Hong Kong Housing Authority

# Public Housing Development at Anderson Road Quarry Site RS-1

## Air Ventilation Assessment Initial Study Report

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Job number

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ARUP

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# 1 Introduction

## 1.1 Background of Study

Ove Arup & Partners Hong Kong Ltd (Arup) will conduct an Air Ventilation Assessment (AVA) for the Public Housing Development at Anderson Road Quarry Site RS-1 (the Development).

The *Technical Guide for Air Ventilation Assessment for the Developments in Hong Kong (Annex A of Technical Circular No.1/06 for Air Ventilation Assessments)*[1] *(termed as AVA Technical Circular hereafter)* dated 19 July 2006 lay down the foundation of methodology in this AVA Initial Study.

## 1.2 Objective of AVA Study

Among all available wind data, an Initial Study will be conducted by using Computational Fluid Dynamics (CFD) techniques. It aims to achieve the following tasks:

- Initially assesses the characteristics of the wind availability of the site;
- Gives a general pattern and a rough quantitative estimate of the wind performance at the pedestrian level using Velocity VR; and
- Identify good design features and problematic areas if any and recommend mitigation measures.

[1] Annex A of Technical Circular No. 1/06 issued by the Housing, Planning and Lands Bureau pertaining specifically to Air Ventilation Assessments (19th July, 2006)

# 2 Study Location

## 2.1 Characteristics of Project Area and Its Surrounding Areas

The Development is located within the Anderson Road Quarry Development area (+192mPD). The Development is situated on the mountain slope, where the north-east is hilly rock face, Tai Sheung Tok. Lower level to the south-west is the Anderson Road Development area (+144mPD), which consists of the existing high-rise On Tat Estate (+280mPD).

Further south-west down the slope is the Sau Mau Ping area (+113mPD) located at a lower topography, which consists of dense mid-rise to high-rise building cluster.

The immediate surroundings of the Development are planned low-rise GIC buildings according to the Anderson Road Quarry Development plan. The west side of the site is a planned public housing development site consists of 3 residential towers. The location of development site and surrounding areas are illustrated in Figure 1.


Figure 1 Site Location and Surrounding Development

# 3 Site Wind Availability

Simulated RAMS data is adopted for the site wind availability in this study.

## 3.1 Wind Data from RAMS

As stipulated in the Technical Guide, the site wind availability would be presented by using appropriate mathematical models (e.g. RAMS simulation). Planning Department (PlanD) has set up a set of wind availability data of the Territory for AVA study, which could be downloaded at Planning Department Website[2].

The location of the Project Area falls within the location grid (x:093, y:043) in the RAMS information database as shown in Figure 2. The wind availability data at 500mPD of location grid (x:093, y:043) is obtained to adopt in the AVA study. 500m height is selected to investigate prevailing wind condition in the AVA study, as it can better represent the incoming wind to the site which include the influence from the surrounding morphology.

The annual and summer wind roses for the study are shown in Figure 3 and Figure 4. The wind data shows that the majority of the wind comes from the northeast quarter under annual and summer wind condition.

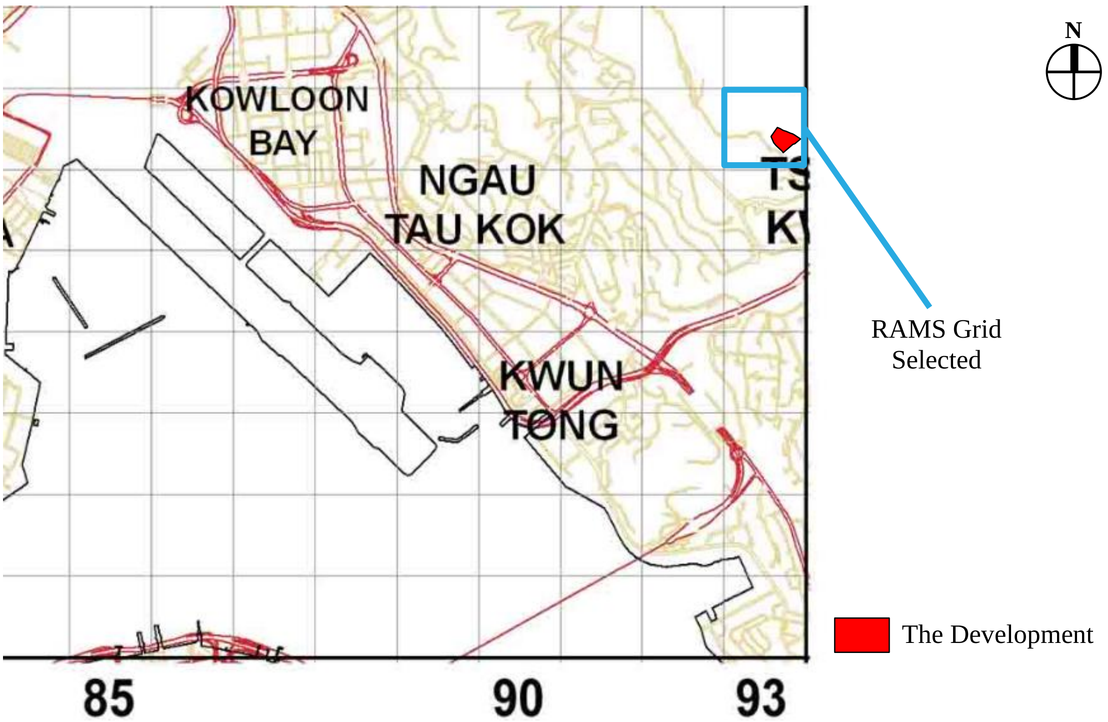



Figure 2 RAMS Grid and the Development Location

[2] http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/

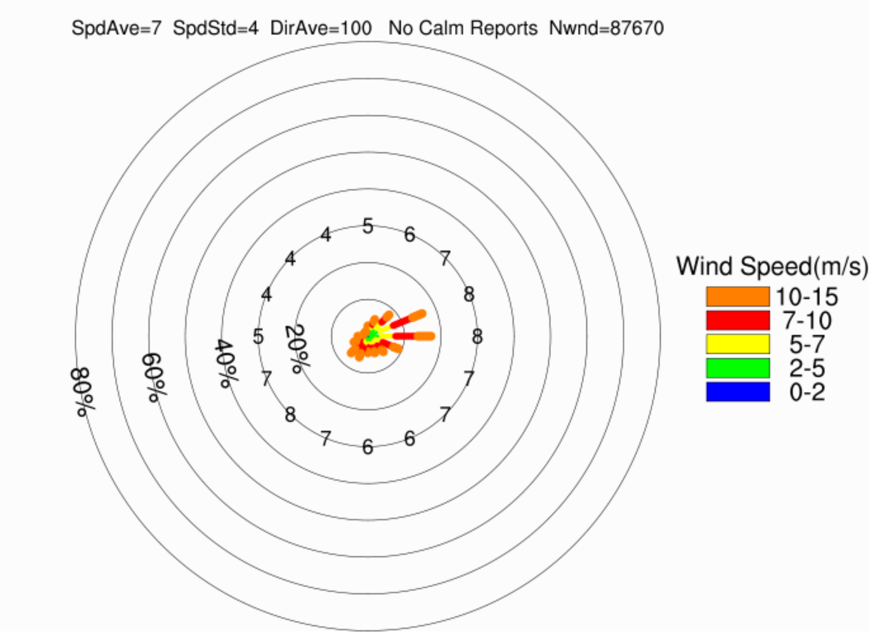



Figure 3 Wind rose for annual wind condition at 500m from RAMS

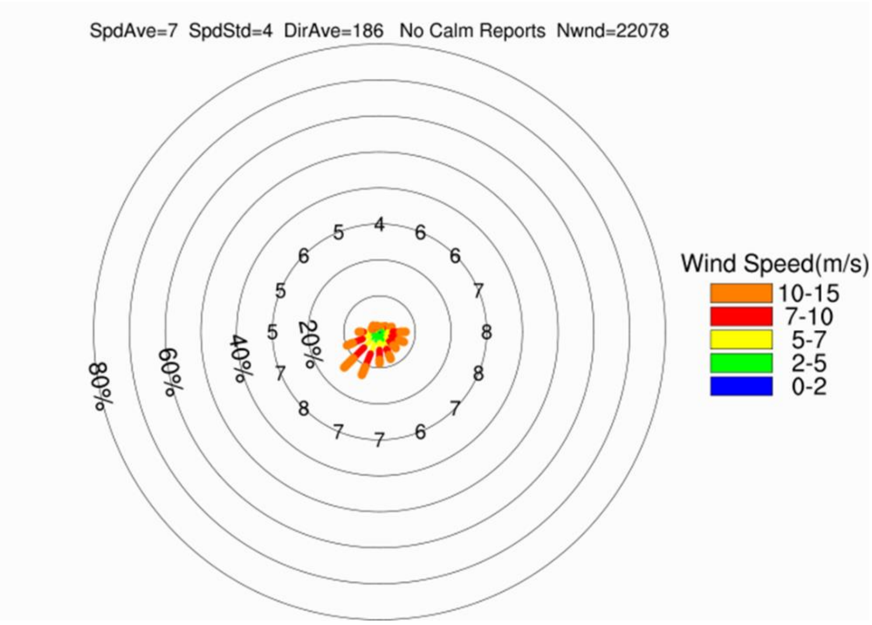



Figure 4 Wind rose for summer wind condition at 500m from RAMS

## 3.2 Wind Directions and Profiles

The RAMS wind data of location grid (x:093, y:043) is extracted and adopted as the site wind availability input in the study.

### 3.2.1 Annual Prevailing Wind

Eight prevailing wind directions (highlighted in red colour in Table 1) are considered in this AVA Study, which covers 76.2% of the total annual wind frequency and fulfils the requirement as stipulated in the Technical Circular (i.e. exceeds 75% of time in a typical reference year).

Table 1 Annual Wind Frequency of the Wind Directions Considered in this Study

| Wind Direction | N | NNE | NE | ENE | E | ESE | SE | SSE | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency | 2.9% | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | 5.0% | |
| Wind Direction | S | SSW | SW | WSW | W | WNW | NW | NNW | **SUM** |
| Frequency | 4.6% | 6.3% | 6.7% | 4.2% | 2.8% | 1.3% | 1.3% | 1.4% | **76.2%** |

** The wind frequency showing in red colour represents the recommended wind direction for the CFD simulation.*

### 3.2.2 Summer Prevailing Wind

Eight prevailing wind directions (highlighted in red colour in Table 2) are considered in this AVA Study, which covers 77.6% of the total annual wind frequency and fulfils the requirement as stipulated in the Technical Circular (i.e. exceeds 75% of time in a typical reference year).

Table 2 Annual Wind Frequency of the Wind Directions Considered in this Study

| Wind Direction | N | NNE | NE | ENE | E | ESE | SE | SSE | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency | 1.3% | 1.7% | 2.5% | 3.9% | 7.9% | 7.6% | 6.6% | 8.2% | |
| Wind Direction | S | SSW | SW | WSW | W | WNW | NW | NNW | **SUM** |
| Frequency | 9.0% | 13.3% | 14.8% | 10.2% | 5.9% | 2.3% | 2.5% | 1.8% | **77.6%** |

** The wind frequency showing in red colour represents the recommended wind direction for the CFD simulation.*

### 3.2.3 Wind Profiles

The wind profile from RAMS at the corresponding location is also adopted in the study, shown in Figure 5. It is recommended to extract the RAMS wind profile data from 10 – 500m directly as it can reflect the exact wind data. 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 discretisation 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 $z_G$

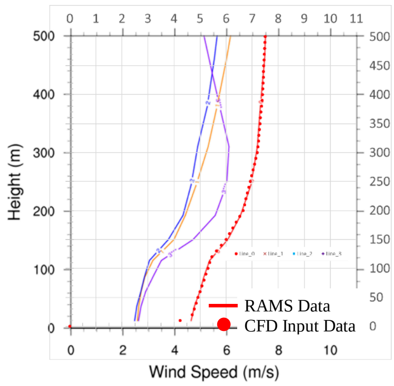
$Z_G$ = reference height

$Z$ = height above ground

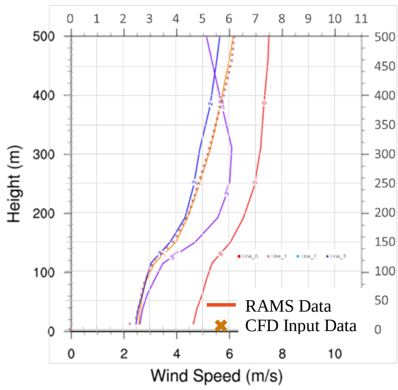
$U_Z$ = velocity at height $z$

$\boldsymbol{n}$ = power law exponent

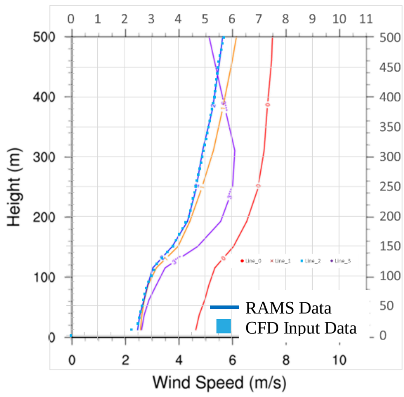
The power ***n*** is related to the ground roughness. A larger value of the power **n** represents the higher roughness of the ground i.e. the dense city. Alternatively, smaller ***n*** represents the lower ground roughness i.e. the sea surface.



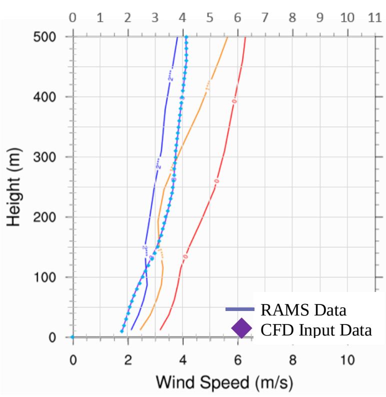

Simulated wind profile 22.5º – 112.4º




Simulated wind profile 112.5º – 202.4º




Simulated wind profile 202.5º – 292.4º




Simulated wind profile 292.5º – 22.5º

Figure 5 RAMS wind profiles for the location grid (x:093, y:043)

# 4 Design Schemes for AVA Study

To investigate the ventilation impacts of the Development. Two schemes, the Baseline Scheme and the Proposed Scheme are to be analysed and compared in this AVA Study.

## 4.1 Baseline Scheme

The Baseline Scheme is formulated following all APP-152 requirements. The Development consists of two 34-storey residential towers, of which the height is ~+302.40 mPD and the gross site area is approximately 1.42 hectares. A 1-storey retail block is located at the south part of the Development. The enhancement features are as below:

- Two G/F empty bay of ~11m and ~5m is located at Block A
- A G/F empty bay of ~8m is located at Block B
- A ~5m opening is located on the western portion of the retail block

The 3D model of the Baseline Scheme was constructed and shown in Figure 7 to Figure 10.

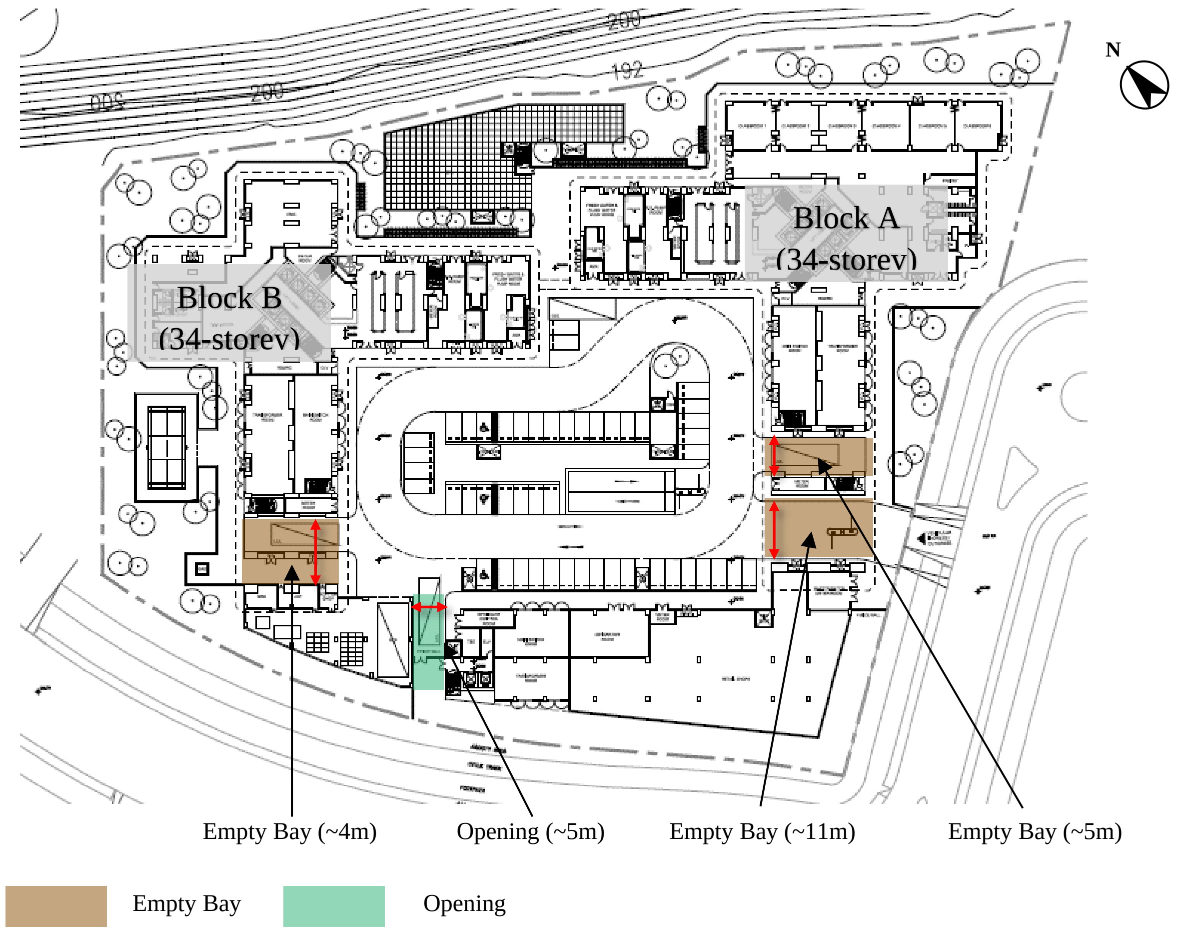



Figure 6 Building Massing of Baseline Scheme


Figure 7 Model of Baseline Scheme, Northerly View

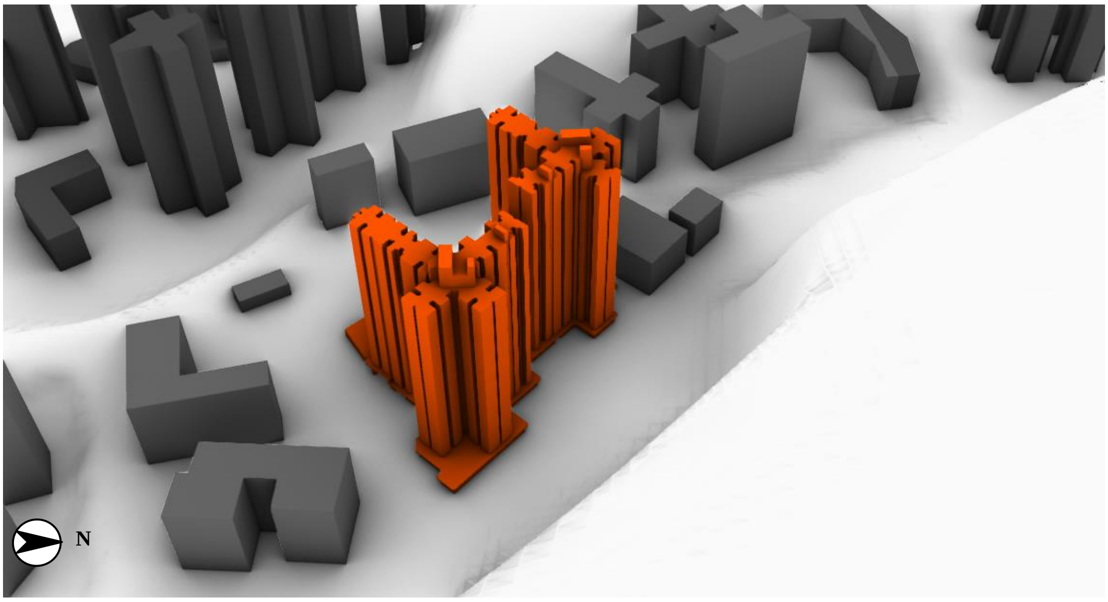



Figure 8 Model of Baseline Scheme, Easterly View


Figure 9 Model of Baseline Scheme, Southerly View

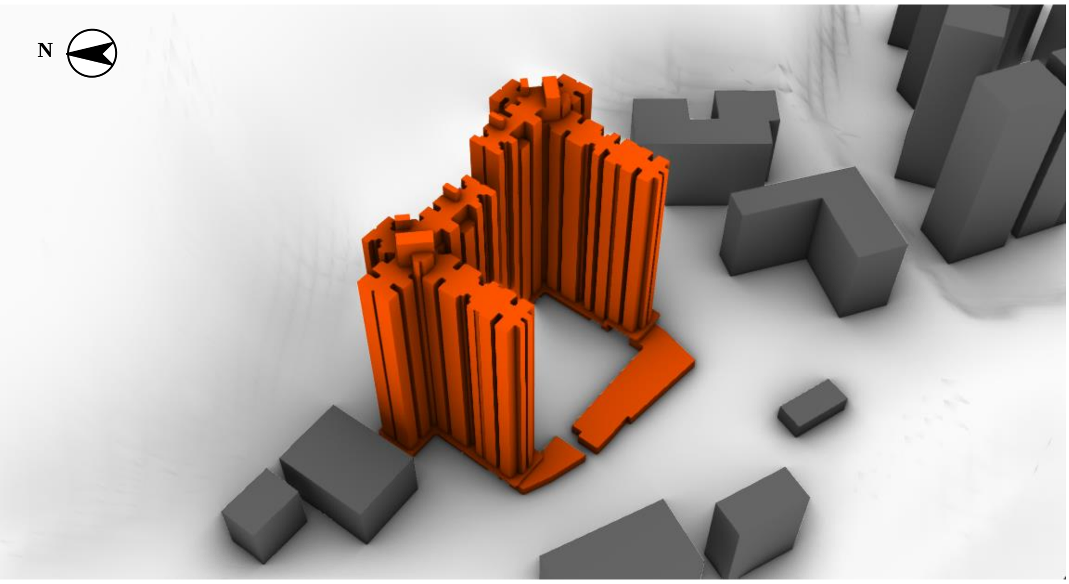



Figure 10 Model of Baseline Scheme, Westerly View

## 4.2 Proposed Scheme

The Proposed Scheme is the intended development scheme. The Development consists of two 34-storey residential towers, namely Block A and Block B. The height of both towers is +298.24 mPD and the gross site area is approximately 1.42 hectares. A 1-storey retail block is located at the south part of the Development.

The changes made as compared to the Baseline Scheme is listed below:

- G/F empty bay at Block B is widened from ~4m to ~6m.
- An additional G/F empty bay of ~14m is located at Block B.
- At Block A, the ~11m G/F empty bay is preserved and the ~5m G/F empty bay is widened to ~7m.
- The opening through the retail block is widened to ~8m and is located at the centre of the retail block.
- An opening of ~3m is located between Block A and the retail block to enhance permeability of the Development.
- A more rounded massing of the retail blocks

3D model of the Proposed Scheme was constructed and is shown in Figure 12 to Figure 15.

