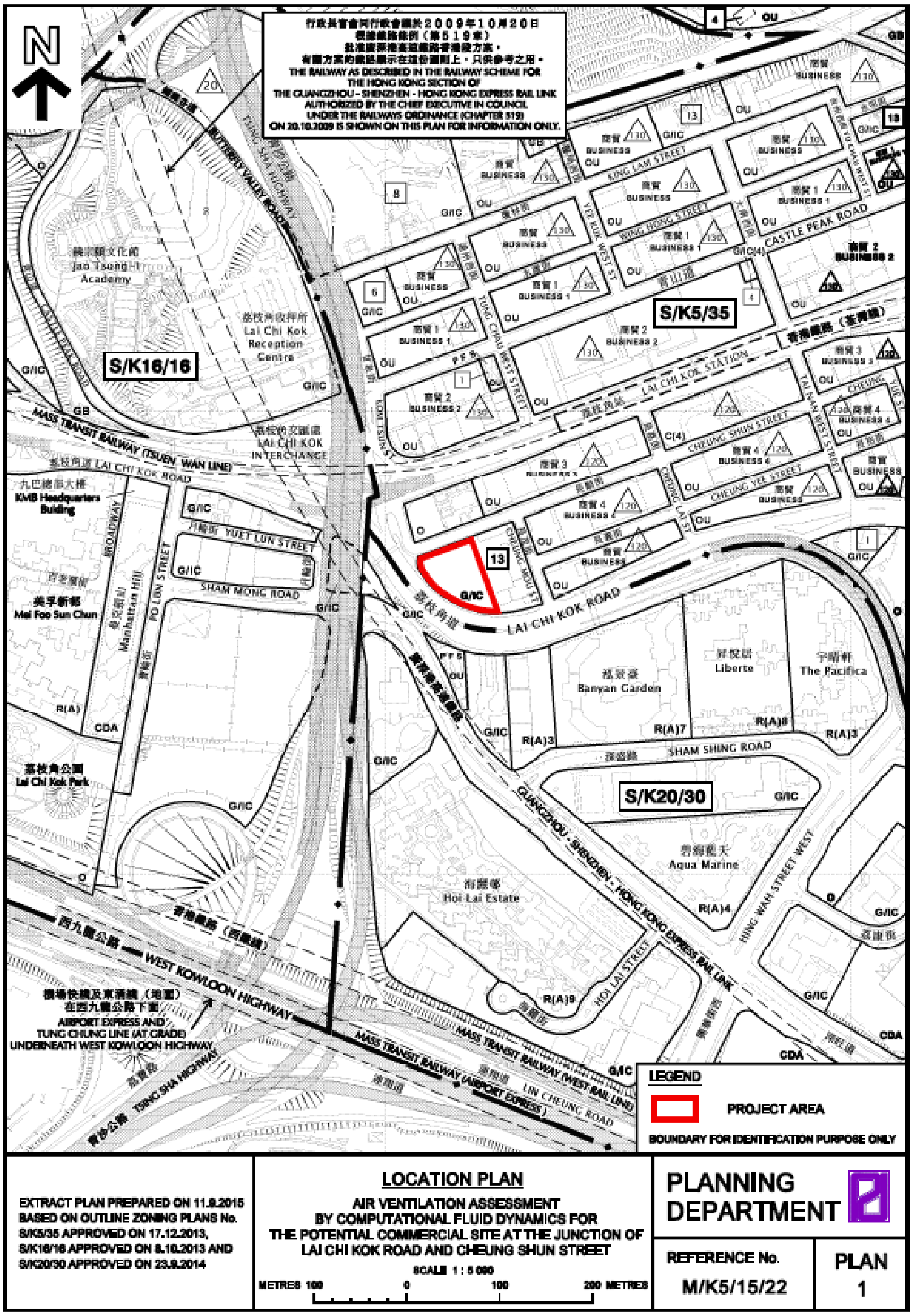


Figure 1 Project Site boundary with OZP zoning (Image Source: Planning Department)

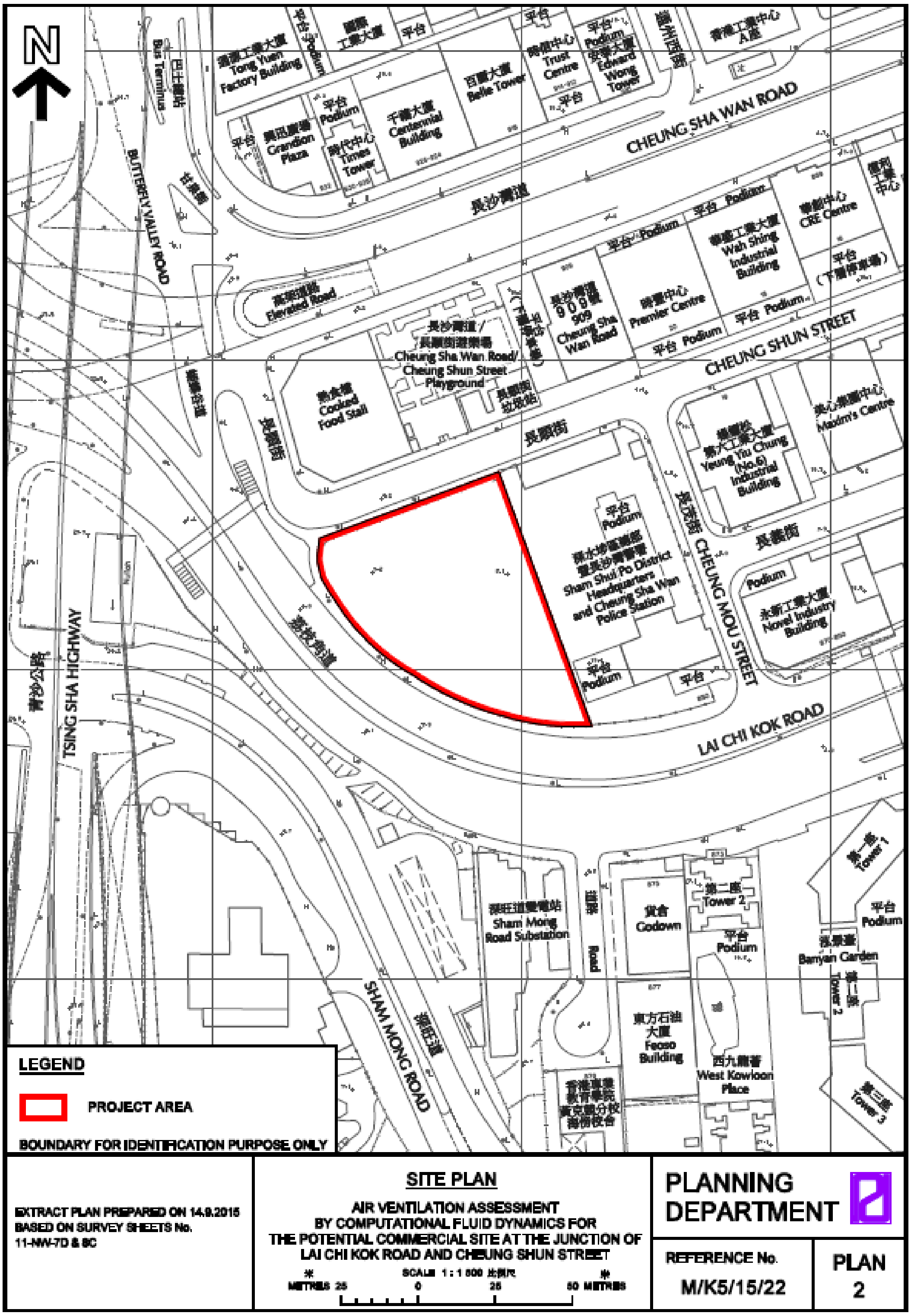


Figure 2 Project Site boundary with the area to be rezoned (Image Source: Planning Department)

2 Study Area

2.1 Characteristics of Project Site and Its Surrounding Area

The Project Site is situated at Lai Chi Kok Area that sandwiched by Mei Foo and Cheung Sha Wan Area (refers to Figure 3). The ground elevation is relatively low and flat with elevation gradually increase towards northeast where Piper's Hills locates (223mPD).

A cluster of medium-rise / high-rise industrial and commercial buildings are located to the east and north of the project site. Some high-rise residential clusters such as Banyan Garden, Liberte, The Pacifica and One West Kowloon are located to the immediate south of the site, whereas Tsing Sha Highway is located at west of the site.

There are two committed developments located near the project site. A medium-rise development (34.5 - 41.5mPD) is located near King Lam Street and another low-rise development (19.5mPD) is located north to Hoi Lai Estate. For details please refers to Figure 4. Several main roads are situated across the Lai Chi Kok Area, such as Castle Peak Road, Cheung Sha Wan Road and Lai Chi Kok Road. Several large elevated structures such as Tsing Sha Highway, West Kowloon Highway are situated at the southwest direction of Lai Chi Kok Road.

Figure 3 Location of the Project Site, Mei Foo, Lai Chi Kok and Cheung Sha Wan Area (Image Source: Google Earth)

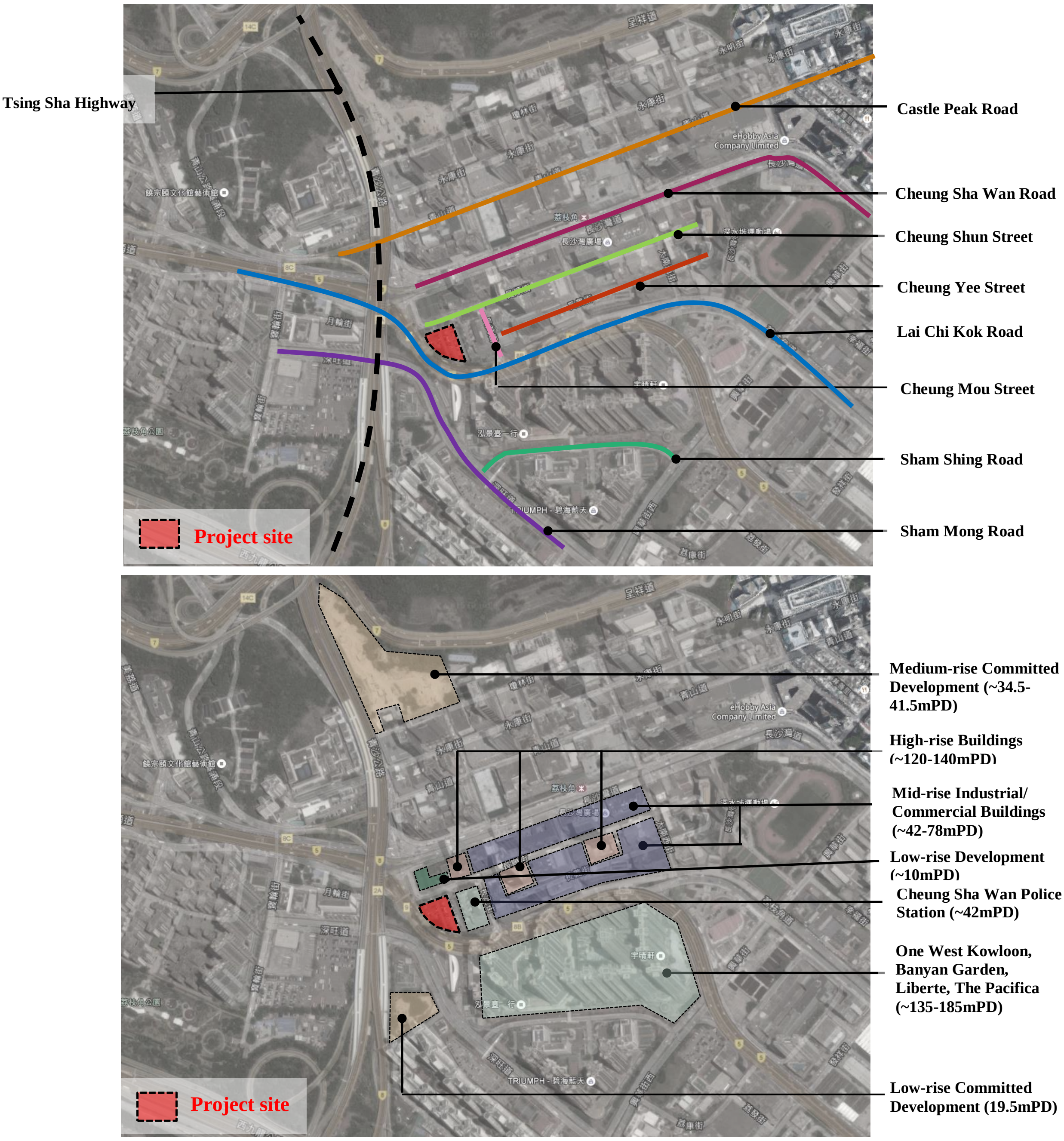


Figure 4 Project Site and its Surrounding Areas (Image Source: Google Earth)

2.2 Previous AVA(s) Conducted near the Project Site

The following table list out the previous air ventilation assessments conducted for the Project Area and its surrounding.

Items	Project	Year of Completion
1	Term Consultancy for AVA Services – Expert Evaluation on Air Ventilation Assessment of Cheung Sha Wan Area Expert Evaluation and Advisory Report for Proposed Amendments to Cheung Sha Wan Outline Zoning Plan[1] (namely "CSW Area EE Report")	2010
2	Cheung Sha Wan Wholesale Food Market (CSWWFM) Phase 2 Site and Fat Tseung Street West (FTSW) Developments	2013
3	Proposed Public Rental Housing (PRH) Development at Lai Chi Kok Road/ Tonkin Street	2014

Three AVA studies have been conducted near the Project Site in Cheung Sha Wan district. The Expert Evaluation for CSW Area used the wind data from the Institute of Environment of The Hong Kong University of Science and Technology.

While two AVA initial studies have been conducted for CSWWFM Phase 2 Site and FTSW Developments and also a PRH Development at Lai Chi Kok Road/ Tonkin Street. Both studies have adopted the site wind availability data from Urban Climate Map[2] (UCMap) Study. As these developments are not located within the Assessment Area, they will not consider in the current AVA study.

[1] Term Consultancy for Expert Evaluation and Advisory Services on Air Ventilation Assessment Services under Agreement No. PLNQ 35/2009 – "Expert Evaluation and Advisory Report for Proposed Amendments to Cheung Sha Wan Outline Zoning Plan", CO2nnsulting, September 2010

[2] Urban Climatic Map and Standards for Wind Environment – Feasibility Study, Department of Architecture, CUHK, 1/22/2009

3 Site Wind Availability

The wind availability of the Project Site and its surrounding area is an essential input for the air ventilation assessment. A study of wind availability and characteristics for Hong Kong was conducted by the City University of Hong Kong. In the study, a meso-scale model Regional Atmospheric Modelling System (RAMS)[3] was used to reproduce the site wind data including wind rose and wind profile. Based on the site wind availability data, the Project Site is located within grid X: 074 Y: 046 and Figure 5 shows the location of the grid.

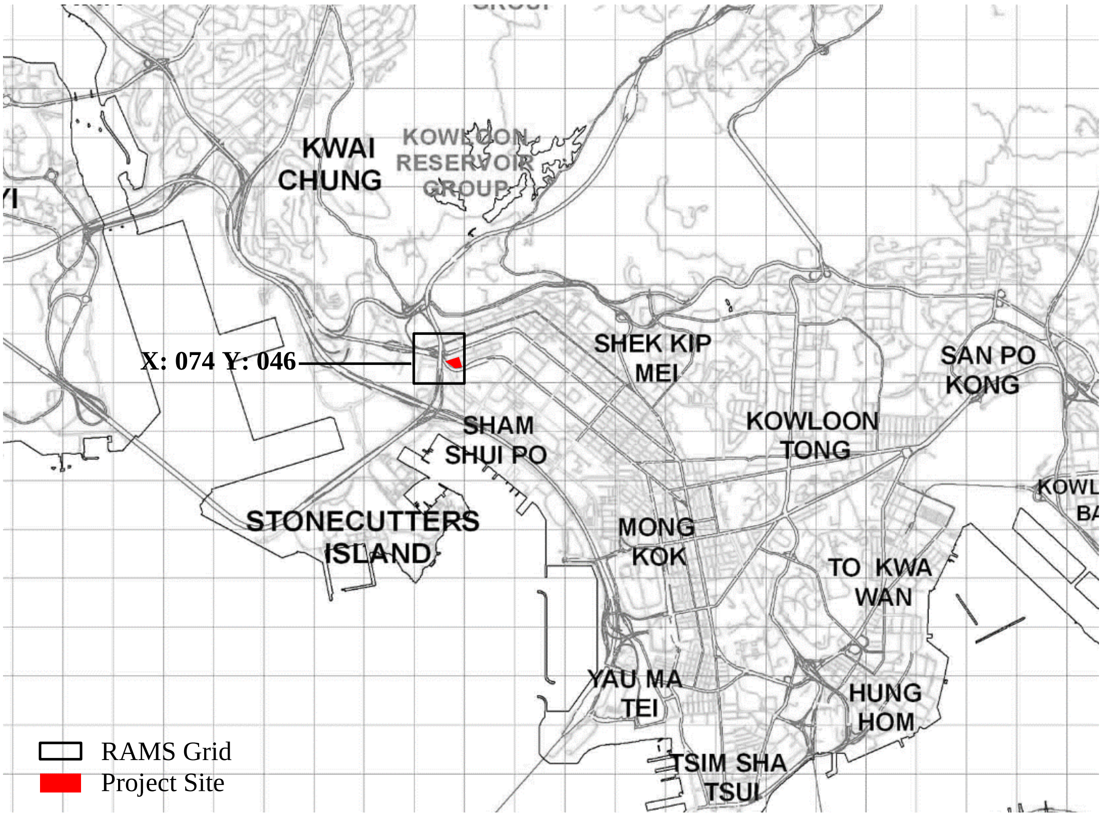


Figure 5 Study areas for site wind availability study

[3] http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/index.html

3.1 Wind Data for Qualitative Assessment

The annual and summer wind rose for this grid are shown in Figure 6 and Figure 7. A low level wind rose at 200m height is selected to investigate prevailing wind condition, as it can better represent the incoming wind to the site which include the influence from the surrounding morphology. The wind availability data shows that NE and E winds dominate under the annual wind condition while E, ESE, SW and SSW dominate under the summer wind condition.

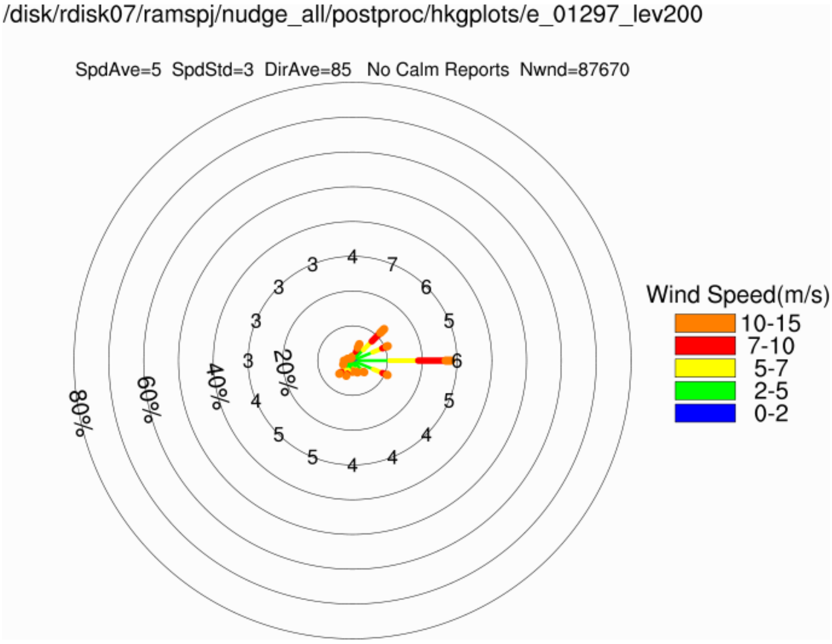


Figure 6 Wind rose for annual wind condition at 200m from site wind availability system

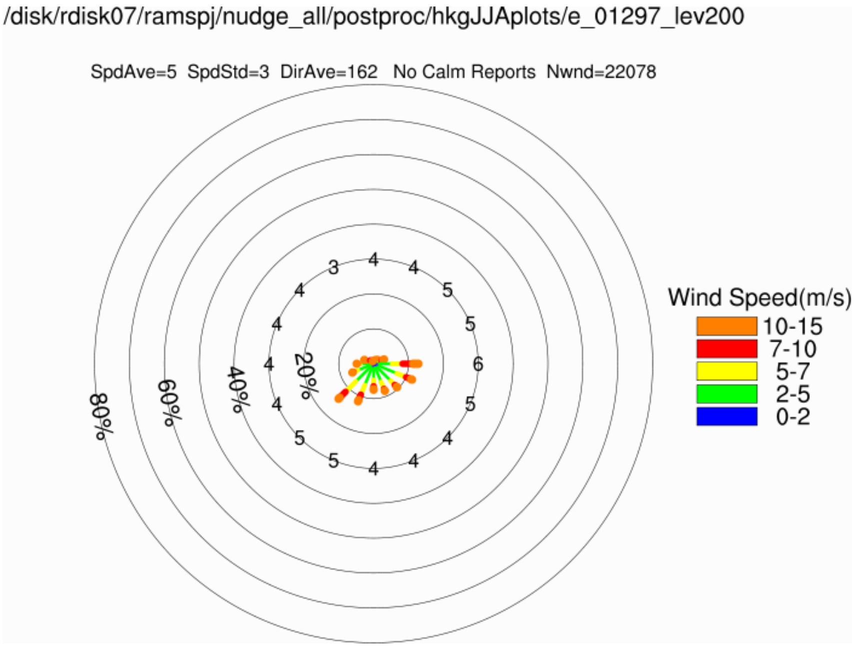


Figure 7 Wind rose for summer wind condition at 200m from site wind availability system

3.1.1 Annual Prevailing Wind

According to the annual wind rose at 200m as shown in Figure 6, two prevailing wind directions (highlighted in Red colour in Table 3) are considered in the qualitative assessment. They are north-easterly (12.9%) and easterly (28.4%) winds.

Table 1 Annual wind frequency of the wind directions considered in this study using 200m wind rose

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE
Frequency	1.2%	5.2%	12.9%	11.0%	28.4%	10.9%	4.7%	3.7%
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW
Frequency	3.2%	4.7%	5.4%	2.9%	2.5%	1.5%	0.9%	0.7%

** The wind frequency showing in red colour represents the selected winds for the qualitative assessment.*

3.1.2 Summer Prevailing Wind

According to the summer wind rose at 200m as shown in Figure 7, four prevailing wind directions (highlighted in Red colour in Table 4) are considered in the qualitative assessment. They are easterly (13.0%), east-south-easterly (12.0%), south-south-westerly (11.7%) and south-westerly (14.3%) winds.

Table 2 Summer wind frequency of the wind directions considered in this study using 200m wind rose

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE
Frequency	0.8%	1.2%	1.6%	3.4%	13.0%	12.0%	9.6%	8.4%
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW
Frequency	7.5%	11.7%	14.3%	6.6%	4.9%	2.9%	1.4%	0.7%

** The wind frequency showing in red colour represents the selected winds for the qualitative assessment.*

3.2 Wind Data for Quantitative Assessment – Initial Study

The annual and summer wind rose for this grid are shown in Figure 8 and Figure 9. 500m height is selected to investigate prevailing wind condition in the Initial Study, as it can better represent the incoming wind to the site which is undisturbed by surrounding buildings. The wind availability data shows that E and ESE winds dominate under the annual wind condition while SW and SSW dominate under the summer wind condition.

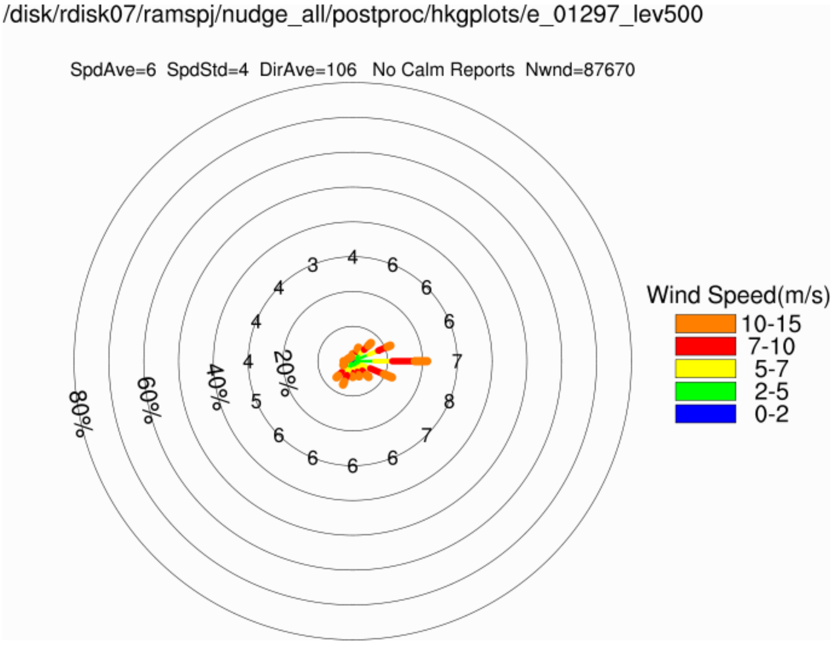


Figure 8 Wind rose for annual wind condition at 500m from site wind availability system

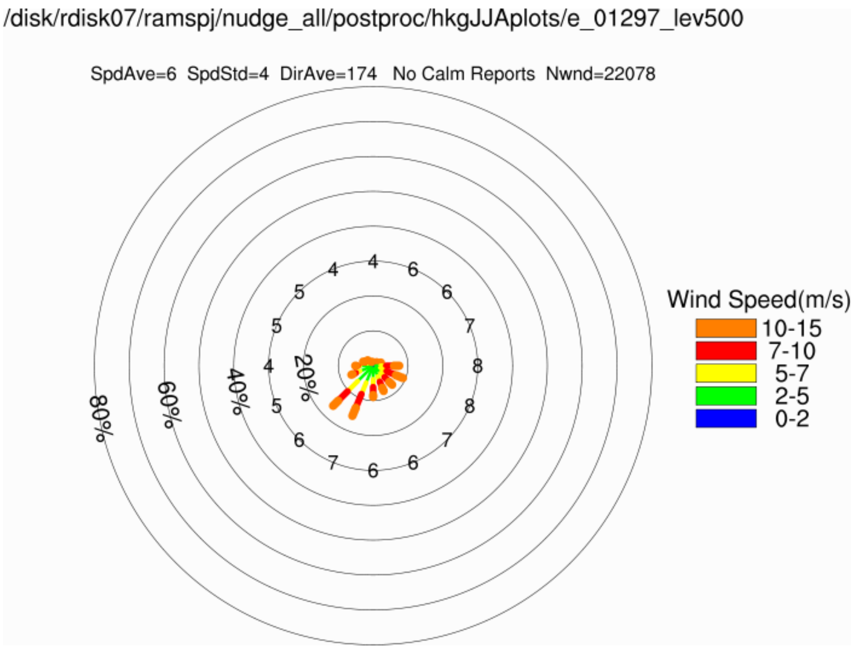


Figure 9 Wind rose for summer wind condition at 500m from site wind availability system

3.2.1 Annual Prevailing Wind

According to the annual wind rose at 500m as shown in Figure 8, eight prevailing wind directions (highlighted in Red colour in Table 3) are considered in this AVA Study which covers 78.9% of the total annual wind frequency. They are north-easterly (7.6%), east-north-easterly (11.9%), easterly (21.8%), east-south-easterly (12.4%), south-easterly (6.5%), south-south-easterly (4.8%), south-south-westerly (7.3%) and south-westerly (6.6%) winds.

Table 3 Annual wind frequency of the wind directions considered in this study using 500m wind rose

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	2.0%	4.4%	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	4.7%	7.3%	6.6%	2.9%	2.6%	1.6%	1.4%	1.2%	78.9%

** The wind frequency showing in red colour represents the selected winds for the CFD simulation.*

3.2.2 Summer Prevailing Wind

According to the summer wind rose at 500m as shown in Figure 9, eight prevailing wind directions (highlighted in Red colour in Table 4) are considered in this AVA Study which covers 81.8% of the total summer wind frequency. They are easterly (8.1%), east-south-easterly (9.7%), south-easterly (7.9%), south-south-easterly (7.9%), southerly (9.3%), south-south-westerly (15.7%), south-westerly (16.4%) and west-south-westerly (6.8%) winds.

Table 4 Summer wind frequency of the wind directions considered in this study using 500m wind rose

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	1.0%	1.1%	1.5%	2.6%	8.1%	9.7%	7.9%	7.9%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	9.3%	15.7%	16.4%	6.8%	5.2%	3.1%	2.2%	1.2%	81.8%

** The wind frequency showing in red colour represents the selected winds for the CFD simulation.*

3.2.3 Wind Profile

The wind profile calculated from RAMS is adopted in this AVA study. It is recommended to extract the RAMS wind profile data from 10 – 500m directly as it can reflect the exact wind data. For the near ground wind speed, the power law equation is used to approximate near ground wind profile. Figure 10 and Table 5 indicate the data points calculated by power law from 0-10m and extracted from RAMS data for 10-500m height. For wind data above 500m height, the velocity is assumed the same as the data at 500m. These wind data will be the input parameters in the CFD simulation.

The vertical discretization of the velocity profile is approximated by using an exponential law, which is a function of ground roughness and height:

$$U_Z = U_G \left(\frac{z}{z_G} \right)^n$$

where

U_G = reference velocity at height z_G

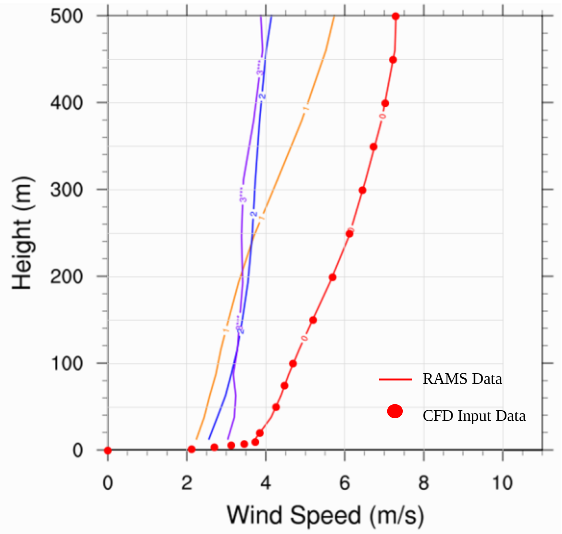
Z_G = reference height

Z = height above ground

U_Z = velocity at height z

$\boldsymbol{n}$ = power law exponent

The power $\boldsymbol{n}$ is related to the ground roughness. A larger value of the power **n** represents the higher roughness of the ground i.e. the dense city. Alternatively, smaller $\boldsymbol{n}$ represents the lower ground roughness i.e. the sea surface.



0: 22.5º-112.4º

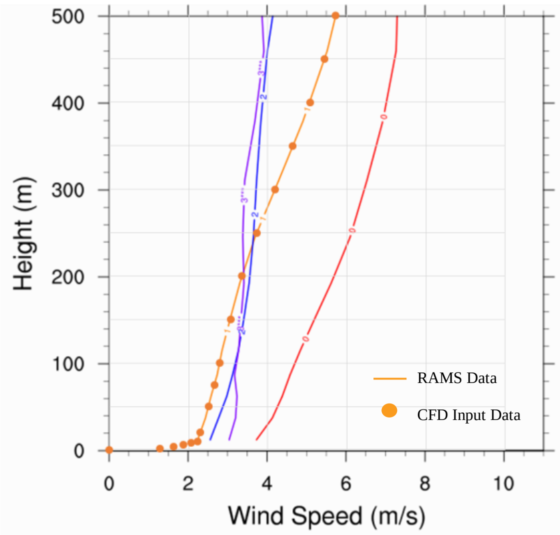
1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 22.5º – 112.4º



0: 22.5º-112.4º

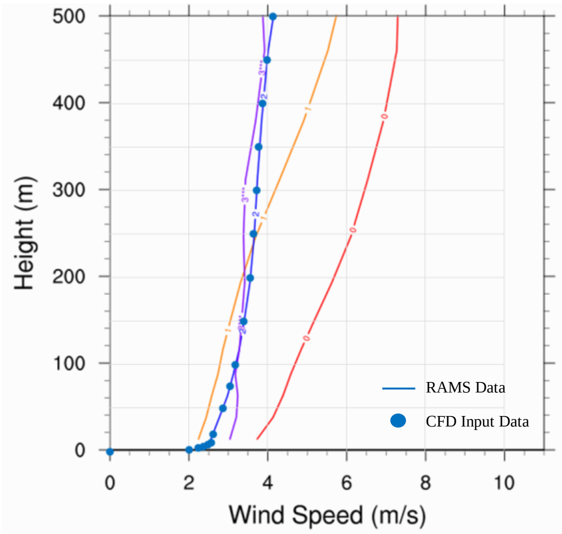
1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 112.5º – 202.4º



0: 22.5º-112.4º

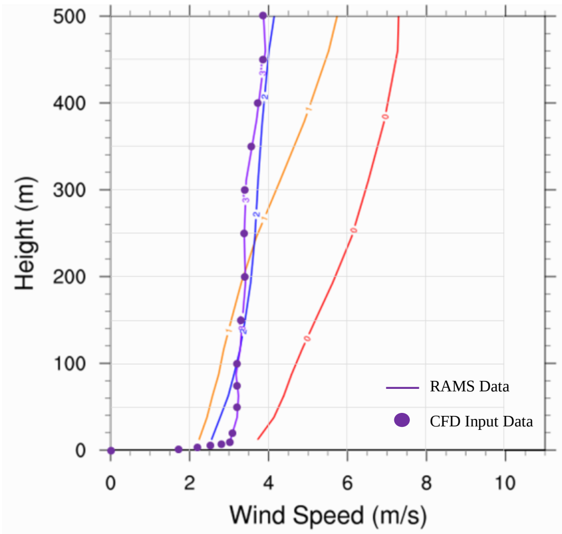
1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 202.5º – 292.4º



0: 22.5º-112.4º

1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 292.5º – 22.4º

Figure 10 Wind profile from RAMS (Grid X:074 Y: 046)

The table below tabulates the data for wind profile, which acts as the input data in the simulation.

Table 5 Wind profile data in different directions

Height (m)	Wind Speed (m/s)			
	22.5º – 112.4º	112.5º – 202.4º	202.5º – 292.4º	292.5º – 22.4º
0	0.00	0.00	0.00	0.00
2	2.12	1.27	2.02	1.73
4	2.71	1.62	2.24	2.20
6	3.12	1.86	2.38	2.53
8	3.45	2.06	2.49	2.80
10	3.73	2.23	2.57	3.03
20	3.85	2.29	2.62	3.09
50	4.26	2.51	2.87	3.21
75	4.47	2.65	3.05	3.21
100	4.69	2.79	3.18	3.21
150	5.19	3.06	3.40	3.30
200	5.69	3.35	3.56	3.41
250	6.11	3.72	3.65	3.38
300	6.45	4.19	3.72	3.40
350	6.73	4.63	3.78	3.56
400	7.02	5.07	3.88	3.74
450	7.21	5.43	3.99	3.87
500	7.29	5.72	4.14	3.87

4 Qualitative Assessment of the Existing Wind Condition

The prevailing wind direction under annual and summer conditions are dominated by E / NE and E / ESE/ SW / SSW wind directions respectively as discussed in Section 3. With the consideration of the existing and committed/ planned developments near the Project Site, the existing wind condition are qualitatively assessed in below.

4.1 Annual Wind Condition

Under annual wind condition, the prevailing winds are mainly coming from Northeast (NE) and East (E) directions.

NE Wind (Figure 11)

Under NE wind condition, Cheung Sha Wan Road is generally aligned in parallel to the prevailing wind directions. Thus, it is expected that the high portion of prevailing wind could flow along Cheung Sha Wan Road (**Orange** Arrow). The presence of the mid-rise building clusters (**Blue** Shaded Region) and some high-rise buildings (**Pink** Shaded Region) are located at the upwind direction from the project site. These building clusters would block the incoming wind and induces wake zone within the site. Although several streets are connected to Cheung Sha Wan Road within the building clusters, they are general narrow and is not effective in term of wind penetration. Hence, the wind environment at the project site is expected to be relatively low.

The high-rise building clusters (**Pink** Shaded Region) is situated at the eastern portion of Lai Chi Kok Area. The building clusters is expected to provide significant wind blockage impacts to Lai Chi Kok Road. Instead, the building clusters is expected to divert most of the NE prevailing wind southward and results in more wind flow towards Cheung Sha Wan Temporary Wholesale Poultry Market (**Red** Arrow).

E Wind (Figure 11)

The eastern portion of Lai Chi Kok Area (**Green** Shaded Region) is a large open area, which includes Cheung Sha Wan Temporary Wholesale Poultry Market and Sham Shui Po Sports Ground. These open space could possibly act as wind entrance for Lai Chi Kok Road and facilitates E wind to flow along and further towards Sham Mong Road (**Green** Arrow).

As the building mass of Cheung Sha Wan (CSW) Police Station is mainly situated at the edge of site boundary along Lai Chi Kok Road. It is expected to shield the incoming wind and induce wind shadow to the project site. Minor wind flow can still reach the project site from the road, but the overall ventilation environment is still expected to be relatively calm.

On the other hand, the high-rise building clusters (**Pink** Shaded Region) would block some of the E prevailing wind from entering Cheung Sha Wan Road, thus the road's wind environment is also excepted to be relatively lower as compared with NE wind condition.

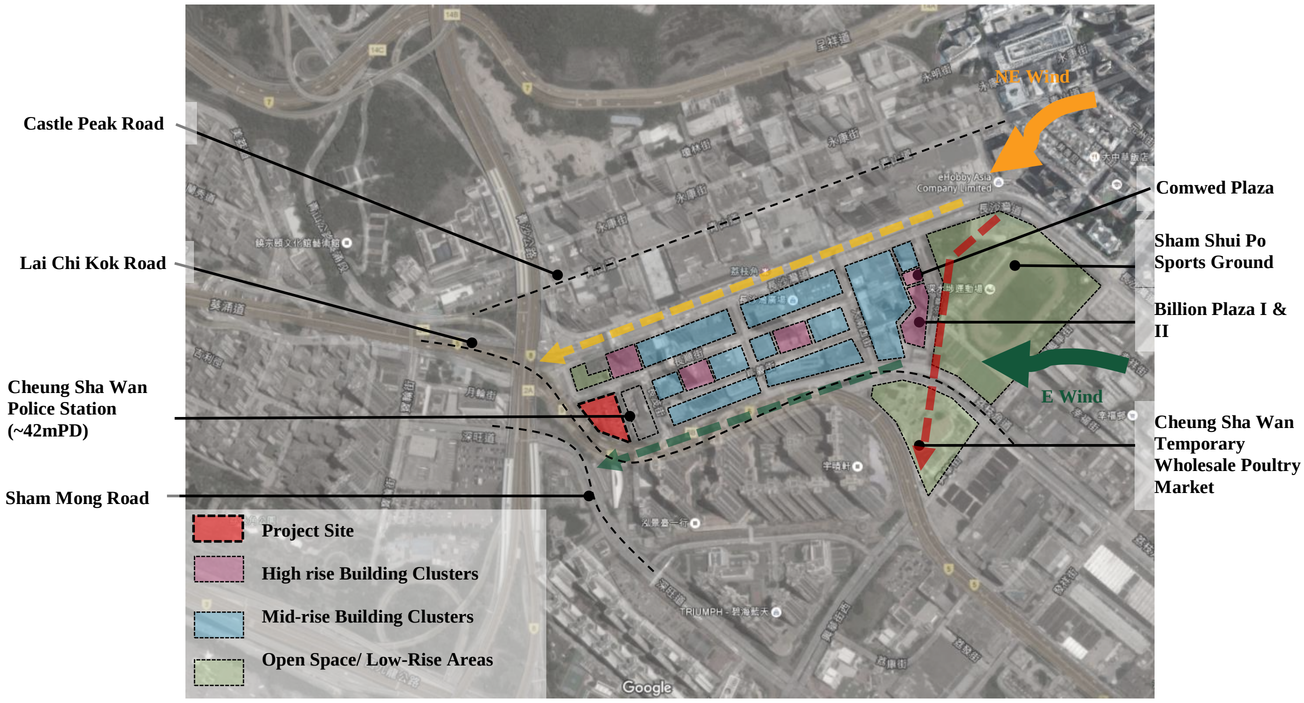


Figure 11 Annual wind condition (Image Source: Google Earth)

As suggested by the CSW EE report, both Cheung Sha Wan Road and Castle Peak Road could potentially act as annual and/ or summer air paths under south-westerly prevailing wind. Also, the large scale development could potentially bring adverse ventilation impacts to Cheung Sha Wan Area.

Nevertheless, under the latest RAMS wind data it is suggested the annual prevailing wind mainly from NE (12.9%) and E (28.4%) direction, while the SW wind frequency only contribute 5.4% of the total annual wind.

Therefore, it is expected the presence of the Proposed Development will not impose significant adverse ventilation impacts to aforementioned air path as the project site is located at the downwind region under the annual wind condition.

4.2 Summer Wind Condition

Under summer condition, the prevailing winds are mainly coming from East (E), East-Southeast (ESE), Southwest (SW) and South-South-West (SSW) directions. For E wind condition, please refer to Section 4.1 for the qualitative assessment.

SW and SSW Winds (Figure 12)

The large building gap space between Hoi Lai Estate and Mei Foo Sun Chuen act as a wind entrance and create a wind path along Tsing Sha Highway. It is expected both SW and SSW winds would penetrate through the open area of KMB Temporary Bus Depot effectively into western portion of Lai Chi Kok Area (**Orange** Arrow) to promote the wind performance.

It is noted that there are some large elevated structure situated in at the entrance upwind direction, such as West Kowloon Highway and Tsing Sha Highway would slightly obstruct the incoming wind and could possibly induce small wind shadow regions at KMB Temporary Bus Depot, Hoi Lai Estate and low-rise committed development.

A portion of incoming winds from Tsing Sha Highway could also penetrate through the low-rise sewage pumping station and across Sham Mong Road into the Project Site (**Blue** Arrow). As the existing condition of the Project Site is open car park, the incoming wind is expected to penetrate across the site freely towards the Cheung Sha Wan Police Station and Cheung Shun Street (**Green** Arrow). Furthermore, the low-rise building at the north of the site allow the incoming wind penetrate atop the building towards Cheung Sha Wan Road (**Red** Arrow).

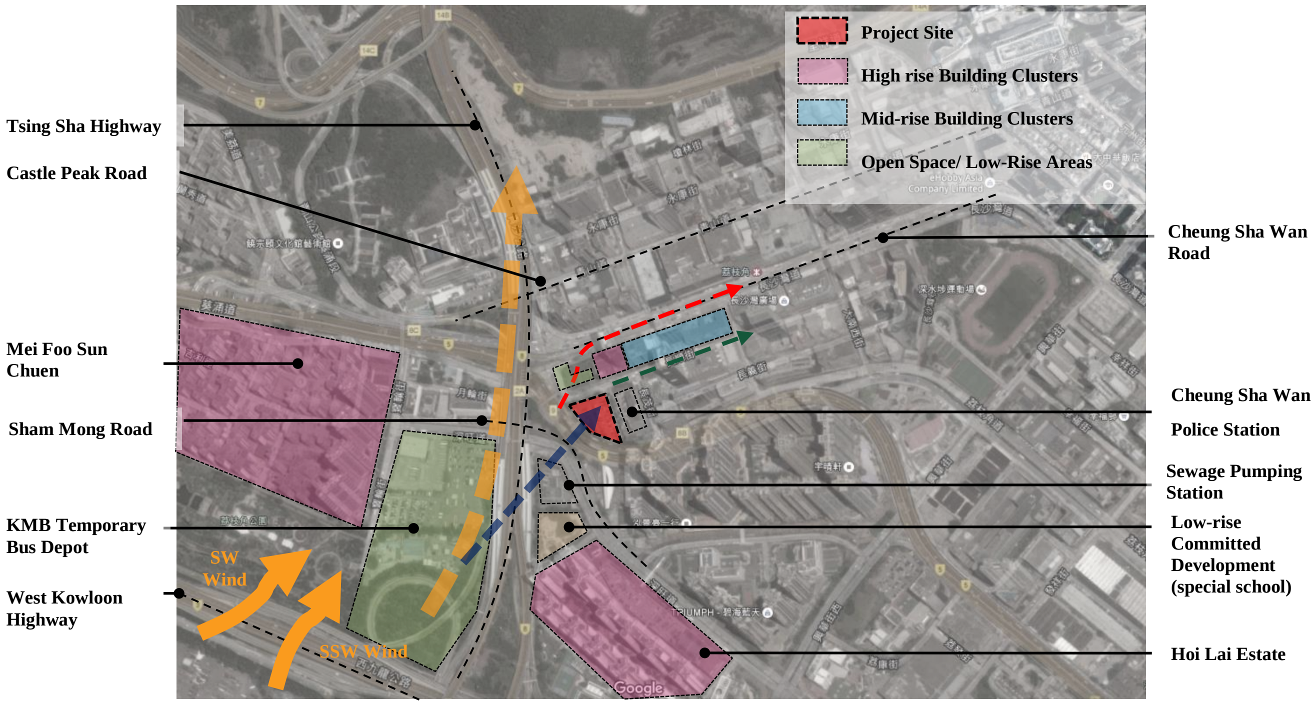


Figure 12 Summer wind condition (Image Source: Google Earth)

Under south-westerly wind condition, both Cheung Sha Road and Castle Peak Road could potentially act as summer air paths with reference to the CSW EE report.

Similarly, the large scale development could potentially bring adverse ventilation impacts to Cheung Sha Wan Area.

For summer wind, the Proposed Development would be located at the upwind region and would potentially block some of the summer wind from SW and SSW direction. However, as the project site is located far away from the wind entrance of the main air paths such as Castle Peak Road, it is expected that the Proposed Development will not impose significant ventilation impact to the inland region. However, it is expected the Development would still induce some localized wake zone at Cheung Shun Street and open area of CSW Police Station.

ESE Wind (Figure 13)

The eastern portion of Lai Chi Kok Area (**Green** Shaded Region) is a large open area includes Cheung Sha Wan Temporary Wholesale Poultry Market. This open area could possibly act as wind entrance for Lai Chi Kok Road and facilitates ESE wind to flow along and further towards Sham Mong Road (**Green** Arrow).

The high-rise residential building clusters (**Pink** Shaded Region) at the southern side such as One West Kowloon, Banyan Garden, Liberte, The Pacifica and Aqua marine would block the ESE prevailing wind significantly from low level to mid-level. In this situation, the wind at pedestrian level would divert to the main road such as Lai Chi Kok Road and Sham Mong Road and approach to the site (**Orange** Arrow and **Green** Arrow).

Even through good wind environment is expected along Lai Chi Kok Road, the presence of the Cheung Sha Wan Police Station at the adjacent site would block a portion of incoming wind and thus the wind environment within the project site is expected to be calm.

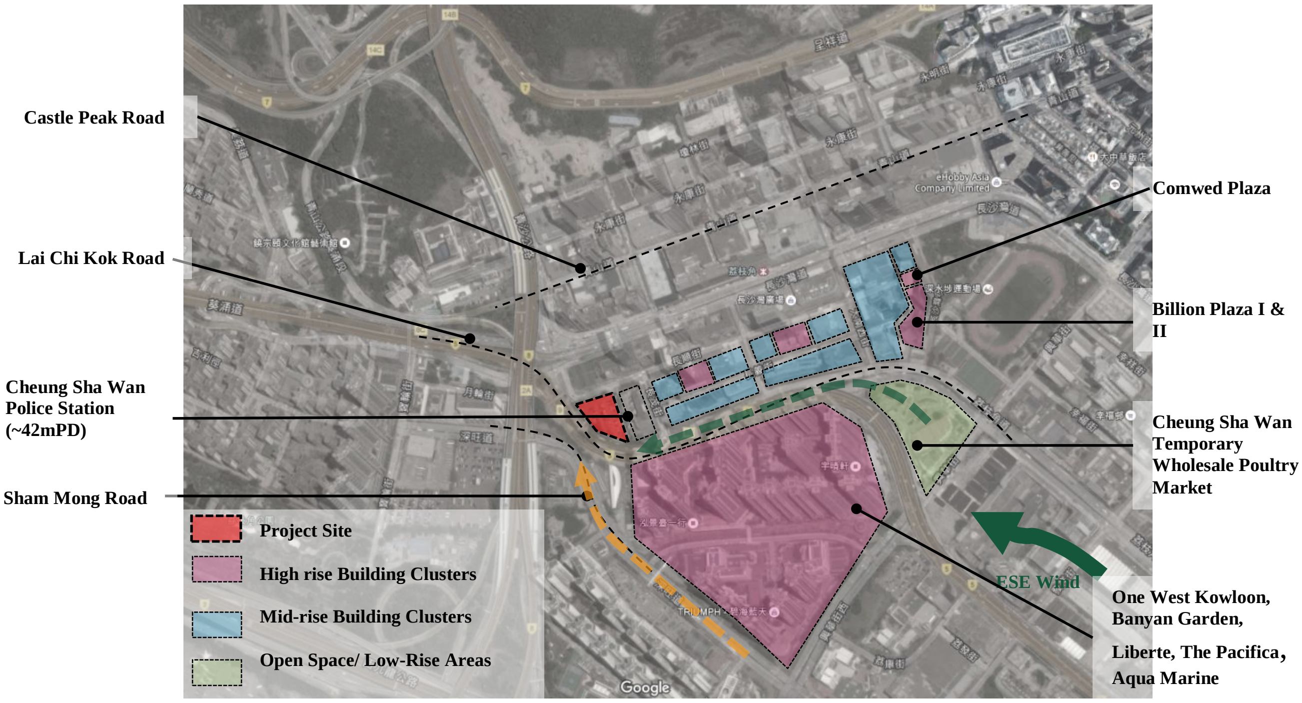


Figure 13 Annual wind condition (Image Source: Google Earth)

From the latest RAMS data, ESE direction contributes to 12% of summer prevailing wind. Similar to E and NE wind direction, as the project site is located at the downwind region, the ventilation impact due to the Proposed Development is insignificant.

5 Methodology

5.1 Studied Scenarios

Three scenarios – namely Baseline Scenario, Scenario A and Scenario B are assessed under both annual and summer wind conditions. The three-dimensional model showing the developments within the surrounding area. The views can be refer through Figure 14 to Figure 17 under different directions.

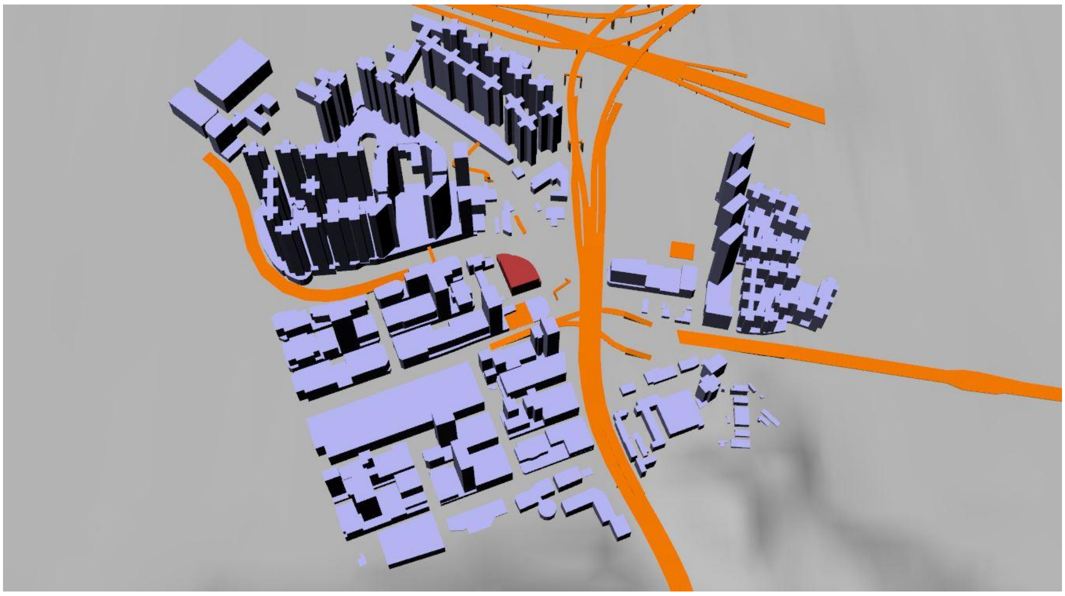


Figure 14 Northerly view for the 3D model

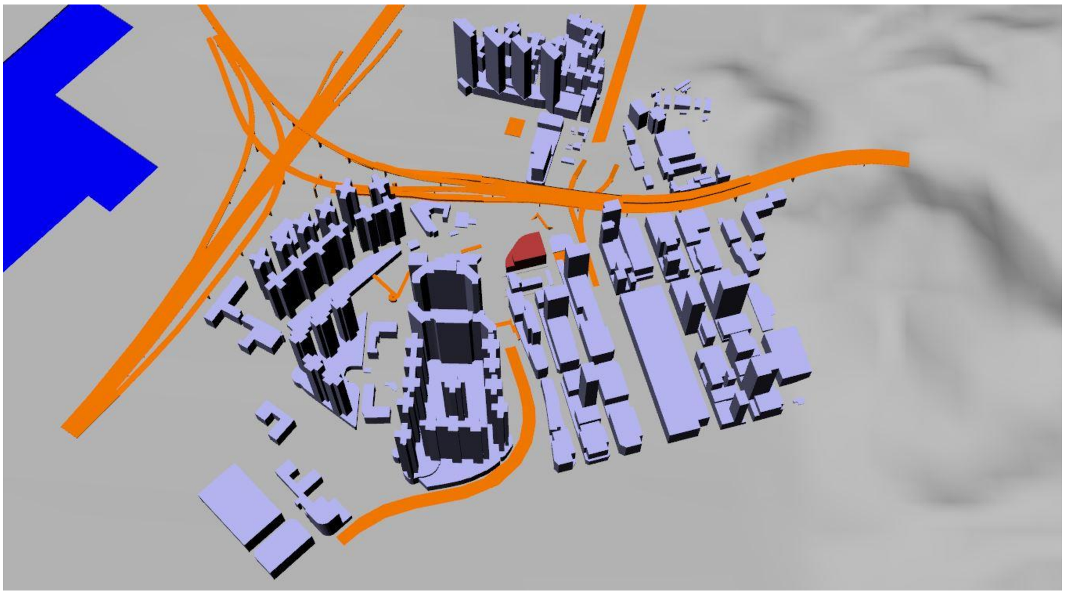


Figure 15 Easterly view for the 3D model

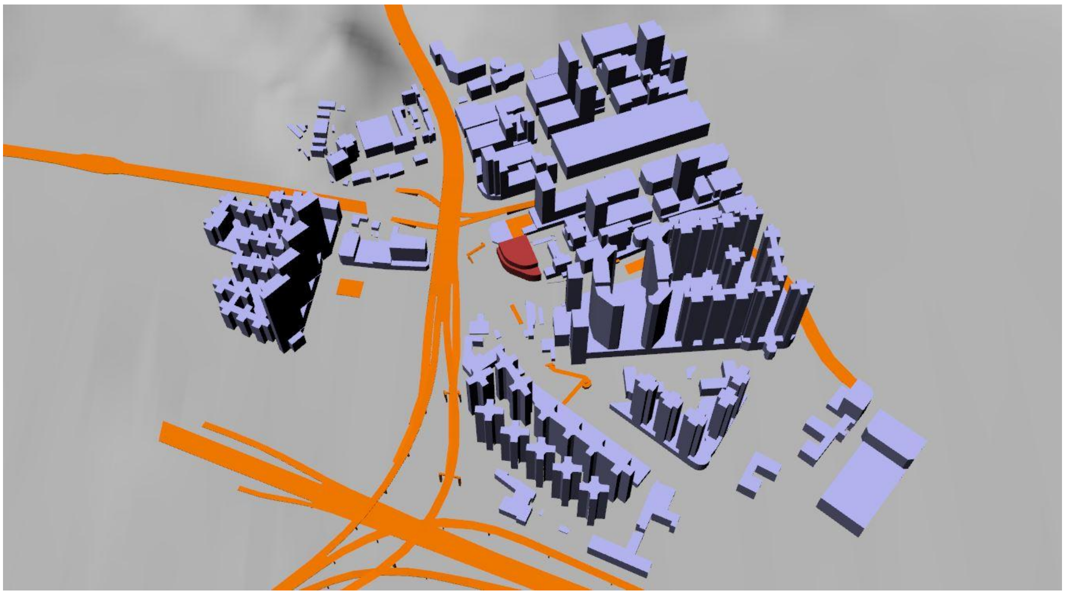


Figure 16 Southerly view for the 3D model

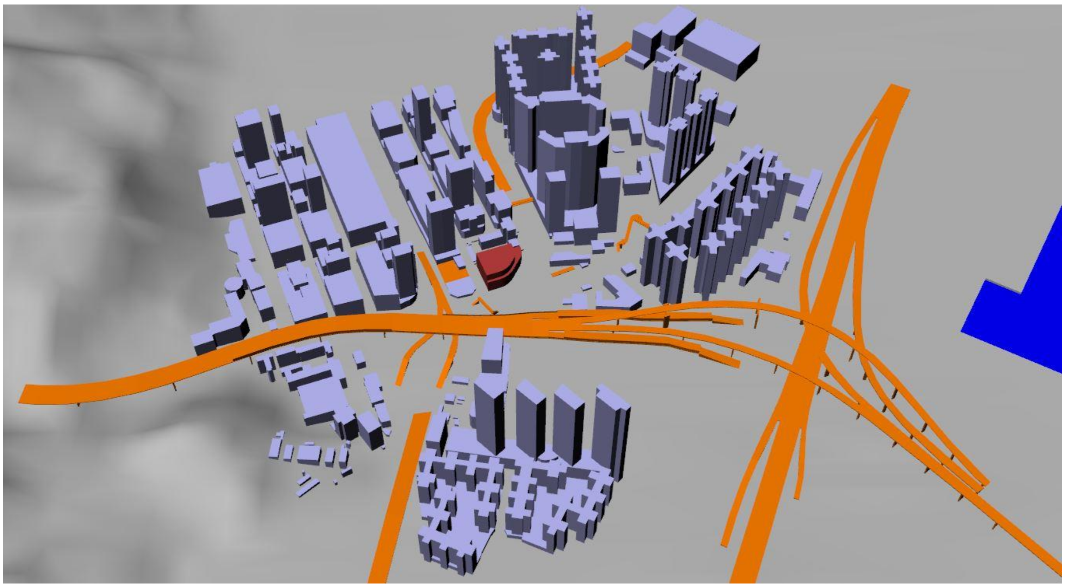


Figure 17 Westerly view for the 3D model

5.1.1 Baseline Scenario

The Baseline Scenario represents a GIC development with building height not exceeding 13 storeys, which is an OZP-conforming scheme. The building tower is setback from south boundary with a podium of ~26.5mPD and there is an around 6.5m building setback from the east boundary. The building layout and three-dimensional views can be referred through Figure 19 to Figure 22.

