Hong Kong Housing Authority

Proposed Subsidised Sale Flats Development at Ma On Shan Road, Ma On Shan Area 81A

Report on Air Ventilation Assessment - Initial Study

Issue (Rev 2) | 20 September 2018

Job number 226853-13

Ove Arup & Partners Hong Kong Ltd
Level 5 Festival Walk
80 Tat Chee Avenue
Kowloon Tong
Kowloon
Hong Kong
www.arup.com

ARUP

Contents

1 Introduction

1.1 Project Background

Ove Arup and Partners Hong Kong Ltd (Arup) was appointed by Hong Kong Housing Authority (HKHA) to carry out an Air Ventilation Assessment (AVA) Initial Study for the Proposed Subsidised Sale Flats Development at Ma On Shan Road, Ma On Shan Area 81A (the Development).

1.2 Objective of the Study

This AVA Report is to support the Section 16 planning application for the proposed subsidised sale flats (SSF) development at Ma On Shan Road under the Town Planning Ordinance

The purpose of this study is to assess the ventilation performance of the proposed development in comparison with a baseline case (prepared for the previous rezoning submission from “Green Belt” to “Residential (Group A) 9 in 2014 under the Approved Ma On Shan Outline Zoning Plan No. S/MOS/18) using the methodology for AVA as stipulated in “Technical Circular No. 1/06 – Air Ventilation Assessments” (the Technical Circular) and Annex A to the Technical Circular “Technical Guide for Air Ventilation Assessment for Developments in Hong Kong” (the Technical Guide) jointly issued by the former Housing, Planning and Lands Bureau and the former Environmental, Transport and Works Bureau on 19th July 2006[1]. The assessment is based on findings from Computational Fluid Dynamics (CFD) Simulations of all identified cases.

1.3 Scope of the Study

This Air Ventilation Assessment (AVA) Initial Study was carried out for two scenarios:

1. **Baseline Scheme** – This is a reference scheme previously designed for the site in 2014 (formerly the Proposed Scheme in previous submission of AVA for rezoning). It consists of 6 housing blocks.

2. **Proposed Scheme** – Modified from the Baseline Scheme, the Development contains 5 housing blocks, a 1-storey carport and 3-storey Commercial and Recreational Block. The latter two are added to the open area on the north-west and north-east sides of site respectively.

The deliverables of current study can be summarised as follows

- To identify the site wind characteristics at the Development and the surrounding area;
- To evaluate the general ventilation pattern over the assessment area;

[1] https://www.devb.gov.hk/filemanager/en/content_679/hplb-etwb-tc-01-06.pdf

- To assess the ventilation performance at the focus areas;
- To identify problem areas and propose mitigation measures as appropriate; and
- To demonstrate good design features of the Development.

2 Background

2.1 Site Characteristics

The Development is located in Ma On Shan Area with mixed building heights and in the east of the Ma On Shan Road. The east side of the Development is Ma On Shan Country Park with a large hilly terrain and lots of greenery while the Tolo Harbour with some high-rise residential clusters (i.e. Oceanaire, Ocean View, La Costa, Sausalito, Mountain Shore and Kam Tai Court) are located on the westside along the waterfront. In addition, high-rise public housing developments of Yan On Estate, Heng On Estate and Kam On Court are facing to the north of the Development while some low-rise clusters, such as, Tai Shui Hang Village and Chevalier Garden are located in the south. Figure 1 below shows the locations of the Study Area and the major surrounding developments.

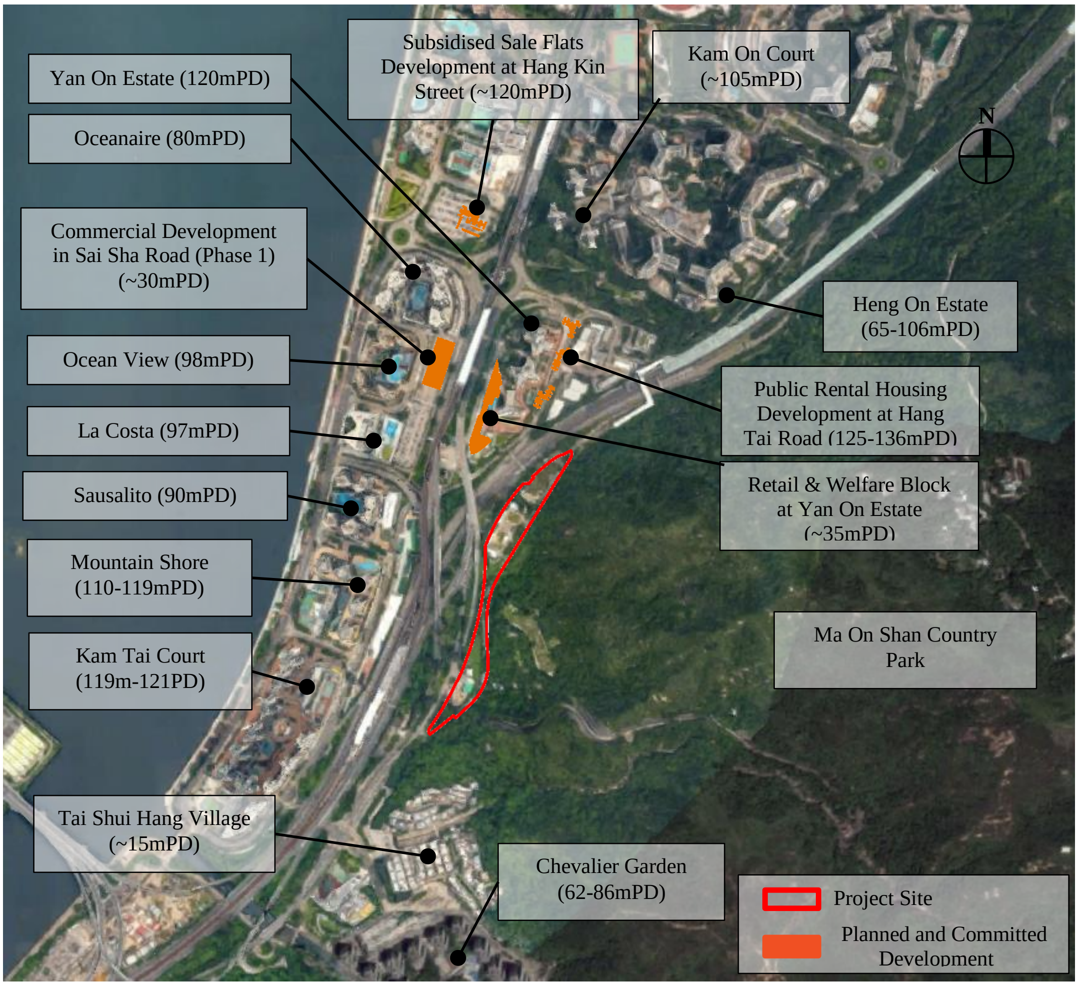


Figure 1 Location of the Development and major surrounding developments

In addition, four planned developments were identified within the surrounding area and have been included in the CFD model for simulation:

- Public Rental Housing Development at Hang Tai Road;
- Retail and Welfare Block at Yan On Estate;

- Subsidised Sale Flats Development at Hang Kin Street;
- Commercial Development in Sai Sha Road, next to Ocean View.

Figure 1 illustrates the locations of planned and committed developments. In addition, street and road are identified in Figure 2.

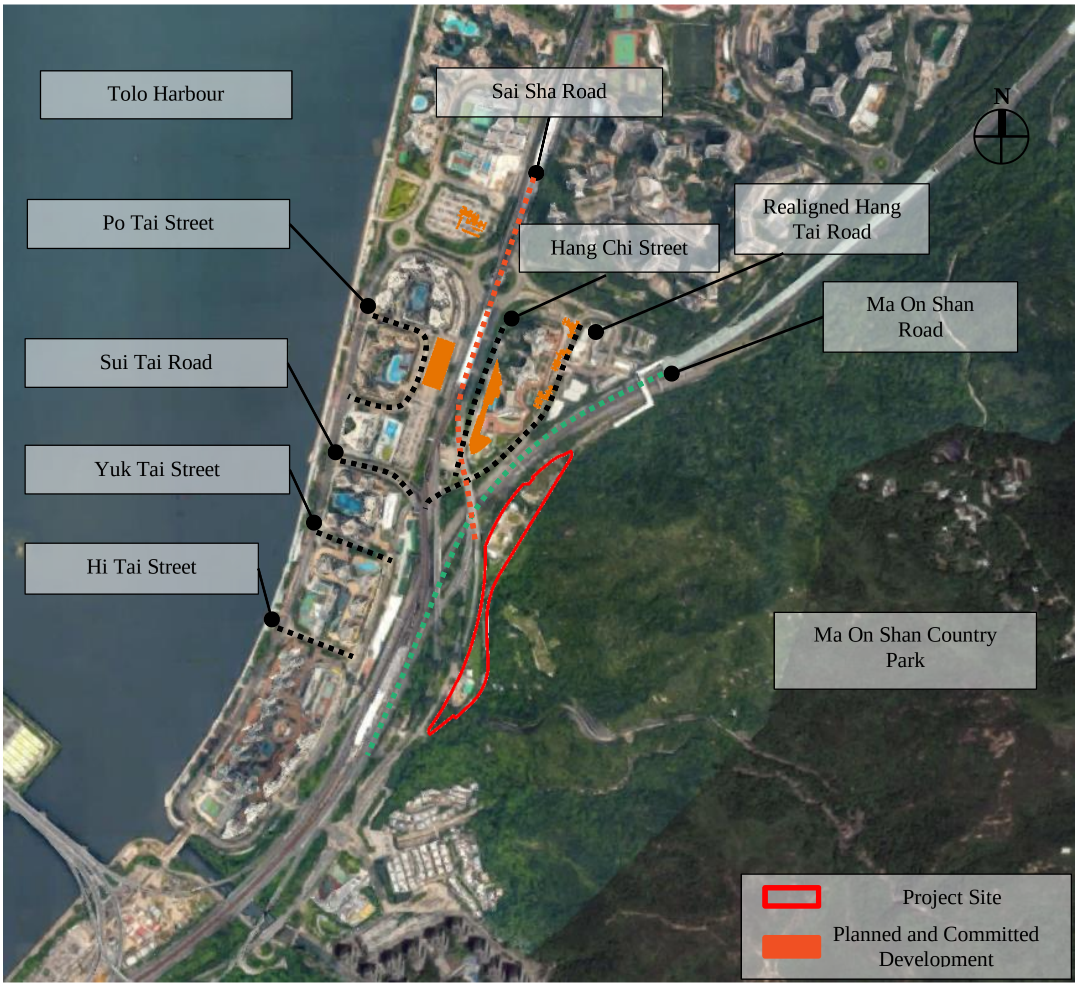


Figure 2 Location of the Development and major surrounding developments

2.2 Studied Scenarios

A total of two cases were investigated in the present AVA study:

2.2.1 Baseline Scheme

The Baseline Scheme is an indicative scheme which was formulated based on the existing development restrictions and exactly the one submitted for rezoning in the year 2014. The key development parameters of Baseline Scheme are presented in Table 1.

Table 1 Development Parameters of Baseline Scheme

Development Parameter	Baseline Scheme
Plot Ratio (domestic portion)	5.5
Plot Ratio (non-domestic portion)	0.3
Maximum Building Height	140mPD

The scheme consists of six domestic blocks with building height of 125mPD to 140mPD. The site ground level is approximately 5.6mPD to 10.4mPD.

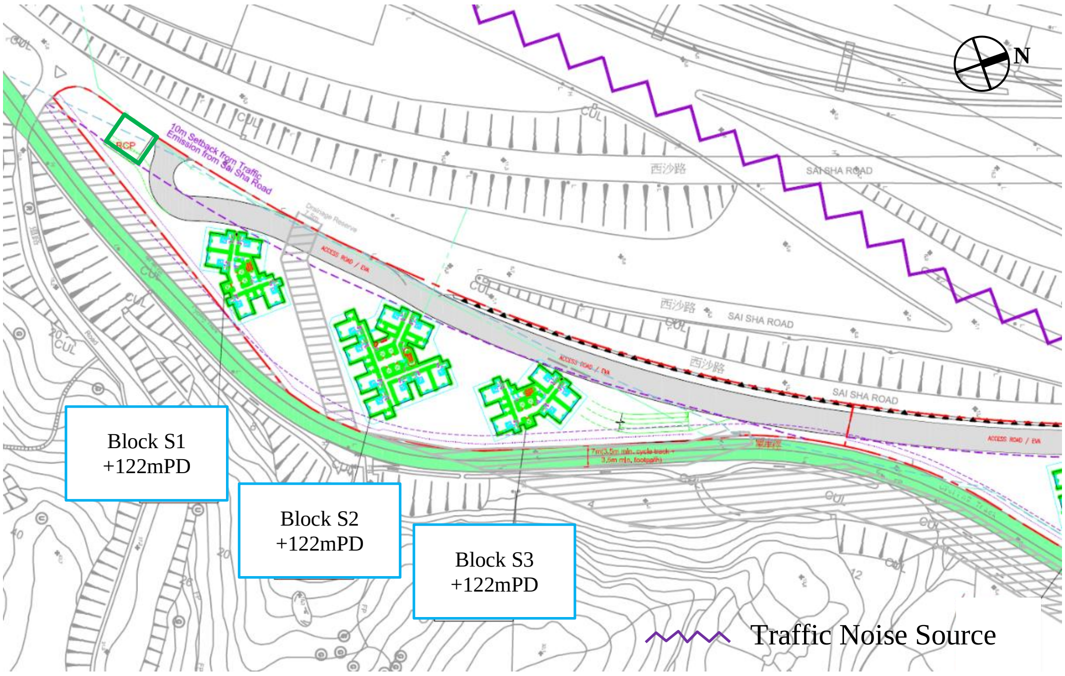


Figure 3 Baseline Scheme Master Layout Plan (Block S1 to S3)

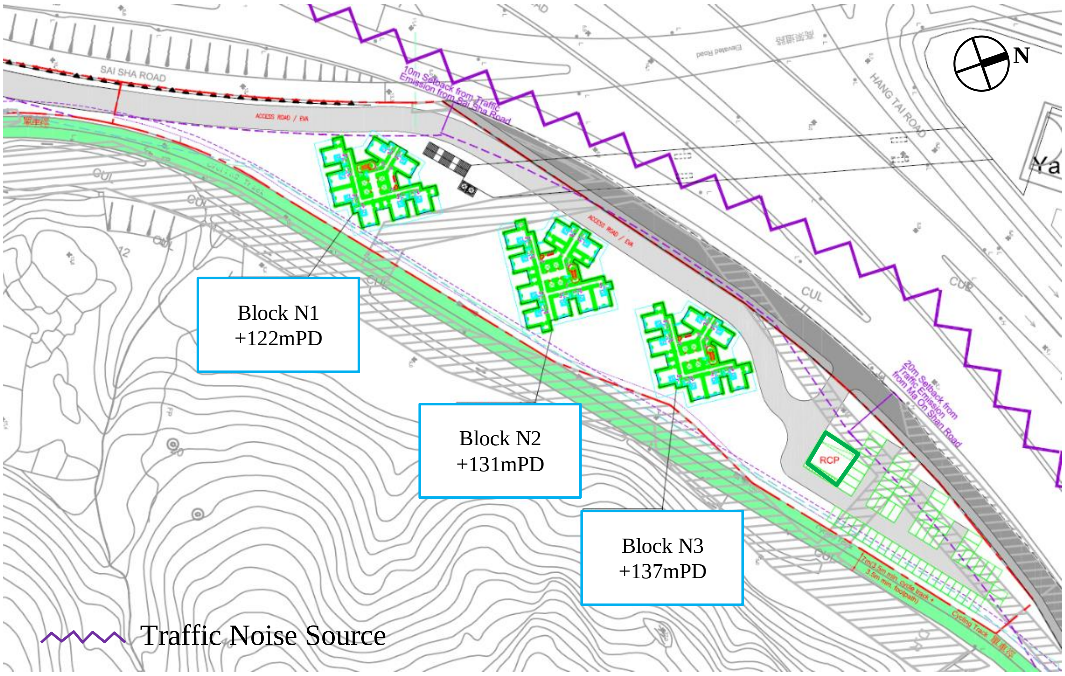


Figure 4 Baseline Scheme Master Layout Plan (Block N1 to N3)

By referring to the CAD drawings of the Baseline Scheme, the 3D model was constructed as shown in Figure 5 to Figure 8.

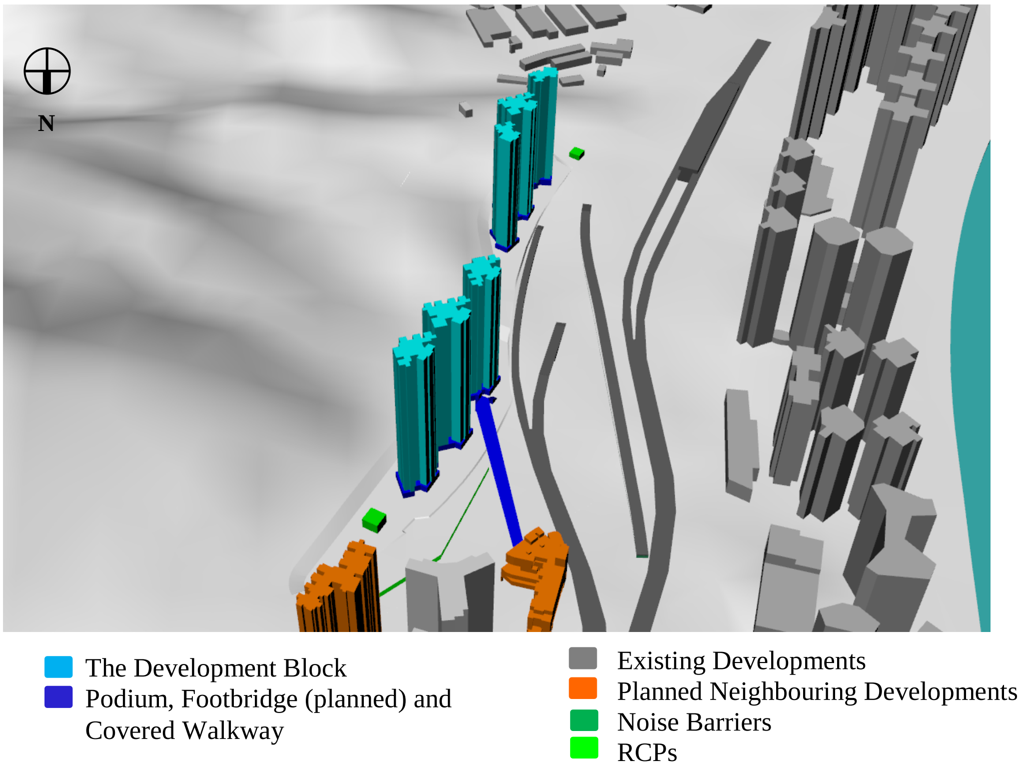
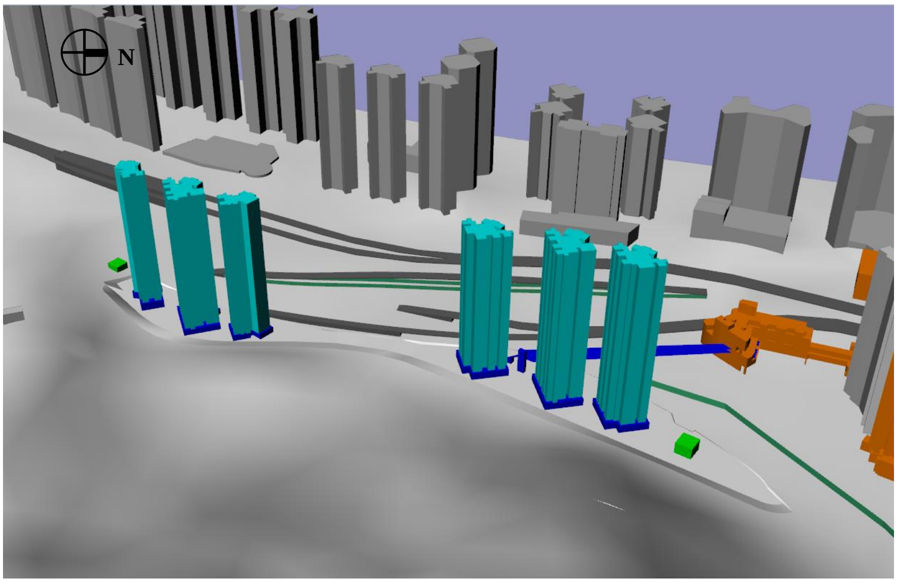
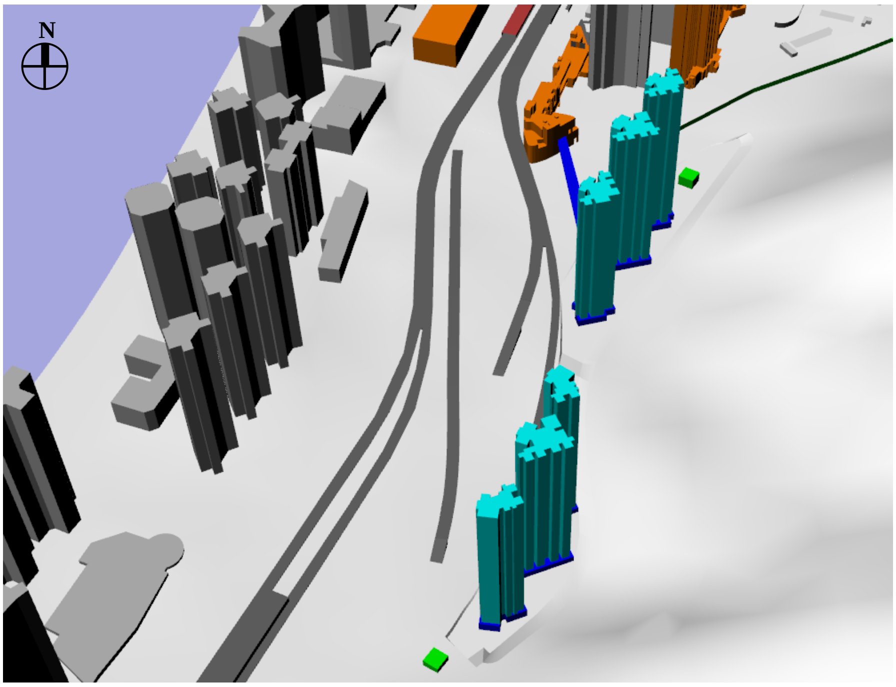


Figure 5 Northerly view of Baseline Scheme



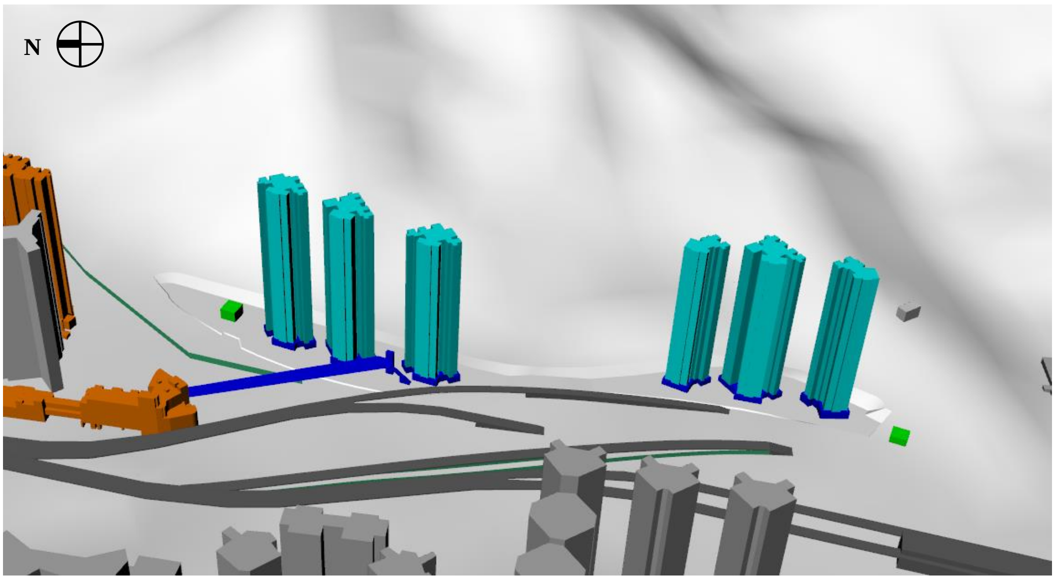
The Development Block
Podium, Footbridge (planned) and Covered Walkway
Existing Developments
Planned Neighbouring Developments
Noise Barriers
RCPs

Figure 6 Easterly view of Baseline Scheme



The Development Block
Podium, Footbridge (planned) and Covered Walkway
MTR Station
Existing Developments
Planned Neighbouring Developments
Noise Barriers
RCPs

Figure 7 Southerly view of Baseline Scheme



The Development Block
Podium, Footbridge (planned) and Covered Walkway
Existing Developments
Planned Neighbouring Developments
Noise Barriers
RCPs

Figure 8 Westerly view of Baseline Scheme

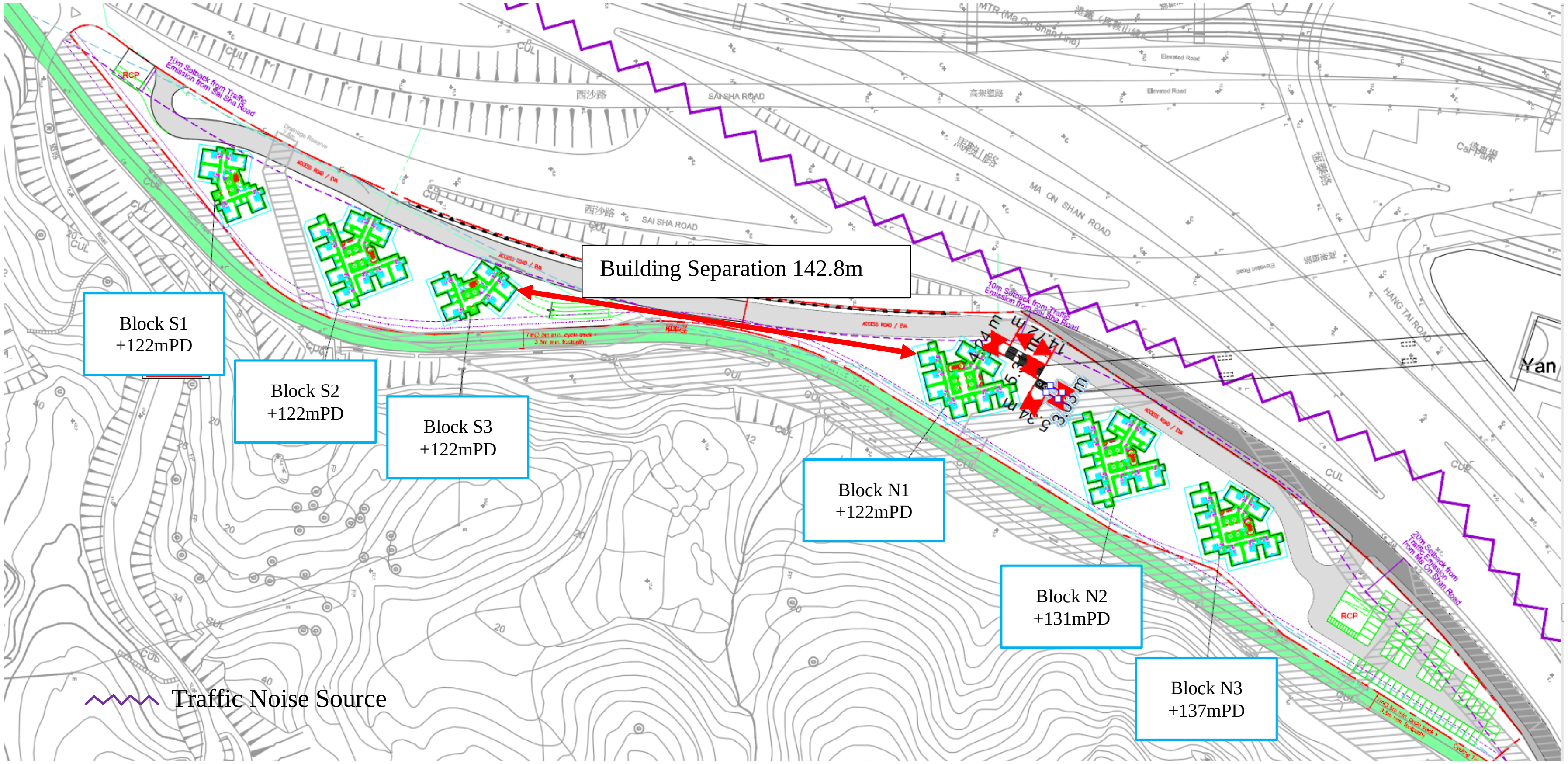


Figure 9 Building Separation in Baseline Scheme Master Layout Plan

2.2.2 Proposed Scheme

The key development parameters of Proposed Scheme is presented in Table 2.

Table 2 Development Parameters of Proposed Scheme

Development Parameter	Proposed Scheme
Plot Ratio (domestic portion)	5.5
Plot Ratio (non-domestic portion)	0.3
Maximum Building Height	140mPD

The scheme consists of five domestic blocks with building height of about 116mPD to 125mPD. A low-rise commercial block is located at the north corner of the development while a 1-storey carport is situated between Blocks D and E. The site ground level is approximately 5.6mPD to 10.4mPD.