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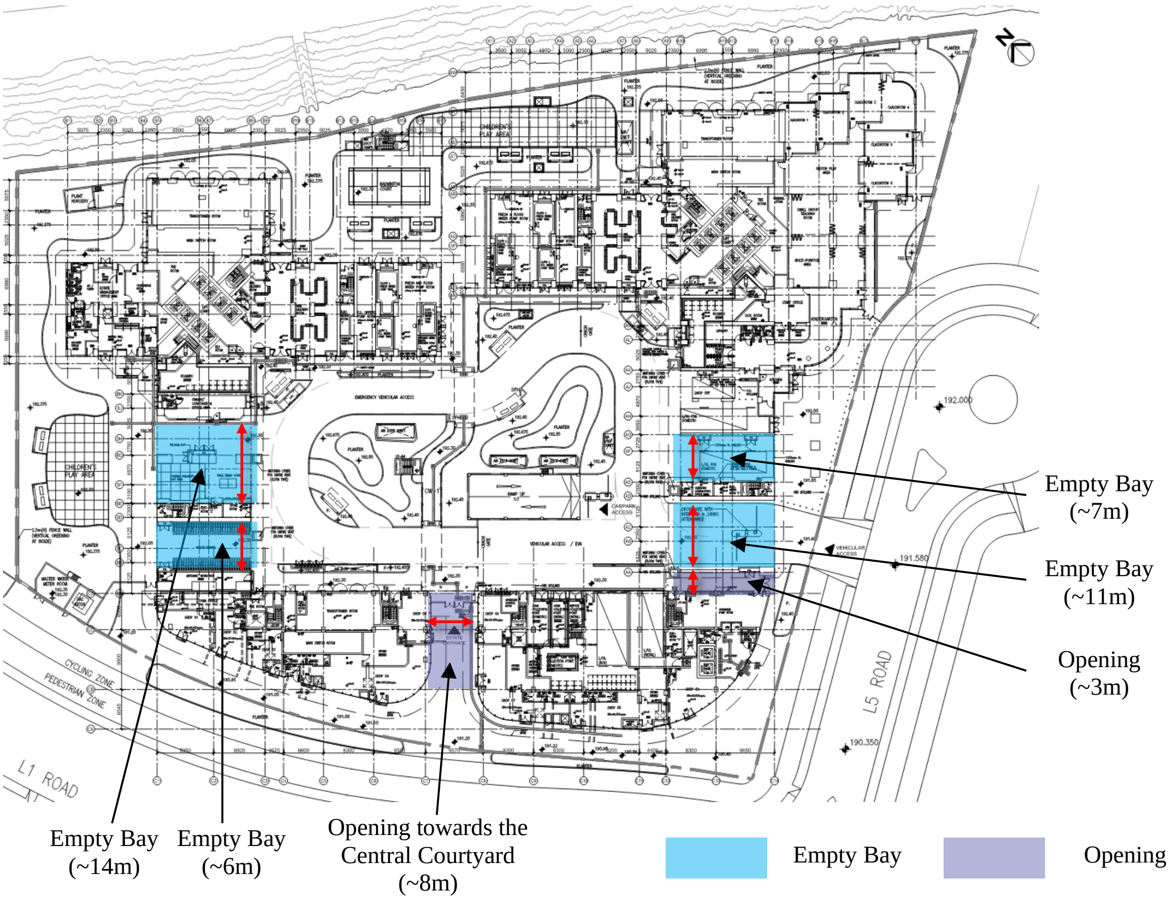



Figure 11 Building Layout of Proposed Scheme


Figure 12 Model of Proposed Scheme, Northerly View

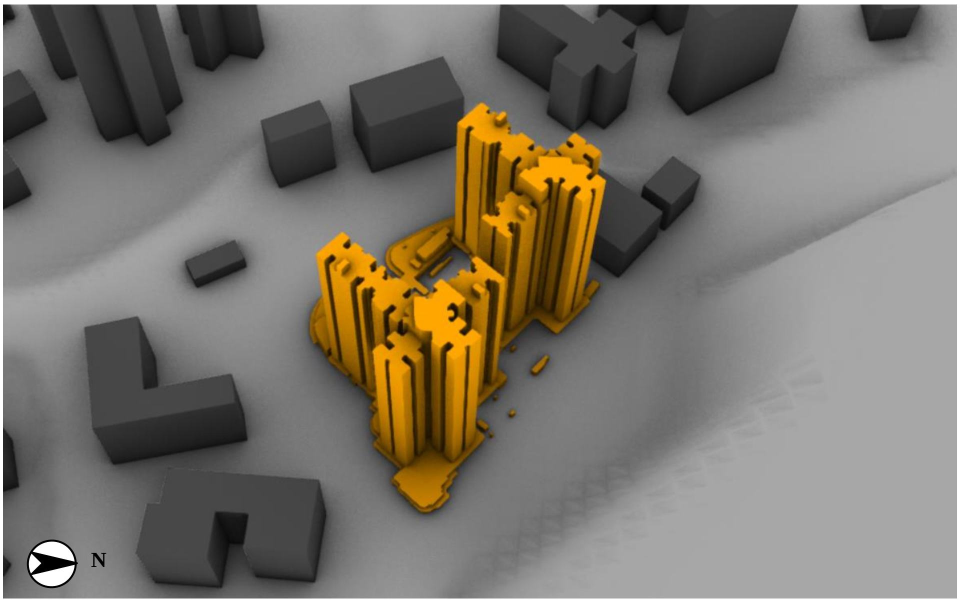



Figure 13 Model of Proposed Scheme, Easterly View


Figure 14 Model of Proposed Scheme, Southerly View


Figure 15 Model of Proposed Scheme, Westerly View

# 5 Methodology

The AVA methodology as stipulated in the Technical Circular and Technical Guide is used for this study. The following sections describe the details of the study methodology.

## 5.1 Project Assessment and Surrounding Areas

With reference to the Technical Guide, the areas of evaluation and assessment should include all area within the Project Area, 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.

Under the two development scenarios, the tallest building of the Development is around H=112.1m. In order to capture a more representative wind profile of the surrounding area of the Development, the Surrounding Area is extended southwards to Lam Tsuen River, which extends far beyond the required 2H as stated in the Technical Guide. The Assessment and Surrounding Areas are indicated in Figure 16.

The size of the computation domain for the AVA study is approximately 2250m(L) x 1900m(W) x 2200m(H) as shown in Figure 17.

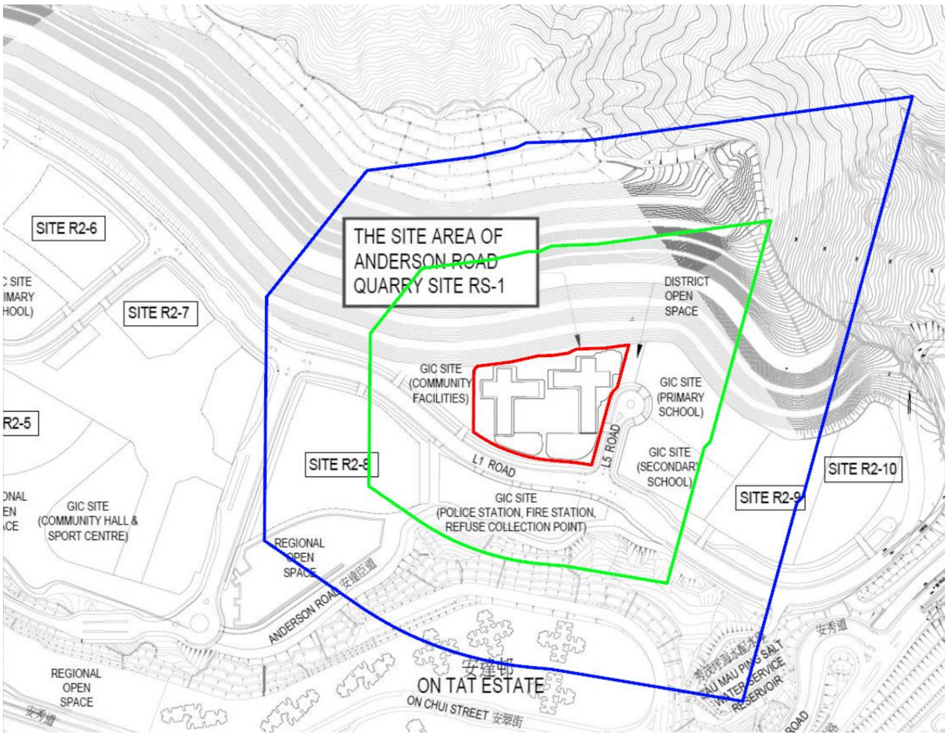



Figure 16 Project Area, Assessment Area, Surrounding Area for the Study

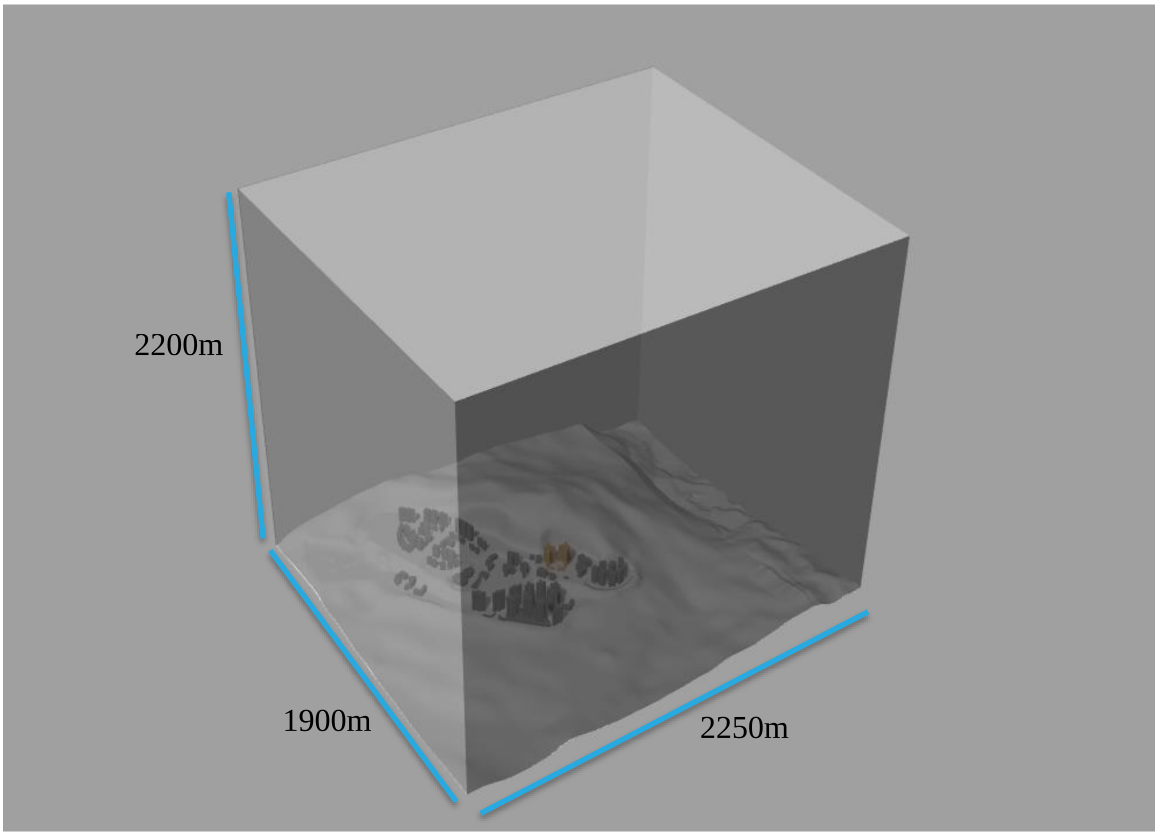



Figure 17 Computation Domain of the AVA Study

## 5.2 Technical Details for CFD simulation

### 5.2.1 Assessment Tool

Computational Fluid Dynamics (CFD) technique is utilized for the AVA Study. Well recognised commercial CFD packages ANSYS ICEM-CFD and STAR-CCM+ are 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, is simulated under the prevailing wind conditions in a year.

### 5.2.2 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. The expansion ratio is 1.3 while the maximum blockage ratio is 3%.

Finer grid system is 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.

### 5.2.3 Turbulence Model

As highlighted in recent academic and industrial research literatures by CFD practitioners, the widely used standard $k$ - $\varepsilon$ 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.

### 5.2.4 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 as mentioned in Section 0 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*.

### 5.2.5 Summary

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

| Parameters | 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** | ~2250m(L) x 1900m(W) x 2200m(H) |
| **Assessment Area** | ≥ 1H area |
| **Surrounding building Area** | ≥ 2H area |
| **Grid Expansion Ratio** | The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.3 |
| **Prismatic layer** | 6 layers of prismatic layers and 0.5m each (i.e. total 3m above ground) |
| **Inflow boundary Condition** | Incoming wind profile as extracted 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<br>Hybrid model for all other equations |
| **Blockage ratio** | < 3% |
| **Convergence criteria** | Below $1.0 \times 10^{-4}$ |

## 5.3 AVA Indicator

The Wind Velocity Ratio (VR) as proposed by the *AVA 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:

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

$V_\infty$= the wind velocity at the top of the wind boundary layer (assumed to be the mean wind speed of the approaching wind flow measured at an elevation equivalent to 500mPD in this study).

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

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 wind condition.

### 5.3.1 Assessment Parameter

CFD simulations were conducted to study the wind environment. As specified in the Technical Circular, indicator of ventilation performance should be the 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 3 Terminology of the AVA Initial Study

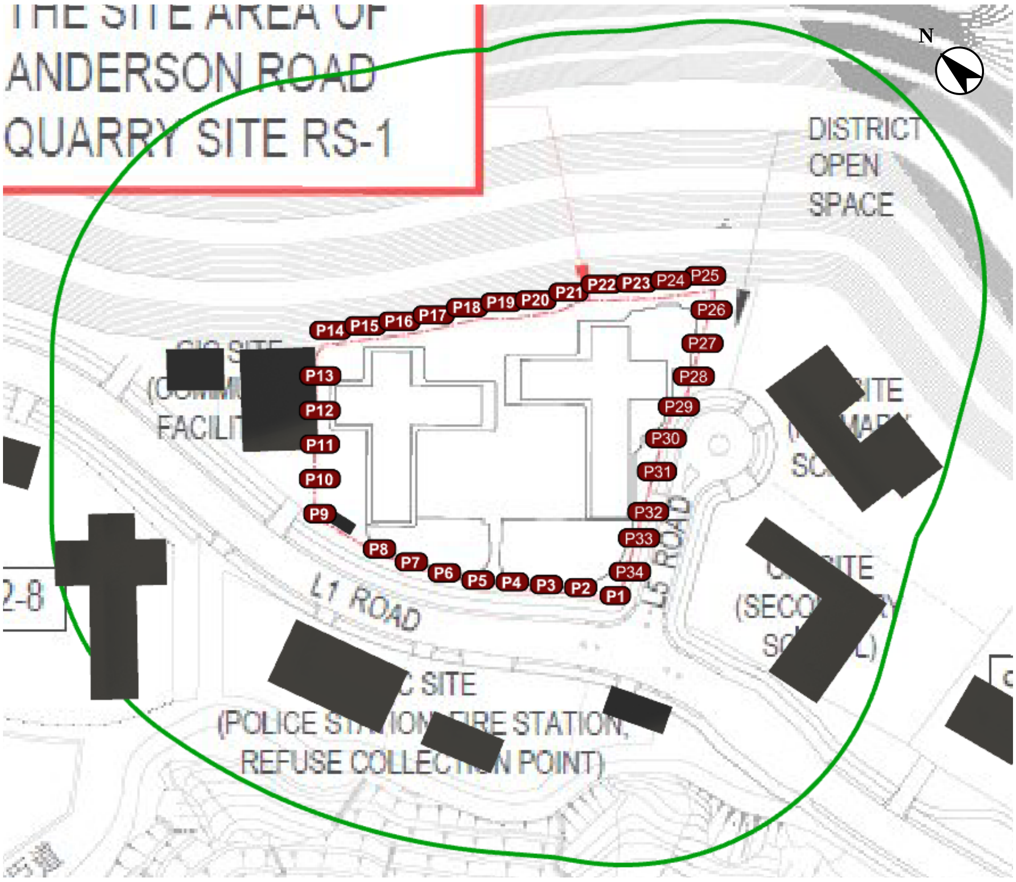
| Terminology | Description |
|---|---|
| **Velocity Ratio (VR)** | The velocity ratio (VR) represents the ratio of the air velocity at the measurement position to the value at the reference points. |
| **Site spatial average velocity ratio (SVR)** | The SVR represent the average VR of all perimeter 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 Point Location

As per the technical circular, two types of test points – perimeter test point and overall test point will be adopted to assess the wind performance within the Assessment Area. The allocation of these test points will be distributed evenly as stated in the *AVA Technical Circular*

### 5.4.1 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 test points are positioned at an interval of 10-15m alongside the site boundary where pedestrians can frequently access. In total there are 34 perimeter test points (**brown** points) in this study. The test point locations are shown in Figure 18.

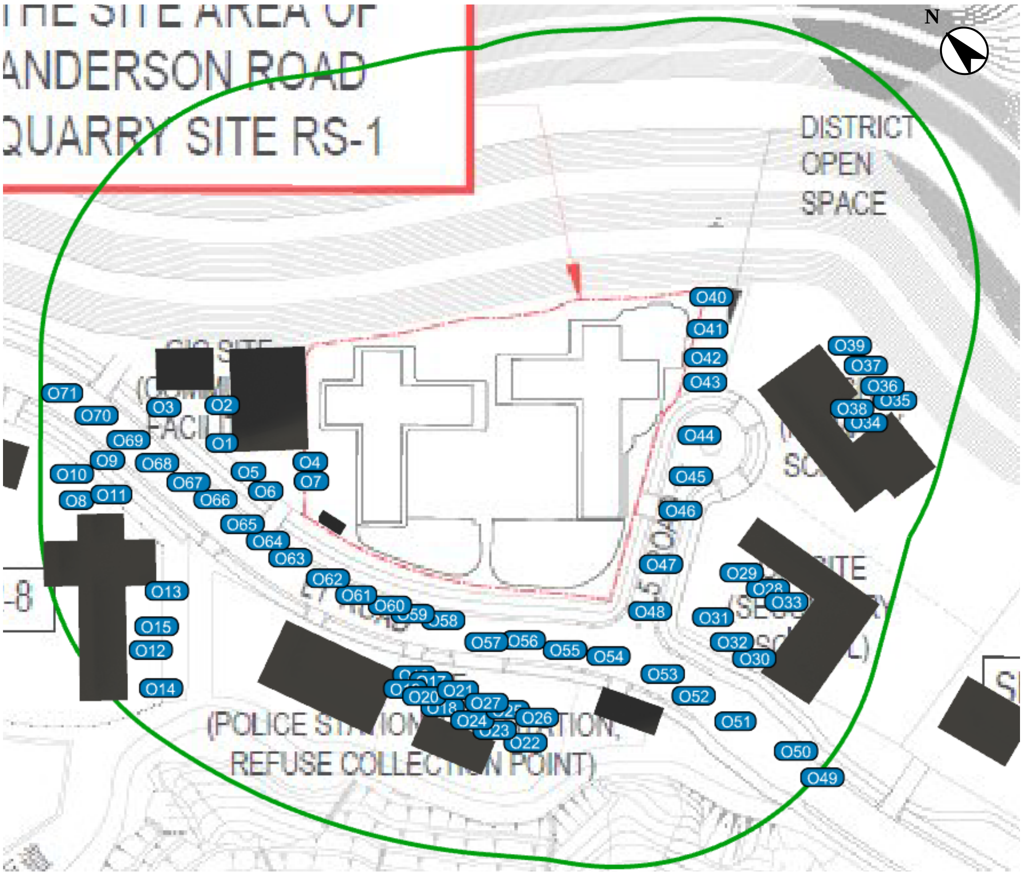



Site Boundary
Assessment Area

Figure 18 Location of Perimeter Test Points

### 5.4.2 Overall Test Points

Overall test points are the points evenly positioned in the open area on the streets and places where pedestrian frequently access within the assessment area. In total there are 71 overall test points (Blue points) within the assessment area are shown in Figure 19.




Site Boundary
Assessment Area

Figure 19 Location of Overall Test Points

## 5.5 Focus Area

Various Focus Areas with frequent pedestrian access and major activity zones were defined, these areas are as below:

1. Planned Community Facility
2. Planned Site R2-8 Development
3. Planned Police Station, Fire Station and Refuse Collection Point
4. Planned Secondary School Open Space
5. Planned Primary School Open Space
6. Planned District Open Space
7. Planned Road L5
8. Planned Road L1

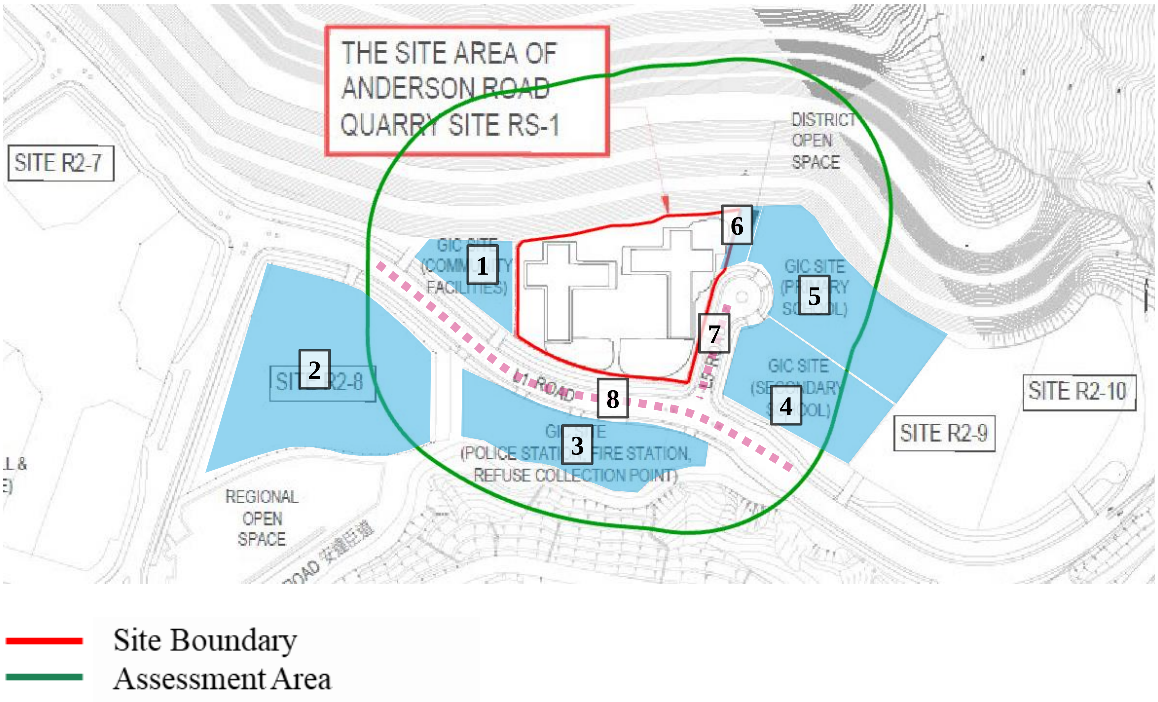



Figure 20. Location of Focus Areas

# 6 Results and Discussion

This section discussed on the anticipated air ventilation performance of the Proposed Scheme as compared with Baseline Scheme. Quantitative assessment has been conducted comparing among Baseline Scheme and Proposed Scheme using computational fluid dynamics.

## 6.1 Annual Overall Wind Performance

The prevailing wind would generally come from NNE to E quadrant. The SVR and LVR are tabulated in Table 4.

Table 4 SVR and LVR under Annual Condition

| | Baseline Scheme | Proposed Scheme |
|---|---|---|
| SVR | 0.32 | 0.32 |
| LVR | 0.30 | 0.31 |

The Proposed Scheme has achieved a higher LVR by 0.01 and an equivalent SVR as compared to Baseline Scheme.

Generally, the overall wind environment of Proposed Scheme is slightly better than that in Baseline Scheme The annual prevailing wind would contribute to approximately 76.2% of the annual condition.

While some prevailing wind would reach the Development directly from the south eastern quadrant, the high Tai Sheung Tok would divert some of the prevailing wind to arrive at the site from the northwest. Generally, wind would be downwashed by the south-eastern façade of Block A, which would then travel along the Planned Road L5 and reach the Planned Road L1.

Under Proposed Scheme, in which the Development has retail blocks with a more rounded massing, more wind travelling along the Planned Road L5 would be diverted to travel along the Planned Road L1 as compared to Baseline Scheme, areas such as the Planned Road L1 itself and the Planned Police Station, Fire Station and Refuse Collection Point would therefore be more ventilated. Moreover, under Proposed Scheme, the eastern façade of Block A is aligned with its podium outline, therefore more wind captured by the eastern façade would be downwashed directly to the pedestrian level, ventilating Road L5 and the adjacent areas.