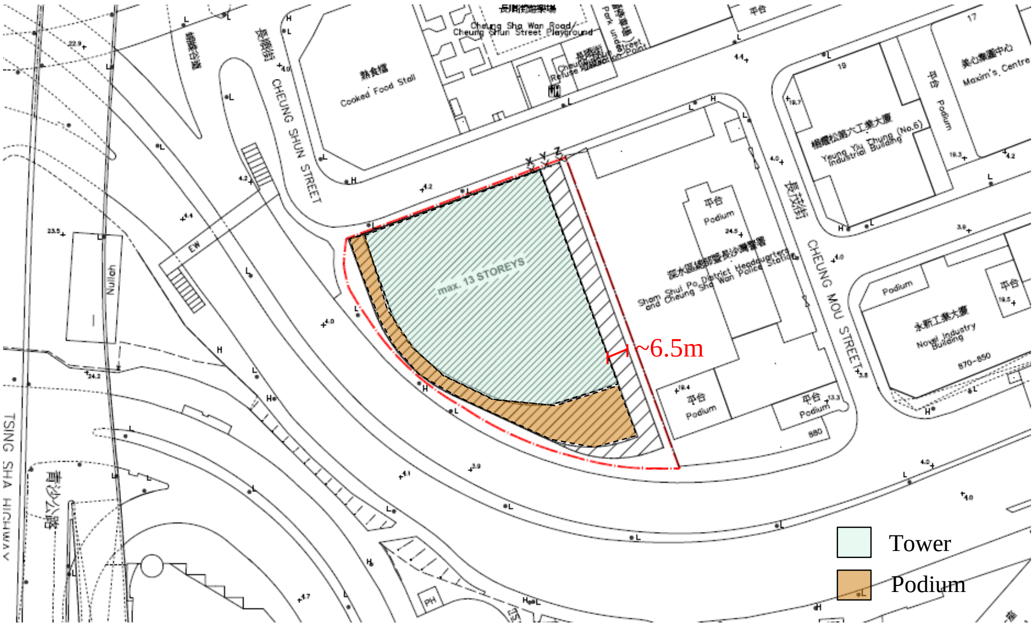


Figure 18 Building layout of Baseline Scenario

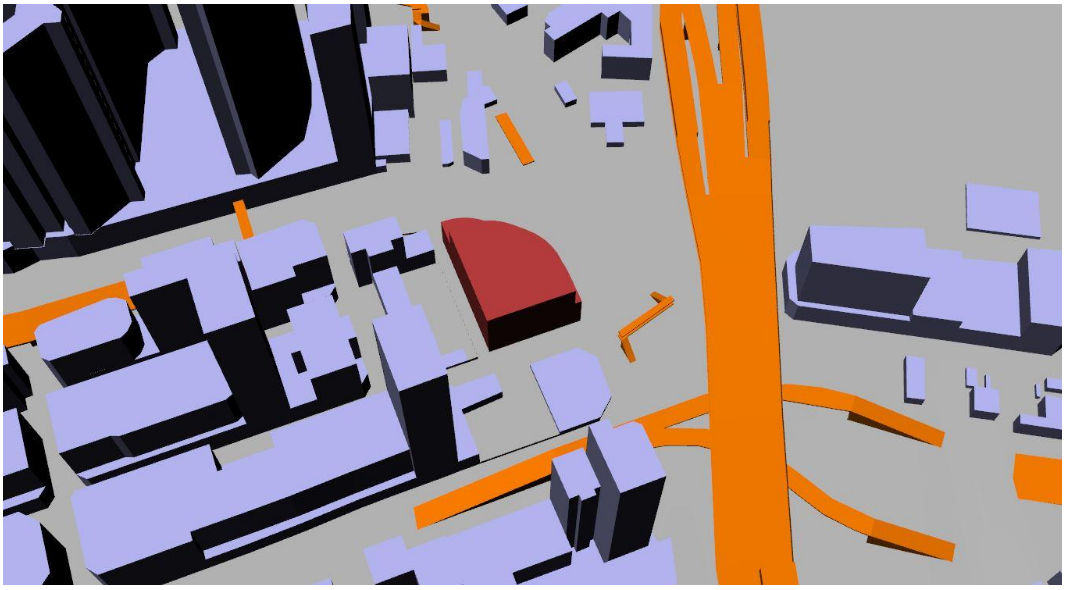


Figure 19 Northerly view for the 3D model under Baseline Scenario

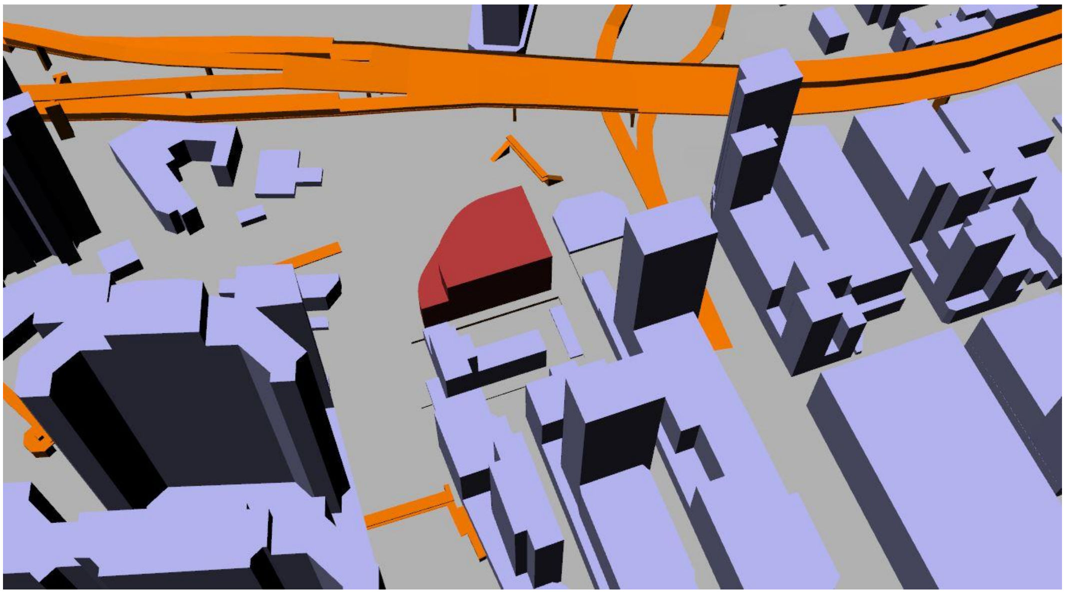


Figure 20 Easterly view for the 3D model under Baseline Scenario

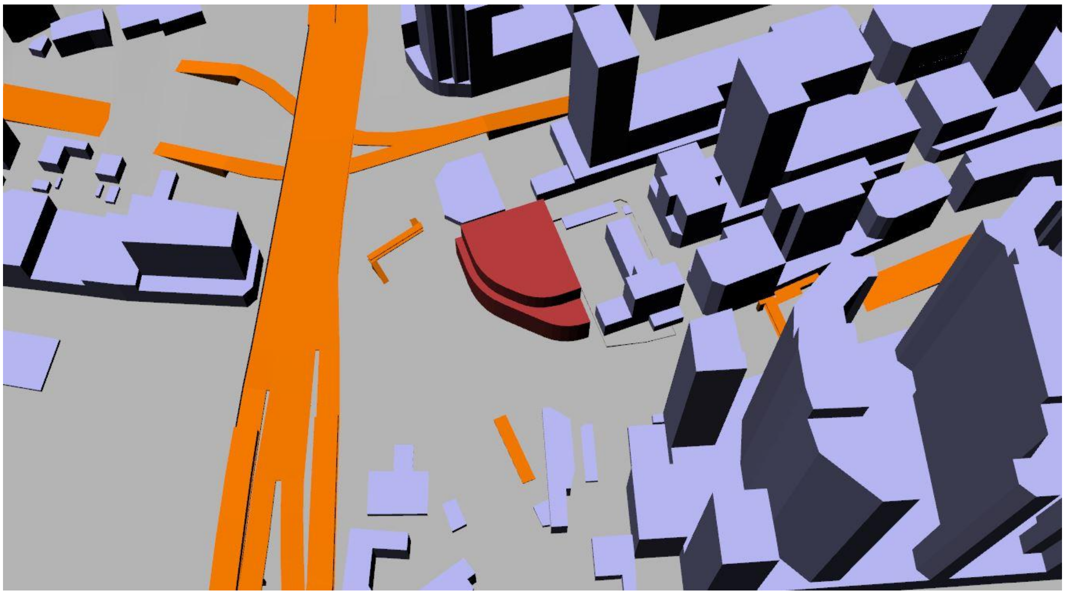


Figure 21 Southerly view for the 3D model under Baseline Scenario

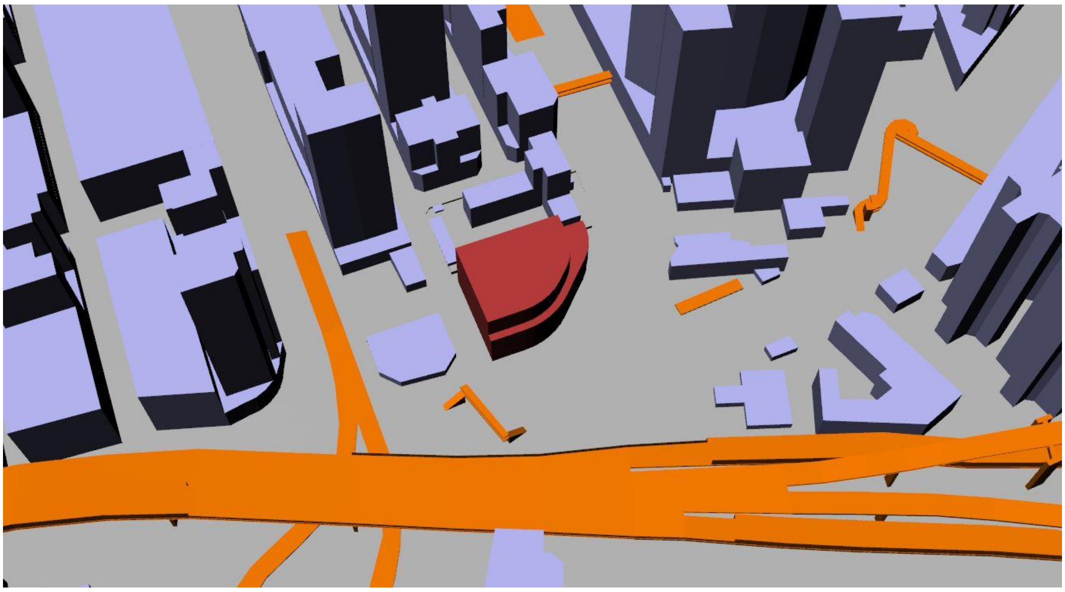


Figure 22 Westerly view for the 3D model under Baseline Scenario

5.1.2 Scenario A

Scenario A presents a commercial development with a Plot Ratio (PR) of 12 and a building height restriction of 120mPD. The design intent is to adopt a conventional podium design with full site coverage at a height of 15m. And a ~10m tower setback design is also adopted from east boundary in Scenario A. A maximum 23m building tower setback is adopted from the south site boundary. The building layout and three-dimensional views can be referred through Figure 24 to Figure 27.

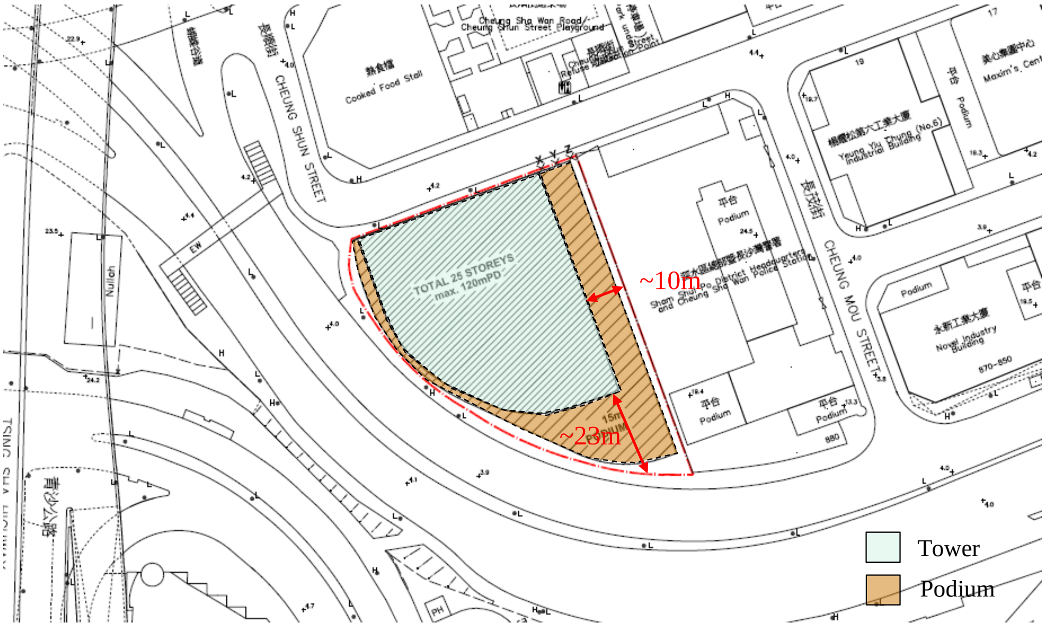


Figure 23 Building layout of Scenario A

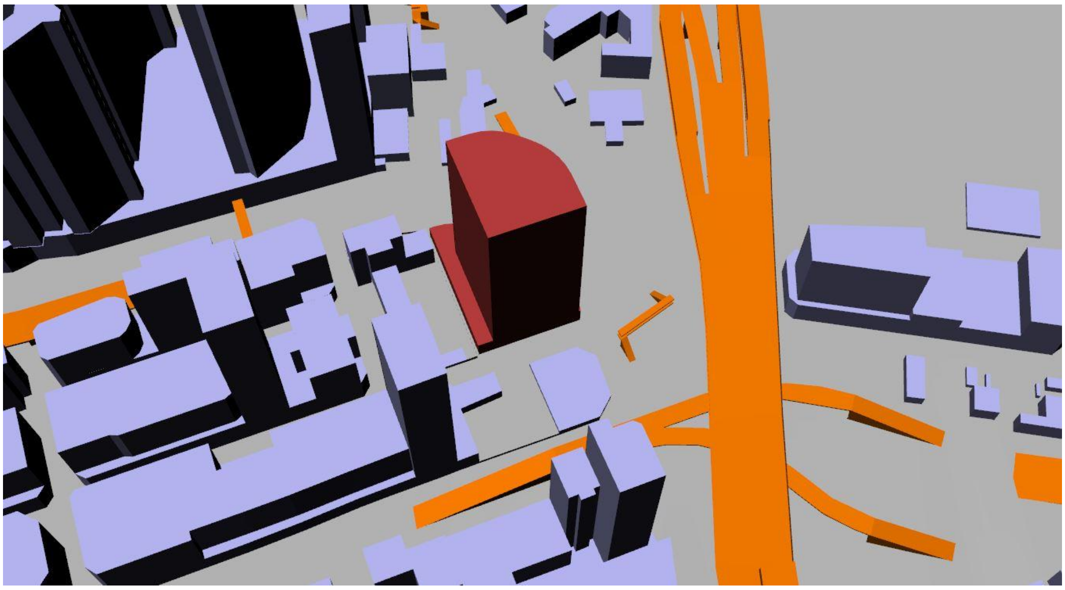


Figure 24 Northerly view for the 3D model under Scenario A

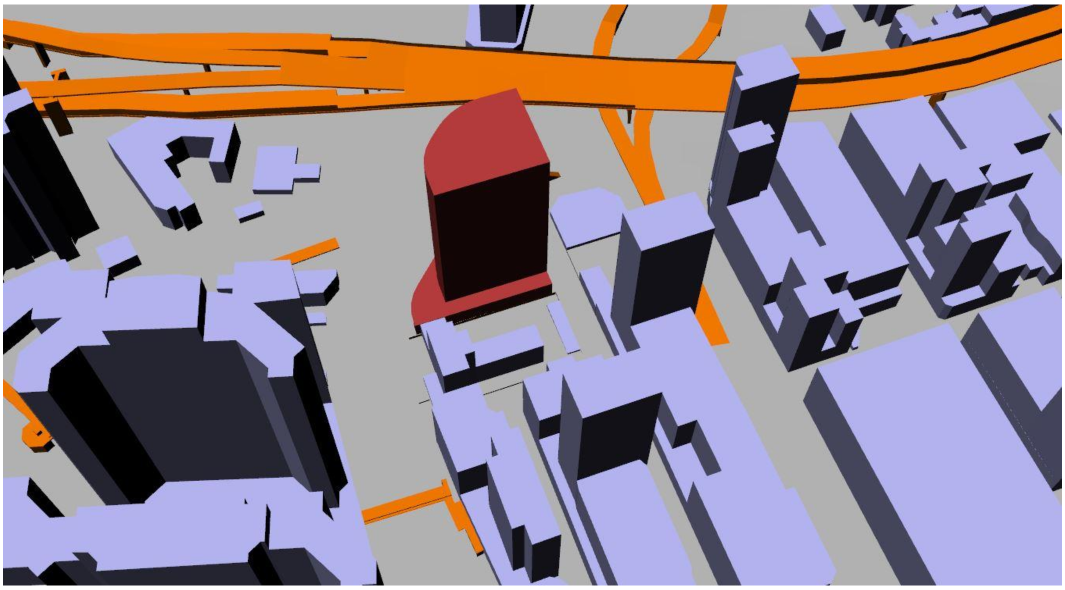


Figure 25 Easterly view for the 3D model under Scenario A

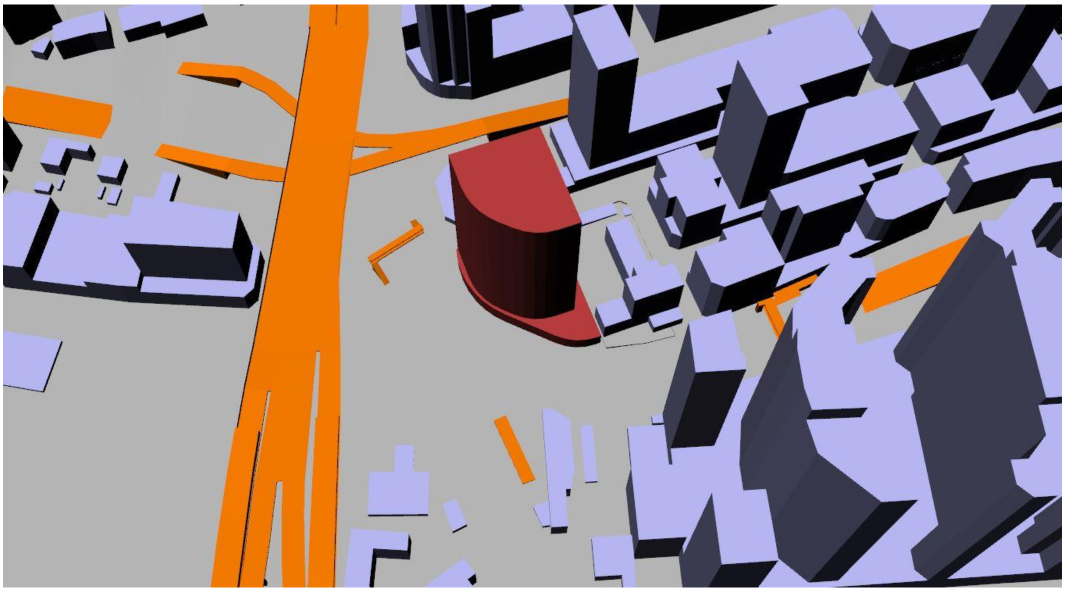


Figure 26 Southerly view for the 3D model under Scenario A

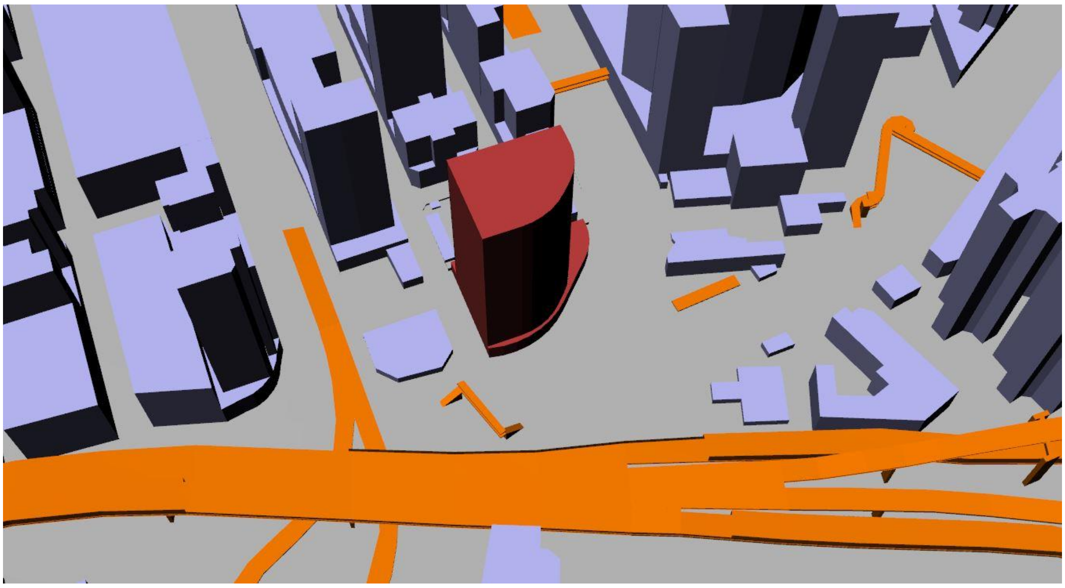


Figure 27 Westerly view for the 3D model under Scenario A

5.1.3 Scenario B

Scenario B presents a commercial development with a PR of 12 and a maximum building height restriction of 120mPD. The design intent is to adopt a pure commercial development with incorporation of mitigation measures to improve air ventilation such as 15m Non-building Area (NBA) and setback from the lot boundaries. There is also a ~4m setback from the north site boundary. At high level, a part of the tower (~25m) at upper level has been trimmed to enlarge the opening for wind penetration. The building layout and three-dimensional views can be referred through Figure 29 to Figure 32.

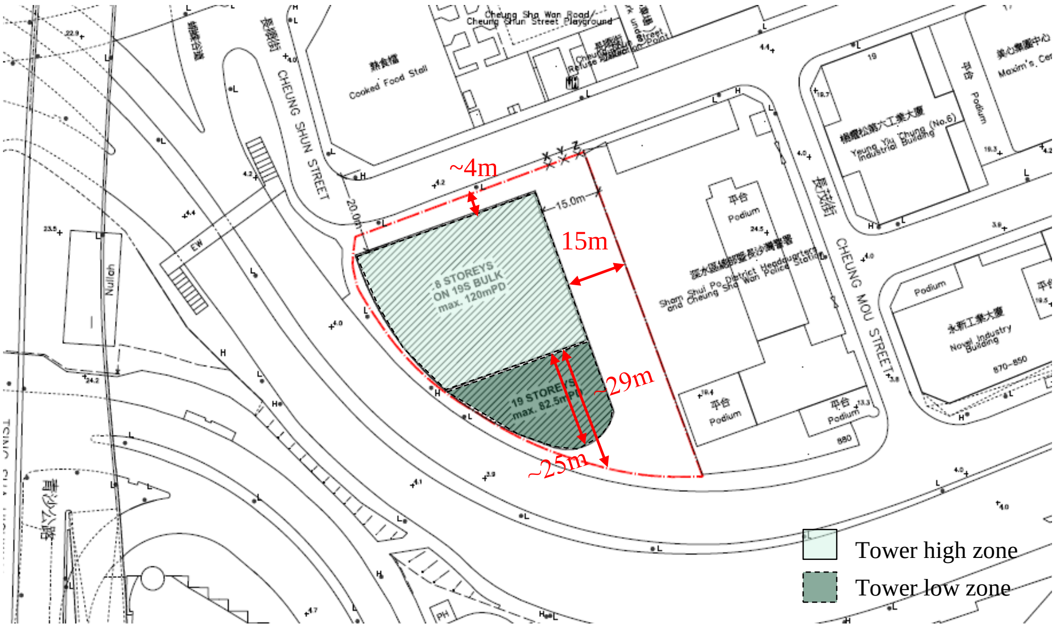


Figure 28 Building layout of Scenario B

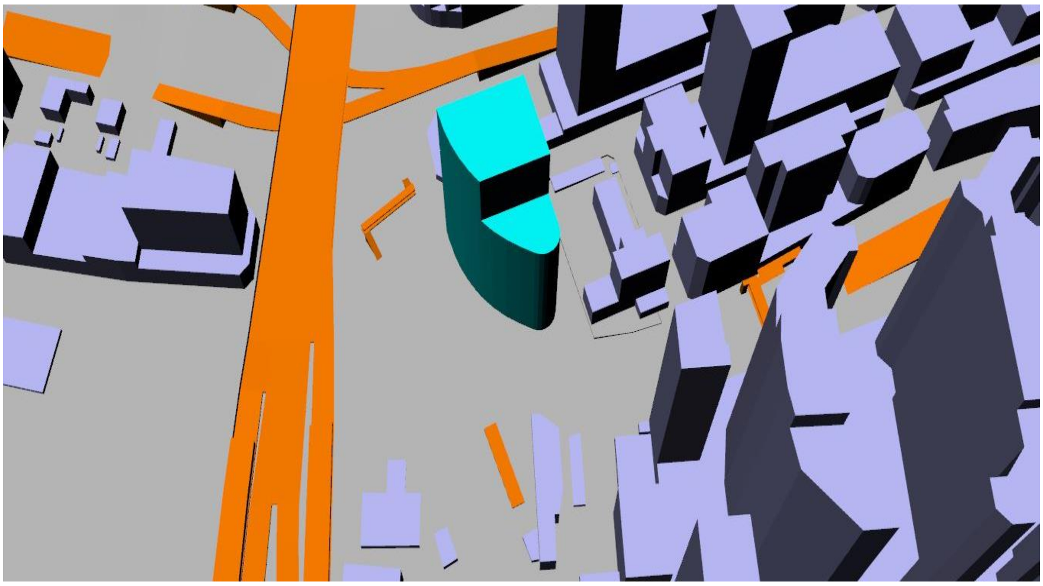


Figure 29 Northerly view for the 3D model under Scenario B

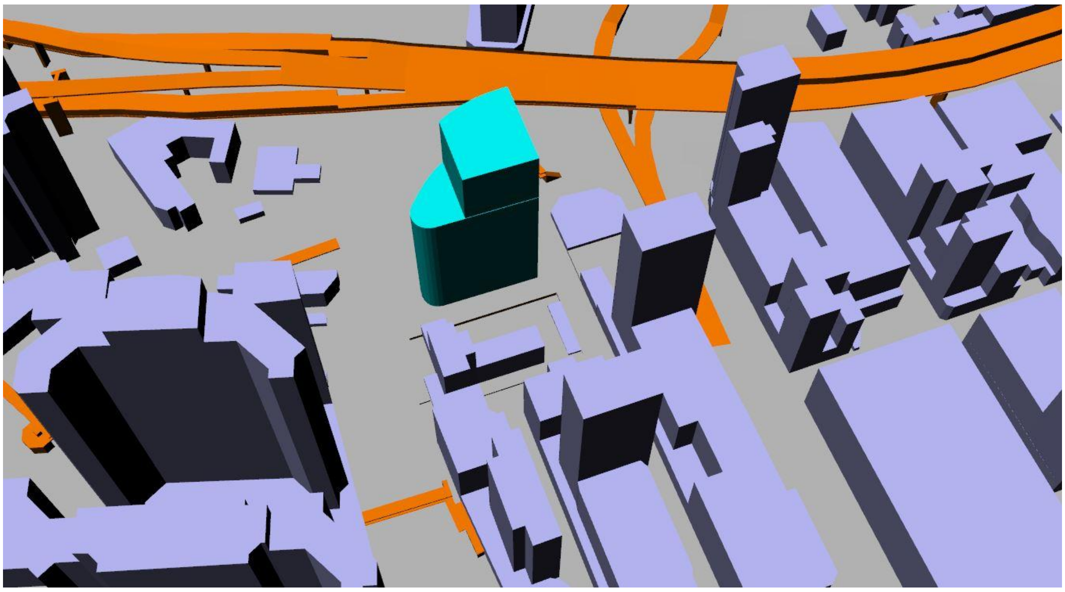


Figure 30 Easterly view for the 3D model under Scenario B

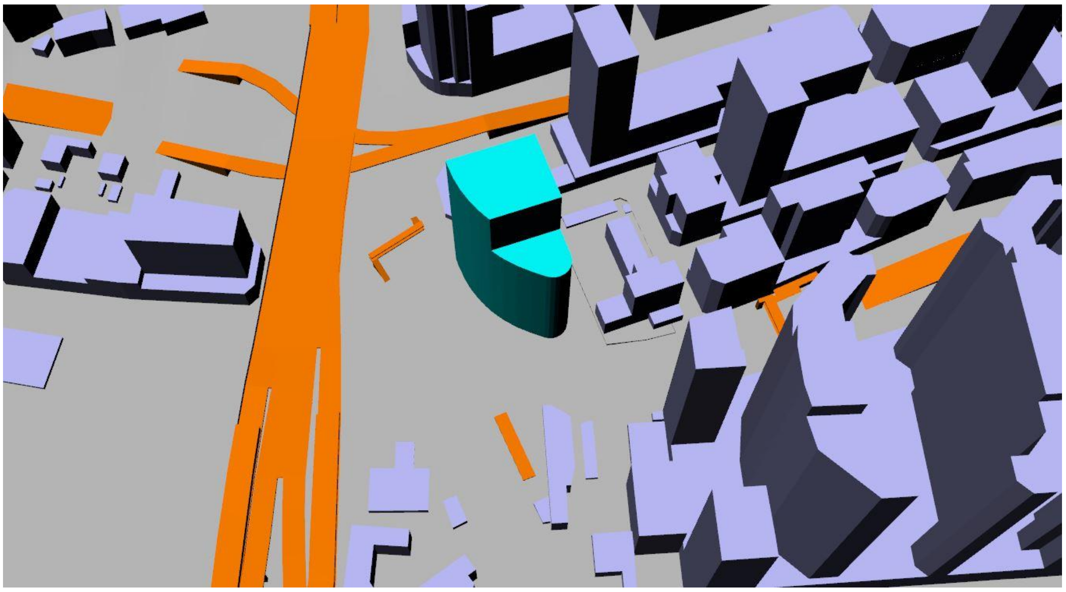


Figure 31 Southerly view for the 3D model under Scenario B

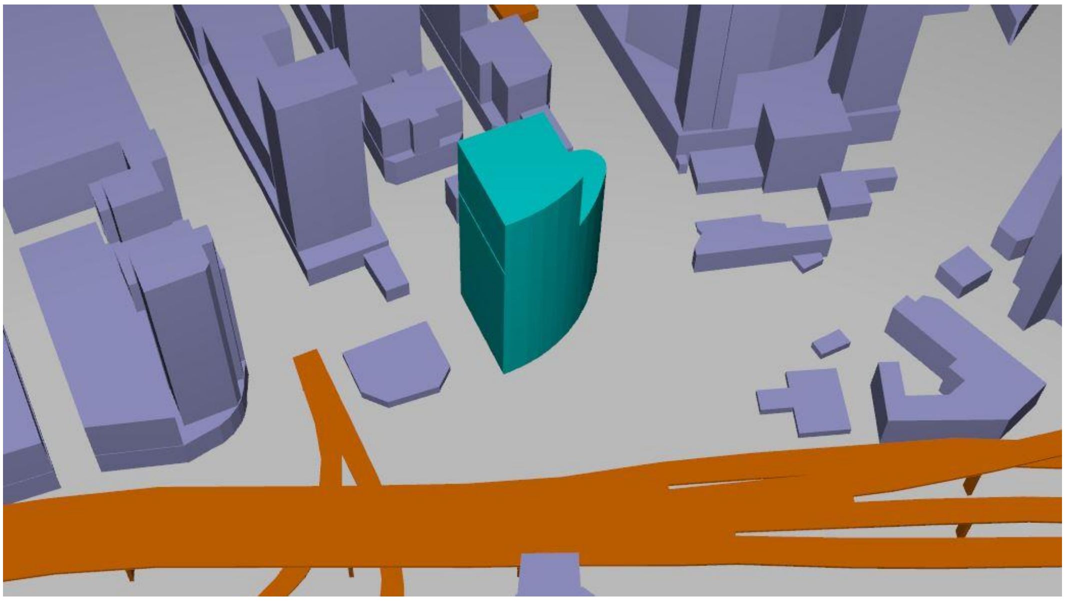


Figure 32 Westerly view for the 3D model under Scenario B

5.2 Technical Details of CFD Simulations

The Air Ventilation Assessment (AVA) methodology for the Study as stipulated in the Technical Circular and Technical Guide was used for this study. The following sections describe the details of the study methodology.

5.2.1 Project Assessment Area and Surrounding Areas

With reference to the Technical Guide, the areas of evaluation and assessment should include all area within the Project Site, as well as a belt up to 1H, where H is the height of the tallest building of the Proposed Development, around the site boundary.

Considering three given development scenarios (shown in Section 5.1), the tallest building of the Proposed Development is 120mPD. Notwithstanding, in order to capture a more representative existing and planned development profile of the surrounding area of the Project Site, the Assessment Area and Surrounding Area are further extend to 200m and 400m respectively, which extend beyond 1H and 2H from the Project Site. The committed/planned developments such as the proposed international school at King Lam Street and the proposed special school near Hoi Lai Estate are included in the current Study. The neighbouring elevated structures, such as West Kowloon Corridor and Tsing Sha Highway was also be modelled in the Study. The Assessment and Surrounding Areas are indicated in Figure 33.

The model takes information of the surrounding buildings and site topography via Geographical Information System (GIS) platform. The size of the CFD model for this Study is approximately 2800m(L) x 2800m(W) x 1800m(H).

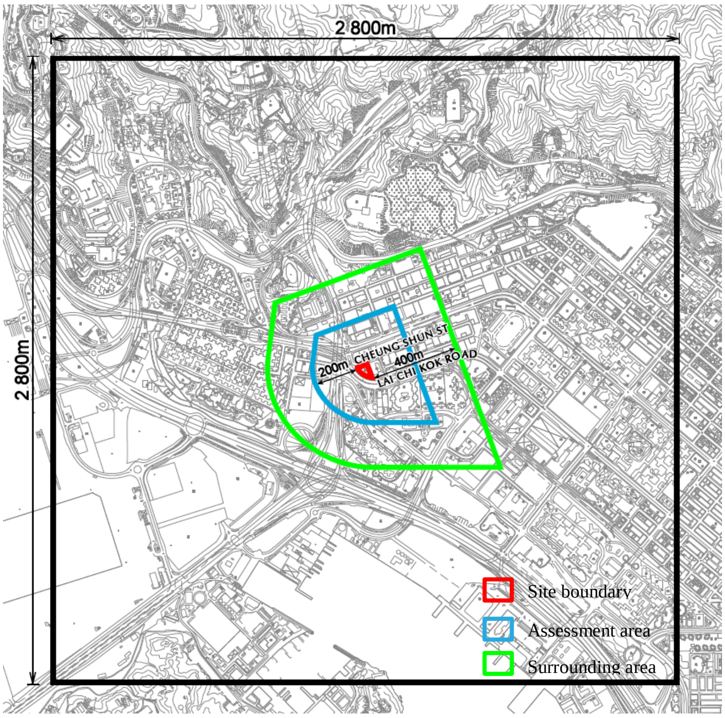


Figure 33 Project Area, Assessment Area, Surrounding Area and Computation Domain for the study (image source: Planning Department)

5.2.2 Assessment Tool

Computational Fluid Dynamics (CFD) technique was utilized for the AVA Initial Study. A well-recognised commercial CFD package ANSYS ICEM-CFD and STAR-CCM+ was used, where both software are widely used in the industry for AVA studies. With the use of three-dimensional CFD method, the local airflow distribution can be visualised in detail. The air velocity distribution within the flow domain, being affected by the site-specific design and the surrounding buildings, are simulated under the prevailing wind conditions in a year.

5.2.3 Mesh Setup

Body-fitted unstructured grid technique is used to fit the geometry to reflect the complexity of the development geometry. A prism layer of 3m above ground (totally 6 layers and each layer is 0.5m) is incorporated in the meshing so as to better capture the approaching wind as shown in Figure 34. The expansion ratio is 1.3 while the maximum blockage ratio is 2%.

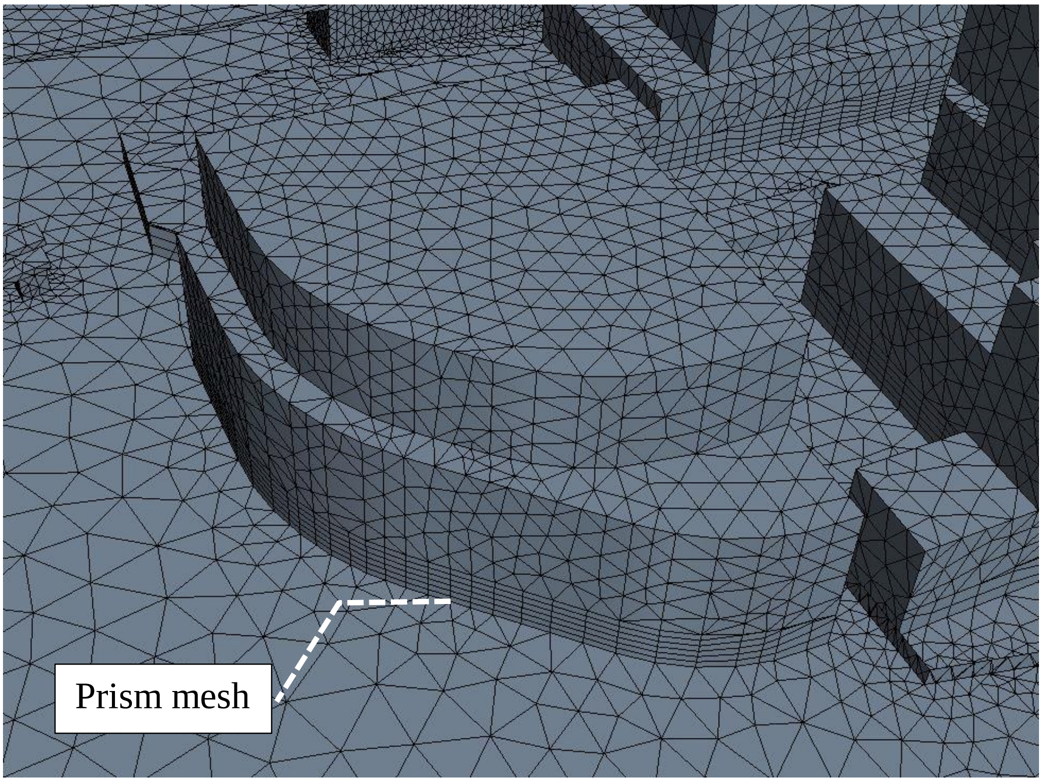


Figure 34 Prism mesh near the pedestrian level

Finer grid system was applied to the most concerned area based on preliminary judgement, while coarse grid system is applied to the area of surrounding buildings for better computational performance while maintaining satisfactory result. The mesh for the computational model is shown in Figure 35.

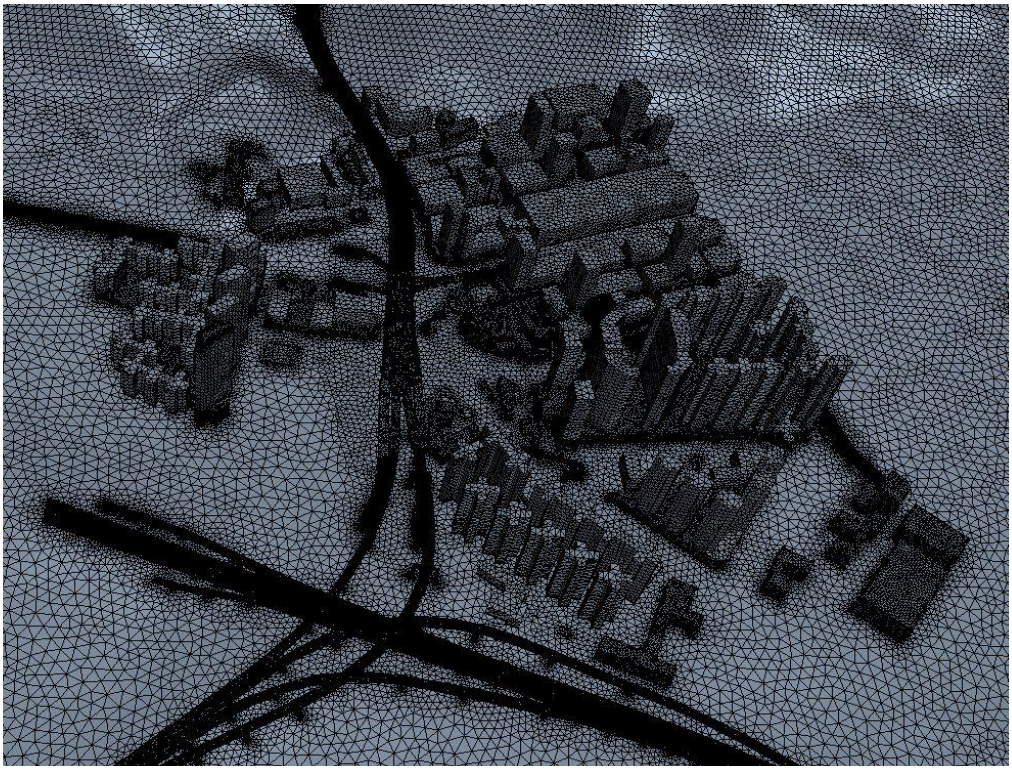


Figure 35 Mesh of the computational model

5.2.4 Turbulence Model

As highlighted in recent academic and industrial research literatures by CFD practitioners, the widely used standard k - ε turbulence model technique may not adequately model the effects of large scale turbulence around buildings and ignores the wind gusts leading to the relatively poor prediction in the recirculation regions around building. Therefore in this CFD simulation, realizable $k - \varepsilon$ turbulence modelling method is applied. This technique provides more accurate representation of the levels of turbulence that can be expected in an urban environment.

5.2.5 Calculation Method

The Segregated Flow model solves the flow equations in a segregated manner. The linkage between the momentum and continuity equations adopted the predictor-corrector approach. A collocated variable arrangement and a Rhie-and-Chow-type pressure-velocity coupling combined with a SIMPLE-type algorithm. A higher order differencing scheme is applied to discretize the governing equations. The convergence criterion is set to 0.0005 on mass conservation. The calculation will repeat until the solution satisfies this convergence criterion.

The prevailing wind direction are set to inlet boundary of the model with wind profile as detailed in Section 3.2.3. The downwind boundary is set to pressure with value of atmospheric pressure. The top and side boundaries are set to symmetry. In addition, to eliminate the boundary effects, the model domain is built beyond the Surrounding Area as required in the Technical Circular.

5.2.6 Summary

Based on previous sections, the detail parameters are summarized below.

	CFD Model
Physical Model Scale	Real scale model, 1:1 scale
Model details	Only include Topography, Buildings blocks, Streets/Highways, no landscape is included
Domain	2800m(L) x 2800m(W) x 1800m(H)
Assessment Area	200m from the Project Site
Surrounding building Area	400m from the Project Site
Grid Expansion Ratio	The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.3
Prismatic layer	6 layer of prismatic layers and 0.5m each (i.e. total 3m above ground)
Inflow boundary Condition	Incoming wind profile as measured from RAMS
Outflow boundary	Pressure boundary condition with dynamic pressure equal to zero
Wall boundary condition	Logarithmic law boundary
Solving algorithms	Rhie and Chow SIMPLE for momentum equation Hybrid model for all other equations
Blockage ratio	<2%
Convergence criteria	Below $1.0E^{-4}$

5.3 AVA Indicator

The Wind Velocity Ratio (VR) as proposed by the Technical Circular was employed to assess the ventilation performances of the Proposed Development and surrounding environment. Higher VR implies better ventilation. The calculation of VR is given by the following formula:

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

V_P = the wind velocity at the pedestrian level (2m above ground) after taking into account the effects of buildings.

V_∞ = the wind velocity at the top of the wind boundary layer (typically assumed to be around 500m above the centre of the site of concern, or at a height where wind is unaffected by the urban roughness below).

The higher the value of VR, the less is the impact due to buildings on wind availability.

The Average VR is defined as the weighted average VR with respect to the percentage of occurrence of all considered wind directions. This gives a general idea of the ventilation performance at the considered location at both annual and summer wind condition.

5.3.1 Assessment Parameters

CFD simulations were conducted to study the wind environment under annual and summer wind condition. As specified in the Technical Circular, indicator of ventilation performance should be the Wind Velocity Ratio (VR), defined as the ratio of the wind velocity at the pedestrian level (2m above ground) to the wind velocity at the top of the wind boundary layer. Site spatial average velocity ratio (SVR) and a Local spatial average velocity ratio (LVR) should be determined.

Table 6 Terminology of the AVA Initial Study

Terminology	Description
Velocity Ratio (VR)	The velocity ratio (VR) represents the ratio of the air velocity at the measurement position to the value at the reference points.
Site spatial average velocity ratio (SVR)	The SVR represent the average VR of all perimeter test points at the site boundary which identified in the report.
Local spatial average velocity ratio (LVR)	The LVR represent the average VR of all points, i.e. perimeter and overall test points at the site boundary which identified in the report.

5.4 Test Points for Site and Local Ventilation Assessment

Test points are evenly placed along the site boundary and within the assessment area of the Proposed Development to determine the ventilation performance. There are three types of test points in the study:

5.4.1 Perimeter Test Points

Perimeter test points are the points positioned at the boundary of the Project Site. In accordance with the Technical Circular for AVA, 30 perimeter points (purple spots) are positioned at interval of 10 – 50m alongside the site boundary as shown in Figure 36.

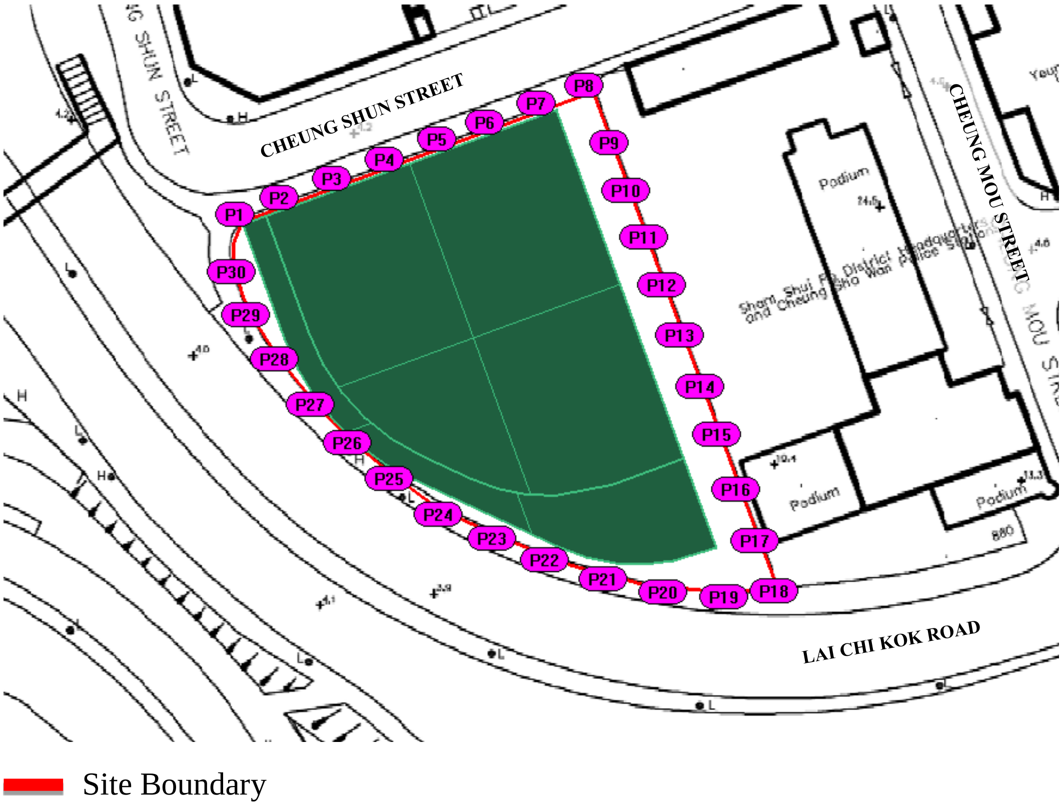
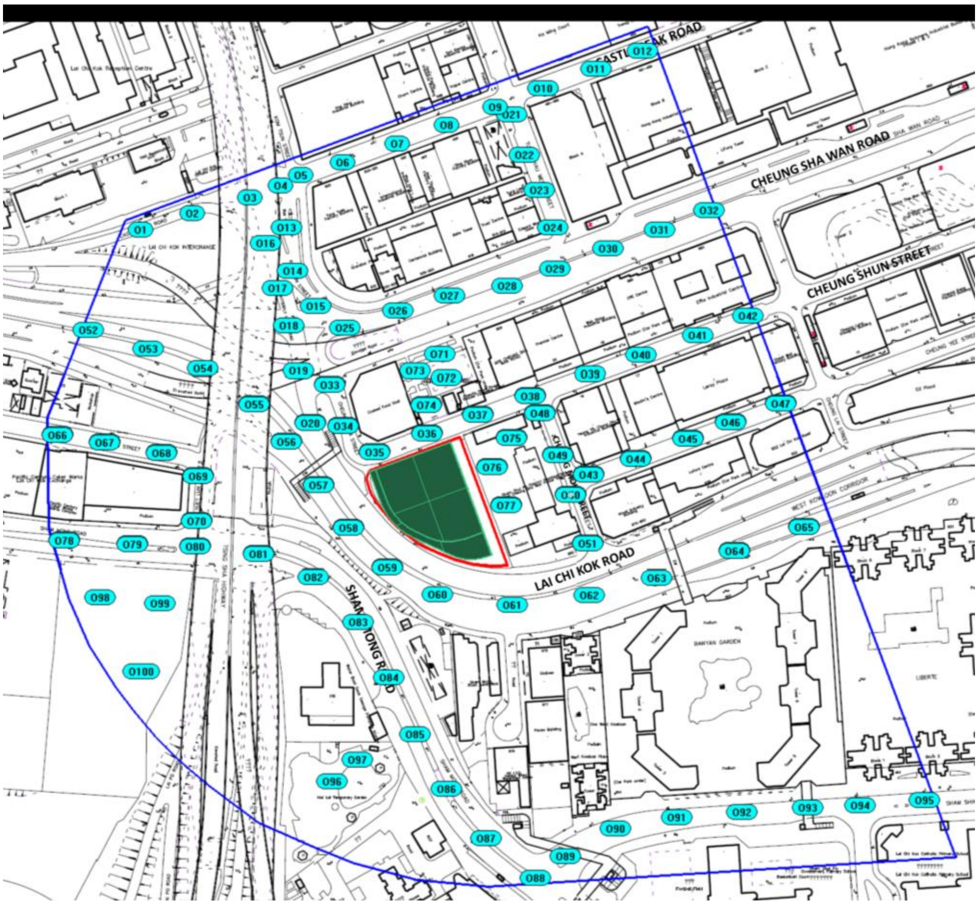


Figure 36 Location of perimeter test points (Image Source: Google Map)

5.4.2 Overall Test Points

Overall test points are those points evenly positioned in the open area, on the streets and places where pedestrian frequently access within the assessment area. 100 overall test points (blue spots) are selected and shown in Figure 37.



Site Boundary
Assessment Area

Figure 37 Location of overall test points (Image Source: Google Map)

5.4.3 Special Test Points

Special test points are the points evenly positioned in the open area that pedestrian can access within the site boundary. 8 special test points (orange spots marked with "SBS") are selected for Scenario B and the location of points are shown in Figure 38.

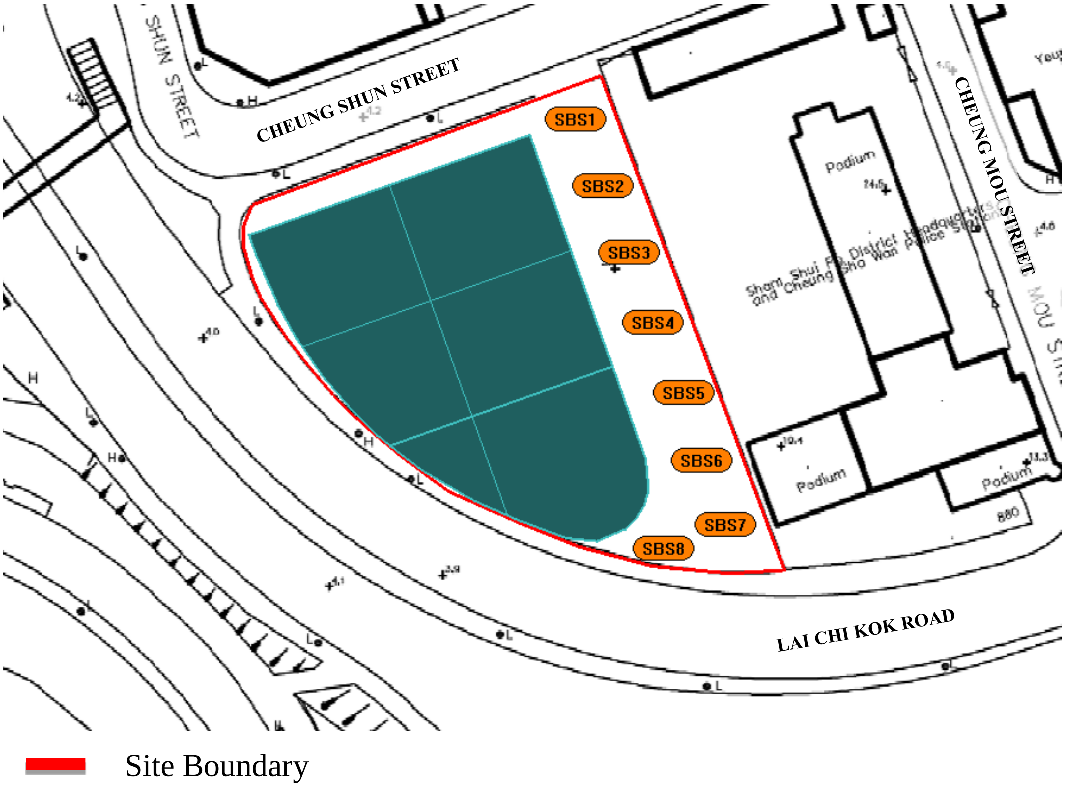


Figure 38 Location of special test points under Scenario B (Image Source: Google Map)

6 Results and Discussion

The following sections discuss the wind performance within the assessment area. The directional contour plots and vector plots are given in Appendix C and D of this report.