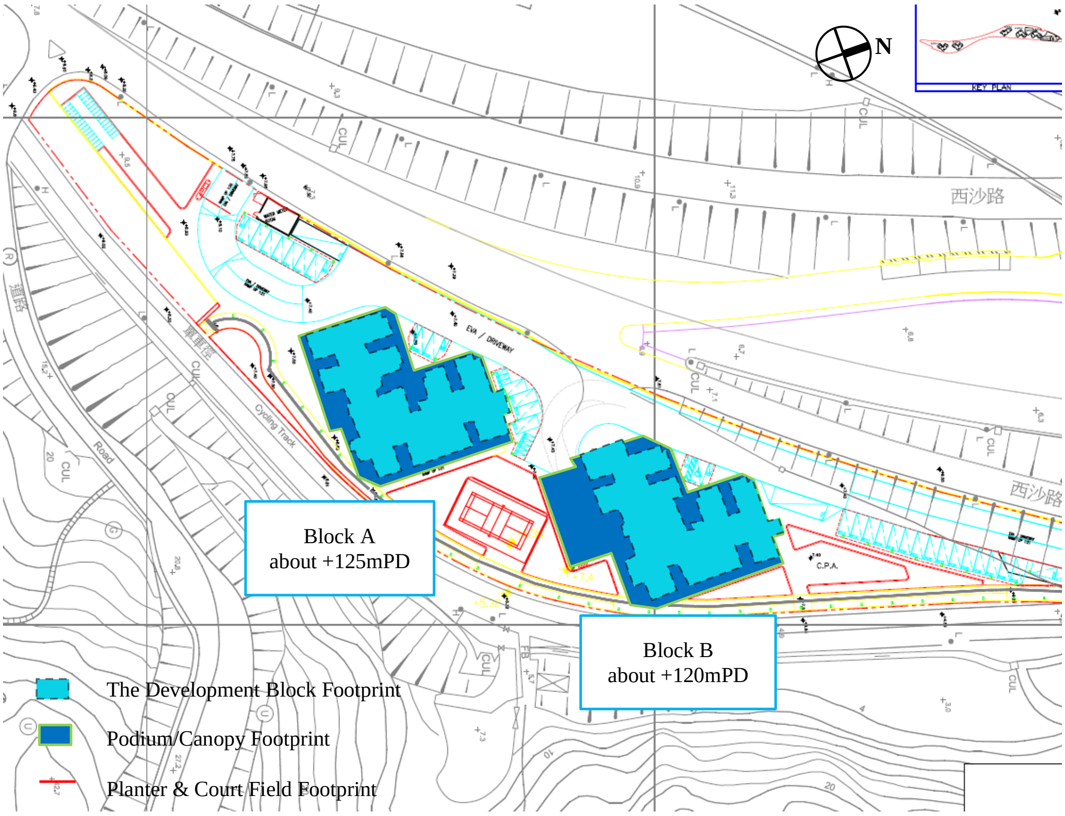


Figure 10 Proposed Scheme Master Layout Plan (Block A & B)

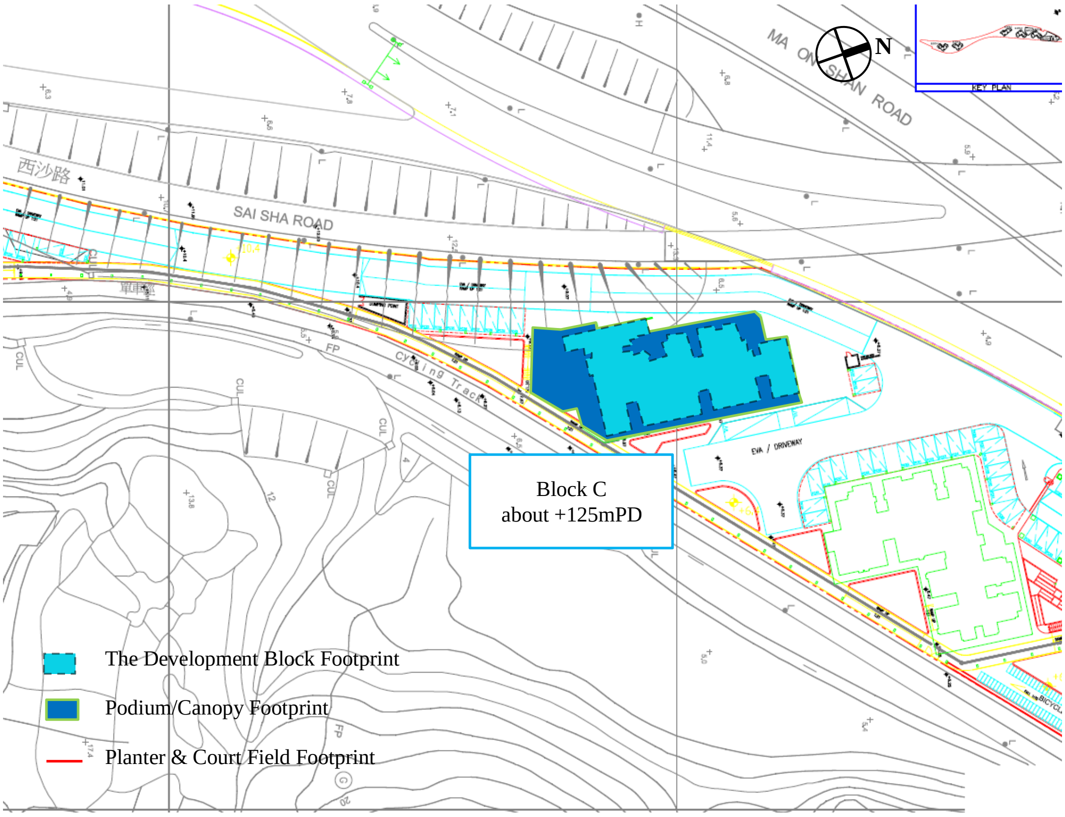


Figure 11 Proposed Scheme Master Layout Plan (Block C)

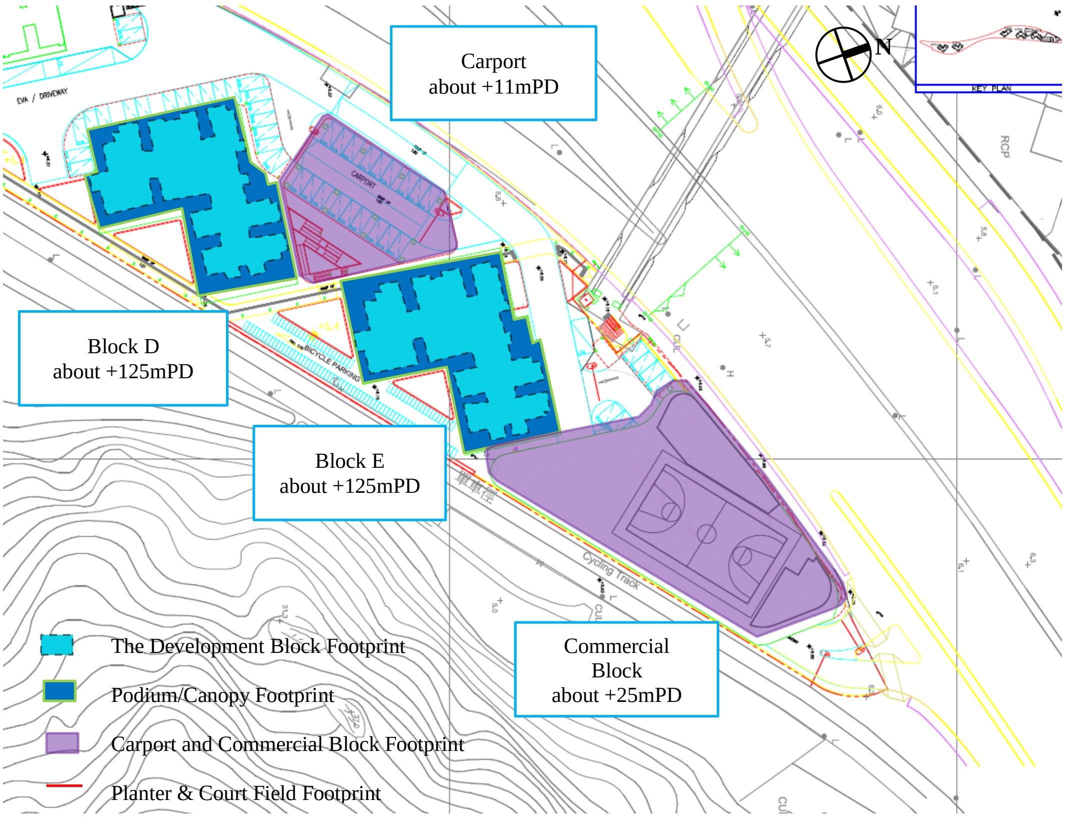


Figure 12 Proposed Scheme Master Layout Plan (Block D & E and Commercial Block)

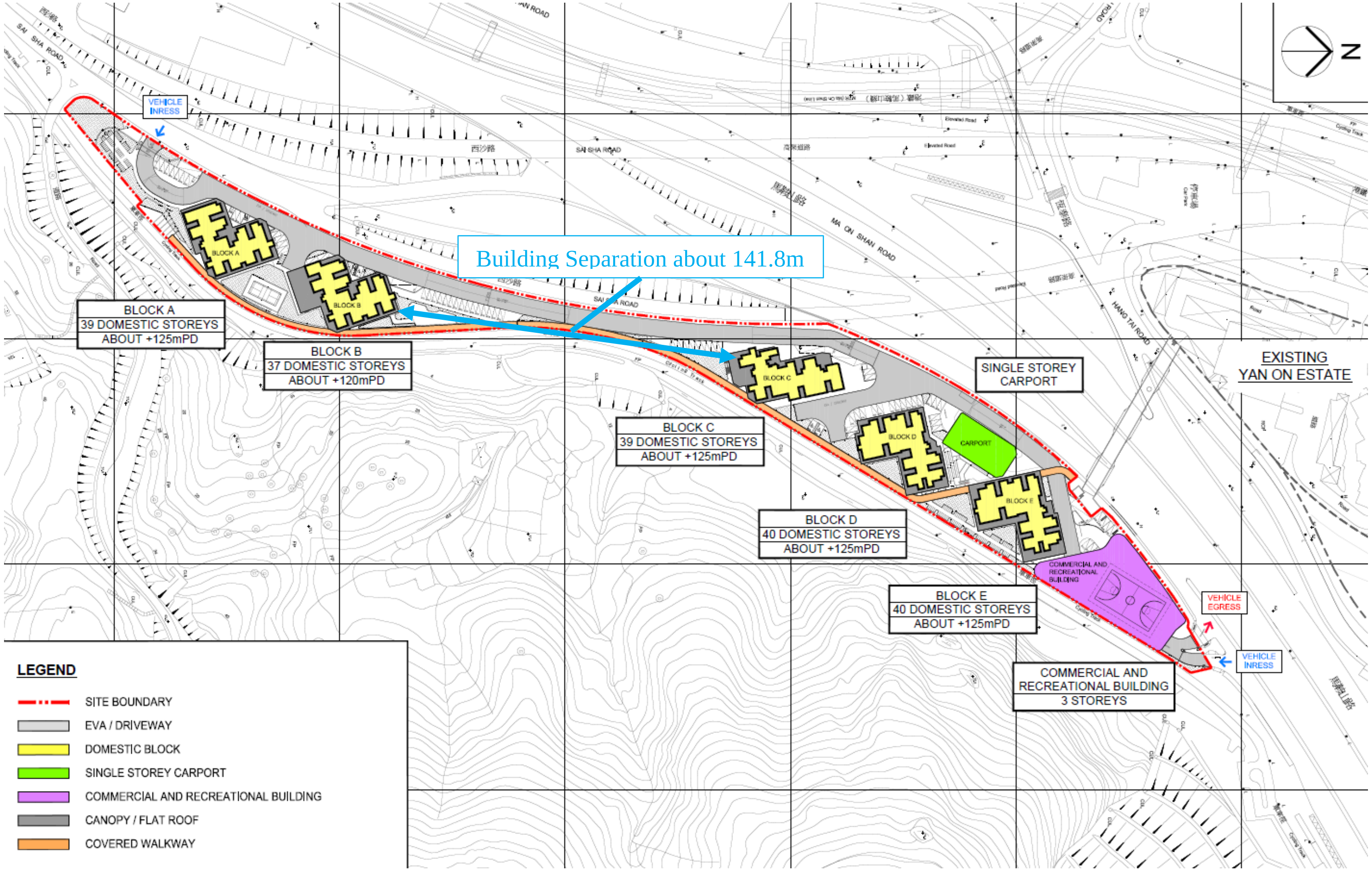
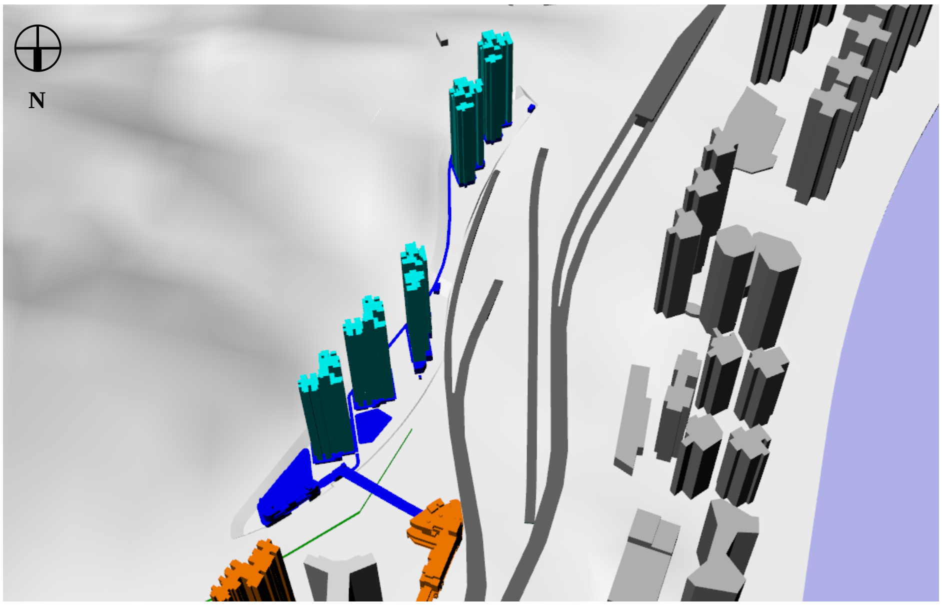


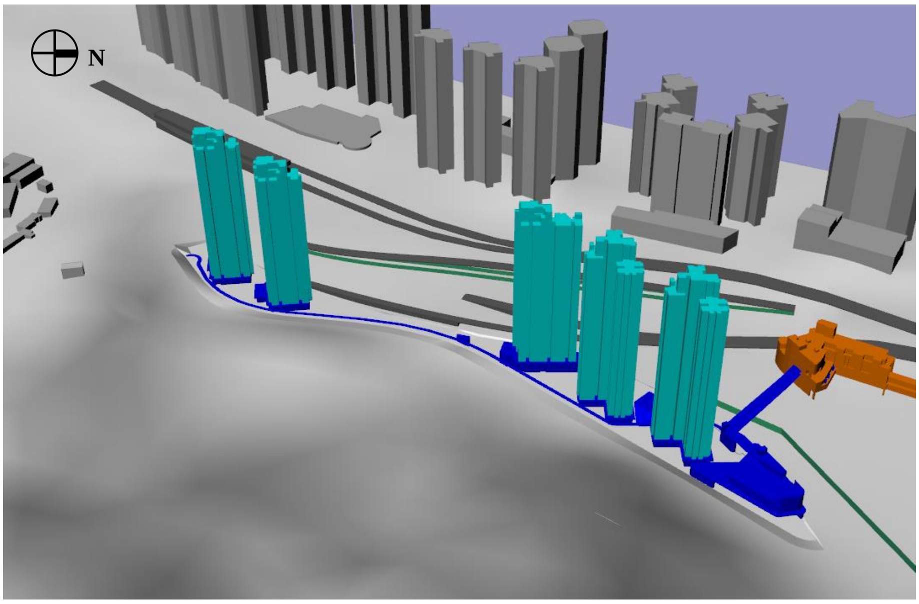
Figure 13 Building Separation in Proposed Scheme Master Layout Plan

By referring to the CAD drawings of the Proposed Scheme, the 3D model was constructed as shown in Figure 14 to Figure 17.



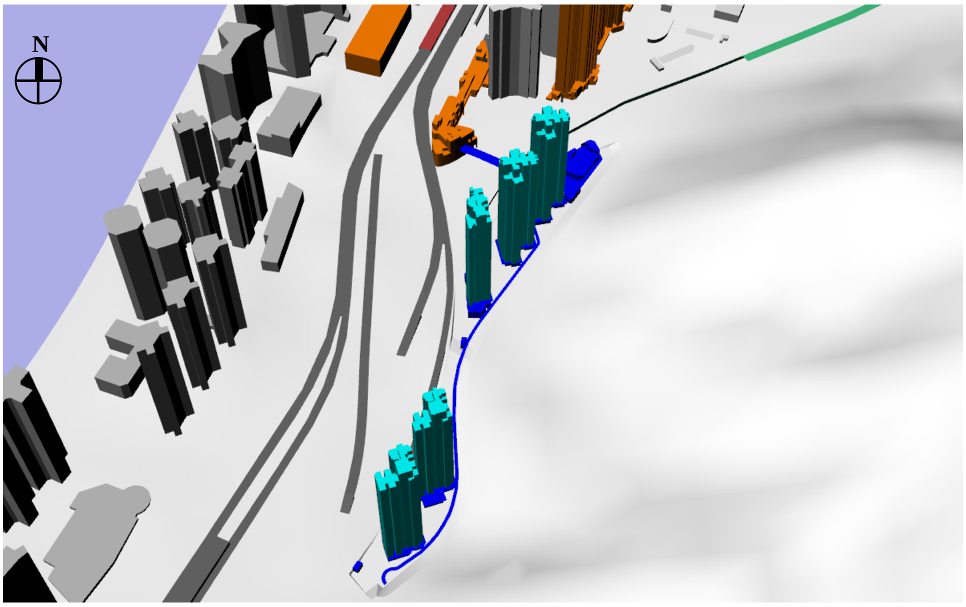
The Development Block
Podium, Commercial & Recreational Block, Footbridge (planned) and Covered Walkway
Existing Developments
Planned Neighbouring Developments
Noise Barriers

Figure 14 Northerly view of Proposed Scheme



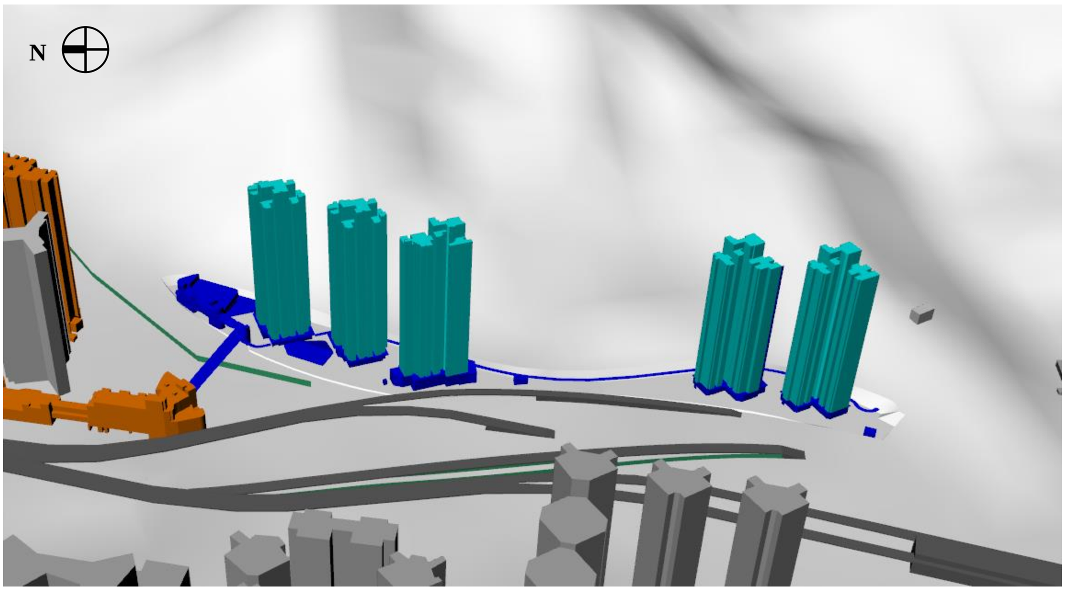
The Development Block
Podium, Commercial & Recreational Block, Footbridge (planned) and Covered Walkway
Existing Developments
Planned Neighbouring Developments
Noise Barriers

Figure 15 Easterly view of Proposed Scheme



- The Development Block
- Podium, Commercial & Recreational Block, Footbridge (planned) and Covered Walkway
- MTR Station
- Existing Developments
- Planned Neighbouring Developments
- Noise Barriers

Figure 16 Southerly view of Proposed Scheme



- The Development Block
- Podium, Commercial & Recreational Block, Footbridge (planned) and Covered Walkway
- Existing Developments
- Planned Neighbouring Developments
- Noise Barriers

Figure 17 Westerly view of Proposed Scheme

3 Methodology of AVA Study

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

3.1 Site Wind Availability

The site wind availability data for the study are obtained from Site Wind Availability Study (SWAS) for MOS Area 86B[2], which is adjacent to the project site.

3.1.1 Wind Directions

According to the wind tunnel data of SWAS at 500mPD (Figure 18), the annual prevailing wind is composed of 8 wind directions: North, North-northeast, Northeast, East-northeast, East, East-southeast, South and Southwest, totalling 81.6% in annual frequency of occurrence (Table 3).

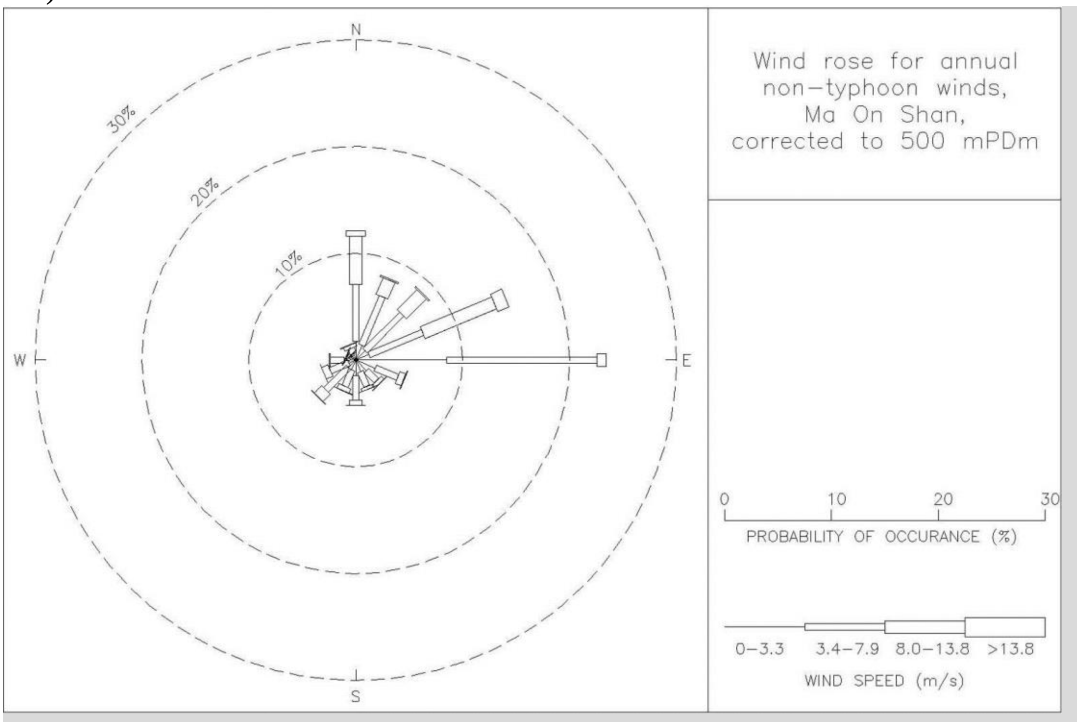


Figure 18 Wind rose for annual wind condition at 500mPD

[2] Experimental Site Wind Availability Study For Public Housing Development Projects In Batch C3: Ma On Shan Area 86 Investigation Report WWTF021-2009

Table 3 Annual Wind Frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Wind Frequency	12.1%	8.2%	8.7%	15.1%	23.4%	4.8%	3.2%	3.0%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	SUM of Selected
Wind Frequency	4.3%	3.2%	5.0%	3.2%	2.5%	1.0%	0.6%	1.4%	81.6%

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

Meanwhile by another set of wind data of the SWAS (Figure 19), the summer prevailing wind is composed of 8 wind directions: East, East-southeast, Southeast, South, South-southwest, Southwest, West-southwest and West, totalling 77.1% in summer frequency of occurrence (Table 4).

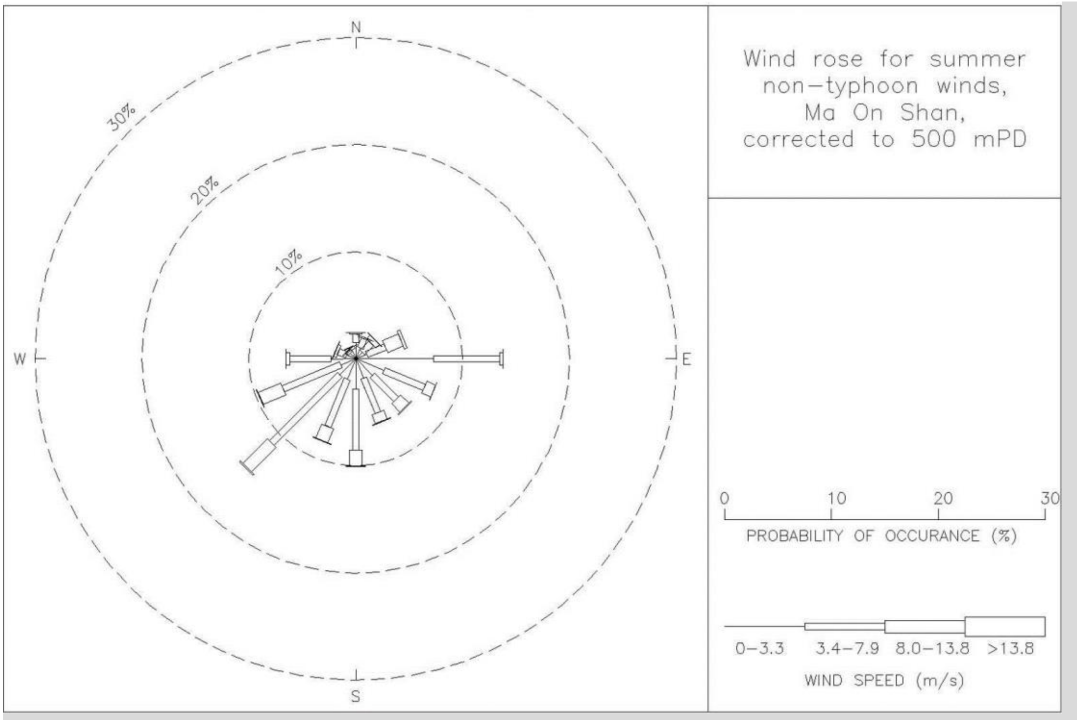


Figure 19 Wind rose for summer wind condition at 500mPD

Table 4 Summer Wind Frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Wind Frequency	2.5%	2.1%	2.6%	4.9%	13.8%	7.9%	6.5%	6.4%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	SUM of Selected
Wind Frequency	10.0%	8.2%	14.4%	9.7%	6.6%	2.1%	1.1%	1.2%	77.1%

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

3.1.2 Wind Profiles

Upon the SWAS of the project site, the exact vertical wind profiles were adopted at 25m and above. For those unavailable wind profiles below 25m, specific n values of the power law were assumed by the characteristics of topography around the Development. The vertical profiles of the winds selected in this study are presented from Figure 20 to Figure 25.