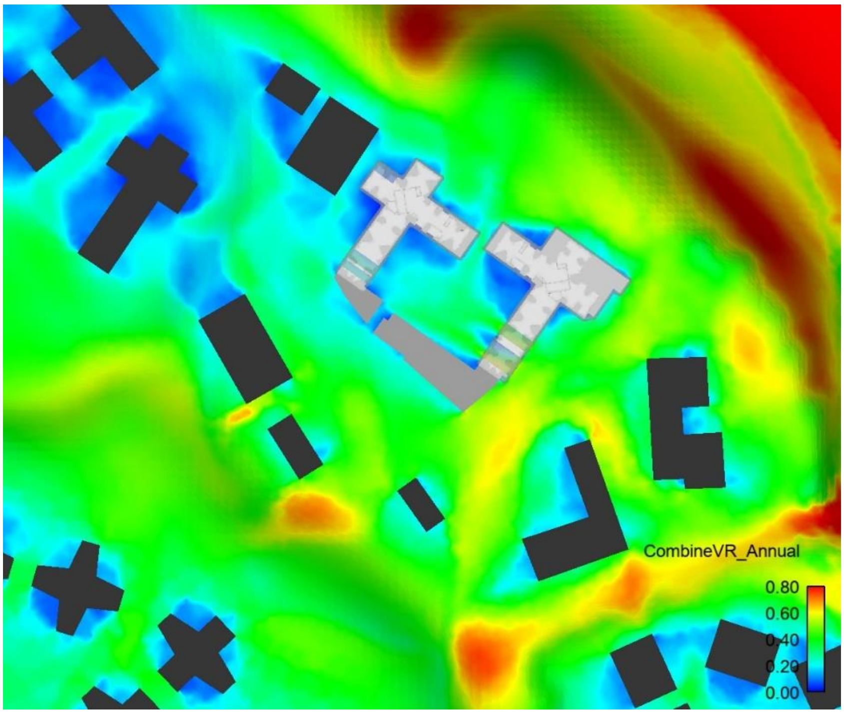



Figure 21 Average annual VR contour plots for Baseline Scheme

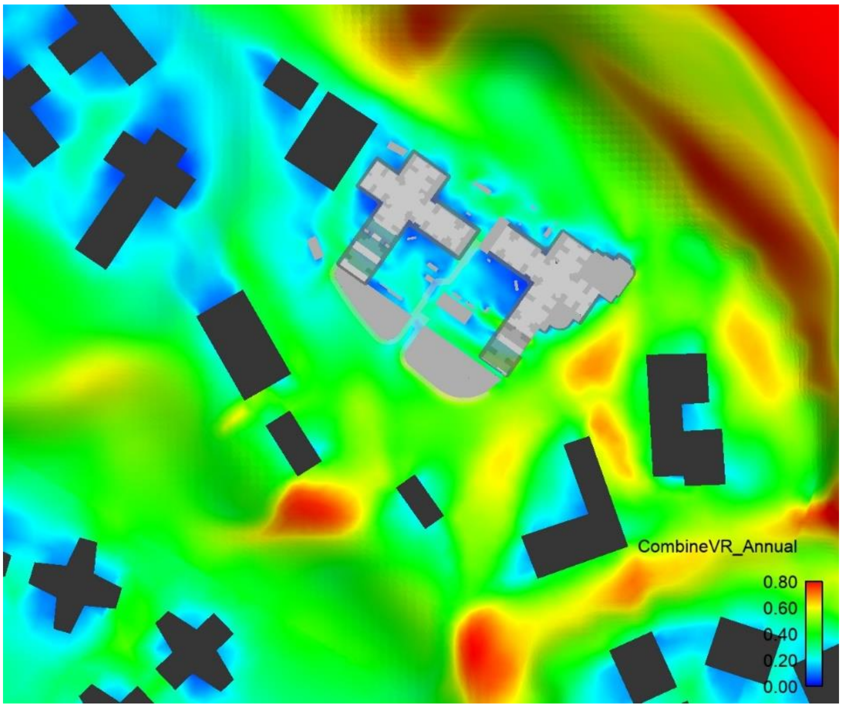



Figure 22 Average annual VR contour plots for Proposed Scheme

## 6.2 Summer Overall Wind Performance

Summer prevailing wind comes generally from the S to SW quadrant. The SVR and LVR are tabulated in Table 5.

Table 5 SVR and LVR under Summer Condition

| | Baseline | Proposed Scheme |
|---|---|---|
| SVR | 0.27 | 0.27 |
| LVR | 0.26 | 0.26 |

The Proposed Scheme here has achieved an equivalent performance as the Baseline Scheme. The summer prevailing wind would contribute to approximately 77.6% of the summer condition.

The upwind surroundings of the Development are mainly high-rise buildings from the On Tat Estate, through the building separations of which the prevailing wind would travel. The prevailing would then reach the site and be captured and downwashed by the southern façades of both blocks. Some prevailing would also reach the Development at pedestrian level by travelling through the building separation of the Planned Police Station, Fire Station and Refuse Collection Point.

With larger and more G/F empty bays at Block B, more prevailing wind downwashed by the façades facing the centre of the Development would penetrate through the G/F empty bays at Block B and ventilate the north-western surroundings of the Development, such as the Planned Community Facility.

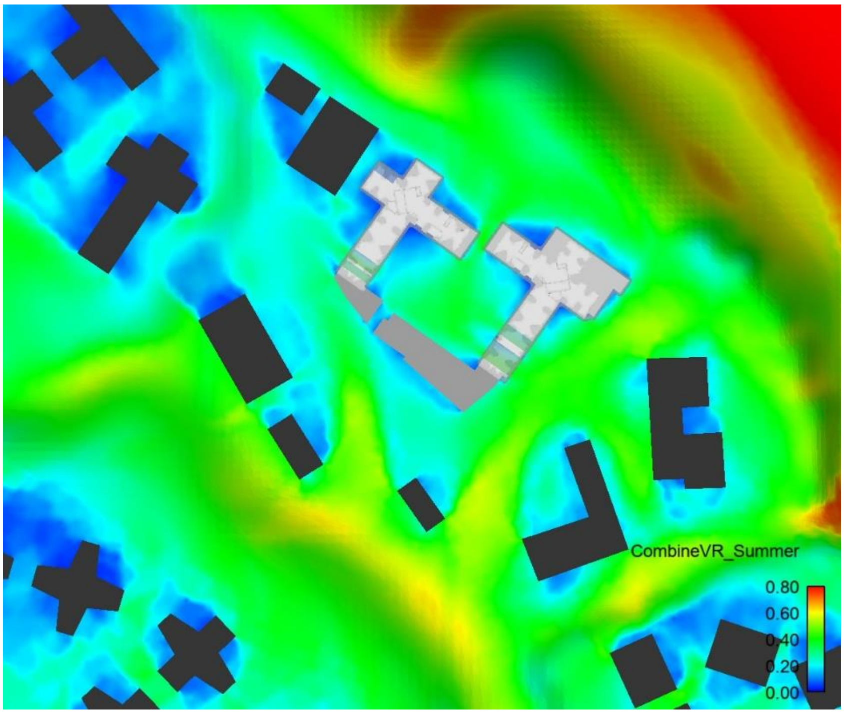



Figure 23 Average summer VR contour plots for Baseline Scheme

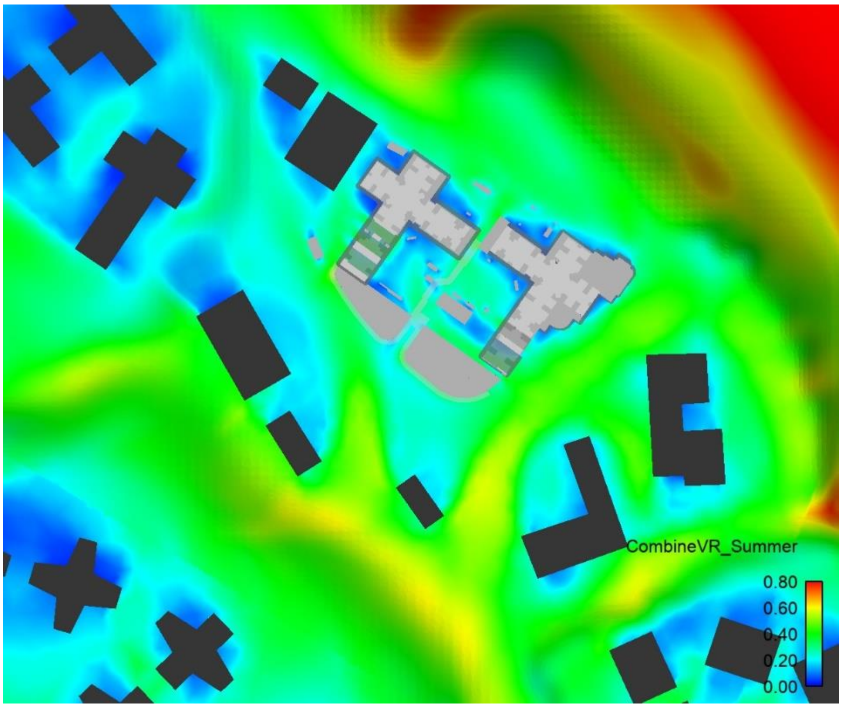



Figure 24 Average summer VR contour plots for Proposed Scheme

## 6.3 Directional Analysis

### 6.3.1 NNE Wind

The prevailing wind coming from NNE wind would contribute to 5.1% in annual condition. The overall ventilation performance under NNE wind can be summarised as below.

Most of the prevailing wind would not arrive at the Development directly from the NNE directions, instead it would be diverted by the high Tai Sheung Tok to flow towards the Development from the north-west along the Planned Road L1. A portion of the incoming wind along the Planned Road L1 would then flow around the Planned Community Facility to reach the north-eastern boundary of the Development (**Blue Arrow**). Another portion would later on be diverted around the corner of the Retail Block to travel along Planned Road L5 (**Red Arrow**).

Under Proposed Scheme, the massing of the Retail Blocks has a rounded massing which facilitate wind flowing along the Planned Road L1 to divert to Planned Road L5 (**Red Arrow**), the Planned Road L5 and the southern portion of the Planned District Open Space would therefore be more ventilated under Proposed Scheme.

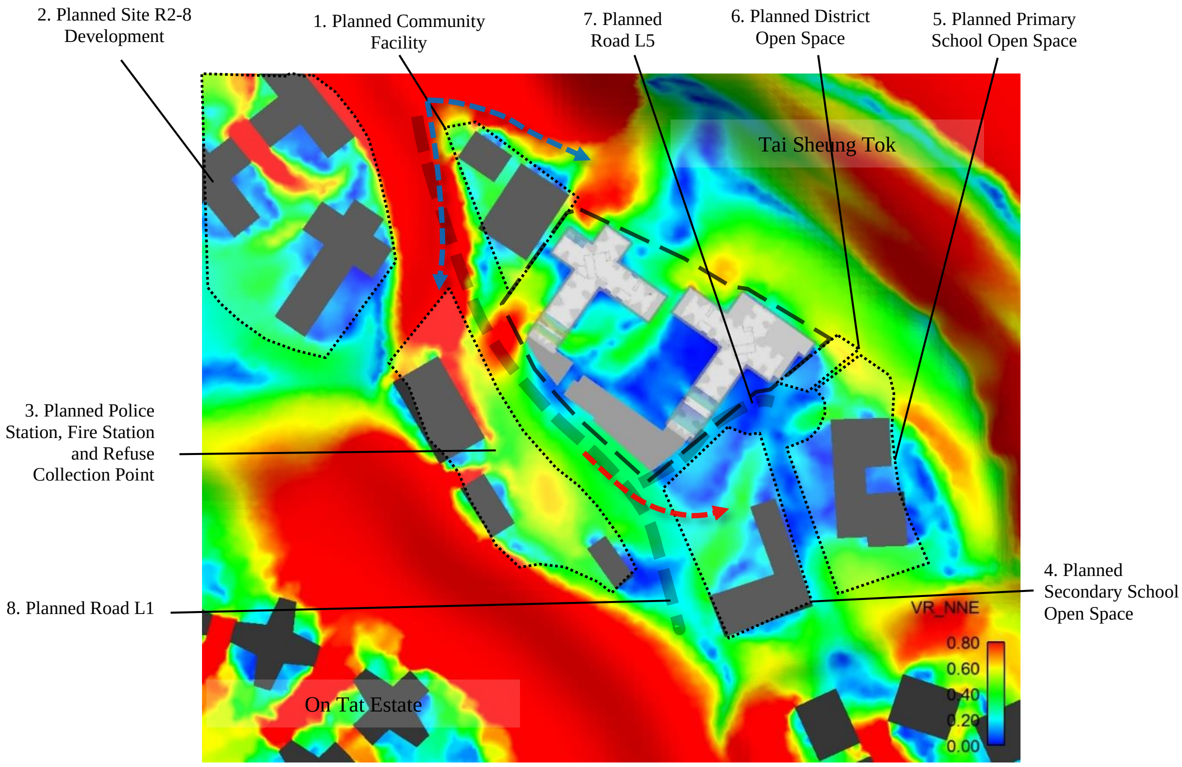



Figure 25 NNE wind VR contour plots for Baseline Scheme

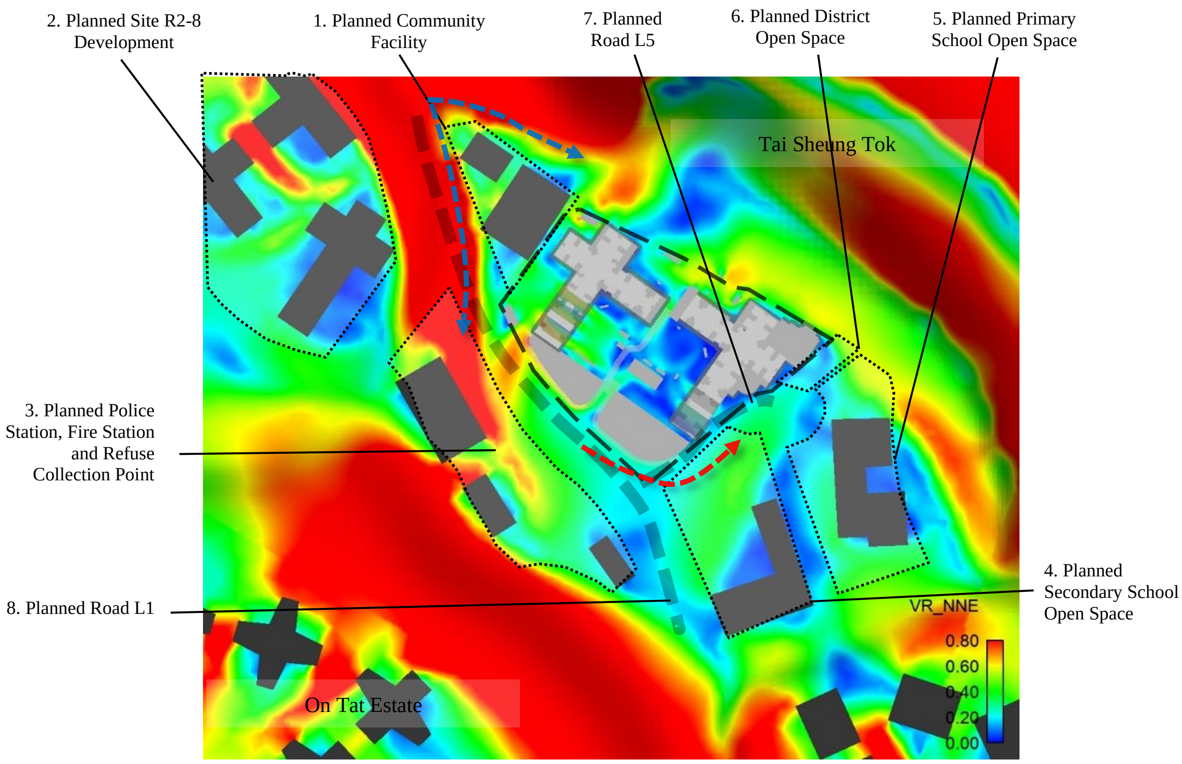



Figure 26 NNE wind VR contour plots for Proposed Scheme

### 6.3.2 NE and ENE Wind

The prevailing wind coming from NE and ENE would contribute to 8.5% and 16.5% in annual condition. The overall ventilation performance under NE and ENE can be summarised as below.

Under both wind conditions, prevailing wind would reach the Development through the building separation between the Planned Primary School and Secondary School, a portion of which would then travel along Planned Road L5 whereas another portion would penetrate into the centre of the Development through the Block A G/F empty bays (**Black Arrows**).

Under NE wind condition, more prevailing would be downwashed by the north-eastern façades of the Development (**Orange Arrow**) under Baseline Scheme as compared to Proposed Scheme, which is due to a taller roof under Baseline Scheme.

The more rounded massing of the retail block under Proposed Scheme has facilitated ENE and NE wind flowing along the Planned Road L5 to be diverted towards the Planned Road L1; this would help ventilate Planned Road L1 and the Planned Police Station, Fire Station and Refuse Collection Point (**Red Circle**).

The VR at the southern portion of Planned Road L5 in Baseline Scheme under ENE wind would be slightly higher than that in Proposed Scheme; this is because more mid-level wind under Baseline Scheme captured by the southeastern façade of Block A (**Pink Arrow**) would be downwashed to pedestrian level due to a smaller Block A podium. As a result, wind coming from between the Planned Primary and Secondary School would be diverted by the downwashed wind to travel towards Planned Road L1. This would ventilate the southern portion of the Planned Road L5 and a localised portion of the Planned Road L1 where it intersects with Planned Road L5 (**Purple Circle**). On the other hand, under Proposed Scheme, because less wind would be downwashed to the pedestrian level, wind coming from between the Planned Primary and Secondary School would travel towards the northern portion of the Planned Road L5 and the Planned District Open Space to ventilate these areas (**Blue Circle**), making their VR higher than that in the Baseline Scheme.

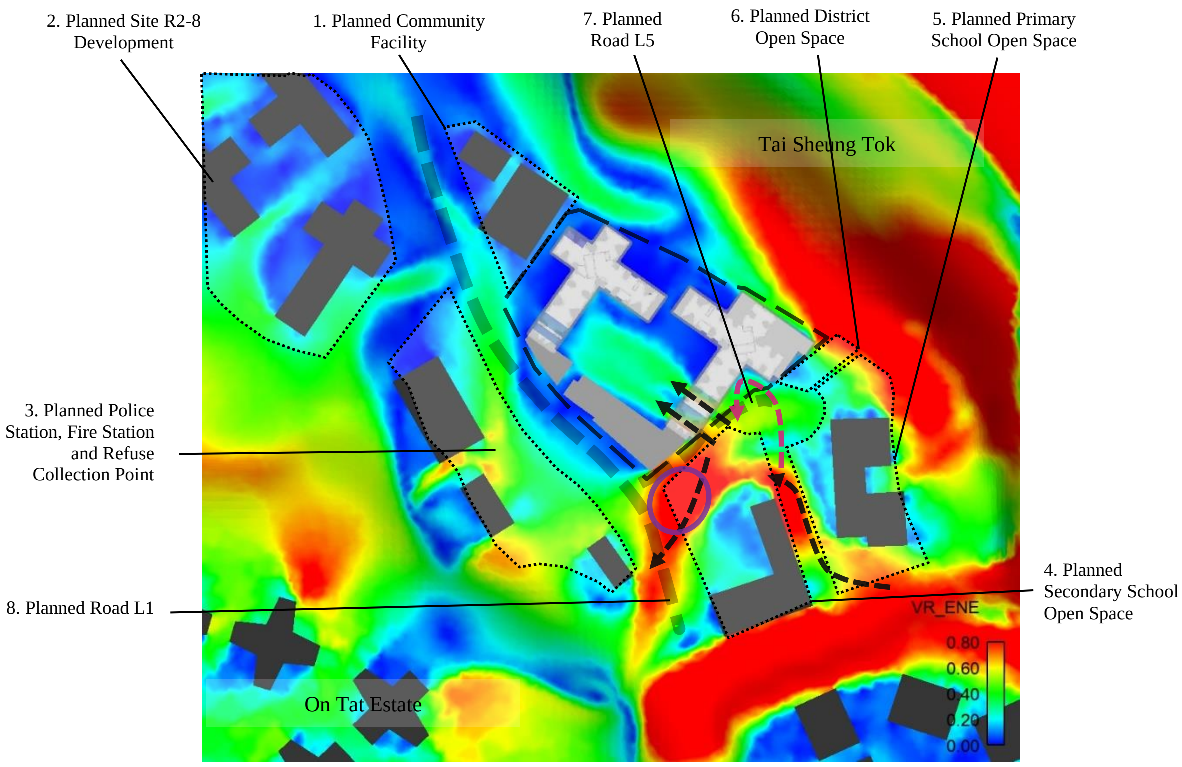



Figure 27 ENE wind VR contour plots for Baseline Scheme

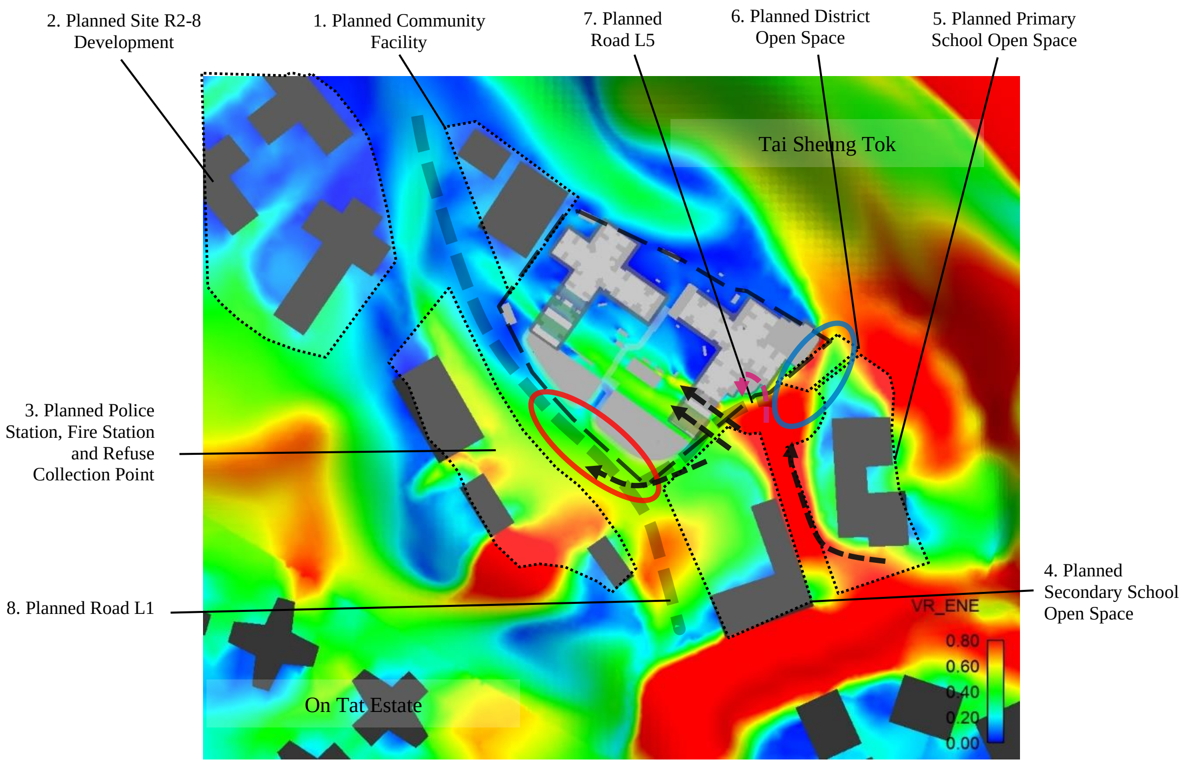



Figure 28 ENE wind VR contour plots for Proposed Scheme

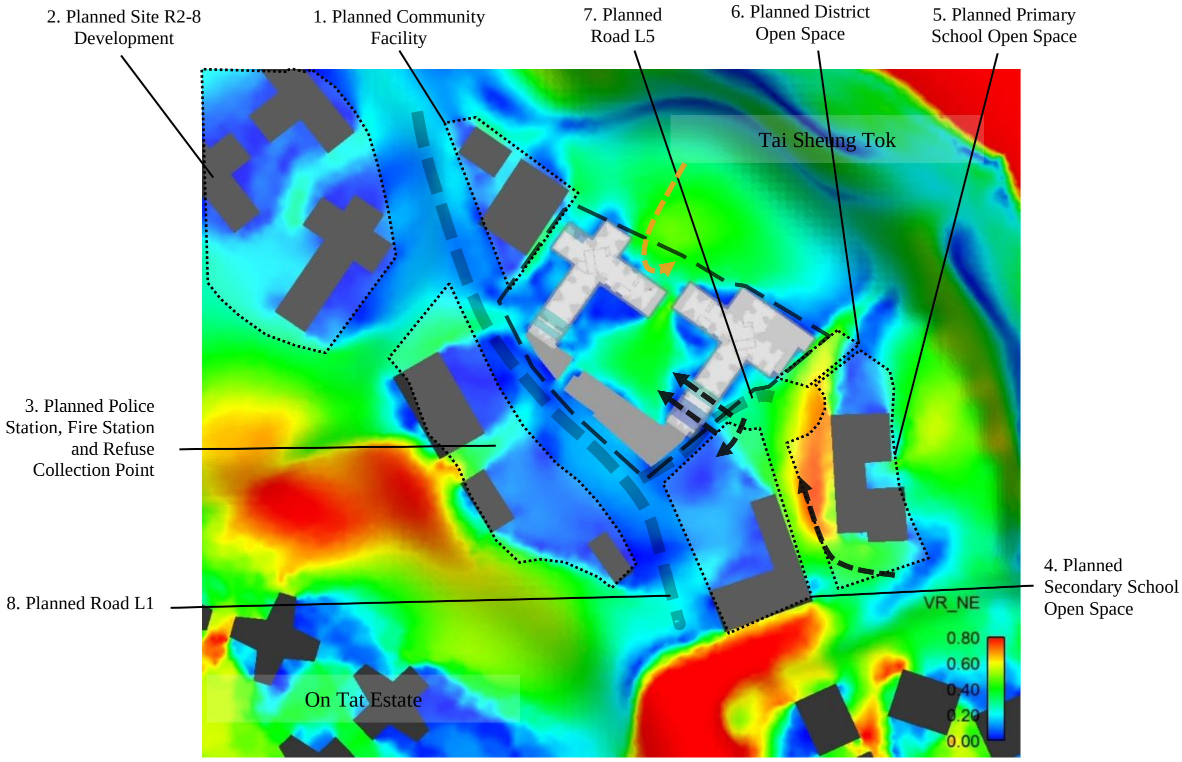



Figure 29 NE wind VR contour plots for Baseline Scheme

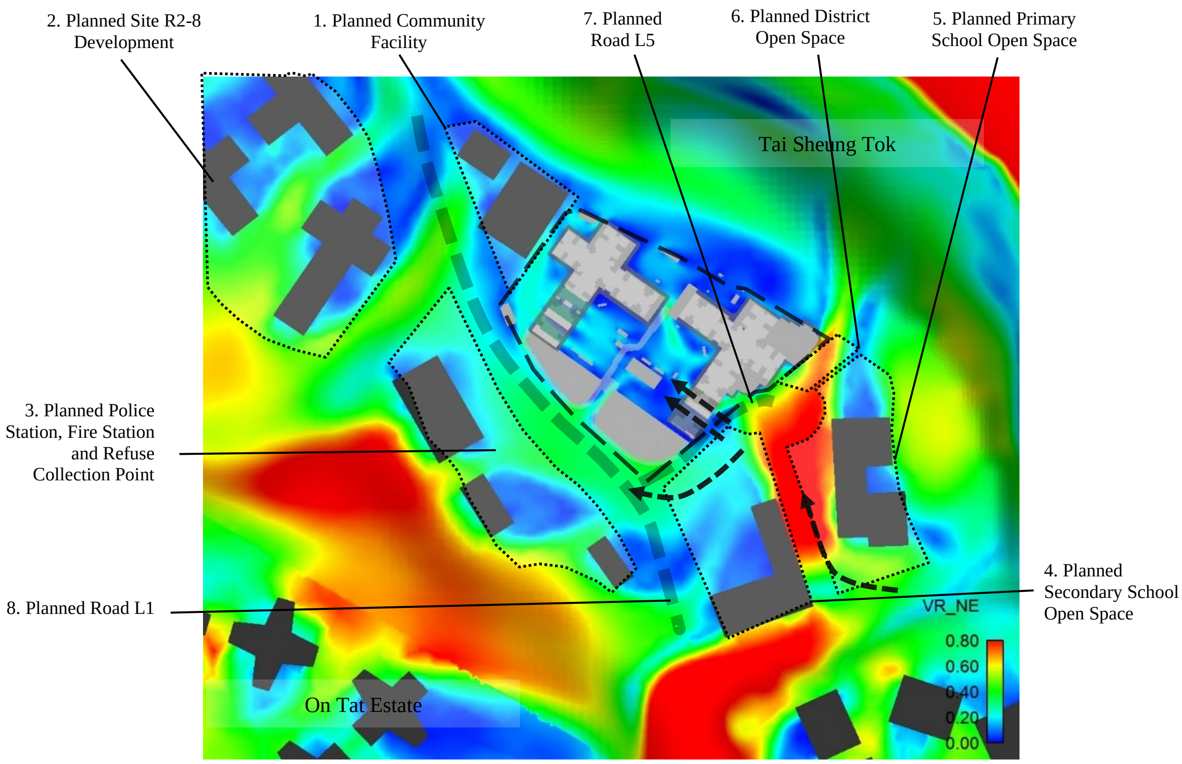



Figure 30 NE wind VR contour plots for Proposed Scheme

### 6.3.3 E and ESE Wind

The prevailing wind coming from E would contribute to 17.8% and 7.9% in annual and summer conditions, and ESE to 9.2% and 7.6% in annual and summer condition. The overall ventilation performance under E and ESE wind can be summarised as below.