6.1 Annual Overall Pattern of Ventilation Performance

The wind performance of Baseline Scenario, Scenario A and Scenario B under annual wind condition are shown in Figure 39 through Figure 41 respectively.

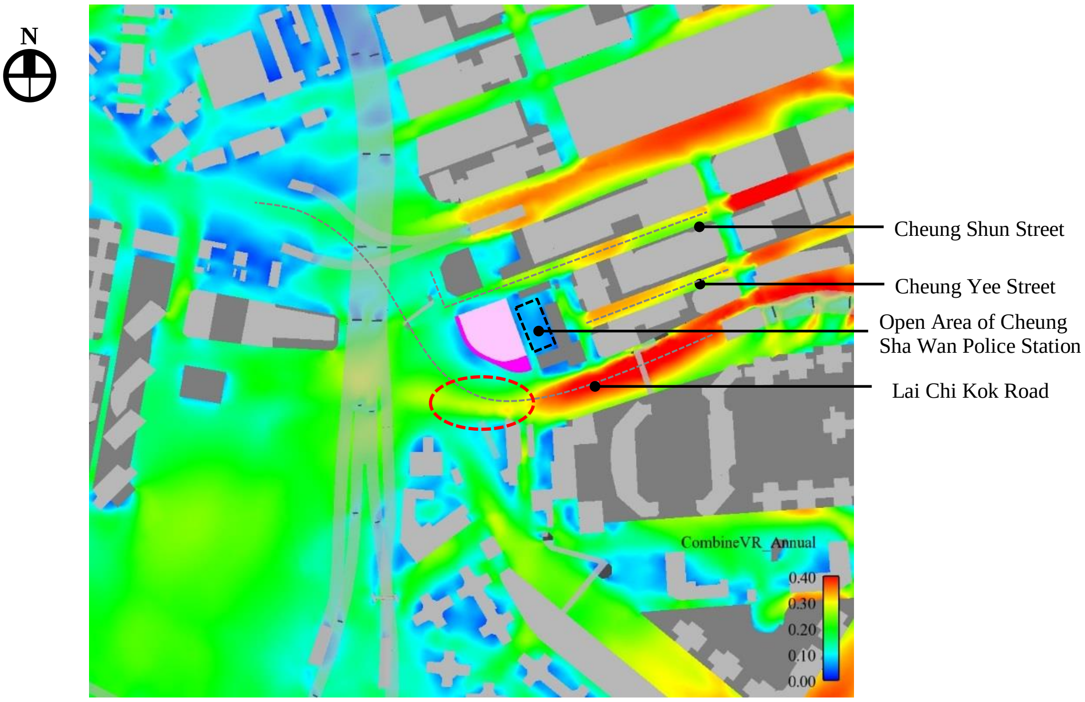


Figure 39 Contour plot of annual weighted VR of Baseline Scenario

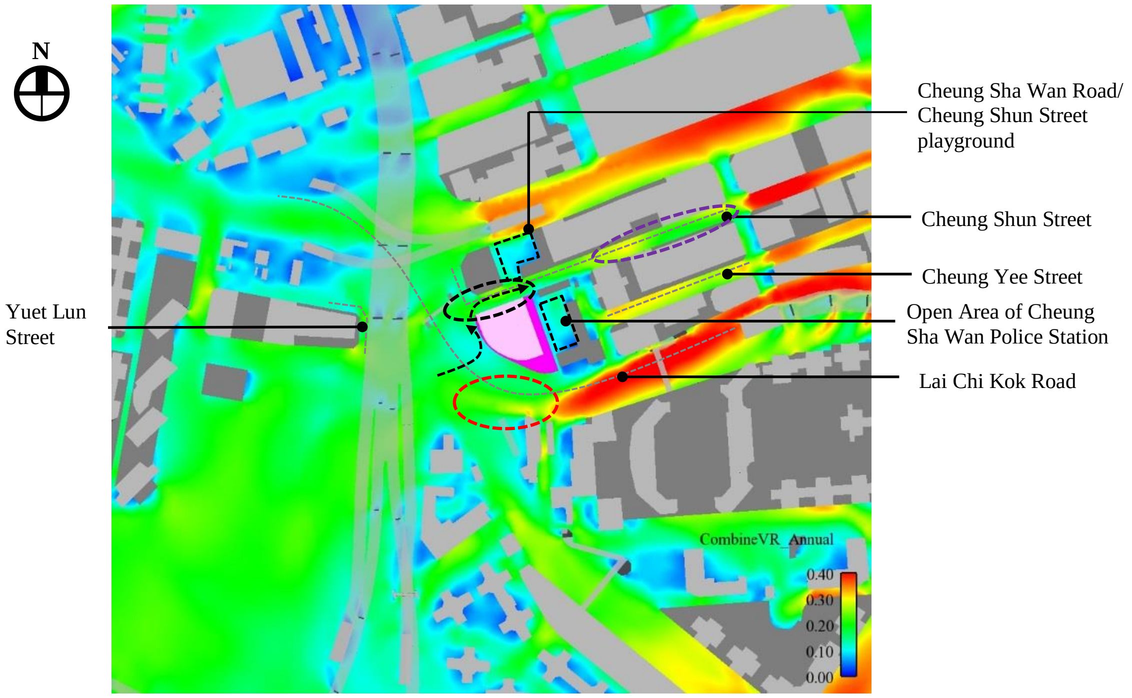


Figure 40 Contour plot of annual weighted VR of Scenario A

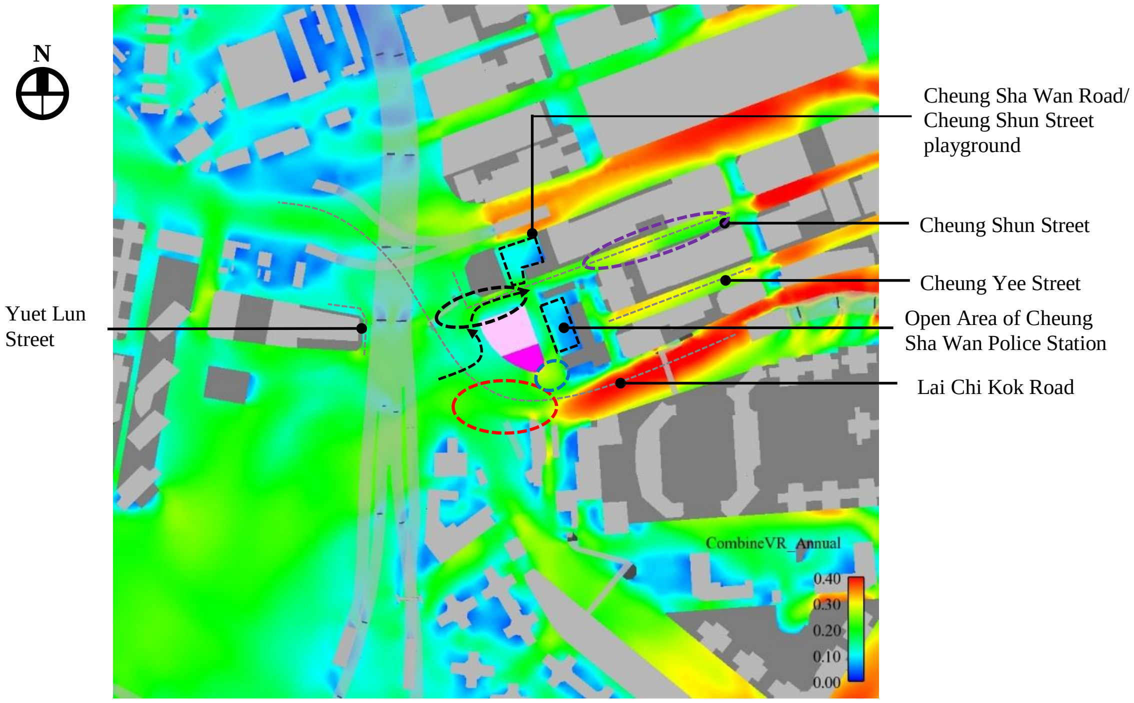


Figure 41 Contour plot of annual weighted VR of Scenario B

For the annual condition, eight wind directions were selected, that accumulating to 78.9% in occurrence of wind frequency. The integrated effect of these winds indicate the overall ventilation performance under annual condition. The major prevailing winds under annual wind condition come from north-eastern quarter. The prevailing wind enters the assessment area from a dense building clusters.

- The overall ventilation performances among Baseline Scenario, Scenario A and Scenario B are quite similar under annual condition.
- The wind environment at the eastern side of the site along Cheung Shun Street has a slightly lower VR under Scenarios A and B (purple circle in Figure 40 to Figure 41). This is due to the increase in building height of Scenarios A and B blocks prevailing wind from south-westerly quarter.
- The northern side of the site along Cheung Shun Street has a slightly higher VR under Scenarios A and B (black circle in Figure 40 to Figure 41) as the prevailing winds from south-westerly quarter are diverted by taller building tower and flow downward to the pedestrian level of the west part of Cheung Shun Street (black arrow in Figure 40 to Figure 41).
- The VR value at Cheung Yee Street under both Scenarios A and B is slightly worse than that under Baseline Scenario due to the blockage of the high-rise tower of Scenario A and B when wind approaches from south-westerly quarter.
- As compared with Baseline Scenario, a slightly lower VR is found at the localized region of Lai Chi Kok Road under Scenarios A and B (red circle in Figure 39 to Figure 41). The downwash wind towards Lai Chi Kok Road slightly disturbs the wind path along Lai Chi Kok Road. Nevertheless, the overall wind performances along the road is still similar among the three scenarios.
- The ventilation performance at the open area of Cheung Sha Wan Police Station achieves a slightly better under Scenarios A and B, which is beneficial by the downwash effect of the taller building height under easterly quarter wind.
- Southern site boundary achieve a slightly higher VR under Scenario B as compared with Scenario A (blue circle in Figure 41). This is mainly due to the east facade of Scenario B has straight building frontage design which facilitate downwash wind to the pedestrian level. While Scenario A has a tower setback design on the east side thus less wind would be downwash to the pedestrian level and resulting a relatively lower VR.
- Under Scenarios A and B, the downwash wind from NE quarter strengthen the air flow along Cheung Shun Street and further enhance the ventilation performance at Yuet Lun Street. While similar ventilation performance is observed between Scenarios A and B.
- Similar ventilation performance is observed at Cheung Sha Wan Road/ Cheung Shun Street Playground among three Scenario under annual condition.

6.2 Summer Overall Pattern of Ventilation Performance

The wind performance of Baseline Scenario, Scenario A and Scenario B under summer wind condition are shown in Figure 42 through Figure 44 respectively.

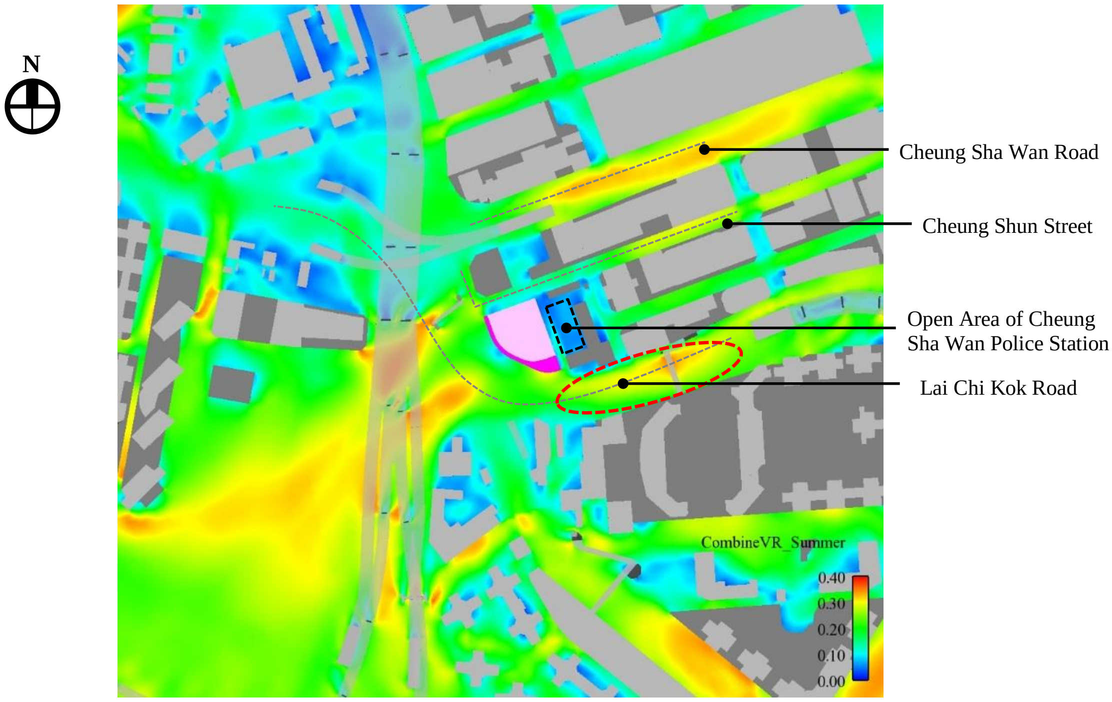


Figure 42 Contour plot of summer weighted VR of Baseline Scenario

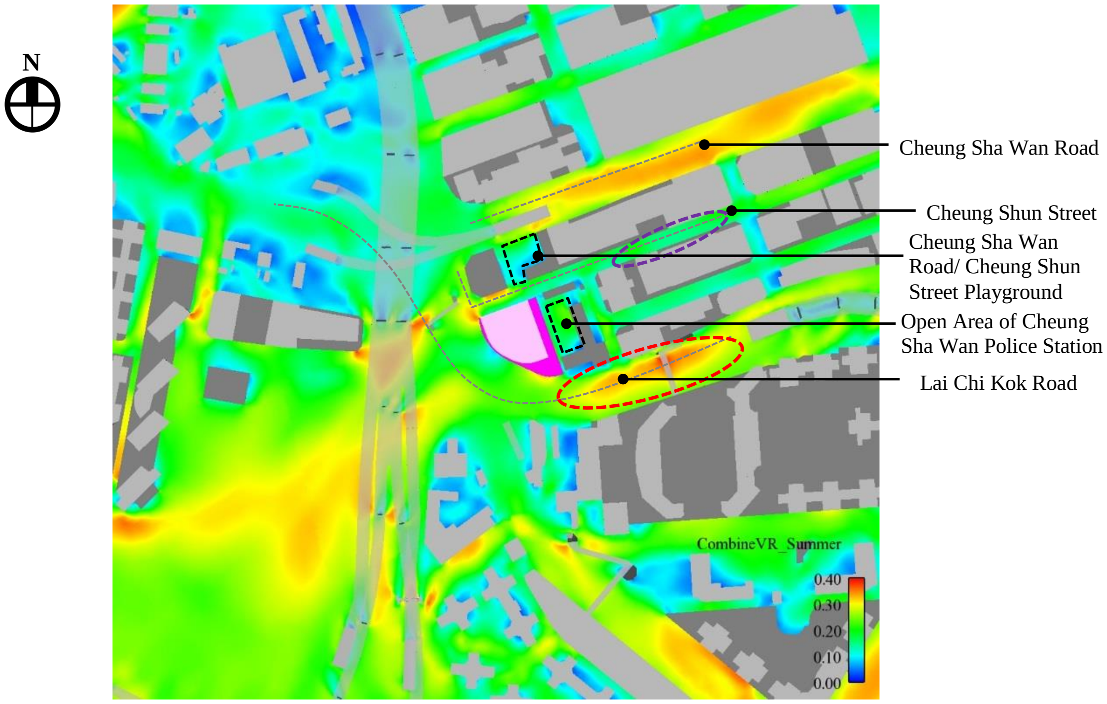


Figure 43 Contour plot of summer weighted VR of Scenario A

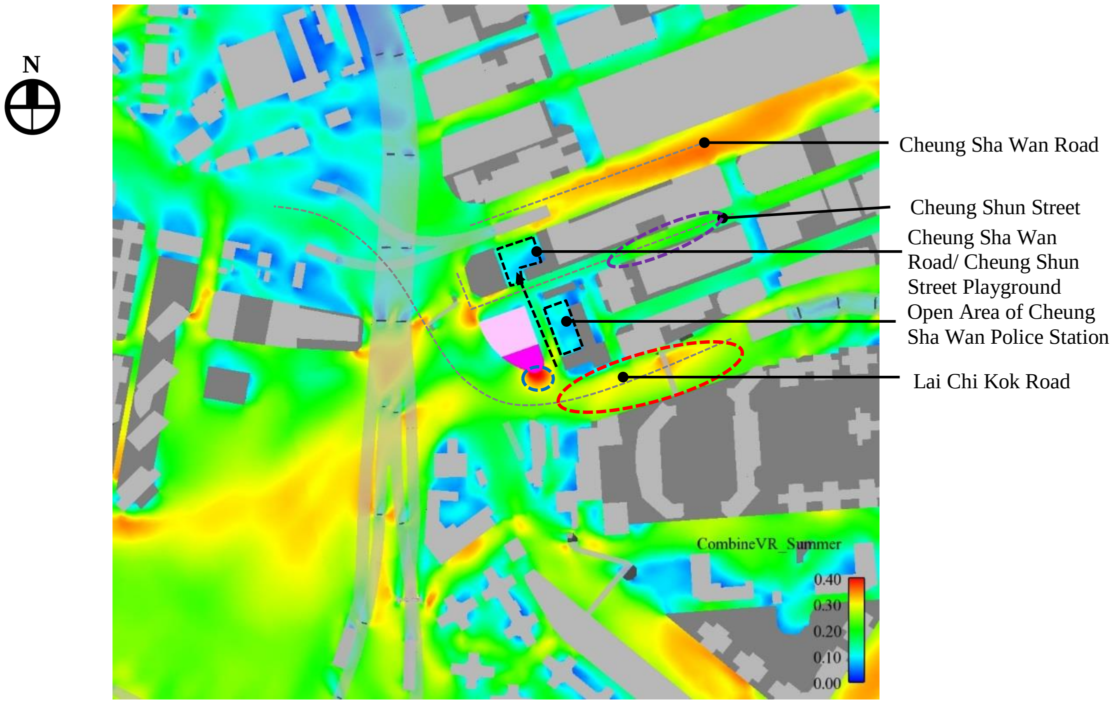


Figure 44 Contour plot of summer weighted VR of Scenario B

For the summer condition, eight wind directions were selected, accumulating to 81.8% in occurrence of wind frequency. The integrated effect of these winds indicates the overall ventilation performance under summer condition. The major prevailing winds under summer wind condition come from south-westerly quarter. The prevailing wind enters the assessment area from a relatively open space.

- The overall ventilation performances among Baseline Scenario, Scenario A and Scenario B are quite similar under summer condition except at Cheung Sha Wan Road, Lai Chi Kok Road and Cheung Shun Street.
- The wind environment at Cheung Sha Wan Road is better under Scenarios A and B as compared to Baseline Scenario. This is due to the higher building tower under Scenarios A and B diverts the south-westerly quarter wind to Cheung Sha Wan Road.
- The downwash effect along Lai Chi Kok Road near the Project Site is also strengthened due to the taller and larger building bulk under Scenarios A and B (red circle in Figure 43). This effect has localized impact and enhances the wind environment of Lai Chi Kok Road. Compared between Scenarios A and B, better ventilation performance is observed under Scenario A. The 15m NBA under Scenario B allow a portion of wind along Lai Chi Kok Road would flow across the NBA and less wind would flow along Lai Chi Kok Road to the east. In contrast, the podium bulk of Scenario A would direct the wind towards Lai Chi Kok Road.
- The east part of the Cheung Shun Street has a slightly lower VR under Scenarios A and B (purple circle in Figure 43 and Figure 44). This is due to the increase in building height of Scenarios A and B blocks prevailing from south-westerly quarter. (similar to annual wind)

- Similar to annual wind condition, Scenario B has a higher VR along the southern site boundary as compare to Scenario A (blue circle in Figure 44). This is mainly due to the straight building frontage of Scenario B facilitate the downwash effect of SW quarter wind.
- The tower setback design of Scenario A allow incoming wind penetrate to the open area of Cheung Sha Wan Police Station. Therefore, ventilation environment at the Open Area of Cheung Sha Wan Police Station is the best under Scenario A, while the 15m NBA has better ventilation performance under Scenario B.
- Comparing with Scenario A and B, similar VR is found at Cheung Sha Wan Road/ Cheung Shun Street Playground.

6.3 Directional Analysis

This section presents the directional analysis on the wind performance. Some wind directions are discussed together as their performance are similar.

6.3.1 Under NE Wind

The NE wind contributes 7.6% of the annual wind rose and its general wind characteristics is discussed in below:

- West of Cheung Sha Wan Road has a higher VR under Scenarios A and B.
- West of Lai Chi Kok Road has a slightly lower VR under Scenarios A and B.
- A higher VR value is achieved at Open Area of Cheung Sha Wan Police Station under Scenarios A and B as compared with Baseline Scenario, while Scenario B has a slightly higher VR than Scenario A.
- A higher VR is found at localized area of Lai Chi Kok Road and Cheung Sha Wan Road/ Cheung Shun Street Playground under Scenario B.

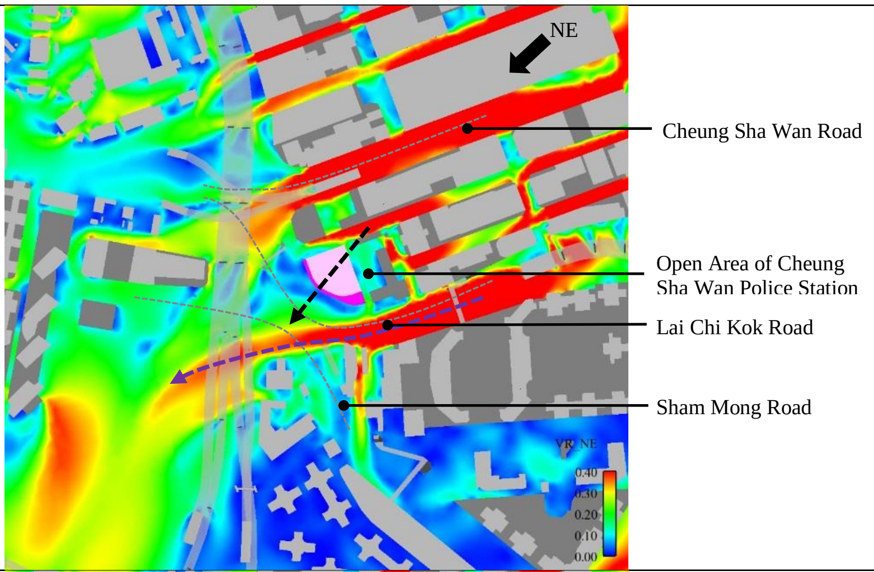
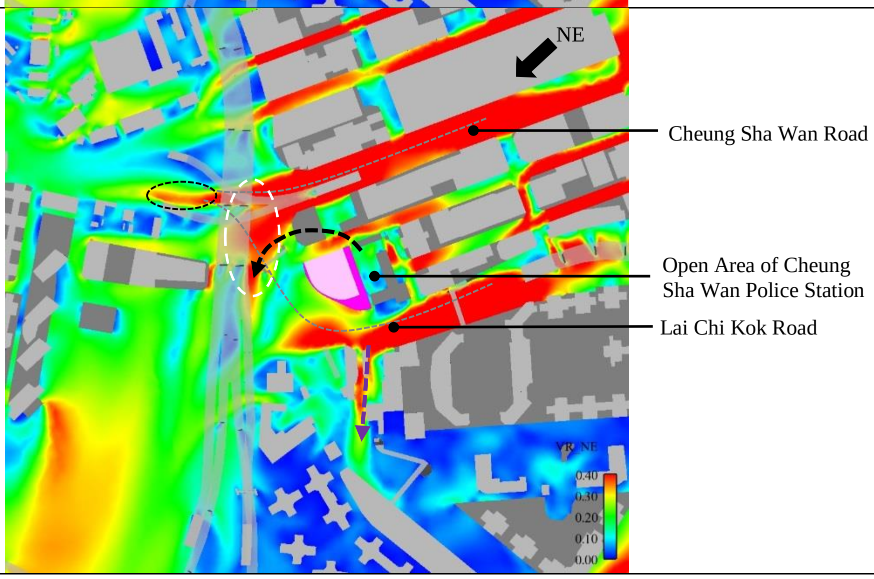
It is observed that the wind environment at west of Cheung Sha Wan Road is better (White Circle of Scenarios A and B in Figure 45) under Scenarios A and B. Scenarios A and B has a taller building height, which is favourable to capture downwash wind towards the area (Black arrow of Scenarios A and B in Figure 45 and Streamline plot in Figure 47 to Figure 49). Furthermore, the downwash wind of Scenarios A and B would push the wind path along Cheung Sha Wan Road northern and resulting a higher VR at west of Cheung Sha Wan Road as compared with the Baseline Scenario (black circle of Scenarios A and B in Figure 45). On the other hand, the high-level wind would flow atop the Baseline building towards the SW region of the site (Black arrow of Baseline Scenario in Figure 45 and Figure 46).

Good ventilation performance is observed along Lai Chi Kok Road. The downwash wind under Scenarios A and B would disturb air stream along Lai Chi Kok Road and divert a portion of wind towards Sham Mong Road (purple arrow of Scenarios A and B in Figure 45). In a contrary, without the intervention of the downwash wind, more wind can flow along the Lai Chi Kok Road under Baseline Scenario (purple arrow of Baseline Scenario in Figure 45).

As compared with Baseline Scenario, higher VR value is achieved at open area of Cheung Sha Wan Police Station under Scenarios A and B due to the taller building height facilitate the downwash wind. Furthermore, the straight aligned frontage design of Scenario B allow the more downwash wind towards pedestrian level. Even though Scenario A also has a tall building height, large portion of downwash wind is blocked by podium and prevent directly reach the street level. Thus, a slightly higher VR is found in Scenario B compared with Scenario A and Baseline Scenario.

Compared with Scenario A, Scenario B has a higher VR at localized area of Lai Chi Kok Road (blue circle of Scenario B in Figure 45). The building tower of Scenario

B has a straight aligned frontage design at east boundary. The downwash wind by the building façade can reach pedestrian level and divert to both north and south of the site and resulting a higher VR at localized area. Moreover, the downwash wind would join the wind path from east of Cheung Shun Street and further flow towards Cheung Sha Wan Road/ Cheung Shun Street Playground resulting a higher VR at that area (blue arrow of Scenario B in Figure 45).

Baseline Scenario	N	
Scenario A	N	

Scenario B

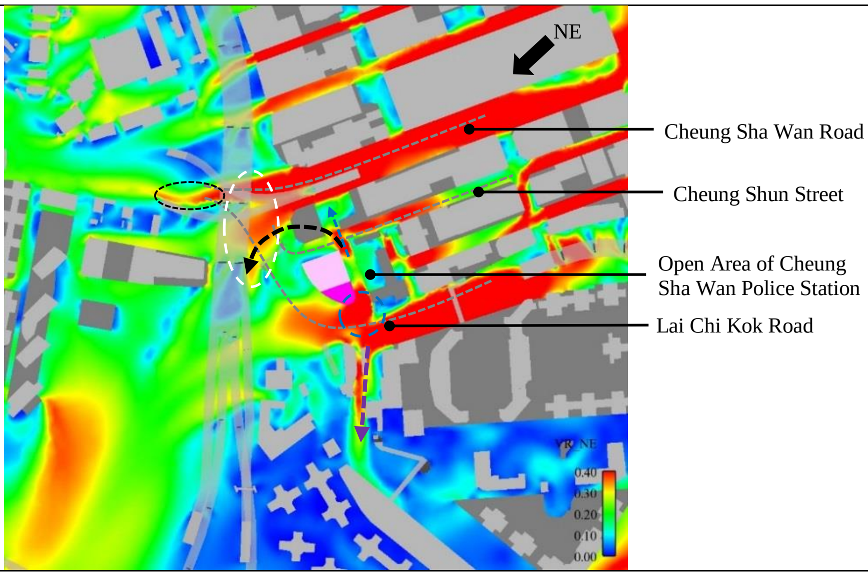


Figure 45 Contour plot of VR under NE wind

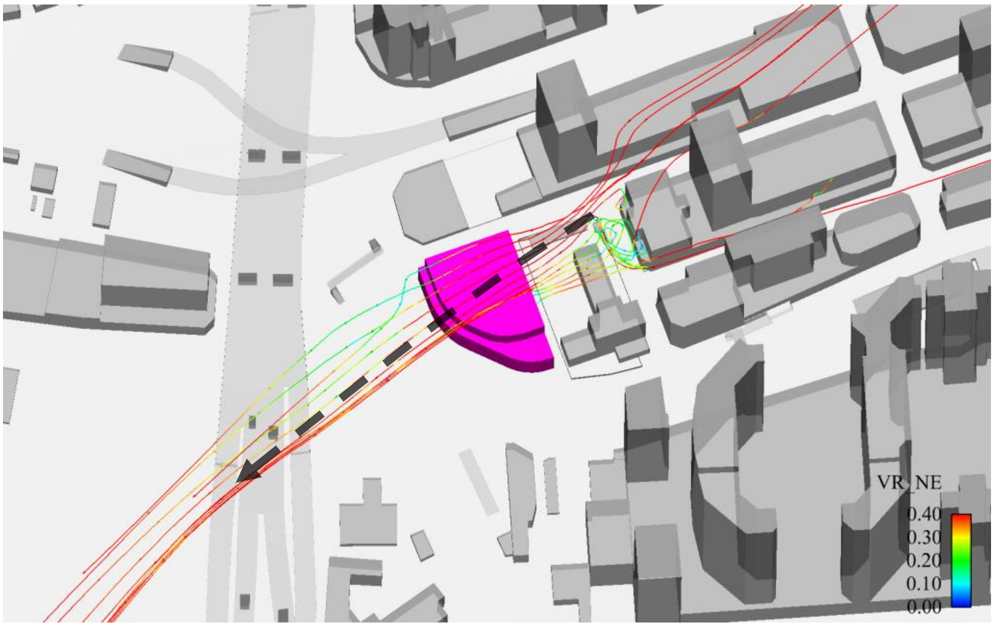


Figure 46 Streamline plot of Baseline Scenario under NE wind

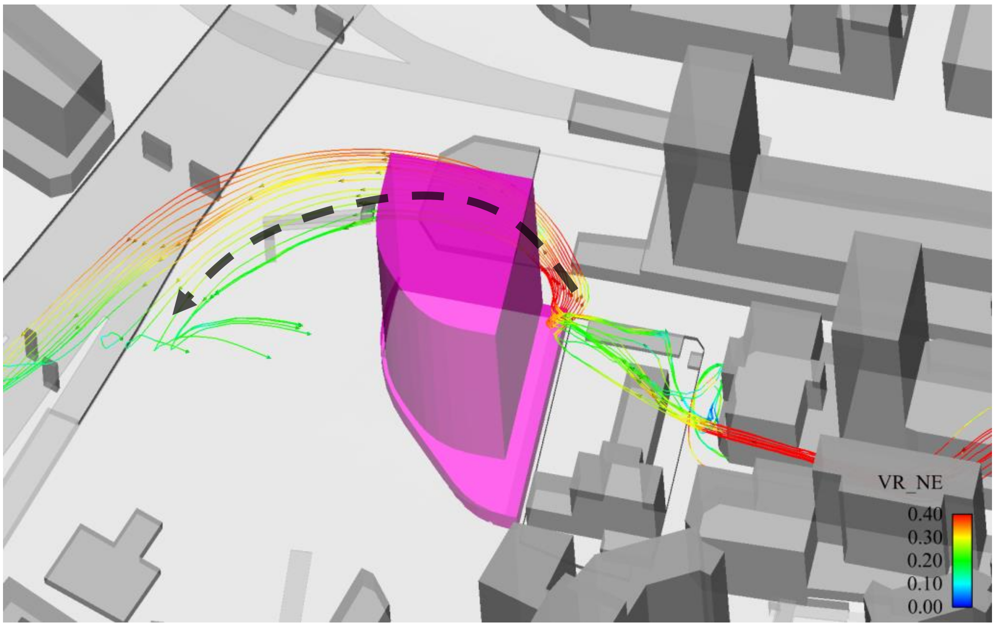


Figure 47 Streamline plot of Scenario A under NE wind

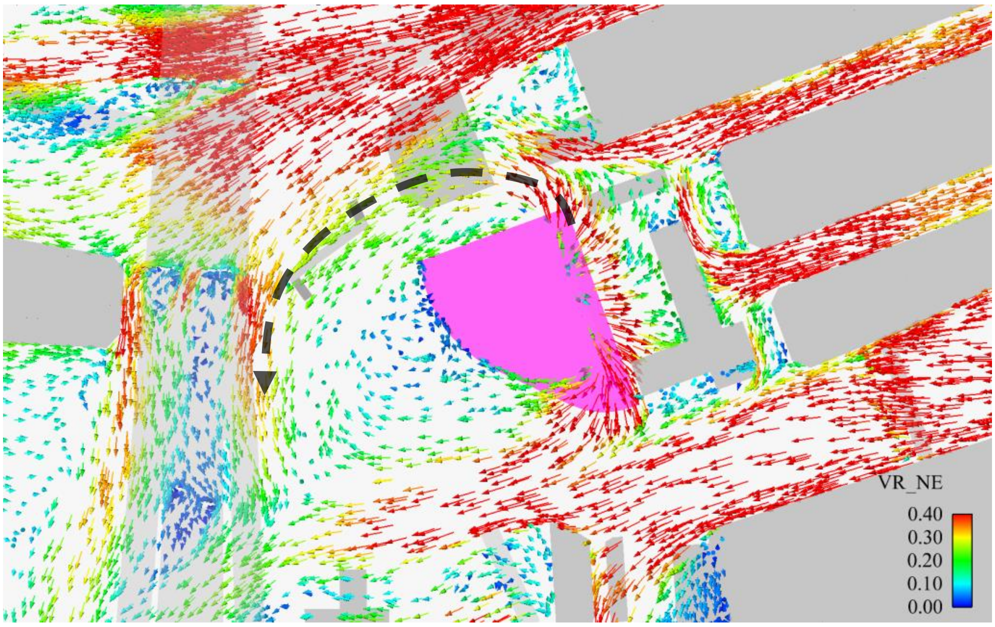


Figure 48 Vector plot of Scenario A under NE wind at 16mPD

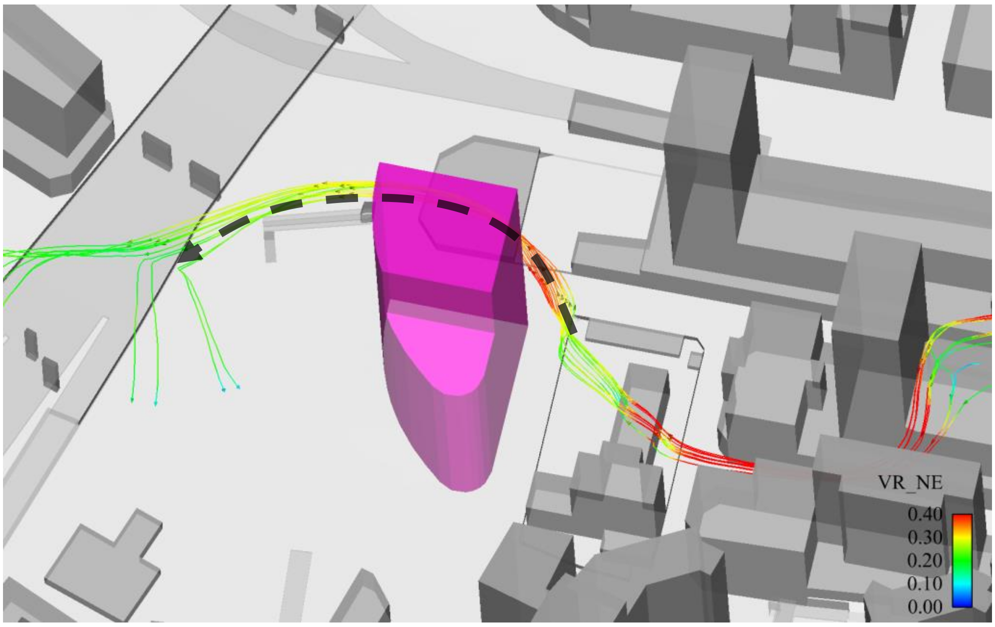


Figure 49 Streamline plot of Scenario B under NE wind

6.3.2 Under ENE Wind

The ENE wind contributes 11.9% of the annual wind rose and its general wind characteristics is discussed in below:

- The ventilation performance at west of Sham Mong Road is worsen under Scenarios A and B.
- A slightly better wind environment at the southwest portion of Project Site is formed under both Scenarios A and B.
- A slightly higher VR is found at the east portion of Yuet Lun Street under Scenarios A and B.
- Scenario B has better wind environment at the SE corner and the entire east portion of the site among all Scenarios.
- Better ventilation performance is observed in open area of Police Station under Baseline Scenario.

Both Scenarios A and B has a much taller building height than Baseline Scenario that enhance the downwash wind.

The 15m NBA under Scenario B would facilitate the diversion of downwash wind and enhance the ventilation performance at the north and south side of the site as well as the 15m NBA zone (purple circle and black dotted box of Scenario B in Figure 50). A portion of wind would further penetrate towards Cheung Sha Wan Road/ Sheung Shun Street Playground resulting a slightly higher VR value.

Under Scenario A, the downwash wind would reach the podium and further flow towards Lai Chi Kok Road thus slightly enhance the south side of the site (purple circle of Scenarios A Figure 51). However, since Scenario A has a staggered alignment along east site boundary, less wind would reach the pedestrian level compared to Scenario B. Therefore, Scenario B performs the best VR in that area.

This downwash effect of Scenarios A and B has locally enhanced the ventilation at the SW portion of Project Site, but also disturbed the wind flow along Lai Chi Kok Road. Under Baseline Scenario, wind entering from the east could flow along Lai Chi Kok Road with less disturb resulting a slightly higher VR at west of Sham Mong Road (black arrow of Baseline Scenario in Figure 50).

The downwash wind in Scenarios A and B also strengthens the air flow along Cheung Shun Street and further enhances the ventilation at Yuet Lun Street (black arrow of Scenarios A and B in Figure 50).

Higher VR value is observed in open area of Police Station under Baseline Scenario. Baseline Scenario has a straight aligned frontage design. Also, it is situated closely to the open area of Cheung Sha Wan Police Station. The incoming wind would downwash by the building façade to the open area of Cheung Sha Wan Police Station (streamline plot of Baseline Scenario in Figure 52). Under Scenario A, the downwash wind would flow towards Lai Chi Kok Road after reach the podium. Due to the 15m NBA under Scenario B, the wind would flow towards the north and south side of the site after downwash to pedestrian level.

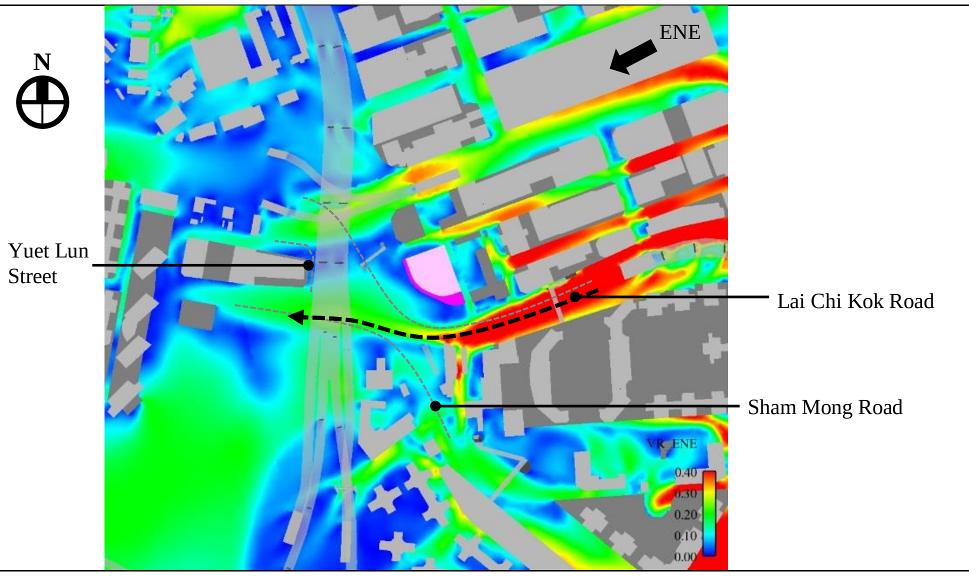
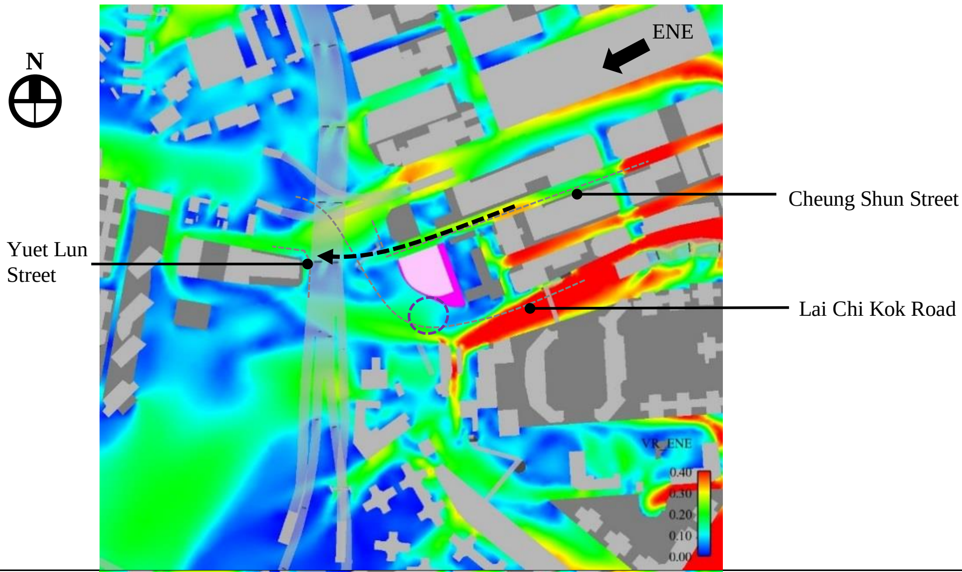
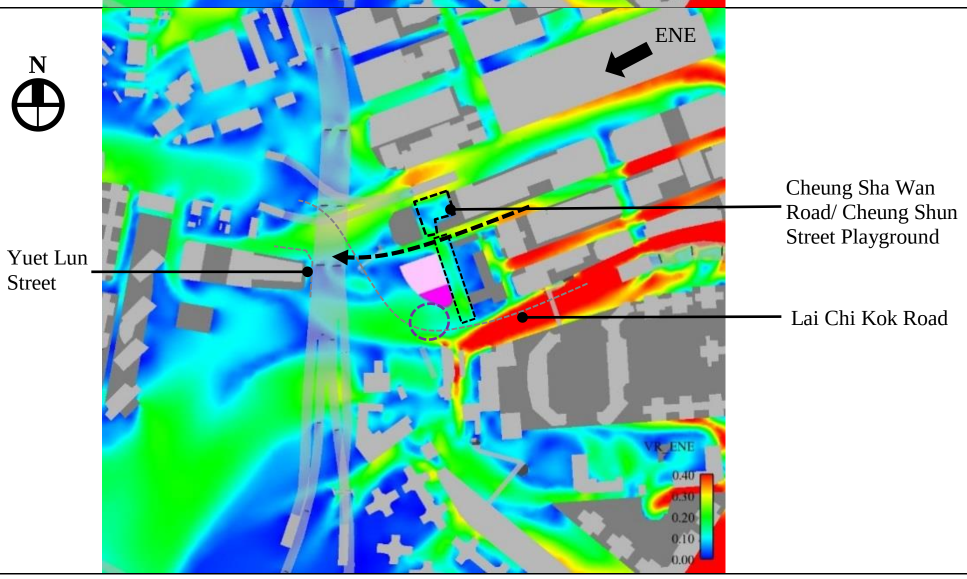
Baseline Scenario	
Scenario A	
Scenario B	

Figure 50 Contour plot of VR under ENE wind

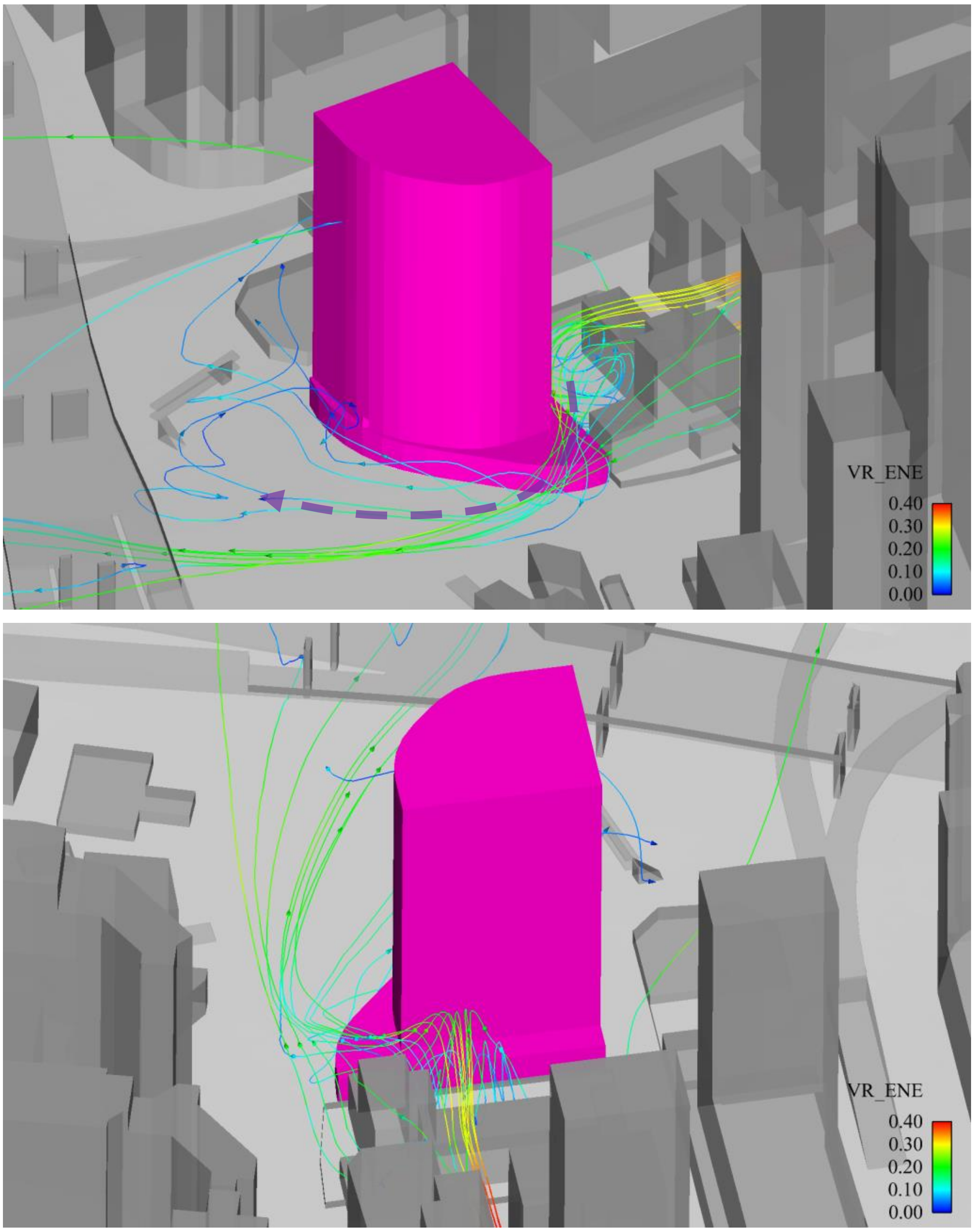


Figure 51 Streamline plot of Scenario A under ENE wind

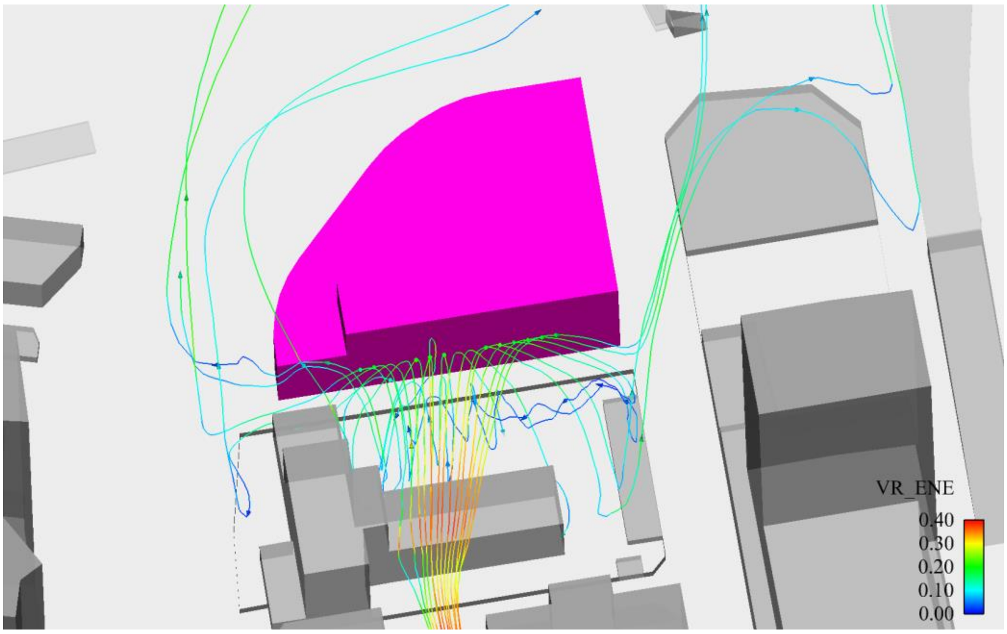


Figure 52 Streamline plot of Baseline Scenario under ENE wind

6.3.3 Under E Wind

The E wind contributes 21.8% of the annual wind rose and 8.1% of the summer wind rose. Its general wind characteristics is discussed in below:

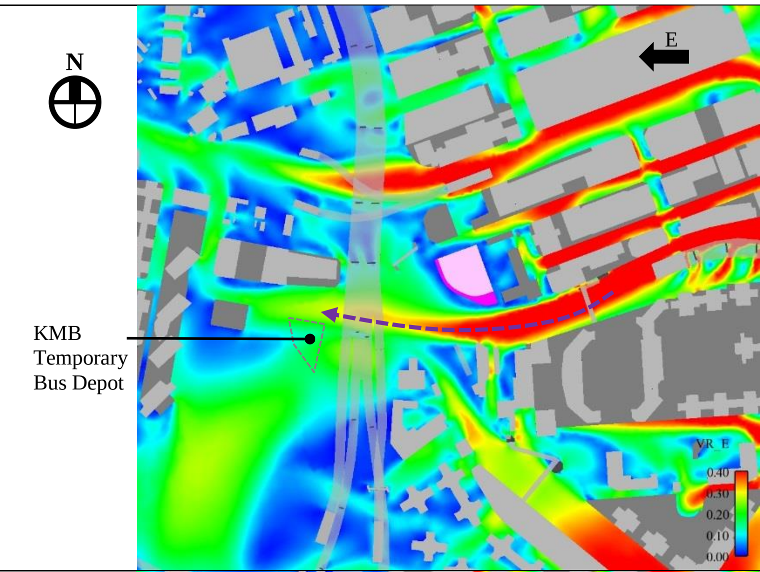
- A higher VR value is observed at the west of Cheung Sha Wan Road under Scenarios A and B.
- A slightly better ventilation performance is observed at the southwest of Project Site under Scenarios A and B.
- A higher VR is found at KMB Temporary Bus Depot under Baseline Scenario.
- Scenario B has better wind environment at the SE corner and the entire east portion of the site among all Scenarios.

The taller building height of Scenarios A and B has strengthened the downwash wind towards Cheung Shun Street and further flow towards Cheung Sha Wan Road (black arrow of Scenarios A and B in Figure 53, Figure 55, Figure 56) and southwest localised region of Project Site (red circle of Scenarios A and B in Figure 53), which resulting a slightly better ventilation performance. On the other hand, the wind would flow atop the Baseline Scenario and towards the higher level of Cheung Sha Wan Road (Streamline plot in Figure 54).

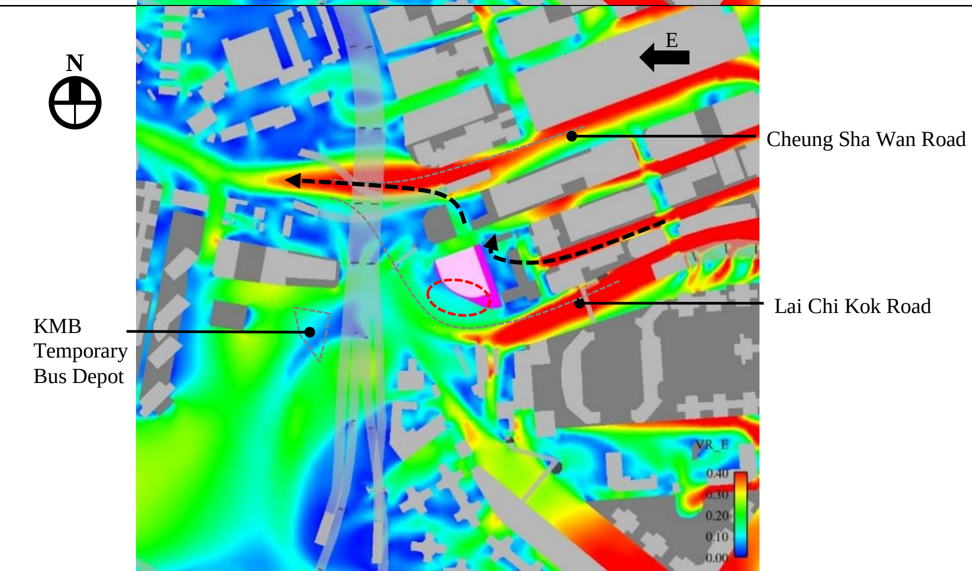
Similar to NE wind, the disturb comes from downwash wind under Scenarios A and B diverts a portion of wind from Lai Chi Kok Road to Sham Mong Road, while under Baseline Scenario, the wind along Lai Chi Kok Road can reach the KMB Temporary Bus Depot area and slightly enhance the wind environment of that region (purple arrow of Baseline Scenarios in Figure 53).

Scenario B has a 15m NBA from east boundary and the building tower has a straight aligned frontage design. The E wind would be captured by the east façade and downwash to the pedestrian level. The pedestrian level wind thus effectively flow towards Lai Chi Kok Road and Cheung Shun Street and open area of Cheung Sha Wan Police Station (red arrow of Scenario B in Figure 53). On a contrary, the podium structure in Scenario A would obstruct a portion of downwash wind to pedestrian level.