<u>Legend for Figure 20 to Figure 25</u>

● Wind data from wind tunnel study

— Wind profile for this AVA study

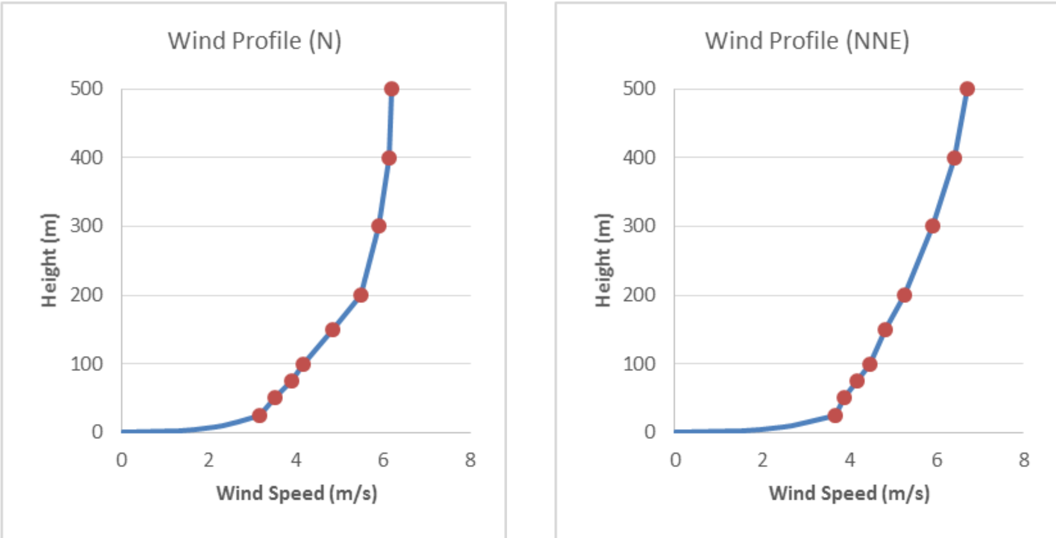


Figure 20 Wind profiles from wind tunnel study for N and NNE wind

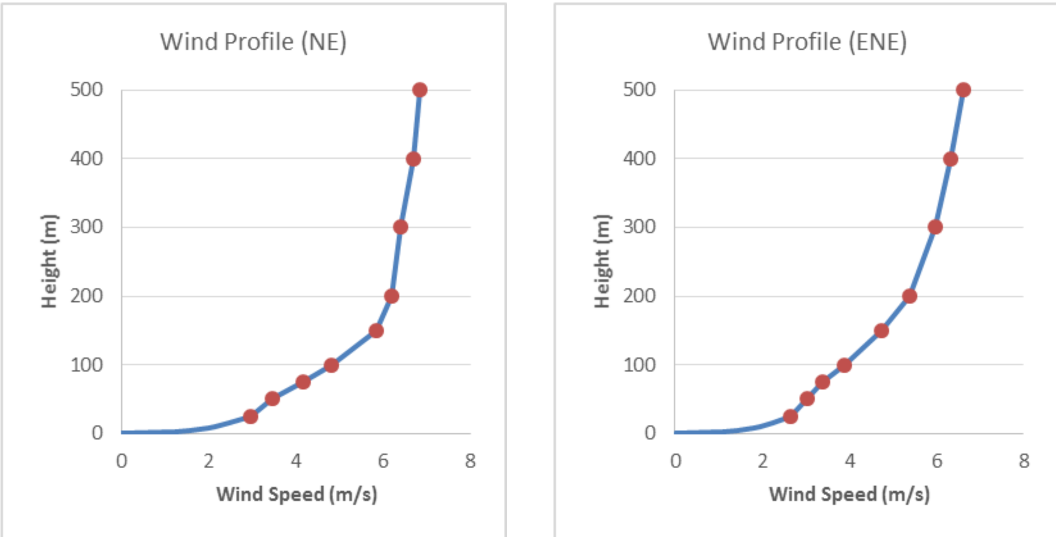


Figure 21 Wind profiles from wind tunnel study for NE and ENE wind

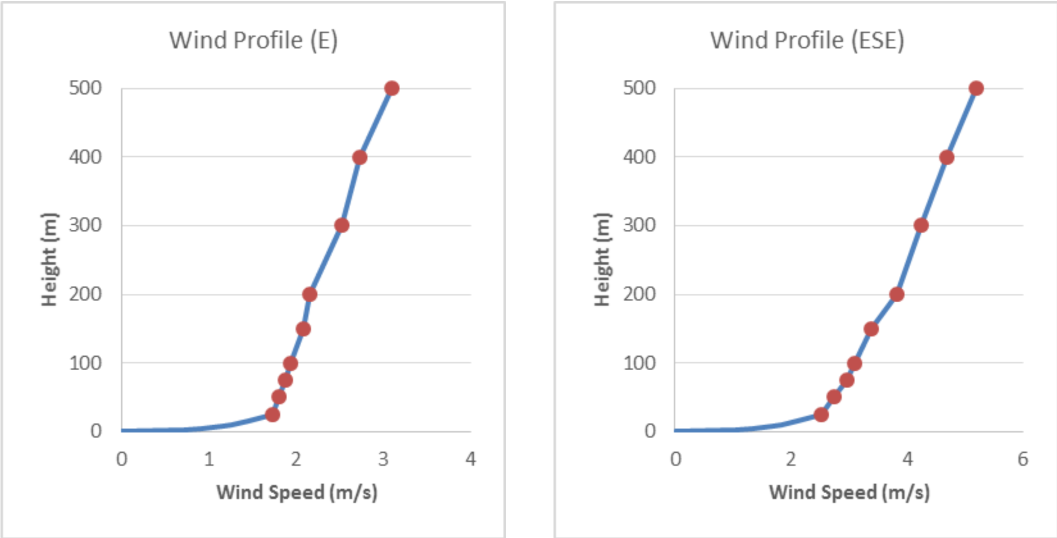


Figure 22 Wind profiles from wind tunnel study for E and ESE wind

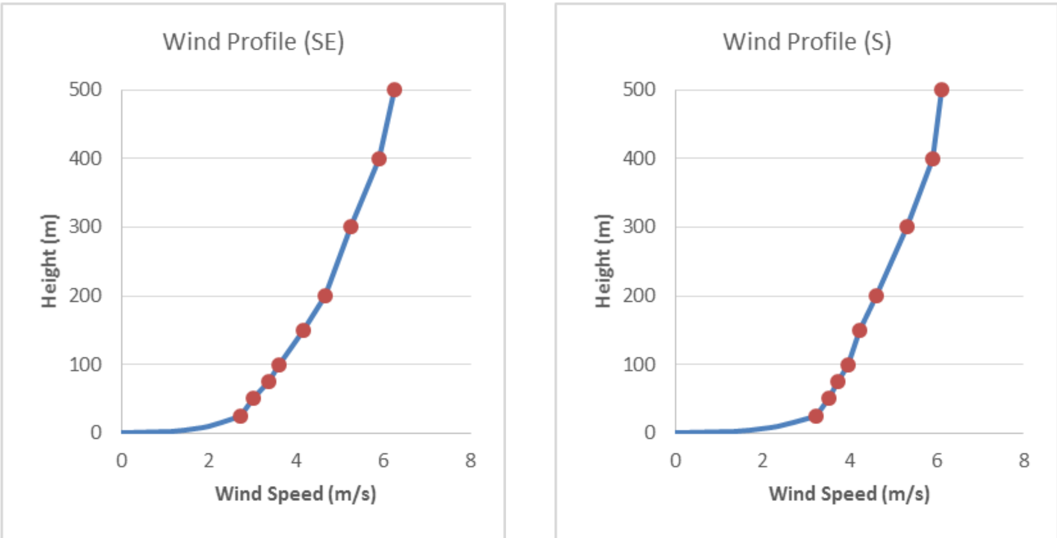


Figure 23 Wind profiles from wind tunnel study for SE and S wind

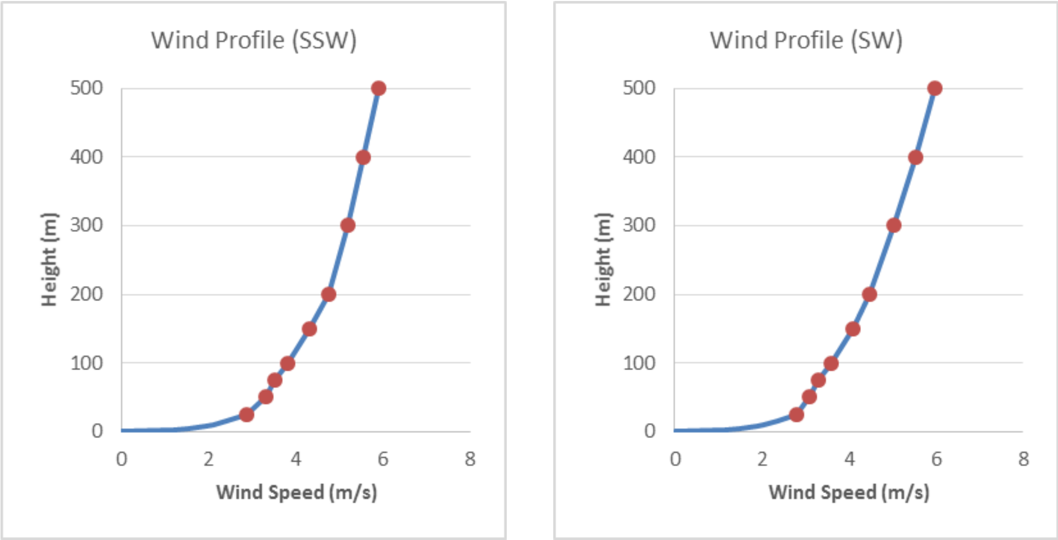


Figure 24 Wind profiles from wind tunnel study for SSW and SW wind

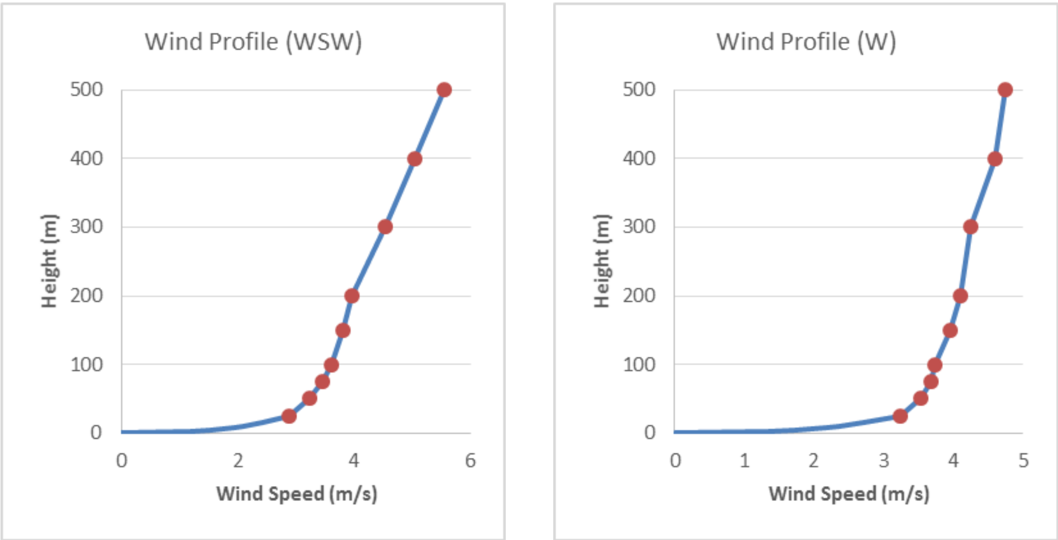


Figure 25 Wind profiles from wind tunnel study for WSW and W wind

For wind profiles under 25m reference level, it was assumed to follow the power law for specific terrains as given in Equation 1:

$$U_z = U_G \times \left(\frac{z}{z_G}\right)^n \qquad \text{Equation 1}$$

where U_G = reference velocity at height z_G

U_z = velocity at height z

z_G = reference height

z = height above ground

n = power law exponent

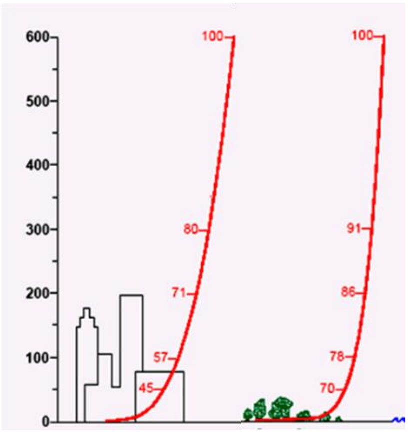


Figure 26 Wind Profile applied in the AVA Initial Study

The power n is related to the ground roughness, which is determined by the type of terrain. The larger the value, the higher is the roughness of ground, i.e. the denser is the city. Alternatively, smaller n represents lower ground roughness, e.g. sea surface.

Table 5 N-value of corresponding type of terrain

Terrain crossed by approaching wind	n-value
Sea and open area	~0.15
Suburban or mid-rise	~0.35
City center or high-rise	~0.50

According to the topography around the project site, the n-values for wind directions N, NNE, NE, ENE, S, SSW, SW, WSW and W were 0.35 while the 3 others selected, E, ESE and SE, were 0.15.

3.2 Project Assessment and Surrounding Areas

With reference to the Technical Guide, the Assessment Area included the immediate surroundings of the development, up to 1H from the site boundary where H was the height of the tallest building of the development. The Surrounding Area included an area up to 2H from the site boundary.

The tallest building of the Development happens to the Baseline Scheme with a building height of about 130m to the level of main roof (whereas 120m max. for the Proposed Scheme), so 1H and 2H would be 130m and 260m respectively. The site boundary, the Assessment Area, and the Surrounding Area of the study are presented in

Figure 27 and Figure 28 illustrate the span of building mass considered in the present CFD simulation model has exceeded the minimum 2H distance.

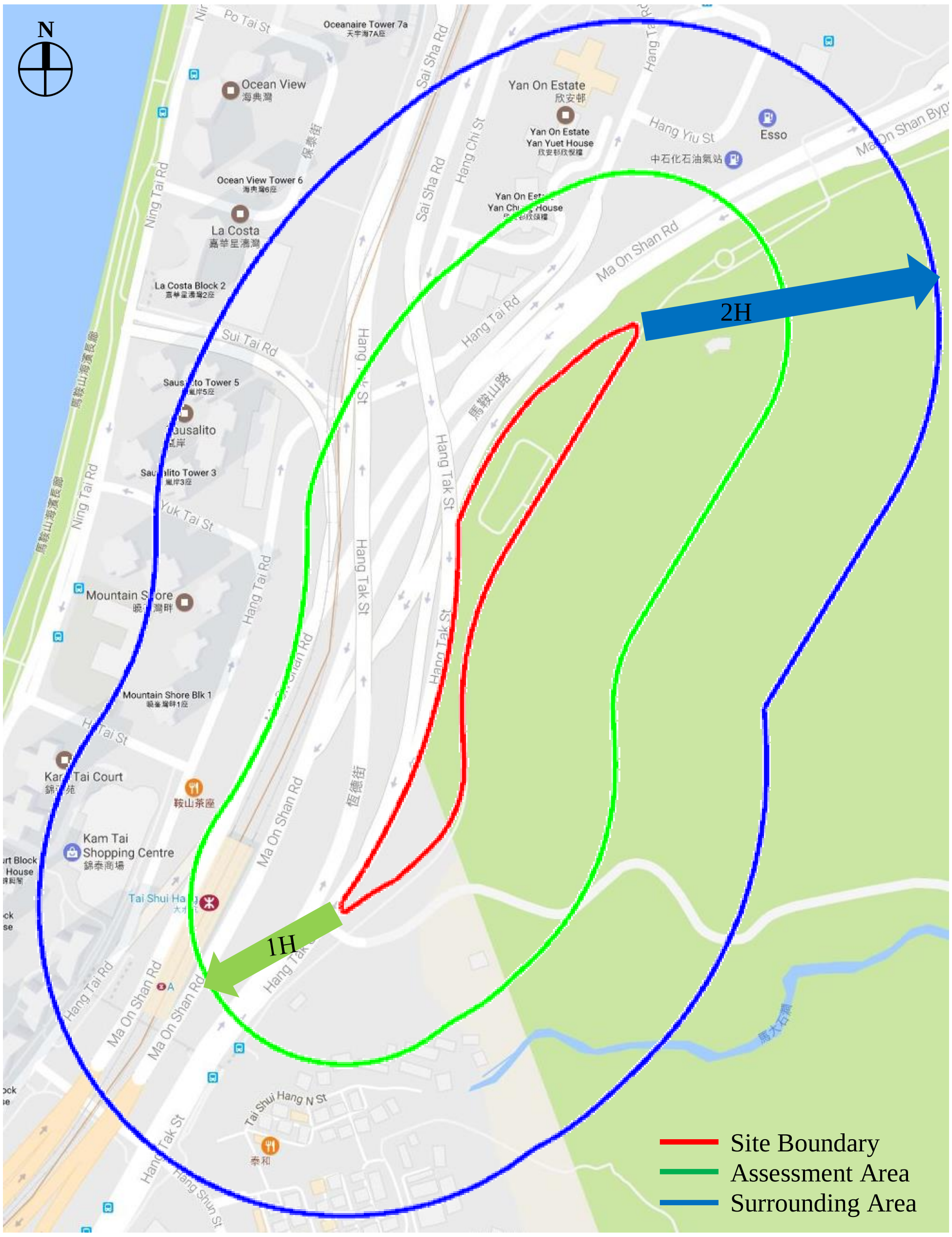


Figure 27 Site boundary, Assessment Area, and Surrounding Area (Image Source: Google Maps)

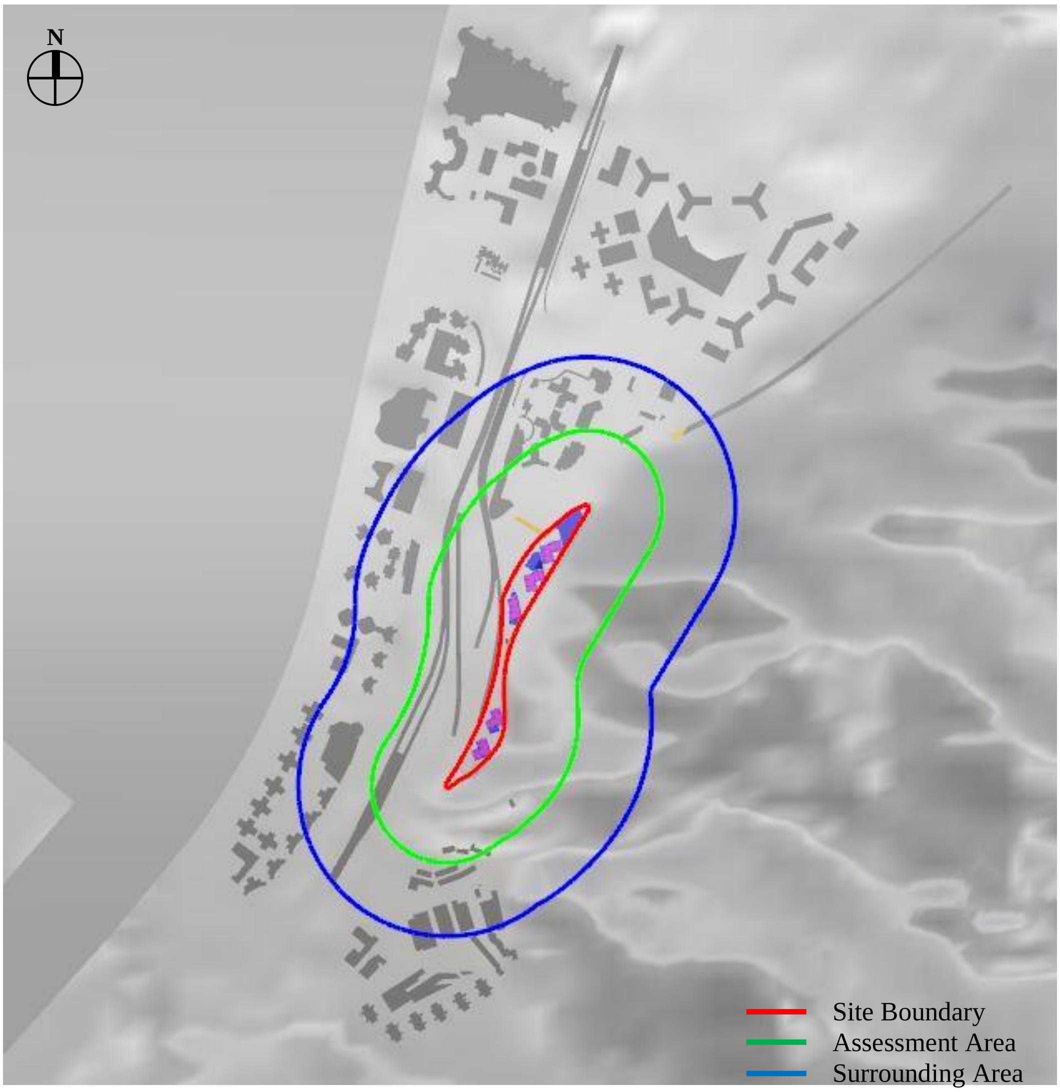


Figure 28 Site boundary, Assessment Area, and Surrounding Area

3.3 Assessment Parameter

The Velocity Ratio (VR) as proposed by the Technical Circular for AVA was employed to assess the impact of the proposed development on the surroundings. High VR implies little impact imposed by the proposed development. The calculation of VR is defined by:

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

V_∞ = wind velocity at the top of wind boundary layer (typically assumed to be around 596m above the centre of the site, or at a height where wind is unaffected by the urban roughness).

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

3.4 Test Points for Local and Site Ventilation Assessment

Monitoring test points were evenly placed at the frequently assessed area along the site boundary and within Assessment Area to determine the ventilation performance. There were three types of test points in the study, namely perimeter test point, overall test point and special test point.

3.4.1 Perimeter Test Points

Perimeter test points are the points positioned at the site boundary of the proposed development. In accordance with the Technical Circular for AVA, perimeter points were positioned at interval of about 15 to 20m alongside the site boundary. In total there were 34 perimeter test points in this study.

3.4.2 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. Owing to the spatial areas occupied by inaccessible traffic highways and flyovers on Ma On Shan Road, Sai Sha Road and Hang Tak Street within the assessment area, in total there were only 48 overall test points located in the rest of the areas for pedestrians.

3.4.3 Special Test Points

Special test points were those points evenly distributed in the open area where building occupants of the Development frequently access within the site boundary. In total there were 7 special test points in this study.

The perimeter test points (red points), overall test points (green points) and special test points (blue points) are presented in Figure 29.

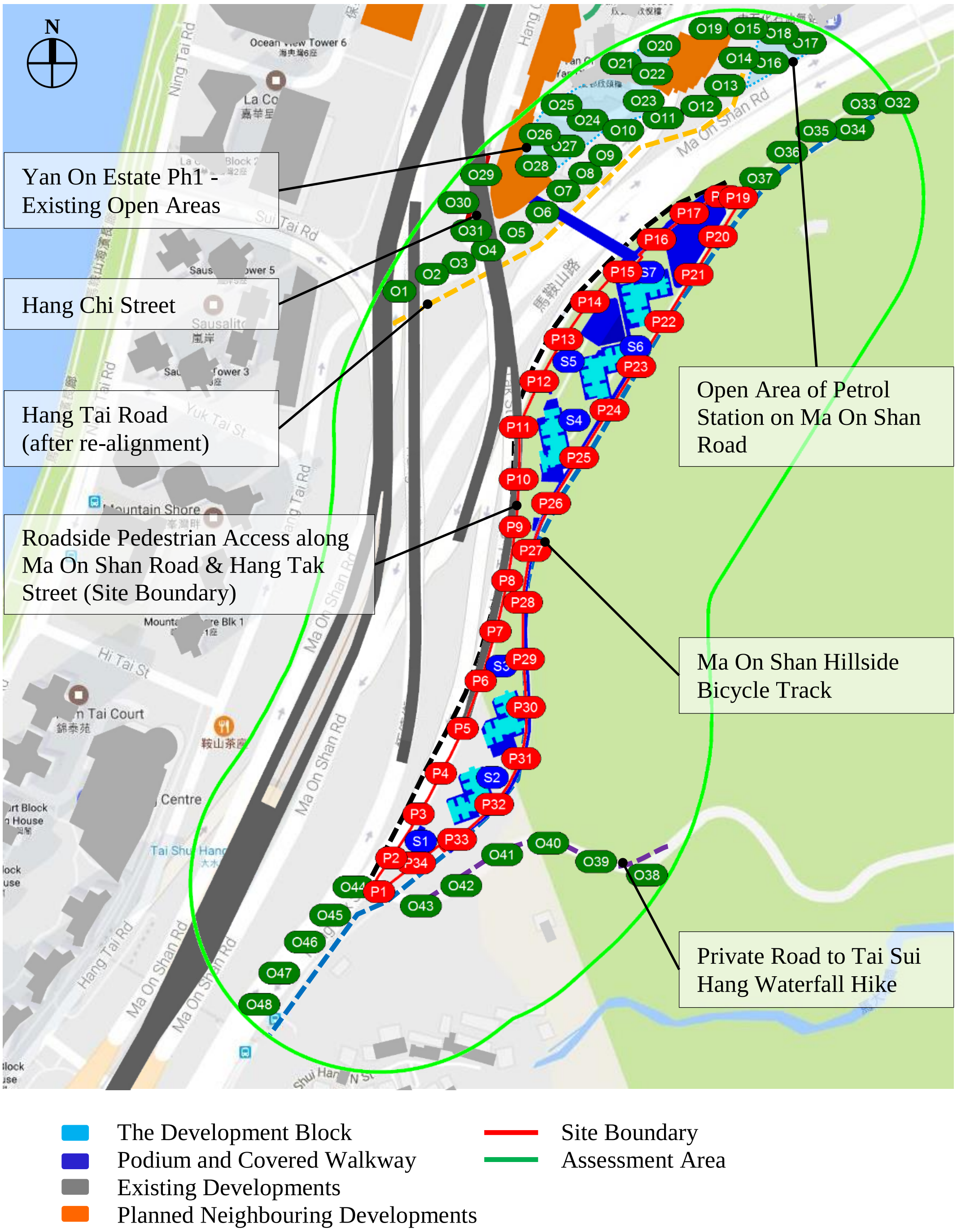


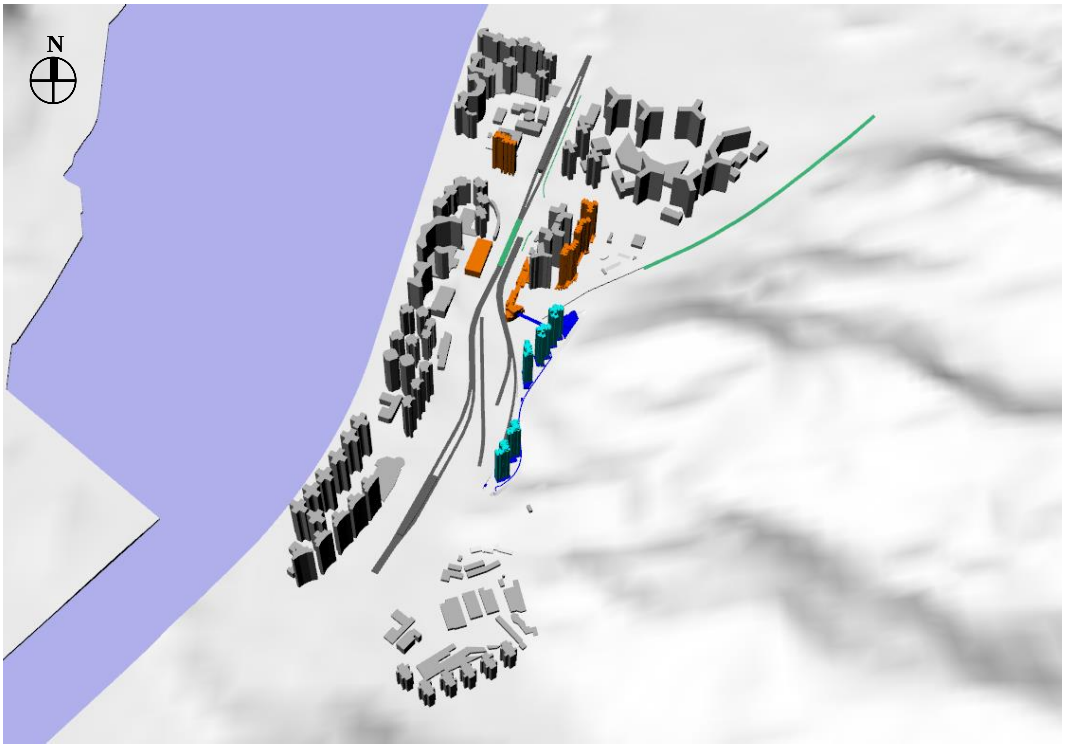
Figure 29 Perimeter and Overall Test Points and Focus Areas within the Assessment Area

3.5 Assessment Tool

Computational Fluid Dynamics (CFD) technique was utilised for this study. With the use of three-dimensional CFD method, the distribution of local airflow could be visualized in details. The velocity distribution within the flow domain, being affected by the site-specific design and the nearby topography, was simulated under the selected prevailing wind conditions.

3.5.1 CFD Tool

The surrounding buildings within Surrounding Area are included in the CFD model for the AVA Initial Study, as presented in Figure 30. The identified planned developments mentioned in Section 2.1 were already included in the model for simulation.



- The Development Block
- Podium and Covered Walkway
- Existing Developments
- Planned Neighbouring Developments
- Noise Barriers

Figure 30 CFD model for the AVA Initial Study

The size of the CFD model for this Study was approximately 3700m (L) x 2900m (W) x 3600m (H). The whole CFD domain covered the development and the surrounding buildings in a span of slightly more than 2H away from the site boundary.