Under both Baseline and Proposed Scheme, incoming E and ESE wind would skim over the eastern surroundings and arrive directly at the mid and high levels of the Development. The wind would be captured and downwashed by the south-eastern façade of Block A (**Purple Arrow**), a portion of the downwashed wind would then stream along Planned Road L5 to reach Planned Road L1, whereas another portion would penetrate into the centre of the Development through the G/F empty bay at Block A (**Black Arrows**).

In both wind conditions, the more rounded massing of the retail block under Proposed Scheme has also facilitated wind on Planned Road L5 to be diverted towards Planned Road L1, hence enhanced ventilation at Planned Road L1 under Proposed Scheme (**Black Circle**).

In ESE wind condition, a localised portion of the Planned Road L5 would have a higher VR under Proposed Scheme (**Blue Circle**); this is because the podium is aligned with the typical floor, which would allow more wind captured by the south-eastern façade of Block A to reach the pedestrian level which would then be diverted by the podium to ventilate the localised portion of the Planned Road L5.

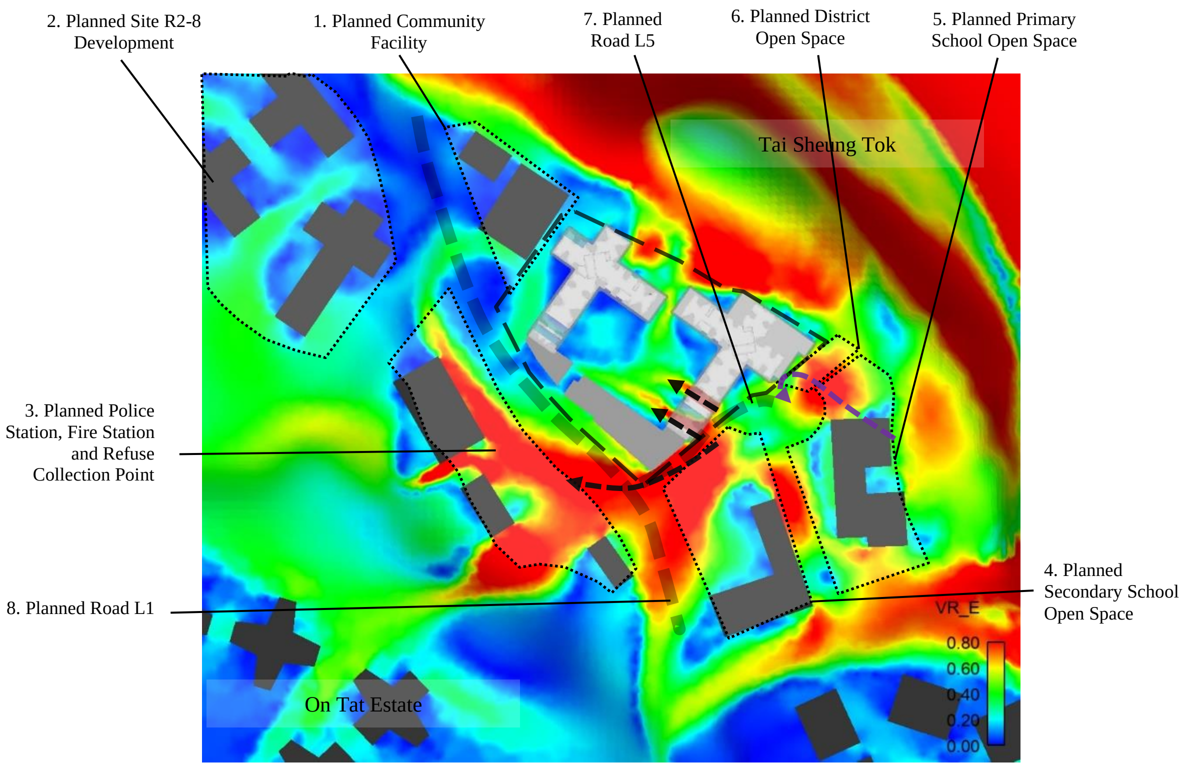



Figure 31 E wind VR contour plots for Baseline Scheme

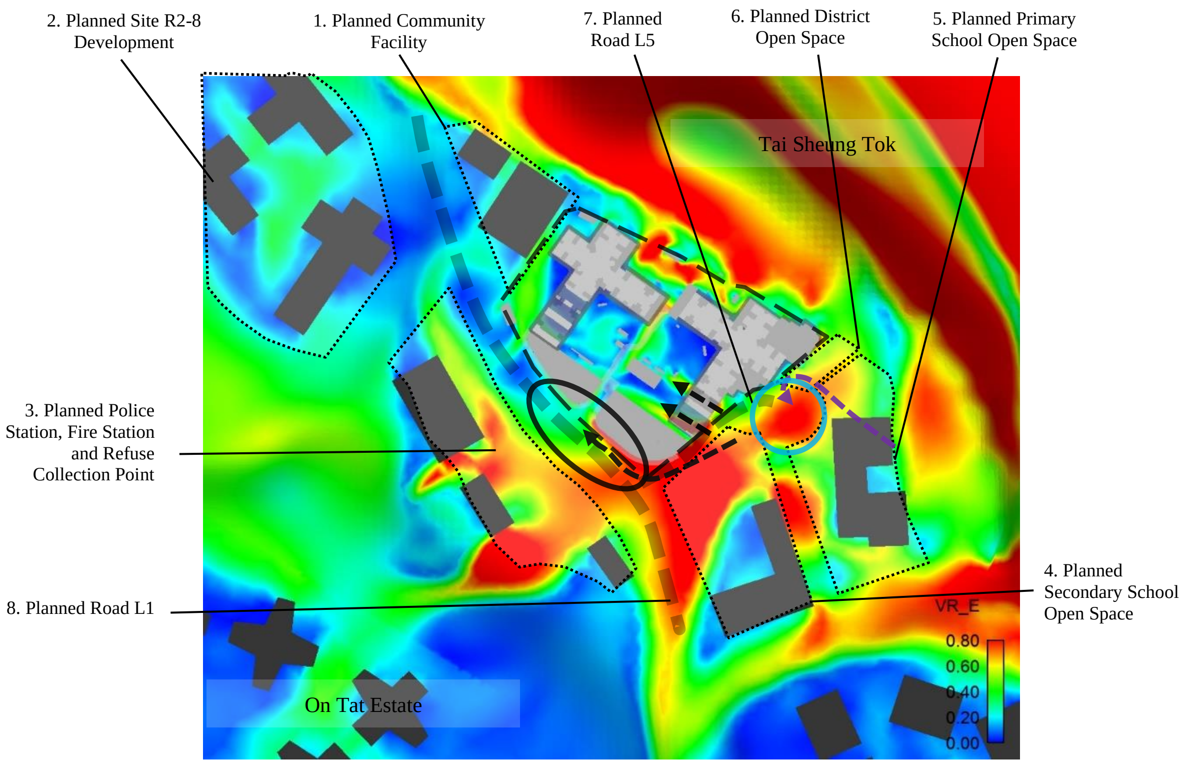



Figure 32 E wind VR contour plots for Proposed Scheme

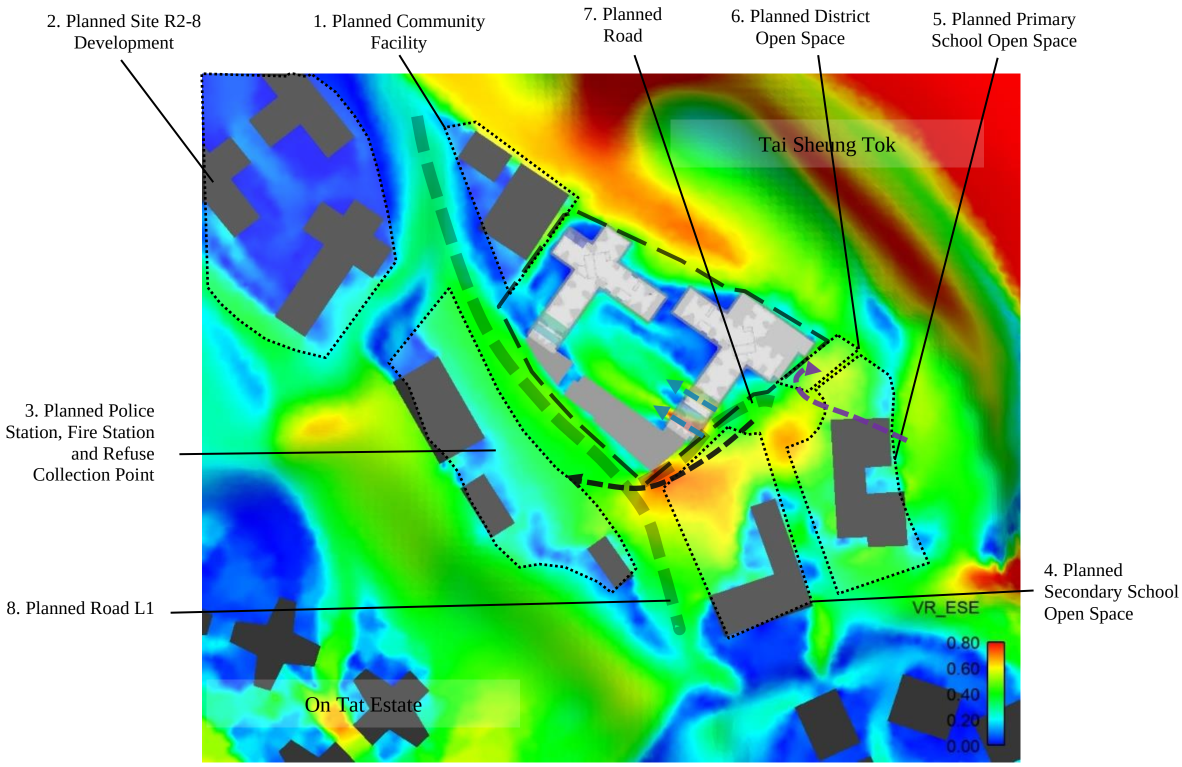



Figure 33 ESE wind VR contour plots for Baseline Scheme

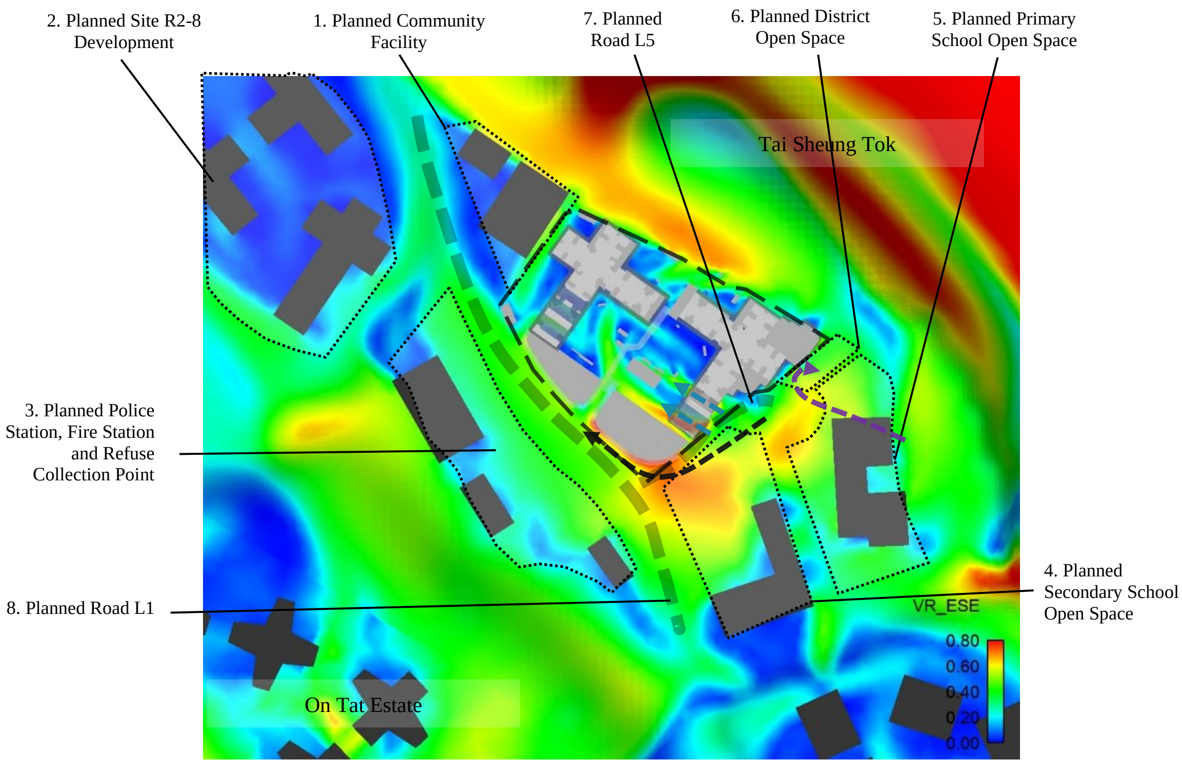



Figure 34 ESE wind VR contour plots for Proposed Scheme

### 6.3.4 SE Wind

The prevailing wind coming from SE would contributes to 6.1% and 6.6% in annual and summer conditions. The overall ventilation performance under SE wind can be summarised as below:

A portion of the incoming SE wind would skim over the southern surroundings of the Development, which would then be captured and downwashed to pedestrian level by the south-eastern façades of Block A; a portion of the downwashed wind would penetrate into the centre of the Development through the Block A G/F empty bay, whereas another portion would travel along Planned Road L5 to reach Planned Road L1(**Purple Arrow**). Some of the prevailing wind would also be captured and downwashed to pedestrian level by the façades of the Development facing the centre (**Pink Arrow**). A small portion of the prevailing wind would flow on pedestrian level, pass on the east side of On Tat Estate, and reach the southern boundary of the Development through the building separation of the Planned Police Station, Fire Station and Refuse Collection Point (**Blue Arrow**).

Under Proposed Scheme, the wind traveling along the Planned Road L5 would be diverted to travel along the Planned Road L1 more easily as it is facilitated by the more rounded massing of the retail block; this would help ventilate a portion (**Red Circle**) of the Planned Road L1.

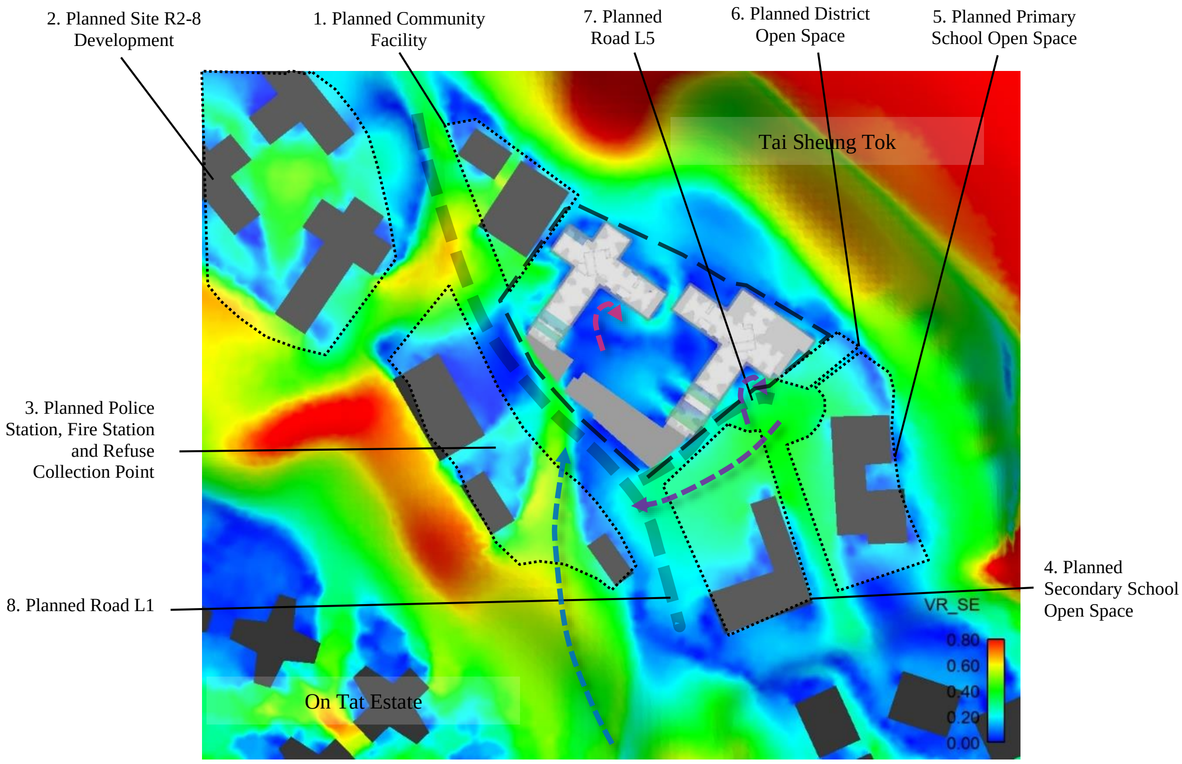



Figure 35 SE wind VR contour plots for Baseline Scheme

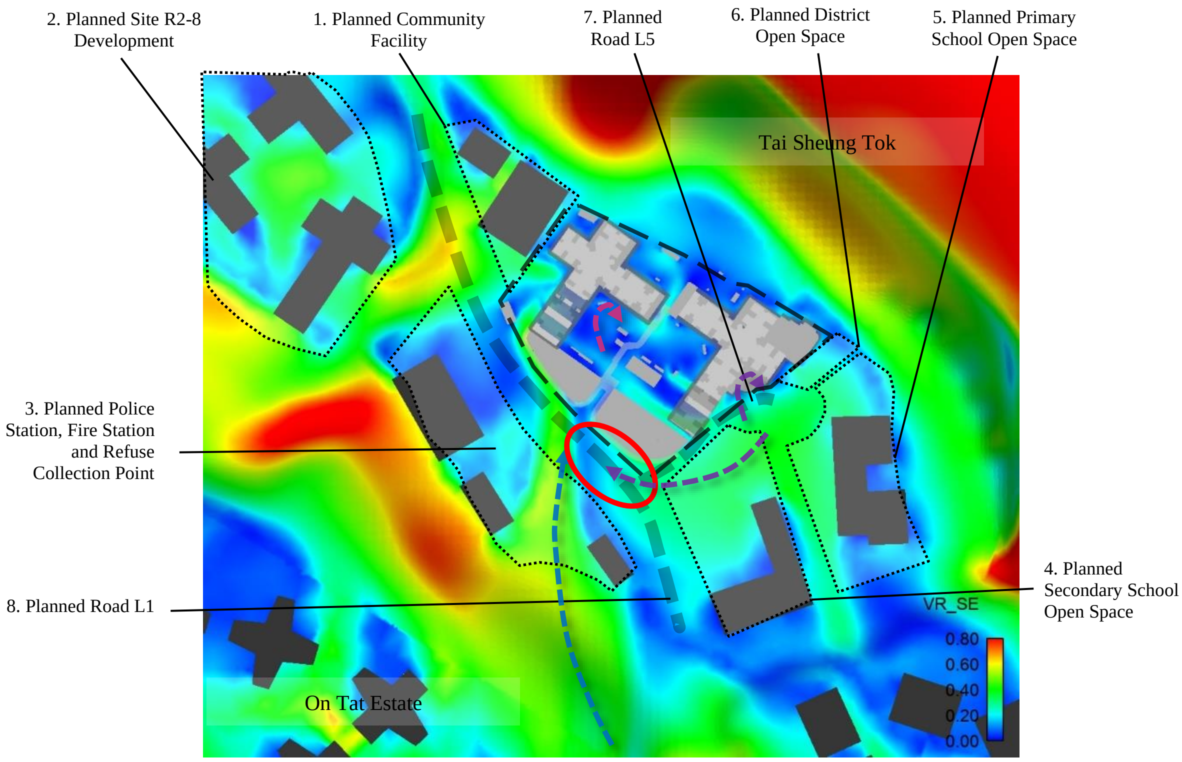



Figure 36 SE wind VR contour plots for Proposed Scheme

### 6.3.5 SSE, S and SSW Wind

The prevailing wind coming from SSE and S wind would contribute to 8.2% and 9.0% in summer condition, whereas SSW wind would contribute to 6.3% and 13.3% in annual and summer conditions respectively. The overall ventilation performance under SSE, S and SSW wind can be summarised as below.

The Development is located at an elevated position as compared to its southern surroundings, as a result, a portion of the incoming SSE, S and SSW wind would skim over the southern surroundings, which would then be captured and downwashed to pedestrian level by the southern façades of Block A (**Red Arrow**); the downwashed wind would then travel towards the Planned District Open Space and Planned Road L5. Another portion of the prevailing wind would skim over the southern surroundings and would then be captured and downwashed to pedestrian level by the façades of the Development facing the centre of the site; the downwashed wind would then penetrate the Block B G/F empty bay and reach the western surroundings (**Purple Arrows**). A portion of the prevailing wind would flow at lower level along the Planned Road L1 and reach the southern boundary of the Development (**Blue Arrows**).

Under Proposed Scheme, the enlarged Block B G/F empty bays under Proposed Scheme would facilitate wind penetrating from the centre of the Development, which would increase the ventilation experienced at the Planned Community Facility, as well as a portion of the Planned Road L1 (**Red Circle**).