Baseline Scenario



Scenario A



Scenario B

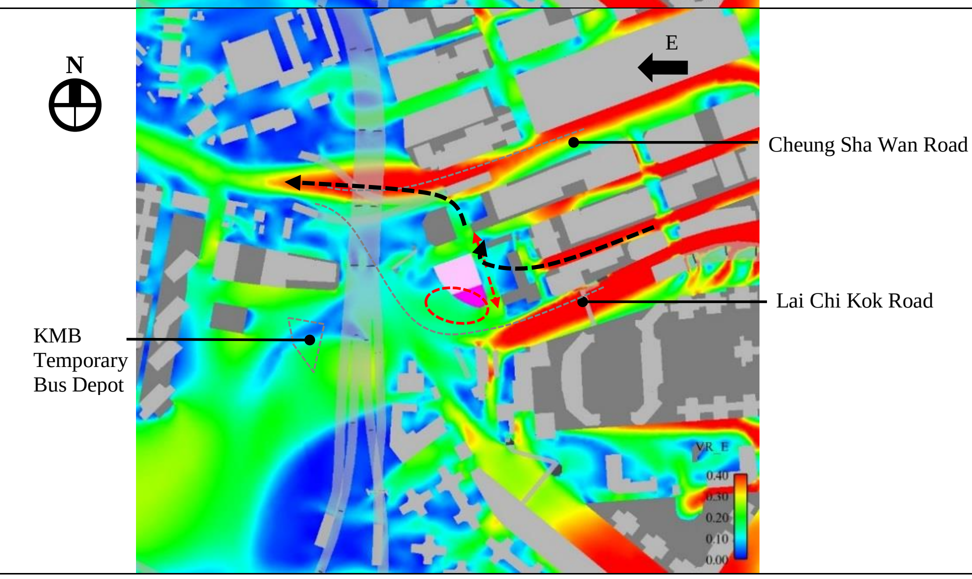


Figure 53 Contour plot of VR under E wind

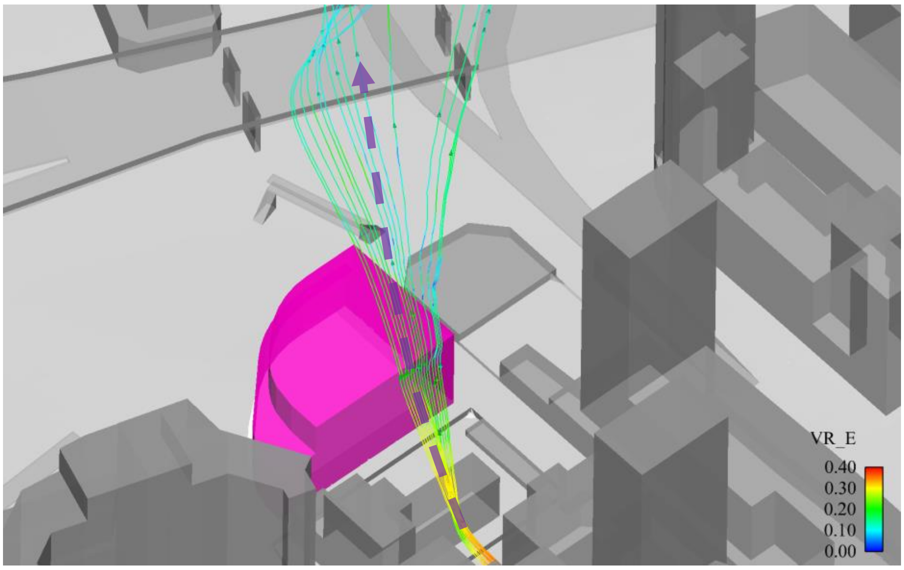


Figure 54 Streamline plot of Baseline Scenario under E wind

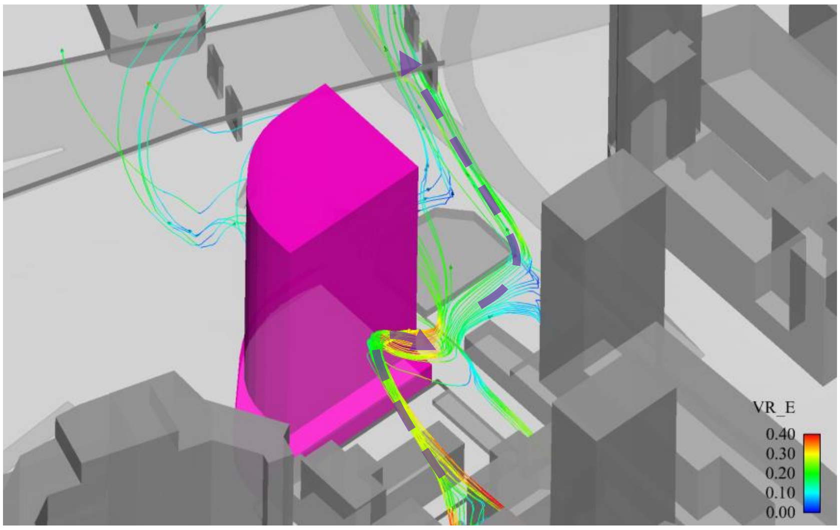


Figure 55 Streamline plot of Scenario A under E wind

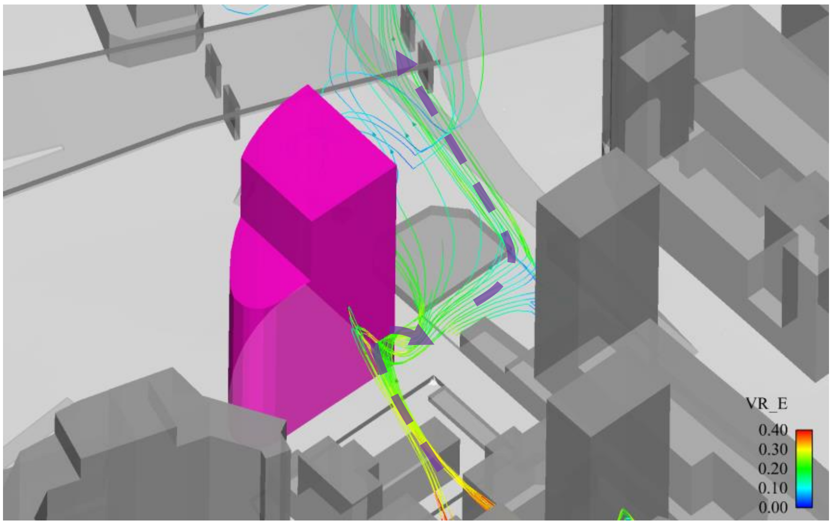


Figure 56 Streamline plot of Scenario B under E wind

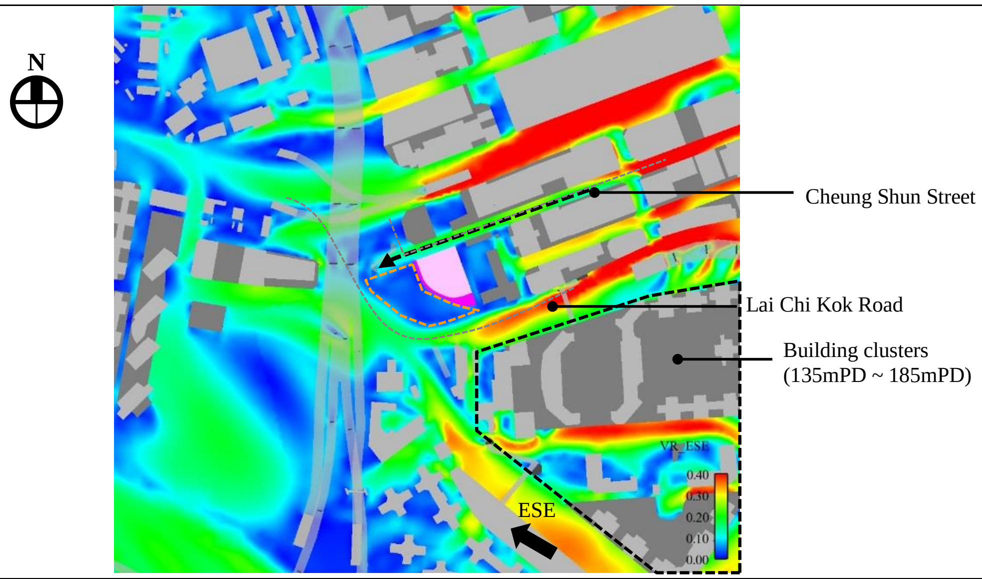
6.3.4 Under ESE Winds

The ESE wind contributes 12.4% of the annual wind rose and 9.7% of the summer wind rose respectively. Its general wind characteristics is discussed in below:

- Building clusters at the southeast would obstruct the prevailing wind flow towards the site
- A large wake zone is found at the immediate west portion of the site under Baseline Scenario and Scenario A.

High-rise building clusters are located at the southeast of Project Site including One West Kowloon, Banyan Garden, Liberte, and the Pacifica. The ESE prevailing wind cannot skim over these building clusters and reach Project Site. It results in more wind flow along Sham Mong Road, Lai Chi Kok Road and Cheung Sha Wan Road. In general, the wind environment among the three scenarios are quite similar under the captioned wind directions.

A wake zone is found at the western side of the site under all Scenarios (orange dotted box of all Scenarios in Figure 57). Baseline Scenario has the worst ventilation performance, while Scenario B perform better than Baseline Scenario and Scenario A. Under Scenario B, its straight aligned frontage design facilitate the downwash wind to the 15m NBA zone (streamline plot in Figure 58), while the wind can further travel to Cheung Shun Street (red arrow of Scenario B in Figure 57) and south side of the site.

Baseline Scenario	

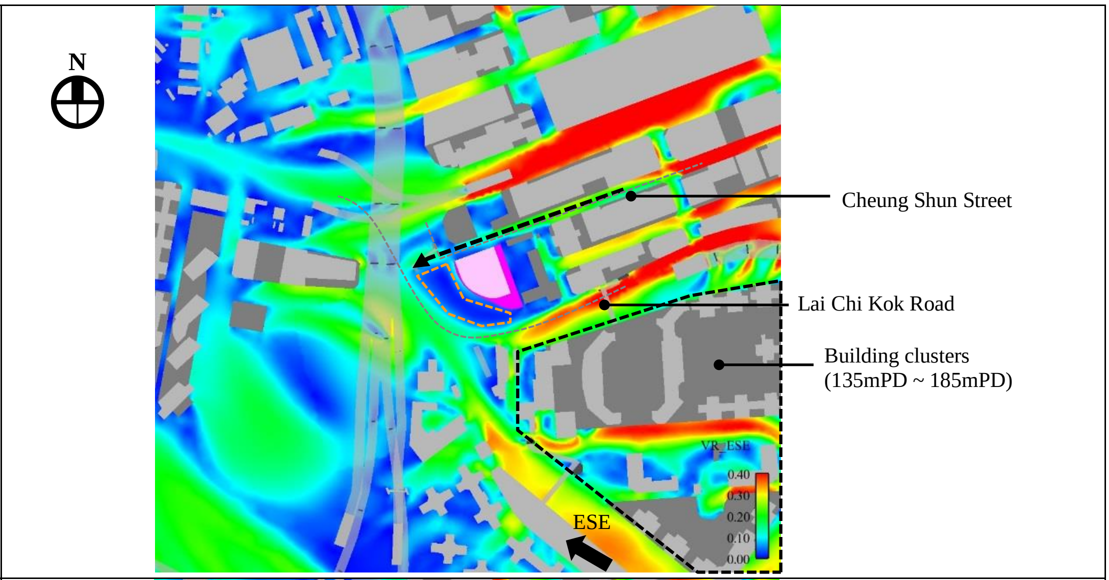
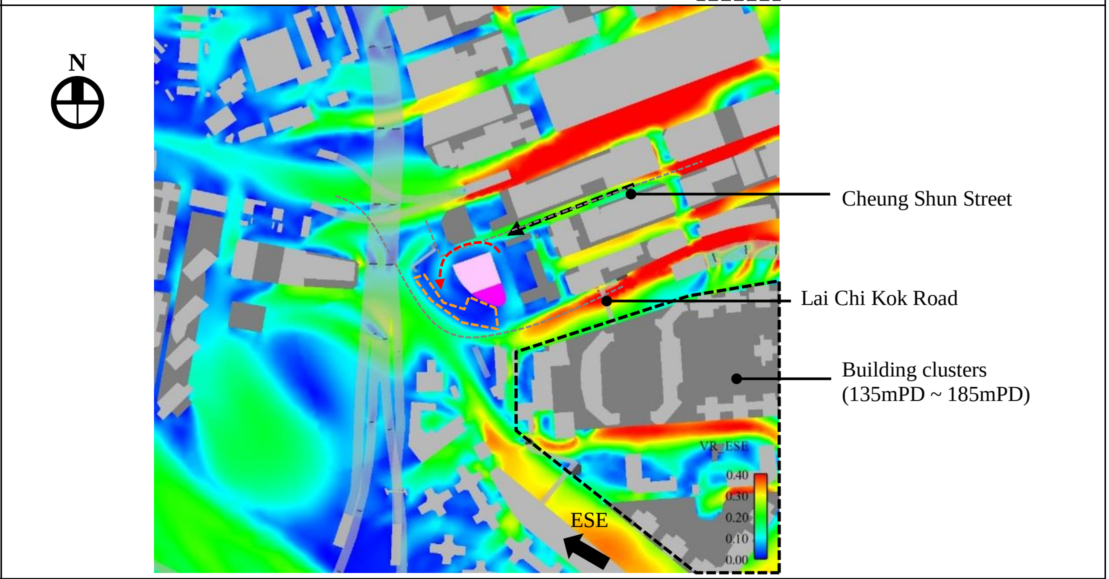
Scenario A	
Scenario B	

Figure 57 Contour plot of VR under ESE wind

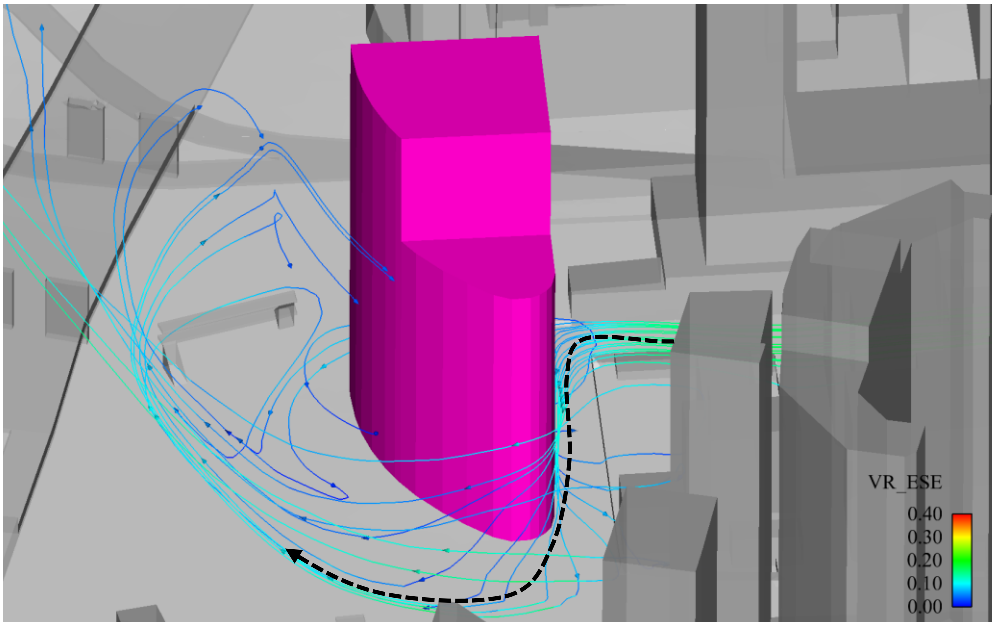


Figure 58 Streamline plot of Scenario B under ESE wind

6.3.5 Under SE Winds

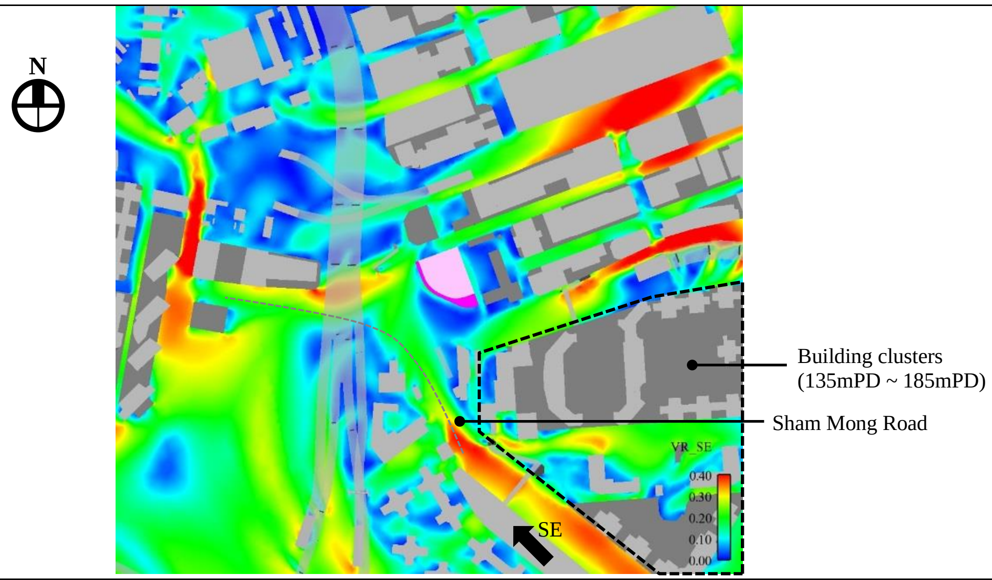
The SE wind contributes 6.5% of the annual wind rose and 7.9% of the summer wind rose respectively. Its general wind characteristics is discussed in below:

- Building clusters at the southeast would obstruct the prevailing wind flow towards the site
- The 15m NBA and localized area of Lai Chi Kok Road south to the site has a slightly higher VR under Scenario B.

Similar to ESE wind, the SE prevailing wind cannot skim over these building clusters and reach Project Site. It results in more wind flow along Sham Mong Road, Lai Chi Kok Road and Cheung Sha Wan Road. In general, the wind environment among the three scenarios are quite similar under the captioned wind directions.

Under Scenario B, the 4m setback at the north boundary enhance the wind penetration from Shum Mong Road to Cheung Shun Street and further flow to 15m NBA zone (black arrow of Scenario B in Figure 59) and 15m NBA zone (red arrow of Scenario B in Figure 59). Thus, it enhances the ventilation performance at the southern side of the site along Lai Chi Kok Road as compared with Baseline Scenario and Scenario A.

Baseline Scenario also observed with similar phenomenon. A minor wind path is found along the building separation between the site and the adjacent school. However, as the separation distance is less than the 15m NBA zone, the wind penetration effect is less effective compared with Scenario B.

Baseline Scenario	

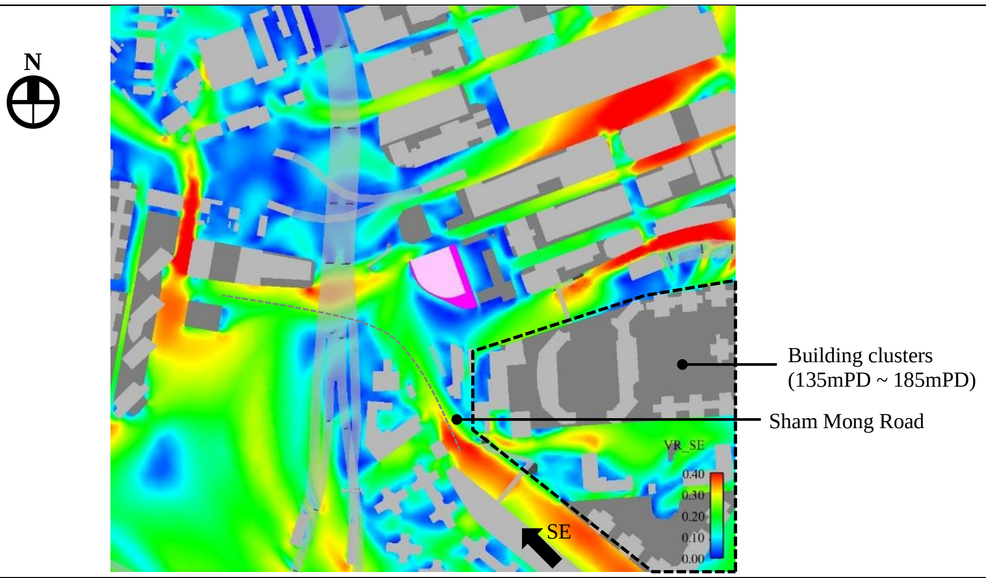
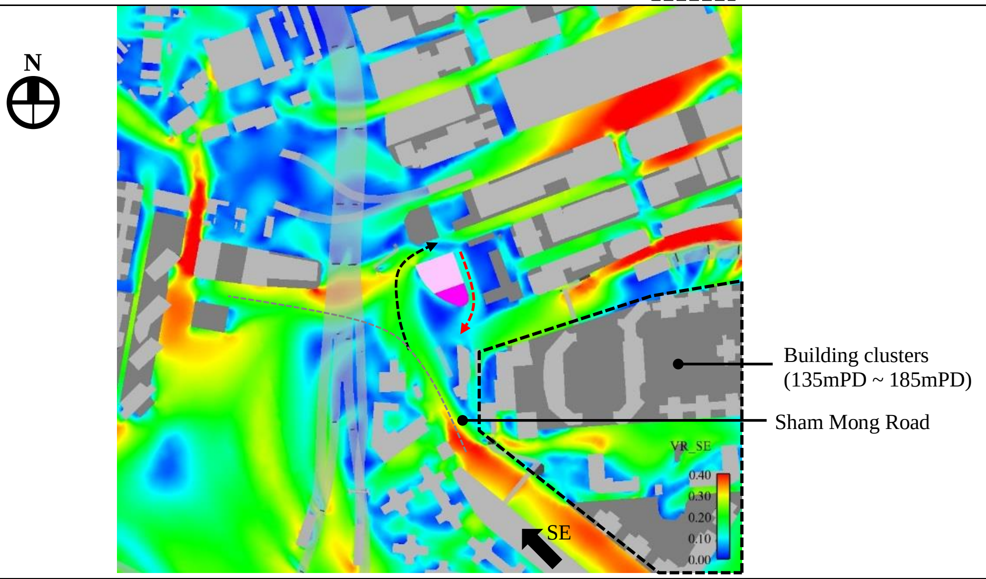
Scenario A	
Scenario B	

Figure 59 Contour plot of VR under SE wind

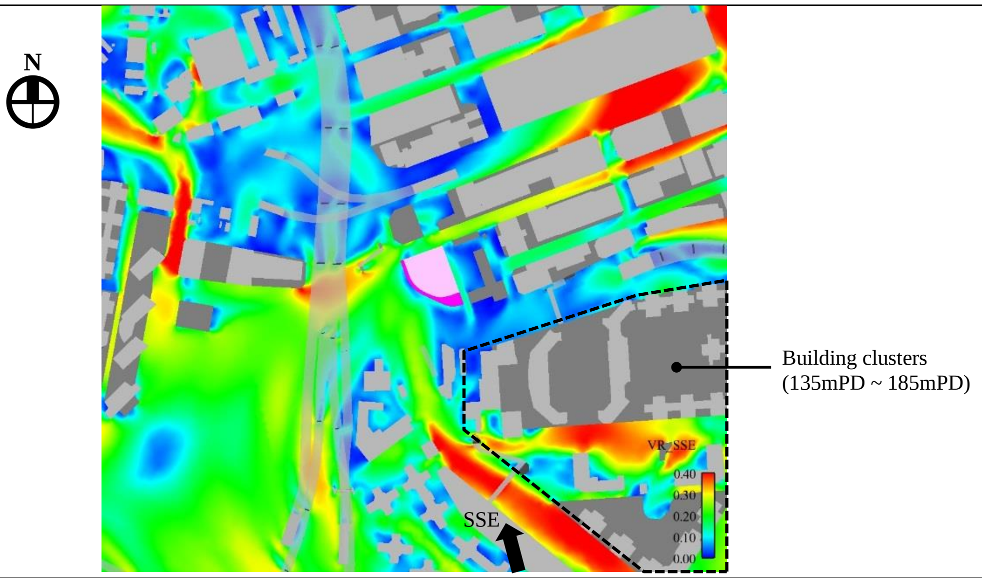
6.3.6 Under SSE Winds

The SSE wind contributes 4.8% of the annual wind rose and 7.9% of the summer wind rose respectively. Its general wind characteristics is discussed in below:

- Building clusters at the southeast would obstruct the prevailing wind flow towards the site
- The 15m NBA and localized area of Lai Chi Kok Road south to the site has a slightly higher VR under Scenario B.

High-rise building clusters are located at the southeast of Project Site including One West Kowloon, Banyan Garden, Liberte, and the Pacifica. The SSE prevailing wind cannot skim over these building clusters and reach Project Site. It results in more wind flow along Sham Mong Road and Cheung Sha Wan Road. In general, the wind environment among the three scenarios are quite similar under the captioned wind directions.

Similar to SE wind, a portion of prevailing wind travel from Shum Mong Road through building separation between the site and the Police Station towards Lai Chi Kok Road thus slightly enhance the ventilation performance. Scenario B achieves the best ventilation performance in that area due to the provision of 4m setback and the largest building separation among all scenarios (15m NBA zone) (red arrow of Scenario B in Figure 60).

Baseline Scenario	

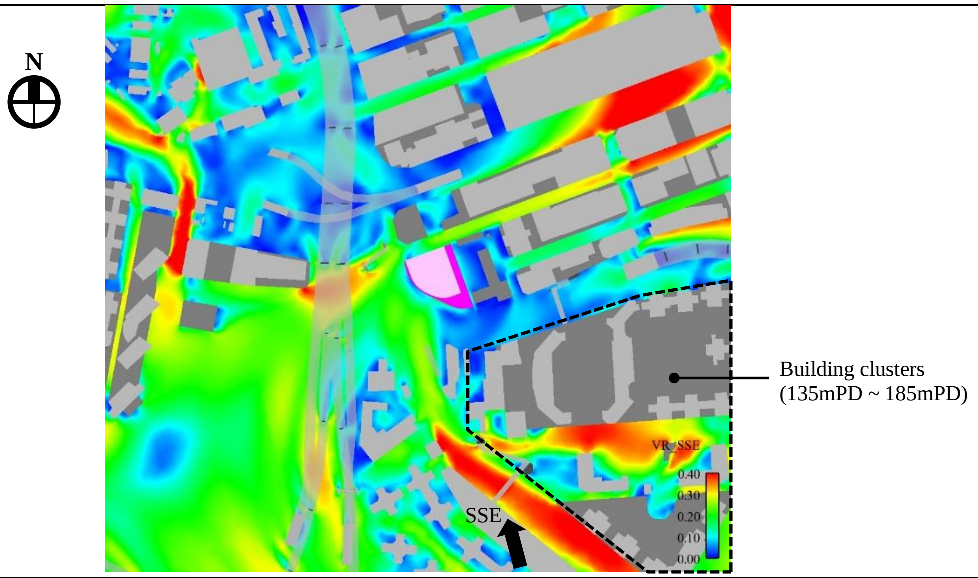
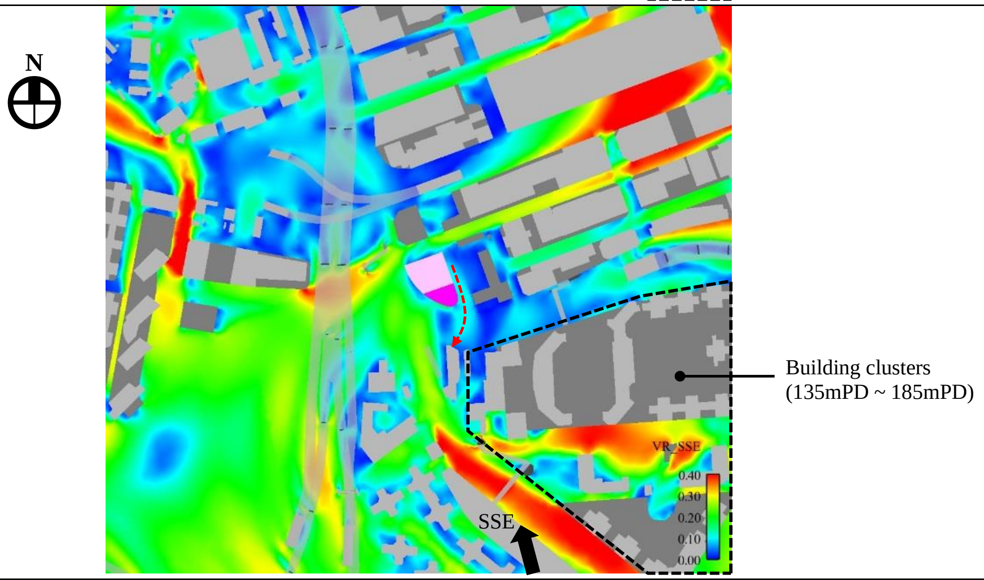
Scenario A	
Scenario B	

Figure 60 Contour plot of VR under SSE wind

6.3.7 Under S Wind

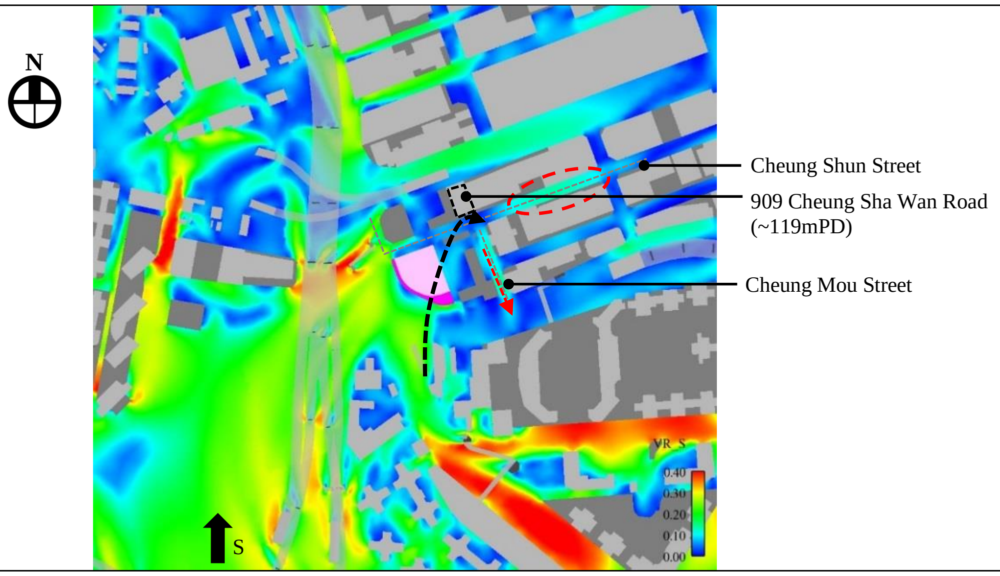
The S wind contributes about 9.3% of summer wind rose. The overall wind performance under S wind among the three scenarios is also generally similar except east of Cheung Shun Street.

- A slightly lower VR is observed at east part of Cheung Shun Street under Scenarios A and B.
- A slightly higher VR is found at Cheung Mou Street under Baseline Scenario.
- A slightly lower VR is found at the east part of Cheung Sha Wan Road under Scenarios A and B (black circle of Scenarios A and B in Figure 61).

Comparing with Baseline Scenario, a slightly worsen VR is observed at the east part of Cheung Shun Street under Scenarios A and B as shown in red circle in Figure 61. The increase in building height of Scenarios A and B would slightly divert the incoming wind at high-level, resulting less downwash wind to this area (black arrow of Scenarios A and B in Figure 61). On the other hand, prevailing wind can flow atop the baseline building and downwash by 909 Cheung Sha Wan Road and further travel along Cheung Shun Street and Cheung Mou Street (red arrow of Baseline Scenario in Figure 61). This results a slightly lower VR at the east portion of Cheung Shun Street under Scenarios A and B. Streamline plots from Figure 62 to Figure 64 indicate the phenomenon mentioned above.

Furthermore, as the wind environment in Cheung Shun Street is relatively stagnant compared with Cheung Sha Wan Road, a larger pressure difference is induced between two streets. The air stream from Cheung Sha Wan Road would tend to divert to Cheung Shun Street through Cheung Lai Street due to its pressure difference under Scenarios A and B (red arrow of Scenarios A and B in Figure 61).

Baseline Scenario



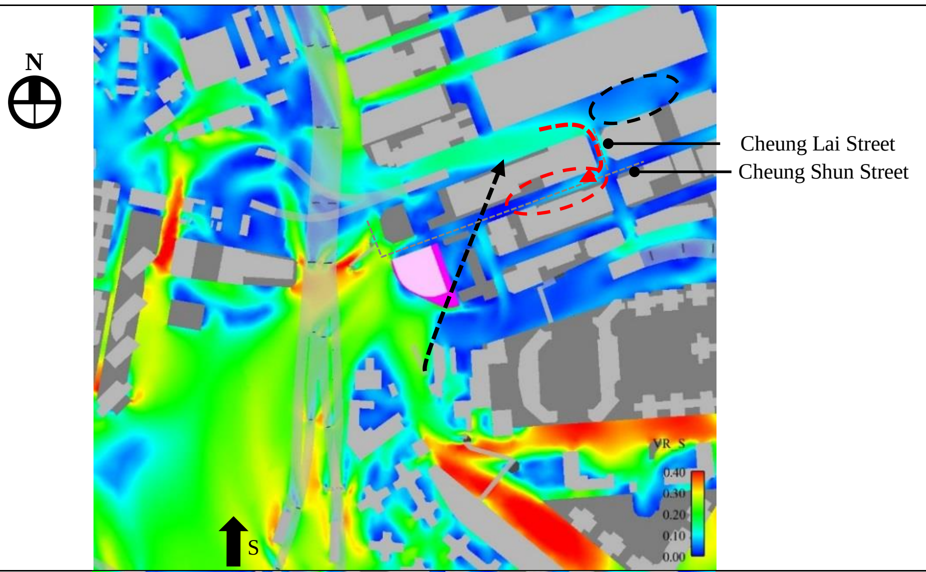
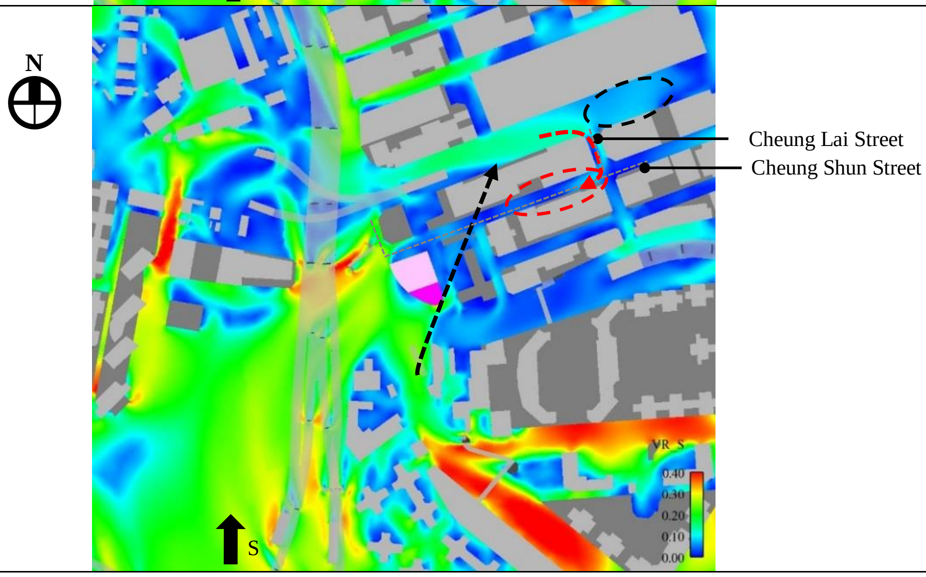
Scenario A	
Scenario B	

Figure 61 Contour plot of VR under S wind

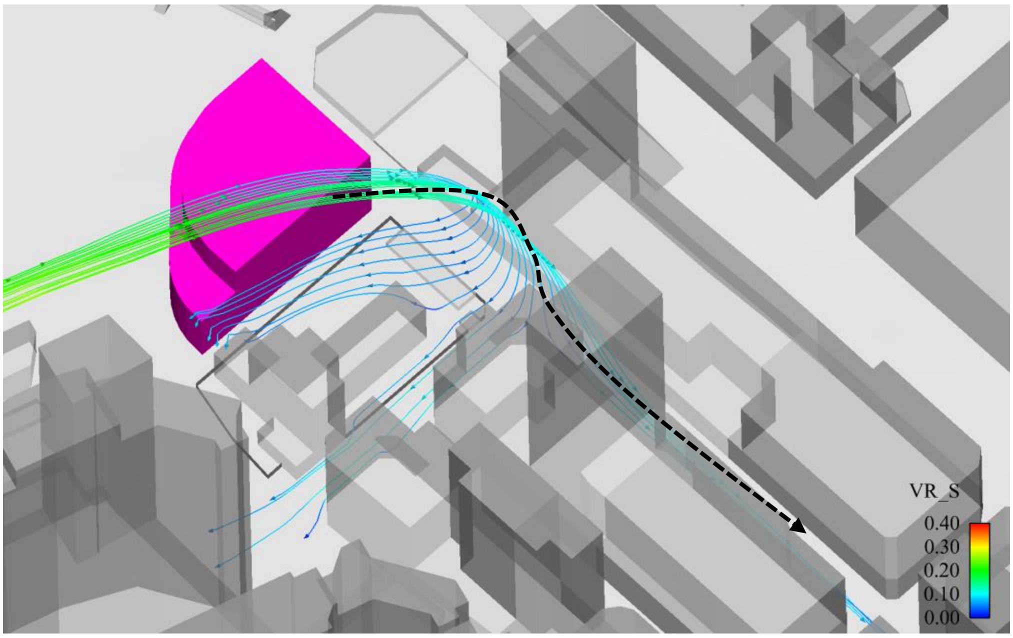


Figure 62 Streamline plot under Baseline Scenario

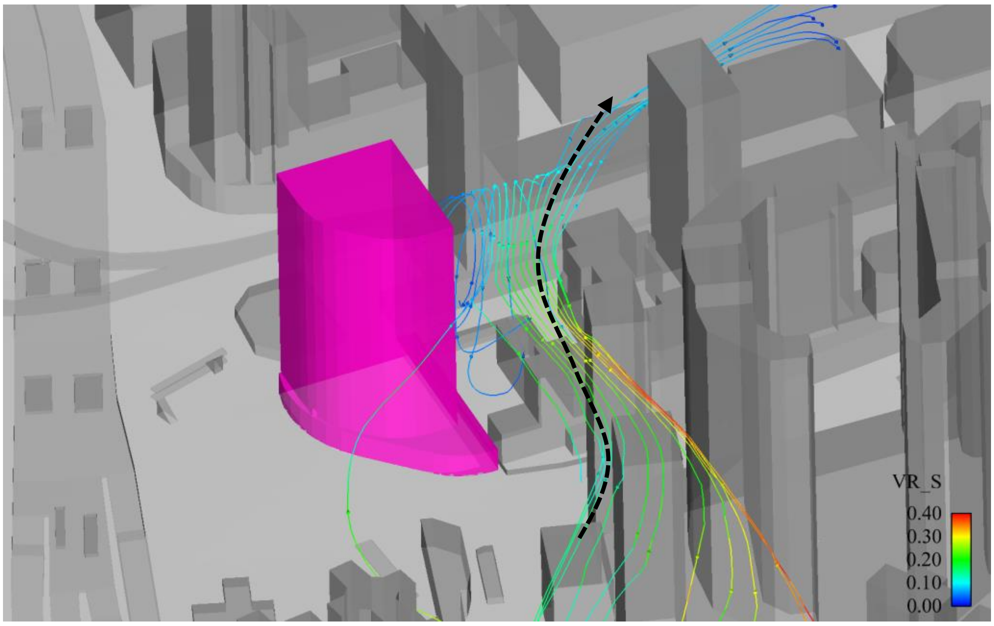


Figure 63 Streamline plot under Scenario A

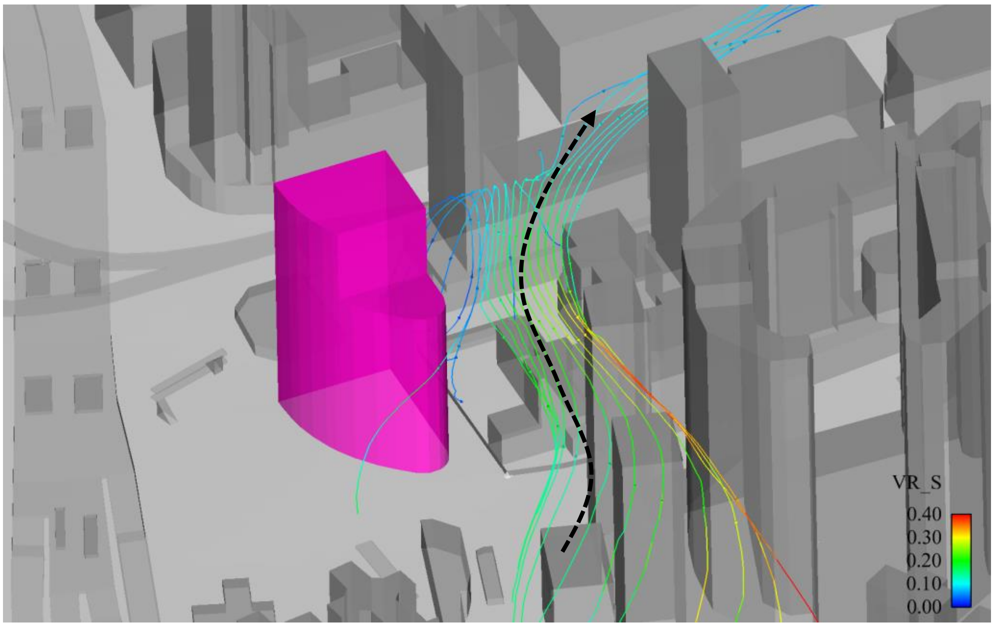


Figure 64 Streamline plot under Scenario B

6.3.8 Under SSW Wind

The SSW wind contributes 7.3% of the annual wind rose and 15.7% of the summer wind rose respectively. Its general wind characteristics is discussed in below:

- East part of Cheung Sha Wan Road and Lai Chi Kok Road are better under Scenarios A and B compared to Baseline Scenario.
- Lai Chi Kok Road has the best ventilation performance under Scenario A.
- Higher VR is observed at the open area of Cheung Sha Wan Police Station under Scenarios A and B, while Scenario A has the highest VR value.
- A slightly lower VR is observed at east part of Cheung Shun Street under Scenarios A and B.

The prevailing wind enters the Lai Chi Kok Area from the open area at SSW direction. Under Scenarios A and B, the taller building tower could induce downwash wind towards Cheung Sha Wan Road and Lai Chi Kok Road (black arrow of Scenarios A and B in Figure 65), resulting better wind performances at the east of Cheung Sha Wan Road and Lai Chi Kok Road (white circle of Scenarios A and B in Figure 65).

Owing to the 15m NBA under Scenario B, a portion of wind along Lai Chi Kok Road would flow across the NBA and beneficial to the wind environment within the site (blue arrow of Scenario B in Figure 65). Thus, less wind would flow along Lai Chi Kok Road to the east. In contrast, the podium bulk of Scenario A would direct the wind towards Lai Chi Kok Road (blue arrow of Scenario A in Figure 65). Thus, Lai Chi Kok Road has the best ventilation performance under Scenario A.

Scenario A has a 23m building tower setback from the south boundary. SSW wind can skim over atop the podium can penetrate to the open area of Cheung Sha Wan Police Station thus the highest VR is resulted. While under Baseline Scenario and Scenario B, the incoming wind is blocked by its building bulk and divert to Lai Chi Kok Road.

Similar to S wind, under Scenarios A and B, a slightly worse VR is observed at the east of Cheung Shun Street as shown in red circle in Figure 65. The increase in building height of Scenarios A and B block a portion of mid-level wind towards leeward region while Baseline Scenario allows the prevailing wind skims over and flow toward the Street (black arrow of Baseline Scenario in Figure 65).

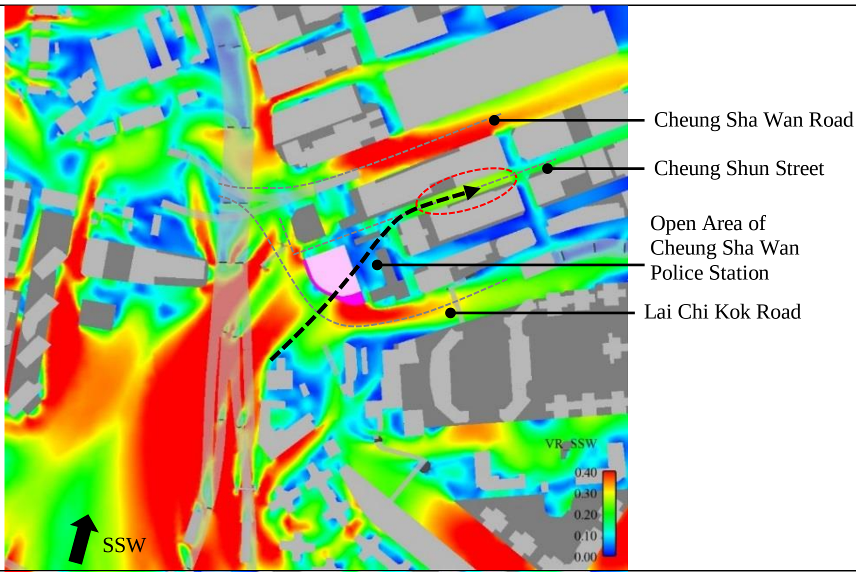
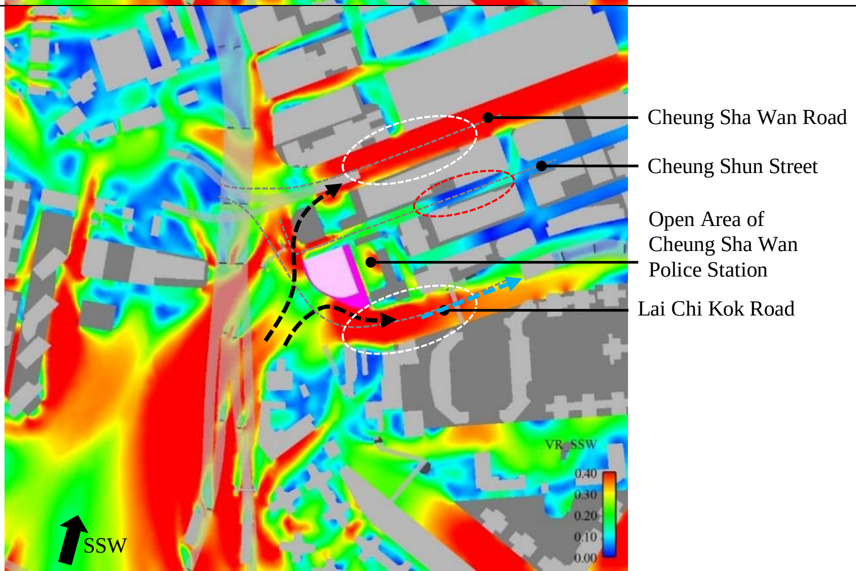
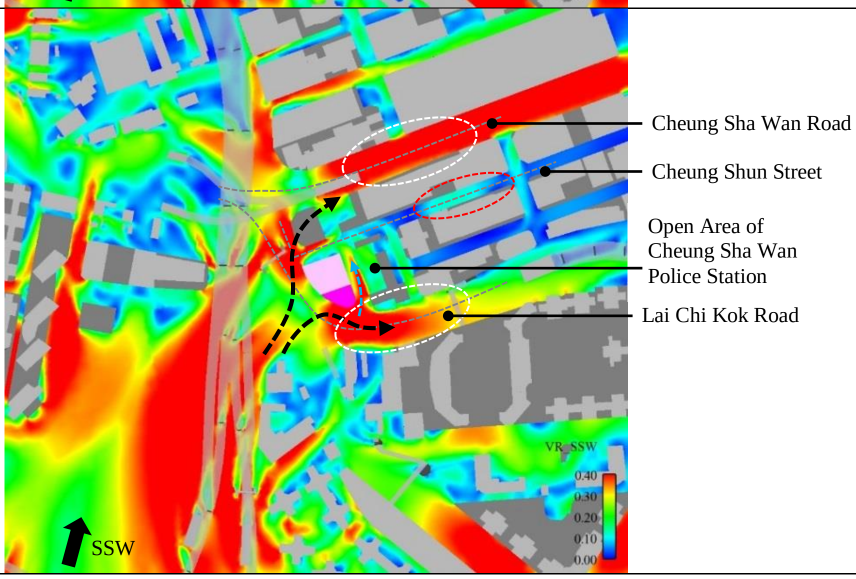
Baseline Scenario	N	
Scenario A	N	
Scenario B	N	

Figure 65 Contour plot of VR under SSW wind

6.3.9 Under SW Wind

The SW wind contributes 6.6% of the annual wind rose and 16.4% of the summer wind rose respectively. Its general wind characteristics is discussed in below:

- The ventilation performance is better at the Cheung Sha Wan Road/ Cheung Shun Street Playground, west of Cheung Shun Street and Lai Chi Kok Road under Scenarios A and B.
- Wind Environment at open area of Cheung Sha Wan Police Station is best under Scenario A.
- The wind performs worse at the east of Cheung Shun Street under Scenarios A and B.

Under Scenarios A and B, the building tower induces downwash wind to the west of Cheung Shun Street and Lai Chi Kok Road, resulting a better wind environment as shown in White Circle of Figure 66 (black arrow of Scenarios A and B in Figure 66). A portion of wind from Cheung Shun Street also divert to Cheung Sha Wan Road/ Cheung Shun Street Playground resulting a better VR value.

The 15m NBA design of Scenario B facilitates the wind penetrate from Lai Chi Kok Road to Cheung Shun Street. Under Scenario A, the separation at grade between building of Scenario A and Police Station is reduced and thus less wind passing through the Site. And this design diverts more wind flow towards Cheung Mou Street (purple arrow of Scenario A in Figure 66).

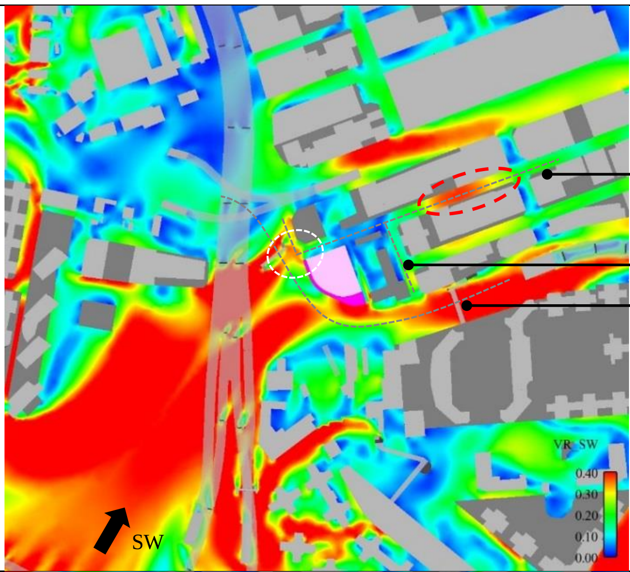
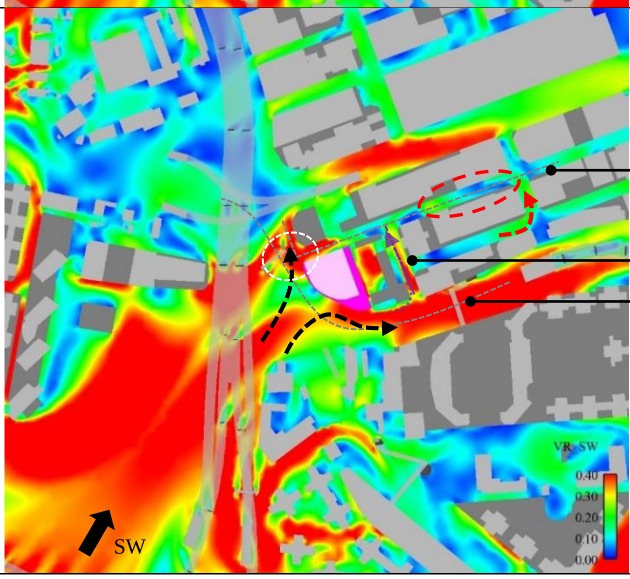
The provision of tower setback of Scenario A allows the prevailing wind skims over atop of the podium and further penetrate to the open area of the Police Station (purple arrow of Scenario A in Figure 66 and Figure 67). This results the best ventilation performance under Scenario A.

Similar to S wind, the taller building of Scenarios A and B would block wind to the east of Cheung Shun Street under Scenarios A and B, resulting slightly lower VR as compared with Baseline Scenario (red circle in Figure 66).

Scenario B achieved slightly higher VR at east of Cheung Shun Street as compared to Scenario A. The building form of Scenario B induce coanda effect and thus the incoming wind would flow towards Leroy Plaza and downwash to Cheung Shun Street. Please refers to streamline plot in Figure 68 and Figure 69.

The results show that Scenario A achieves a slightly higher VR at east part of Cheung Yee Street and Scenario B achieves a slightly higher VR at west part of Cheung Yee Street. Compared to Scenario B, the building form of Scenario A induce less coanda effect thus more wind would flow towards east part of Cheung Yee Street from higher level (Streamline plot in Figure 68). While under Scenario B, since the velocity is lower at Cheung Mou Street, it will induce a larger pressure difference between Cheung Mou Street and Cheung Yee Street. More wind would divert to Cheung Yee Street from Cheung Mou Street and downwash to the pedestrian level thus resulting a slightly higher VR at the west part of Cheung Yee Street. (Streamline plot and vector plot in Figure 70).

A slightly higher VR is observed at Cheung Lai Street and east part of Cheung Sha Wan Road near Cheung Sha Wan Plaza under Scenario A when compared with Scenario B. Higher speed wind at east of Cheung Yee Street would cause the diversion of wind towards Cheung Lai Street. At the same time, a portion of wind would entrant from east of Cheung Sha Wan to Cheung Lai Street resulting a better ventilation performance in these two areas.