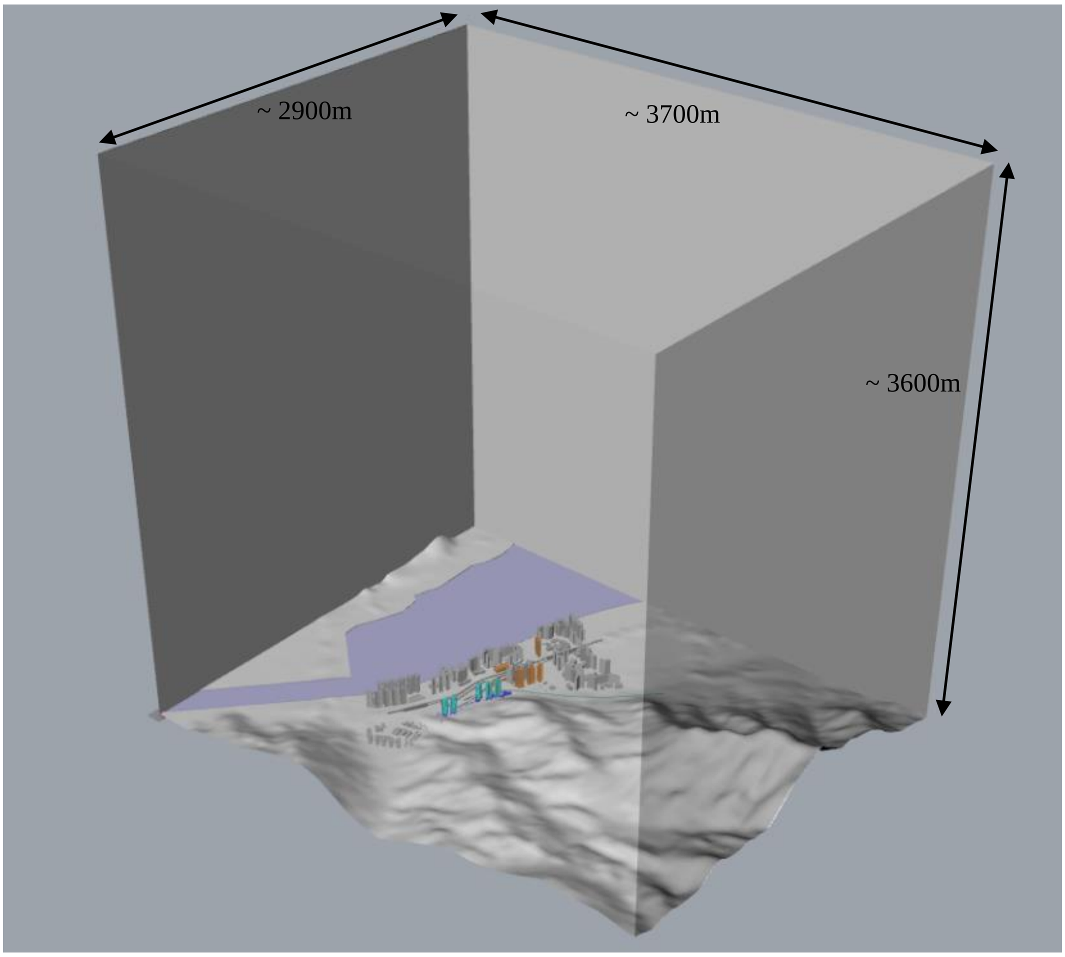


Figure 31 Domain of CFD model

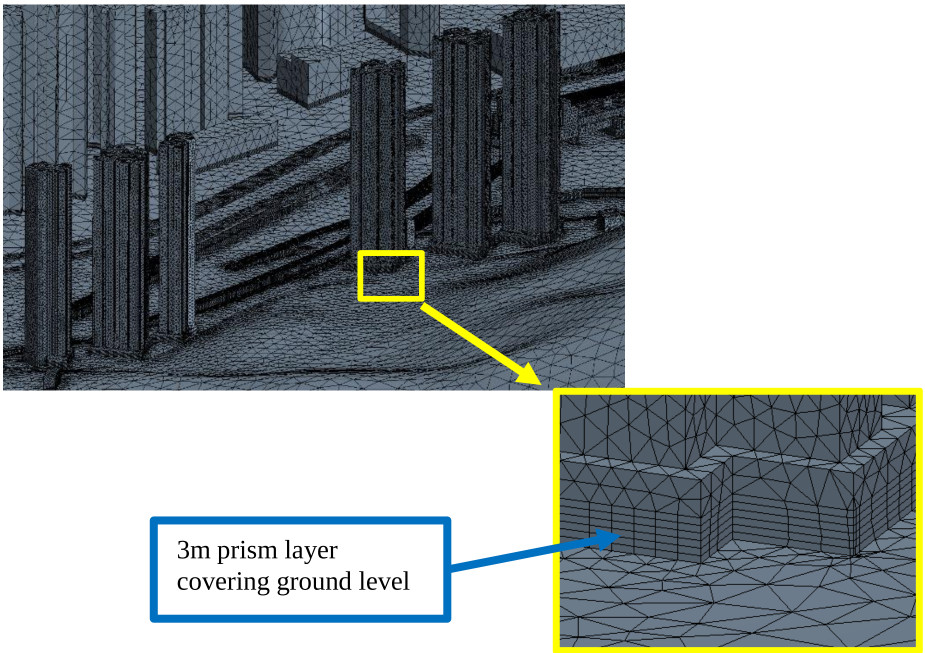


Figure 32 Meshing details of CFD model for the Baseline Scheme

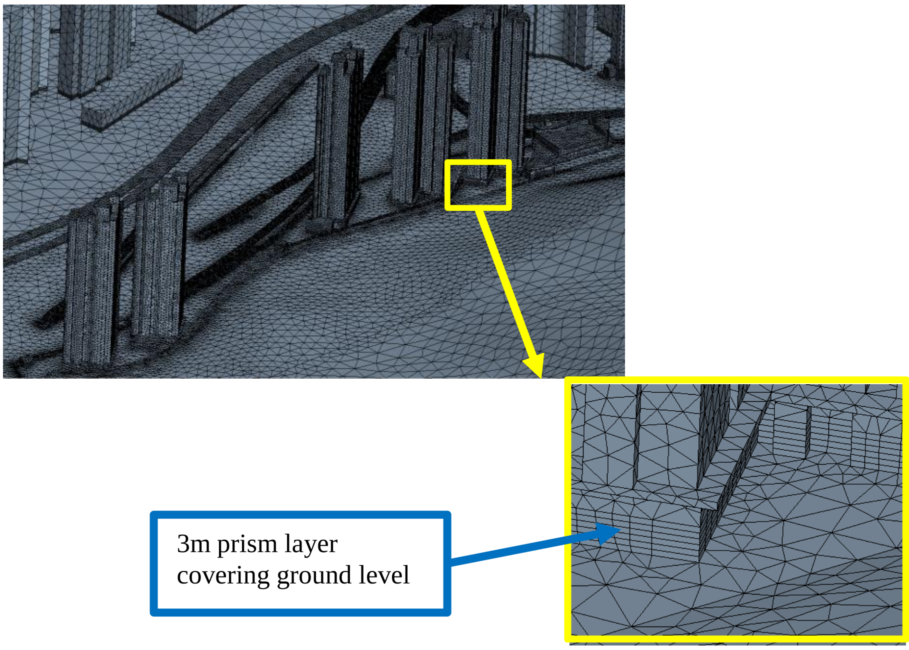


Figure 33 Meshing details of CFD model for the Proposed Scheme

3.5.2 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 therefore, may ignore wind gusts leading to a relatively poor prediction in the recirculation regions around buildings. In this simulation, realisable k- ε modelling method was applied. This technique provides more accurate representation of the levels of turbulence that can be expected in an urban environment.

3.5.3 Calculation Method

The Segregated Flow model solved the flow equations in an individual 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 differentiating scheme was applied to discretize the governing equations. The convergence criterion was set to 0.001 on mass conservation. The calculation had repeated until the solution satisfied this convergence criterion.

The prevailing wind direction as mentioned in Section 3.1.1 was set at the inlet boundary of the model with wind profiles as detailed in Section 3.1.2. The downwind boundary was set with a pressure at the atmospheric condition. The top and side boundaries were set in symmetry. In addition, to eliminate the boundary effects, the model domain was built beyond the Surrounding Area as required in the Technical Circular (refer to Figure 28).

3.5.4 Key parameters

Key parameters of the CFD model are summarized in Table 6.

Table 6 Key Parameters of the CFD model

Parameter	**Modelling Detail**
Program Tool	STAR-CCM+
Physical Model Scale	Real-scale Model, 1:1 to the real environment
Model Details	Only to include Topography, Buildings blocks, Streets/Highways, no landscape is included
Domain	3700m(L) x 2900m(W) x 3600m(H)
Assessment Area	1H from Site Boundary
Surrounding building Area	2H from Site Boundary
Grid Expansion Ratio	The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.2
Prismatic Layer	6 layer of prismatic layers and 0.5m each (i.e. total 3m above ground)
Inflow Boundary Condition	Incoming wind profile as described in Section 3.1.2
Outflow Boundary	Pressure boundary condition with dynamic pressure equal to zero
Wall Boundary Condition	Logarithmic law boundary
Turbulence Model	Realizable k-ε model
Solving Algorithms	Rhie and Chow SIMPLE for momentum equation Hybrid model for all other equations
Blockage Ratio	< 3%
Convergence Criteria	Below 1.0×10^{-4}

3.5.5 AVA Study Parameters

As specified in the Technical Circular, the indicator of ventilation performance should be the Wind Velocity Ratio (VR), defined by 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 also be derived for assessment.

Table 7 Terminology of AVA Initial Study

Terminology	**Description**
Velocity Ratio (VR)	Represents the ratio of the air velocity at the measuring position to the air velocity at the reference height.
Site spatial average velocity ratio (SVR)	*(**Red** **spots** in* Figure 29*)* Represents the average VR of all perimeter test points along the site boundary of the Development.
Local spatial average velocity ratio (LVR)	*(**Red** **&** **Green** **&** **Blue** **spots** in* Figure 29*)* Represents the average VR of all points, i.e. perimeter and overall test points within the 1H assessment area.

4 Result and Discussion

4.1 Overall Pattern of Ventilation Performance

Contour plots of average VR (annual and summer) were made at 2m above the pedestrian ground to provide an overview of ventilation performance in both studied schemes.

4.1.1 Annual Wind Condition

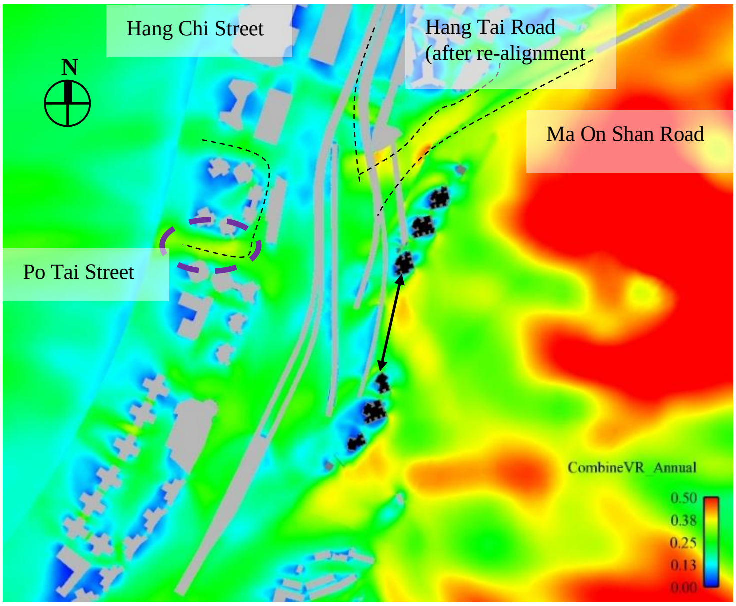


Figure 34 Contour map of annual-average VR for Baseline Scheme

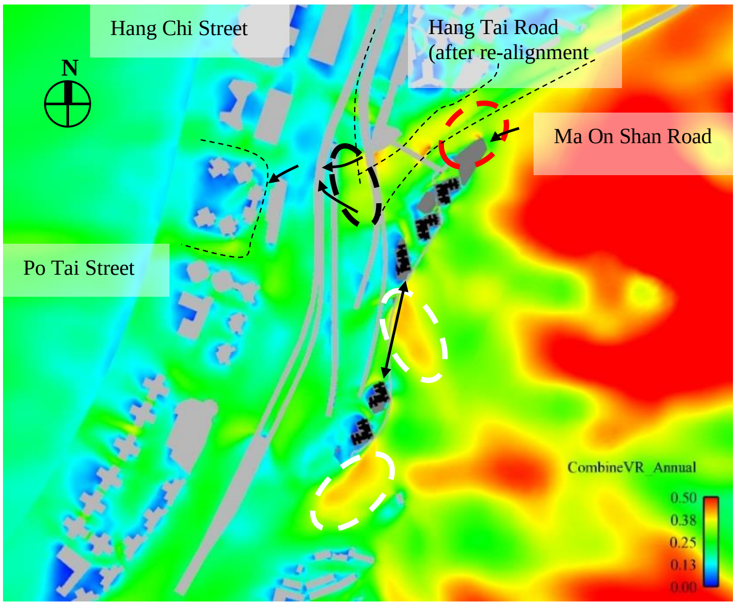


Figure 35 Contour map of annual-average VR for Proposed Scheme

The ventilation performance of the two studied schemes is generally similar to each other. A slight wind enhancement is found in the Proposed Scheme at the 140m building separation (between the north and south portions of the site) and the south end-part of the bicycle track (**white circled** area in Figure 35). They are primarily contributed by the building blocks reduction from 3 blocks to 2 blocks at the south portion of the Development. Less blockage of the building width along the NNE-SSW axis in the south portion and building disposition of Blocks allows more wind, particularly N wind, to flow through the 140m building separation and across the south portion of the site. In addition, the building dispositions of Blocks A and C in the Proposed Scheme different from those of Blocks S1 & N1 in the Baseline Scheme would favour more windward facade areas to face the ENE to ESE wind, resulting in more downdraughts to these pedestrian areas / bicycle tracks.

Likewise, another slight wind enhancement is found with the Proposed Scheme at Hang Chi Street and within the site boundary due to the building disposition changed from Block N1 in the Baseline Scheme to Block C in the Proposed Scheme. The building form is changed from a diamond shape in the Baseline Scheme to an L-shape aligned in NNW-SSE fashion in the Proposed Scheme, allowing more wind to penetrate to and from a local air path on Hang Chi Street (**black circled** area in Figure 35) in the near-field region. The drawback is that in the far-field region another local air path on Po Tai Street (**violet circled** area in Figure 34) results in lower VRs due to the changes as Block C in the Proposed Scheme would shield down the wind from the E quadrant.

With the addition of Carport-cum-Commercial and Recreational Block with empty bays at the ground level in the Proposed Scheme, the dominant wind from N to E to S half is directed to flow into that north part of the site area. Thus higher VRs are observed around the building (**red circled** area in Figure 35) due to this channelling effect.

4.1.2 Summer Wind Condition

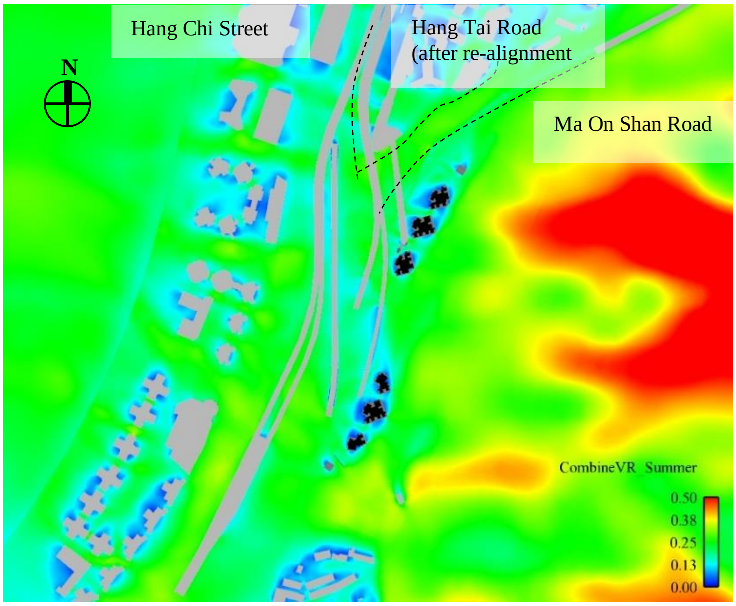


Figure 36 Contour map of summer-average VR for Baseline Scheme

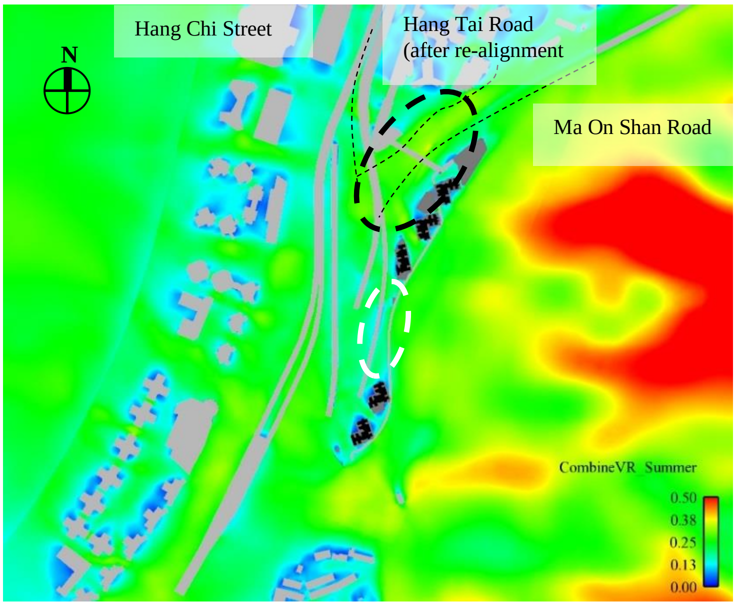


Figure 37 Contour map of summer-average VR for Proposed Scheme

The ventilation performance of the two studied schemes is generally similar to each other. Slight wind enhancement is found in the Proposed Scheme at 140m building separation (**white circle** in Figure 37) due to the reduction of building mass from 3 towers to 2 towers in the south portion of the Development. This would favour more wind flow from the south-half sector to the area.

With the building disposition changed from the diamond shape of Block N1 in the Baseline Scheme to the L-shape massing of Block C in a NNW-SSE alignment in the Proposed Scheme, the dominating summer prevailing wind from the SE to SW quadrant finds it easier to blow over Hang Chi Street and Ma On Shan Road. Thus, higher VRs are observed along the two local air path (**black circle** in Figure 37).

4.2 Directional Analysis

All 12 wind directions simulated are further analysed below with complete sets of contour and vector plots of velocity ratios (VR) in both design schemes are shown in Appendix B and Appendix C.

4.2.1 Northerly Wind

Accounting for 12.1% of the overall frequency of annual prevailing wind, the N wind enter the Development by passing through major high-rise residential buildings such as Kam On Court and Yan On Estate in the up-wind area and with about 5-meter-tall noise barriers along Ma On Shan Road which further reduce the wind penetration at the pedestrian level. Thus a relatively calm wind environment is shown on the project site.

In the north part of the site, there are two more facilities added to the Proposed Scheme, 1-story Carport in between Block D and Block E and 3-story Commercial and Recreational Block at the north end of the site, rather than a 1-story Refuge Collection Point at the north-east end of Baseline Scheme.

With the Proposed Scheme, the incoming wind from Ma On Shan Road is captured and downwashed by the NW-facing façades Blocks D & E. Particularly, the existence of a 1-story-tall Carport shields the downdraught from the ground level and diverts it to mix with the upward wind flowed from the noise barriers on Ma On Shan Road. This effect create a wake-zone in a local area with relatively low VR at the pedestrian level of Ma On Shan Road near the Carport position (**black circle** in Figure 39). On the other hand with the Baseline Scheme, the windward facades of Blocks N2 and N3 are able to bring down the downdraughts to the ground level of the same local area without obstruction (**black arrows** in Figure 38 Contour map of average VR for Baseline Scheme).

It is observed that larger building separations between three blocks in the north portion are arranged in the Proposed Scheme rather than in the Baseline Scheme. In addition, a covered walkway located at the building separation before Block N1 and N2 create more blockage effect in the Baseline Scheme. The N wind is split by Block D in the Proposed Scheme and penetrates into the site through the building separations on either side (**black arrows** in Figure 39) and then the hillside bicycle track more easily than that with the Baseline Scheme where the elevator building linking to the footbridge deflects some of the wind there up to a higher altitude (Figure 40 and Figure 41).

In the south part, building blocks reduce from 3 blocks in the Baseline Scheme (Blocks S1, S2 & S3) to 2 blocks in the Proposed Scheme (Blocks A & B). Block B in the Proposed Scheme would bring down more downdraught to the pedestrian ground with its wider windward facades than Block S3 (**red arrows** in Figure 38 and Figure 39).

The incoming wind from North direction which mainly comes along from Sai Sha Road passes through the site with less wind blockage. The combined effect of the long-stretched built form of Block C and the presence of a minute building (refuse-collecting point) located within the 140m building separation in the Proposed Scheme narrows the aperture of airflow through the separation, resulting in less windy environment in the adjacent portion of bicycle track compared to the case with Baseline Scheme (**white box** in Figure 38).

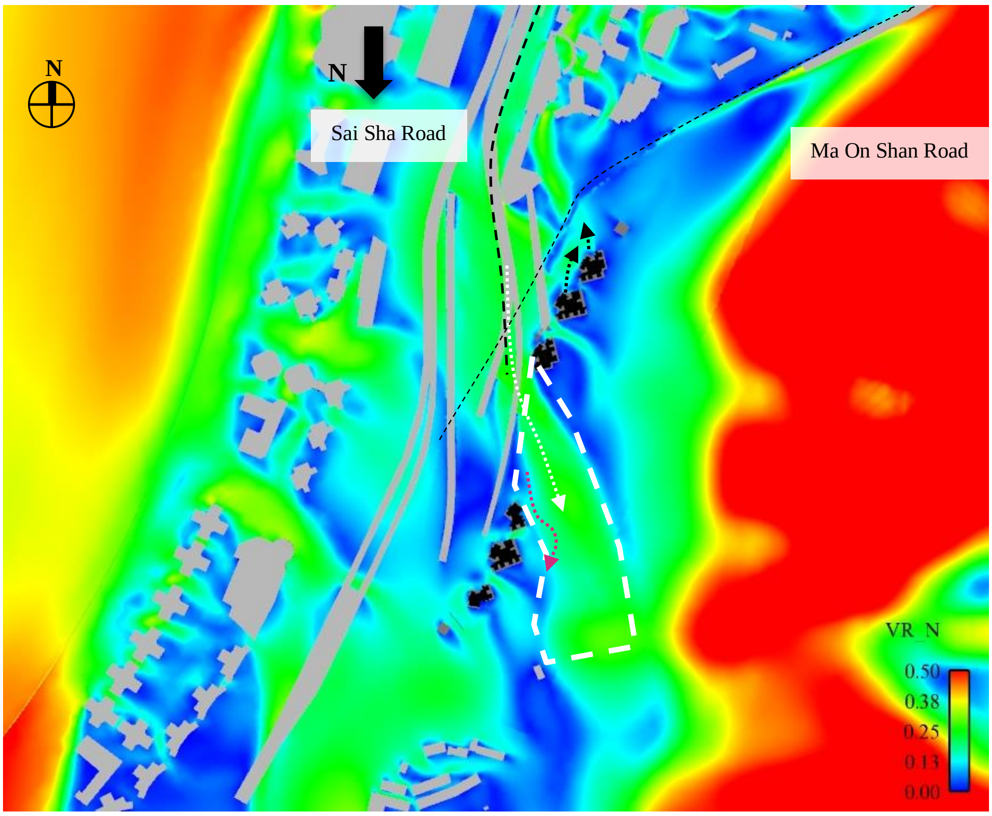


Figure 38 Contour map of average VR for Baseline Scheme (N wind)

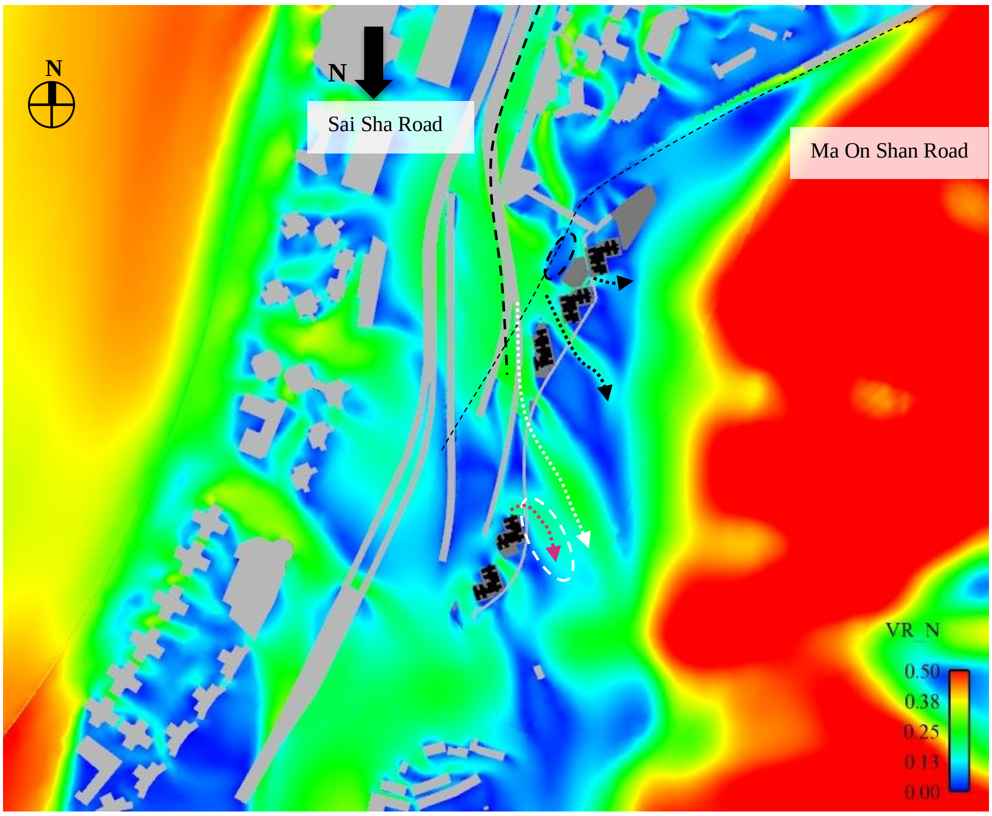


Figure 39 Contour map of average VR for Proposed Scheme (N wind)

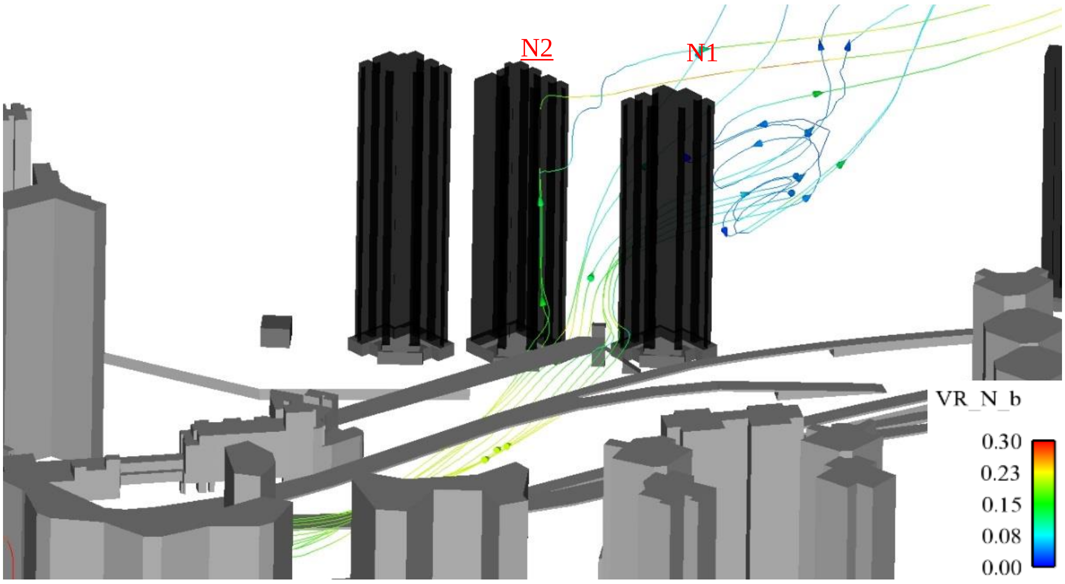


Figure 40 Streamline plot with Baseline Scheme (N wind)

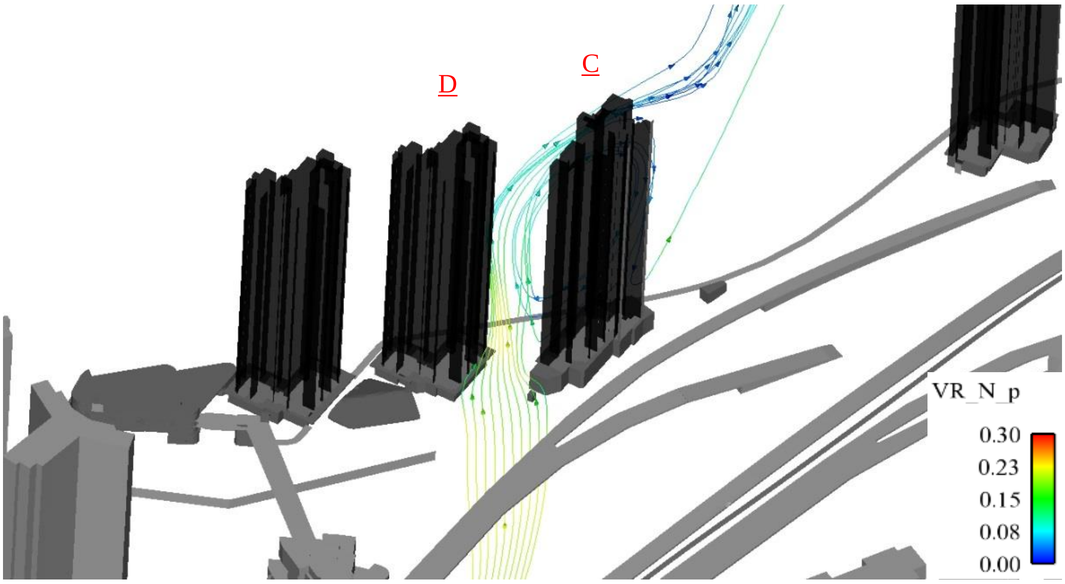


Figure 41 Streamline plot with Proposed Scheme (N wind)

4.2.2 North-north-easterly Wind

Accounting 8.2% of the overall frequency of annual prevailing wind, the NNE wind enters the Project Site through Sai Sha Road as well as from the mountain range of Ma On Shan and Ma On Shan Road along with the noise barriers.

The incoming wind from Ma On Shan Road firstly encounter the 3-story Commercial and Recreational Blocks in the Proposed Scheme or 1-story Refuge Collection Point in the Baseline Scheme. Due to higher and larger building mass of Commercial and Recreational Blocks in the Proposed Scheme, more wind is captured and downwashed to the ground level around the adjacent segment of the noise barrier on Ma On Shan Road, leading to slightly higher VRs in the region (**white box** in Figure 43). Since the Commercial and Recreational Blocks are made permeable at the ground floor level on the NE, SE and SW sides to facilitate the vehicular access, the incoming wind from Ma On Shan Road can slightly more easily penetrate into the site area (**black arrow** in Figure 43).

As the wind flows down to Block C in the Proposed Scheme, the rearranged building orientation of the tower would create a larger wind shadow on the lee-side of the Development (**black circle** in Figure 43).

It is also because of the orientation of Block C and less blocks in the south portion in the Proposed Scheme, slightly more wind from Ma On Shan Country Park would preferentially reach Tai Shui Hang Village with higher VRs there, in the south part of Hang Tak Street and in the east of Tai Shui Hang MTR Station (**brown arrows and box** in Figure 43). On the other hand with the Baseline Scheme, more wind flows across the 140m building separation to reach the middle part of Hang Tak Street and the north of the MTR station (**brown arrows and box** in Figure 42).