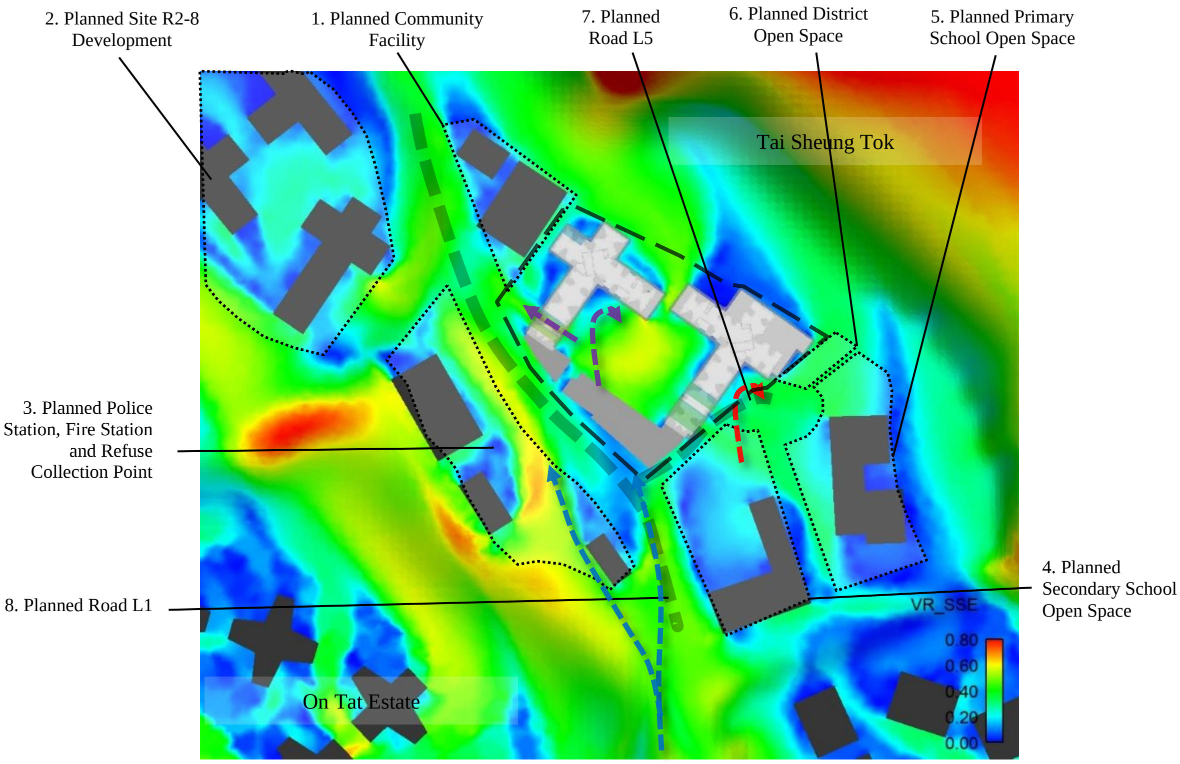



Figure 37 SSE wind VR contour plots for Baseline Scheme

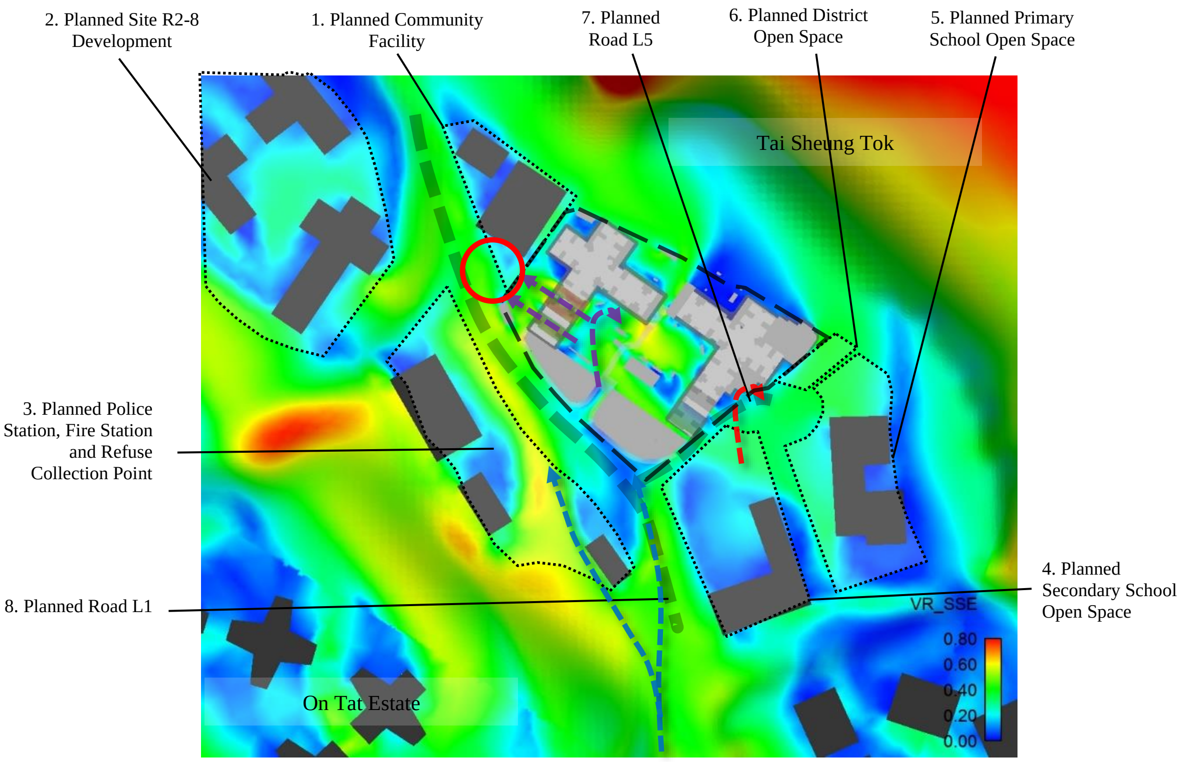



Figure 38 SSE wind VR contour plots for Proposed Scheme

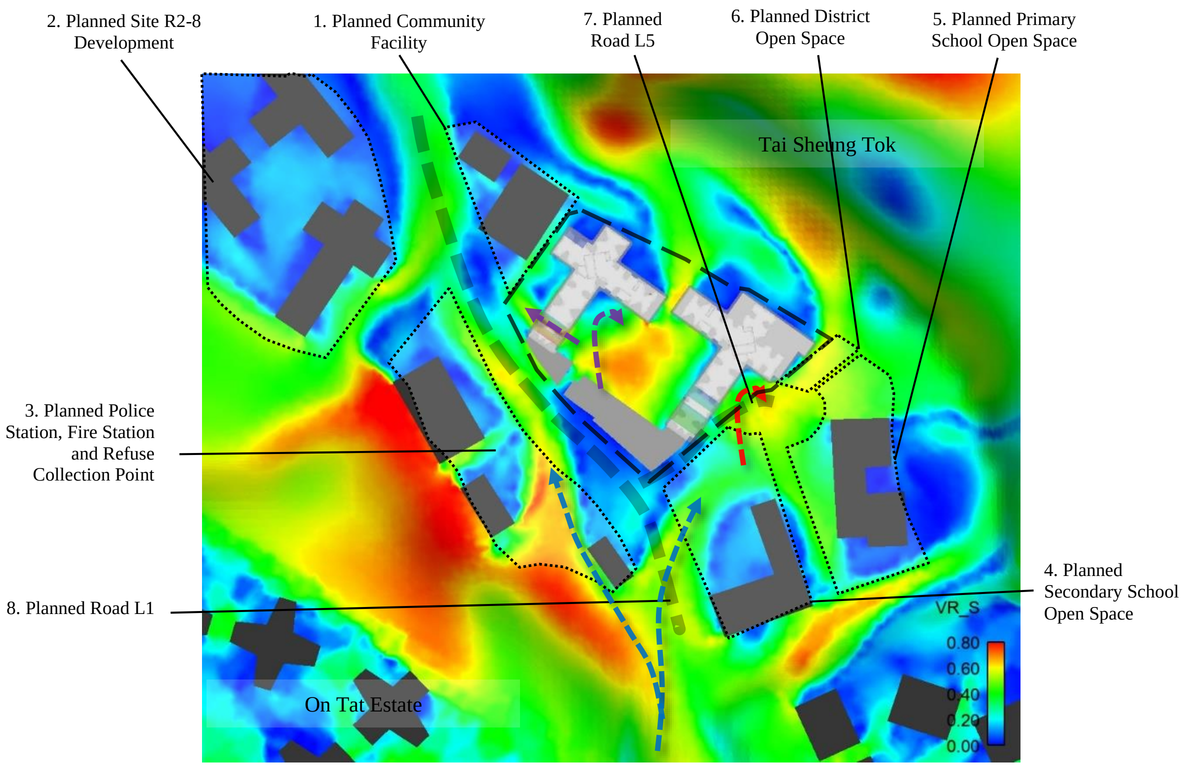



Figure 39 S wind VR contour plots for Baseline Scheme

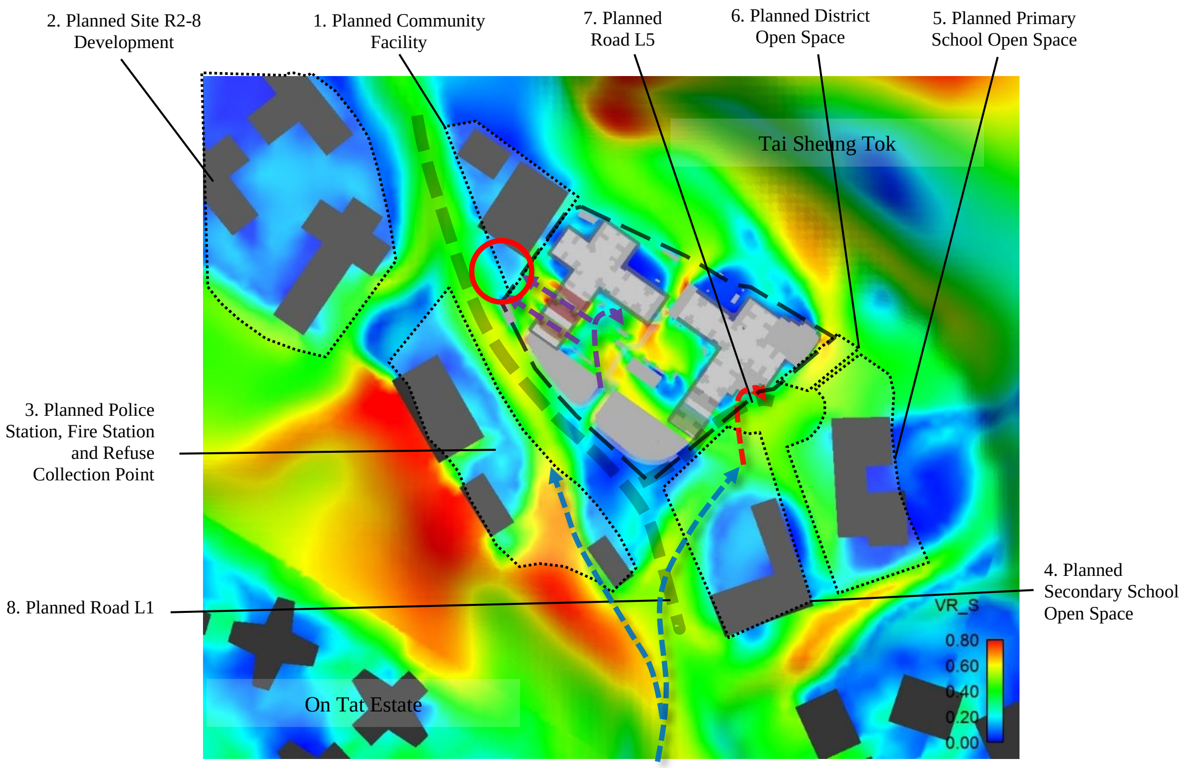



Figure 40 S wind VR contour plots for Proposed Scheme

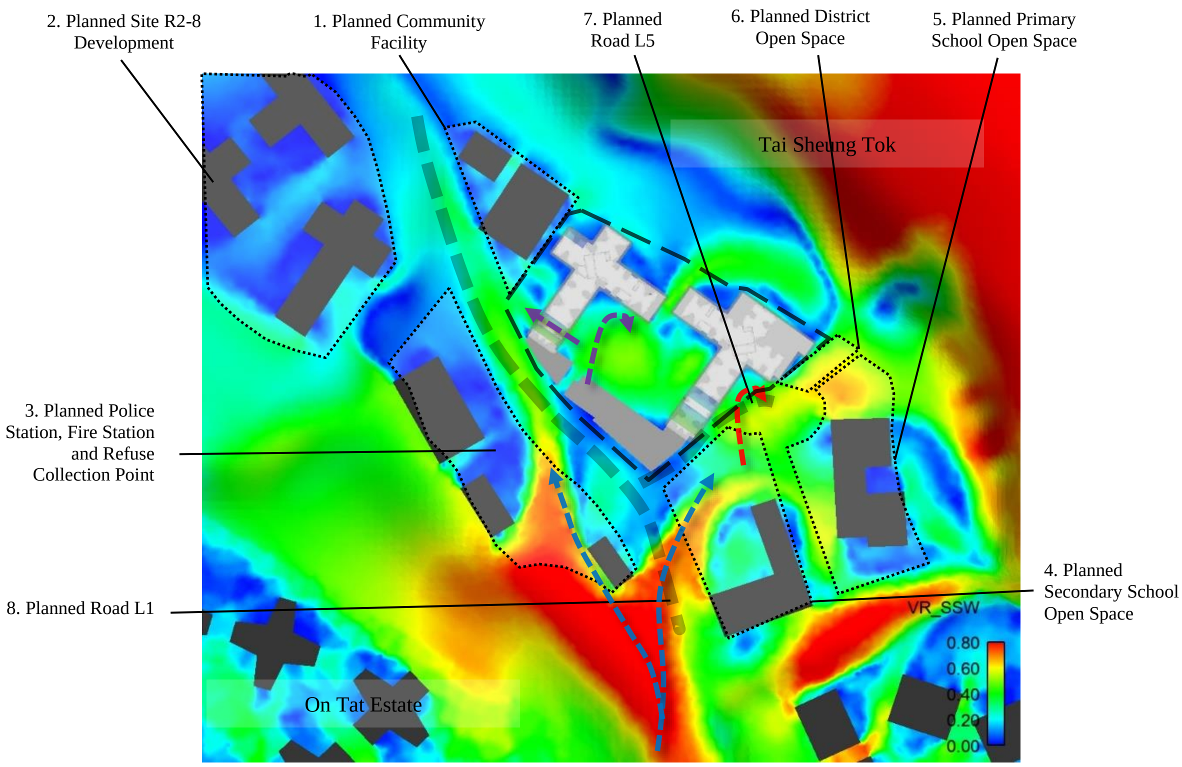



Figure 41 SSW wind VR contour plots for Baseline Scheme

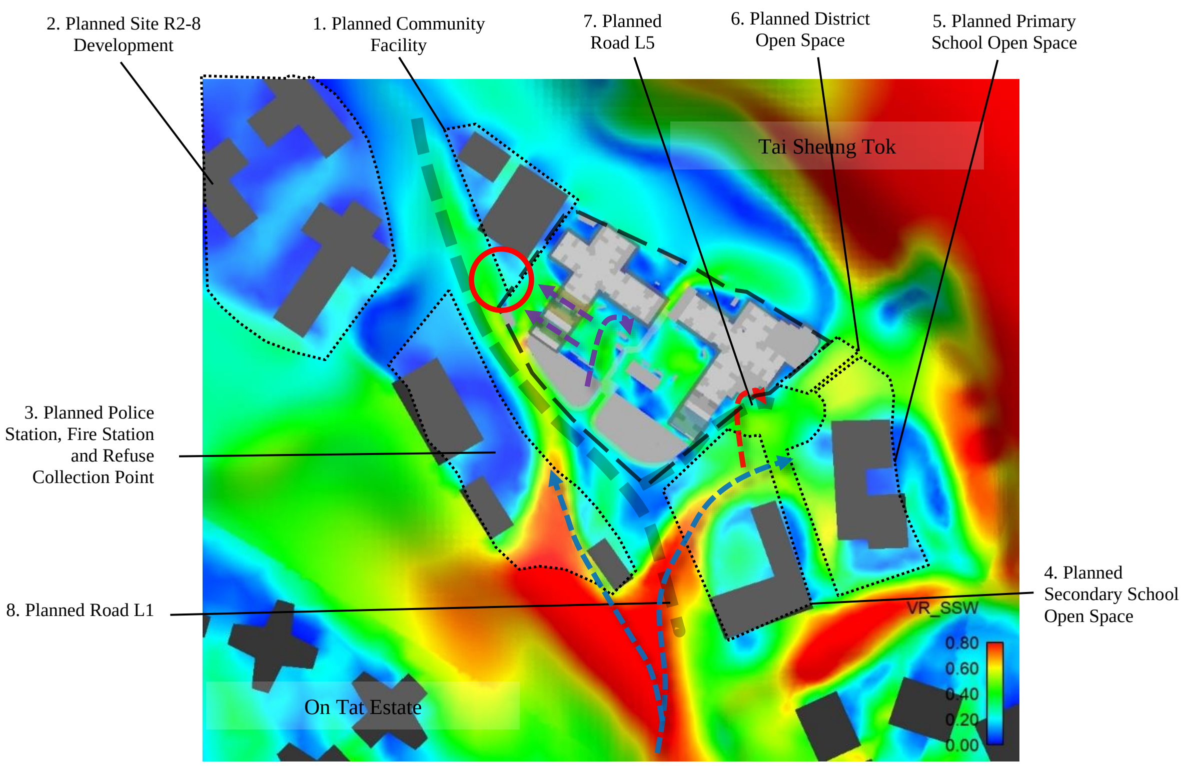



Figure 42 SSW wind VR contour plots for Proposed Scheme

### 6.3.6 SW Wind

The prevailing wind coming from SW would contribute to 6.7% and 14.8% in annual and summer conditions. The overall ventilation performance under SW wind can be summarised as below.

The southern surroundings of the Development would generally be mid and high-rise. Most prevailing wind approaching the Development would be slightly diverted by the high-rise buildings at On Tat Estate and would arrive at the Development from its south and another portion would reach the Development from the south-west (**Blue Arrows**).

Under both schemes, the Development would be located at the wind shadow of existing surroundings, therefore the ventilation performance of the southern and western surroundings of the Development would be very similar.

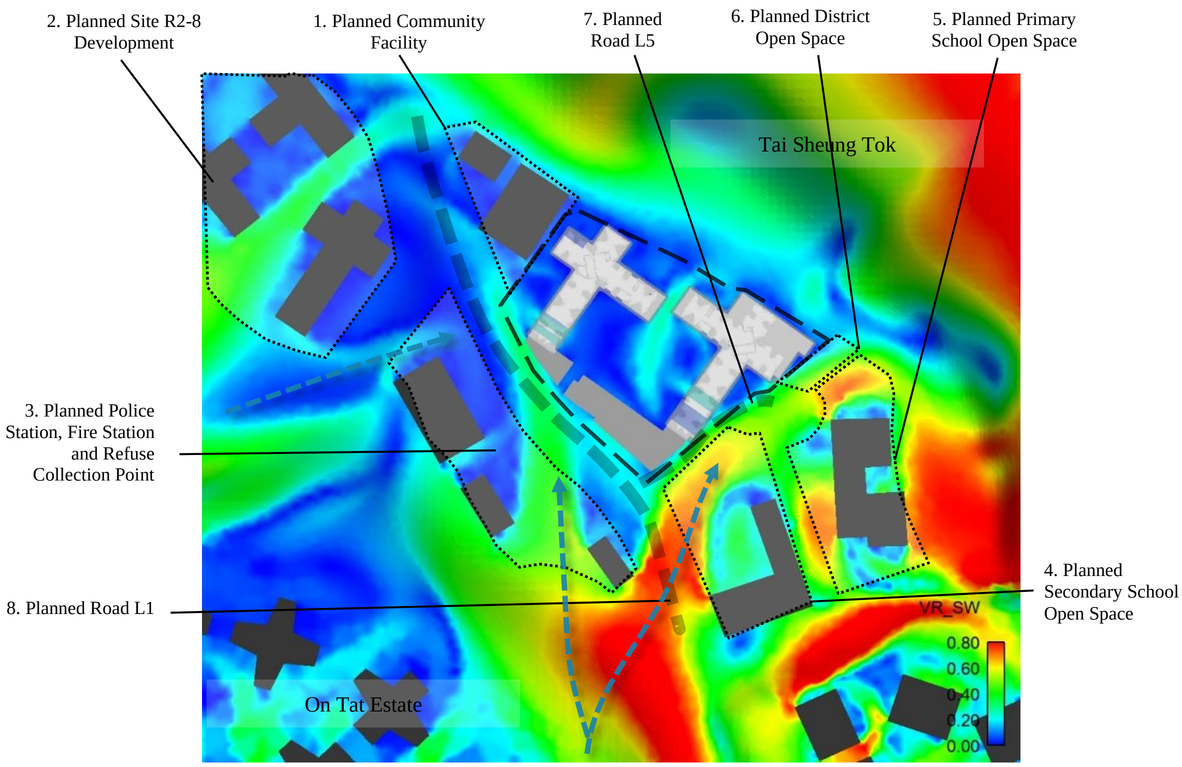



Figure 43 SW wind VR contour plots for Baseline Scheme

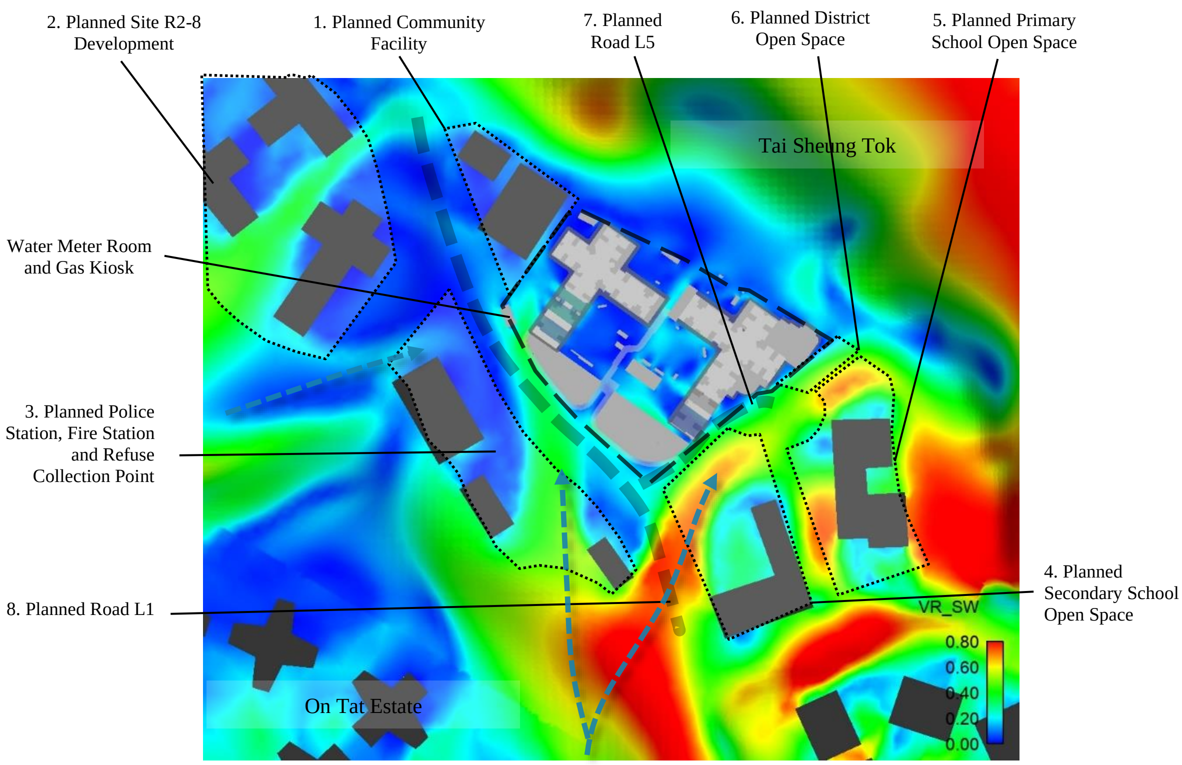



Figure 44 SW wind VR contour plots for Proposed Scheme

### 6.3.7 WSW Wind

The prevailing wind coming from WSW would contribute to 10.2% in summer conditions. The overall ventilation performance under WSW wind can be summarised as below.

The incoming WSW wind would skim over the mid-rise Planned Site R2-8 Development and would then arrive at the Development mainly from the west. The north-western façades of Block B would capture a large portion of the incoming wind and downwash it to the pedestrian level and the wind would flow towards the Planned Road L1 (**Purple Arrow**). Another portion of incoming wind would flow atop the Planned Site R2-8 Development and the Planned Community Facility and would be diverted by the steep slope of Tai Sheung Tok to reach the north-eastern boundary of the Development; the wind would proceed to enter the centre of the Development through the building separation between Block A and B (**Black Arrows**). Another portion of incoming wind would travel at a lower level, passing on the east of the Planned Police Station, Fire Station and Refuse Collection Point (**Red Arrows**).

Under both schemes the ventilation performance of the immediate surroundings of the Development would be very similar because the Development would be in the downwind area for most immediate surroundings.