Baseline Scenario	N	
Scenario A	N	

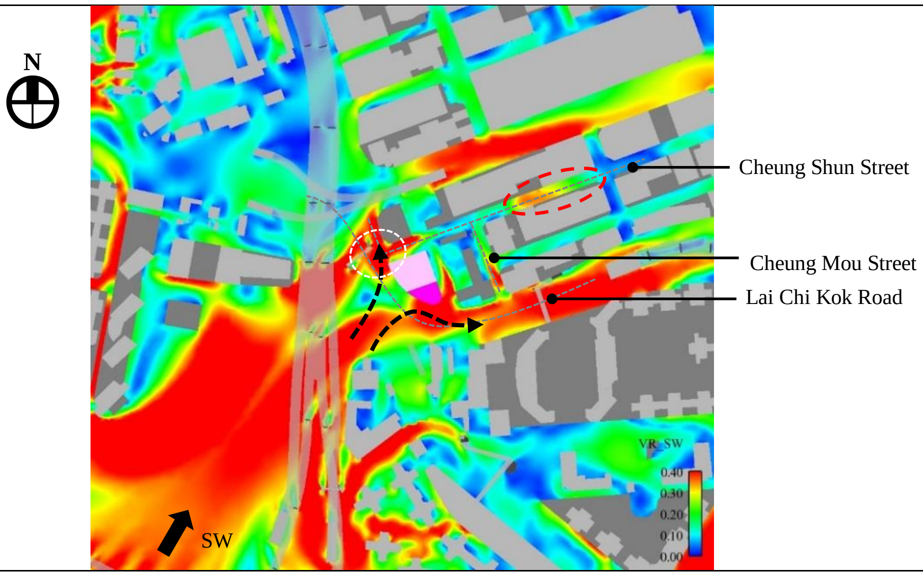
Scenario B	

Figure 66 Contour plot of VR under SW wind

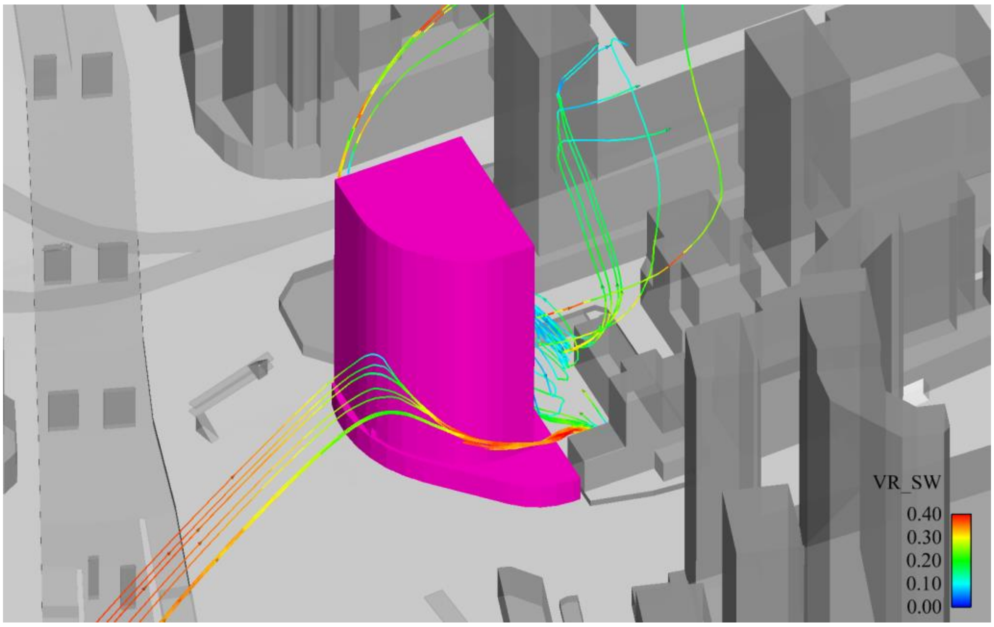


Figure 67 Streamline plot of Scenario A under SW wind

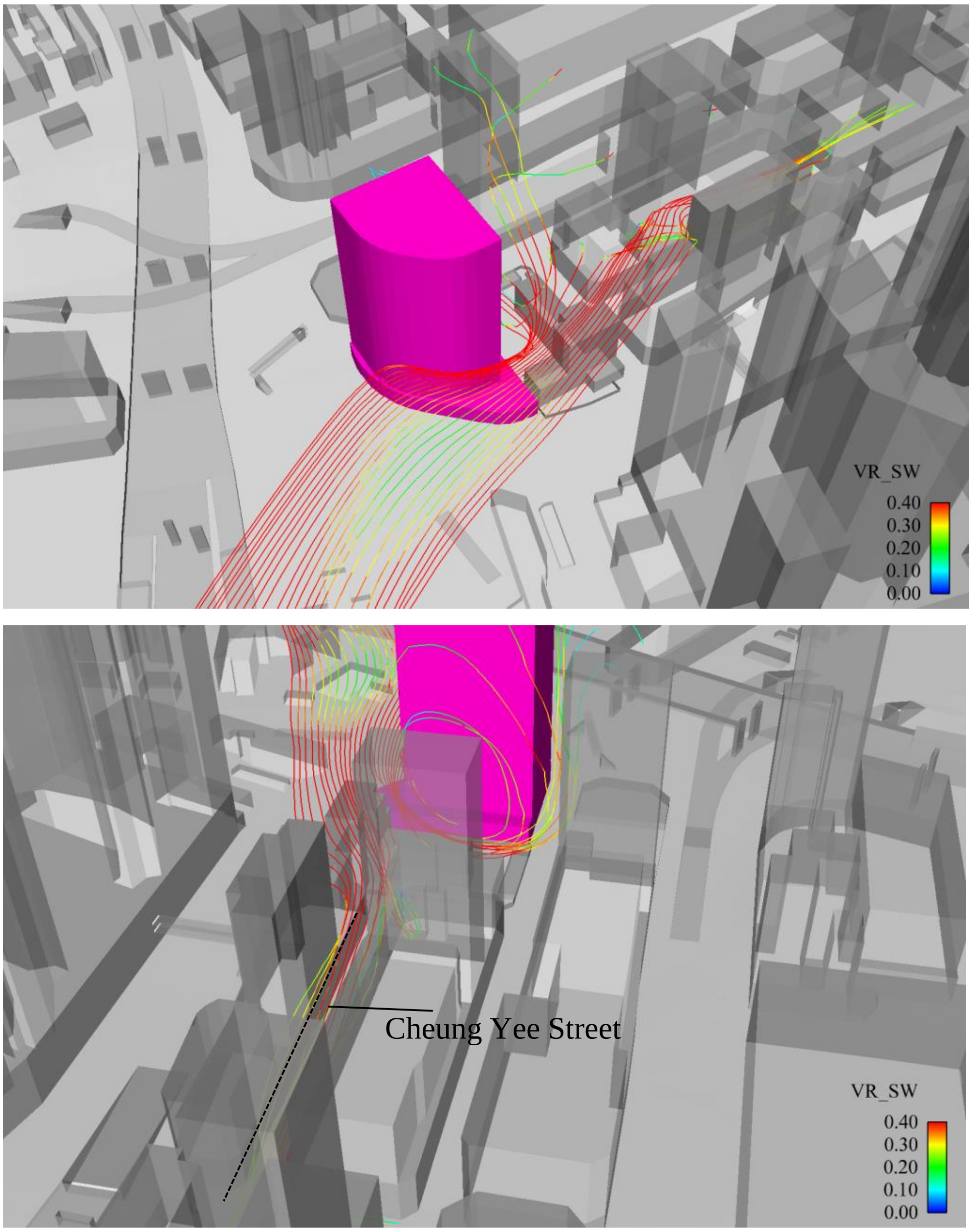


Figure 68 Streamline plot of Scenario A under SW wind

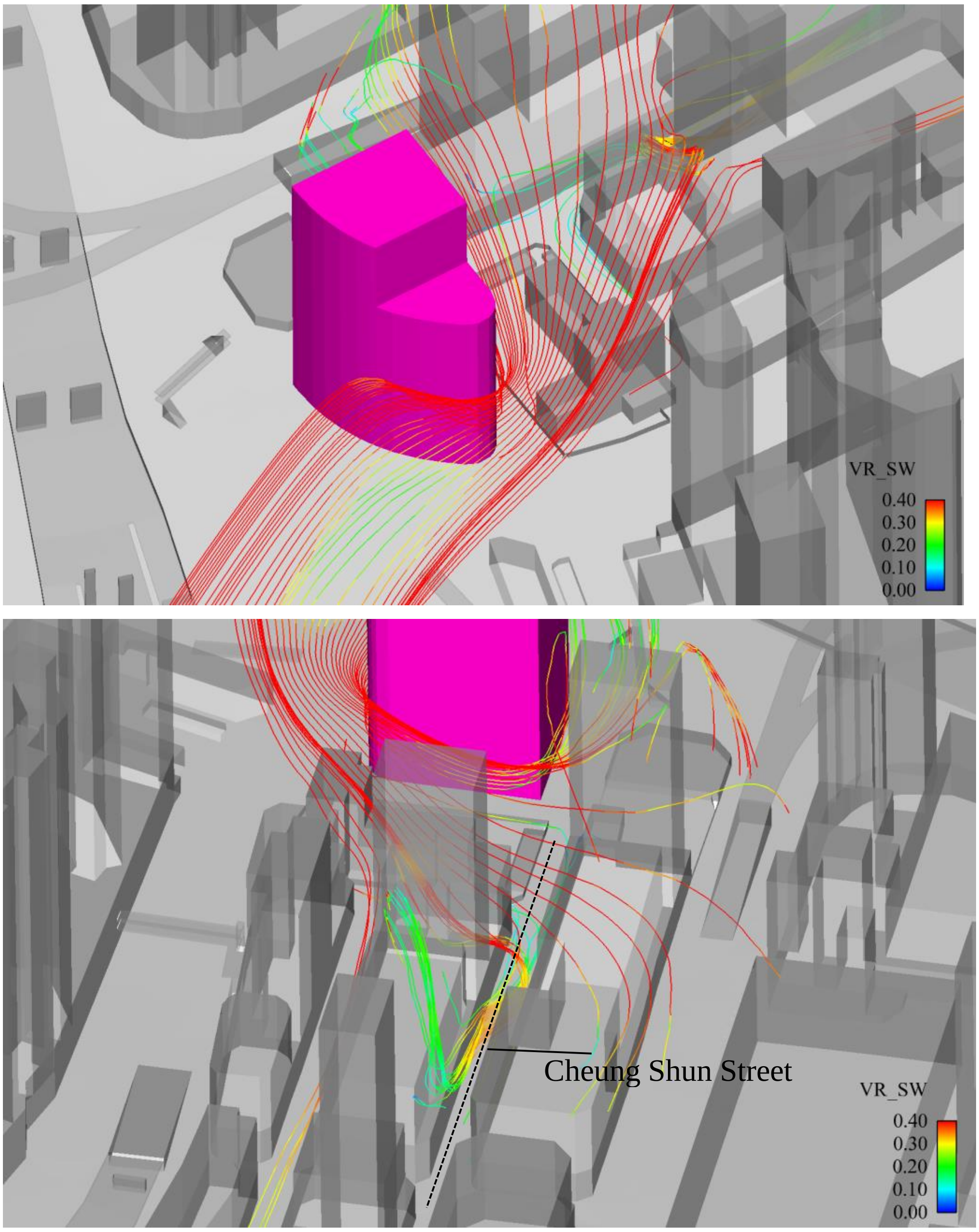


Figure 69 Streamline plot of Scenario B under SW wind

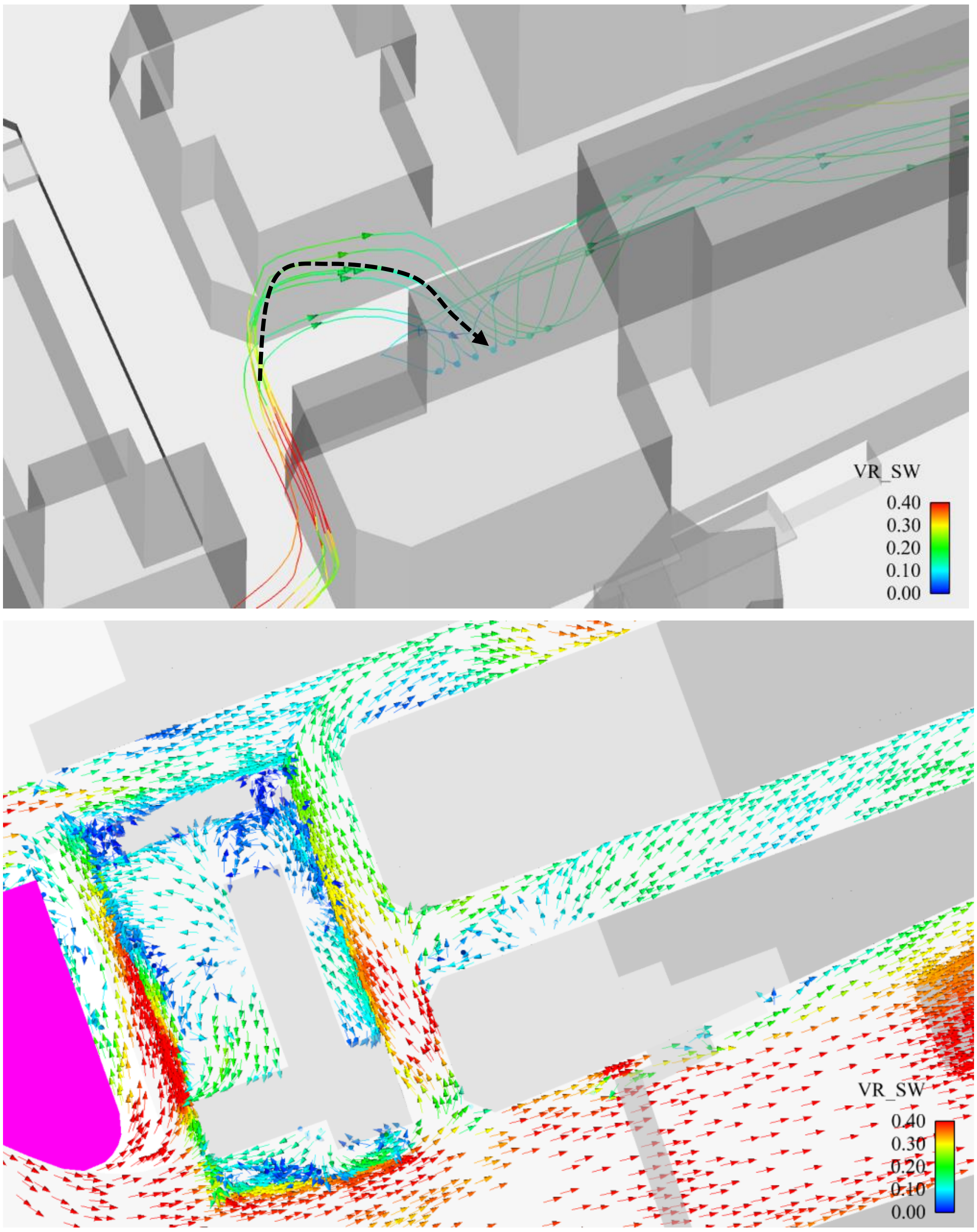


Figure 70 Streamline plot and vector plot of Scenario B under SW wind

6.3.10 Under WSW Wind

The WSW wind contributes about 6.8% of summer wind rose. Its general wind characteristics is discussed in below:

- Higher VR value is observed at east of Cheung Sha Wan Road under Scenarios A and B.
- Open area of Cheung Sha Wan Police Station has the highest VR under Scenario A.
- Slightly worse VR is observed at east of Cheung Shun Street under Scenarios A and B.
- Under Scenario A, the highest VR is found at Cheung Mou Street while lowest VR is found at Cheung Yee Street.

The taller building height of Scenarios A and B facilitates the downwash effect and wind is diverted to Cheung Sha Wan Road, resulting in a better wind environment as shown in White Circle of Figure 71 (black arrow of Scenarios A and B in Figure 71 and Figure 72 to Figure 74).

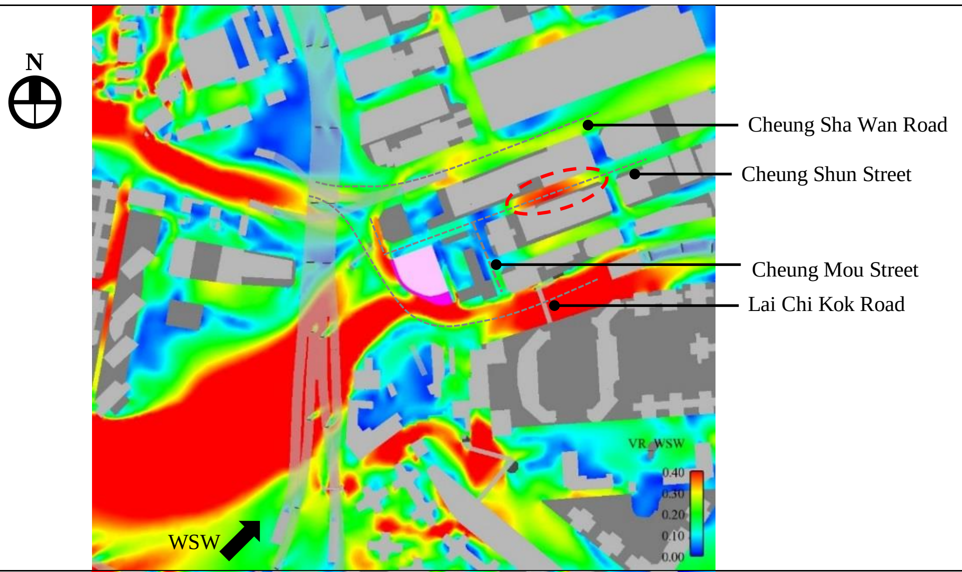
The ~19m building tower setback from south boundary under Scenario A allows more wind to flow atop the podium towards open area of Cheung Sha Wan Police Station and enhances the ventilation performance (purple arrow of Scenario A in Figure 71).

The taller building of Scenarios A and B would block wind to the east of Cheung Shun Street under Scenarios A and B, resulting slightly lower VR (red circle of Scenarios A and B in Figure 71).

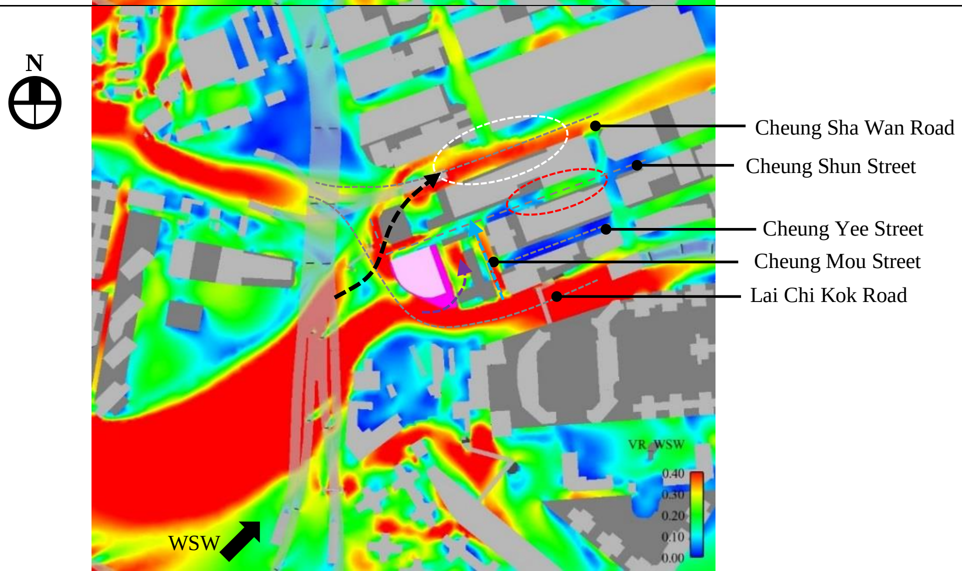
Due to the taller building height, both Scenarios A and B facilitate downwash wind towards Lai Chi Kok Road. Scenario B provides a 15m NBA to allow portion of downwash wind penetrate to Cheung Shun Street (purple arrow of Scenario B in Figure 71). On a contrary, Scenario A podium would divert most of the downwash wind to flow along Lai Chi Kok Road and some would further penetrate into Cheung Mou Street thus Lai Chi Kok Road and Cheung Mou Street have better VR under Scenario A as compared with Scenario B (blue arrow of Scenario A in Figure 71).

The results show that Scenario B achieved slightly higher VR at east of Cheung Shun Street as compared to Scenario A. The building form of Scenario B induce coanda effect and thus the incoming wind would flow towards Leroy Plaza and downwash to Cheung Shun Street. For Scenario A, the incoming wind is mainly diverted to Lai Chi Kok Road.

Baseline Scenario



Scenario A



Scenario B

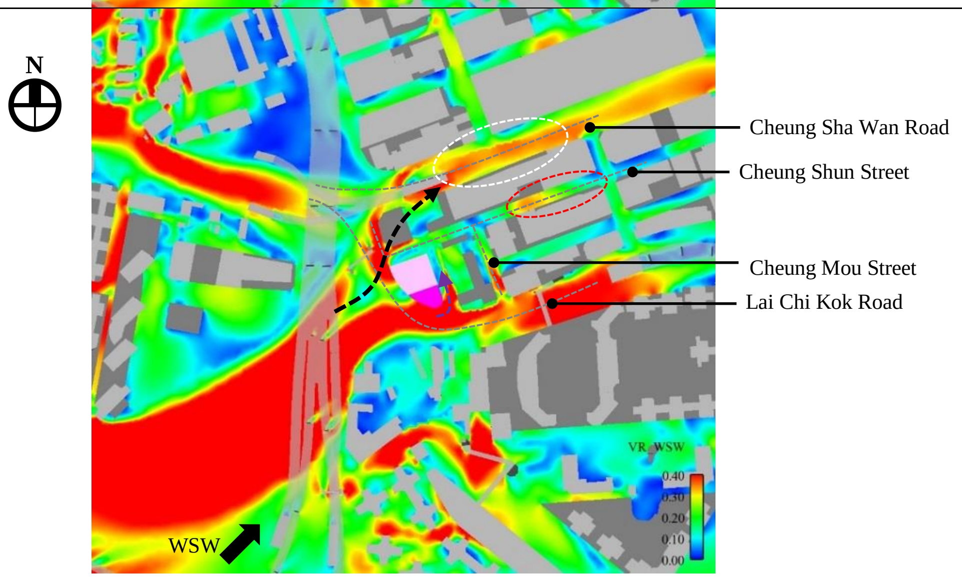


Figure 71 Contour plot of VR under WSW wind

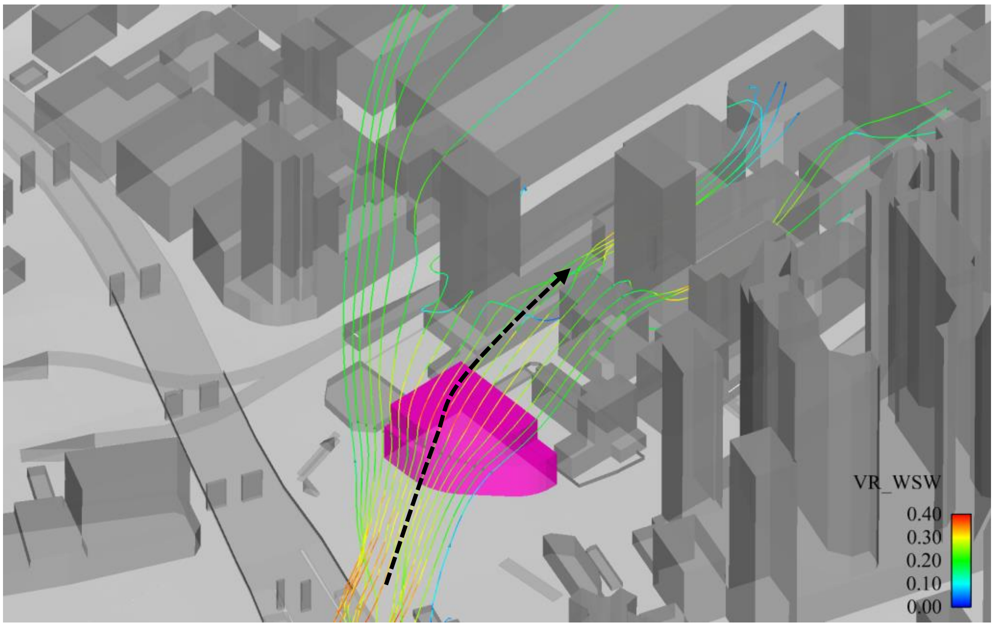


Figure 72 Streamline plot of Baseline Scenario under WSW wind

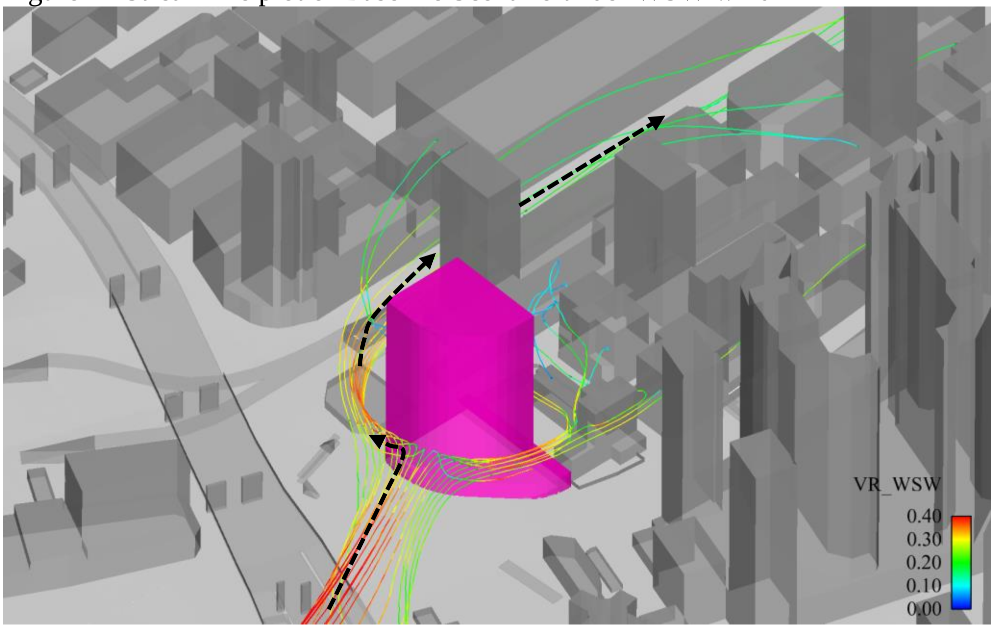


Figure 73 Streamline plot of Scenario A under WSW wind

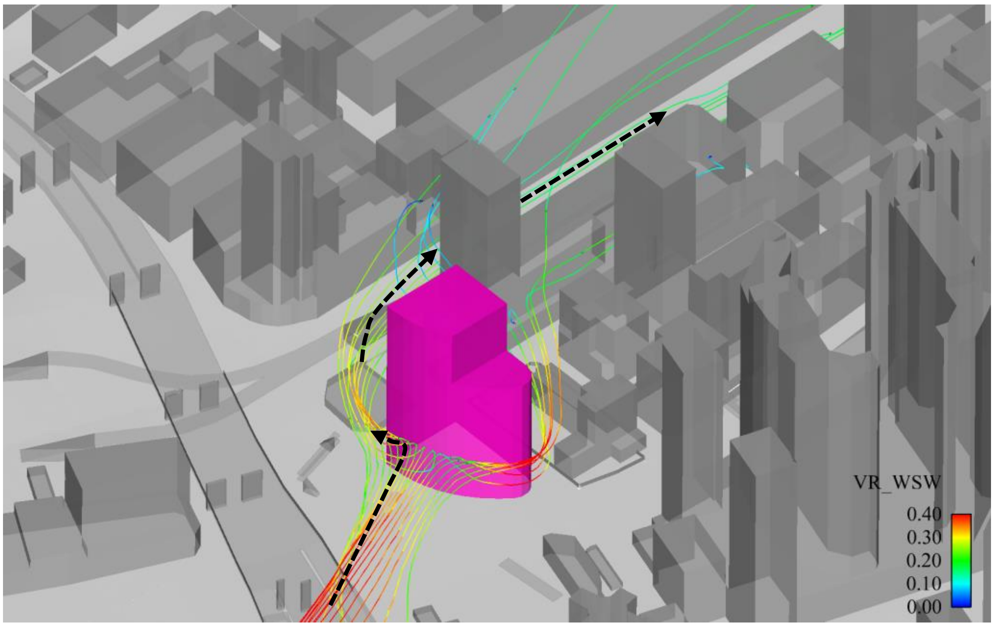


Figure 74 Streamline plot of Scenario B under WSW wind

7 Annual Overall Pattern of Ventilation Performance

7.1 SVR and LVR

The average Velocity Ratios of all test points are determined and extracted. The results of all test points are presented in the Appendix A. According to the Technical Circular, the Velocity Ratio at each test point is assessed and the SVR and the LVR under the prevailing winds are determined and reported to assess the impact of the Proposed Development Scenarios to the wind environment. The SVR and LVR value of the test points are summarized as follows:

Annual wind condition

Table 7 Annual SVR and LVR for Baseline Scenario, Scenario A and Scenario B

	Comparison between Baseline Scenario, Scenarios A, and B		
	Baseline Scenario	Scenario A	Scenario B
SVR	0.10	0.14	0.17
LVR	0.18	0.19	0.20

The SVR and LVR of both Scenarios A and B is higher than Baseline Scenario, indicating that ventilation performance at the immediate area and local area are both better. Among the three scenarios, Scenario B achieves the best wind performance with SVR of 0.17 and LVR of 0.20 respectively.

Summer wind condition

Table 8 Summer SVR and LVR for Baseline Scenario, Scenario A and Scenario B

	Comparison between Baseline Scenario, Scenarios A, and B		
	Baseline Scenario	Scenario A	Scenario B
SVR	0.15	0.18	0.21
LVR	0.18	0.20	0.20

Scenarios A and B also have better SVR and LVR than Baseline Scenario, achieving a better wind environment at the immediate surroundings and local area. Furthermore, for the LVR, both Scenarios A and B achieves a similar value, reflecting that their local ventilation performance is similar.

7.2 Focus Areas

Various Focus Areas with frequent pedestrian access and within major activity zones listed below are defined for further analysis:

1. Castle Peak Road
2. Kom Tsun Street and Bus Terminus
3. Butterfly Valley Road
4. Tung Chau West Street
5. Cheung Sha Wan Road
6. Cheung Shun Street
7. Cheung Yee Street
8. Cheung Mou Street
9. Lai Chi Kok Road
10. Yuet Lun Street
11. Cheung Sha Wan Road/ Cheung Shun Street Playground
12. Open Area of Cheung Sha Wan Police Station
13. Sham Mong Road
14. Sham Shing Road
15. Open Area of Proposed Special School
16. KMB Temporary Bus Depot
17. Non-building Area

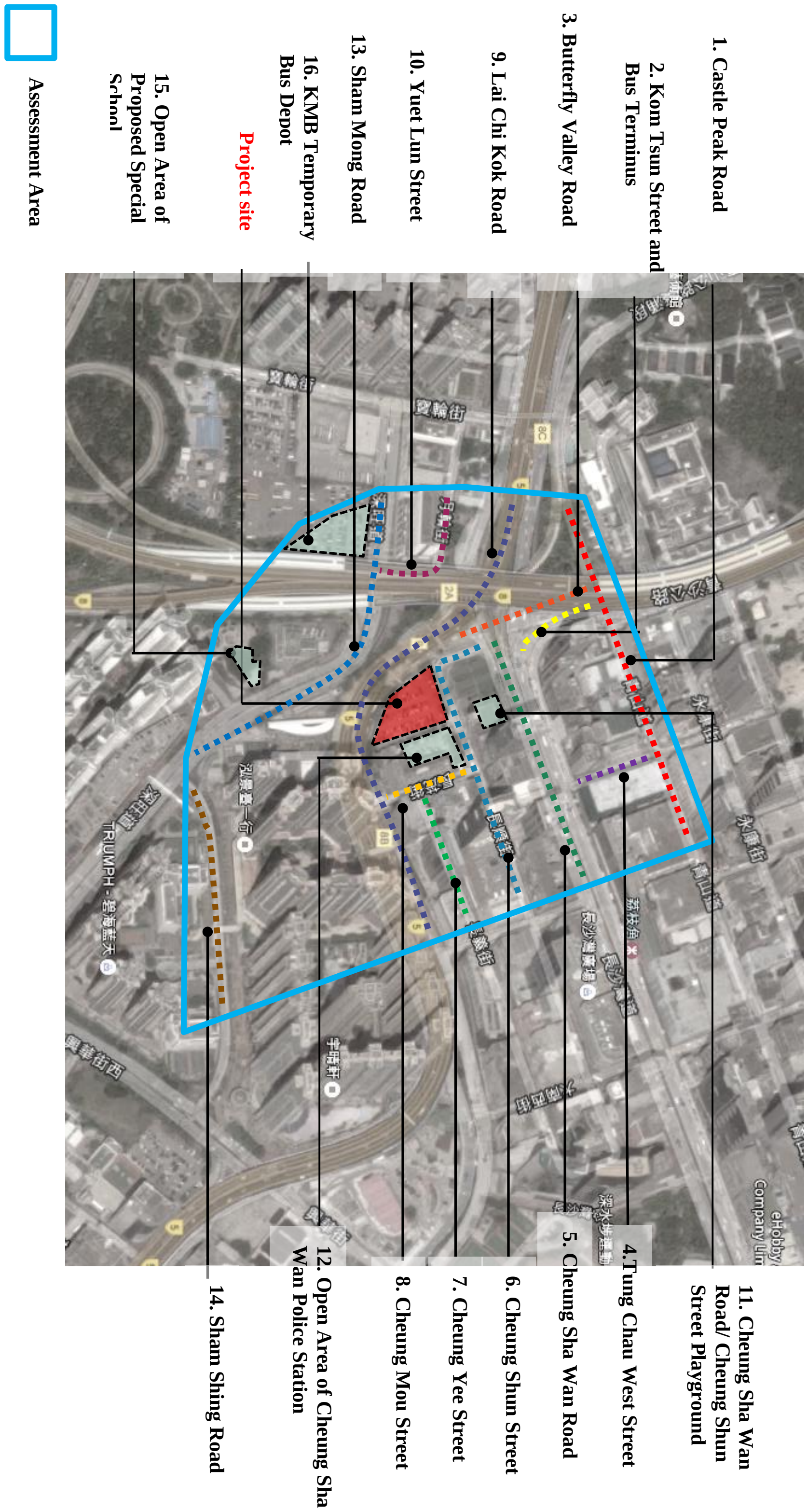


Figure 75 Highlights of the Focus Areas for the study (image Source: Lands Department)

7.2.1 Under Annual Wind Condition

Table 9 VR Results for Focus Areas under Annual Wind Condition under Baseline Scenario, Scenario A and Scenario B

	Focus Areas	Test Points	Baseline Scenario	Scenario A	Scenario B
1	Castle Peak Road	O1 – O12	0.19	0.20	0.20
2	Kom Tsun Street and Bus Terminus	O4, O13 – O15	0.17	0.19	0.19
3	Butterfly Valley Road	O3, O16 – O20	0.16	0.17	0.18
4	Tung Chau West Street	O21 – O24	0.15	0.15	0.15
5	Cheung Sha Wan Road	O25 – O32	0.33	0.33	0.33
6	Cheung Shun Street	O33 – O42	0.24	0.23	0.23
7	Cheung Yee Street	O43 – O47	0.32	0.29	0.29
8	Cheung Mou Street	O48 – O51	0.13	0.14	0.13
9	Lai Chi Kok Road	O52 – O65	0.21	0.22	0.22
10	Yuet Lun Street	O66 – O70	0.14	0.17	0.16
11	Cheung Sha Wan Road/ Cheung Shun Street Playground	O71 – O74	0.11	0.11	0.12
12	Open Area of Cheung Sha Wan Police Station	O75 – O77	0.07	0.11	0.08
13	Sham Mong Road	O78 – O88	0.22	0.21	0.20
14	Sham Shing Road	O89 – O95	0.18	0.18	0.18
15	Open Area of Proposed Special School	O96 – O97	0.09	0.10	0.09
16	KMB Temporary Bus Depot	O98 – O100	0.20	0.18	0.18
17	Non-building Area	SBS1 – SBS8	NA	NA	0.20

Under annual condition, similar wind performances are achieved among the three scenarios at Castle Peak Road, Tung Chau West Street, Cheung Sha Wan Road, Cheung Shun Street, Cheung Mou Street, Cheung Sha Wan Road/ Cheung Shun Street Playground, Sham Mong Road ,Sham Shing Road and open area of proposed Special School.

Localized area of Lai Chi Kok Road near the site is better under Scenario B. The 15m NBA and 4m setback would facilitate the wind flow around the site under SE quarter wind. Thus, better ventilation performance is observed at localized area of Lai Chi Kok Road near the Site.

Generally, the taller building height of Scenarios A and B induces downwash wind, and thus, the rest of the focus areas generally achieve a slightly better VR except Chung Yee Street. Baseline Scenario has higher wind permeability and allows more wind penetration across the site toward Cheung Yee Street and resulting in a better ventilation performance.

Comparing Scenario B to Scenario A, the ventilation performance of the focus areas are generally similar except the open area of Cheung Sha Wan Police Station. The provision of tower setback in Scenario A allows larger separation between the building and the adjacent Police Station that facilitates the SW quarterly wind penetrate into the open area.

For the Yuet Lun Street, the downwash wind from NE quarter strengthen the air flow along Cheung Shun Street and further enhance the ventilation performance at Yuet Lun Street under Scenarios A and B.

For the KMB Temporary Bus Depot, the downwash wind of the project site under annual wind condition would disturb the air stream along Lai Chi Kok Road under Scenarios A and B. While under Baseline Scheme, without the intervention, the air stream can flow along Lai Chi Kok Road to the west thus slightly higher VR in found under Baseline Scenario.

Under Scenario B, the Non-building Area has a VR of 0.20 higher than the SVR and similar to the LVR, which indicates the 15m NBA is quite effective.

7.2.2 Under Summer Wind Condition

Table 10 VR Results for Focus Areas under Summer Wind Condition under Baseline Scenario, Scenario A and Scenario B

	Focus Areas	Test Points	Baseline Scenario	Scenario A	Scenario B
1	Castle Peak Road	O1 – O12	0.18	0.19	0.19
2	Kom Tsun Street and Bus Terminus	O4, O13 – O15	0.19	0.18	0.19
3	Butterfly Valley Road	O3, O16 – O20	0.15	0.16	0.16
4	Tung Chau West Street	O21 – O24	0.13	0.14	0.13
5	Cheung Sha Wan Road	O25 – O32	0.27	0.29	0.30
6	Cheung Shun Street	O33 – O42	0.20	0.20	0.21
7	Cheung Yee Street	O43 – O47	0.20	0.15	0.16
8	Cheung Mou Street	O48 – O51	0.12	0.18	0.15
9	Lai Chi Kok Road	O52 – O65	0.20	0.21	0.21
10	Yuet Lun Street	O66 – O70	0.16	0.18	0.17
11	Cheung Sha Wan Road/ Cheung Shun Street Playground	O71 – O74	0.10	0.13	0.12
12	Open Area of Cheung Sha Wan Police Station	O75 – O77	0.06	0.14	0.08
13	Sham Mong Road	O78 – O88	0.25	0.24	0.24
14	Sham Shing Road	O89 – O95	0.23	0.23	0.23
15	Open Area of Proposed Special School	O96 – O97	0.08	0.08	0.08
16	KMB Temporary Bus Depot	O98 – O100	0.27	0.26	0.25
17	Non-building Area	SBS1 – SBS8	NA	NA	0.22

Under summer condition, similar wind performances are achieved at Castle Peak Road, Kom Tsun Street and Bus Terminus, Butterfly Valley Road, Tung Chau West Street, Cheung Shun Street, Lai Chi Kok Road, Yuet Lun Street, Sham Mong Road, Sham Shing Road and open area of the proposed Special School.

The wind performance at Cheung Mou Street and Open Area of Cheung Sha Wan Police Station are better under Scenarios A and B. Among all the scenarios, Scenario A achieves the best wind performance at these focus areas.

For the Cheung Mou Street, under Scenario B, the 15m NBA design facilitates the wind penetrate from Lai Chi Kok Road to Cheung Shun Street while under Scenario A, the separation between Scenario A building and Police Station is reduced and the wind cannot pass the Site. Thus, it results more wind flow along Cheung Mou Street.

For the open area of Cheung Sha Wan Police Station, the tower setback of Scenario A allows more SW quarterly wind penetrate the Site to that area.

The wind environment at Cheung Yee Street is better under Baseline Scenario, as the wind from SW can flow over the low-rise building tower not exceeding 13 storeys and reach to Cheung Yee Street while it is blocked by the high-rise building tower (~120mPD) under Scenarios A and B.

The KMB Temporary Bus Depot has a slightly lower VR under Scenarios A and B. This is due to the downwash wind induced by the taller building of Scenarios A and B disturbs the air stream from Lai Chi Kok Road leading to less wind reach to that area.

Cheung Sha Wan Road/ Cheung Shun Street Playground has a higher VR results under Scenarios A and B. This is due to the downwashed wind under SW quarter allow more wind flow along Cheung Shun Street, in which a portion of wind would divert to Cheung Sha Wan Road/ Cheung Shun Street Playground resulting a better ventilation performance.

Similar to annual wind condition, the 15m NBA and 4m setback would facilitate the wind flow around the site under SE quarter wind. Thus, better ventilation performance is observed at localized area of Lai Chi Kok Road near the site.

Under Scenario B, the 15m NBA within Site has a VR of 0.22 higher than the SVR and LVR, which indicates the 15m NBA is quite effective.

8 Recommendation

As comparing Scenario B to Scenario A, Scenario B achieves the higher SVR and LVR for annual wind condition and also in SVR for summer wind condition. The results indicate that Scenario B performs general better than Scenario A in terms of ventilation performance.

Under Scenario B, the provision of 15m NBA from the east boundary of the site and 4m setback from lot boundary abutting Cheung Shun Street create larger wind entrance thus further enhance wind penetration using 15m NBA towards Cheung Shun Street, open area of Cheung Sha Wan Police Station and Cheung Sha Wan Road/ Cheung Shun Street Playground.

In the future detail design, the development could be considered to further chamfer the southern portion building edge and create a larger separation between the building block and adjacent Cheung Sha Wan Police Station. The separation shall be aligned with the SW prevailing wind direction to facilitate the summer wind penetration. It shall enhance the wind environment leeward region such as east part of Cheung Shun Street. In addition, if the future development cannot fulfil the 15m NBA and 4m setback requirement, a quantitative analysis would be carried out to demonstrate no adverse ventilation impact could be imposed to the surrounding wind environment.

9 Conclusion

Ove Arup & Partners Hong Kong Ltd. (Arup) was commissioned by Planning Department (PlanD) to carry out an Air Ventilation Assessment by Computational Fluid Dynamics (CFD) for Potential Commercial Site at Cheung Shun Street near Lai Chi Kok Road, Cheung Sha Wan. The Project Site is situated at Lai Chi Kok Area. A cluster of medium-rise business/ industrial buildings are located to the east and north of the site. High-rise residential developments of Banyan Garden, Liberte, The Pacifica and One West Kowloon are located to the immediate south of the site, whereas elevated Tsing Sha Highway is located west of the project site.

Qualitative Assessment of the Existing Wind Condition

In general, the Project Site is expected to experience relatively low wind speed under annual condition as congested mid/ high rise developments are situated at the upwind direction and shield the prevailing winds to the site. In the contrast, the Project Site is expected to experience a good wind environment under summer condition due to relatively open space at the southwest of the site.

Annual Wind Condition

- The prevailing winds are mainly Easterly (E) and North-Easterly (NE) directions.
- Several main Road such as Lai Chi Kok Road, Sham Mong Road and Cheung Shun Street would form a potential wind path under annual prevailing wind.
- Annual incoming wind would be partially blocked by the existing buildings clusters to the East of Project Site. Hence, relatively calm environment is expected.

Summer Wind Condition

- The prevailing winds are mainly East-South-Easterly (ESE), South-South-Westerly (SSW), South-Westerly (SW) and Easterly (E) directions.
- Tsing Sha Highway forms an effective wind path and facilitate the wind penetration from waterfront towards the site.
- The SW summer wind is likely to penetrate to the Project Site effectively and a relatively good wind environment would be expected.

Quantitative Assessment – Initial Study

A series of CFD simulations using realizable k– ε turbulence model are performed based on the AVA methodology for the Initial Study as stipulated in the Technical Circular. Ten wind directions, which cover 78.9% and 81.8% of annual and summer wind condition of the area respectively, have been considered. The ventilation performance for the Development at the site boundary and within the assessment area was assessed under Baseline Scenario, Scenario A and Scenario B.

According to the Technical Circular, the Velocity Ratio at each testing point is assessed in terms of SVR and LVR, respectively. A total of 30 perimeter test points and 100 overall test points are selected to assess the ventilation performance of the Development. 8 special test points are allocated in Scenarios to assess the ventilation performance within the site.

Major findings for the quantitative study of Baseline Scenario, Scenario A and Scenario B:

Annual condition

- Among the three scenarios, Scenario B has the best wind performance with SVR of 0.17 and LVR of 0.20 respectively.
- The ventilation environment of both Scenarios A and B is better than that of Baseline Scenario.
- Under Scenarios A and B, the wind performance at Kom Tsun Street, Bus Terminus, Butterfly Valley Road and Yuet Lun Street and Open Area of Cheung Sha Wan Police Station is better, while it is worse at Cheung Yee Street compared to Baseline Scenario.

Summer condition

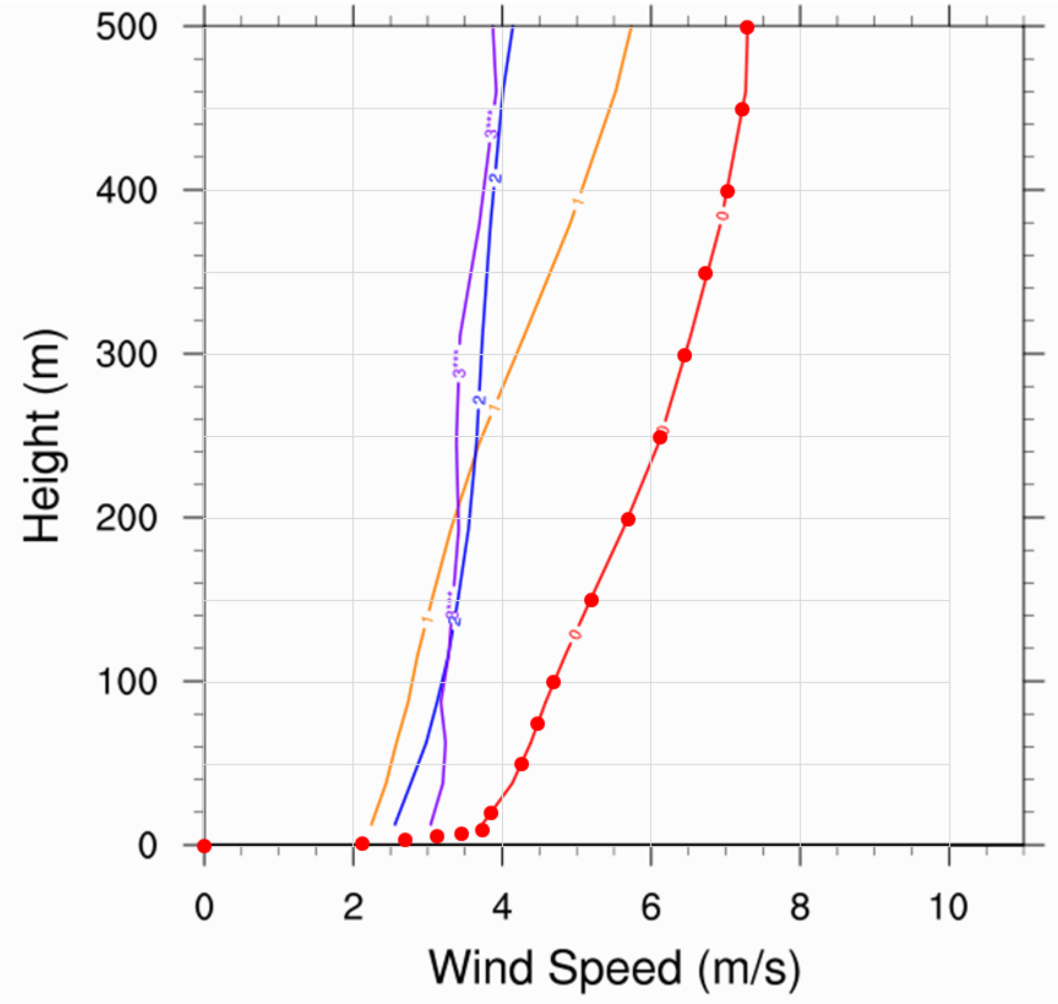
- Scenario B has the highest SVR of 0.21, while Scenarios A and B achieve the same LVR of 0.20.
- Scenarios A and B have better wind environment than Baseline Scenario.
- The wind performance at Cheung Mou Street, Cheung Mou Street and open area of Cheung Sha Wan Police Station is better under Scenarios A and B, while it is worse at Cheung Yee Street and KMB Temporary Bus Depot compared to Baseline Scenario.

Scenario B, which has incorporated the design features of a 15m NBA and 4m setback, achieves higher SVR and LVR for annual wind condition and also in SVR for summer wind condition, indicating that Scenario B performs generally better than Scenario A in terms of ventilation performance. In the future detailed design, the development could be considered to further chamfer the southern portion building edge and create a larger separation between the building block and adjacent Cheung Sha Wan Police Station, aligning with the SW prevailing wind direction to facilitate the summer wind penetration. In addition, if the future development cannot fulfil the 15m NBA and 4m setback requirement, a quantitative analysis would be carried out to demonstrate no adverse ventilation impact could be imposed to the surrounding wind environment.

Appendix A

Experimental Site Wind Availability Data

A1 Site Wind Characteristic



0: 22.5º-112.4º

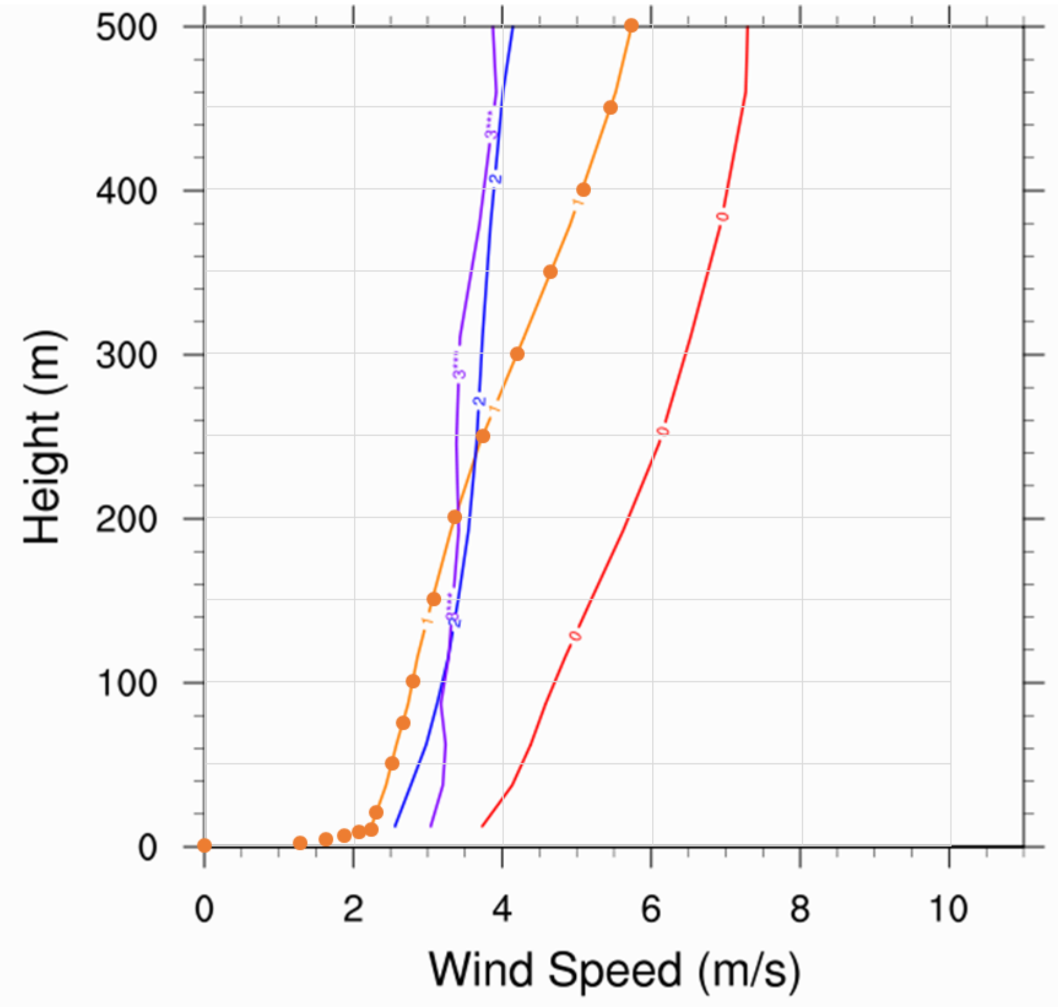
1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profiles from 22.5º – 112.4º at grid X: 074 Y: 046



0: 22.5º-112.4º

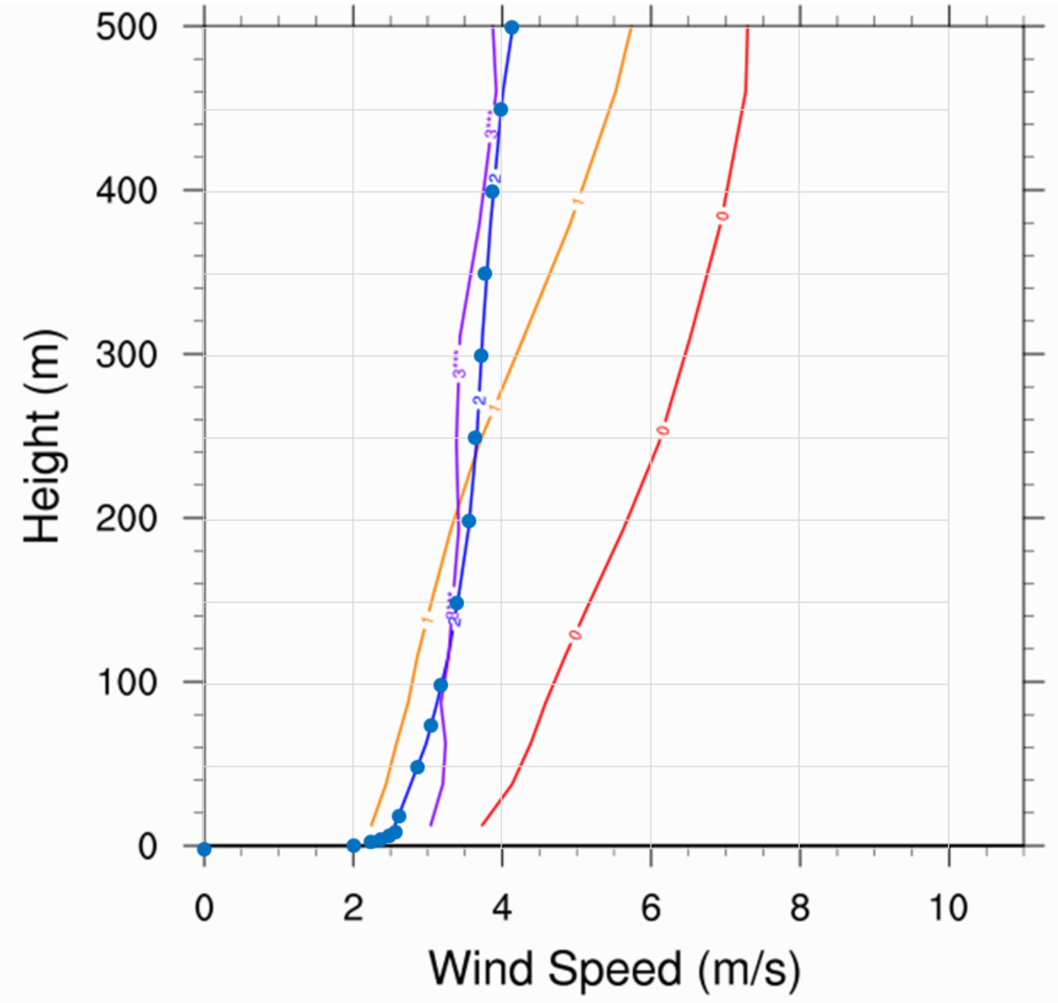
1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profiles from 112.5º – 202.4º at grid X: 074 Y: 046



0: 22.5º-112.4º

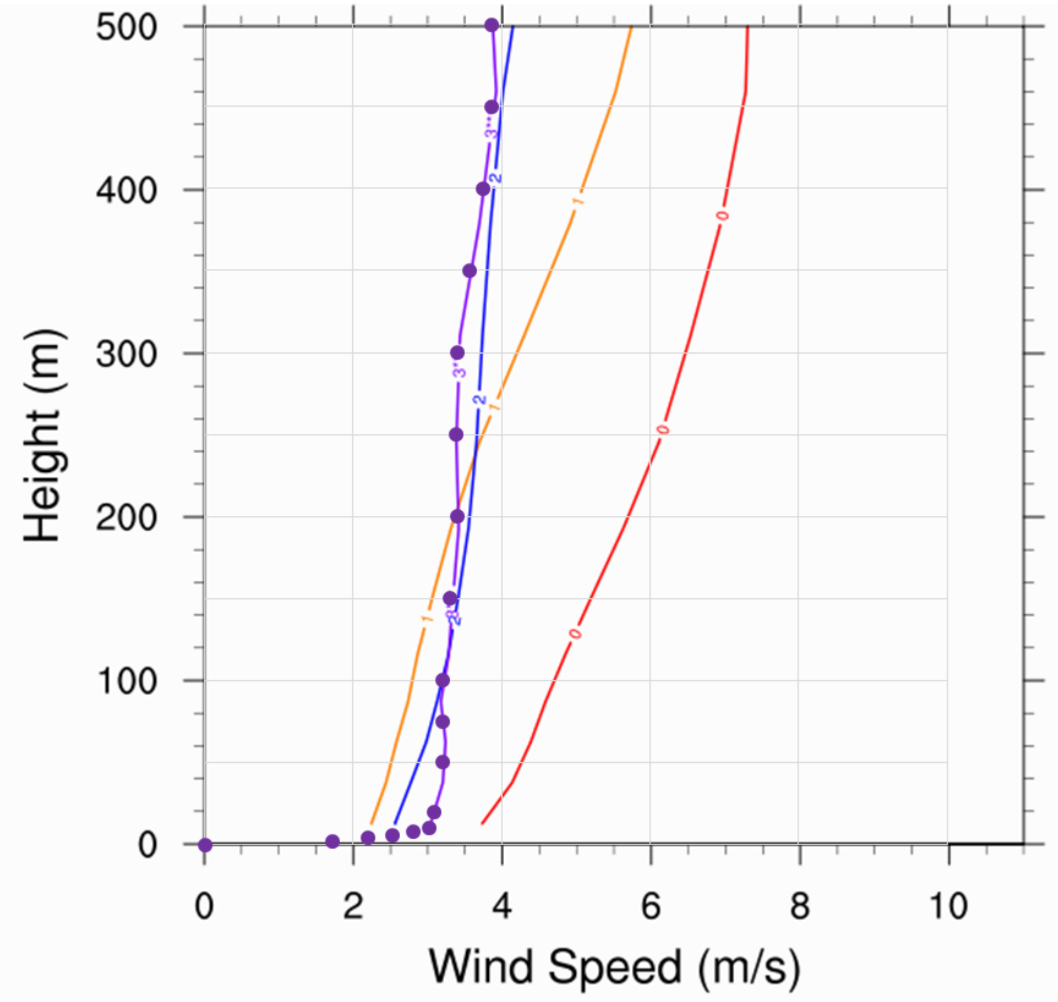
1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profiles from 202.5º – 292.4º at grid X: 074 Y: 046