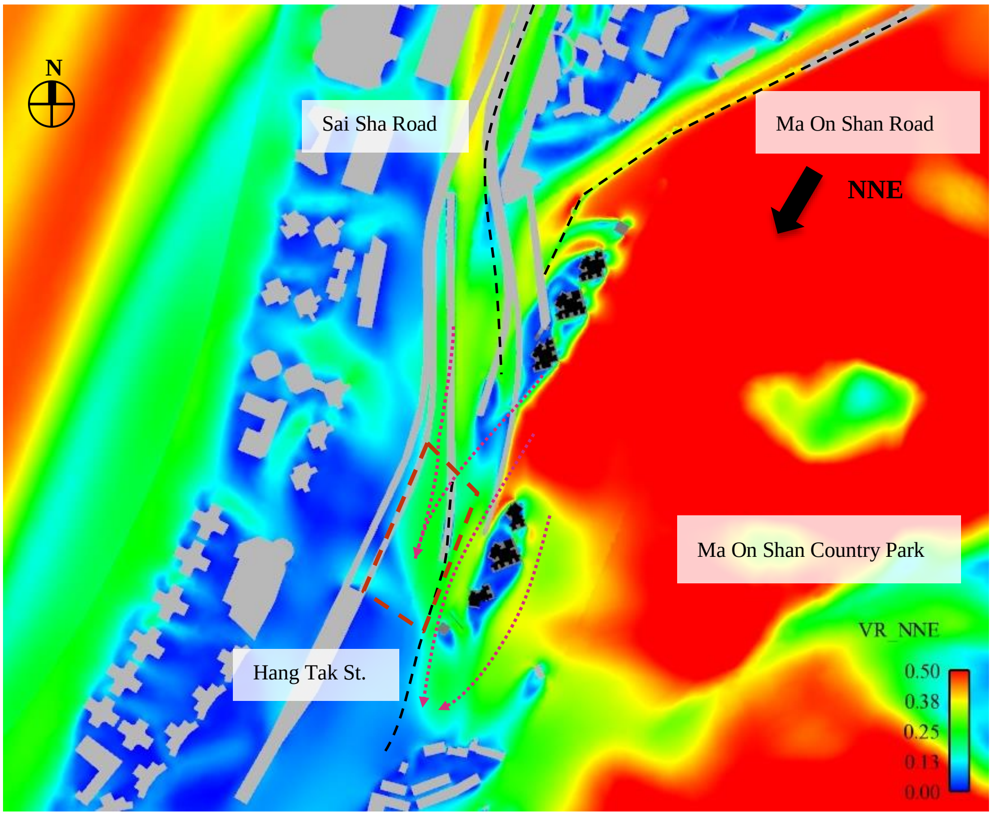


Figure 42 Contour map of average VR for Baseline Scheme (NNE wind)

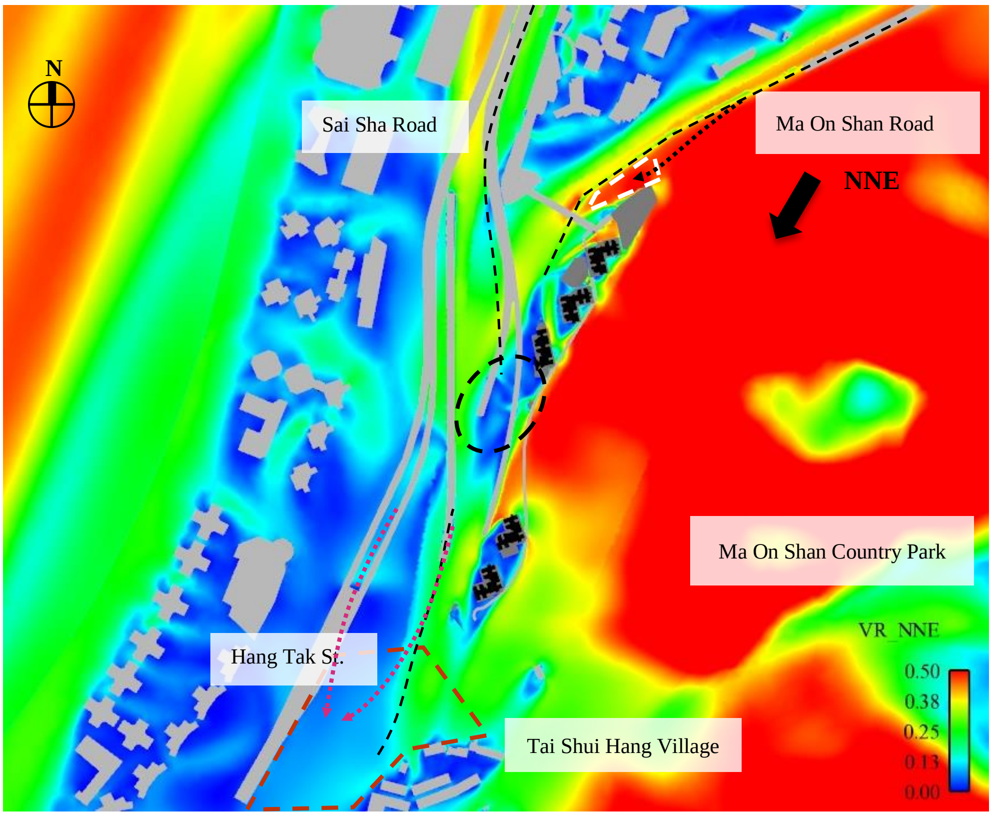


Figure 43 Contour map of average VR for Proposed Scheme (NNE wind)

4.2.3 North-easterly Wind

Accounting 8.7% of the overall frequency of annual prevailing wind, the NNE wind reaches the Project Site through Ma On Shan Road with a long stretch of 5-meter-tall noise barriers and down from Ma On Shan Country Park.

In the upwind region, the 3-story Commercial and Recreational Blocks in the Proposed Scheme splits the incoming wind and then captures the downdraught along the noise barriers on Ma On Shan Road which shows in a slightly higher VR region at the north-west corner of the block **(black box** in Figure 45).

For the wind blowing along the site boundary to Block C in the Proposed Scheme, the long-span building facade creates a little more downdraught to the windward pedestrian ground between Blocks C and D (**black arrow** in Figure 45).

In the south portion, with the reduction of building blocks in the Proposed Scheme, less wind shadow is found in a part of Hang Tak Street on the lee-side of the Development (**violet box** in Figure 45). Combining it with the effect of Block C's building orientation, more NE wind would utilise the 140m building separation to blow across the main traffic roads and Tai Shui Hang MTR Station to reach Kam Tai Court (**white box**), resulting in more downdraughts captured by the latter development to the local pedestrian level (**brown arrows**).

With the Baseline Scheme, slight more NE wind hits on the facades of Block S2 and comes down as a downdraught. Then it merges with the other airstreams coming down from Ma On Shan Country Park to blow further over the south of the MTR station and the front side of Kam On Court, resulting in higher VRs there instead (**white box** in Figure 44).

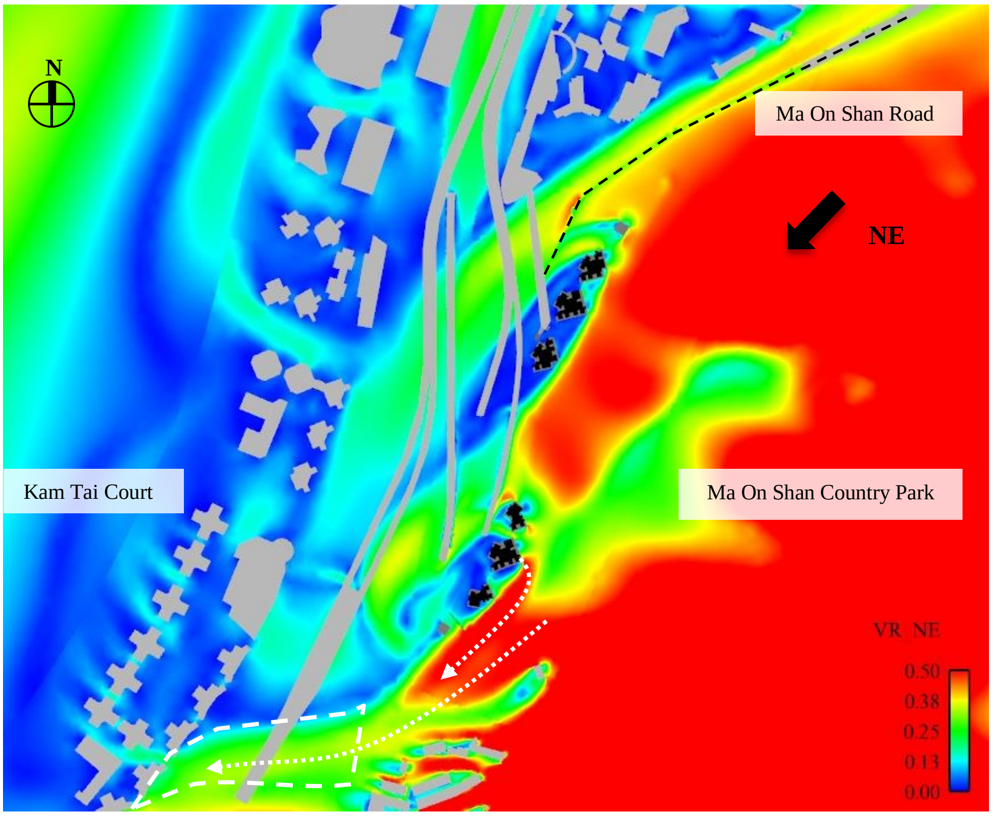


Figure 44 Contour map of average VR for Baseline Scheme (NE wind)

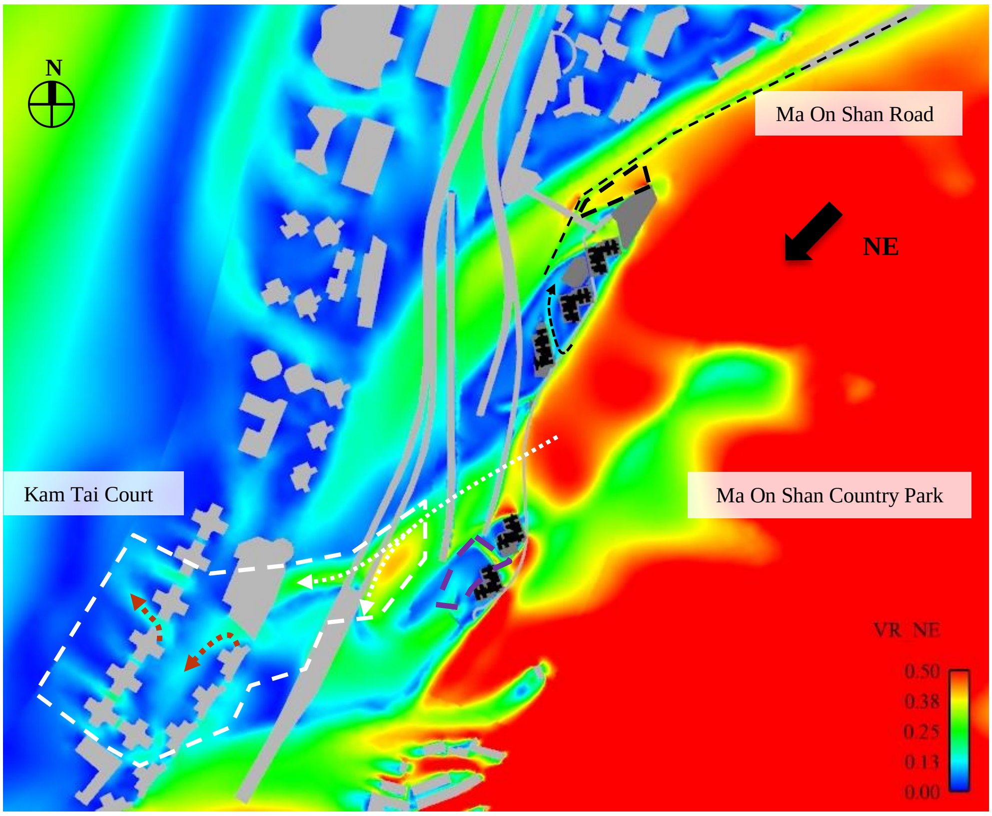


Figure 45 Contour map of average VR for Proposed Scheme (NE wind)

4.2.4 East-north-easterly Wind

Representing the second most frequent annual wind condition (15.1%) and summer wind condition (13.8%), the ENE wind comes from the hilly terrain of Ma On Shan Country Park and along the local air path of Ma On Shan Road to reach the site.

For two more podium structures added to the north portion in the Proposed Scheme which makes a difference in the wind pattern flowing from Ma On Shan Road. Firstly, the wind encounter the Commercial and Recreational Blocks and is captured down by the northwest façade to the nearby region of Ma On Shan Road which result in slightly higher VRs (**white circle** in Figure 47). Some of the wind utilises the G/F empty bays to reach the inner site area.

On the other hand without the podium structures in the Baseline Scheme, more ENE airstreams are able to cross the main traffic roads to reach Sausalito and come down as downdraughts to Sui Tai Road (**black box and arrows** in Figure 46).

For the wind downwashed by Block D in the Proposed Scheme, the roof of the 1-story Carport serves as a platform deflecting the downdraught. As a result, comparatively lower VRs near Ma On Shan Road adjacent to the Carport (**white arrows** in Figure 47). Meanwhile, in a way similar to the NE wind condition, Block C in the Proposed Scheme would present a larger wake-zone to a local area of Hang Tak Street and Ma On Shan Road on its leeside (**white box**).

However, the present orientation of Block C in the Proposed Scheme would deflect some of the high-altitude ENE wind that passes through the 140m building separation to the north Kam Tai Court, favouring more downdraughts to Hi Tai Street as a result (**brown arrows and box** in in Figure 47).

In the south portion of the Development, the difference in the number of blocks between the Proposed and Baseline Schemes causes two places with variations of airflow. With the Proposed Scheme, slightly higher VRs are observed in a part of Ma On Shan Road near the north of Tai Shui Hang MTR Station (**violet arrow and box** in Figure 47) due to the building disposition of Blocks A & B slightly more favourable for the passage of wind through their own building separation and their downdraughts. Further in the downstream areas though, some of the wind at the pedestrian level on Hang Tak Street next to Tai Shui Hang Village and on the front side of Kam Tai Court (**pink boxes** in Figure 46 and Figure 47) varies in distribution due to the difference of these blocks in the south portion.

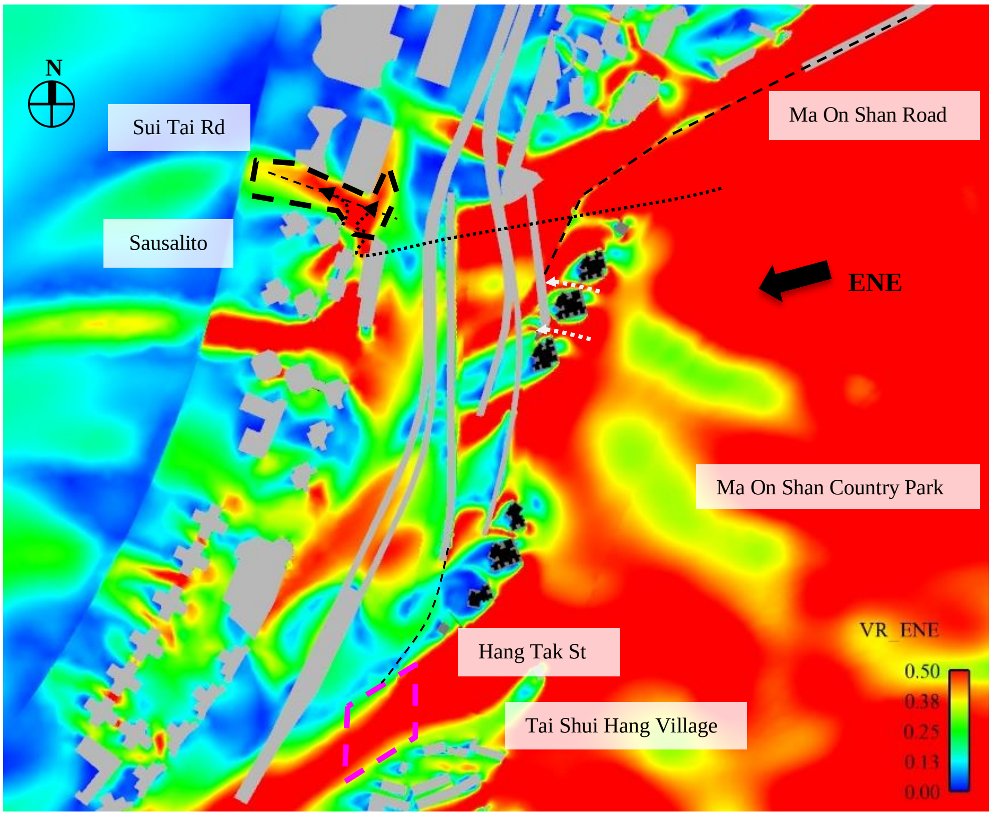


Figure 46 Contour map of average VR for Baseline Scheme (ENE wind)

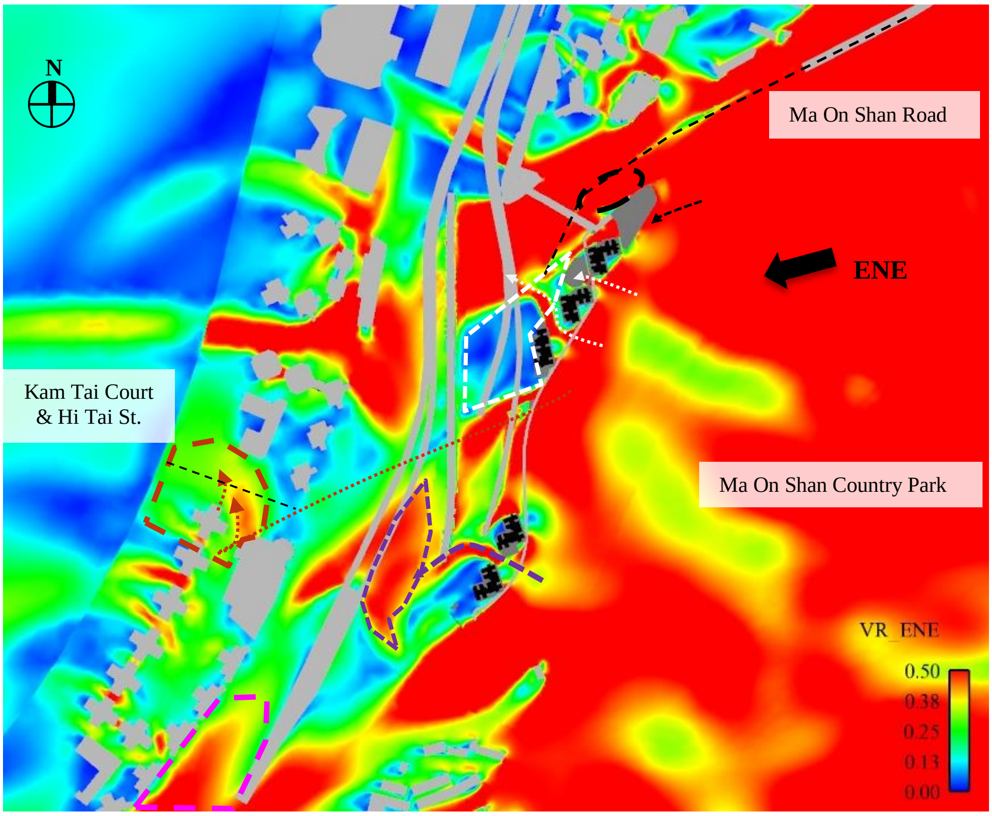


Figure 47 Contour map of average VR for Proposed Scheme (ENE wind)

4.2.5 Easterly Wind

Representing the most frequent annual wind condition (23.4%) and the second most frequent summer wind condition (13.8%), the ENE wind plays a key role in distinguishing the wind performance of the two design schemes.

Up-wind mainly comes from the hilly terrain of Ma On Shan Country Park and the local air path of Ma On Shan Road to reach the site.

For two more podium structures in the Proposed Scheme, which makes a difference in the wind pattern flowing through the north portion of the site, firstly, the wind encounters the Commercial and Recreational Block and is directed to the nearby existing open areas of Yan On Estate Phase 1 (**white circle and arrow** in Figure 49). Secondly, the roof top of the Carport serves as a platform to divert the downdraughts from Blocks D and E in the Proposed Scheme to reach the road intersection of Ma On Shan Road, Hang Tai Road and Sai Sha Road (**black circle and arrow**).

Again similar to the phenomenon in NE and ENE wind conditions, the long-stretch of Block C's building facade in the Proposed Scheme brings down more downdraught on the windward side to the ground of the said road intersection as well as a part of the hillside bicycle track adjacent to the 140m building separation. Yet, a larger window shadow is formed on its leeside around the flyover of Hang Tak Street (**brown dotted enclosures and arrows** in Figure 49).

On the other hand, due to the building mass changed from Block N1 in the Baseline Scheme to Block C in the Proposed Scheme, the slight shift in the location of 140m building separation would cause a certain differences of wind distribution on the far side of the downwind areas under this wind condition. With the Baseline Scheme, Yuk Tai Street and Hi Tai Street benefit from slightly more downdraughts brought down by the front towers of Mountain Shore (**black circles and arrows** in Figure 48).

The south part of Hang Tak Street (at the south entrance of the project site) and the front side of Kam Tai Court result in slightly higher VRs from the reduced number of building blocks in the south portion of the site with the Proposed Scheme as Block A captures more downdraught to the pedestrian level and extend the airflow to these downwind areas along with other airstreams in Ma On Shan Road and Hang Tak Street (**violet circles and arrows** in Figure 49).

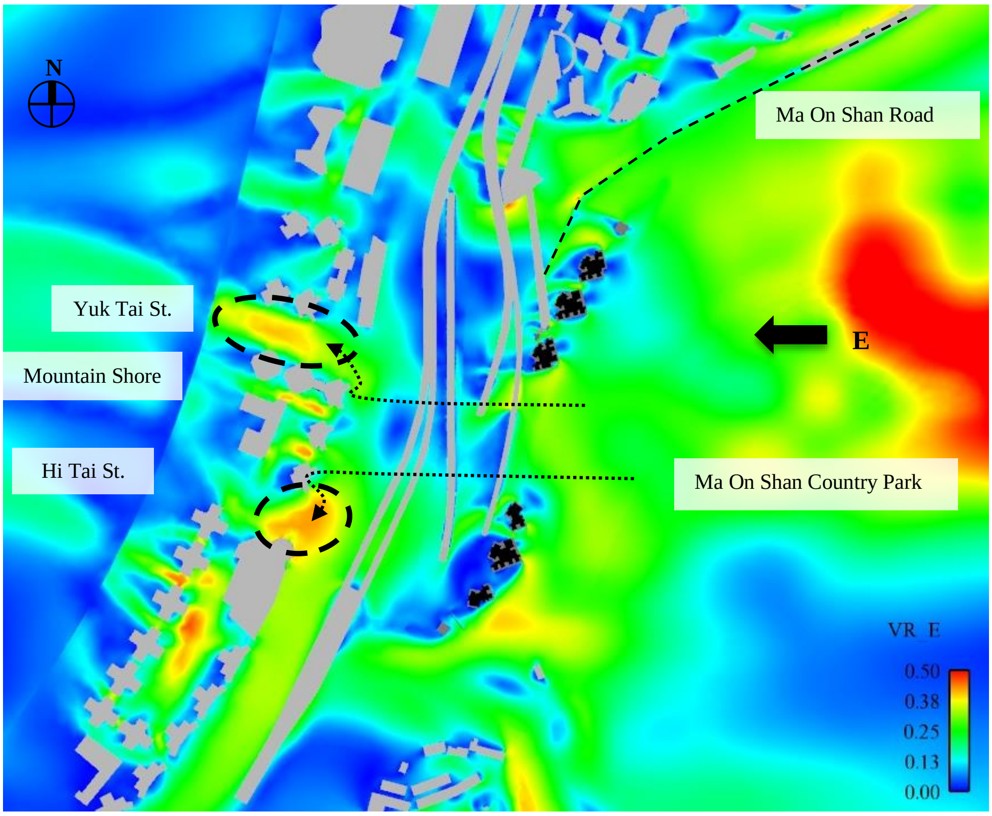


Figure 48 Contour map of average VR for Baseline Scheme (E wind)

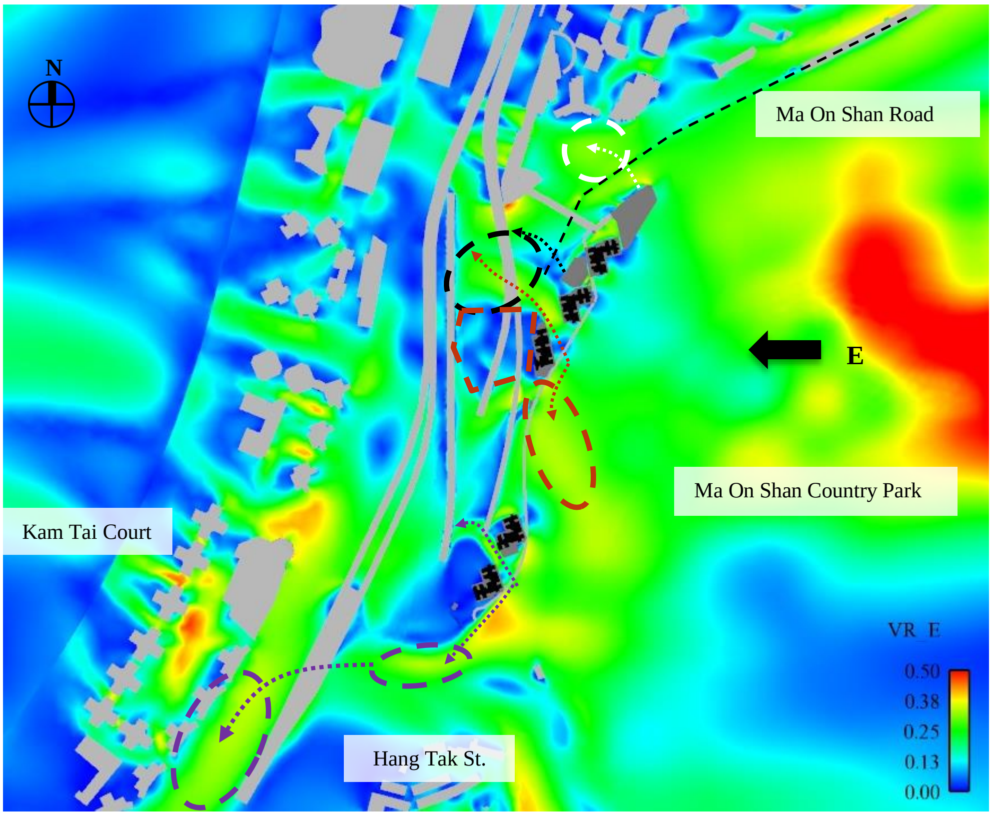


Figure 49 Contour map of average VR for Proposed Scheme (E wind)

4.2.6 East-south-easterly

Representing 4.8% and 7.9% of overall frequency of annual and summer prevailing wind, the ESE wind shows similar wind pattern in both schemes.

Under this wind condition, the local wind direction to reach the south portion of the site is the ESE wind from the south of Ma On Shan Country Park at a low altitude whereas the one to reach the north portion is in fact the ENE. Since the ridge line of Ma On Shan Country Park stretch a lot longer than the extent of the project site, the local wind finds it easier to come in the ENE fashion along Ma On Shan Road with the noise barriers rather than to blow downhill from the high mountains located next to the site (red arrow in Figure 50 and Figure 51).

Both design schemes exhibits similar wind performance except two immediate downstream places.

The reduced number of blocks in the south portion with the Proposed Scheme minimises the overall frontage and therefore favours more penetration of incoming ESE wind into the lee-side of the Development (branched flyovers of Hang Tak Street as shown **black box and arrows** in Figure 50 and Figure 51). On the other half of the site, which is more influenced by the local ENE incoming wind, Block C of the Proposed Scheme would still cast a local wind shadow on its lee-side (Hang Tak Street as **boxed in black** in Figure 51) due to a reason similar to the ENE wind condition.

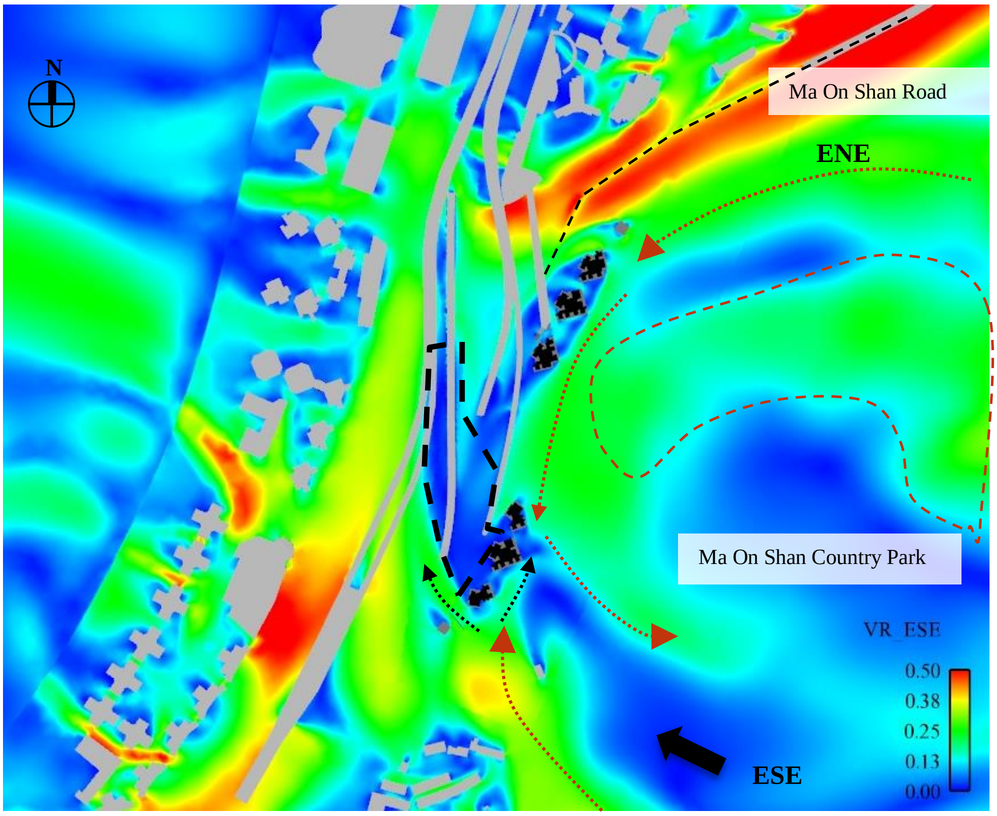


Figure 50 Contour map of average VR for Baseline Scheme (ESE wind)

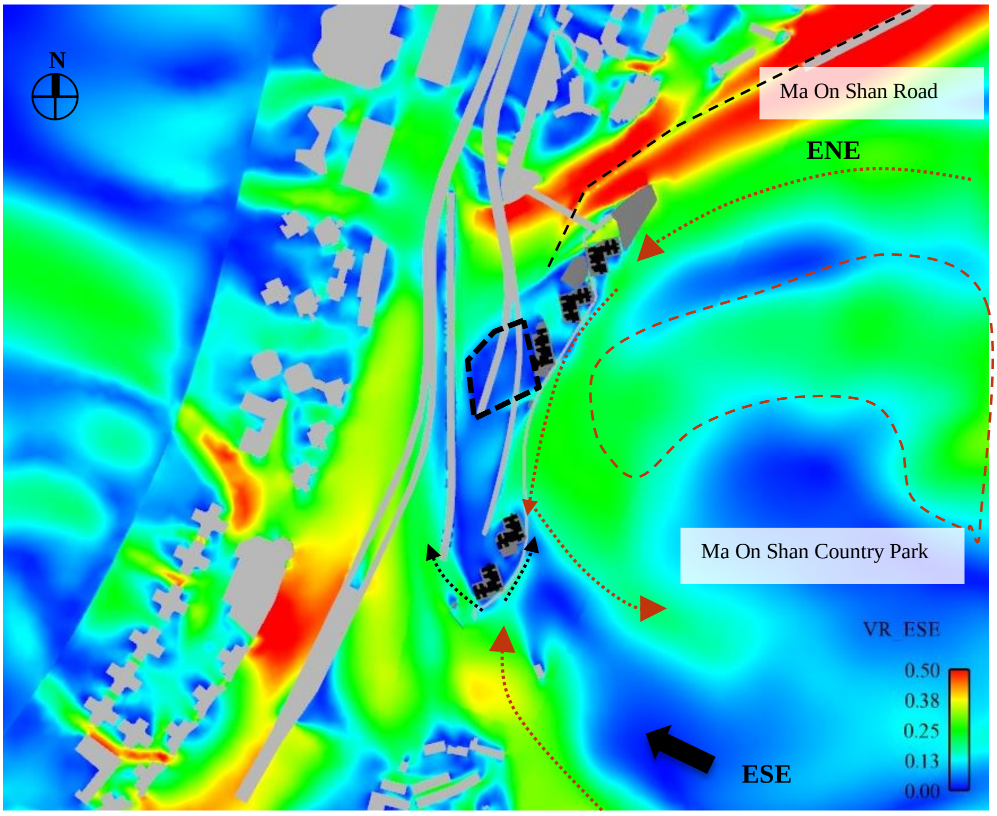


Figure 51 Contour map of average VR for Proposed Scheme (ESE wind)

4.2.7 South-easterly Wind

Representing 6.5% of overall frequency of summer prevailing wind, SE wind enters the site down from the hilly terrain of the Ma On Shan Country Park.