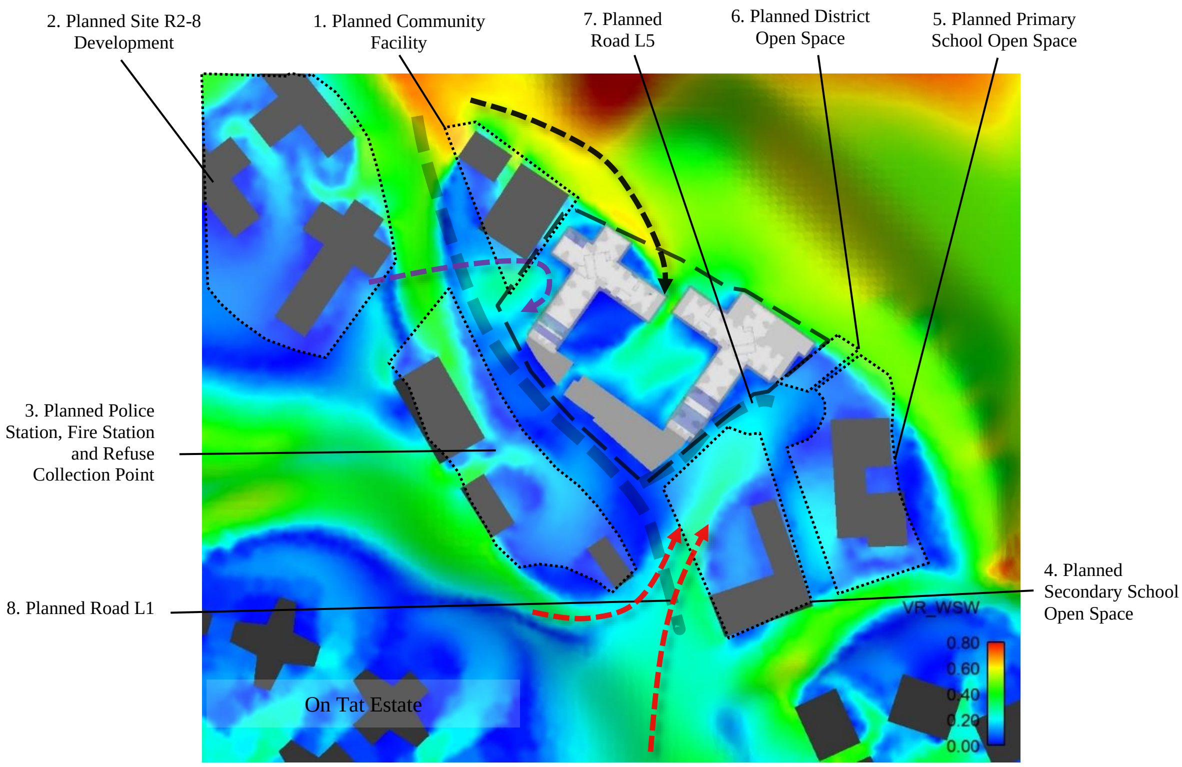



Figure 45 WSW wind VR contour plots for Baseline Scheme

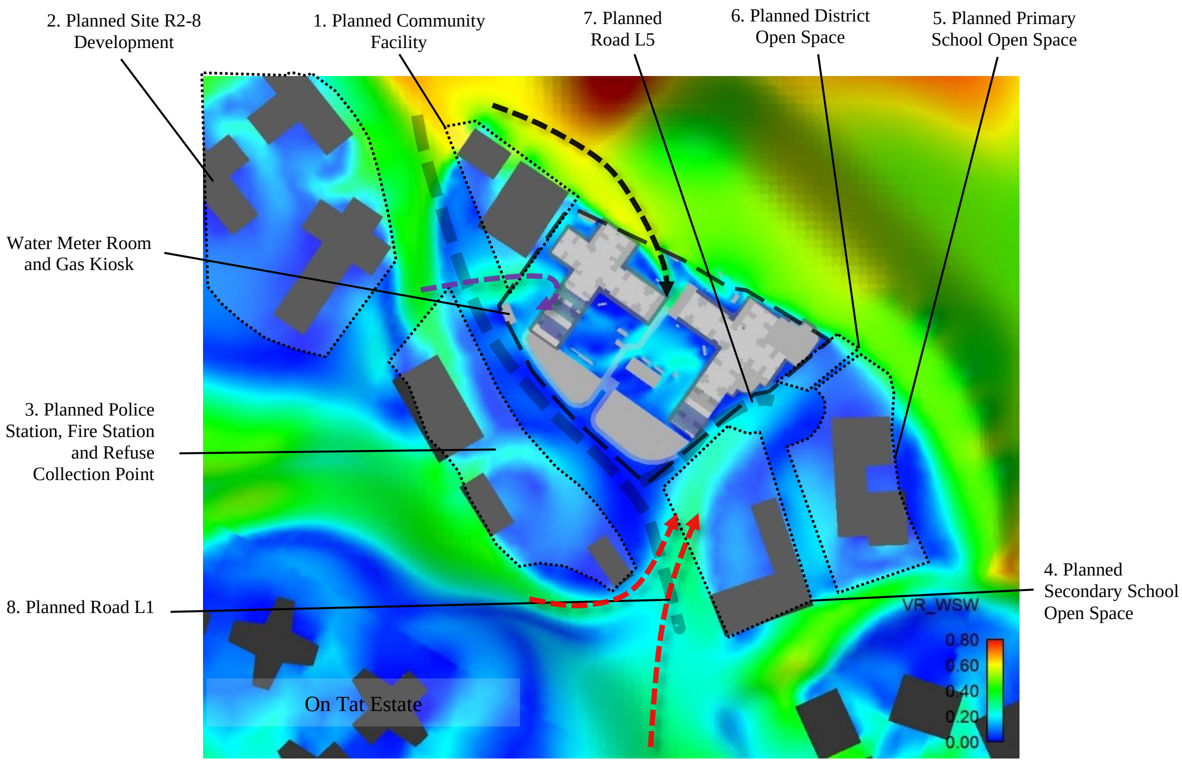



Figure 46 WSW wind VR contour plots for Proposed Scheme

## 6.4 Focus Areas

Table 6. VR Results for Focus Areas under Annual and Summer Wind Condition

| | Focus Areas | Test Points | Annual Average VR | | Summer Average VR | |
|---|---|---|---|---|---|---|
| | | | Baseline | Proposed | Baseline | Proposed |
| 1 | Planned Community Facility | O1-O7 | 0.16 | 0.19 | 0.17 | 0.18 |
| 2 | Planned Site R2-8 Development | O8-O15 | 0.15 | 0.15 | 0.16 | 0.16 |
| 3 | Planned Police Station, fire station and Refuse Collection Point | O16-O27 | 0.34 | 0.36 | 0.25 | 0.24 |
| 4 | Planned Secondary School Open Space | O28-O33 | 0.26 | 0.29 | 0.25 | 0.25 |
| 5 | Planned Primary School Open Space | O34-O39 | 0.33 | 0.33 | 0.21 | 0.22 |
| 6 | Planned District Open Space | O40-O43 | 0.44 | 0.47 | 0.39 | 0.37 |
| 7 | Planned Road L5 | O44-O48 | 0.44 | 0.51 | 0.37 | 0.40 |
| 8 | Planned Road L1 | O49-O71 | 0.30 | 0.31 | 0.27 | 0.27 |

### 6.4.1 Annual Condition

In general, the Proposed Scheme would achieve a better VR as compared to Baseline for the Planned Community Facility, Planned Police Station, Fire Station and Refuse Collection Point, Planned Secondary School Open Space, Planned District Open Space, Planned Road L5 and Planned Road L1. More downwashed wind from the eastern façades of Block A would be diverted along and ventilate the Planned Road L5 as compared to the Baseline Scheme because more wind would be downwashed by the eastern façade of Block A which is aligned with the podium outline; the nearby Secondary School Open Space would be as well ventilated. Moreover, under the Proposed Scheme, the more rounded retail block would allow more wind travelling along the Planned Road L5 be diverted to travel along the Planned Road L1, hence also better ventilation there and the adjacent Planed Police Station, Fire Station and Refuse Collection Point.

Both schemes would achieve a similar VR at the Planned Site R2-8 Development, the Planned Primary School Open Space. The Baseline Scheme would have a slightly higher VR at the Planned District Open Space.

### 6.4.2 Summer Condition

S:\fw\bs\from\TW\To Wincy\TP9&CNRUnder summer condition, the Proposed Scheme would achieve a better VR for the Planned Community Facility, Planned Primary School Open Space and Planned Road L5. This would be mainly a result of the enhanced G/F empty bays at Block B, and the wider opening between the retail blocks that is also aligned with the building separation between Block A and B as compared to the Baseline Scheme, allowing more prevailing downwashed to the centre of the Development to penetrate through the Development and ventilate the immediate surroundings.

Both Schemes would have a similar VR at the Planned Site R2-8 Development, Planned Secondary School Open Space and Planned Road L1. The Baseline Scheme would have a slightly higher VR at the Planned Police Station, fire station and Refuse Collection Point and the Planned District Open Space. Similar to annual condition, the smaller podium mass under the Baseline Scheme for Block A would be able to downwash more prevailing wind to the pedestrian level and ventilate the Planned District Open Space.

# 7 Conclusion

## 7.1 Overview

An AVA – Detailed Study was conducted using CFD modelling to assess the ventilation performance of the Proposed Scheme of the Public Housing Development at Anderson Road Quarry Site RS-1, in accordance with the *AVA Technical Circular* No. 1/06, "*Environment, Transport and Works Bureau - Technical Circular No. 1/06*" issued on 19th July 2006 and "*Annex A of Technical Circular - Technical Guide for Air Ventilation Assessment for Development in Hong Kong*".

Ventilation performance under Baseline Scheme and Proposed Scheme was assessed using Computation Fluid Dynamics (CFD) techniques. A series of CFD simulation using Realizable k–ε turbulence model were performed with 11 wind directions covering 76.2% and 77.6% of wind frequency for annual and summer conditions respectively.

The Velocity Ratio (VR) as proposed by the *AVA Technical Circular*[1] was employed to assess the ventilation performance. The wind speed would also be reported.

With reference to the *AVA Technical Circular*[1], a total of 34 perimeter test points and 71 overall test points have been allocated within the study site and assessment area to assess the overall and local ventilation performance.

## 7.2 Results

Upon the CFD simulation Proposed Scheme achieved generally a similar or higher SVR and LVR by 0.01 comparing to Baseline Scheme under both annual and summer conditions.

The results of the SVR, LVR are summarized as below.

| | Annual Condition | | Summer Condition | |
|---|---|---|---|---|
| | **Baseline Scheme** | **Proposed Scheme** | **Baseline Scheme** | **Proposed Scheme** |
| **SVR** | 0.32 | 0.32 | 0.27 | 0.27 |
| **LVR** | 0.30 | 0.31 | 0.26 | 0.26 |

# 8 Reference

[1] Annex A of Technical Circular No. 1/06 issued by the Housing, Planning and Lands Bureau pertaining specifically to Air Ventilation Assessments, 19th July, 2006

(https://www.devb.gov.hk/filemanager/en/content_679/hplb-etwb-tc-01-06.pdf)

[2] Planning Department RAMS Data (http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/)

# Appendix A Velocity Ratio Table

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Baseline Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| P1 | 0.27 | 0.08 | 0.56 | 0.79 | 0.60 | 0.24 | 0.19 | 0.13 | 0.13 | 0.16 | 0.05 | 0.45 | 0.25 |
| P2 | 0.29 | 0.12 | 0.05 | 0.47 | 0.22 | 0.05 | 0.11 | 0.06 | 0.10 | 0.17 | 0.04 | 0.21 | 0.15 |
| P3 | 0.30 | 0.13 | 0.07 | 0.44 | 0.29 | 0.04 | 0.11 | 0.04 | 0.09 | 0.20 | 0.03 | 0.21 | 0.15 |
| P4 | 0.27 | 0.13 | 0.08 | 0.40 | 0.38 | 0.05 | 0.18 | 0.04 | 0.06 | 0.18 | 0.04 | 0.21 | 0.16 |
| P5 | 0.17 | 0.09 | 0.03 | 0.35 | 0.42 | 0.30 | 0.24 | 0.07 | 0.11 | 0.18 | 0.03 | 0.21 | 0.19 |
| P6 | 0.09 | 0.07 | 0.09 | 0.27 | 0.43 | 0.31 | 0.29 | 0.18 | 0.24 | 0.24 | 0.08 | 0.21 | 0.24 |
| P7 | 0.17 | 0.04 | 0.11 | 0.06 | 0.38 | 0.21 | 0.32 | 0.36 | 0.32 | 0.27 | 0.03 | 0.17 | 0.25 |
| P8 | 0.50 | 0.12 | 0.08 | 0.17 | 0.37 | 0.20 | 0.29 | 0.31 | 0.37 | 0.29 | 0.05 | 0.22 | 0.26 |
| P9 | 0.44 | 0.08 | 0.24 | 0.05 | 0.16 | 0.23 | 0.37 | 0.18 | 0.34 | 0.21 | 0.22 | 0.19 | 0.23 |
| P10 | 0.44 | 0.14 | 0.13 | 0.15 | 0.17 | 0.32 | 0.25 | 0.23 | 0.20 | 0.10 | 0.25 | 0.18 | 0.20 |
| P11 | 0.33 | 0.25 | 0.08 | 0.20 | 0.30 | 0.23 | 0.24 | 0.30 | 0.16 | 0.09 | 0.15 | 0.19 | 0.19 |
| P12 | 0.19 | 0.28 | 0.10 | 0.18 | 0.43 | 0.10 | 0.27 | 0.25 | 0.12 | 0.06 | 0.17 | 0.18 | 0.18 |
| P13 | 0.41 | 0.11 | 0.10 | 0.15 | 0.40 | 0.17 | 0.26 | 0.19 | 0.09 | 0.05 | 0.19 | 0.17 | 0.17 |
| P14 | 0.66 | 0.29 | 0.31 | 0.11 | 0.53 | 0.24 | 0.35 | 0.20 | 0.22 | 0.17 | 0.51 | 0.28 | 0.28 |
| P15 | 0.67 | 0.22 | 0.30 | 0.14 | 0.58 | 0.23 | 0.39 | 0.22 | 0.19 | 0.16 | 0.53 | 0.29 | 0.29 |
| P16 | 0.37 | 0.28 | 0.26 | 0.27 | 0.58 | 0.19 | 0.40 | 0.15 | 0.18 | 0.14 | 0.53 | 0.29 | 0.29 |
| P17 | 0.19 | 0.41 | 0.14 | 0.53 | 0.60 | 0.18 | 0.41 | 0.22 | 0.16 | 0.13 | 0.51 | 0.32 | 0.31 |
| P18 | 0.11 | 0.43 | 0.08 | 0.47 | 0.62 | 0.15 | 0.40 | 0.41 | 0.13 | 0.10 | 0.46 | 0.29 | 0.31 |
| P19 | 0.44 | 0.39 | 0.16 | 0.77 | 0.60 | 0.12 | 0.29 | 0.40 | 0.24 | 0.10 | 0.41 | 0.40 | 0.34 |
| P20 | 0.58 | 0.34 | 0.23 | 0.85 | 0.57 | 0.11 | 0.05 | 0.17 | 0.38 | 0.15 | 0.38 | 0.45 | 0.32 |