0: 22.5º-112.4º

1: 112.5º-202.4º

2: 202.5º-292.4º

3: 292.5º-22.4º

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profiles from 292.5º – 22.4º at grid X: 074 Y: 046

Appendix B

Velocity Ratio Table of the Test Points

B1 Baseline Scheme

B1.1 Perimeter Test Points

Baseline	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
P1	0.08	0.05	0.04	0.09	0.20	0.19	0.24	0.36	0.31	0.34	0.13	0.24
P2	0.09	0.04	0.03	0.11	0.08	0.08	0.05	0.08	0.08	0.06	0.07	0.07
P3	0.09	0.04	0.03	0.12	0.06	0.13	0.05	0.14	0.06	0.09	0.07	0.09
P4	0.08	0.03	0.04	0.11	0.08	0.18	0.07	0.20	0.09	0.13	0.09	0.12
P5	0.09	0.03	0.03	0.11	0.14	0.18	0.06	0.18	0.11	0.12	0.09	0.12
P6	0.11	0.04	0.03	0.12	0.16	0.20	0.04	0.12	0.06	0.11	0.08	0.10
P7	0.22	0.11	0.06	0.12	0.17	0.23	0.03	0.08	0.06	0.12	0.11	0.10
P8	0.17	0.10	0.06	0.10	0.16	0.21	0.06	0.06	0.06	0.10	0.10	0.09
P9	0.17	0.13	0.07	0.03	0.06	0.07	0.06	0.03	0.04	0.05	0.08	0.05
P10	0.16	0.14	0.07	0.05	0.08	0.08	0.08	0.03	0.05	0.03	0.08	0.05
P11	0.14	0.12	0.06	0.05	0.10	0.11	0.08	0.03	0.12	0.06	0.08	0.08
P12	0.14	0.12	0.07	0.06	0.11	0.12	0.09	0.02	0.18	0.14	0.09	0.10
P13	0.15	0.14	0.08	0.07	0.11	0.12	0.09	0.04	0.21	0.14	0.11	0.11
P14	0.14	0.12	0.06	0.05	0.10	0.12	0.08	0.06	0.23	0.19	0.10	0.12
P15	0.17	0.15	0.08	0.06	0.09	0.11	0.07	0.11	0.31	0.30	0.12	0.15
P16	0.16	0.13	0.04	0.05	0.09	0.11	0.05	0.22	0.36	0.37	0.12	0.18
P17	0.21	0.17	0.05	0.04	0.08	0.12	0.11	0.26	0.29	0.35	0.13	0.18
P18	0.11	0.15	0.13	0.03	0.05	0.11	0.13	0.38	0.31	0.40	0.15	0.22
P19	0.21	0.08	0.15	0.03	0.06	0.08	0.09	0.43	0.38	0.47	0.16	0.24
P20	0.08	0.03	0.10	0.05	0.04	0.08	0.17	0.49	0.45	0.58	0.14	0.28
P21	0.04	0.02	0.05	0.06	0.05	0.10	0.20	0.50	0.47	0.63	0.13	0.29
P22	0.04	0.02	0.05	0.06	0.06	0.09	0.16	0.42	0.42	0.58	0.11	0.26
P23	0.04	0.04	0.05	0.06	0.07	0.11	0.12	0.32	0.37	0.51	0.11	0.22
P24	0.03	0.04	0.05	0.06	0.08	0.11	0.10	0.25	0.33	0.44	0.09	0.19
P25	0.03	0.04	0.03	0.05	0.12	0.09	0.05	0.15	0.24	0.28	0.07	0.14
P26	0.06	0.02	0.03	0.05	0.15	0.07	0.04	0.06	0.13	0.16	0.06	0.08
P27	0.08	0.03	0.04	0.03	0.15	0.06	0.08	0.13	0.16	0.26	0.07	0.12
P28	0.07	0.03	0.03	0.02	0.10	0.09	0.14	0.24	0.21	0.35	0.08	0.16
P29	0.04	0.03	0.03	0.02	0.11	0.12	0.18	0.30	0.22	0.37	0.08	0.18
P30	0.04	0.04	0.03	0.02	0.13	0.14	0.22	0.35	0.26	0.39	0.10	0.21

B1.2 Overall Test Points

Baseline	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O1	0.20	0.07	0.05	0.06	0.04	0.09	0.07	0.18	0.07	0.03	0.09	0.08
O2	0.25	0.07	0.08	0.17	0.11	0.09	0.09	0.26	0.04	0.05	0.13	0.12
O3	0.29	0.07	0.18	0.31	0.27	0.12	0.06	0.06	0.04	0.08	0.18	0.12
O4	0.36	0.11	0.21	0.31	0.28	0.17	0.28	0.37	0.13	0.17	0.24	0.25
O5	0.38	0.11	0.18	0.32	0.28	0.17	0.22	0.38	0.20	0.20	0.24	0.25
O6	0.37	0.13	0.17	0.32	0.29	0.18	0.16	0.21	0.18	0.15	0.22	0.21
O7	0.37	0.12	0.16	0.31	0.30	0.20	0.18	0.25	0.17	0.19	0.22	0.22
O8	0.38	0.09	0.11	0.23	0.28	0.21	0.19	0.27	0.18	0.18	0.19	0.21
O9	0.40	0.14	0.15	0.26	0.29	0.23	0.17	0.29	0.15	0.17	0.22	0.22
O10	0.43	0.04	0.19	0.28	0.27	0.23	0.08	0.16	0.06	0.10	0.20	0.16
O11	0.49	0.12	0.22	0.23	0.21	0.25	0.07	0.13	0.11	0.19	0.22	0.16
O12	0.51	0.11	0.14	0.13	0.13	0.27	0.06	0.10	0.13	0.30	0.17	0.15
O13	0.16	0.15	0.11	0.03	0.03	0.05	0.28	0.36	0.17	0.16	0.13	0.17
O14	0.19	0.10	0.09	0.05	0.13	0.11	0.21	0.31	0.16	0.11	0.13	0.16
O15	0.07	0.07	0.39	0.19	0.12	0.11	0.11	0.21	0.18	0.12	0.20	0.18
O16	0.13	0.09	0.13	0.02	0.12	0.09	0.23	0.29	0.10	0.05	0.11	0.14
O17	0.12	0.13	0.19	0.10	0.12	0.11	0.17	0.31	0.12	0.07	0.16	0.16
O18	0.09	0.06	0.43	0.21	0.05	0.08	0.14	0.26	0.15	0.17	0.21	0.19
O19	0.33	0.24	0.12	0.24	0.16	0.07	0.09	0.19	0.05	0.12	0.18	0.13
O20	0.33	0.08	0.09	0.03	0.02	0.04	0.17	0.40	0.20	0.13	0.13	0.17
O21	0.26	0.20	0.18	0.16	0.17	0.16	0.10	0.23	0.16	0.22	0.19	0.17
O22	0.09	0.23	0.23	0.08	0.07	0.04	0.04	0.18	0.20	0.24	0.16	0.14
O23	0.07	0.12	0.16	0.03	0.02	0.01	0.04	0.11	0.19	0.24	0.10	0.11
O24	0.29	0.15	0.20	0.12	0.05	0.02	0.06	0.12	0.14	0.18	0.15	0.11
O25	0.43	0.29	0.42	0.23	0.06	0.07	0.08	0.12	0.12	0.17	0.27	0.15
O26	0.55	0.36	0.50	0.29	0.06	0.03	0.13	0.21	0.14	0.30	0.33	0.20
O27	0.54	0.33	0.47	0.33	0.15	0.02	0.16	0.34	0.30	0.26	0.35	0.27
O28	0.46	0.26	0.41	0.39	0.19	0.07	0.15	0.43	0.33	0.30	0.35	0.30
O29	0.42	0.22	0.37	0.41	0.22	0.10	0.15	0.44	0.35	0.26	0.33	0.31
O30	0.44	0.19	0.33	0.42	0.25	0.14	0.14	0.40	0.37	0.29	0.32	0.31
O31	0.49	0.19	0.32	0.44	0.30	0.20	0.13	0.38	0.35	0.25	0.33	0.31
O32	0.56	0.20	0.34	0.46	0.34	0.25	0.13	0.38	0.34	0.24	0.36	0.32
O33	0.38	0.20	0.06	0.13	0.10	0.07	0.12	0.20	0.20	0.18	0.15	0.14
O34	0.18	0.03	0.04	0.03	0.07	0.15	0.18	0.28	0.29	0.31	0.10	0.19
O35	0.16	0.09	0.08	0.16	0.16	0.19	0.15	0.19	0.20	0.11	0.13	0.16
O36	0.29	0.17	0.13	0.19	0.19	0.24	0.06	0.12	0.08	0.09	0.17	0.13
O37	0.48	0.33	0.30	0.23	0.23	0.26	0.07	0.07	0.06	0.13	0.26	0.15
O38	0.46	0.34	0.32	0.24	0.23	0.27	0.04	0.13	0.07	0.06	0.27	0.16
O39	0.46	0.37	0.42	0.28	0.24	0.29	0.09	0.23	0.23	0.18	0.34	0.24
O40	0.37	0.31	0.38	0.23	0.27	0.29	0.13	0.26	0.37	0.36	0.32	0.29
O41	0.28	0.24	0.34	0.22	0.30	0.31	0.14	0.28	0.36	0.37	0.29	0.29
O42	0.28	0.26	0.44	0.31	0.33	0.32	0.11	0.27	0.28	0.29	0.33	0.29

Baseline	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O43	0.52	0.42	0.44	0.30	0.18	0.17	0.03	0.11	0.19	0.09	0.33	0.18
O44	0.43	0.41	0.44	0.29	0.18	0.17	0.05	0.08	0.25	0.24	0.32	0.20
O45	0.32	0.39	0.43	0.30	0.21	0.18	0.08	0.05	0.29	0.27	0.31	0.22
O46	0.31	0.37	0.40	0.27	0.17	0.15	0.07	0.02	0.28	0.26	0.29	0.19
O47	0.44	0.39	0.45	0.29	0.18	0.15	0.06	0.02	0.26	0.24	0.32	0.20
O48	0.11	0.08	0.06	0.05	0.04	0.05	0.08	0.16	0.13	0.04	0.08	0.09
O49	0.15	0.08	0.09	0.05	0.02	0.02	0.11	0.13	0.12	0.04	0.08	0.08
O50	0.31	0.22	0.22	0.16	0.10	0.11	0.11	0.08	0.21	0.12	0.19	0.14
O51	0.24	0.13	0.15	0.11	0.12	0.06	0.11	0.19	0.23	0.22	0.15	0.16
O52	0.13	0.03	0.11	0.16	0.06	0.10	0.10	0.11	0.15	0.43	0.11	0.14
O53	0.16	0.09	0.11	0.18	0.02	0.08	0.02	0.13	0.14	0.38	0.12	0.13
O54	0.07	0.12	0.09	0.07	0.05	0.04	0.11	0.09	0.19	0.31	0.09	0.12
O55	0.34	0.24	0.07	0.19	0.11	0.05	0.05	0.16	0.06	0.27	0.15	0.12
O56	0.32	0.04	0.13	0.05	0.04	0.08	0.16	0.28	0.17	0.08	0.13	0.14
O57	0.06	0.08	0.14	0.10	0.23	0.28	0.32	0.27	0.41	0.22	0.17	0.26
O58	0.05	0.10	0.14	0.04	0.19	0.21	0.26	0.30	0.21	0.20	0.14	0.20
O59	0.18	0.11	0.18	0.03	0.06	0.21	0.20	0.23	0.38	0.51	0.16	0.23
O60	0.32	0.10	0.38	0.08	0.03	0.08	0.20	0.33	0.23	0.12	0.22	0.20
O61	0.53	0.46	0.45	0.33	0.16	0.06	0.07	0.22	0.17	0.13	0.35	0.20
O62	0.55	0.48	0.41	0.27	0.23	0.07	0.06	0.23	0.34	0.36	0.35	0.25
O63	0.57	0.45	0.38	0.24	0.25	0.07	0.04	0.26	0.41	0.45	0.35	0.27
O64	0.56	0.40	0.30	0.18	0.18	0.05	0.07	0.24	0.42	0.41	0.30	0.25
O65	0.53	0.35	0.26	0.12	0.03	0.11	0.06	0.24	0.45	0.41	0.26	0.23
O66	0.31	0.16	0.03	0.05	0.06	0.07	0.03	0.05	0.22	0.17	0.10	0.09
O67	0.30	0.12	0.05	0.10	0.05	0.03	0.04	0.04	0.09	0.14	0.09	0.07
O68	0.26	0.05	0.05	0.17	0.09	0.04	0.05	0.05	0.05	0.04	0.09	0.07
O69	0.28	0.04	0.20	0.21	0.04	0.20	0.33	0.49	0.23	0.09	0.20	0.25
O70	0.21	0.09	0.13	0.11	0.30	0.35	0.38	0.41	0.49	0.13	0.21	0.32
O71	0.23	0.10	0.12	0.07	0.08	0.05	0.03	0.14	0.11	0.10	0.11	0.09
O72	0.25	0.09	0.10	0.04	0.06	0.08	0.03	0.16	0.11	0.07	0.10	0.09
O73	0.15	0.10	0.11	0.04	0.10	0.09	0.07	0.11	0.07	0.10	0.10	0.09
O74	0.17	0.09	0.12	0.04	0.08	0.11	0.06	0.23	0.09	0.08	0.11	0.11
O75	0.11	0.08	0.08	0.05	0.02	0.04	0.06	0.11	0.04	0.11	0.07	0.07
O76	0.14	0.11	0.06	0.07	0.04	0.04	0.09	0.05	0.08	0.09	0.08	0.07
O77	0.12	0.08	0.09	0.04	0.05	0.05	0.04	0.04	0.05	0.06	0.07	0.05
O78	0.16	0.14	0.21	0.23	0.24	0.20	0.17	0.14	0.23	0.25	0.19	0.20
O79	0.10	0.16	0.23	0.22	0.23	0.22	0.08	0.13	0.21	0.19	0.19	0.18
O80	0.15	0.17	0.25	0.21	0.32	0.33	0.30	0.39	0.44	0.08	0.26	0.32
O81	0.14	0.20	0.26	0.18	0.25	0.30	0.28	0.31	0.45	0.38	0.25	0.31
O82	0.19	0.20	0.28	0.14	0.21	0.18	0.27	0.37	0.41	0.48	0.25	0.31
O83	0.38	0.15	0.23	0.16	0.20	0.22	0.20	0.24	0.31	0.22	0.23	0.23
O84	0.14	0.12	0.10	0.16	0.23	0.28	0.22	0.15	0.12	0.11	0.14	0.17
O85	0.11	0.10	0.24	0.26	0.27	0.29	0.23	0.13	0.20	0.06	0.20	0.20
O86	0.05	0.13	0.32	0.31	0.36	0.30	0.24	0.14	0.40	0.37	0.26	0.30

Baseline	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O87	0.17	0.17	0.28	0.31	0.39	0.35	0.36	0.25	0.05	0.28	0.25	0.26
O88	0.04	0.20	0.24	0.27	0.35	0.35	0.30	0.20	0.10	0.46	0.22	0.25
O89	0.06	0.06	0.23	0.12	0.13	0.16	0.28	0.23	0.07	0.35	0.15	0.19
O90	0.03	0.06	0.08	0.28	0.26	0.30	0.32	0.29	0.08	0.10	0.15	0.21
O91	0.02	0.04	0.06	0.31	0.32	0.34	0.34	0.32	0.08	0.08	0.16	0.23
O92	0.07	0.11	0.20	0.35	0.31	0.37	0.35	0.32	0.19	0.10	0.23	0.28
O93	0.04	0.08	0.20	0.34	0.23	0.35	0.31	0.17	0.22	0.11	0.20	0.24
O94	0.04	0.06	0.19	0.34	0.21	0.33	0.33	0.18	0.15	0.14	0.19	0.23
O95	0.04	0.06	0.21	0.35	0.21	0.31	0.35	0.21	0.09	0.10	0.19	0.22
O96	0.13	0.10	0.12	0.15	0.11	0.08	0.04	0.08	0.06	0.05	0.11	0.09
O97	0.15	0.09	0.05	0.06	0.07	0.08	0.04	0.07	0.09	0.06	0.08	0.07
O98	0.12	0.10	0.18	0.14	0.23	0.22	0.13	0.22	0.39	0.09	0.18	0.22
O99	0.22	0.14	0.19	0.17	0.11	0.23	0.24	0.41	0.37	0.22	0.21	0.27
O100	0.25	0.10	0.17	0.09	0.12	0.25	0.25	0.46	0.44	0.53	0.20	0.31

B2 Scenario A

B2.1 Perimeter Test Points

Scenario A	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
P1	0.24	0.13	0.15	0.07	0.28	0.15	0.22	0.42	0.51	0.48	0.21	0.31
P2	0.26	0.16	0.14	0.03	0.20	0.07	0.05	0.09	0.24	0.09	0.14	0.12
P3	0.28	0.17	0.17	0.03	0.14	0.12	0.04	0.10	0.23	0.13	0.15	0.13
P4	0.28	0.17	0.20	0.03	0.05	0.14	0.06	0.13	0.26	0.15	0.16	0.14
P5	0.29	0.17	0.20	0.05	0.03	0.18	0.07	0.11	0.24	0.13	0.16	0.13
P6	0.29	0.17	0.20	0.06	0.03	0.20	0.05	0.08	0.19	0.08	0.16	0.11
P7	0.29	0.15	0.20	0.06	0.03	0.20	0.02	0.11	0.22	0.09	0.16	0.13
P8	0.28	0.11	0.13	0.04	0.05	0.19	0.03	0.16	0.23	0.15	0.13	0.13
P9	0.18	0.03	0.04	0.02	0.11	0.09	0.04	0.14	0.16	0.23	0.08	0.11
P10	0.17	0.05	0.06	0.04	0.13	0.11	0.05	0.17	0.22	0.26	0.10	0.14
P11	0.17	0.05	0.06	0.04	0.13	0.11	0.06	0.21	0.29	0.27	0.11	0.16
P12	0.18	0.04	0.07	0.03	0.13	0.11	0.07	0.24	0.32	0.28	0.11	0.17
P13	0.11	0.03	0.04	0.01	0.12	0.10	0.06	0.24	0.32	0.26	0.09	0.16
P14	0.14	0.06	0.06	0.02	0.11	0.09	0.04	0.24	0.35	0.29	0.11	0.17
P15	0.10	0.05	0.06	0.03	0.09	0.08	0.02	0.23	0.37	0.32	0.10	0.17
P16	0.11	0.05	0.08	0.03	0.11	0.10	0.04	0.25	0.34	0.24	0.11	0.17
P17	0.25	0.10	0.12	0.05	0.09	0.09	0.07	0.14	0.13	0.18	0.12	0.11
P18	0.20	0.09	0.11	0.05	0.06	0.06	0.11	0.37	0.36	0.44	0.14	0.22
P19	0.26	0.07	0.14	0.02	0.02	0.06	0.14	0.46	0.45	0.57	0.16	0.27
P20	0.31	0.08	0.14	0.04	0.05	0.10	0.19	0.53	0.49	0.64	0.19	0.31
P21	0.32	0.10	0.13	0.04	0.07	0.11	0.18	0.53	0.46	0.61	0.19	0.30
P22	0.31	0.11	0.12	0.03	0.08	0.12	0.16	0.48	0.42	0.56	0.18	0.27
P23	0.30	0.11	0.11	0.04	0.08	0.13	0.13	0.41	0.38	0.52	0.17	0.25
P24	0.29	0.11	0.10	0.04	0.09	0.12	0.11	0.33	0.31	0.44	0.15	0.21
P25	0.29	0.11	0.10	0.06	0.12	0.09	0.07	0.23	0.22	0.30	0.13	0.16
P26	0.28	0.10	0.09	0.07	0.13	0.08	0.04	0.18	0.09	0.14	0.12	0.11
P27	0.25	0.10	0.07	0.09	0.13	0.07	0.07	0.22	0.13	0.21	0.12	0.13
P28	0.17	0.09	0.05	0.10	0.10	0.08	0.13	0.30	0.26	0.37	0.12	0.19
P29	0.08	0.08	0.05	0.09	0.09	0.12	0.19	0.36	0.34	0.46	0.12	0.23
P30	0.06	0.06	0.07	0.10	0.13	0.14	0.23	0.42	0.43	0.53	0.14	0.28

B2.2 Overall Test Points

Scenario A	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O1	0.20	0.09	0.03	0.07	0.05	0.09	0.09	0.21	0.12	0.02	0.09	0.10
O2	0.25	0.10	0.06	0.18	0.09	0.08	0.07	0.30	0.09	0.03	0.13	0.13
O3	0.30	0.07	0.19	0.31	0.26	0.13	0.05	0.04	0.08	0.07	0.18	0.13
O4	0.37	0.15	0.21	0.31	0.27	0.17	0.27	0.36	0.09	0.16	0.24	0.23
O5	0.40	0.14	0.20	0.32	0.28	0.17	0.22	0.35	0.21	0.23	0.25	0.25
O6	0.39	0.15	0.19	0.32	0.29	0.19	0.17	0.28	0.26	0.15	0.25	0.24
O7	0.38	0.13	0.17	0.31	0.30	0.20	0.19	0.36	0.22	0.18	0.24	0.25
O8	0.39	0.10	0.12	0.23	0.28	0.21	0.19	0.37	0.21	0.15	0.21	0.23
O9	0.40	0.14	0.16	0.26	0.29	0.23	0.17	0.34	0.16	0.19	0.23	0.23
O10	0.43	0.05	0.19	0.28	0.27	0.23	0.14	0.22	0.07	0.10	0.21	0.18
O11	0.50	0.12	0.22	0.22	0.21	0.25	0.08	0.09	0.11	0.18	0.21	0.16
O12	0.51	0.11	0.14	0.13	0.13	0.27	0.06	0.12	0.13	0.32	0.18	0.15
O13	0.19	0.27	0.10	0.03	0.04	0.05	0.27	0.36	0.12	0.05	0.14	0.15
O14	0.21	0.16	0.12	0.06	0.13	0.11	0.19	0.34	0.10	0.03	0.14	0.15
O15	0.39	0.09	0.42	0.20	0.12	0.11	0.09	0.25	0.06	0.11	0.24	0.17
O16	0.12	0.09	0.05	0.03	0.12	0.10	0.20	0.28	0.03	0.03	0.09	0.11
O17	0.08	0.09	0.28	0.11	0.13	0.12	0.15	0.33	0.06	0.07	0.17	0.16
O18	0.44	0.07	0.44	0.22	0.05	0.09	0.13	0.27	0.03	0.22	0.25	0.17
O19	0.35	0.30	0.15	0.25	0.05	0.07	0.09	0.29	0.03	0.11	0.20	0.14
O20	0.38	0.17	0.08	0.05	0.10	0.05	0.17	0.38	0.36	0.26	0.17	0.21
O21	0.26	0.20	0.19	0.16	0.17	0.16	0.11	0.20	0.17	0.24	0.19	0.18
O22	0.09	0.23	0.23	0.08	0.07	0.04	0.04	0.13	0.20	0.24	0.16	0.13
O23	0.07	0.14	0.14	0.03	0.02	0.01	0.04	0.15	0.19	0.23	0.10	0.11
O24	0.30	0.15	0.19	0.12	0.05	0.01	0.05	0.24	0.16	0.18	0.16	0.14
O25	0.48	0.28	0.44	0.23	0.09	0.08	0.09	0.14	0.08	0.23	0.28	0.16
O26	0.60	0.36	0.50	0.29	0.08	0.04	0.11	0.32	0.25	0.42	0.36	0.25
O27	0.54	0.31	0.44	0.34	0.15	0.04	0.14	0.41	0.35	0.34	0.35	0.29
O28	0.45	0.24	0.38	0.39	0.19	0.06	0.14	0.40	0.37	0.43	0.33	0.31
O29	0.40	0.20	0.34	0.41	0.22	0.09	0.13	0.44	0.39	0.37	0.32	0.32
O30	0.42	0.17	0.30	0.42	0.25	0.14	0.13	0.44	0.40	0.37	0.32	0.33
O31	0.48	0.17	0.30	0.44	0.30	0.20	0.12	0.44	0.36	0.34	0.33	0.33
O32	0.55	0.19	0.33	0.45	0.34	0.24	0.11	0.44	0.32	0.33	0.35	0.33
O33	0.43	0.25	0.06	0.18	0.15	0.07	0.12	0.36	0.27	0.28	0.20	0.21
O34	0.22	0.06	0.04	0.04	0.03	0.17	0.17	0.45	0.41	0.45	0.14	0.25
O35	0.23	0.17	0.13	0.06	0.23	0.13	0.17	0.34	0.46	0.38	0.19	0.26
O36	0.30	0.19	0.20	0.11	0.03	0.24	0.06	0.29	0.39	0.32	0.21	0.23
O37	0.34	0.25	0.13	0.19	0.21	0.26	0.06	0.17	0.16	0.13	0.20	0.16
O38	0.37	0.30	0.26	0.23	0.22	0.27	0.04	0.15	0.18	0.19	0.25	0.18
O39	0.40	0.35	0.38	0.28	0.23	0.28	0.01	0.16	0.08	0.03	0.30	0.17
O40	0.33	0.29	0.36	0.24	0.26	0.29	0.03	0.02	0.14	0.07	0.26	0.16
O41	0.25	0.22	0.32	0.23	0.30	0.30	0.08	0.04	0.04	0.23	0.23	0.16
O42	0.25	0.26	0.42	0.32	0.33	0.32	0.09	0.10	0.07	0.18	0.29	0.20

Scenario A	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O43	0.45	0.39	0.42	0.29	0.17	0.16	0.04	0.11	0.08	0.06	0.30	0.15
O44	0.37	0.39	0.42	0.29	0.18	0.17	0.04	0.13	0.06	0.01	0.30	0.15
O45	0.26	0.37	0.42	0.29	0.21	0.18	0.05	0.08	0.10	0.01	0.29	0.15
O46	0.27	0.35	0.39	0.27	0.17	0.15	0.04	0.02	0.15	0.02	0.27	0.14
O47	0.43	0.38	0.45	0.29	0.19	0.15	0.05	0.05	0.21	0.03	0.31	0.17
O48	0.12	0.06	0.06	0.04	0.03	0.04	0.08	0.11	0.27	0.29	0.08	0.13
O49	0.13	0.07	0.08	0.05	0.02	0.02	0.09	0.15	0.31	0.34	0.09	0.15
O50	0.32	0.25	0.23	0.18	0.11	0.11	0.08	0.24	0.42	0.37	0.23	0.23
O51	0.21	0.15	0.13	0.11	0.08	0.07	0.07	0.26	0.36	0.40	0.16	0.20
O52	0.28	0.12	0.35	0.18	0.06	0.10	0.09	0.04	0.20	0.40	0.20	0.16
O53	0.36	0.04	0.20	0.18	0.03	0.08	0.06	0.19	0.16	0.36	0.16	0.16
O54	0.12	0.06	0.14	0.06	0.05	0.02	0.06	0.15	0.18	0.29	0.10	0.13
O55	0.37	0.29	0.06	0.24	0.06	0.06	0.05	0.25	0.12	0.24	0.17	0.14
O56	0.37	0.16	0.06	0.05	0.09	0.08	0.14	0.37	0.23	0.19	0.15	0.18
O57	0.18	0.09	0.17	0.05	0.21	0.28	0.31	0.25	0.34	0.18	0.17	0.24
O58	0.13	0.05	0.12	0.02	0.19	0.20	0.25	0.20	0.15	0.21	0.12	0.17
O59	0.24	0.14	0.13	0.02	0.09	0.21	0.20	0.19	0.33	0.46	0.15	0.21
O60	0.36	0.13	0.17	0.05	0.04	0.09	0.19	0.40	0.32	0.34	0.18	0.22
O61	0.47	0.32	0.44	0.32	0.14	0.05	0.03	0.45	0.27	0.27	0.34	0.27
O62	0.49	0.47	0.42	0.28	0.22	0.09	0.03	0.40	0.39	0.32	0.37	0.29
O63	0.53	0.45	0.38	0.24	0.25	0.05	0.03	0.34	0.40	0.40	0.35	0.28
O64	0.54	0.40	0.30	0.18	0.18	0.04	0.05	0.32	0.41	0.42	0.30	0.26
O65	0.50	0.34	0.26	0.12	0.03	0.11	0.06	0.32	0.43	0.43	0.27	0.24
O66	0.30	0.21	0.08	0.11	0.05	0.07	0.03	0.05	0.22	0.21	0.13	0.11
O67	0.28	0.22	0.12	0.14	0.06	0.03	0.04	0.07	0.09	0.15	0.14	0.08
O68	0.24	0.18	0.08	0.19	0.11	0.03	0.04	0.07	0.07	0.17	0.12	0.09
O69	0.34	0.15	0.17	0.23	0.09	0.21	0.34	0.47	0.37	0.12	0.23	0.29
O70	0.27	0.07	0.20	0.15	0.32	0.35	0.37	0.38	0.49	0.13	0.24	0.33
O71	0.22	0.11	0.10	0.11	0.09	0.10	0.08	0.34	0.21	0.35	0.14	0.19
O72	0.19	0.11	0.06	0.07	0.08	0.09	0.03	0.12	0.10	0.18	0.09	0.09
O73	0.14	0.05	0.07	0.05	0.05	0.12	0.07	0.25	0.21	0.28	0.10	0.15
O74	0.13	0.09	0.16	0.05	0.10	0.07	0.03	0.11	0.16	0.09	0.12	0.10
O75	0.17	0.08	0.15	0.05	0.01	0.02	0.05	0.13	0.12	0.13	0.10	0.09
O76	0.22	0.08	0.12	0.04	0.04	0.03	0.07	0.27	0.41	0.36	0.14	0.20
O77	0.11	0.04	0.08	0.02	0.05	0.04	0.04	0.18	0.29	0.22	0.09	0.13
O78	0.21	0.04	0.27	0.20	0.24	0.19	0.16	0.15	0.22	0.24	0.19	0.20
O79	0.13	0.07	0.21	0.19	0.24	0.22	0.08	0.11	0.22	0.16	0.17	0.17
O80	0.22	0.11	0.13	0.23	0.32	0.33	0.30	0.39	0.42	0.09	0.23	0.31
O81	0.30	0.12	0.11	0.21	0.26	0.31	0.28	0.26	0.37	0.41	0.20	0.28
O82	0.13	0.18	0.18	0.17	0.21	0.18	0.27	0.30	0.37	0.47	0.20	0.28
O83	0.38	0.20	0.13	0.16	0.21	0.22	0.19	0.25	0.30	0.22	0.21	0.22
O84	0.09	0.13	0.14	0.16	0.24	0.27	0.21	0.16	0.15	0.07	0.16	0.17
O85	0.13	0.10	0.15	0.24	0.29	0.28	0.22	0.06	0.24	0.08	0.17	0.19
O86	0.08	0.15	0.29	0.31	0.36	0.30	0.23	0.13	0.32	0.31	0.25	0.27

Scenario A	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O87	0.16	0.15	0.27	0.31	0.39	0.35	0.36	0.25	0.15	0.38	0.25	0.29
O88	0.06	0.17	0.24	0.27	0.35	0.35	0.30	0.20	0.22	0.45	0.23	0.28
O89	0.05	0.06	0.23	0.11	0.13	0.16	0.29	0.23	0.17	0.33	0.15	0.20
O90	0.03	0.08	0.08	0.28	0.26	0.30	0.32	0.29	0.13	0.13	0.16	0.22
O91	0.03	0.03	0.06	0.31	0.32	0.34	0.34	0.33	0.09	0.08	0.16	0.23
O92	0.07	0.10	0.20	0.35	0.31	0.37	0.35	0.32	0.04	0.06	0.21	0.24
O93	0.03	0.08	0.20	0.34	0.23	0.35	0.31	0.16	0.15	0.10	0.19	0.22
O94	0.04	0.06	0.19	0.34	0.21	0.33	0.33	0.18	0.16	0.14	0.19	0.23
O95	0.04	0.06	0.21	0.35	0.21	0.31	0.35	0.21	0.14	0.10	0.19	0.23
O96	0.16	0.09	0.07	0.16	0.11	0.09	0.04	0.07	0.07	0.05	0.10	0.08
O97	0.15	0.09	0.09	0.07	0.08	0.08	0.04	0.06	0.11	0.08	0.09	0.08
O98	0.20	0.10	0.15	0.16	0.23	0.22	0.13	0.21	0.36	0.15	0.18	0.22
O99	0.21	0.05	0.06	0.21	0.12	0.23	0.24	0.40	0.35	0.18	0.17	0.25
O100	0.20	0.15	0.16	0.09	0.12	0.26	0.25	0.45	0.40	0.57	0.20	0.31

B3 Scenario B

B3.1 Perimeter Test Points

Scenario B	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
P1	0.12	0.04	0.15	0.07	0.28	0.16	0.18	0.38	0.46	0.34	0.18	0.28
P2	0.11	0.06	0.17	0.05	0.22	0.06	0.05	0.09	0.29	0.10	0.13	0.14
P3	0.12	0.07	0.18	0.05	0.20	0.12	0.05	0.07	0.25	0.07	0.13	0.13
P4	0.13	0.07	0.18	0.05	0.15	0.13	0.06	0.10	0.27	0.08	0.13	0.14
P5	0.14	0.08	0.17	0.06	0.09	0.13	0.05	0.13	0.22	0.08	0.13	0.13
P6	0.27	0.15	0.20	0.07	0.05	0.17	0.03	0.16	0.16	0.13	0.16	0.13
P7	0.43	0.18	0.22	0.07	0.06	0.19	0.03	0.21	0.11	0.14	0.19	0.13
P8	0.39	0.14	0.19	0.05	0.11	0.20	0.06	0.16	0.07	0.18	0.16	0.12
P9	0.37	0.16	0.18	0.06	0.05	0.06	0.06	0.21	0.13	0.24	0.16	0.13
P10	0.35	0.17	0.18	0.07	0.06	0.04	0.06	0.24	0.15	0.24	0.16	0.14
P11	0.34	0.18	0.19	0.08	0.06	0.04	0.06	0.30	0.22	0.23	0.18	0.17
P12	0.31	0.17	0.17	0.08	0.07	0.06	0.05	0.40	0.35	0.36	0.19	0.22
P13	0.31	0.15	0.17	0.08	0.07	0.07	0.04	0.42	0.39	0.37	0.19	0.23
P14	0.32	0.16	0.17	0.08	0.07	0.07	0.10	0.46	0.47	0.53	0.21	0.28
P15	0.38	0.18	0.19	0.09	0.07	0.07	0.12	0.48	0.50	0.60	0.23	0.30
P16	0.46	0.21	0.23	0.10	0.07	0.08	0.09	0.34	0.38	0.46	0.23	0.24
P17	0.49	0.22	0.26	0.10	0.05	0.06	0.12	0.20	0.20	0.27	0.21	0.16
P18	0.30	0.16	0.18	0.06	0.03	0.05	0.09	0.42	0.36	0.50	0.19	0.24
P19	0.44	0.15	0.21	0.07	0.08	0.09	0.03	0.43	0.42	0.54	0.22	0.26
P20	0.45	0.14	0.21	0.07	0.11	0.10	0.11	0.57	0.58	0.71	0.25	0.34
P21	0.47	0.16	0.21	0.04	0.07	0.10	0.26	0.74	0.75	0.89	0.28	0.44
P22	0.29	0.12	0.14	0.01	0.06	0.16	0.20	0.67	0.68	0.79	0.22	0.39
P23	0.21	0.11	0.11	0.01	0.08	0.16	0.13	0.47	0.48	0.57	0.17	0.28
P24	0.24	0.12	0.12	0.01	0.08	0.11	0.09	0.34	0.35	0.40	0.15	0.21
P25	0.22	0.10	0.13	0.01	0.11	0.08	0.05	0.26	0.27	0.19	0.13	0.16
P26	0.17	0.07	0.12	0.01	0.11	0.06	0.04	0.23	0.21	0.10	0.11	0.13
P27	0.10	0.02	0.10	0.02	0.13	0.06	0.06	0.27	0.24	0.23	0.10	0.16
P28	0.13	0.03	0.07	0.03	0.09	0.09	0.12	0.35	0.32	0.37	0.11	0.20
P29	0.13	0.02	0.06	0.03	0.09	0.13	0.18	0.42	0.40	0.46	0.12	0.25
P30	0.11	0.02	0.06	0.05	0.17	0.17	0.24	0.52	0.53	0.54	0.16	0.32

B3.2 Overall Test Points

Scenario B	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O1	0.22	0.09	0.02	0.06	0.04	0.09	0.10	0.19	0.10	0.02	0.08	0.09
O2	0.25	0.10	0.06	0.18	0.10	0.08	0.06	0.31	0.06	0.04	0.13	0.13
O3	0.31	0.06	0.20	0.30	0.26	0.13	0.04	0.05	0.04	0.08	0.18	0.12
O4	0.37	0.14	0.20	0.31	0.28	0.17	0.27	0.37	0.16	0.17	0.24	0.25
O5	0.40	0.13	0.20	0.32	0.28	0.17	0.22	0.34	0.23	0.22	0.25	0.26
O6	0.38	0.15	0.19	0.32	0.29	0.19	0.17	0.27	0.21	0.15	0.24	0.23
O7	0.38	0.13	0.17	0.31	0.30	0.20	0.19	0.35	0.20	0.18	0.24	0.25
O8	0.40	0.10	0.12	0.23	0.28	0.21	0.19	0.37	0.20	0.15	0.21	0.23
O9	0.40	0.14	0.15	0.26	0.29	0.23	0.17	0.33	0.16	0.18	0.23	0.23
O10	0.43	0.05	0.19	0.28	0.27	0.23	0.13	0.27	0.08	0.09	0.21	0.19
O11	0.50	0.13	0.22	0.22	0.21	0.25	0.03	0.20	0.12	0.17	0.23	0.17
O12	0.52	0.12	0.14	0.13	0.13	0.26	0.05	0.20	0.15	0.30	0.19	0.17
O13	0.18	0.26	0.04	0.03	0.03	0.05	0.27	0.37	0.20	0.10	0.13	0.17
O14	0.18	0.15	0.12	0.06	0.13	0.10	0.20	0.37	0.16	0.04	0.15	0.17
O15	0.39	0.09	0.42	0.20	0.12	0.10	0.10	0.28	0.17	0.08	0.26	0.19
O16	0.10	0.08	0.05	0.02	0.12	0.08	0.21	0.30	0.10	0.05	0.09	0.13
O17	0.08	0.09	0.28	0.11	0.13	0.12	0.15	0.33	0.12	0.06	0.17	0.17
O18	0.46	0.07	0.44	0.22	0.04	0.09	0.14	0.28	0.12	0.19	0.26	0.19
O19	0.32	0.28	0.16	0.24	0.06	0.06	0.08	0.29	0.08	0.10	0.20	0.15
O20	0.34	0.15	0.10	0.11	0.06	0.04	0.18	0.37	0.38	0.26	0.17	0.22
O21	0.27	0.21	0.19	0.15	0.17	0.16	0.11	0.23	0.16	0.23	0.19	0.18
O22	0.10	0.24	0.23	0.08	0.07	0.04	0.04	0.10	0.20	0.22	0.16	0.13
O23	0.07	0.14	0.14	0.03	0.02	0.01	0.04	0.07	0.19	0.20	0.10	0.09
O24	0.29	0.15	0.19	0.12	0.05	0.02	0.05	0.23	0.15	0.14	0.16	0.13
O25	0.46	0.28	0.42	0.23	0.08	0.06	0.07	0.17	0.12	0.22	0.27	0.17
O26	0.59	0.35	0.49	0.29	0.08	0.04	0.12	0.31	0.25	0.37	0.35	0.25
O27	0.55	0.32	0.44	0.33	0.14	0.01	0.15	0.42	0.35	0.34	0.35	0.29
O28	0.45	0.25	0.38	0.39	0.19	0.07	0.13	0.43	0.39	0.38	0.34	0.32
O29	0.41	0.21	0.34	0.41	0.22	0.10	0.13	0.45	0.40	0.34	0.33	0.32
O30	0.43	0.18	0.31	0.42	0.25	0.14	0.13	0.45	0.43	0.36	0.33	0.34
O31	0.48	0.18	0.30	0.44	0.30	0.20	0.13	0.46	0.42	0.35	0.34	0.34
O32	0.55	0.19	0.33	0.46	0.34	0.25	0.12	0.46	0.39	0.35	0.36	0.35
O33	0.40	0.23	0.08	0.14	0.15	0.08	0.13	0.38	0.33	0.29	0.20	0.23
O34	0.17	0.05	0.09	0.07	0.03	0.16	0.18	0.47	0.43	0.44	0.15	0.27
O35	0.19	0.13	0.20	0.09	0.21	0.17	0.16	0.37	0.46	0.32	0.21	0.27
O36	0.33	0.18	0.20	0.12	0.09	0.24	0.05	0.20	0.35	0.20	0.20	0.20
O37	0.40	0.27	0.17	0.20	0.23	0.26	0.07	0.11	0.06	0.19	0.21	0.15
O38	0.41	0.31	0.24	0.23	0.26	0.27	0.04	0.07	0.10	0.03	0.24	0.14
O39	0.42	0.35	0.37	0.28	0.29	0.28	0.04	0.05	0.15	0.19	0.30	0.18
O40	0.33	0.29	0.35	0.23	0.29	0.29	0.03	0.12	0.33	0.33	0.29	0.24
O41	0.23	0.23	0.33	0.22	0.30	0.30	0.05	0.10	0.27	0.23	0.26	0.22
O42	0.23	0.27	0.43	0.31	0.28	0.32	0.08	0.05	0.15	0.12	0.29	0.20

Scenario B	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O43	0.49	0.40	0.41	0.29	0.18	0.16	0.04	0.05	0.17	0.16	0.31	0.17
O44	0.39	0.40	0.42	0.29	0.19	0.16	0.03	0.05	0.13	0.13	0.30	0.16
O45	0.28	0.38	0.42	0.29	0.21	0.17	0.04	0.02	0.12	0.15	0.29	0.16
O46	0.29	0.36	0.39	0.27	0.18	0.15	0.04	0.02	0.13	0.13	0.27	0.15
O47	0.43	0.38	0.44	0.29	0.18	0.15	0.04	0.03	0.16	0.10	0.31	0.16
O48	0.11	0.07	0.06	0.04	0.04	0.05	0.08	0.11	0.15	0.12	0.08	0.09
O49	0.12	0.07	0.08	0.05	0.02	0.03	0.08	0.13	0.20	0.21	0.08	0.11
O50	0.35	0.24	0.23	0.17	0.12	0.09	0.07	0.16	0.33	0.33	0.22	0.20
O51	0.23	0.15	0.15	0.12	0.12	0.06	0.08	0.20	0.29	0.35	0.16	0.18
O52	0.24	0.11	0.33	0.17	0.06	0.10	0.09	0.04	0.18	0.41	0.19	0.16
O53	0.31	0.05	0.20	0.18	0.03	0.07	0.08	0.19	0.16	0.37	0.16	0.16
O54	0.11	0.07	0.16	0.07	0.05	0.04	0.08	0.17	0.20	0.30	0.12	0.14
O55	0.34	0.28	0.09	0.18	0.10	0.07	0.05	0.28	0.08	0.26	0.17	0.14
O56	0.33	0.13	0.05	0.11	0.06	0.08	0.14	0.38	0.22	0.13	0.15	0.18
O57	0.17	0.03	0.12	0.02	0.23	0.29	0.33	0.31	0.36	0.21	0.15	0.25
O58	0.15	0.07	0.11	0.06	0.20	0.21	0.25	0.21	0.17	0.21	0.13	0.18
O59	0.34	0.17	0.17	0.02	0.05	0.20	0.18	0.18	0.31	0.47	0.17	0.20
O60	0.37	0.12	0.16	0.04	0.06	0.05	0.19	0.44	0.41	0.46	0.19	0.26
O61	0.47	0.38	0.43	0.33	0.16	0.04	0.07	0.42	0.27	0.18	0.35	0.26
O62	0.52	0.46	0.42	0.27	0.22	0.09	0.04	0.36	0.37	0.28	0.37	0.28
O63	0.55	0.45	0.38	0.24	0.25	0.05	0.03	0.30	0.38	0.40	0.35	0.27
O64	0.55	0.40	0.30	0.18	0.18	0.04	0.05	0.27	0.39	0.38	0.30	0.24
O65	0.52	0.35	0.26	0.12	0.03	0.11	0.05	0.26	0.42	0.37	0.26	0.23
O66	0.29	0.17	0.07	0.08	0.06	0.07	0.03	0.04	0.21	0.24	0.12	0.10
O67	0.27	0.19	0.12	0.10	0.07	0.02	0.05	0.07	0.07	0.20	0.12	0.08
O68	0.24	0.15	0.11	0.16	0.12	0.05	0.04	0.07	0.05	0.05	0.12	0.08
O69	0.27	0.10	0.16	0.25	0.11	0.18	0.32	0.44	0.31	0.19	0.21	0.27
O70	0.23	0.05	0.16	0.14	0.32	0.35	0.37	0.38	0.49	0.19	0.22	0.33
O71	0.26	0.13	0.11	0.12	0.10	0.06	0.06	0.30	0.16	0.29	0.15	0.16
O72	0.21	0.12	0.06	0.06	0.07	0.09	0.03	0.09	0.07	0.09	0.09	0.07
O73	0.13	0.06	0.10	0.05	0.07	0.11	0.03	0.21	0.14	0.20	0.10	0.12
O74	0.25	0.12	0.19	0.04	0.08	0.06	0.04	0.10	0.10	0.05	0.13	0.09
O75	0.10	0.05	0.10	0.04	0.02	0.05	0.06	0.05	0.04	0.07	0.06	0.05
O76	0.20	0.08	0.13	0.05	0.02	0.03	0.07	0.22	0.12	0.23	0.11	0.12
O77	0.17	0.03	0.09	0.02	0.03	0.04	0.04	0.09	0.13	0.11	0.07	0.08
O78	0.18	0.08	0.23	0.20	0.24	0.20	0.16	0.15	0.22	0.26	0.19	0.20
O79	0.13	0.05	0.19	0.20	0.23	0.22	0.09	0.10	0.21	0.18	0.16	0.17
O80	0.17	0.10	0.06	0.22	0.32	0.33	0.29	0.40	0.42	0.10	0.20	0.30
O81	0.12	0.12	0.12	0.22	0.25	0.30	0.28	0.25	0.40	0.44	0.19	0.29
O82	0.25	0.18	0.15	0.19	0.22	0.18	0.27	0.29	0.32	0.43	0.20	0.26
O83	0.32	0.18	0.14	0.17	0.21	0.22	0.18	0.26	0.33	0.34	0.21	0.24
O84	0.07	0.14	0.16	0.18	0.24	0.26	0.20	0.18	0.14	0.12	0.16	0.18
O85	0.11	0.08	0.12	0.27	0.30	0.29	0.22	0.06	0.22	0.10	0.17	0.19
O86	0.06	0.19	0.27	0.31	0.36	0.30	0.23	0.13	0.36	0.36	0.25	0.28

Scenario B	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
O87	0.16	0.18	0.27	0.31	0.39	0.35	0.36	0.25	0.08	0.28	0.25	0.26
O88	0.04	0.18	0.23	0.27	0.35	0.35	0.30	0.20	0.07	0.43	0.21	0.24
O89	0.06	0.06	0.23	0.12	0.13	0.16	0.29	0.22	0.15	0.33	0.15	0.20
O90	0.03	0.08	0.08	0.28	0.27	0.30	0.32	0.29	0.10	0.10	0.16	0.22
O91	0.03	0.03	0.06	0.31	0.32	0.34	0.34	0.32	0.07	0.09	0.16	0.23
O92	0.07	0.11	0.20	0.35	0.31	0.37	0.35	0.32	0.10	0.10	0.22	0.26
O93	0.03	0.08	0.20	0.34	0.23	0.35	0.31	0.17	0.19	0.10	0.19	0.23
O94	0.04	0.06	0.19	0.34	0.22	0.33	0.33	0.18	0.16	0.13	0.19	0.23
O95	0.04	0.06	0.21	0.35	0.22	0.31	0.35	0.21	0.12	0.10	0.19	0.22
O96	0.12	0.07	0.08	0.16	0.11	0.09	0.05	0.07	0.05	0.05	0.09	0.08
O97	0.12	0.09	0.09	0.06	0.07	0.08	0.04	0.06	0.12	0.07	0.09	0.08
O98	0.10	0.10	0.12	0.14	0.23	0.22	0.13	0.19	0.37	0.17	0.16	0.21
O99	0.22	0.05	0.06	0.19	0.11	0.22	0.23	0.40	0.35	0.11	0.17	0.24
O100	0.22	0.13	0.18	0.08	0.12	0.25	0.25	0.45	0.42	0.55	0.21	0.31

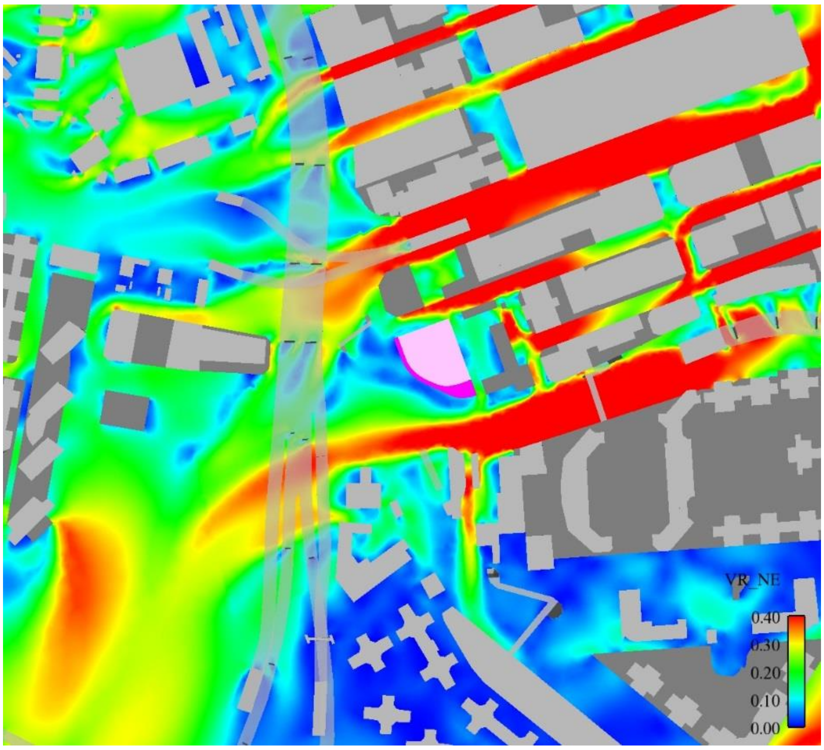
B3.3 Special Test Points

Scenario B	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Annual	7.6%	11.9%	21.8%	12.4%	6.5%	4.8%		7.3%	6.6%		78.9%	
Summer			8.1%	9.7%	7.9%	7.9%	9.3%	15.7%	16.4%	6.8%		81.8%
S1	0.41	0.17	0.20	0.06	0.10	0.10	0.05	0.24	0.13	0.12	0.18	0.13
S2	0.31	0.15	0.16	0.06	0.10	0.04	0.06	0.30	0.19	0.12	0.16	0.15
S3	0.24	0.13	0.13	0.06	0.10	0.06	0.06	0.33	0.22	0.10	0.15	0.16
S4	0.25	0.13	0.13	0.07	0.10	0.08	0.05	0.34	0.25	0.15	0.16	0.17
S5	0.34	0.15	0.16	0.08	0.11	0.09	0.05	0.43	0.40	0.37	0.20	0.24
S6	0.44	0.18	0.21	0.09	0.11	0.10	0.11	0.41	0.42	0.48	0.23	0.27
S7	0.46	0.18	0.23	0.09	0.09	0.09	0.10	0.35	0.38	0.48	0.22	0.25
S8	0.49	0.16	0.22	0.07	0.11	0.09	0.18	0.59	0.61	0.73	0.26	0.37

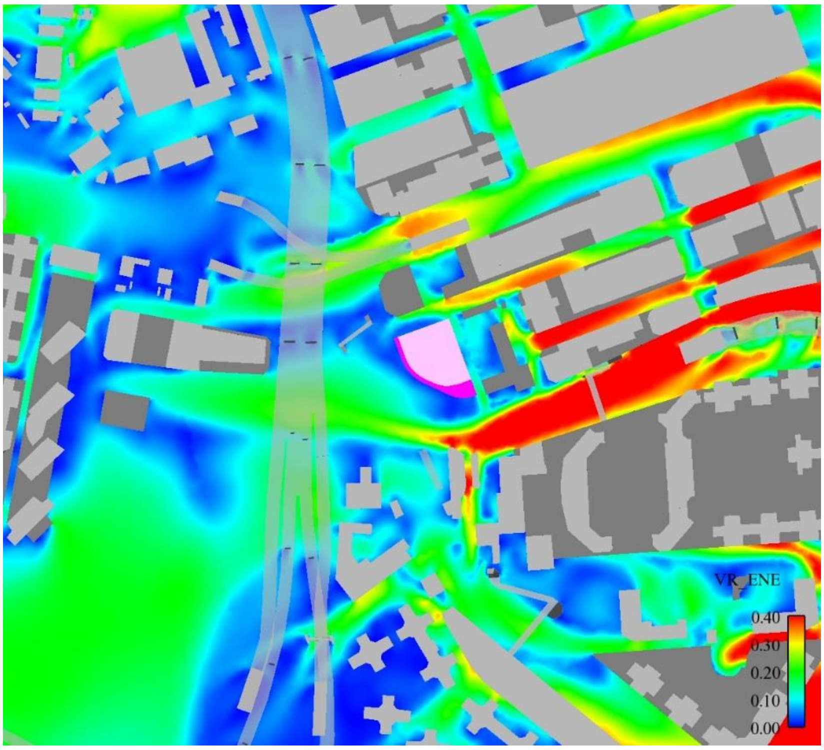
Appendix C

Directional VR Contour Plots

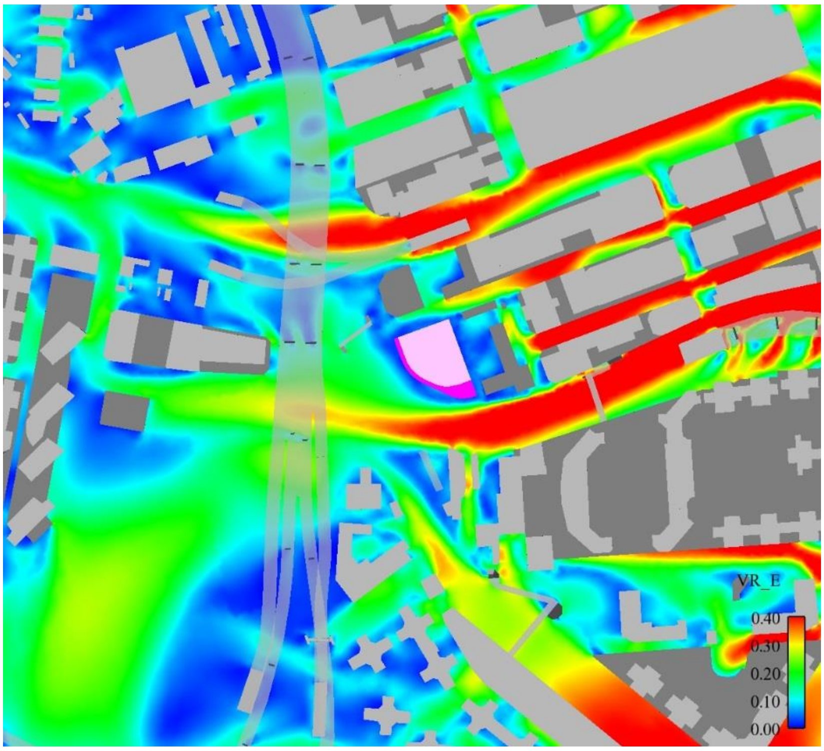
C1 Baseline Scheme



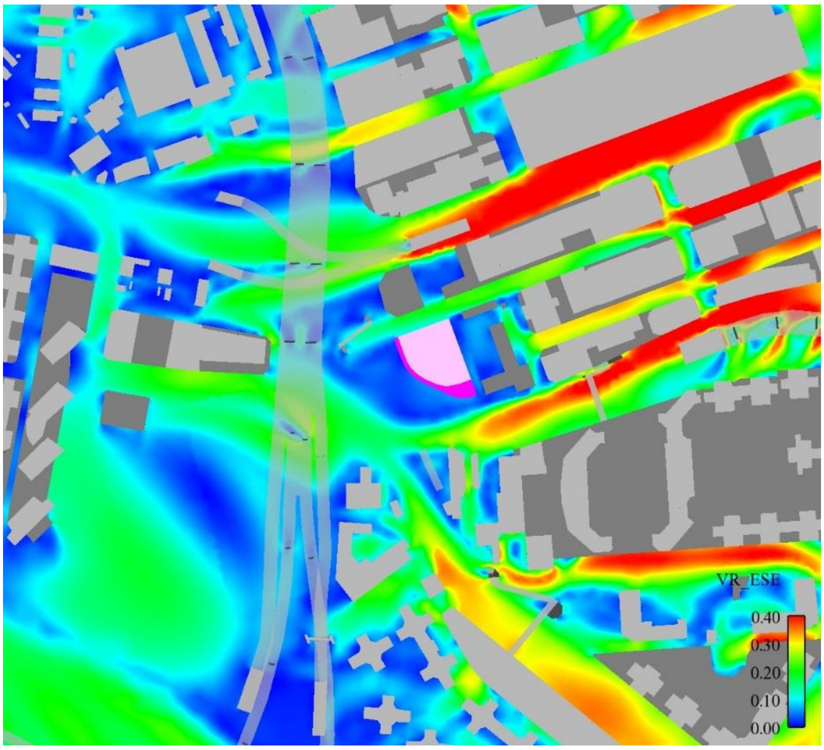
NE direction (Baseline Scheme)