For the south portion of the Development, due to the slightly more building setback from the south site boundary and the building disposition of Block A in the Proposed Scheme, SE wind is more favourable to get diverted to the south end of the site and further crosses to the other side of Ma On Shan Road near Mountain Shore (**black box and arrows** in Figure 53).

For the north portion, Block C and Block N1 has significant building form difference. It is observed that more wind is downwahsed by Block N1 in the Baseline Scheme to the south front of the building (**violet box** in Figure 52) due to a larger windward façade with N1 than that with Block C. On the other hand, Block C has longer SSE-aligned façade which would divert more wind to penetrate into the intersection of Ma On Shan Road, Hang Tai Road and Hang Tak Street in the Proposed Scheme (**violet boxes and arrows** in Figure 53). However, there is still a wake-zone behind Block C.

Meanwhile, the original location of 140m building separation and the less building frontage of Block N1 in the Baseline Scheme favour more SE wind to blow to the other side of Ma On Shan Road and come down as downdraughts to Sui Tai Road and Yuk Tai Street after colliding with the windward facades of Sausalito (**black boxes and arrows** in Figure 53).

At the north end with the Proposed Scheme, the existence of the Commercial and Recreational Block form together with the V-shape building façade of Blocks D and E as a larger building blockage to the SE wind. The wind would instead bend to reach the open area of Yan On Estate near the junction of Hang Tai Road and Ma On Shan Road (**pink circle and arrows** in Figure 52 and Figure 53). As a result slightly less wind comes down from Yan On Estate as a downdraught with the Proposed Scheme.

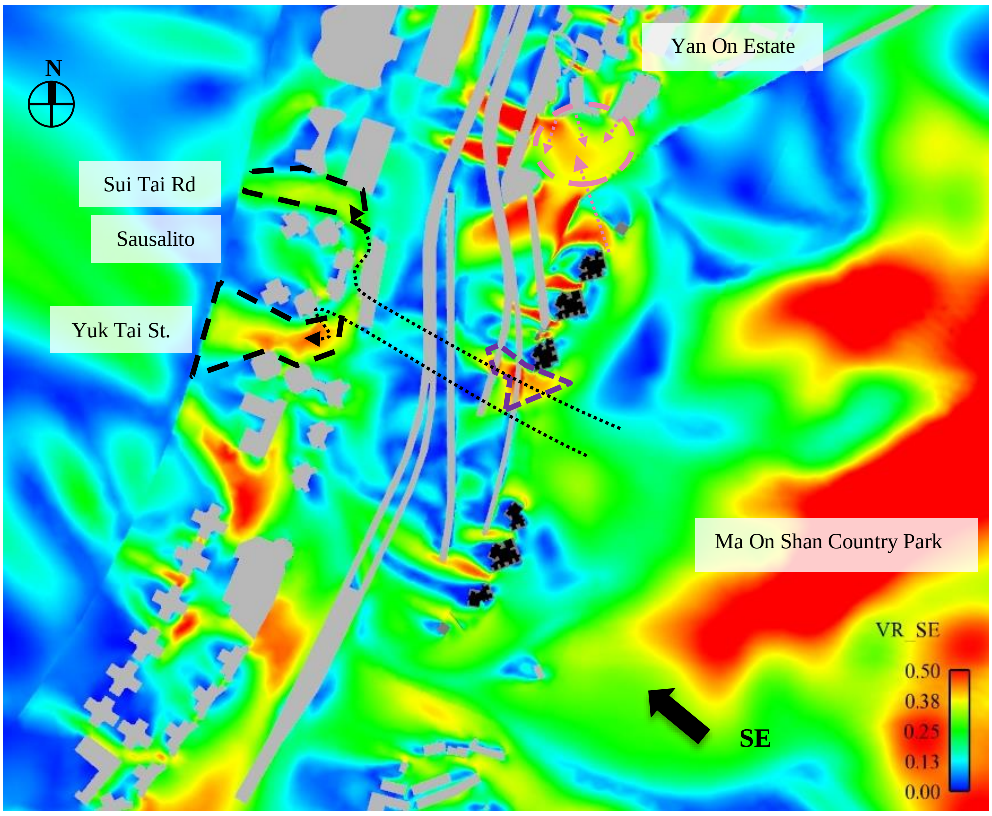


Figure 52 Contour map of average VR for Baseline Scheme (SE wind)

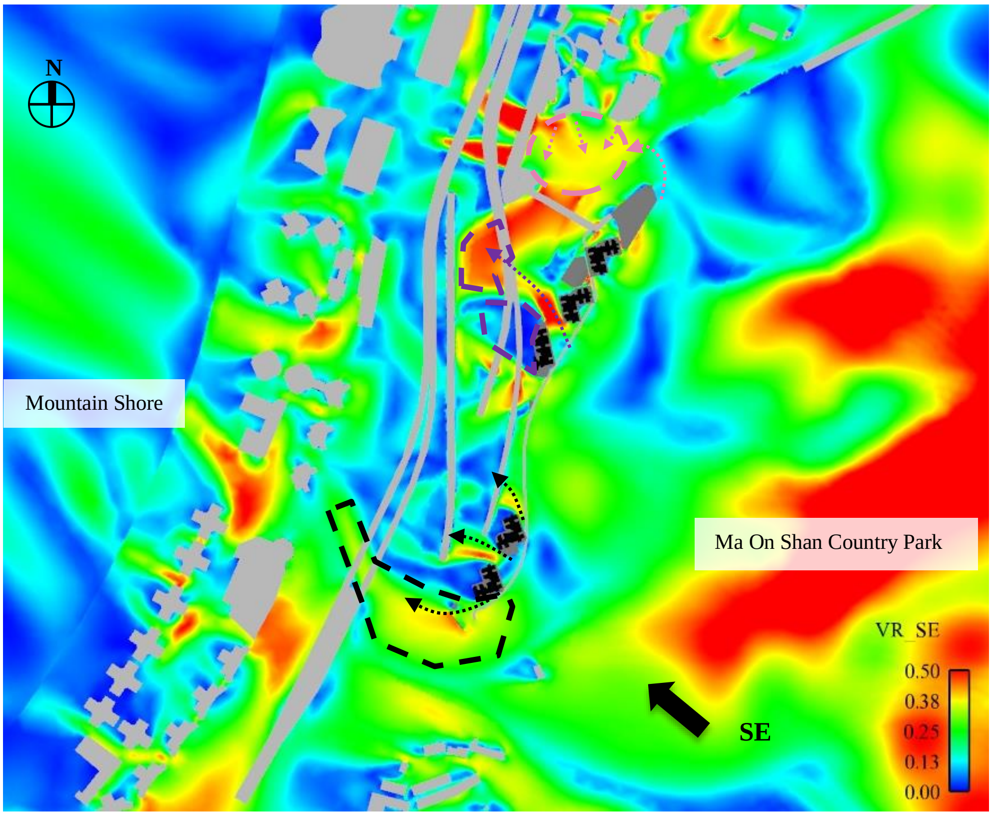


Figure 53 Contour map of average VR for Proposed Scheme (SE wind)

4.2.8 Southerly Wind

Representing 4.3 % of overall frequency of annual prevailing wind and the third most frequent summer wind condition (10%), the S wind comes from the lower residential building clusters such as Chevalier Garden and Tai Shui Hang Village.

The incoming wind first encounters the block at the south end of the site. Since Block A is positioned with a slightly more setback from the south end than Block S1 and Block B has more windward facade area than Block S2/S3, slightly more wind blows over Hang Tak Street and Ma On Shan Road or comes down as a downdraught to a part of the bicycle track next to the 140m building separation with the Proposed Scheme (**black arrows** in Figure 55).

With the building disposition of Block C in the Proposed Scheme, the S wind is streamlined more easily on either side of the building and through the building separation between Blocks C and D to reach the front end Hang Chi Street and Sai Sha Road. As a result, better VR values observed at the region near Hang Chi Street (**violet arrows** in Figure 55).

Similar to the SSE wind condition at the north end of the site, the Carport and Commercial and Recreational Block together with Blocks D and E in the Proposed Scheme, a larger wind blockage is formed (**pink arrows and circle** in Figure 54 and Figure 55). Therefore, less amount of S wind can reach the open area of Yan On Estate (**white circle** in Figure 55).

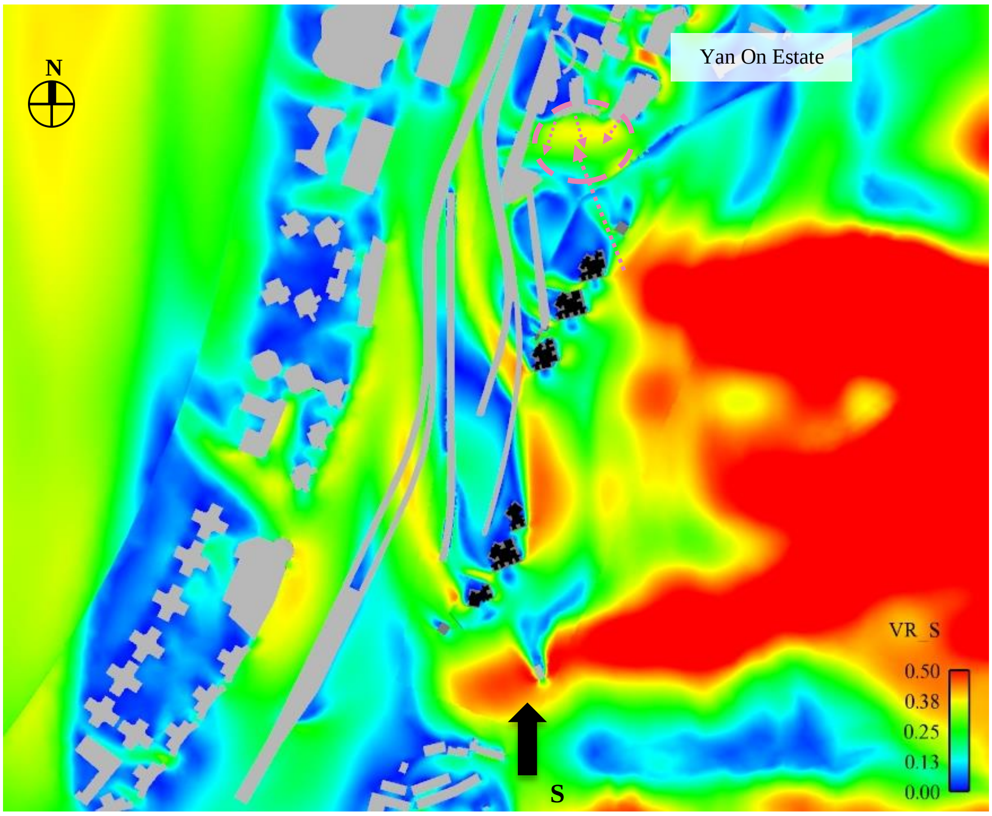


Figure 54 Contour map of average VR for Baseline Scheme (S wind)

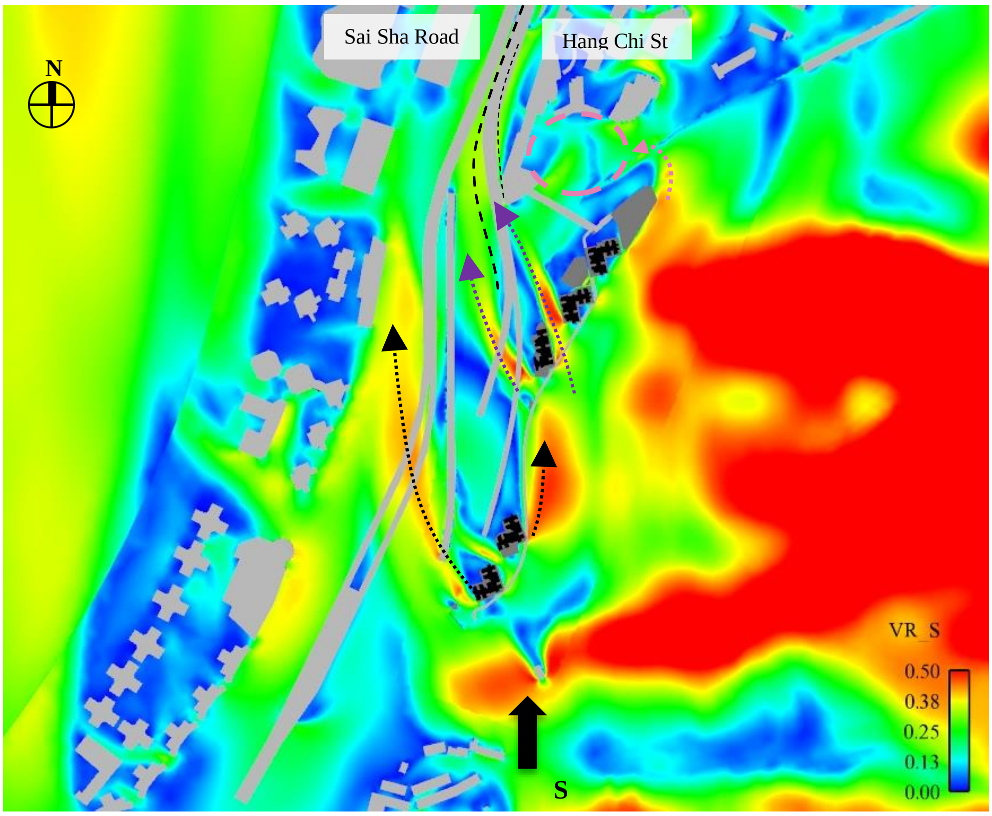


Figure 55 Contour map of average VR for Proposed Scheme (S wind)

4.2.9 South-south-westerly Wind & South-westerly Wind

Representing 8.2% of overall frequency of summer prevailing wind, the SSW wind travel along Ma On Shan Road to the south portion of the site in SSW direction and down the hilly terrain of Ma On Shan Country Park to reach the north portion at the site in a SSE fashion (**black arrow** in Figure 56 and Figure 57).

Due to the building setback of Block A in the Proposed Scheme from the south boundary, the incoming SSW wind experiences less building blockage and then blows more to the ground underneath the flyovers of Ma On Shan Road and Hang Tak Street (**pink arrow** in Figure 57).

The building orientation of Block C in the Proposed Scheme actually favours the downhill wind of Ma On Shan Country Park from SSE direction to penetrate into the intersection of Ma On Shan Road and Hang Tai Road (**violet arrow and box** in Figure 57) after merging with another major flow from the SSW direction at the front end of Ma On Shan Road.

Rather, the location and the disposition of Block N1 in the Baseline Scheme would divert the SSE downhill wind towards the far side of Sai Sha Road to combine with the major SSW stream coming from the front end of Ma On Shan Road (**violet arrow and box** in Figure 56).

Representing the most frequent prevailing wind in summer, the SW wind enters the Development along Ma On Shan Road and through the 140m building separation from the hilly terrain in a way similar to the SSW prevailing wind condition.

Resulting from very similar effects of the setback in the south portion and the disposition of Block C in the Proposed Scheme, the same downwind areas of Ma On Shan Road, Hang Tak Street and Hang Tai Road have higher VRs than those with the Baseline Scheme (**black and pink arrows** in Figure 61). Figure 62 and Figure 63 demonstrate the airflow patterns around the north portion of the site with the two design schemes.

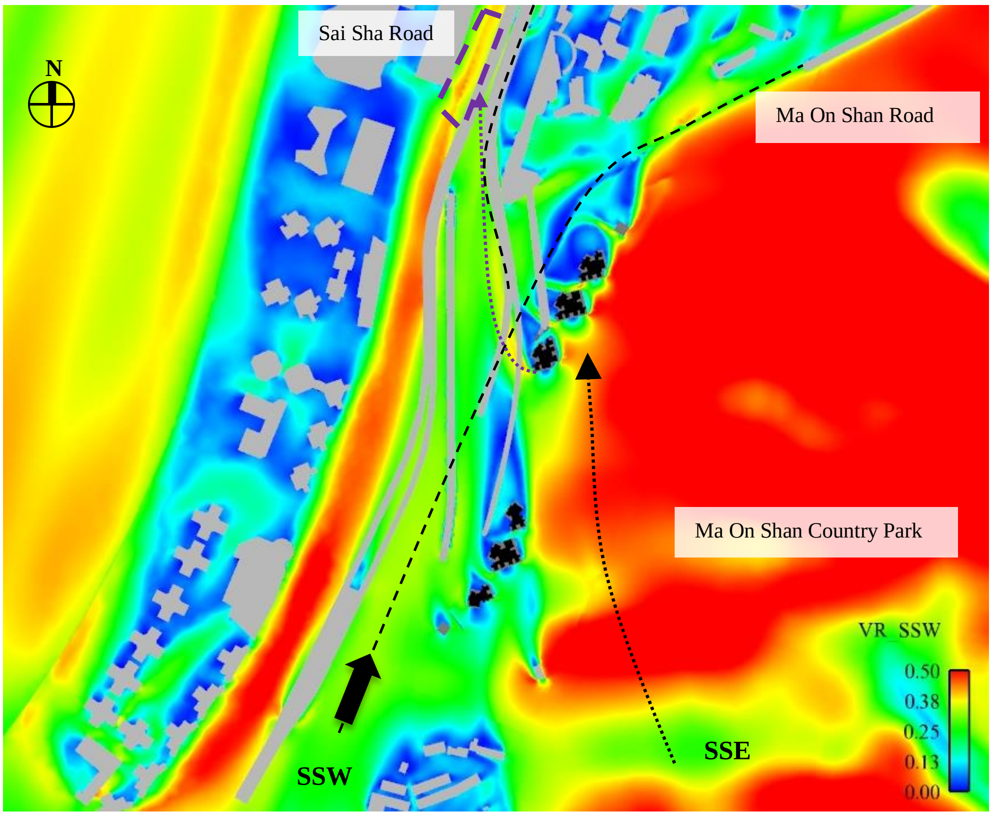


Figure 56 Contour map of average VR for Baseline Scheme (SSW wind)

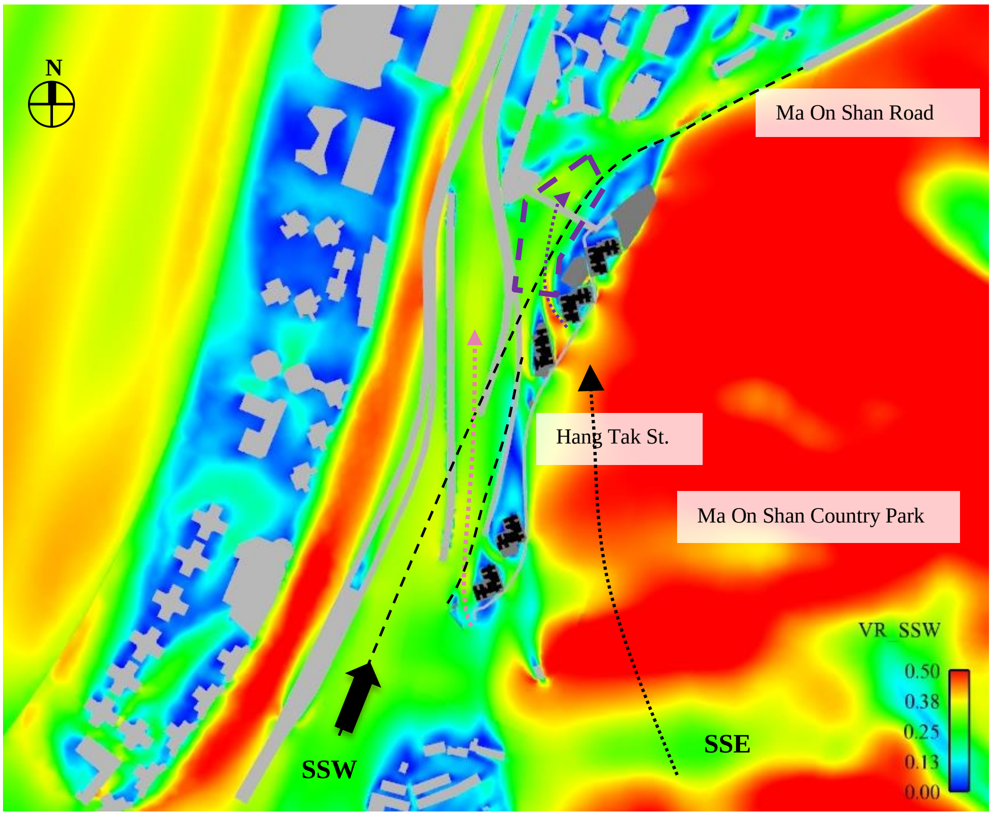


Figure 57 Contour map of average VR for Proposed Scheme (SSW wind)

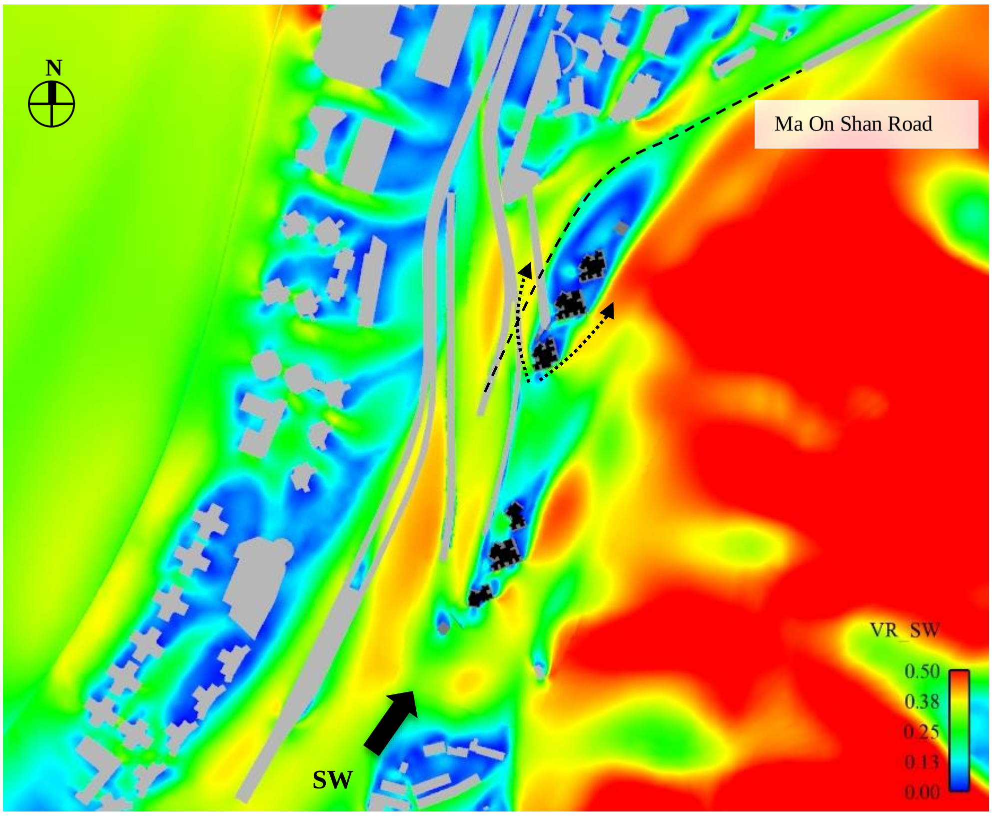


Figure 58 Contour map of average VR for Baseline Scheme (SW wind)

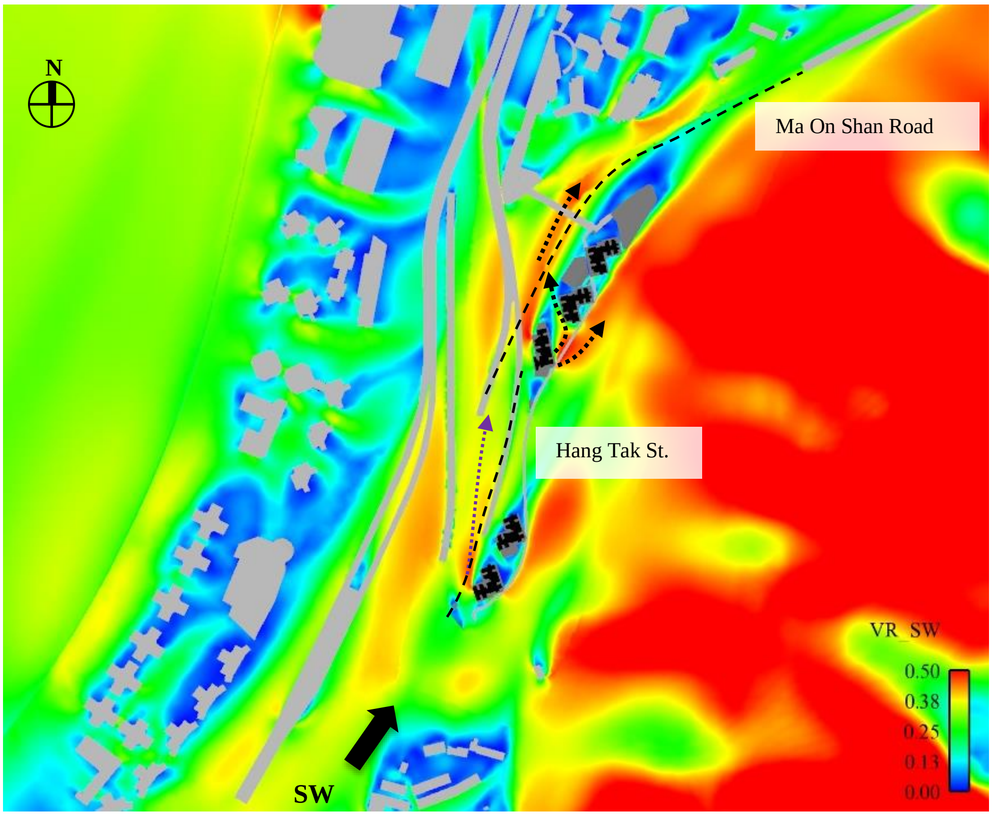


Figure 59 Contour map of average VR for Proposed Scheme (SW wind)

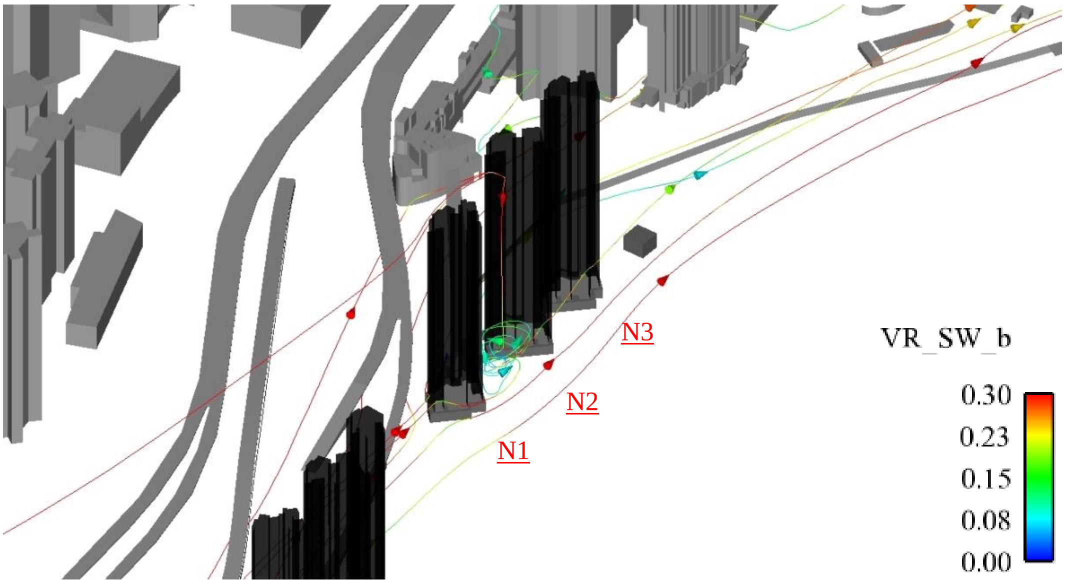


Figure 60 Streamline Plot with Baseline Scheme (SW wind)

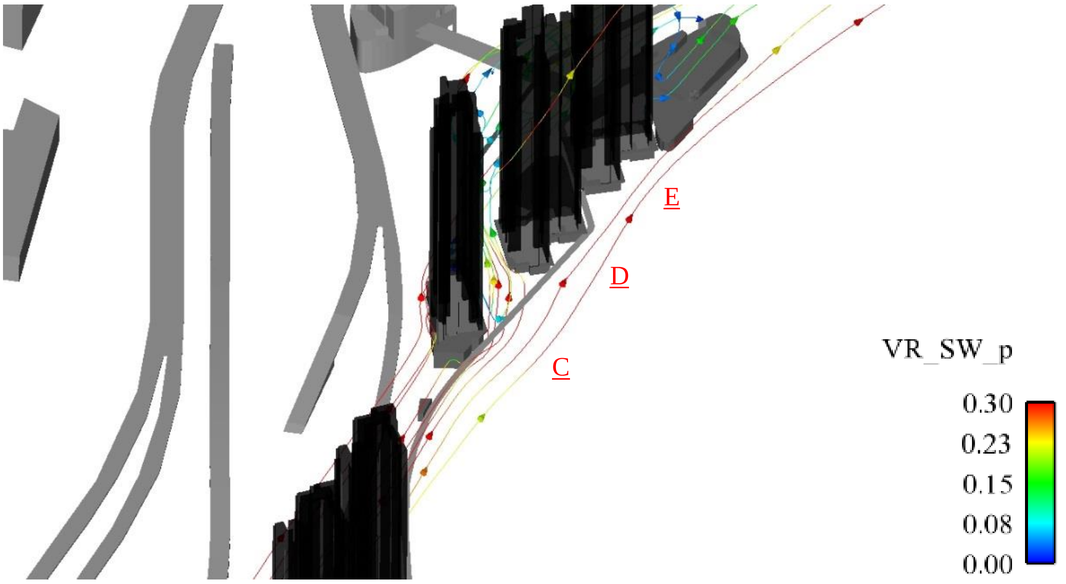


Figure 61 Streamline Plot with Proposed Scheme (SW wind)

4.2.10 West-south-westerly Wind

Representing 9.7% of overall frequency of summer prevailing wind, WSW wind blows from Tolo Harbour towards the inner area of Ma On Shan.