| **Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Baseline Scheme)** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| /Test Points | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| P21 | 0.49 | 0.31 | 0.32 | 0.77 | 0.50 | 0.13 | 0.09 | 0.18 | 0.34 | 0.13 | 0.39 | 0.43 | 0.30 |
| P22 | 0.46 | 0.26 | 0.56 | 0.69 | 0.43 | 0.18 | 0.13 | 0.22 | 0.31 | 0.12 | 0.45 | 0.44 | 0.30 |
| P23 | 0.43 | 0.18 | 0.67 | 0.65 | 0.40 | 0.18 | 0.19 | 0.14 | 0.29 | 0.18 | 0.46 | 0.45 | 0.30 |
| P24 | 0.47 | 0.12 | 0.75 | 0.62 | 0.44 | 0.13 | 0.28 | 0.31 | 0.19 | 0.19 | 0.46 | 0.45 | 0.31 |
| P25 | 0.48 | 0.30 | 0.77 | 0.48 | 0.36 | 0.22 | 0.30 | 0.43 | 0.32 | 0.13 | 0.45 | 0.44 | 0.32 |
| P26 | 0.52 | 0.45 | 0.64 | 0.49 | 0.40 | 0.15 | 0.31 | 0.51 | 0.43 | 0.17 | 0.35 | 0.45 | 0.34 |
| P27 | 0.08 | 0.45 | 0.25 | 0.64 | 0.45 | 0.23 | 0.30 | 0.51 | 0.43 | 0.20 | 0.07 | 0.39 | 0.34 |
| P28 | 0.14 | 0.35 | 0.14 | 0.40 | 0.28 | 0.22 | 0.26 | 0.44 | 0.36 | 0.32 | 0.12 | 0.28 | 0.30 |
| P29 | 0.08 | 0.26 | 0.28 | 0.45 | 0.25 | 0.30 | 0.31 | 0.49 | 0.42 | 0.27 | 0.12 | 0.31 | 0.32 |
| P30 | 0.04 | 0.24 | 0.45 | 0.29 | 0.36 | 0.25 | 0.25 | 0.45 | 0.40 | 0.24 | 0.14 | 0.31 | 0.30 |
| P31 | 0.10 | 0.23 | 0.50 | 0.43 | 0.33 | 0.24 | 0.26 | 0.41 | 0.43 | 0.34 | 0.14 | 0.37 | 0.33 |
| P32 | 0.14 | 0.05 | 0.62 | 0.71 | 0.45 | 0.21 | 0.24 | 0.18 | 0.23 | 0.45 | 0.17 | 0.44 | 0.33 |
| P33 | 0.16 | 0.08 | 0.61 | 0.79 | 0.52 | 0.20 | 0.21 | 0.12 | 0.14 | 0.35 | 0.13 | 0.46 | 0.29 |
| P34 | 0.10 | 0.09 | 0.65 | 0.82 | 0.64 | 0.25 | 0.26 | 0.08 | 0.08 | 0.26 | 0.10 | 0.48 | 0.28 |
| O1 | 0.34 | 0.07 | 0.09 | 0.05 | 0.05 | 0.47 | 0.20 | 0.13 | 0.13 | 0.05 | 0.06 | 0.12 | 0.12 |
| O2 | 0.34 | 0.13 | 0.11 | 0.04 | 0.07 | 0.38 | 0.06 | 0.11 | 0.14 | 0.03 | 0.11 | 0.12 | 0.11 |
| O3 | 0.58 | 0.15 | 0.03 | 0.10 | 0.13 | 0.28 | 0.30 | 0.27 | 0.15 | 0.09 | 0.14 | 0.14 | 0.17 |
| O4 | 0.45 | 0.16 | 0.08 | 0.21 | 0.20 | 0.35 | 0.23 | 0.26 | 0.20 | 0.09 | 0.22 | 0.19 | 0.21 |
| O5 | 0.36 | 0.09 | 0.18 | 0.23 | 0.09 | 0.38 | 0.21 | 0.08 | 0.23 | 0.13 | 0.13 | 0.20 | 0.18 |
| O6 | 0.29 | 0.10 | 0.21 | 0.08 | 0.14 | 0.41 | 0.27 | 0.05 | 0.26 | 0.14 | 0.18 | 0.18 | 0.19 |
| O7 | 0.45 | 0.14 | 0.13 | 0.15 | 0.17 | 0.31 | 0.25 | 0.24 | 0.20 | 0.10 | 0.25 | 0.18 | 0.20 |
| O8 | 0.08 | 0.04 | 0.02 | 0.07 | 0.04 | 0.25 | 0.23 | 0.13 | 0.07 | 0.06 | 0.29 | 0.07 | 0.13 |
| O9 | 0.87 | 0.07 | 0.04 | 0.08 | 0.11 | 0.18 | 0.16 | 0.08 | 0.17 | 0.07 | 0.36 | 0.14 | 0.15 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Baseline Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| O10 | 0.36 | 0.09 | 0.04 | 0.13 | 0.04 | 0.23 | 0.18 | 0.10 | 0.12 | 0.06 | 0.38 | 0.11 | 0.15 |
| O11 | 0.53 | 0.05 | 0.05 | 0.03 | 0.03 | 0.20 | 0.11 | 0.09 | 0.12 | 0.04 | 0.27 | 0.09 | 0.11 |
| O12 | 0.08 | 0.05 | 0.29 | 0.23 | 0.19 | 0.25 | 0.21 | 0.31 | 0.19 | 0.04 | 0.06 | 0.19 | 0.17 |
| O13 | 0.05 | 0.06 | 0.27 | 0.13 | 0.27 | 0.44 | 0.45 | 0.44 | 0.22 | 0.06 | 0.11 | 0.19 | 0.24 |
| O14 | 0.19 | 0.13 | 0.32 | 0.26 | 0.17 | 0.18 | 0.10 | 0.29 | 0.16 | 0.08 | 0.04 | 0.21 | 0.15 |
| O15 | 0.09 | 0.03 | 0.26 | 0.18 | 0.22 | 0.29 | 0.28 | 0.36 | 0.18 | 0.04 | 0.10 | 0.18 | 0.19 |
| O16 | 0.48 | 0.21 | 0.49 | 0.68 | 0.18 | 0.16 | 0.12 | 0.25 | 0.07 | 0.09 | 0.14 | 0.37 | 0.19 |
| O17 | 0.39 | 0.17 | 0.47 | 0.71 | 0.21 | 0.14 | 0.09 | 0.15 | 0.03 | 0.05 | 0.18 | 0.36 | 0.17 |
| O18 | 0.33 | 0.08 | 0.52 | 0.69 | 0.16 | 0.13 | 0.09 | 0.11 | 0.04 | 0.03 | 0.08 | 0.34 | 0.14 |
| O19 | 0.28 | 0.25 | 0.37 | 0.49 | 0.09 | 0.16 | 0.19 | 0.34 | 0.10 | 0.13 | 0.12 | 0.29 | 0.19 |
| O20 | 0.42 | 0.21 | 0.54 | 0.76 | 0.16 | 0.10 | 0.09 | 0.12 | 0.04 | 0.04 | 0.21 | 0.38 | 0.17 |
| O21 | 0.49 | 0.10 | 0.42 | 0.66 | 0.23 | 0.14 | 0.19 | 0.10 | 0.05 | 0.06 | 0.08 | 0.34 | 0.16 |
| O22 | 0.37 | 0.08 | 0.46 | 0.73 | 0.14 | 0.43 | 0.46 | 0.51 | 0.61 | 0.35 | 0.08 | 0.44 | 0.42 |
| O23 | 0.39 | 0.08 | 0.23 | 0.35 | 0.21 | 0.28 | 0.35 | 0.36 | 0.32 | 0.23 | 0.08 | 0.26 | 0.27 |
| O24 | 0.28 | 0.10 | 0.33 | 0.30 | 0.15 | 0.17 | 0.08 | 0.09 | 0.09 | 0.04 | 0.10 | 0.21 | 0.12 |
| O25 | 0.52 | 0.09 | 0.25 | 0.48 | 0.20 | 0.49 | 0.56 | 0.60 | 0.60 | 0.35 | 0.06 | 0.36 | 0.42 |
| O26 | 0.50 | 0.09 | 0.40 | 0.64 | 0.21 | 0.44 | 0.50 | 0.58 | 0.65 | 0.39 | 0.11 | 0.43 | 0.44 |
| O27 | 0.51 | 0.09 | 0.28 | 0.43 | 0.22 | 0.27 | 0.40 | 0.35 | 0.30 | 0.24 | 0.05 | 0.30 | 0.27 |
| O28 | 0.17 | 0.06 | 0.11 | 0.18 | 0.16 | 0.17 | 0.15 | 0.13 | 0.25 | 0.27 | 0.09 | 0.16 | 0.19 |
| O29 | 0.24 | 0.09 | 0.11 | 0.17 | 0.37 | 0.27 | 0.18 | 0.12 | 0.19 | 0.29 | 0.09 | 0.20 | 0.21 |
| O30 | 0.26 | 0.13 | 0.25 | 0.31 | 0.34 | 0.16 | 0.09 | 0.17 | 0.37 | 0.40 | 0.15 | 0.28 | 0.27 |
| O31 | 0.27 | 0.12 | 0.36 | 0.56 | 0.49 | 0.24 | 0.11 | 0.25 | 0.48 | 0.44 | 0.17 | 0.40 | 0.35 |
| O32 | 0.33 | 0.15 | 0.33 | 0.50 | 0.42 | 0.19 | 0.07 | 0.21 | 0.44 | 0.48 | 0.16 | 0.37 | 0.33 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Baseline Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| O33 | 0.15 | 0.05 | 0.14 | 0.14 | 0.17 | 0.10 | 0.10 | 0.09 | 0.24 | 0.24 | 0.08 | 0.15 | 0.16 |
| O34 | 0.07 | 0.17 | 0.28 | 0.17 | 0.18 | 0.10 | 0.04 | 0.03 | 0.04 | 0.25 | 0.04 | 0.18 | 0.11 |
| O35 | 0.15 | 0.27 | 0.38 | 0.50 | 0.42 | 0.18 | 0.08 | 0.05 | 0.24 | 0.56 | 0.02 | 0.37 | 0.27 |
| O36 | 0.13 | 0.37 | 0.54 | 0.51 | 0.42 | 0.18 | 0.09 | 0.04 | 0.23 | 0.57 | 0.02 | 0.42 | 0.27 |
| O37 | 0.16 | 0.38 | 0.48 | 0.49 | 0.39 | 0.16 | 0.10 | 0.07 | 0.15 | 0.52 | 0.07 | 0.39 | 0.26 |
| O38 | 0.09 | 0.20 | 0.26 | 0.19 | 0.20 | 0.13 | 0.05 | 0.02 | 0.03 | 0.18 | 0.03 | 0.18 | 0.10 |
| O39 | 0.36 | 0.35 | 0.55 | 0.51 | 0.42 | 0.20 | 0.10 | 0.09 | 0.13 | 0.46 | 0.18 | 0.42 | 0.26 |
| O40 | 0.52 | 0.34 | 0.70 | 0.51 | 0.40 | 0.13 | 0.30 | 0.46 | 0.43 | 0.20 | 0.42 | 0.45 | 0.35 |
| O41 | 0.28 | 0.49 | 0.41 | 0.62 | 0.46 | 0.21 | 0.31 | 0.52 | 0.50 | 0.29 | 0.09 | 0.44 | 0.37 |
| O42 | 0.11 | 0.51 | 0.19 | 0.71 | 0.47 | 0.24 | 0.31 | 0.52 | 0.53 | 0.43 | 0.09 | 0.43 | 0.42 |
| O43 | 0.07 | 0.49 | 0.27 | 0.66 | 0.46 | 0.29 | 0.32 | 0.52 | 0.54 | 0.48 | 0.11 | 0.44 | 0.43 |
| O44 | 0.10 | 0.38 | 0.42 | 0.32 | 0.51 | 0.34 | 0.30 | 0.51 | 0.49 | 0.45 | 0.15 | 0.38 | 0.39 |
| O45 | 0.15 | 0.29 | 0.35 | 0.26 | 0.49 | 0.34 | 0.29 | 0.41 | 0.40 | 0.50 | 0.20 | 0.34 | 0.37 |
| O46 | 0.09 | 0.13 | 0.57 | 0.61 | 0.54 | 0.30 | 0.25 | 0.27 | 0.30 | 0.54 | 0.22 | 0.45 | 0.38 |
| O47 | 0.10 | 0.02 | 0.79 | 0.81 | 0.61 | 0.27 | 0.07 | 0.26 | 0.20 | 0.59 | 0.17 | 0.53 | 0.37 |
| O48 | 0.23 | 0.10 | 0.75 | 0.70 | 0.56 | 0.25 | 0.32 | 0.20 | 0.14 | 0.55 | 0.09 | 0.50 | 0.35 |
| O49 | 0.61 | 0.82 | 0.96 | 0.46 | 0.16 | 0.25 | 0.44 | 0.36 | 0.42 | 0.46 | 0.23 | 0.56 | 0.36 |
| O50 | 0.47 | 0.62 | 0.68 | 0.14 | 0.28 | 0.08 | 0.42 | 0.40 | 0.41 | 0.44 | 0.22 | 0.39 | 0.32 |
| O51 | 0.27 | 0.20 | 0.50 | 0.50 | 0.28 | 0.14 | 0.42 | 0.48 | 0.61 | 0.62 | 0.22 | 0.41 | 0.44 |
| O52 | 0.07 | 0.08 | 0.68 | 0.66 | 0.33 | 0.16 | 0.40 | 0.45 | 0.68 | 0.68 | 0.19 | 0.48 | 0.48 |
| O53 | 0.21 | 0.03 | 0.58 | 0.62 | 0.39 | 0.17 | 0.35 | 0.27 | 0.35 | 0.52 | 0.10 | 0.42 | 0.36 |
| O54 | 0.35 | 0.09 | 0.44 | 0.61 | 0.47 | 0.18 | 0.10 | 0.17 | 0.17 | 0.11 | 0.03 | 0.36 | 0.21 |
| O55 | 0.36 | 0.11 | 0.32 | 0.74 | 0.40 | 0.11 | 0.14 | 0.11 | 0.21 | 0.10 | 0.09 | 0.36 | 0.22 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Baseline Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| O56 | 0.41 | 0.12 | 0.22 | 0.80 | 0.35 | 0.18 | 0.20 | 0.21 | 0.13 | 0.22 | 0.12 | 0.36 | 0.26 |
| O57 | 0.46 | 0.06 | 0.23 | 0.74 | 0.33 | 0.42 | 0.41 | 0.50 | 0.51 | 0.34 | 0.11 | 0.41 | 0.41 |
| O58 | 0.39 | 0.14 | 0.18 | 0.45 | 0.36 | 0.22 | 0.44 | 0.46 | 0.40 | 0.27 | 0.04 | 0.30 | 0.33 |
| O59 | 0.40 | 0.13 | 0.23 | 0.34 | 0.36 | 0.14 | 0.49 | 0.43 | 0.26 | 0.15 | 0.07 | 0.26 | 0.27 |
| O60 | 0.43 | 0.04 | 0.31 | 0.25 | 0.36 | 0.05 | 0.50 | 0.46 | 0.22 | 0.08 | 0.07 | 0.23 | 0.23 |
| O61 | 0.57 | 0.04 | 0.37 | 0.17 | 0.35 | 0.04 | 0.50 | 0.47 | 0.17 | 0.04 | 0.07 | 0.23 | 0.21 |
| O62 | 0.60 | 0.06 | 0.31 | 0.15 | 0.35 | 0.08 | 0.47 | 0.46 | 0.20 | 0.04 | 0.08 | 0.22 | 0.21 |
| O63 | 0.61 | 0.23 | 0.23 | 0.09 | 0.35 | 0.28 | 0.38 | 0.37 | 0.18 | 0.04 | 0.13 | 0.22 | 0.20 |
| O64 | 0.79 | 0.16 | 0.17 | 0.08 | 0.35 | 0.41 | 0.30 | 0.29 | 0.18 | 0.04 | 0.14 | 0.22 | 0.20 |
| O65 | 0.90 | 0.12 | 0.14 | 0.11 | 0.32 | 0.53 | 0.30 | 0.26 | 0.16 | 0.04 | 0.10 | 0.23 | 0.20 |
| O66 | 0.92 | 0.10 | 0.09 | 0.31 | 0.27 | 0.56 | 0.37 | 0.32 | 0.19 | 0.06 | 0.10 | 0.26 | 0.24 |
| O67 | 0.91 | 0.12 | 0.05 | 0.14 | 0.28 | 0.47 | 0.42 | 0.42 | 0.22 | 0.08 | 0.22 | 0.22 | 0.26 |
| O68 | 0.87 | 0.12 | 0.04 | 0.06 | 0.28 | 0.22 | 0.38 | 0.38 | 0.22 | 0.09 | 0.39 | 0.17 | 0.24 |
| O69 | 0.80 | 0.09 | 0.07 | 0.03 | 0.23 | 0.10 | 0.32 | 0.29 | 0.19 | 0.04 | 0.40 | 0.14 | 0.20 |
| O70 | 0.80 | 0.13 | 0.12 | 0.05 | 0.21 | 0.13 | 0.30 | 0.25 | 0.18 | 0.09 | 0.42 | 0.16 | 0.20 |
| O71 | 0.81 | 0.17 | 0.16 | 0.09 | 0.18 | 0.06 | 0.26 | 0.22 | 0.17 | 0.20 | 0.44 | 0.19 | 0.21 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Proposed Scheme) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| P1 | 0.18 | 0.29 | 0.44 | 0.67 | 0.58 | 0.25 | 0.21 | 0.15 | 0.10 | 0.18 | 0.03 | 0.41 | 0.24 |
| P2 | 0.23 | 0.31 | 0.45 | 0.75 | 0.55 | 0.24 | 0.12 | 0.07 | 0.16 | 0.16 | 0.04 | 0.43 | 0.23 |
| P3 | 0.23 | 0.27 | 0.40 | 0.62 | 0.53 | 0.21 | 0.08 | 0.08 | 0.21 | 0.20 | 0.04 | 0.39 | 0.23 |
| P4 | 0.20 | 0.23 | 0.32 | 0.40 | 0.50 | 0.13 | 0.17 | 0.34 | 0.18 | 0.20 | 0.04 | 0.31 | 0.23 |
| P5 | 0.25 | 0.31 | 0.23 | 0.23 | 0.45 | 0.26 | 0.20 | 0.22 | 0.26 | 0.19 | 0.05 | 0.27 | 0.22 |
| P6 | 0.33 | 0.22 | 0.21 | 0.21 | 0.45 | 0.35 | 0.27 | 0.31 | 0.39 | 0.27 | 0.04 | 0.28 | 0.28 |
| P7 | 0.44 | 0.18 | 0.15 | 0.13 | 0.43 | 0.30 | 0.37 | 0.42 | 0.47 | 0.30 | 0.06 | 0.25 | 0.31 |
| P8 | 0.55 | 0.18 | 0.08 | 0.25 | 0.41 | 0.26 | 0.46 | 0.49 | 0.53 | 0.31 | 0.11 | 0.28 | 0.36 |
| P9 | 0.27 | 0.09 | 0.06 | 0.18 | 0.14 | 0.19 | 0.28 | 0.18 | 0.30 | 0.14 | 0.22 | 0.15 | 0.20 |
| P10 | 0.28 | 0.12 | 0.19 | 0.25 | 0.19 | 0.24 | 0.21 | 0.17 | 0.19 | 0.12 | 0.25 | 0.20 | 0.20 |
| P11 | 0.32 | 0.18 | 0.14 | 0.35 | 0.34 | 0.19 | 0.15 | 0.32 | 0.22 | 0.13 | 0.13 | 0.24 | 0.22 |
| P12 | 0.13 | 0.19 | 0.13 | 0.34 | 0.45 | 0.14 | 0.28 | 0.10 | 0.06 | 0.14 | 0.15 | 0.22 | 0.19 |
| P13 | 0.36 | 0.10 | 0.08 | 0.22 | 0.45 | 0.20 | 0.31 | 0.22 | 0.10 | 0.09 | 0.17 | 0.19 | 0.20 |
| P14 | 0.44 | 0.11 | 0.21 | 0.15 | 0.54 | 0.23 | 0.35 | 0.27 | 0.23 | 0.09 | 0.50 | 0.23 | 0.28 |
| P15 | 0.54 | 0.16 | 0.23 | 0.22 | 0.58 | 0.24 | 0.39 | 0.32 | 0.21 | 0.07 | 0.52 | 0.27 | 0.30 |
| P16 | 0.30 | 0.14 | 0.25 | 0.26 | 0.57 | 0.19 | 0.38 | 0.32 | 0.21 | 0.04 | 0.52 | 0.26 | 0.29 |
| P17 | 0.13 | 0.11 | 0.23 | 0.54 | 0.60 | 0.17 | 0.37 | 0.34 | 0.19 | 0.05 | 0.49 | 0.30 | 0.31 |
| P18 | 0.19 | 0.11 | 0.18 | 0.32 | 0.62 | 0.15 | 0.36 | 0.41 | 0.16 | 0.04 | 0.45 | 0.24 | 0.29 |
| P19 | 0.35 | 0.07 | 0.06 | 0.48 | 0.61 | 0.12 | 0.25 | 0.46 | 0.19 | 0.05 | 0.41 | 0.26 | 0.30 |
| P20 | 0.46 | 0.04 | 0.02 | 0.64 | 0.60 | 0.11 | 0.03 | 0.27 | 0.31 | 0.10 | 0.38 | 0.30 | 0.29 |
| P21 | 0.54 | 0.04 | 0.05 | 0.76 | 0.56 | 0.14 | 0.08 | 0.19 | 0.32 | 0.08 | 0.39 | 0.34 | 0.29 |
| P22 | 0.50 | 0.02 | 0.08 | 0.57 | 0.45 | 0.18 | 0.11 | 0.17 | 0.28 | 0.12 | 0.43 | 0.29 | 0.28 |
| P23 | 0.49 | 0.12 | 0.19 | 0.54 | 0.38 | 0.18 | 0.17 | 0.17 | 0.22 | 0.19 | 0.44 | 0.31 | 0.28 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Proposed Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| P24 | 0.53 | 0.12 | 0.56 | 0.44 | 0.31 | 0.14 | 0.28 | 0.47 | 0.12 | 0.18 | 0.45 | 0.35 | 0.28 |
| P25 | 0.52 | 0.45 | 0.64 | 0.40 | 0.26 | 0.24 | 0.32 | 0.43 | 0.30 | 0.11 | 0.45 | 0.40 | 0.30 |
| P26 | 0.28 | 0.60 | 0.46 | 0.46 | 0.35 | 0.10 | 0.34 | 0.54 | 0.39 | 0.18 | 0.12 | 0.39 | 0.31 |
| P27 | 0.18 | 0.58 | 0.71 | 0.45 | 0.34 | 0.19 | 0.29 | 0.50 | 0.31 | 0.26 | 0.08 | 0.44 | 0.30 |
| P28 | 0.18 | 0.43 | 0.58 | 0.50 | 0.43 | 0.19 | 0.22 | 0.39 | 0.26 | 0.32 | 0.12 | 0.42 | 0.30 |
| P29 | 0.18 | 0.35 | 0.52 | 0.43 | 0.29 | 0.17 | 0.23 | 0.32 | 0.18 | 0.28 | 0.13 | 0.35 | 0.25 |
| P30 | 0.19 | 0.42 | 0.59 | 0.34 | 0.17 | 0.20 | 0.20 | 0.35 | 0.31 | 0.19 | 0.14 | 0.35 | 0.24 |
| P31 | 0.18 | 0.11 | 0.56 | 0.46 | 0.31 | 0.23 | 0.24 | 0.36 | 0.30 | 0.25 | 0.18 | 0.36 | 0.29 |
| P32 | 0.18 | 0.15 | 0.37 | 0.67 | 0.44 | 0.21 | 0.29 | 0.41 | 0.28 | 0.34 | 0.20 | 0.39 | 0.35 |
| P33 | 0.18 | 0.22 | 0.30 | 0.82 | 0.54 | 0.22 | 0.24 | 0.05 | 0.12 | 0.28 | 0.14 | 0.41 | 0.28 |
| P34 | 0.19 | 0.30 | 0.41 | 0.74 | 0.63 | 0.26 | 0.26 | 0.08 | 0.16 | 0.20 | 0.07 | 0.44 | 0.27 |
| O1 | 0.47 | 0.19 | 0.14 | 0.14 | 0.04 | 0.46 | 0.26 | 0.16 | 0.15 | 0.05 | 0.05 | 0.17 | 0.15 |
| O2 | 0.45 | 0.08 | 0.11 | 0.18 | 0.05 | 0.34 | 0.05 | 0.13 | 0.17 | 0.04 | 0.12 | 0.16 | 0.13 |
| O3 | 0.71 | 0.20 | 0.11 | 0.12 | 0.09 | 0.29 | 0.32 | 0.22 | 0.15 | 0.08 | 0.15 | 0.17 | 0.16 |
| O4 | 0.33 | 0.14 | 0.13 | 0.24 | 0.22 | 0.31 | 0.22 | 0.17 | 0.16 | 0.10 | 0.22 | 0.19 | 0.19 |
| O5 | 0.53 | 0.14 | 0.13 | 0.22 | 0.06 | 0.36 | 0.32 | 0.23 | 0.28 | 0.11 | 0.12 | 0.20 | 0.20 |
| O6 | 0.45 | 0.13 | 0.20 | 0.21 | 0.06 | 0.38 | 0.40 | 0.28 | 0.33 | 0.10 | 0.18 | 0.21 | 0.23 |
| O7 | 0.28 | 0.12 | 0.19 | 0.26 | 0.20 | 0.23 | 0.22 | 0.18 | 0.20 | 0.13 | 0.25 | 0.21 | 0.20 |
| O8 | 0.16 | 0.08 | 0.02 | 0.13 | 0.06 | 0.25 | 0.25 | 0.14 | 0.06 | 0.07 | 0.24 | 0.09 | 0.14 |
| O9 | 0.86 | 0.07 | 0.14 | 0.12 | 0.10 | 0.17 | 0.09 | 0.12 | 0.14 | 0.04 | 0.33 | 0.16 | 0.14 |
| O10 | 0.32 | 0.08 | 0.02 | 0.15 | 0.02 | 0.23 | 0.20 | 0.11 | 0.09 | 0.06 | 0.34 | 0.10 | 0.14 |
| O11 | 0.44 | 0.07 | 0.07 | 0.10 | 0.05 | 0.19 | 0.16 | 0.09 | 0.10 | 0.07 | 0.24 | 0.11 | 0.12 |
| O12 | 0.09 | 0.17 | 0.23 | 0.20 | 0.21 | 0.27 | 0.21 | 0.33 | 0.18 | 0.05 | 0.08 | 0.19 | 0.17 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Proposed Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| O13 | 0.11 | 0.23 | 0.14 | 0.11 | 0.28 | 0.48 | 0.43 | 0.44 | 0.18 | 0.06 | 0.08 | 0.18 | 0.23 |
| O14 | 0.17 | 0.46 | 0.25 | 0.24 | 0.19 | 0.16 | 0.11 | 0.32 | 0.18 | 0.09 | 0.05 | 0.23 | 0.16 |
| O15 | 0.07 | 0.11 | 0.18 | 0.16 | 0.23 | 0.32 | 0.28 | 0.37 | 0.17 | 0.05 | 0.12 | 0.16 | 0.19 |
| O16 | 0.56 | 0.19 | 0.46 | 0.61 | 0.19 | 0.16 | 0.12 | 0.21 | 0.06 | 0.07 | 0.13 | 0.35 | 0.17 |
| O17 | 0.55 | 0.25 | 0.52 | 0.63 | 0.24 | 0.18 | 0.09 | 0.17 | 0.03 | 0.06 | 0.19 | 0.38 | 0.17 |
| O18 | 0.28 | 0.10 | 0.57 | 0.68 | 0.19 | 0.17 | 0.07 | 0.14 | 0.03 | 0.06 | 0.07 | 0.36 | 0.15 |
| O19 | 0.38 | 0.15 | 0.40 | 0.46 | 0.11 | 0.15 | 0.15 | 0.28 | 0.09 | 0.09 | 0.12 | 0.28 | 0.17 |
| O20 | 0.45 | 0.24 | 0.59 | 0.68 | 0.19 | 0.13 | 0.09 | 0.13 | 0.05 | 0.04 | 0.18 | 0.38 | 0.16 |
| O21 | 0.56 | 0.13 | 0.52 | 0.61 | 0.26 | 0.15 | 0.17 | 0.13 | 0.05 | 0.08 | 0.07 | 0.36 | 0.17 |
| O22 | 0.30 | 0.14 | 0.68 | 0.67 | 0.14 | 0.43 | 0.47 | 0.51 | 0.62 | 0.35 | 0.07 | 0.47 | 0.41 |
| O23 | 0.28 | 0.08 | 0.35 | 0.34 | 0.22 | 0.31 | 0.34 | 0.35 | 0.34 | 0.21 | 0.08 | 0.28 | 0.27 |
| O24 | 0.18 | 0.08 | 0.38 | 0.43 | 0.16 | 0.19 | 0.11 | 0.14 | 0.11 | 0.08 | 0.11 | 0.26 | 0.15 |
| O25 | 0.50 | 0.09 | 0.45 | 0.44 | 0.21 | 0.44 | 0.52 | 0.53 | 0.57 | 0.33 | 0.07 | 0.38 | 0.39 |
| O26 | 0.38 | 0.09 | 0.62 | 0.60 | 0.23 | 0.44 | 0.50 | 0.60 | 0.67 | 0.39 | 0.09 | 0.46 | 0.44 |
| O27 | 0.53 | 0.08 | 0.44 | 0.47 | 0.26 | 0.23 | 0.39 | 0.32 | 0.27 | 0.23 | 0.06 | 0.34 | 0.27 |
| O28 | 0.07 | 0.04 | 0.32 | 0.07 | 0.33 | 0.19 | 0.15 | 0.14 | 0.25 | 0.25 | 0.09 | 0.19 | 0.19 |
| O29 | 0.25 | 0.11 | 0.38 | 0.09 | 0.49 | 0.27 | 0.18 | 0.14 | 0.21 | 0.24 | 0.10 | 0.25 | 0.21 |
| O30 | 0.27 | 0.16 | 0.30 | 0.23 | 0.34 | 0.17 | 0.09 | 0.15 | 0.32 | 0.34 | 0.14 | 0.26 | 0.24 |
| O31 | 0.33 | 0.11 | 0.53 | 0.75 | 0.51 | 0.25 | 0.10 | 0.22 | 0.47 | 0.45 | 0.17 | 0.48 | 0.37 |
| O32 | 0.34 | 0.17 | 0.47 | 0.56 | 0.43 | 0.21 | 0.09 | 0.21 | 0.44 | 0.45 | 0.17 | 0.42 | 0.33 |
| O33 | 0.06 | 0.06 | 0.20 | 0.14 | 0.18 | 0.09 | 0.07 | 0.10 | 0.23 | 0.27 | 0.09 | 0.16 | 0.16 |
| O34 | 0.07 | 0.08 | 0.28 | 0.16 | 0.20 | 0.08 | 0.06 | 0.03 | 0.06 | 0.36 | 0.05 | 0.18 | 0.14 |
| O35 | 0.14 | 0.34 | 0.41 | 0.50 | 0.41 | 0.17 | 0.05 | 0.07 | 0.22 | 0.58 | 0.03 | 0.39 | 0.27 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Proposed Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| O36 | 0.11 | 0.39 | 0.54 | 0.50 | 0.39 | 0.16 | 0.08 | 0.07 | 0.17 | 0.59 | 0.03 | 0.41 | 0.26 |
| O37 | 0.13 | 0.46 | 0.47 | 0.53 | 0.38 | 0.14 | 0.08 | 0.10 | 0.12 | 0.57 | 0.04 | 0.40 | 0.26 |
| O38 | 0.08 | 0.10 | 0.26 | 0.19 | 0.24 | 0.09 | 0.05 | 0.03 | 0.06 | 0.26 | 0.03 | 0.18 | 0.12 |
| O39 | 0.40 | 0.47 | 0.53 | 0.56 | 0.41 | 0.18 | 0.09 | 0.06 | 0.08 | 0.48 | 0.13 | 0.44 | 0.25 |
| O40 | 0.48 | 0.42 | 0.56 | 0.47 | 0.34 | 0.09 | 0.33 | 0.47 | 0.41 | 0.21 | 0.30 | 0.41 | 0.33 |
| O41 | 0.11 | 0.63 | 0.45 | 0.49 | 0.38 | 0.18 | 0.33 | 0.54 | 0.44 | 0.34 | 0.06 | 0.42 | 0.35 |
| O42 | 0.14 | 0.63 | 0.63 | 0.57 | 0.46 | 0.26 | 0.33 | 0.52 | 0.45 | 0.43 | 0.09 | 0.50 | 0.39 |
| O43 | 0.20 | 0.62 | 0.69 | 0.64 | 0.51 | 0.26 | 0.32 | 0.48 | 0.40 | 0.45 | 0.11 | 0.54 | 0.39 |
| O44 | 0.28 | 0.64 | 0.84 | 0.70 | 0.50 | 0.32 | 0.30 | 0.47 | 0.42 | 0.45 | 0.12 | 0.60 | 0.41 |
| O45 | 0.35 | 0.45 | 0.69 | 0.64 | 0.50 | 0.33 | 0.31 | 0.45 | 0.39 | 0.53 | 0.14 | 0.54 | 0.41 |
| O46 | 0.34 | 0.19 | 0.32 | 0.71 | 0.53 | 0.31 | 0.28 | 0.36 | 0.36 | 0.58 | 0.18 | 0.45 | 0.42 |
| O47 | 0.25 | 0.23 | 0.35 | 0.89 | 0.62 | 0.28 | 0.07 | 0.30 | 0.28 | 0.56 | 0.24 | 0.50 | 0.40 |
| O48 | 0.20 | 0.23 | 0.48 | 0.73 | 0.58 | 0.27 | 0.35 | 0.24 | 0.17 | 0.46 | 0.16 | 0.46 | 0.36 |
| O49 | 0.56 | 0.90 | 0.99 | 0.40 | 0.13 | 0.26 | 0.43 | 0.36 | 0.44 | 0.45 | 0.21 | 0.56 | 0.35 |
| O50 | 0.38 | 0.69 | 0.89 | 0.19 | 0.29 | 0.13 | 0.41 | 0.39 | 0.42 | 0.42 | 0.21 | 0.46 | 0.33 |
| O51 | 0.19 | 0.35 | 0.40 | 0.63 | 0.26 | 0.12 | 0.41 | 0.48 | 0.64 | 0.61 | 0.21 | 0.43 | 0.45 |
| O52 | 0.16 | 0.09 | 0.61 | 0.59 | 0.34 | 0.13 | 0.39 | 0.47 | 0.71 | 0.68 | 0.22 | 0.46 | 0.48 |
| O53 | 0.14 | 0.07 | 0.61 | 0.53 | 0.40 | 0.16 | 0.37 | 0.31 | 0.40 | 0.45 | 0.11 | 0.41 | 0.35 |
| O54 | 0.18 | 0.23 | 0.50 | 0.52 | 0.47 | 0.19 | 0.08 | 0.16 | 0.15 | 0.09 | 0.02 | 0.36 | 0.19 |
| O55 | 0.21 | 0.22 | 0.54 | 0.65 | 0.44 | 0.13 | 0.17 | 0.08 | 0.25 | 0.09 | 0.08 | 0.40 | 0.22 |
| O56 | 0.29 | 0.30 | 0.49 | 0.61 | 0.39 | 0.20 | 0.24 | 0.31 | 0.29 | 0.26 | 0.13 | 0.41 | 0.30 |
| O57 | 0.35 | 0.32 | 0.47 | 0.54 | 0.37 | 0.44 | 0.46 | 0.51 | 0.57 | 0.35 | 0.16 | 0.44 | 0.42 |
| O58 | 0.34 | 0.30 | 0.38 | 0.31 | 0.38 | 0.17 | 0.50 | 0.47 | 0.29 | 0.27 | 0.04 | 0.32 | 0.30 |

| Velocity Ratio (VR) of Test Points under Annual and Summer Prevailing Wind Conditions (Proposed Scheme) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | Annual Average | Summer Average |
| Frequencies /Test Points | 5.1% | 8.5% | 16.5% | 17.8% | 9.2% | 6.1% | | | 6.3% | 6.7% | | 76.2% | |
| | | | | 7.9% | 7.6% | 6.6% | 8.2% | 9.0% | 13.3% | 14.8% | 10.2% | | 77.6% |
| O59 | 0.45 | 0.28 | 0.35 | 0.28 | 0.37 | 0.12 | 0.51 | 0.43 | 0.13 | 0.13 | 0.06 | 0.28 | 0.23 |
| O60 | 0.56 | 0.27 | 0.31 | 0.20 | 0.37 | 0.06 | 0.53 | 0.44 | 0.10 | 0.07 | 0.06 | 0.24 | 0.21 |
| O61 | 0.56 | 0.23 | 0.26 | 0.21 | 0.36 | 0.08 | 0.52 | 0.40 | 0.09 | 0.03 | 0.05 | 0.23 | 0.19 |
| O62 | 0.55 | 0.20 | 0.19 | 0.18 | 0.36 | 0.11 | 0.48 | 0.43 | 0.15 | 0.04 | 0.07 | 0.21 | 0.21 |
| O63 | 0.85 | 0.22 | 0.15 | 0.08 | 0.37 | 0.18 | 0.41 | 0.43 | 0.16 | 0.04 | 0.10 | 0.21 | 0.20 |
| O64 | 0.90 | 0.23 | 0.14 | 0.05 | 0.36 | 0.34 | 0.33 | 0.41 | 0.18 | 0.03 | 0.16 | 0.22 | 0.21 |
| O65 | 0.96 | 0.29 | 0.12 | 0.15 | 0.31 | 0.50 | 0.30 | 0.36 | 0.18 | 0.03 | 0.11 | 0.25 | 0.21 |
| O66 | 0.96 | 0.40 | 0.09 | 0.19 | 0.25 | 0.57 | 0.36 | 0.37 | 0.20 | 0.07 | 0.07 | 0.27 | 0.23 |
| O67 | 0.94 | 0.38 | 0.11 | 0.07 | 0.27 | 0.48 | 0.40 | 0.42 | 0.22 | 0.09 | 0.18 | 0.24 | 0.25 |
| O68 | 0.89 | 0.11 | 0.20 | 0.08 | 0.29 | 0.27 | 0.37 | 0.41 | 0.21 | 0.06 | 0.37 | 0.21 | 0.24 |
| O69 | 0.82 | 0.09 | 0.20 | 0.12 | 0.25 | 0.10 | 0.30 | 0.34 | 0.19 | 0.01 | 0.37 | 0.19 | 0.20 |
| O70 | 0.82 | 0.12 | 0.15 | 0.16 | 0.23 | 0.11 | 0.21 | 0.30 | 0.16 | 0.09 | 0.39 | 0.20 | 0.20 |
| O71 | 0.83 | 0.23 | 0.11 | 0.17 | 0.21 | 0.05 | 0.15 | 0.29 | 0.15 | 0.22 | 0.41 | 0.20 | 0.21 |