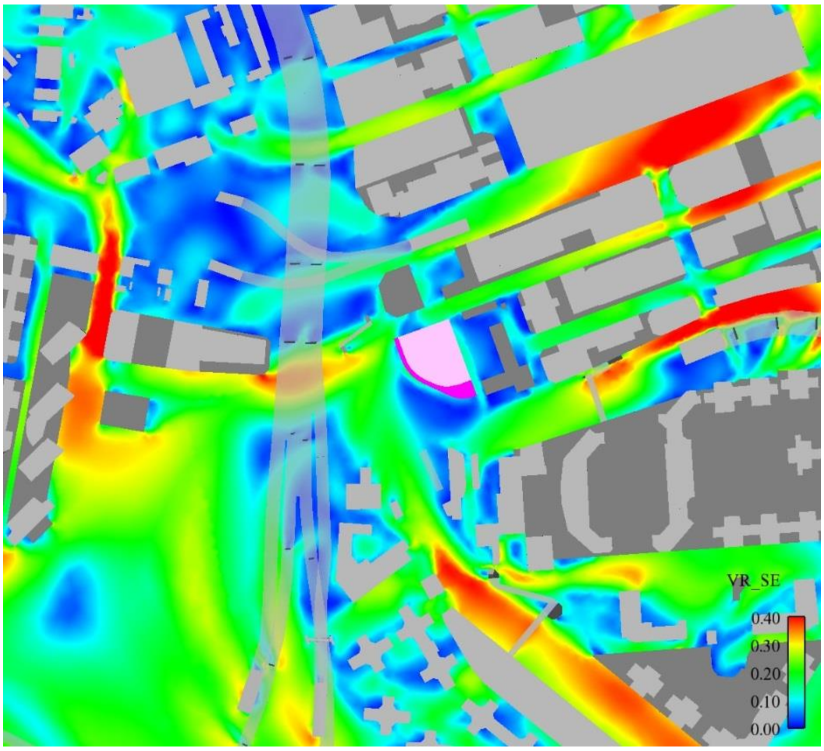
ENE direction (Baseline Scheme)



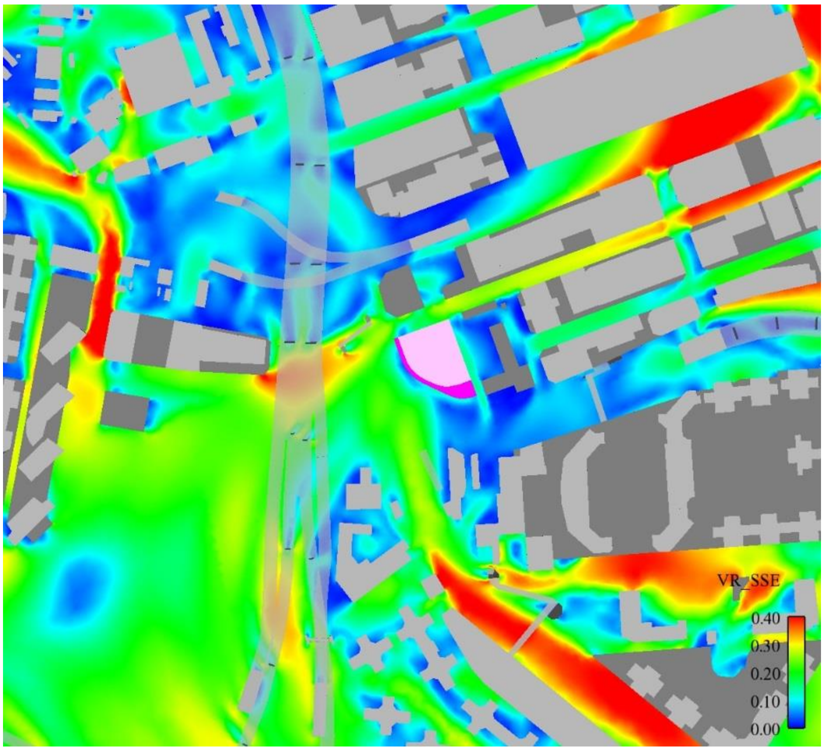
E direction (Baseline Scheme)



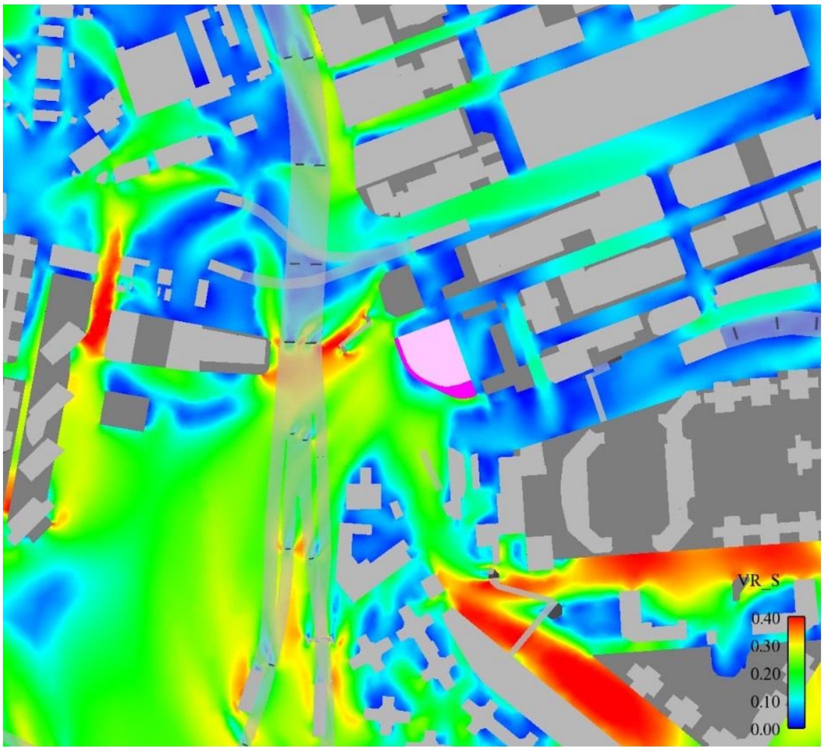
ESE direction (Baseline Scheme)



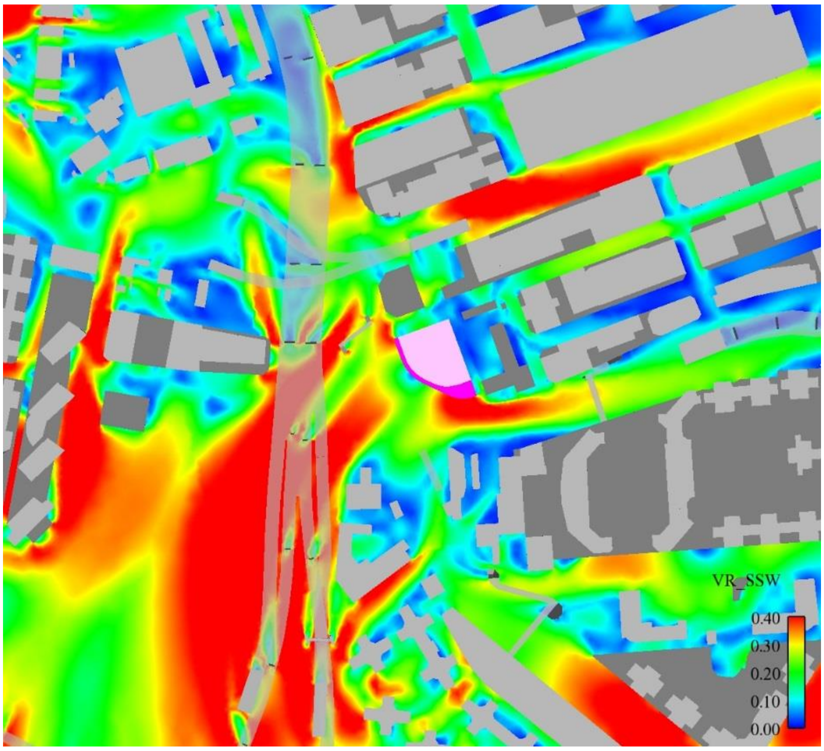
SE direction (Baseline Scheme)



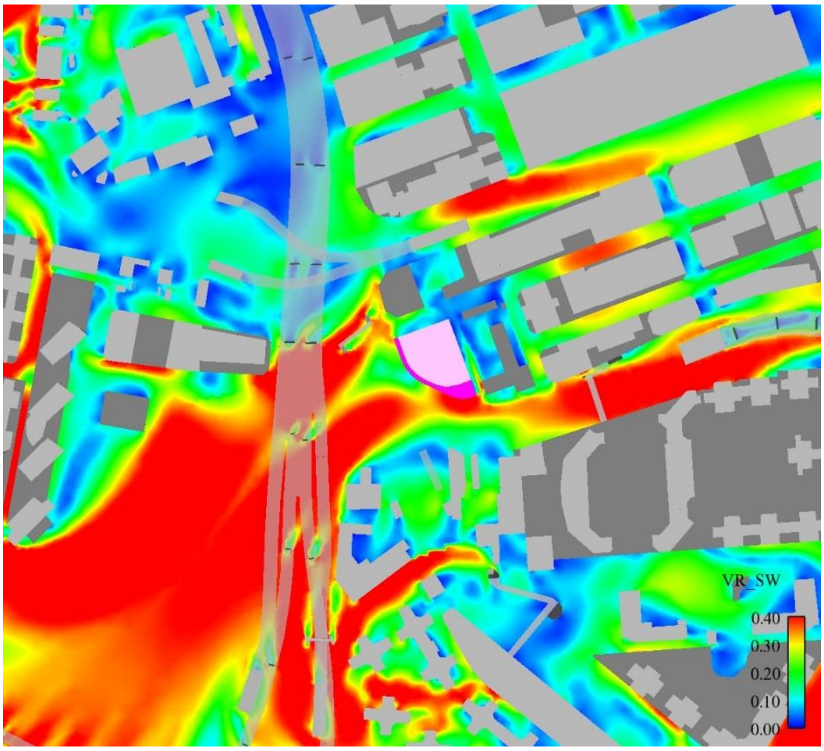
SSE direction (Baseline Scheme)



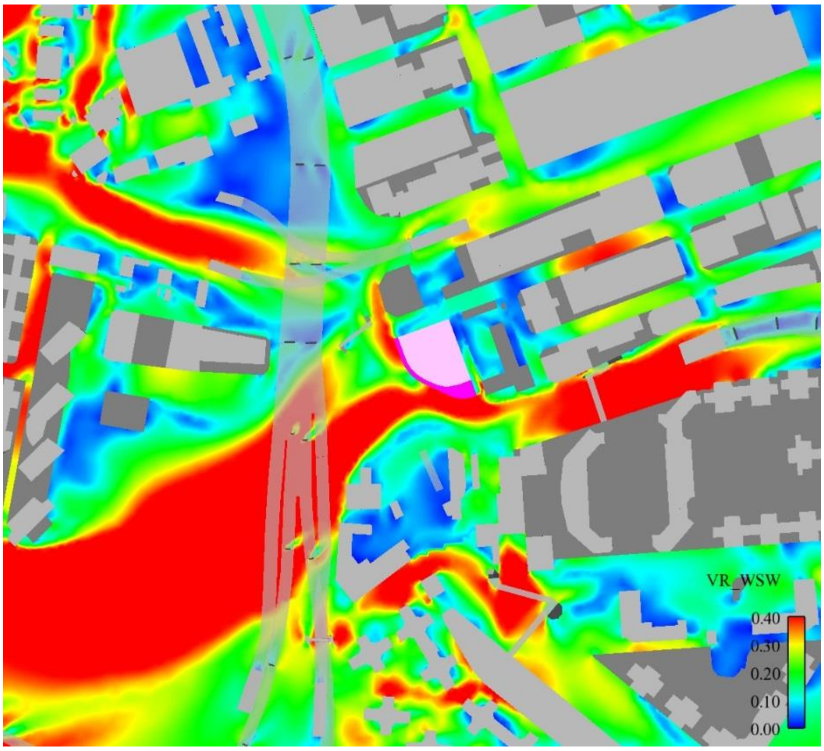
S direction (Baseline Scheme)



SSW direction (Baseline Scheme)

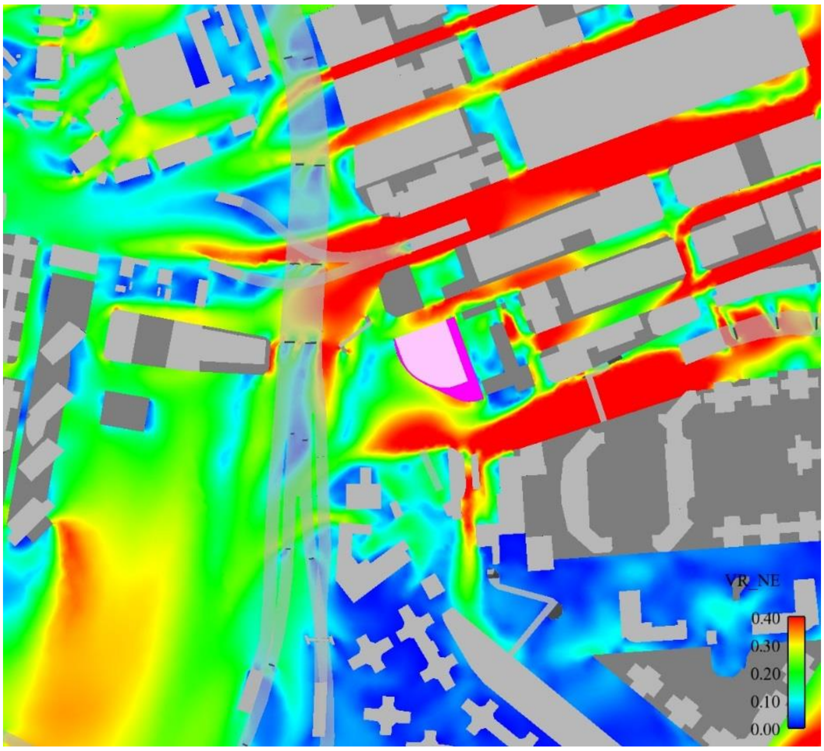


SW direction (Baseline Scheme)

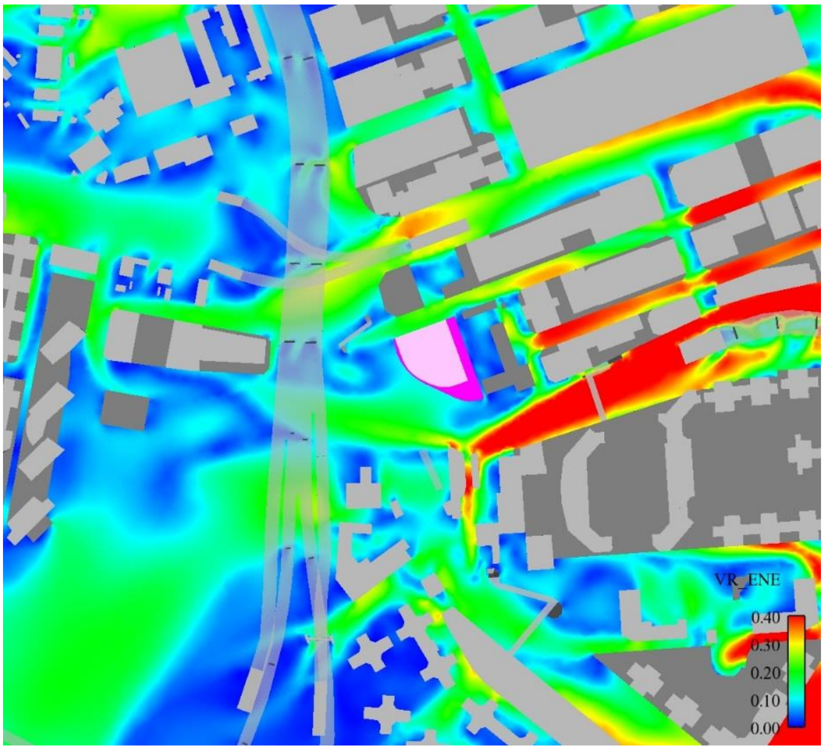


WSW direction (Baseline Scheme)

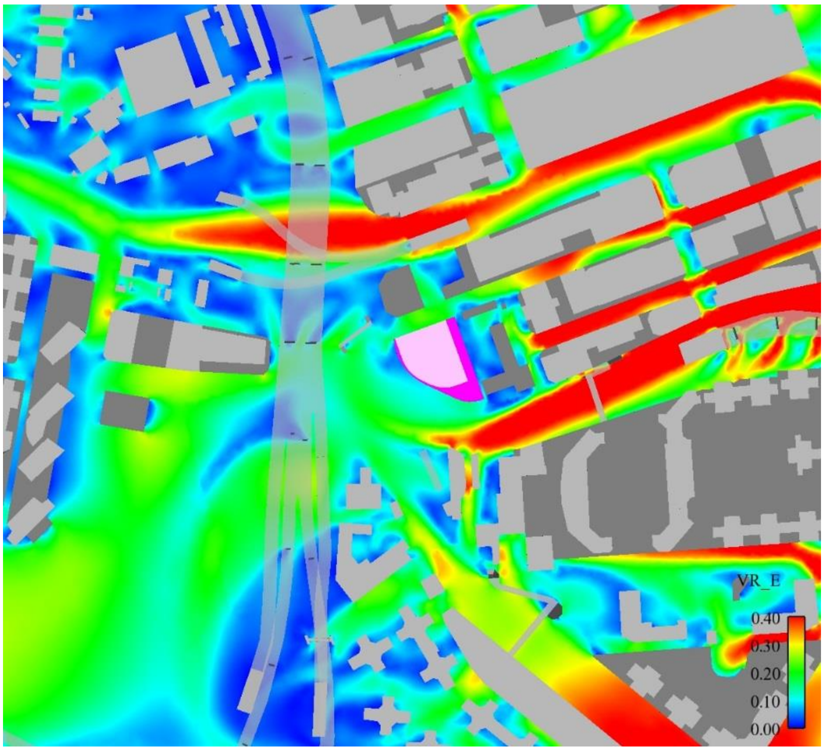
C2 Scenario A



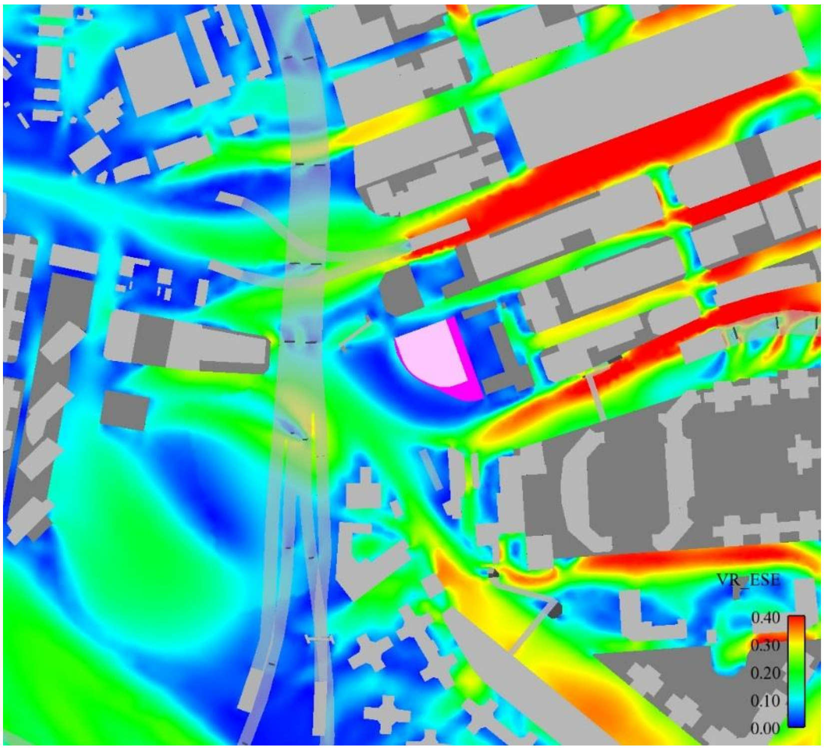
NE direction (Scenario A)



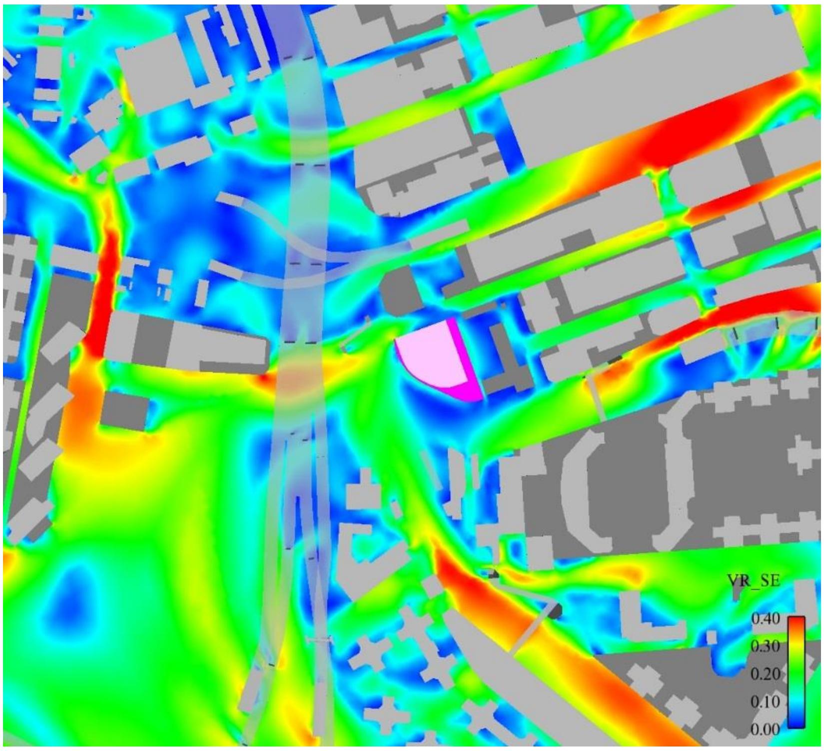
ENE direction (Scenario A)



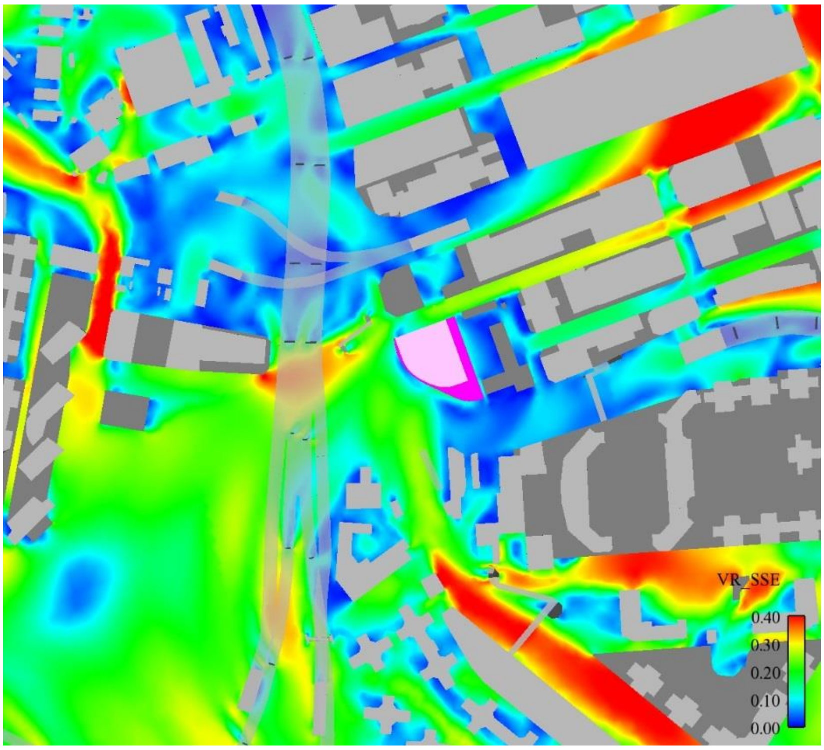
E direction (Scenario A)



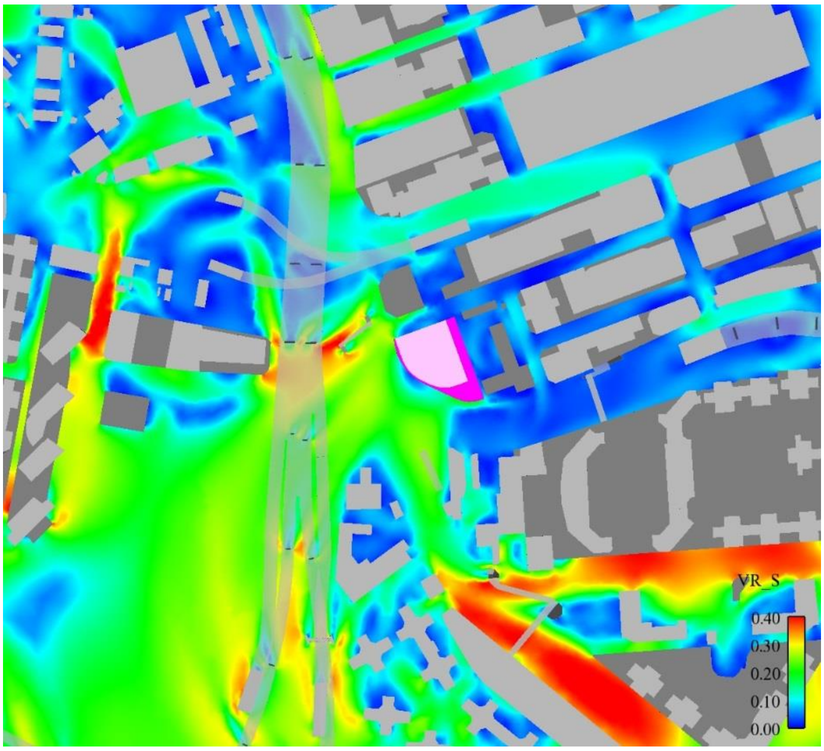
ESE direction (Scenario A)



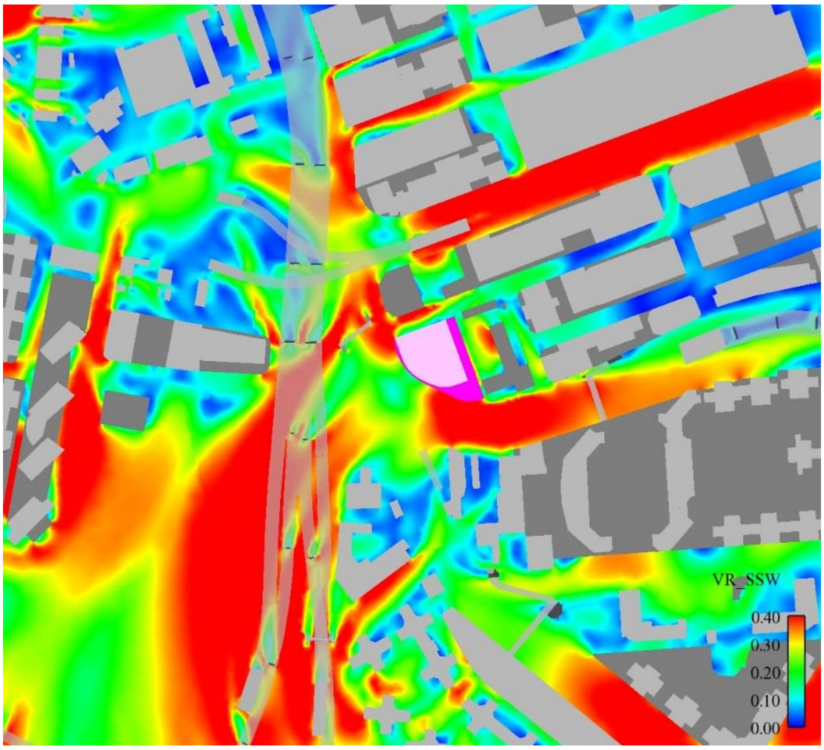
SE direction (Scenario A)



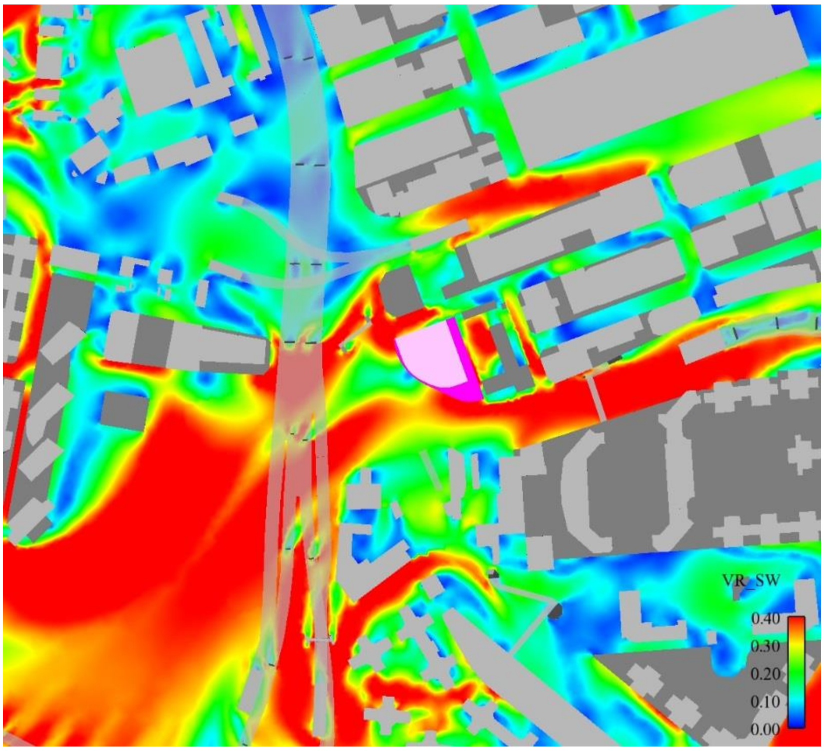
SSE direction (Scenario A)



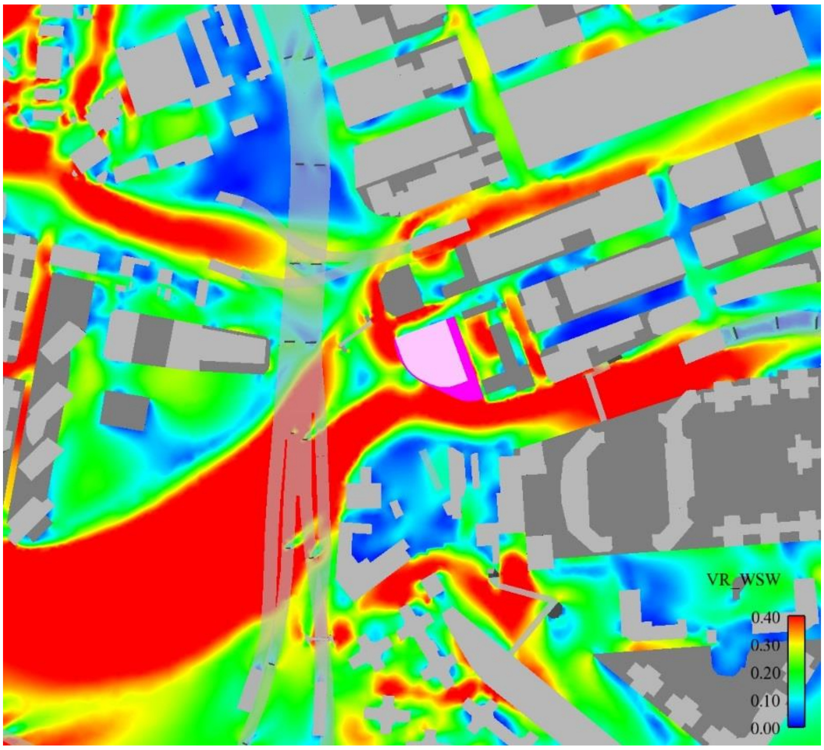
S direction (Scenario A)



SSW direction (Scenario A)

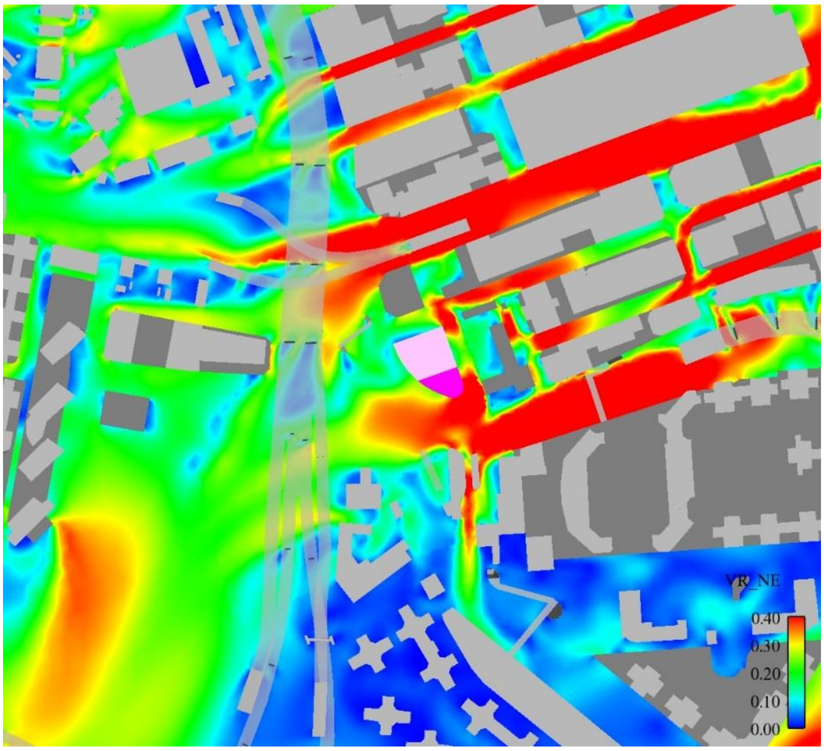


SW direction (Scenario A)

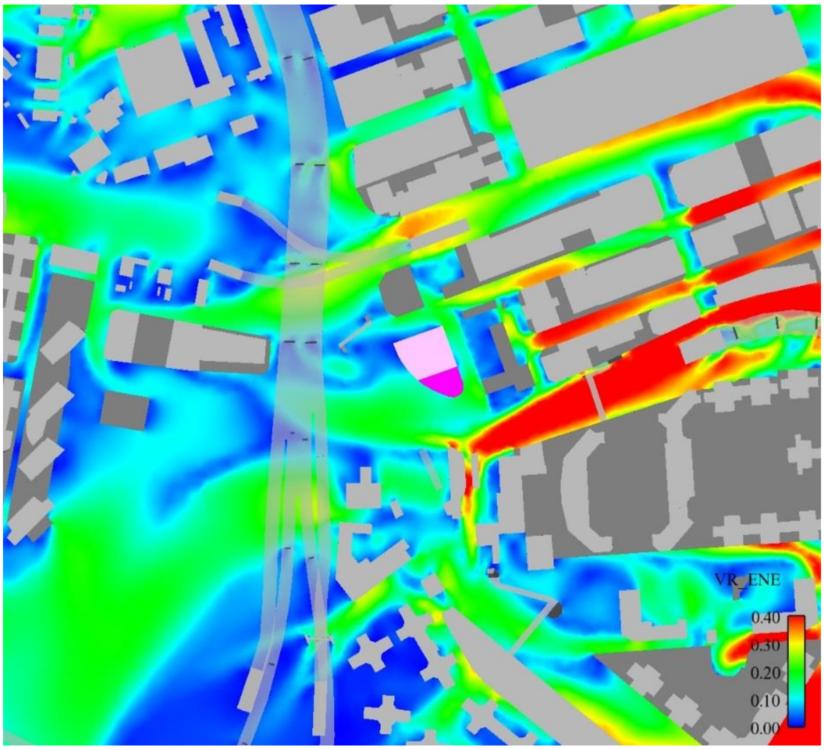


WSW direction (Scenario A)

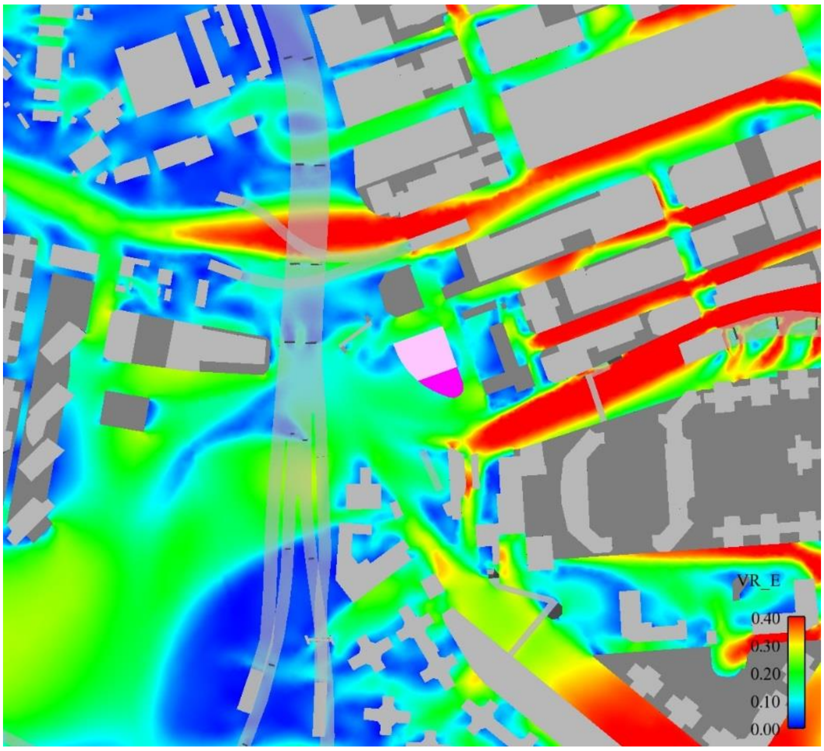
C3 Scenario B



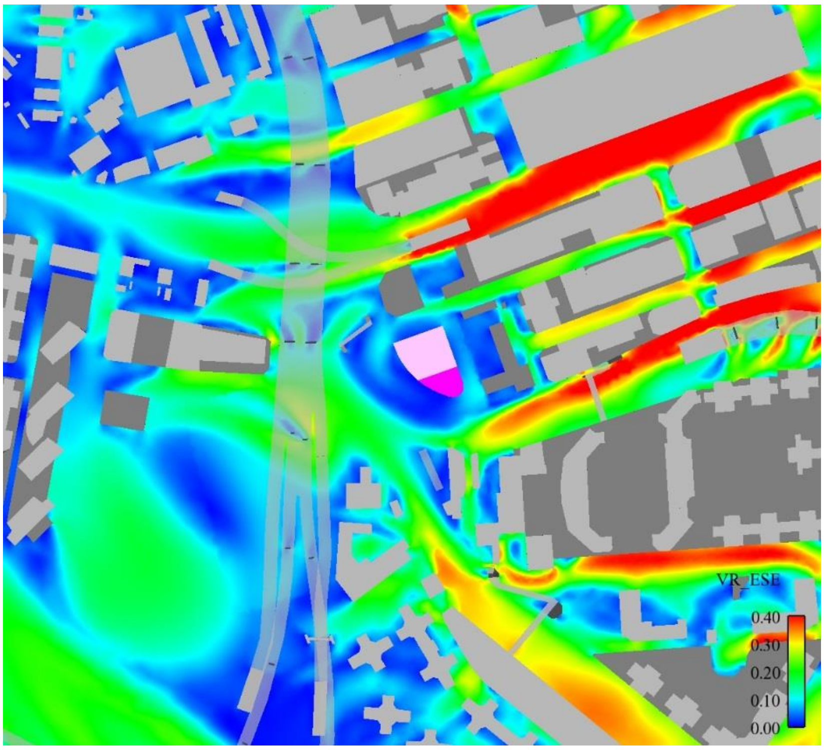
NE direction (Scenario B)



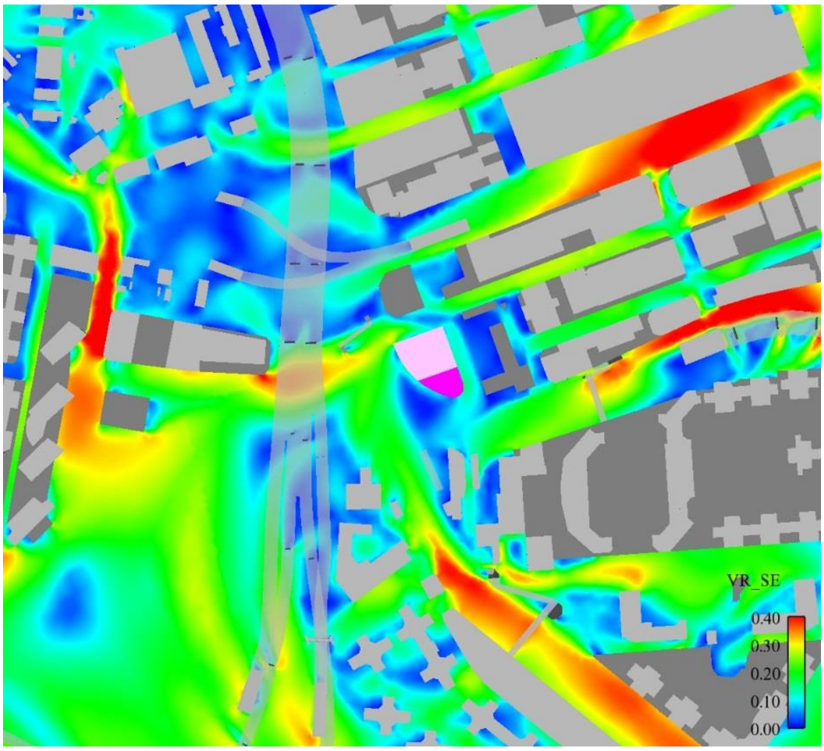
ENE direction (Scenario B)



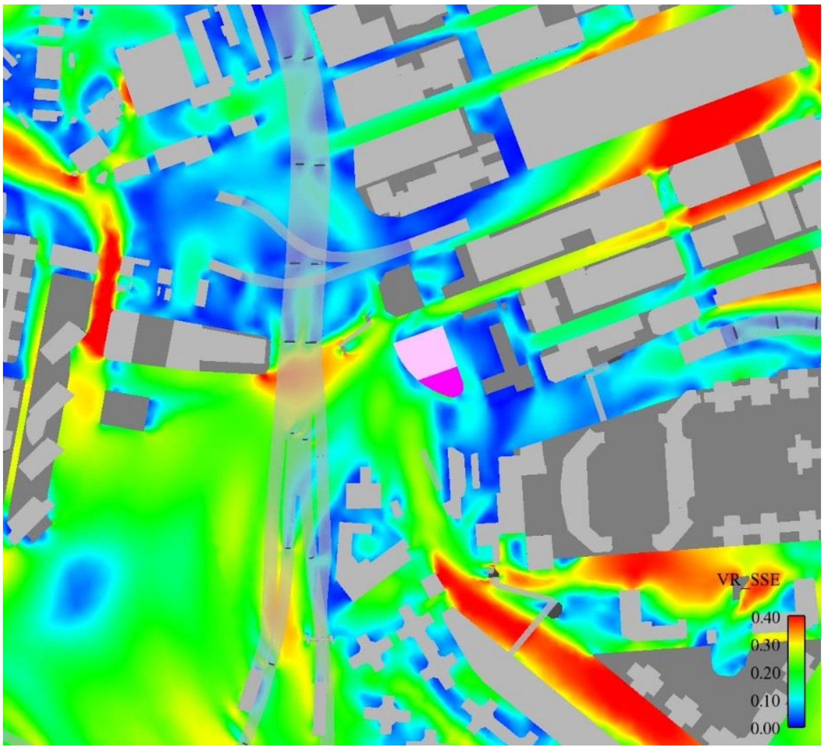
E direction (Scenario B)



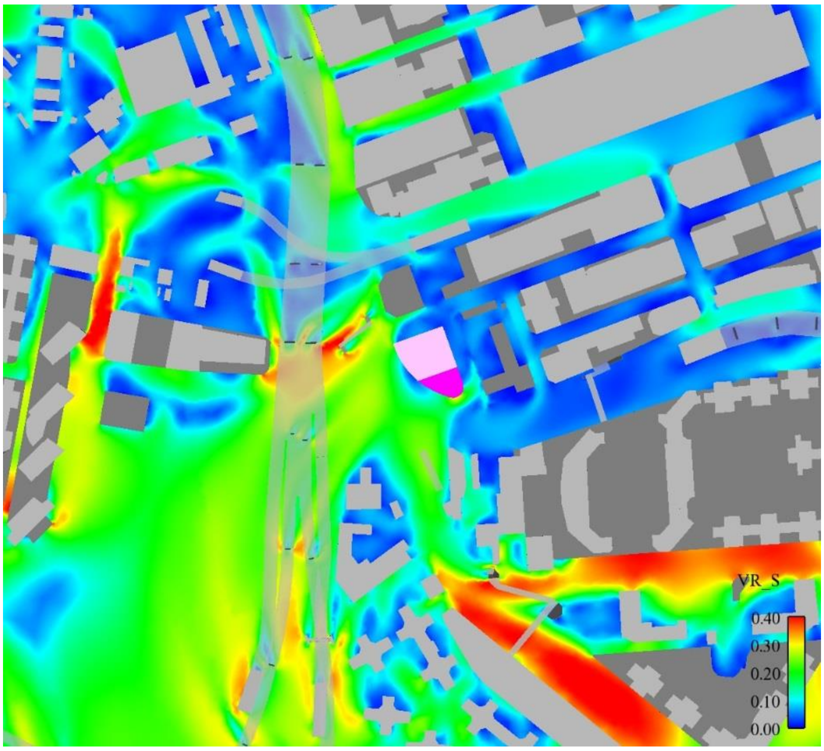
ESE direction (Scenario B)



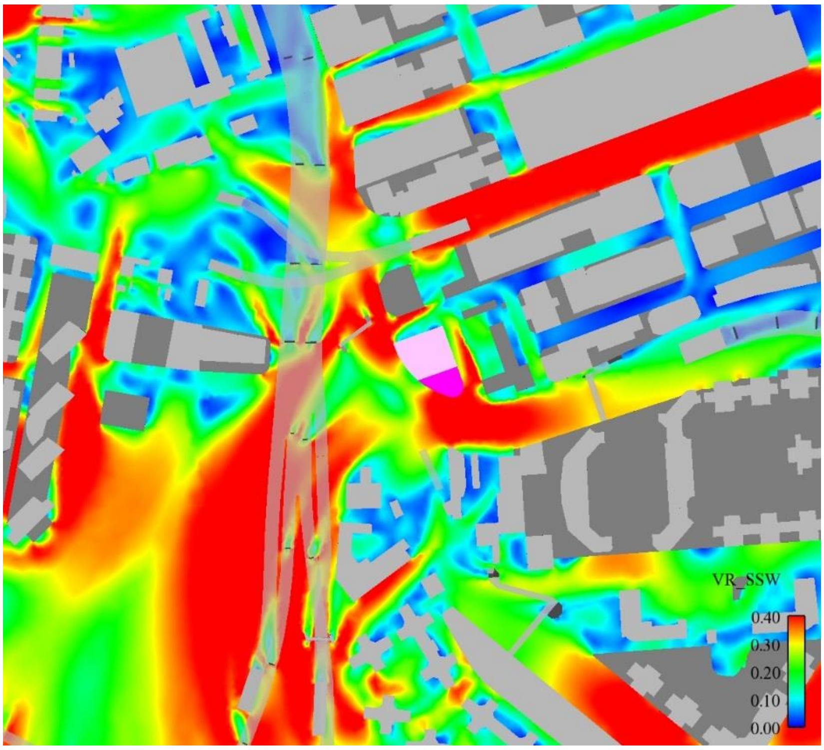
SE direction (Scenario B)



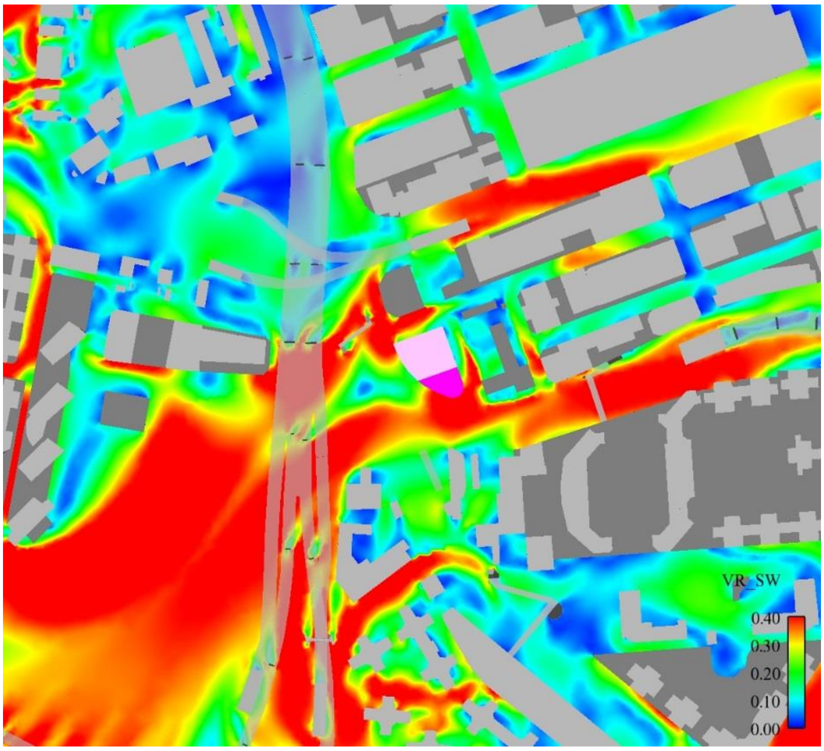
SSE direction (Scenario B)



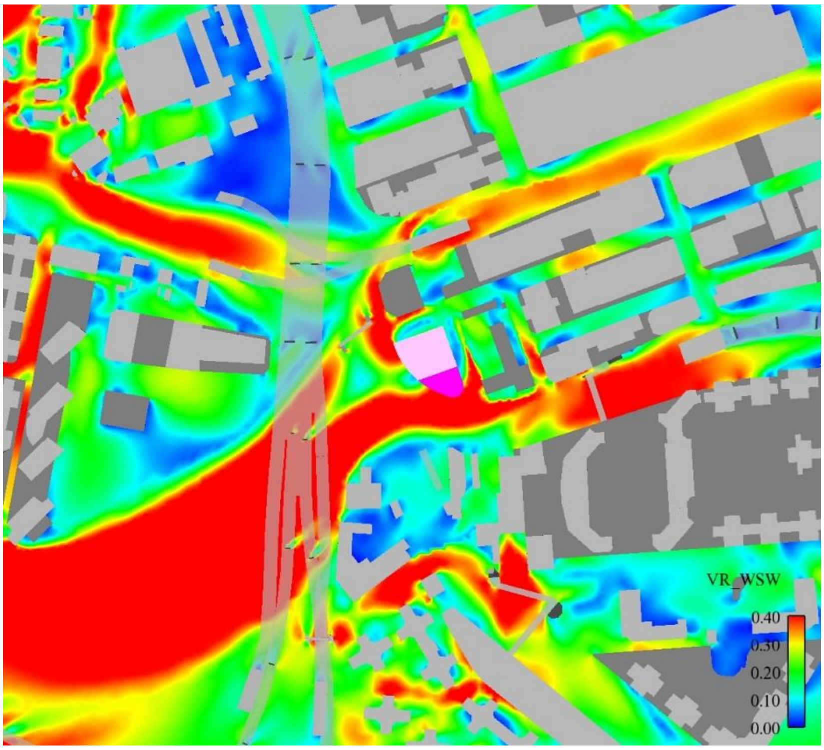
S direction (Scenario B)



SSW direction (Scenario B)



SW direction (Scenario B)

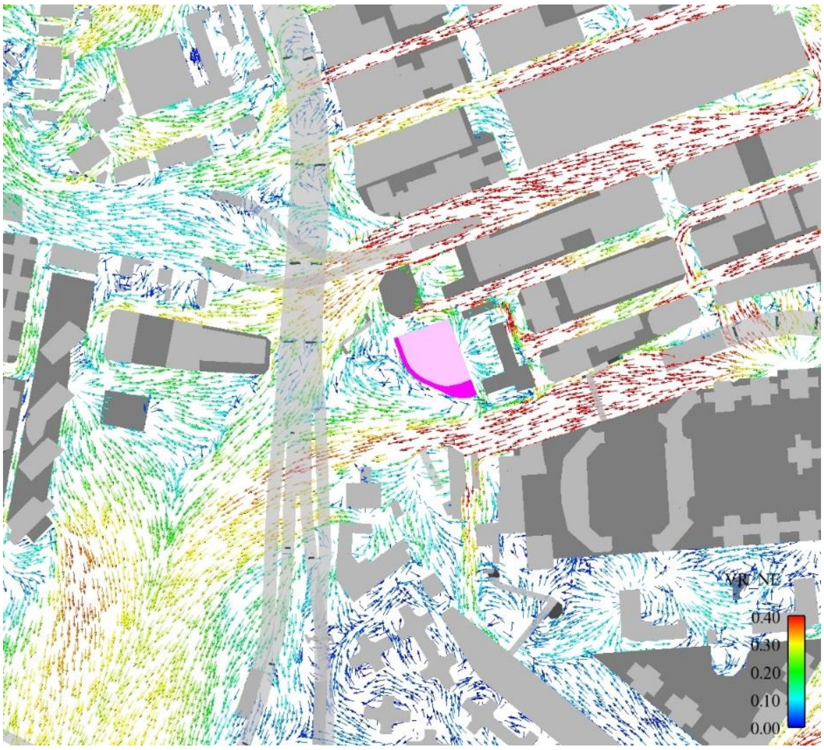


WSW direction (Scenario B)