As the Development sits in the innermost downwind area in the region under this wind condition, there is inconspicuous impact observed with the two design schemes. Both schemes exhibit very similar wind performance except one location at the windward front of the south portion.

Since building blocks reduce from 3 (Block S1 to S3) in the Baseline Scheme to 2 (Blocks A&B) in the Proposed Scheme, less high-altitude prevailing wind can be captured down to the pedestrian ground near the intersection of Ma On Shan Road and Hang Tak Street with the Proposed Scheme. Instead, Block S3 in the Baseline Scheme provides another stream of downdraught to the area (**black circle and arrows** in Figure 62).

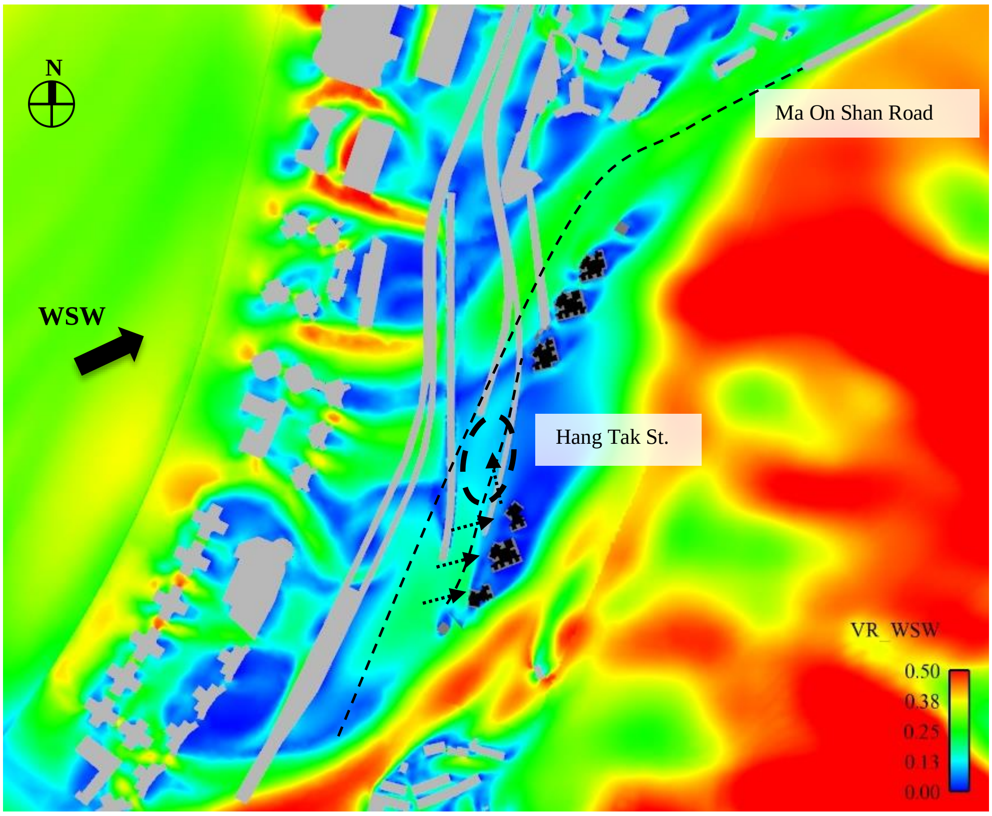


Figure 62 Contour map of average VR for Baseline Scheme (WSW wind)

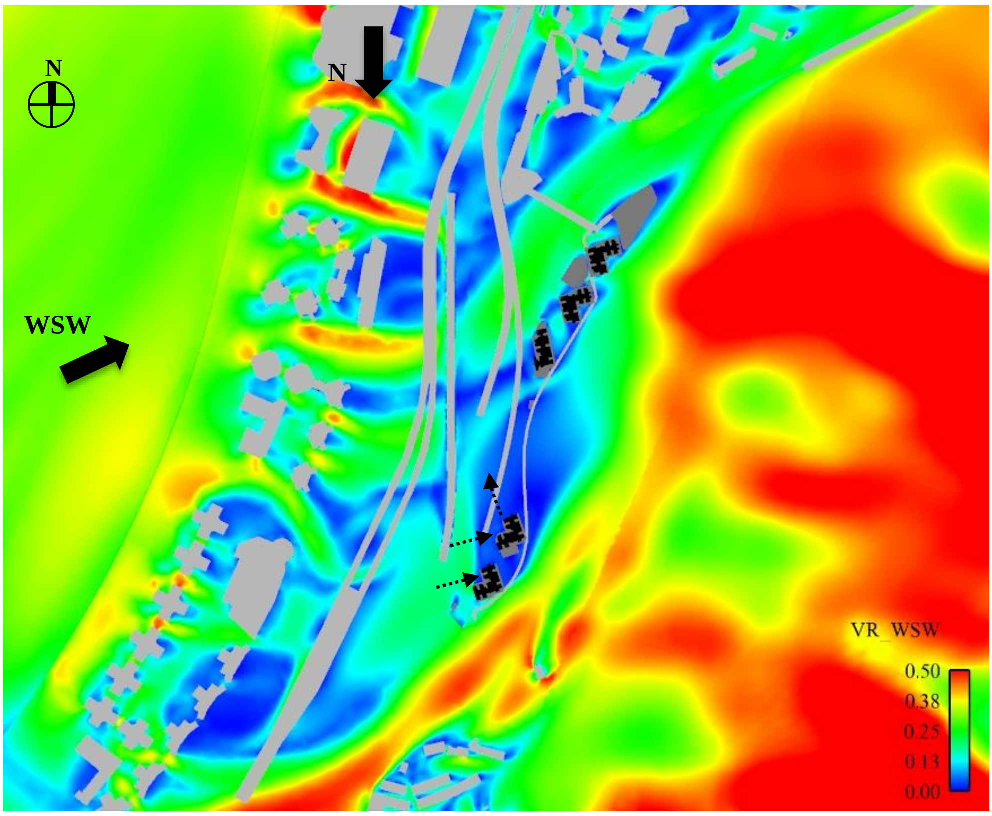


Figure 63 Contour map of average VR for Proposed Scheme (WSW wind)

4.2.11 Westerly Wind

Representing 6.6% of overall frequency of summer wind condition, the W wind reaches the site in a way similar to the WSW wind. Nevertheless, the local air paths of Hi Tai Street, Yuk Tai Street, Sui Tai Road and To Tai Street channel the W wind from the Tolo Harbour to the site rather in a WNW fashion due to the region-wide alignment of buildings.

For the south portion of the site, due to the larger building span with a third building (Block S3) situated, a larger wind shadow is cast on the lee-side of the south portion (**black circle** in Figure 64).

The wind coming from Yuk Tai Street blows towards Block C in the Proposed Scheme or Block N1 in the Baseline Scheme. The long-stretch of windward façades of Block C brings down more high-altitude wind to the pedestrian level of Ma On Shan Road covering the northwest side of the site and a part of the bicycle track at the back (**black arrows** in Figure 65).

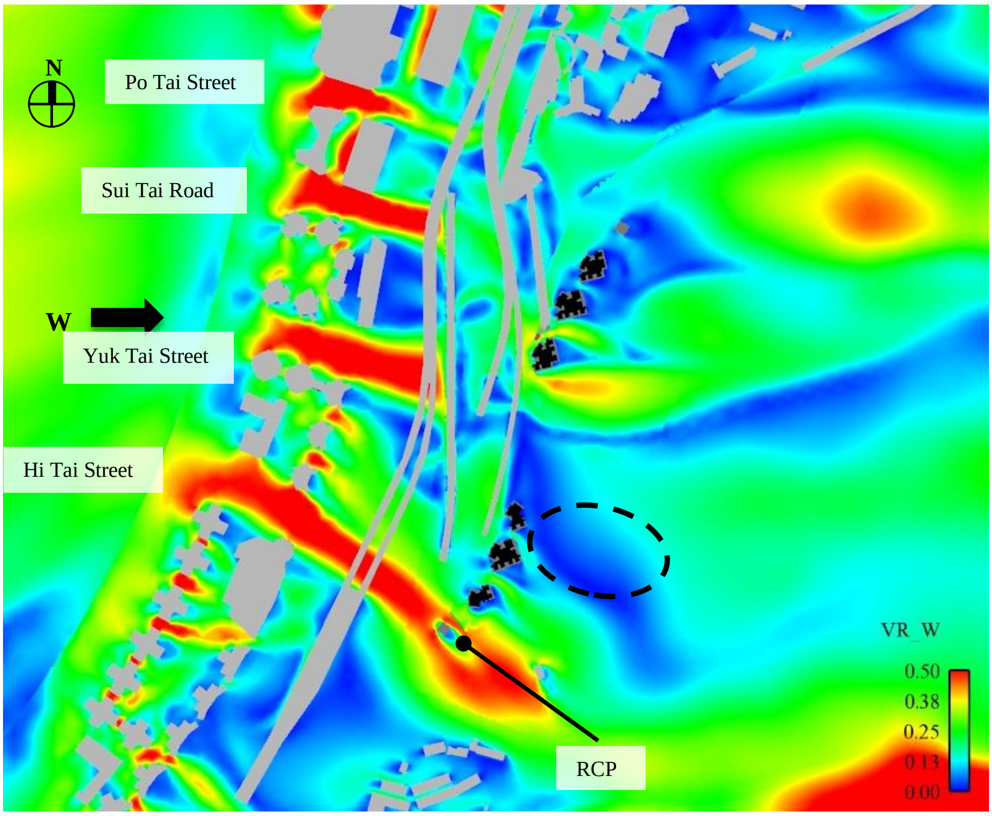


Figure 64 Contour map of average VR for Baseline Scheme (W wind)

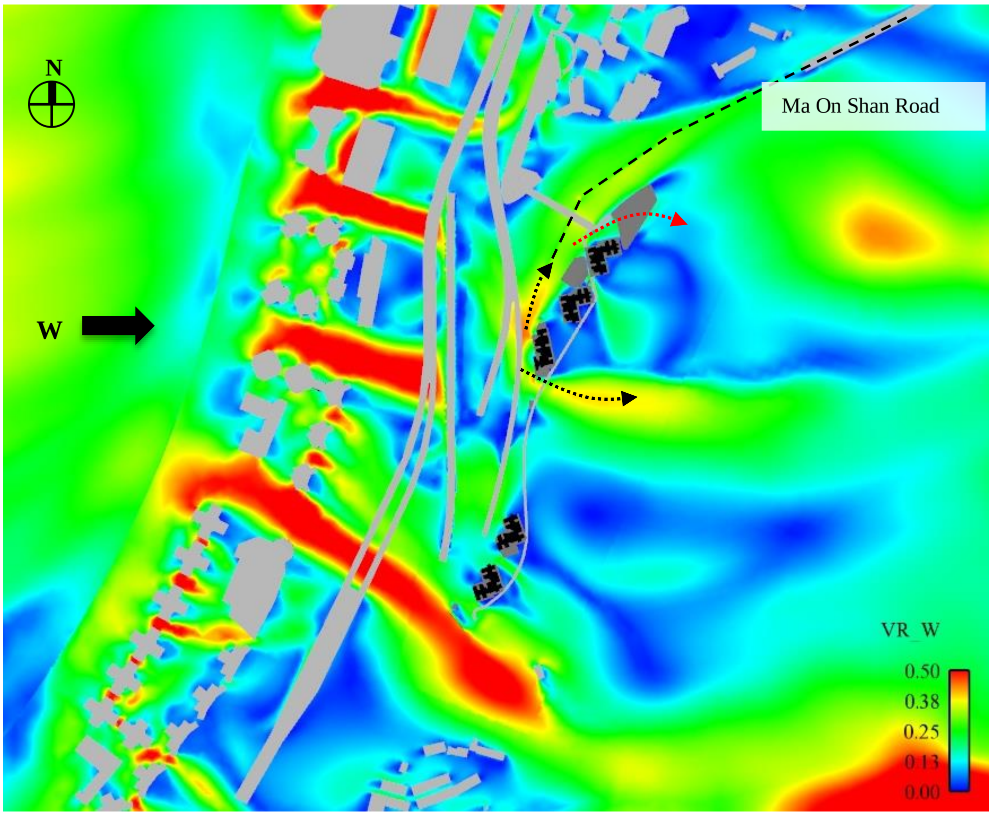


Figure 65 Contour map of average VR for Proposed Scheme (W wind)

4.3 SVR and LVR

As described in Section 3.5.5, two types of velocity ratio were obtained from the selected test points in the simulations to determine the ventilation performance under the annual and summer wind conditions:

Table 8 Comparison of average velocity ratios of Baseline and Proposed Schemes

Annual	Baseline Scheme	Proposed Scheme
SVR	0.27	0.27
LVR	0.27	0.27
Summer	**Baseline Scheme**	**Proposed Scheme**
SVR	0.20	0.22
LVR	0.22	0.23

The Site Spatial-average Velocity Ration (SVR) of both schemes are the same at 0.27 in annual-avearge condition and respectively 0.20 and 0.22 with the Baseline Scheme and the Proposed Scheme respectively in summer-average condition. This means that that the wind performance around the site boundary shows similarity between the two design schemes under the annual condition and a slight enhancement by the Proposed Scheme in the summer condition.

The Local Spatial-average Velocity Ratios (LVR) are also the same for both schemes at 0.27 in the annual condition and respectively 0.22 and 0.23 with the Baseline Scheme and the Proposed Scheme in the summer condition. This implies that the Proposed Scheme is slightly better than the Baseline Scheme in terms of near-field and far-field wind environment under the summer-average condition (from the sector of E to S to W wind).

4.4 Focus Area

To further assess the impact of the Development on the neighbourhood's wind environment, 7 focus areas were identified using the test-points addressed in Section 3.4 and are accessible to pedestrians in the region

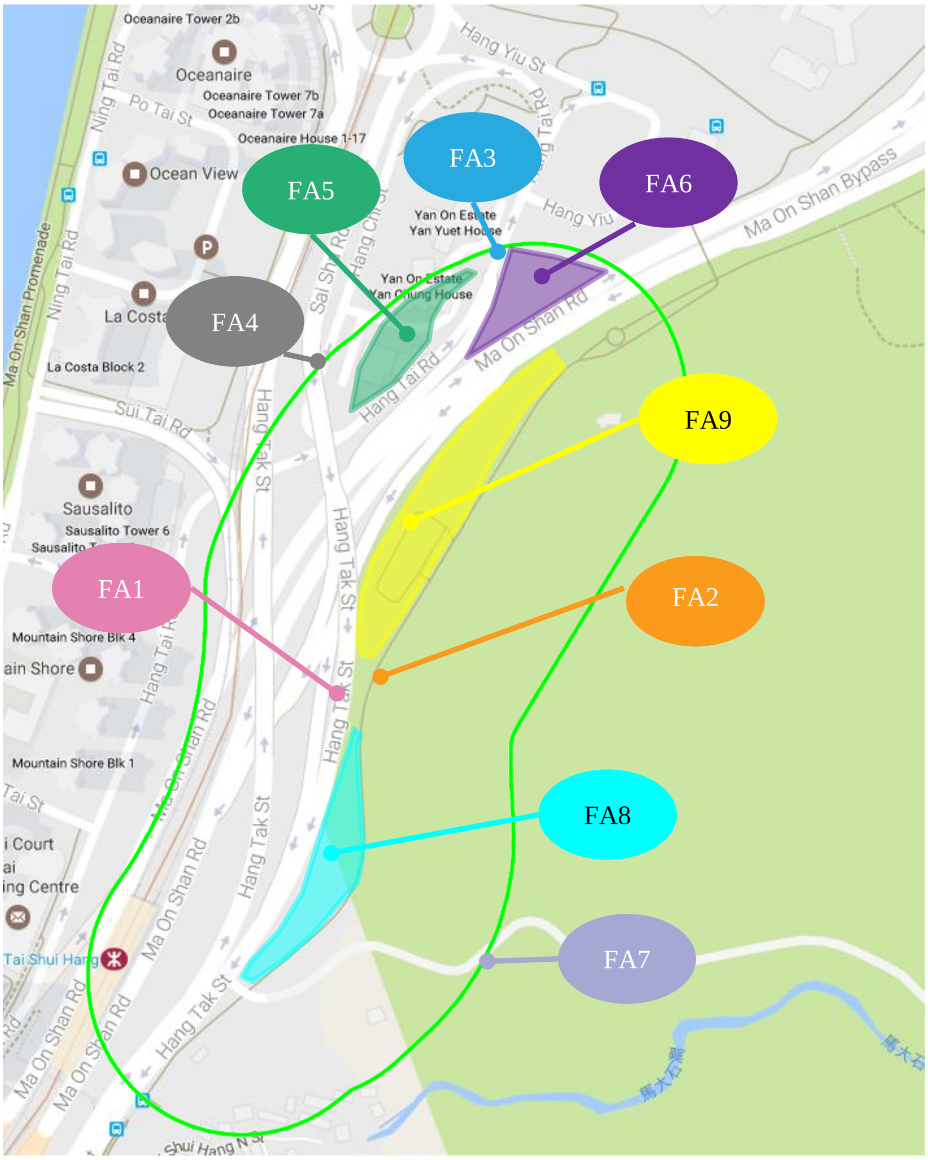


Figure 66 Locations of the focus area within 1H assessment area (light green circle)

Annual Condition

Table 9 Spatial-average velocity ratios for different focus areas under annual-average wind condition

	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
1	Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary)	P1-18	0.24	0.23
2	Ma On Shan Hillside Bicycle Track	P1, P19-34, O32-37, O44-48	0.30	0.30
3	Hang Tai Road (after re-alignment)	O1-15	0.26	0.27
4	Hang Chi Street	O4, O29-31	0.28	0.29
5	Yan On Estate Ph1 - Existing Open Areas	O19-28	0.19	0.19
6	Open Area of Petrol Station on Ma On Shan Road	O16-18	0.17	0.17
7	Private Road to Tai Sui Hang Waterfall Hike	O38-43	0.40	0.40
8	Open Area in South Blocks	S1-3	0.13	0.19
9	Open Area in North Blocks	S4-7	0.19	0.24

The result shows that both schemes are similar to one another even with slight differences in VR in 3 out of 9 focus areas but prominent improvements within the site area (2 other focus areas), which means that both have similar influence to the wind environment under the annual-average condition.

A slightly larger VR at Hang Tai Road (after re-alignment) (FA3) in the Proposed Scheme is mainly benefited by the empty bay of a 3-story tall Commercial and Recreational Block at the north end of the site boundary that diverts more airflow to the pedestrian level near Ma On Shan Road and Hang Tai Road under ENE condition. Under ESE wind condition, actually the incoming wind for the north portion of the site is the downhill wind along the ridge line of Ma On Shan Country Park, which is similar to the ENE direction. As a result, similar enhancement of wind environment appears at Hang Tai Road.

Hang Chi Street (FA4) also has a slightly larger VR in the Proposed Scheme. It is benefited by the existence of Commercial and Recreation Block at the north end of the site boundary that creates more downdraughts under N and ENE wind conditions. Moreover, the building disposition of Block C actually have a long span of windward façade directing the E, ESE and S wind to penetrate into the ground level of the site area and to further reach Hang Chi Street.

Under the NNE and ENE wind conditions, less airflow is available at the pedestrian level of the Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary) (FA1) due to the long span of Block C that would create a larger wind shadow on the lee-side where part of this focus area is situated.

For special test points put in the open area in the site area, both of the Open Areas in South Blocks (FA8) and North blocks (FA9) of the Proposed Scheme recorded larger VRs due to larger permeability of the building blocks (reduced number of blocks) in the proposed design, particularly in the south part of the site.. Both Blocks A and B in the Proposed Scheme are set back from the south boundary slightly more than Blocks S1 to S3 in the Baseline Scheme, so that more wind can flow through the south portion of the Development under N, NE, ENE, E and S wind conditions. In the north part of the site, with the existence of Commercial and Recreational Block, the empty bay at the Ground Floor favours more wind to be diverted into the north part of the site area. In addition with the building disposition of Block C, the larger windward facade actually create more downdraughts to flow through the building gaps. As a result, the open area in the north part of the Development also records a significant increase in VRs under N, NNE, NE E, ESE, S and SSW wind conditions.

Summer Condition

Table 10 Spatial-average velocity ratios for different focus areas under summer-average wind condition

	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
1	Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary)	P1-18	0.18	0.20
2	Ma On Shan Hillside Bicycle Track	P1, P19-34, O32-37, O44-48	0.24	0.25
3	Hang Tai Road (after re-alignment)	O1-15	0.23	0.23
4	Hang Chi Street	O4, O29-31	0.22	0.23
5	Yan On Estate Ph1 - Existing Open Areas	O19-28	0.19	0.17
6	Open Area of Petrol Station on Ma On Shan Road	O16-18	0.20	0.19
7	Private Road to Tai Sui Hang Waterfall Hike	O38-43	0.33	0.33
8	Open Area in South Blocks	S1-3	0.13	0.15
9	Open Area in North Blocks	S4-7	0.14	0.20

The results show 7 of the focus areas with slight differences in VR under the summer-average condition.

On the contrary to the annual condition, Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary) (FA1) has a better wind environment with the Proposed Scheme in the summer condition dominated by S and SW wind. Block A has around a 6m shift from the original location of Block S1 and Block B has round a 8.5m from Block S3. These actually favour more wind to flow through the south portion of the site at the pedestrian level. Meanwhile, Block C has a long span of windward façade to capture more downdraught to the pedestrian level under SSW, SW and W wind condition. All together contribute to the slight increase in VR in FA1.

A slightly larger VR at Ma On Shan Hillside Bicycle Track (FA2) in the Proposed Scheme is observed due to the similar effect of building shift of Block A that favours more airflow to reach the adjacent part of the bicycle track at the south end of the site under S and SW wind conditions.

For Hang Chi Street (FA4), similar to the annual wind condition, the building disposition of Block C has a longer span of windward façade which diverts the airflow from E, ESE, S, SSW and SW wind directions to downdraughts to the whole area of pedestrian level of Ma On Shan Road and Hang Chi Street nearby.

With the Proposed Scheme, the airflow under W wind condition is more easily diverted by Block C to Hang Chi Street and along the Ma On Shan Road, so comparatively less airflow is driven to the Existing Open Areas of Yan On Estate Phase 1 (FA5). Under the S wind with the Proposed Scheme, the presence of Commercial and Recreational Block in the north would reduce a certain low to mid-altitude wind coming down Yan On Estate Phases 1 & 2 as the downdraughts to the open area. As a result, a slightly larger VRs with the Baseline Scheme are observed.

Likewise, the Open Area of Petrol Station on Ma On Shan Road (FA6) neighbouring with the open area of Yan On Estate experience similar wind environment resulting from the same causes under S, SW and W wind conditions.

For Open Areas in South Blocks (FA8) and North Blocks (FA9), they experience similar effects as described in the annual wind conditions with the Proposed Scheme. Thus, similar increase in VRs are recorded under E to SW (clockwise) wind conditions.

5 Wind Enhancement Design

Despite the addition of Carport and Commercial and Recreational Block in the north portion of the project site, which certainly affects the wind environment compared to the Baseline Scheme, the Proposed Scheme introduces three major measures for wind enhancement and to minimise of wake-zone around the Development:

- Building Setbacks of Blocks A and B;
- Building Disposition of Block C;
- Empty Bays at pedestrian level of Commercial and Recreational Block.

It is expected that the latest proposed design would be beneficial to the local wind performance especially under summer wind condition. The feature designs with exemplary streamline plots of airflow are illustrated as follows.

5.1 Building Setbacks of Blocks A and B

One of the obvious changes is that the building blocks reduce from 3 blocks (Block S1-S3) in Baseline Scheme to 2 blocks (Block A and B) in Proposed Scheme. The changes produce extra setback in builidng postion in Proposed Scheme rather than Baseline design as illustrate in Figure 67. The footprint of Block A is further set back northward from Block S1 by around 6m in the Proposed Scheme and the footprint of Block B is further set back southewad from Block S3 by around 8.5m. The building setback actually favours airflow over the south portion of Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary) and Ma On Shan Hillside Bicycle Track under the incoming wind from the low residential culster ath the south, Ma On Shan Country Park and Tolo Harbour.

The streamline plots of NE, E and SW direction in Figure 68 to Figure 73 show that less airflow are experiencing the building blockage due to the setbacks in south portion of the Development.