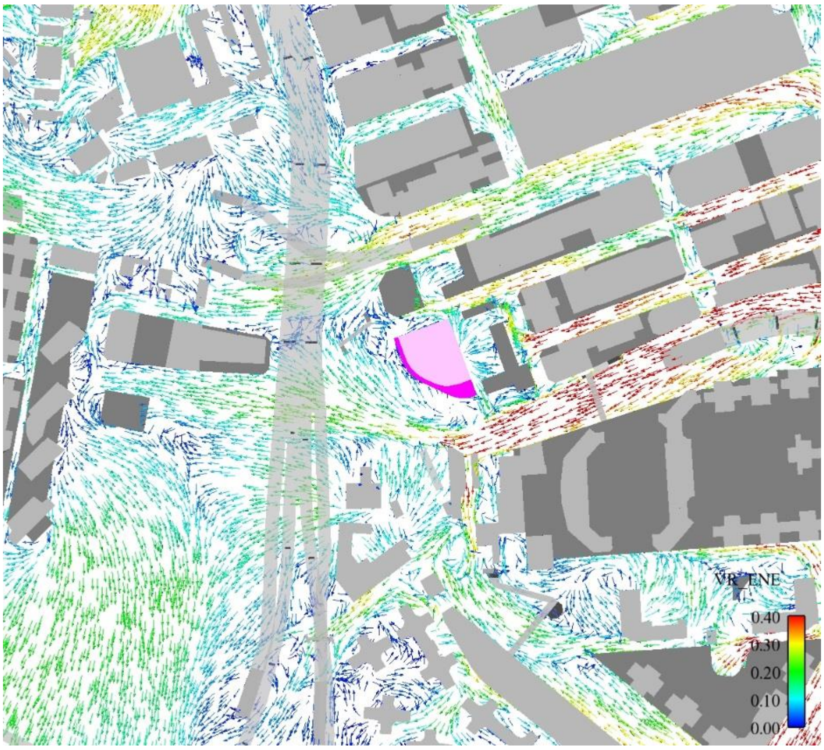
Appendix D

Directional VR Vector Plots

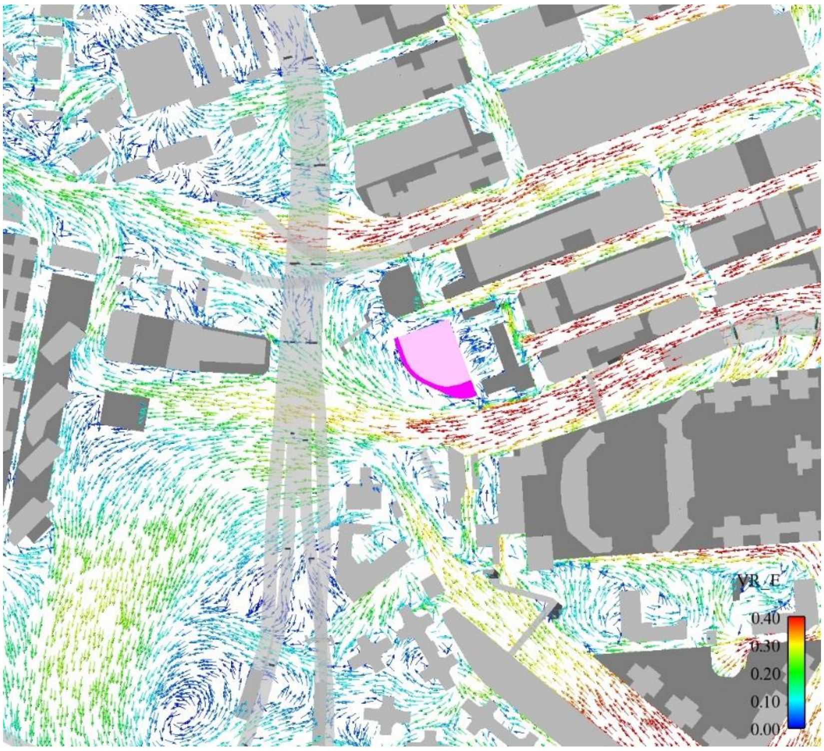
D1 Baseline Scheme



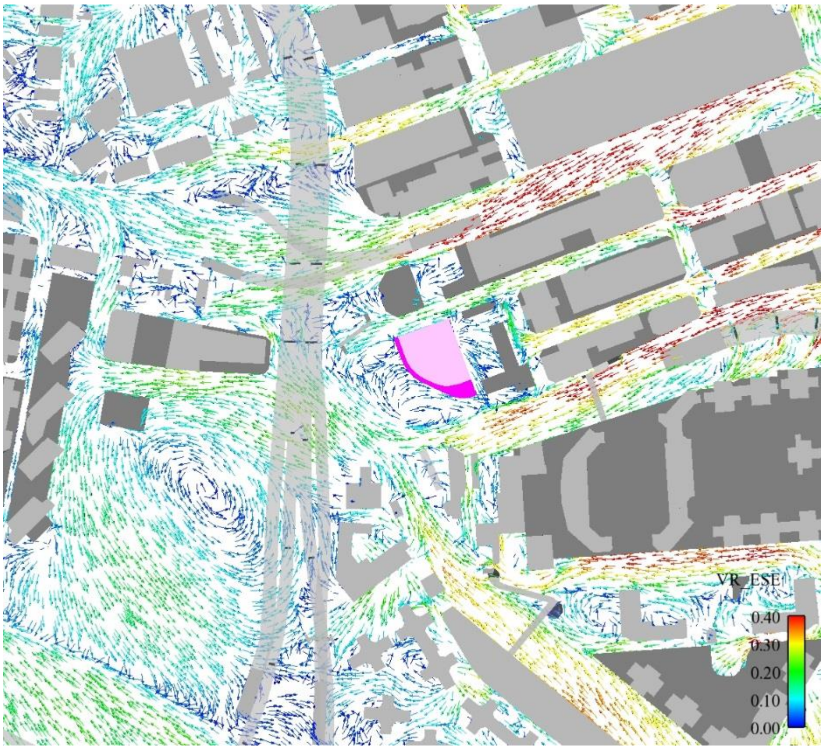
NE direction (Baseline Scheme)



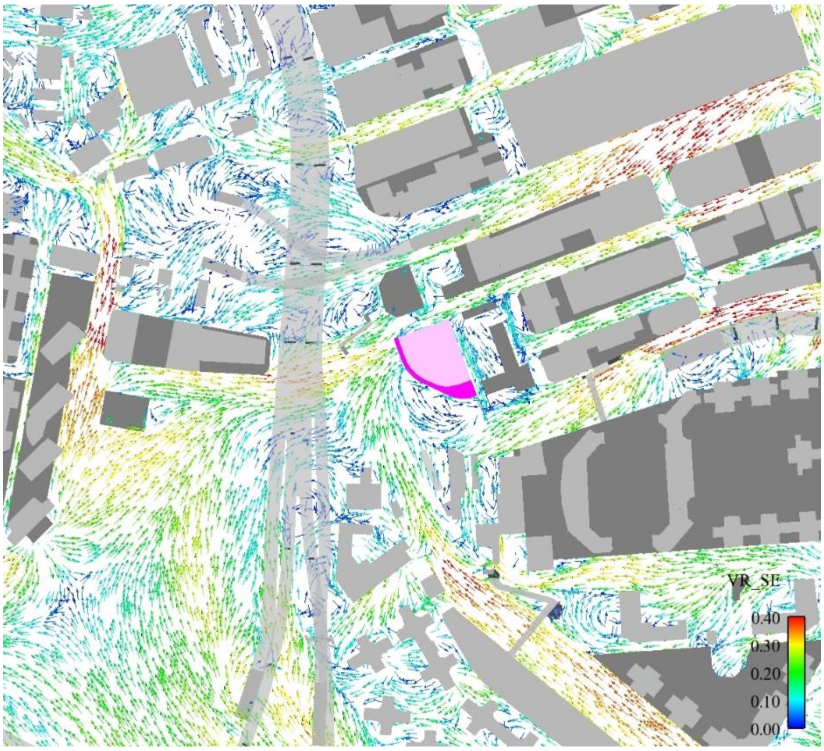
ENE direction (Baseline Scheme)



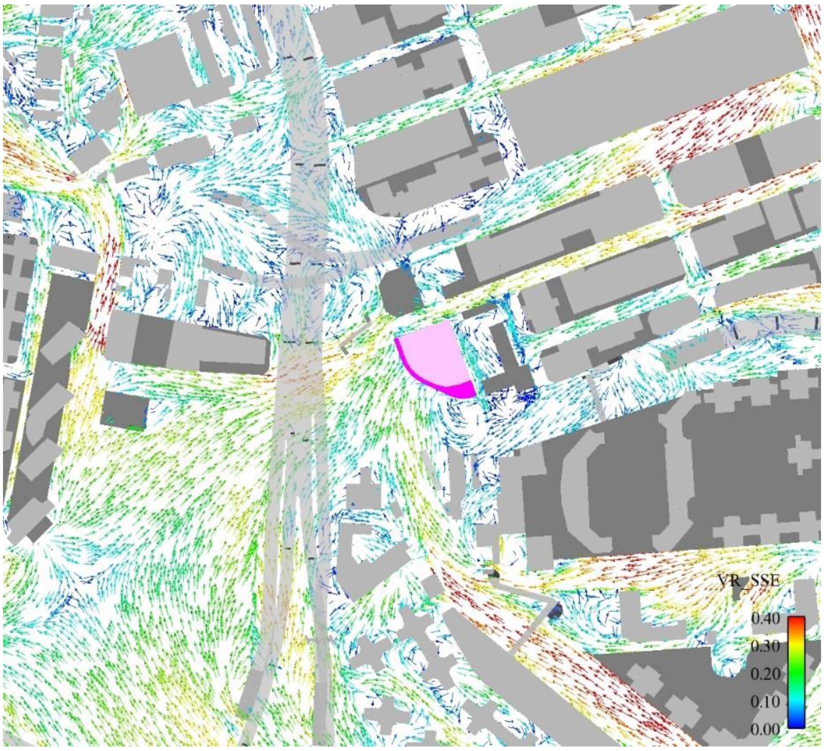
E direction (Baseline Scheme)



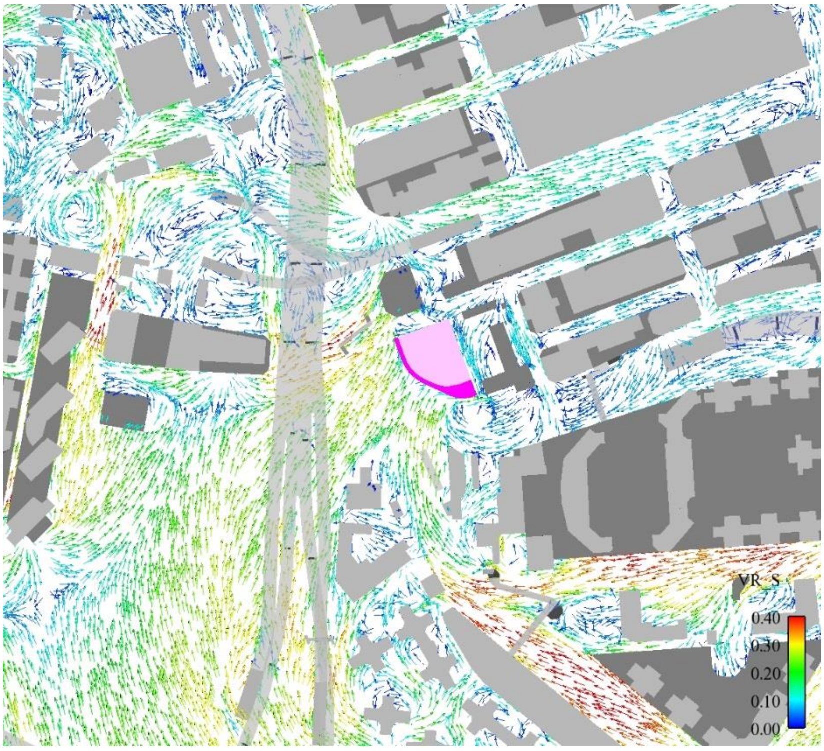
ESE direction (Baseline Scheme)



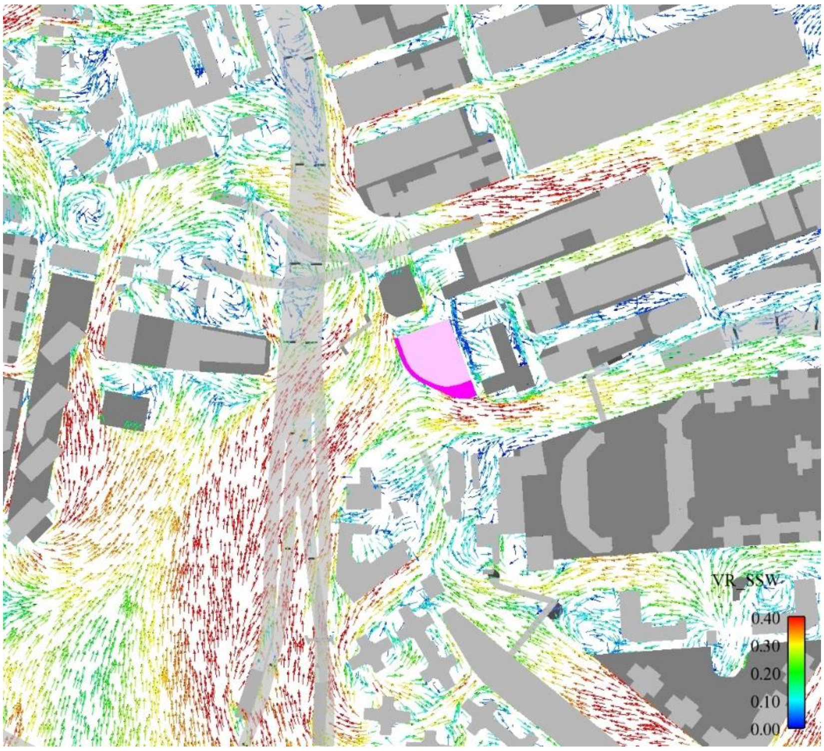
SE direction (Baseline Scheme)



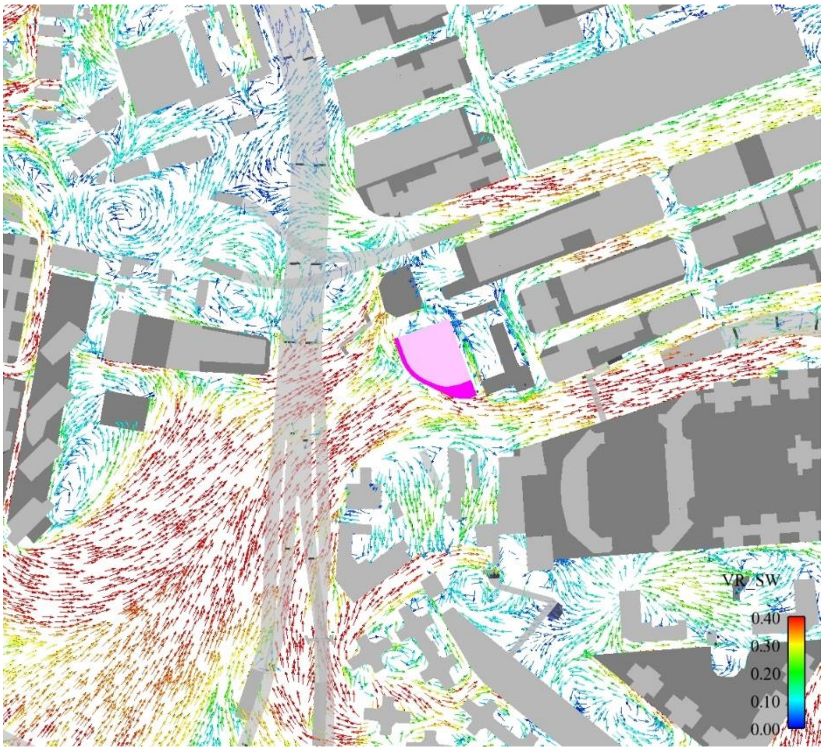
SSE direction (Baseline Scheme)



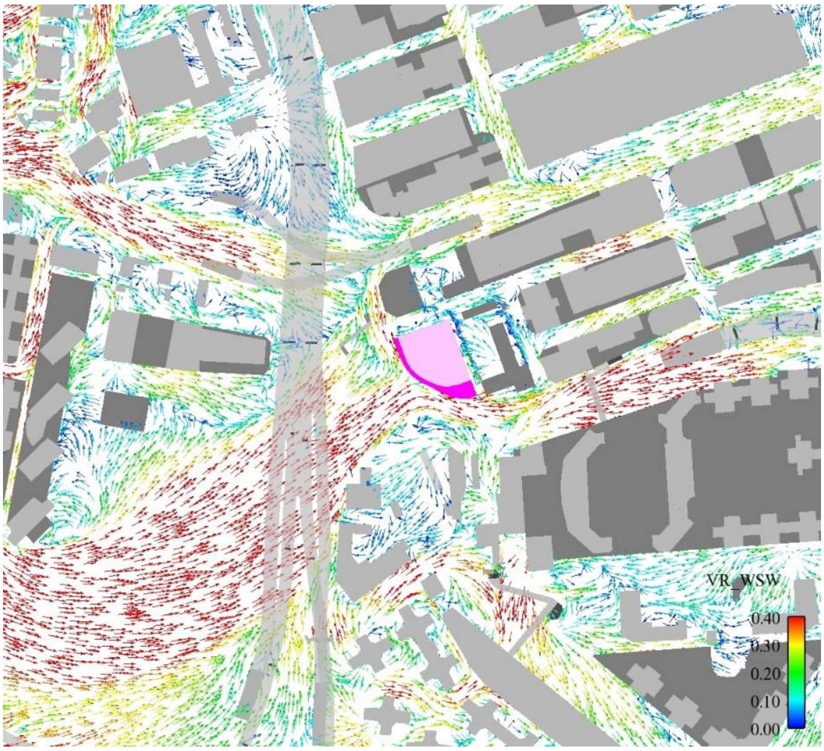
S direction (Baseline Scheme)



SSW direction (Baseline Scheme)

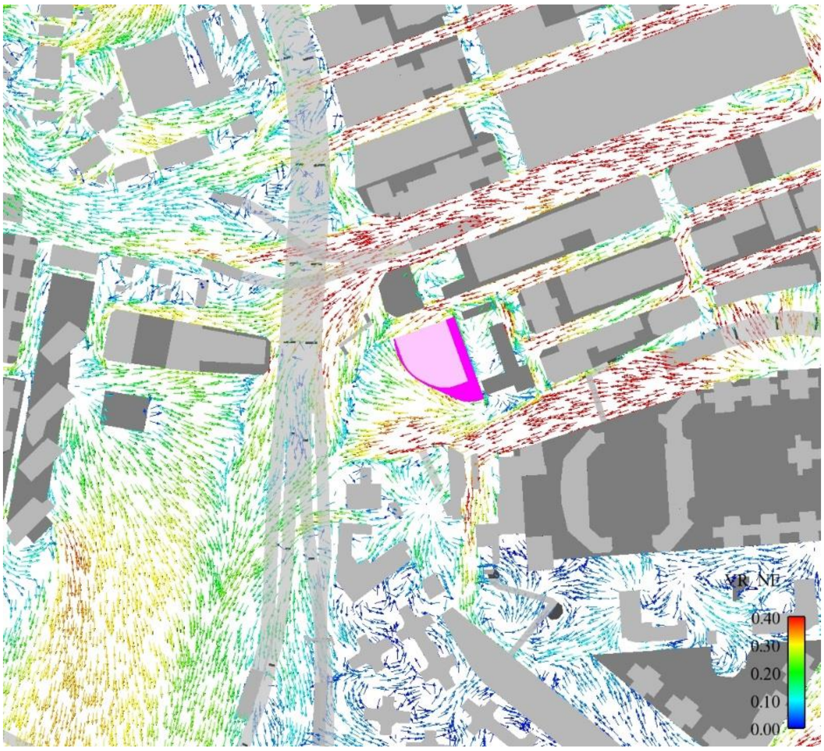


SW direction (Baseline Scheme)

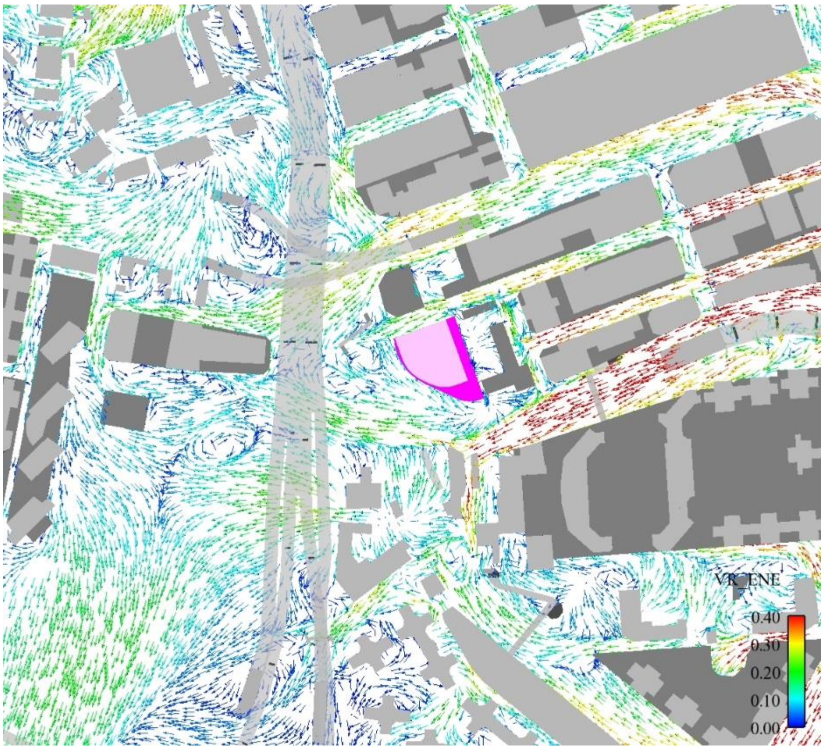


WSW direction (Baseline Scheme)

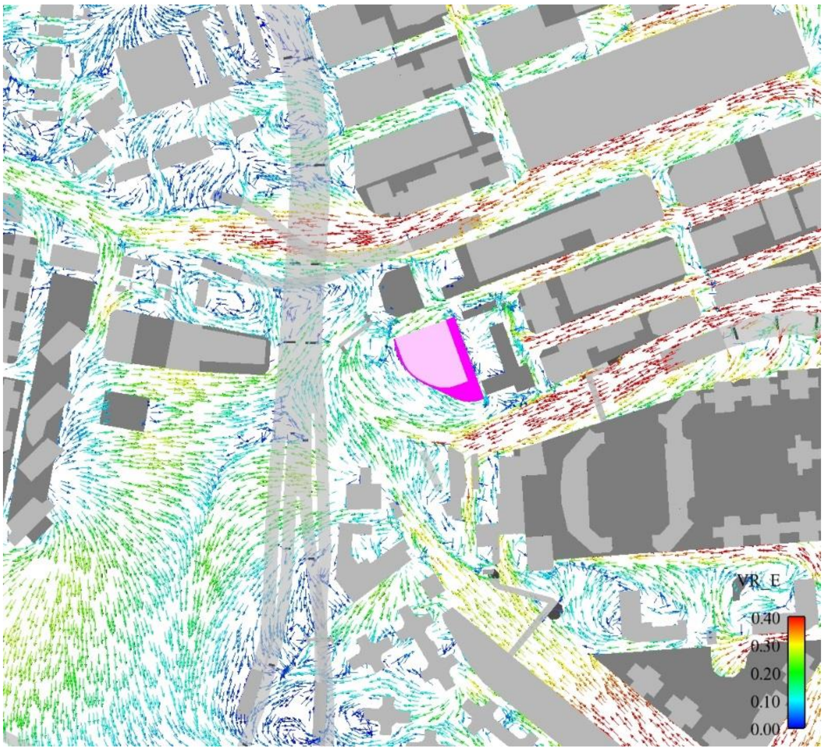
D2 Scenario A



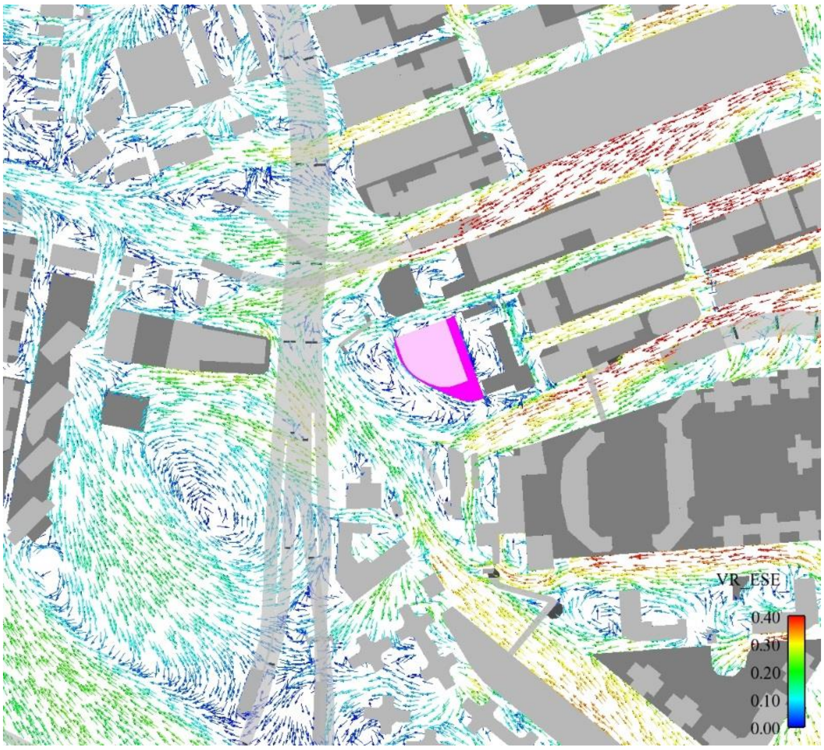
NE direction (Scenario A)



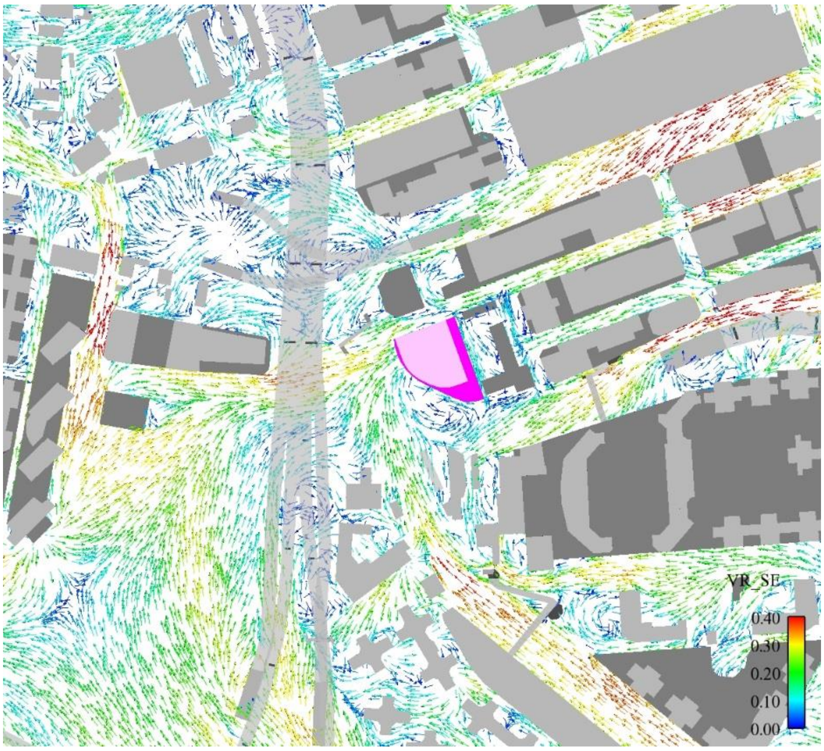
ENE direction (Scenario A)



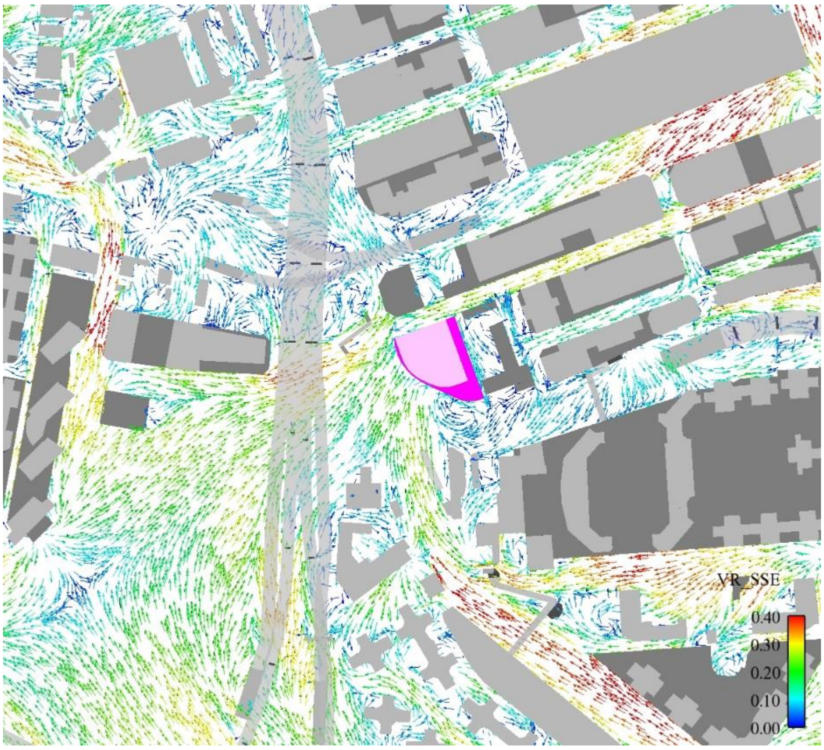
E direction (Scenario A)



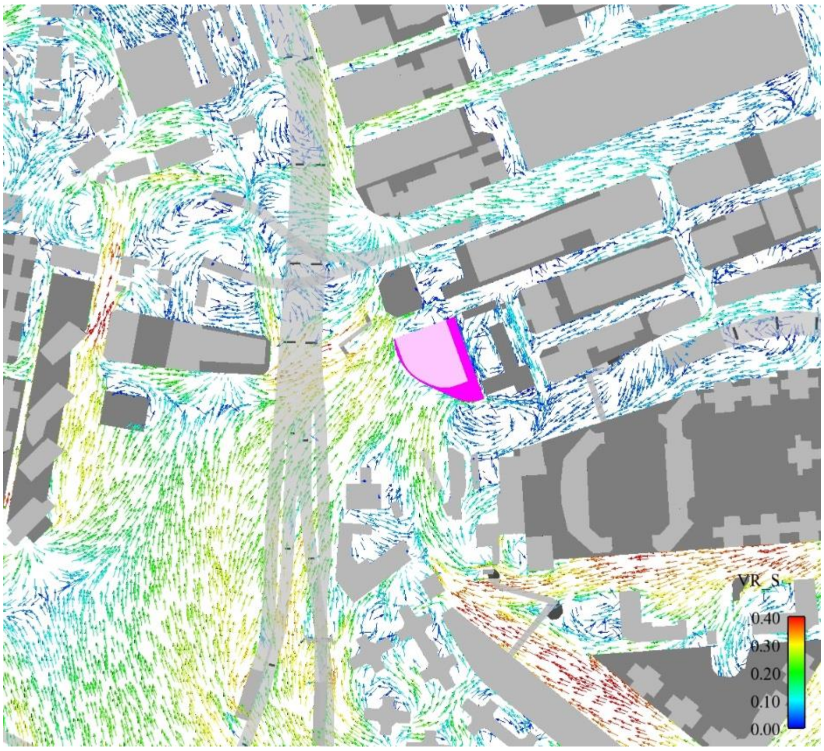
ESE direction (Scenario A)



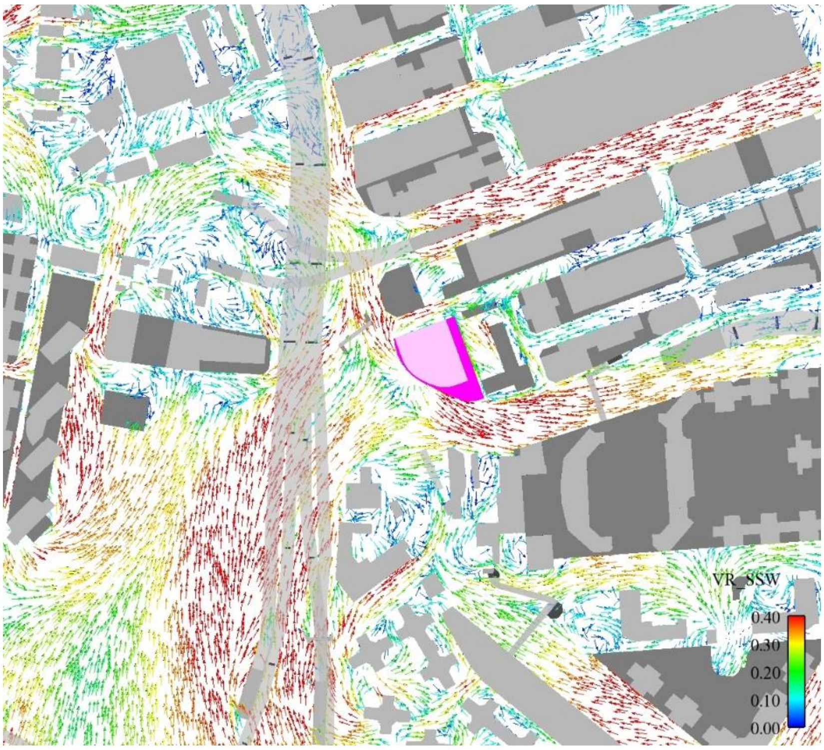
SE direction (Scenario A)



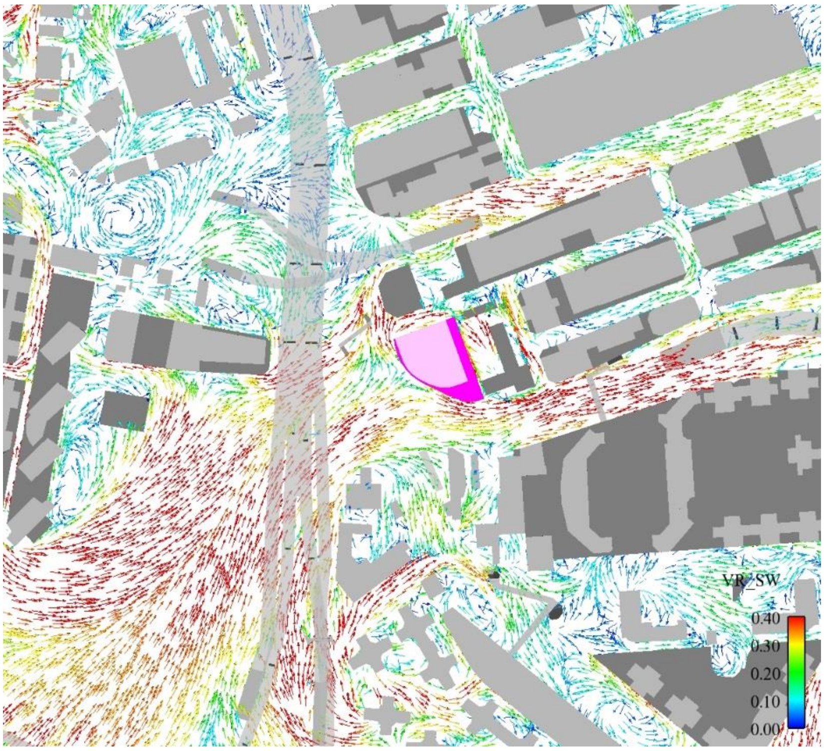
SSE direction (Scenario A)



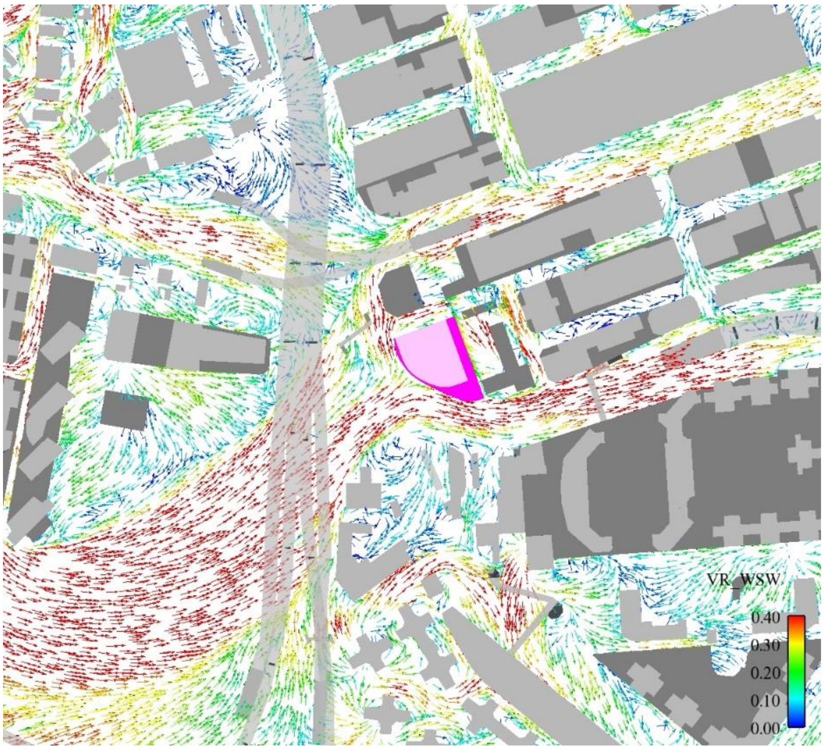
S direction (Scenario A)



SSW direction (Scenario A)

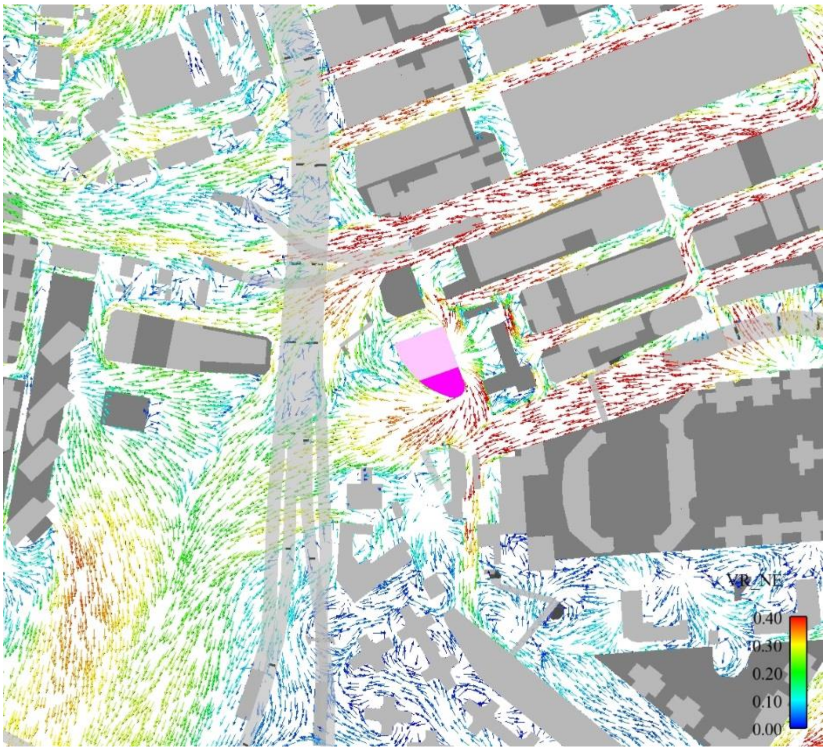


SW direction (Scenario A)

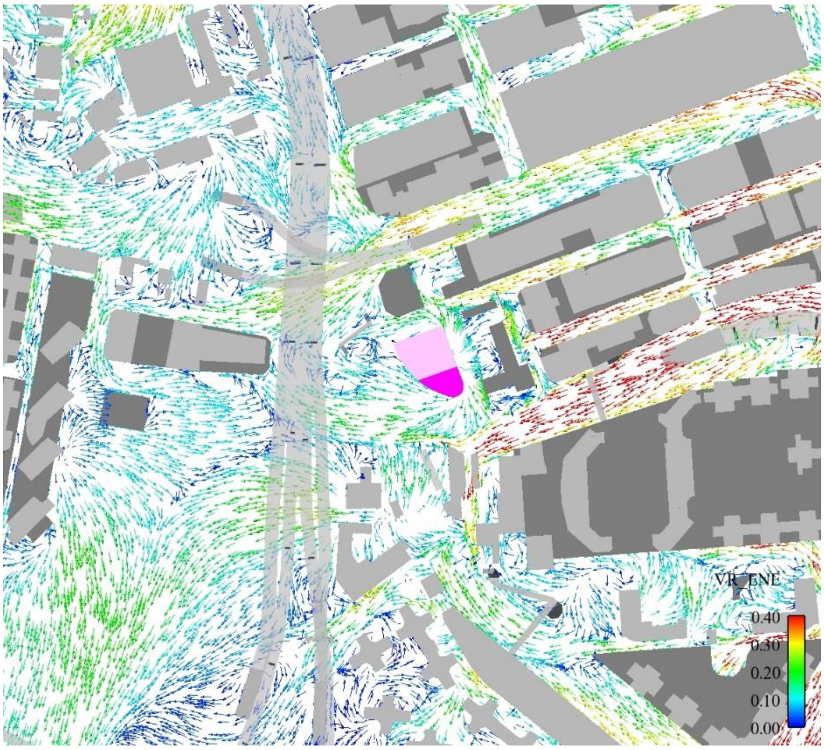


WSW direction (Scenario A)

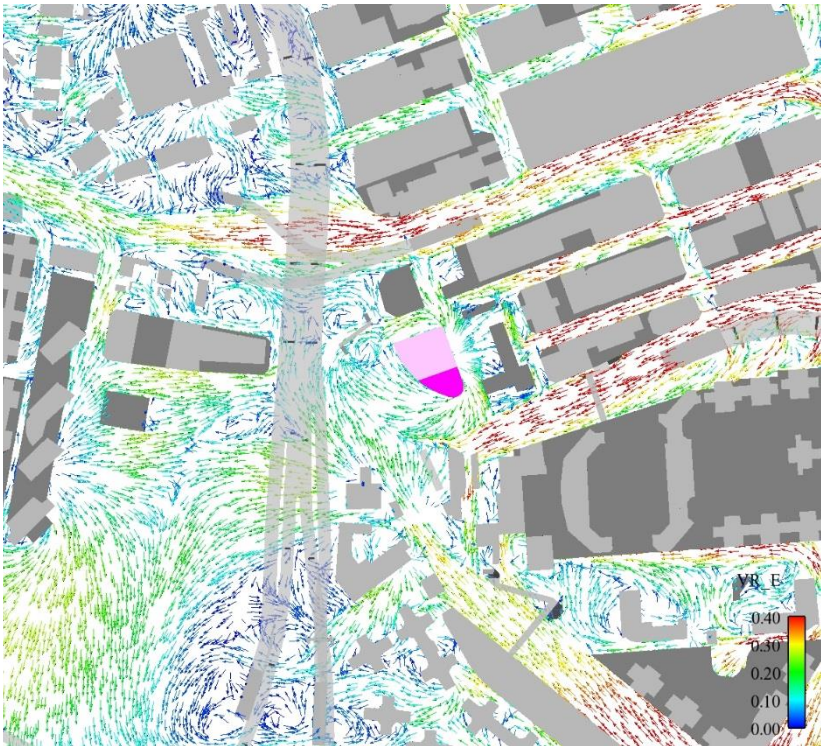
D3 Scenario B



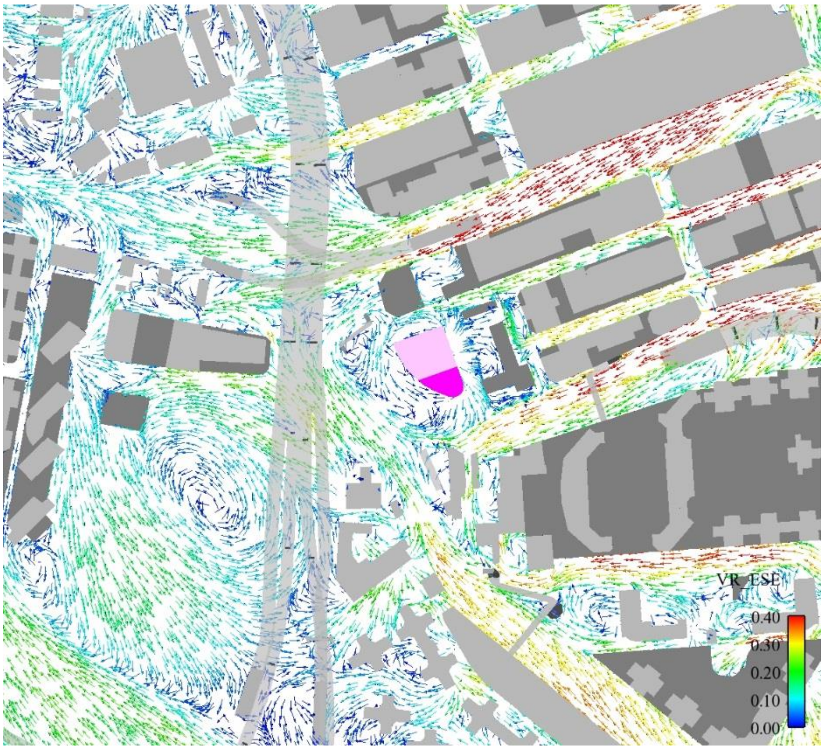
NE direction (Scenario B)



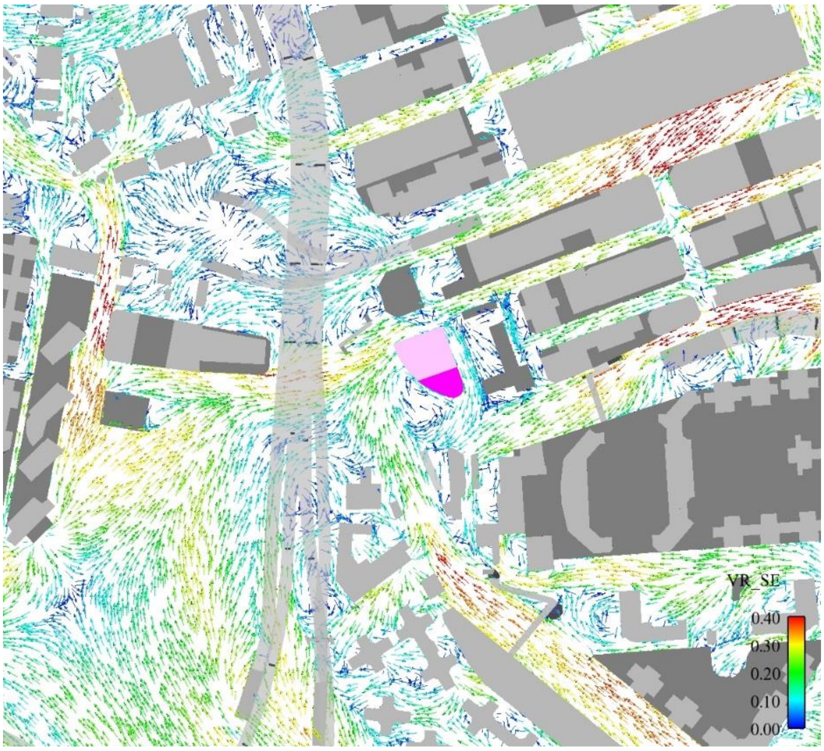
ENE direction (Scenario B)



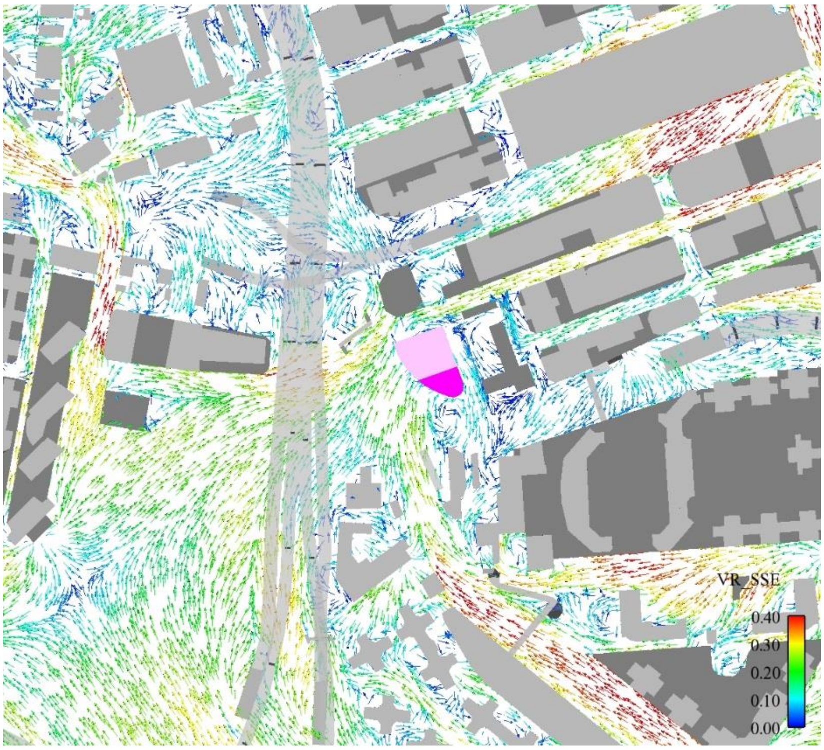
E direction (Scenario B)



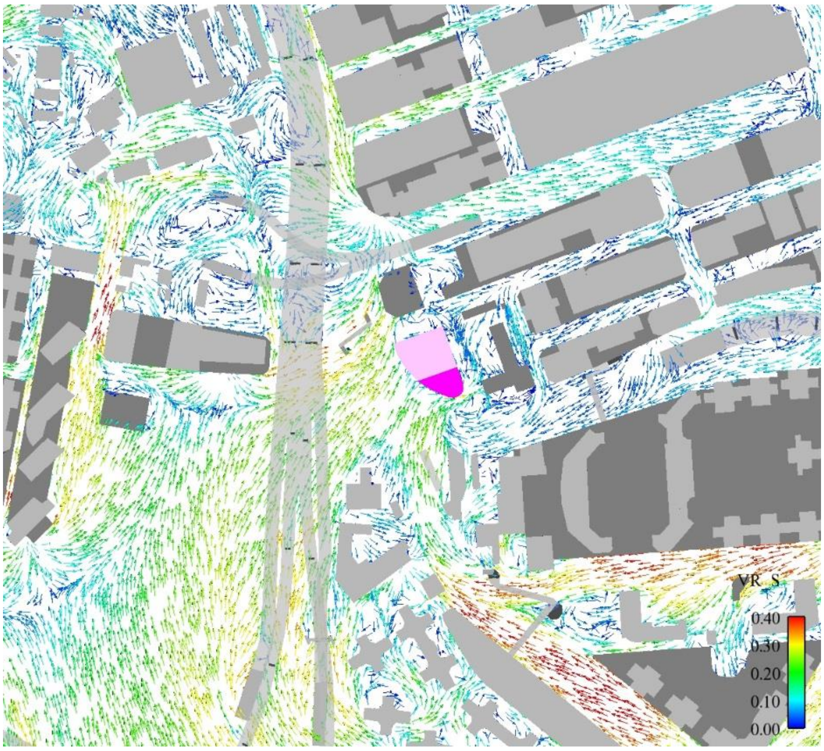
ESE direction (Scenario B)



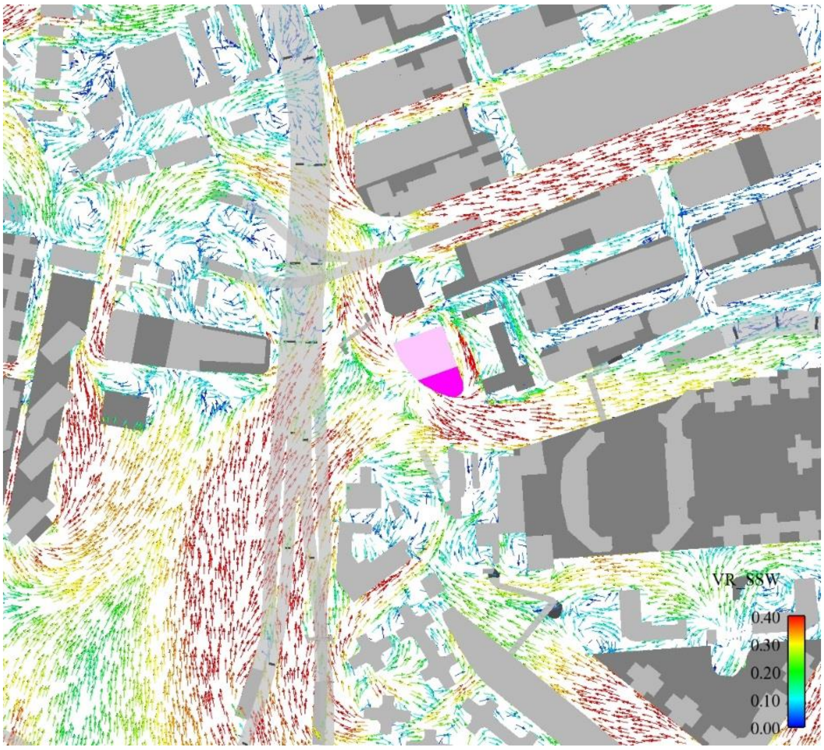
SE direction (Scenario B)



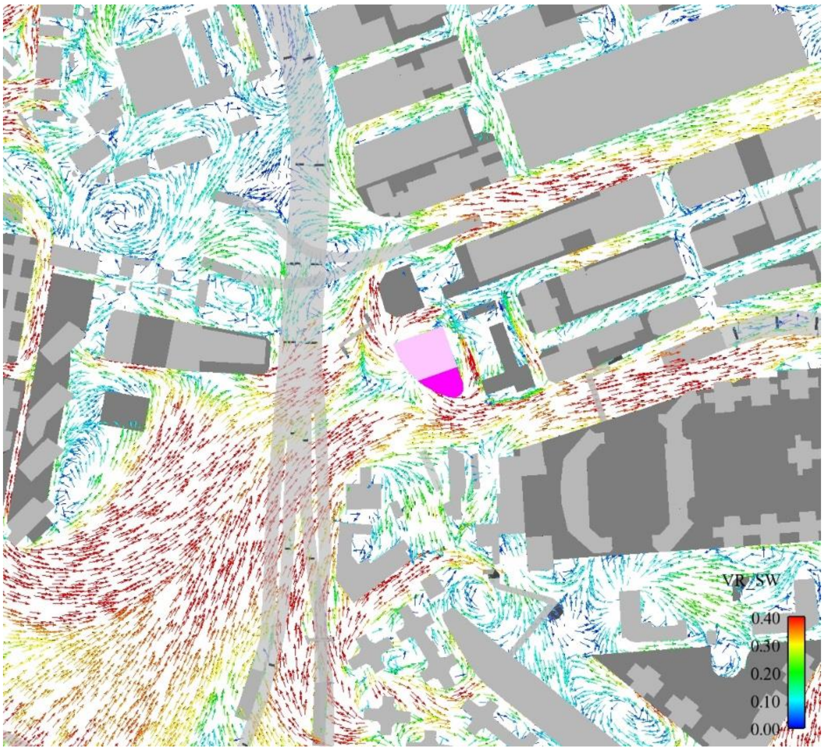
SSE direction (Scenario B)



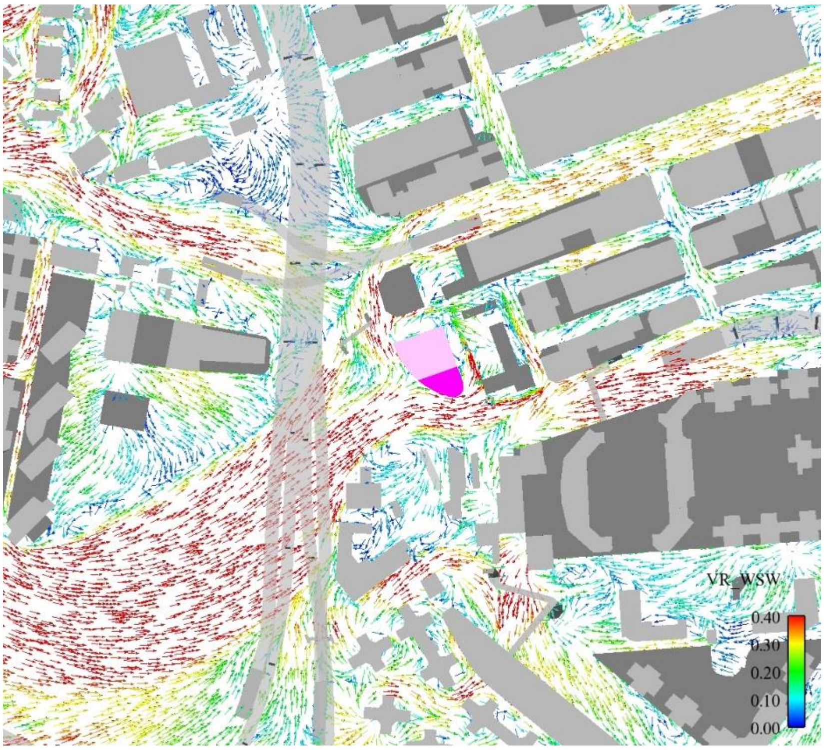
S direction (Scenario B)



SSW direction (Scenario B)



SW direction (Scenario B)



WSW direction (Scenario B)