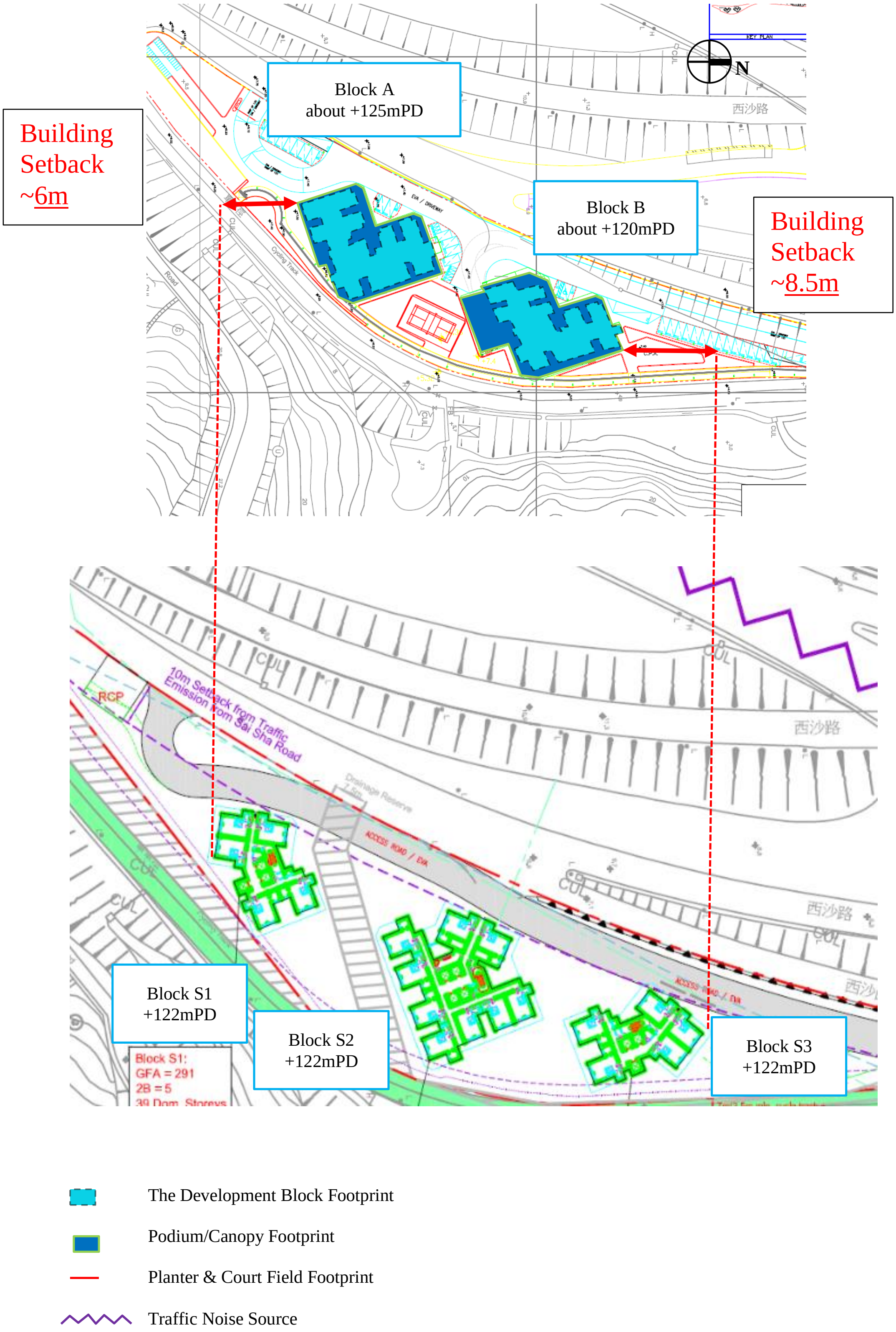


Figure 67 Building Setback illustration between Proposed and Baseline Scheme

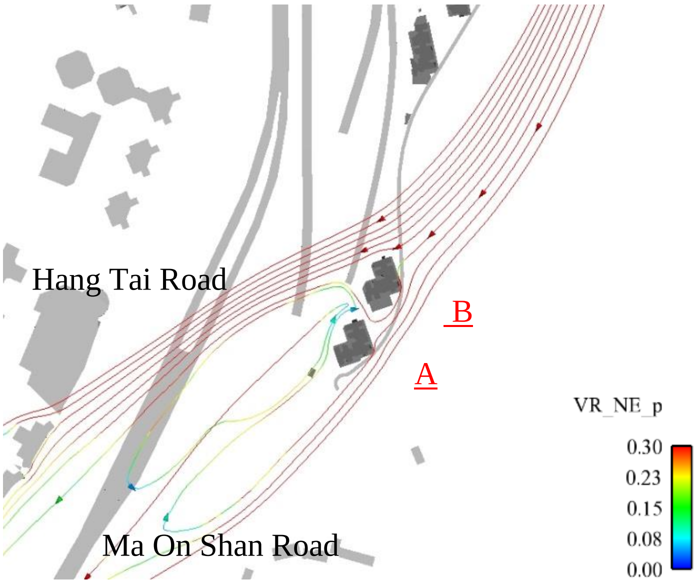


Figure 68 Streamline plot of Proposed Scheme under NE wind condition

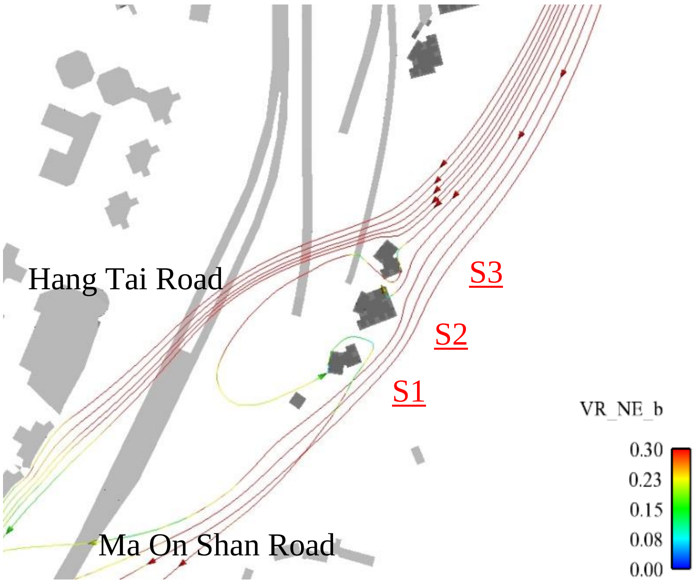


Figure 69 Streamline plot of Baseline Scheme under NE wind condition

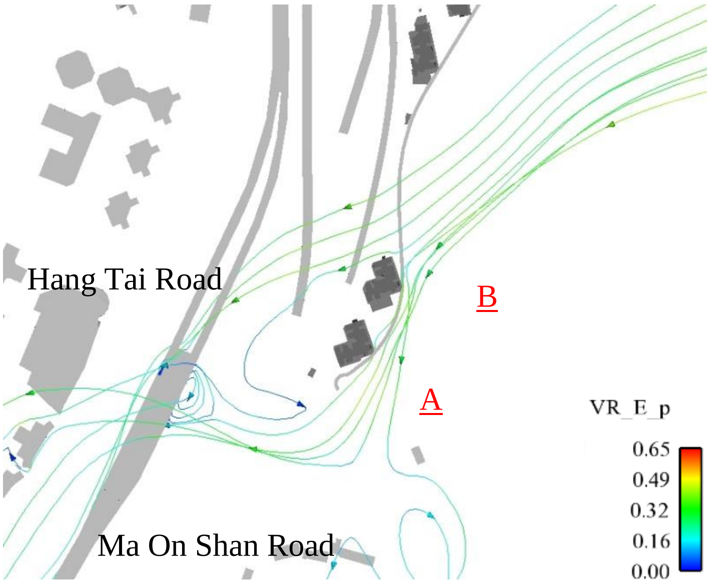


Figure 70 Streamline plot of Proposed Scheme under E wind condition

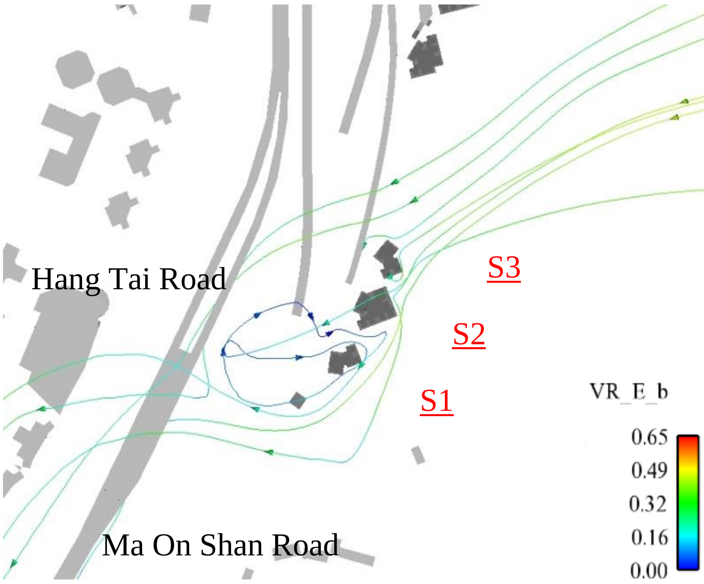


Figure 71 Streamline plot of Baseline Scheme under E wind condition

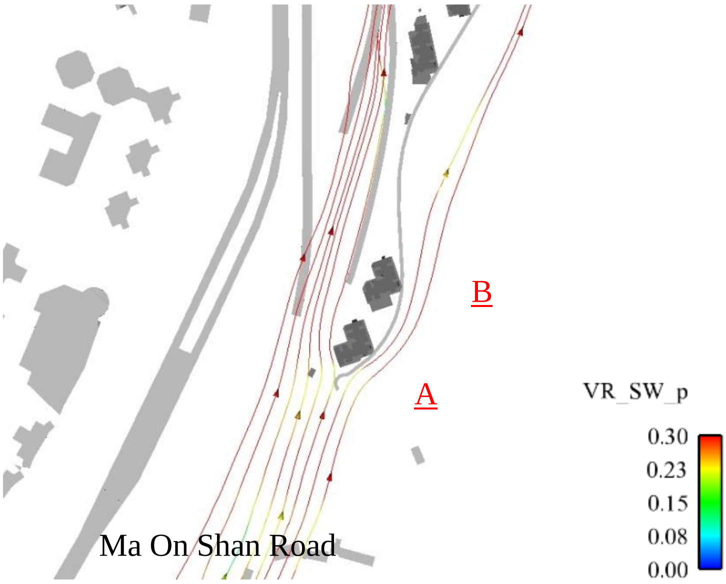


Figure 72 Streamline plot of Proposed Scheme under SW wind condition

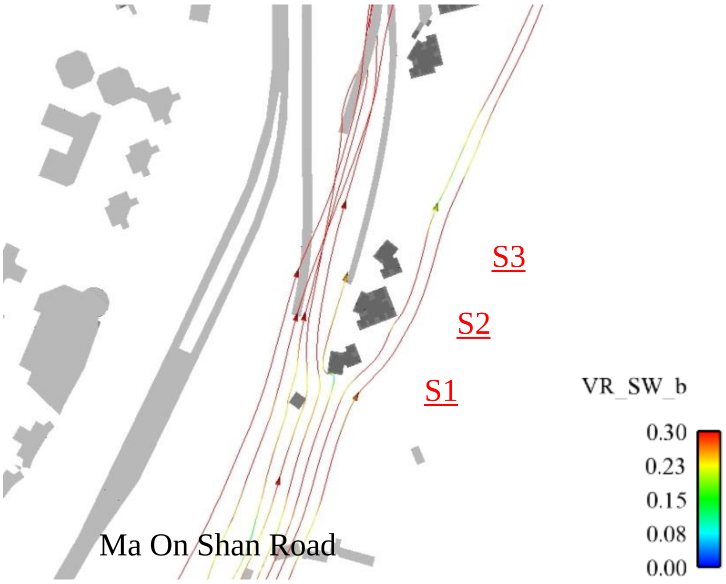


Figure 73 Streamline plot of Baseline Scheme under SW wind condition

5.2 Building Disposition of Block C

Another significant change in the proposed design is the building disposition of Block C, the building footprint changes from a diamond shape of Block N1 to a longer L-shape spanning over NNW to SSE alignment. The main benefits from the L-shape orientation are to divert and streamline the wind to Ma On Shan Road, Hang Tai Road (after realignment) and Hang Chi Street from E to S to W wind sector (red arrow in Figure 74). Especially under summer wind conditions which are dominated by S to W prevailing wind, the longer, SW-facing windward façade of Block C captures and downwashes more airflow to the designated focus areas (violet arrow in Figure 74).

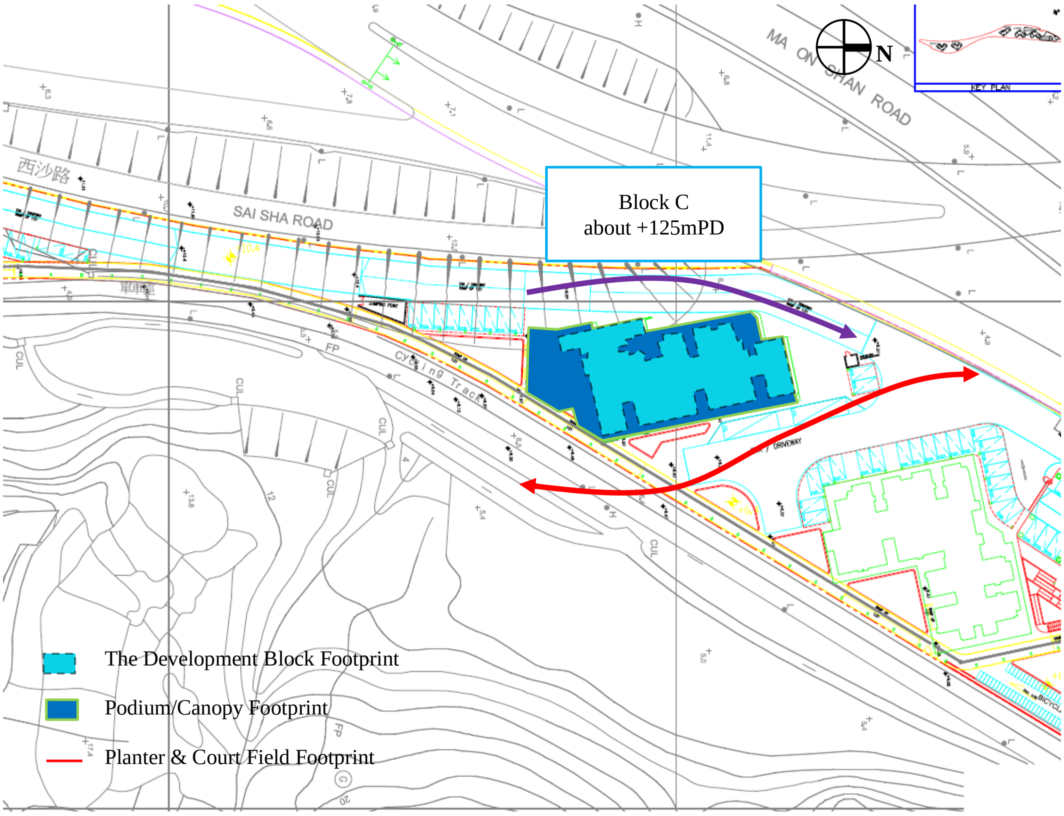


Figure 74 Building layout of Block C in Proposed Scheme

Wind flow of S and W directions is shown in Figure 75 to Figure 80 as examples to indicate sufficient airflow diverted through the proposed development, enhancing the wind performance in the focus areas.

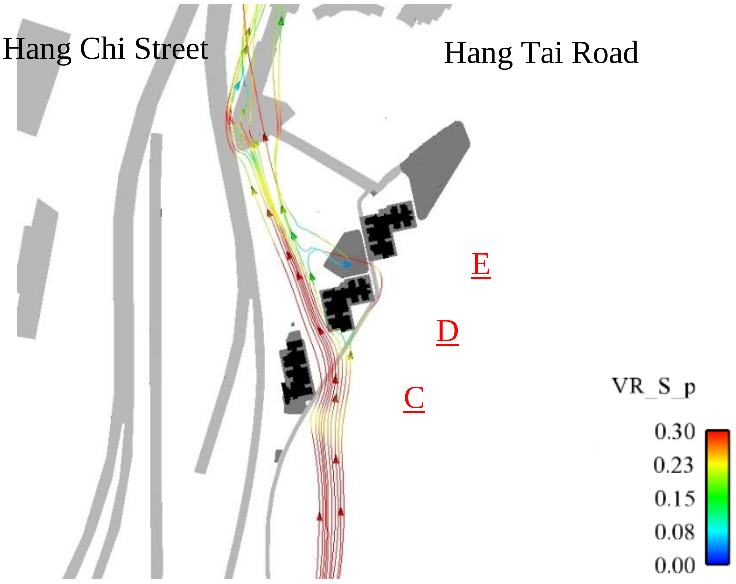


Figure 75 Streamline plot of Proposed Scheme under S wind condition

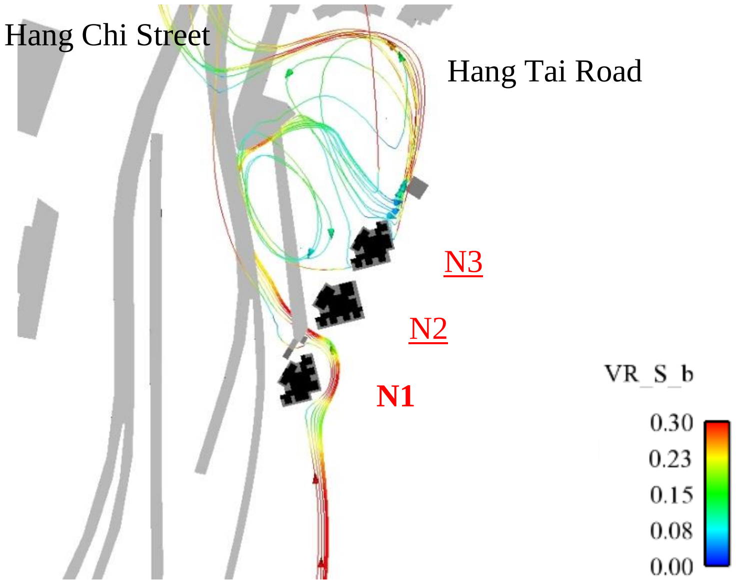


Figure 76 Streamline plot of Baseline Scheme under S wind condition

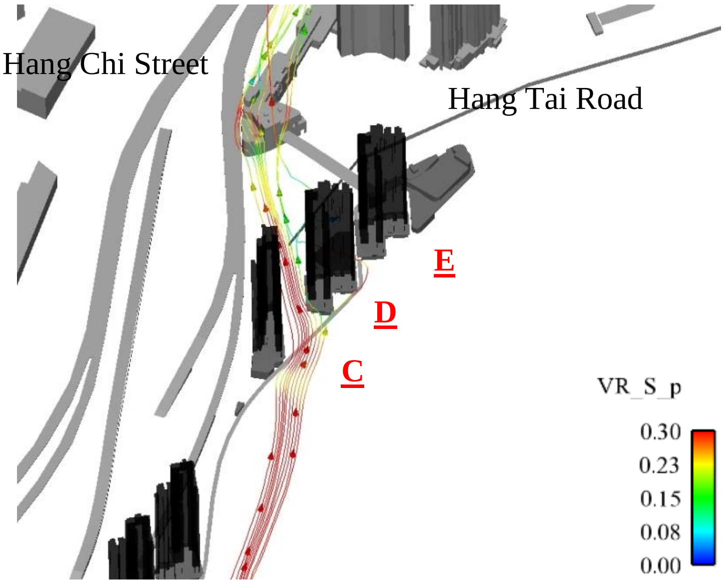


Figure 77 Streamline plot of Proposed Scheme under S wind condition

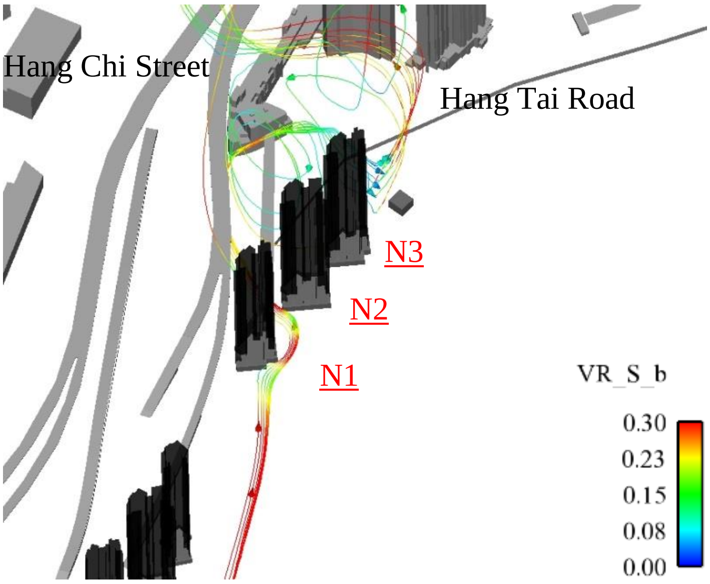


Figure 78 Streamline plot of Baseline Scheme under S wind condition

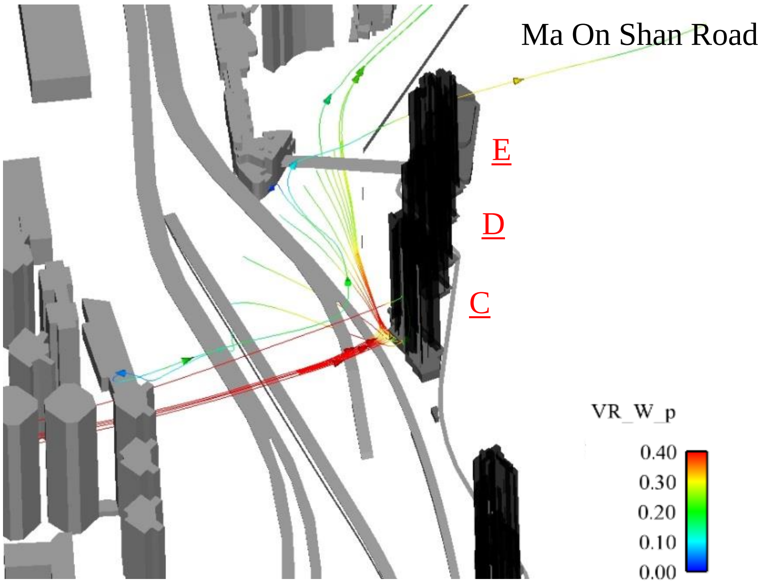


Figure 79 Streamline plot of Proposed Scheme under W wind condition

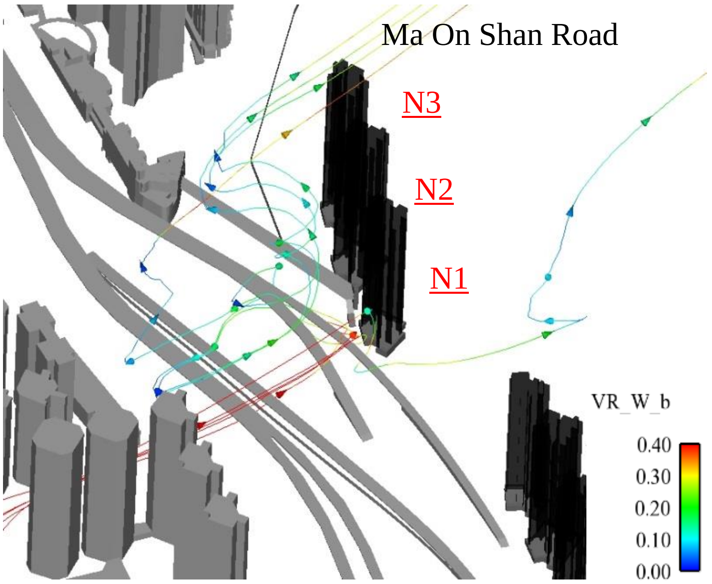


Figure 80 Streamline plot of Baseline Scheme under W wind condition

5.3 Empty Bays at pedestrian level of Commercial and Recreation Block

Despite the addition of a 3-story-high Commercial and Recreation Block at the north end of the site, the proposed scheme now includes a driveway for vehicular access on G/F with empty bays (red highlighted in Figure 81) to minimise the negative impact on the immediate surroundings. These empty bays primarily favour ventilation through the site to Ma On Shan Road under NE prevailing wind (as shown in Figure 82 and Figure 83).

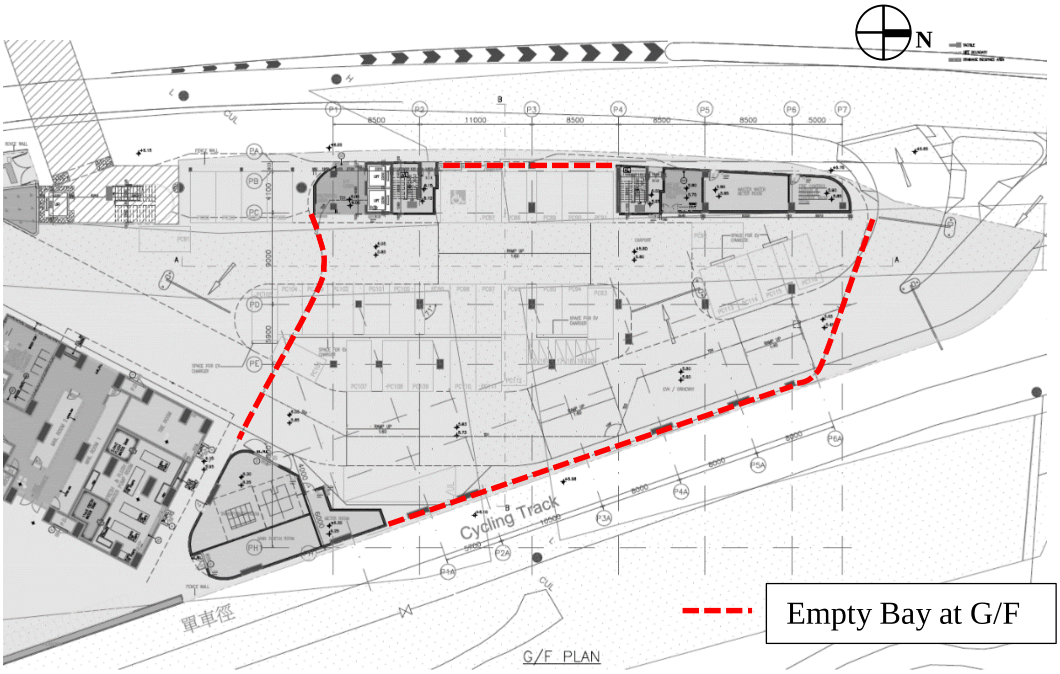


Figure 81 Empty Bay at G/F of Commercial and Recreational Block

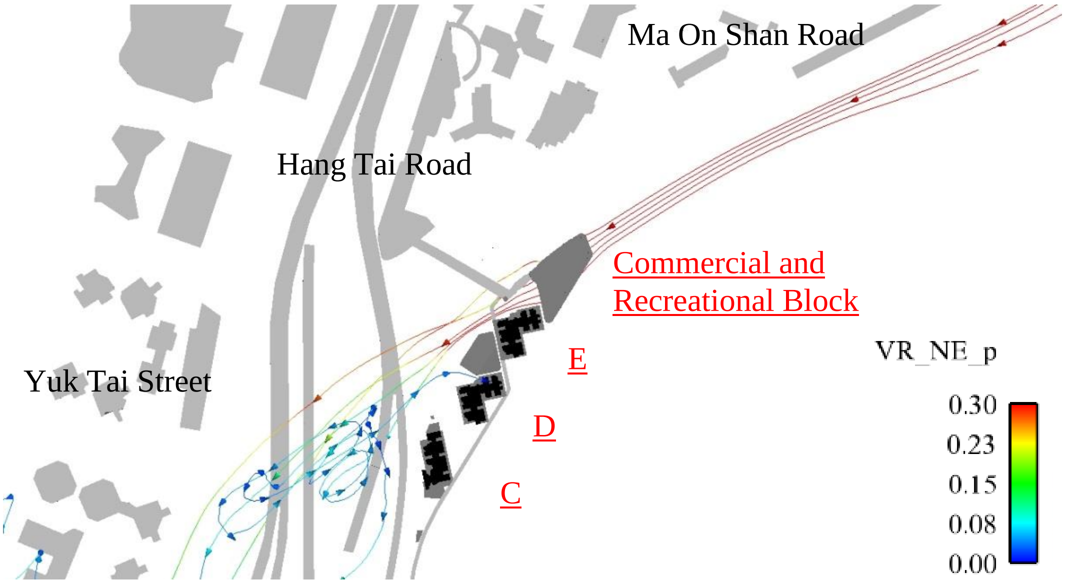


Figure 82 Streamline plot of Proposed Scheme under NE wind condition

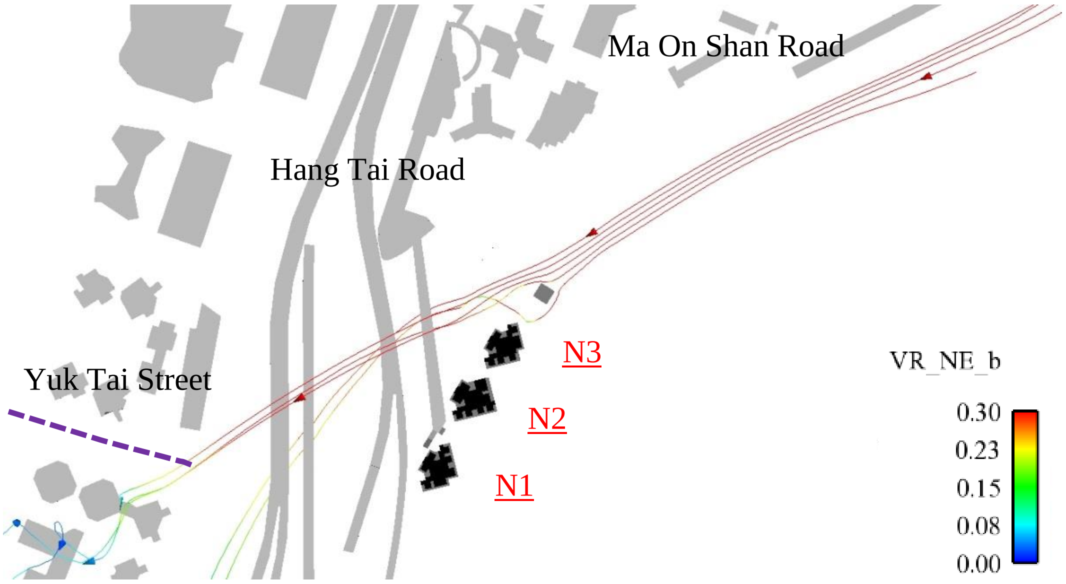


Figure 83 Streamline plot of Baseline Scheme under NE wind condition

6 Conclusion

A series of CFD simulations using realisable k – ε turbulence modelling were performed using the methodology of Air Ventilation Assessment (AVA) – Initial Study as stipulated in the Technical Circular and the Technical Guide. A total of 12 wind directions were selected with N, NNE, NE, ENE, E, ESE, S and SW representing 81.6% of wind availability in annual condition and E, ESE, SE, S, SSW, SW, WSW and W accounting for 77.1% of the occurrence frequency in summer condition. Two design scenarios of the Development, namely Baseline Scheme and Proposed Scheme, were studied.

Velocity Ratio (VR) as proposed by the Technical Circular was employed to assess the ventilation performances of the Development and the surrounding environment. With reference to the Technical Guide, a total of 34 perimeter test-points, 48 overall test points and 7 special test-points were identified to reckon the VRs.

The major findings of this study can be summarized as follows,

- The Site Spatial-average Velocity Ratios (SVRs) & the Local Spatial-average Velocity Ratios (LVRs) indicate that both design schemes (Baseline and Proposed) are similar to each other in the overall performance as well as around the site periphery under the annual and summer conditions.

Annual	Baseline Scheme	Proposed Scheme
SVR	0.27	0.27
LVR	0.27	0.27
Summer	**Baseline Scheme**	**Proposed Scheme**
SVR	0.20	0.22
LVR	0.22	0.23

- 9 focus areas were identified within the 1H distance (as defined by the Technical Circular) from the site boundary of the Development. Their VRs demonstrate similarity in wind performance between the two design schemes with 5 focus areas showing deviations in annual-average condition and 7 in summer-average condition.

Annual-average

	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
1	Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary)	P1-18	0.24	0.23
2	Ma On Shan Hillside Bicycle Track	P1, P19-34, O32-37, O44-48	0.30	0.30
3	Hang Tai Road (after re-alignment)	O1-15	0.26	0.27
4	Hang Chi Street	O4, O29-31	0.28	0.29
5	Yan On Estate Ph1 - Existing Open Areas	O19-28	0.19	0.19

	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
6	Open Area of Petrol Station on Ma On Shan Road	O16-18	0.17	0.17
7	Private Road to Tai Sui Hang Waterfall Hike	O38-43	0.40	0.40
8	Open Area in South Blocks	S1-3	0.13	0.19
9	Open Area in North Blocks	S4-7	0.19	0.24

Summer-average

	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
1	Roadside Pedestrian Access along Ma On Shan Road & Hang Tak Street (West Site Boundary)	P1-18	0.18	0.20
2	Ma On Shan Hillside Bicycle Track	P1, P19-34, O32-37, O44-48	0.24	0.25
3	Hang Tai Road (after re-alignment)	O1-15	0.23	0.23
4	Hang Chi Street	O4, O29-31	0.22	0.23
5	Yan On Estate Ph1 - Existing Open Areas	O19-28	0.19	0.17
6	Open Area of Petrol Station on Ma On Shan Road	O16-18	0.20	0.19
7	Private Road to Tai Sui Hang Waterfall Hike	O38-43	0.33	0.33
8	Open Area in South Blocks	S1-3	0.13	0.15
9	Open Area in North Blocks	S4-7	0.14	0.20

To minimise the impact on air ventilation of the neighbourhoods, the Development has adopted the following 3 design measures:

- Building Rearrangement and Setbacks of Blocks A and B;
- Building Disposition of Block C;
- Empty Bays at pedestrian level of Commercial and Recreational Block.

These features increase the permeability of the Development and therefore, minimise its impact on the ventilation of the neighbouring roads and buildings around the Development.