# Appendix B   Directional VR Vector Plots (Summer Condition)

## Baseline Scheme

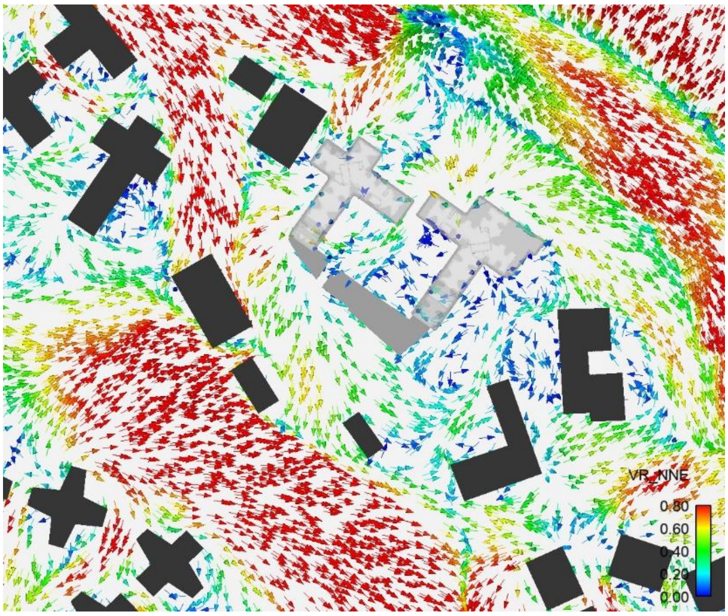



Figure 47  Velocity Vector Plot under NNE wind at Ground Level in Baseline Scheme

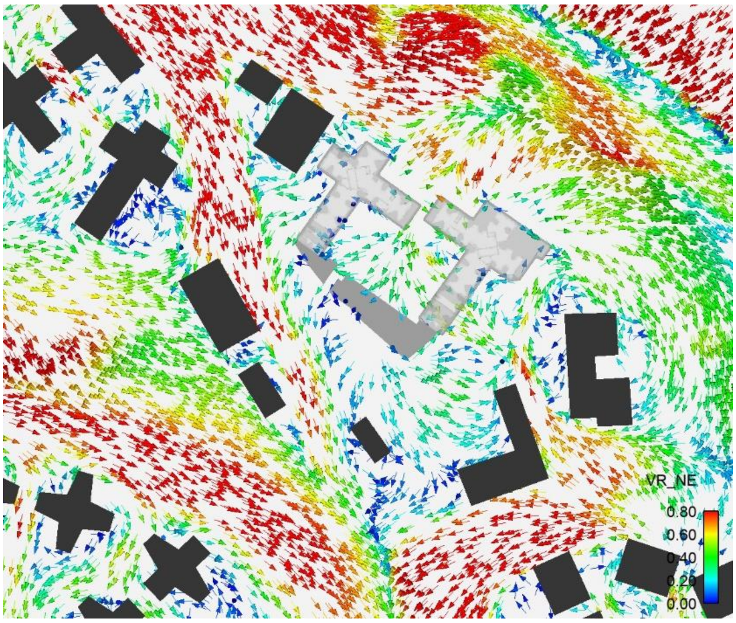
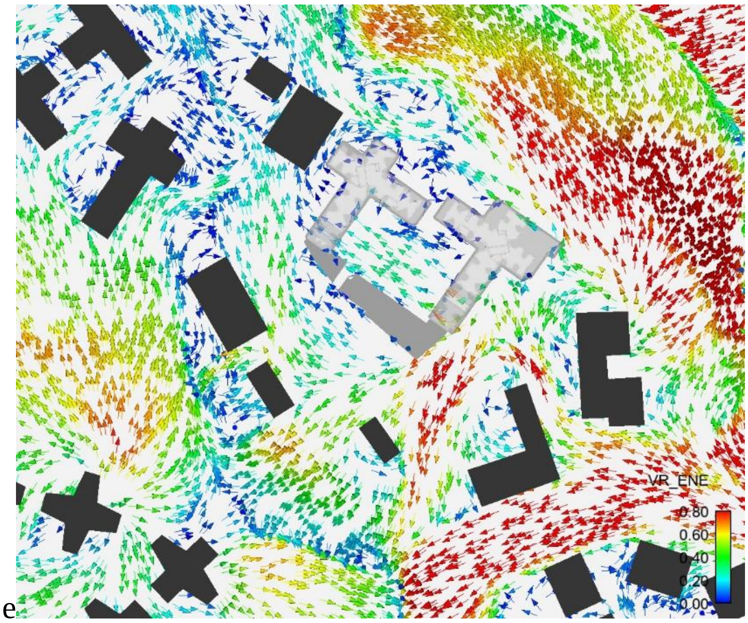



Figure 48  Velocity Vector Plot under NE wind at Ground Level in Baseline Scheme




e

Figure 49 Velocity Vector Plot under ENE wind at Ground Level in Baseline Scheme

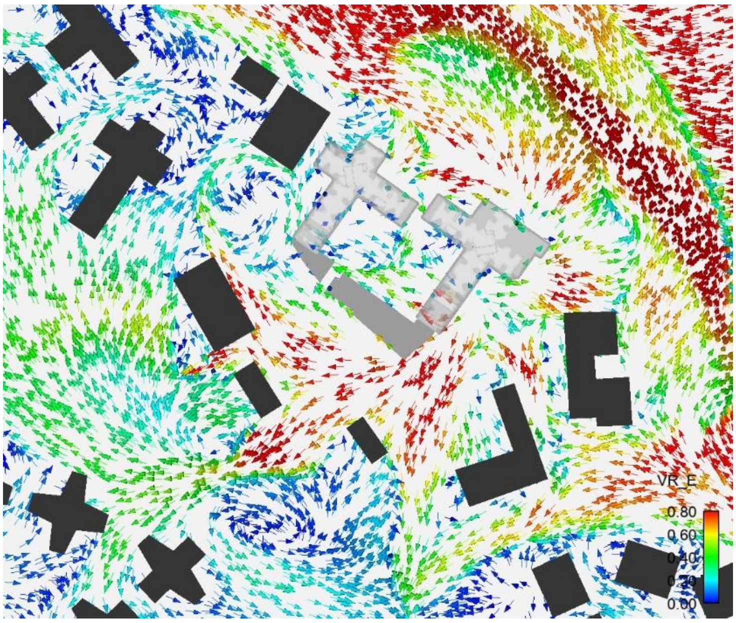



Figure 50 Velocity Vector Plot under E wind at Ground Level in Baseline Scheme

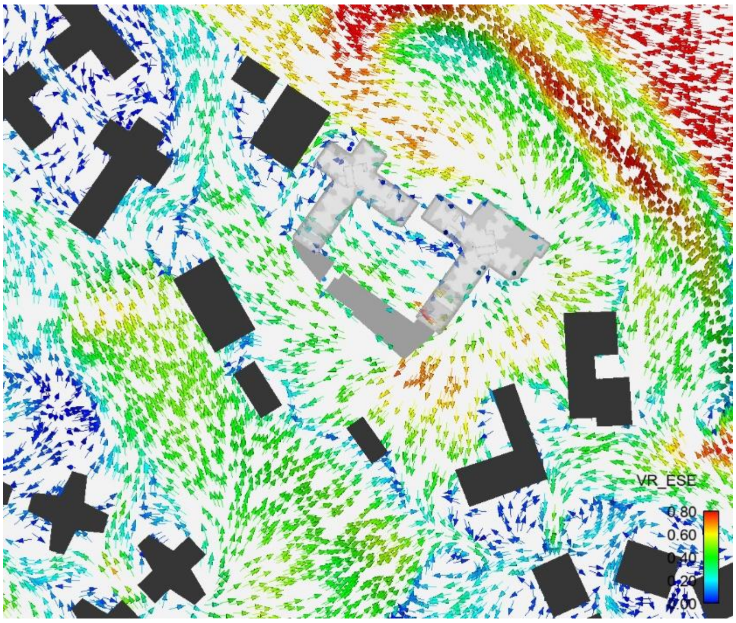



Figure 51  Velocity Vector Plot under ESE wind at Ground Level in Baseline Scheme

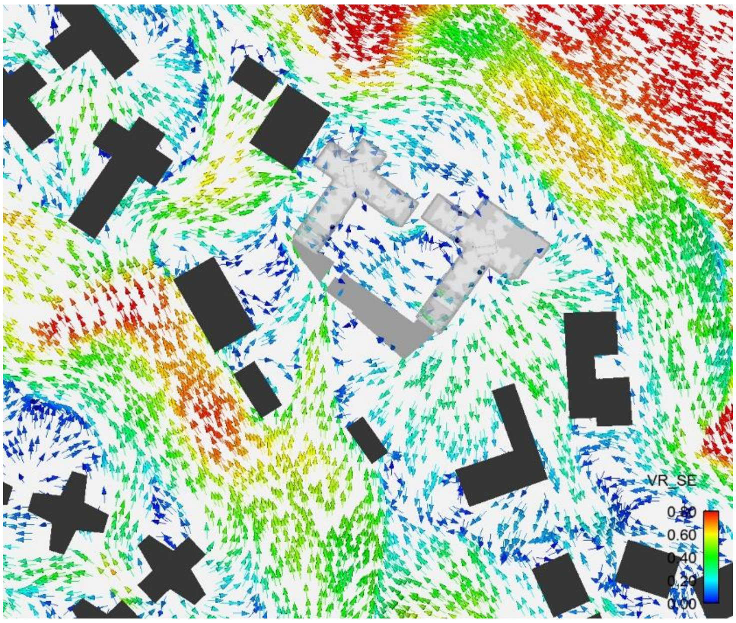



Figure 52  Velocity Vector Plot under SE wind at Ground Level in Baseline Scheme

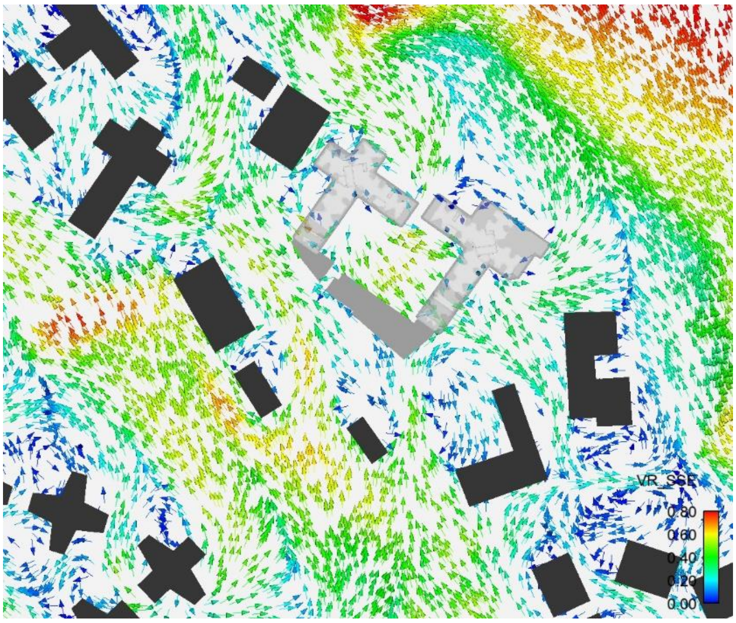



Figure 53 Velocity Vector Plot under SSE wind at Ground Level in Baseline Scheme

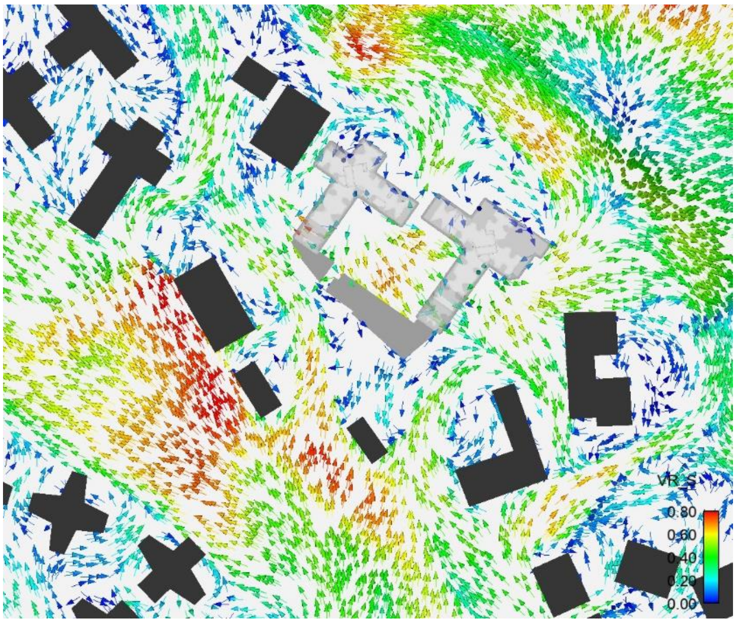



Figure 54 Velocity Vector Plot under S wind at Ground Level in Baseline Scheme

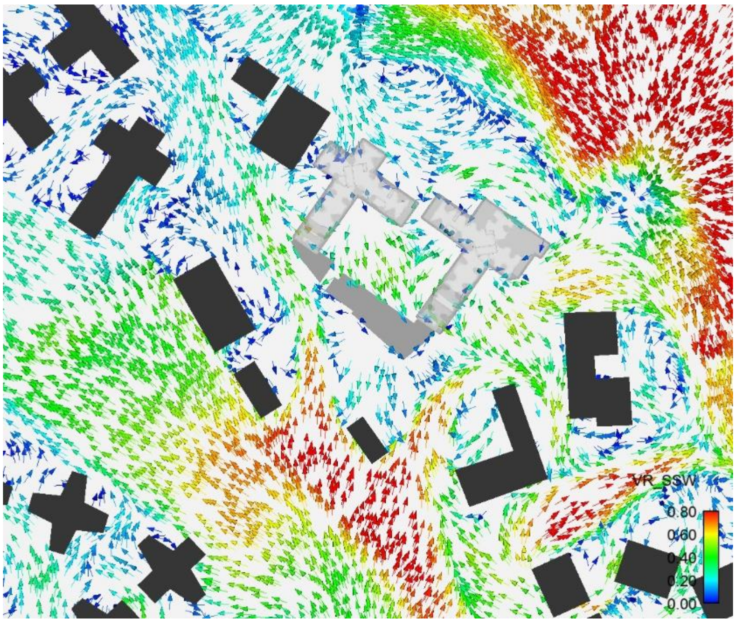



Figure 55 Velocity Vector Plot under SSW wind at Ground Level in Baseline Scheme

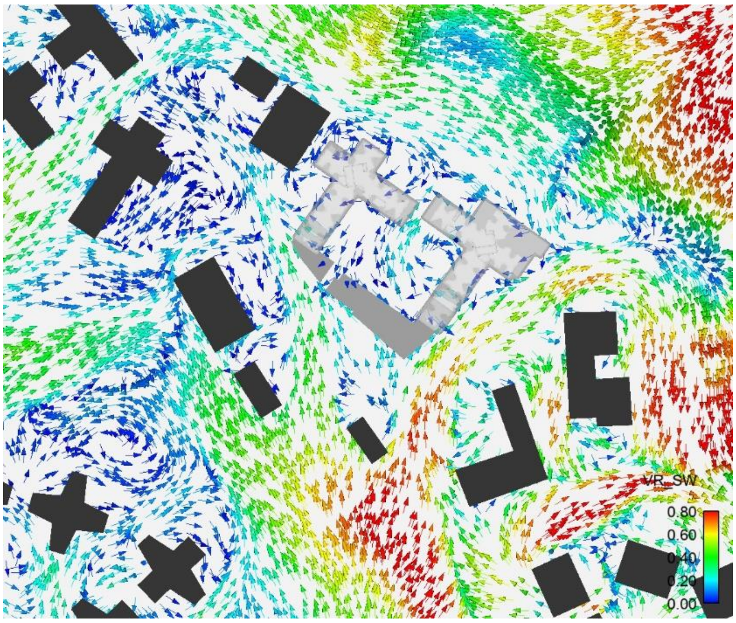



Figure 56 Velocity Vector Plot under SW wind at Ground Level in Baseline Scheme

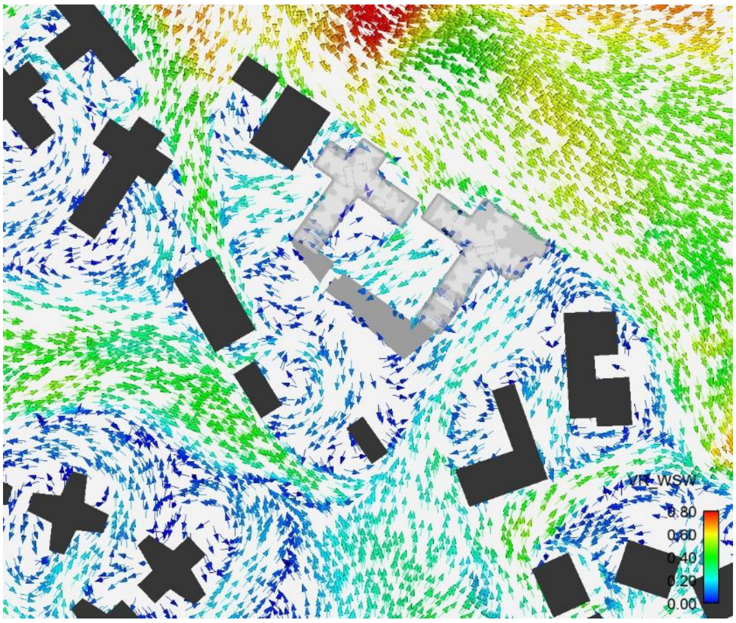



Figure 57 Velocity Vector Plot under WSW wind at Ground Level in Baseline Scheme

# Proposed Scheme

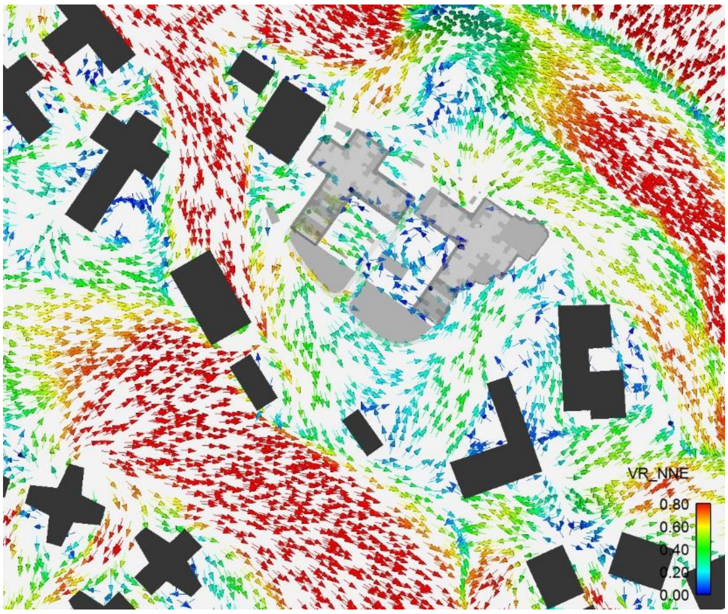



Figure 58 Velocity Vector Plot under NNE wind at Ground Level in Proposed Scheme

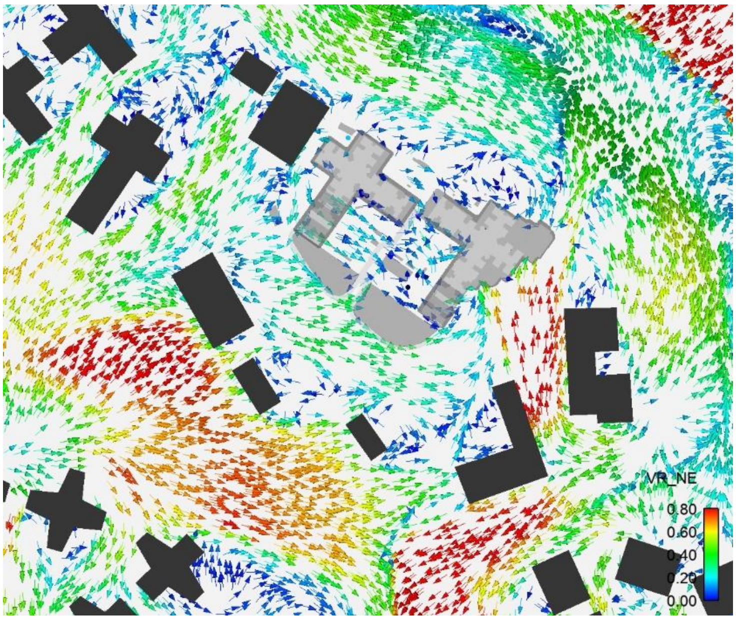



Figure 59 Velocity Vector Plot under NE wind at Ground Level in Proposed Scheme

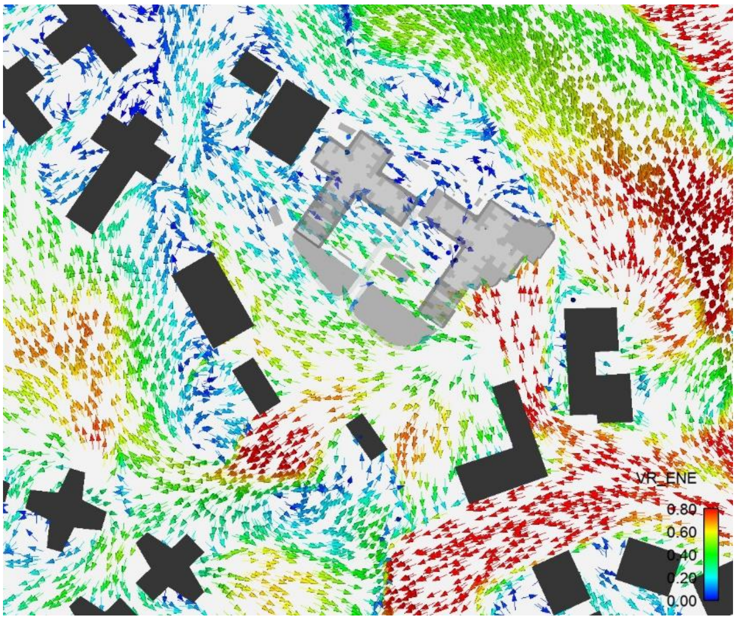



Figure 60  Velocity Vector Plot under ENE wind at Ground Level in Proposed Scheme

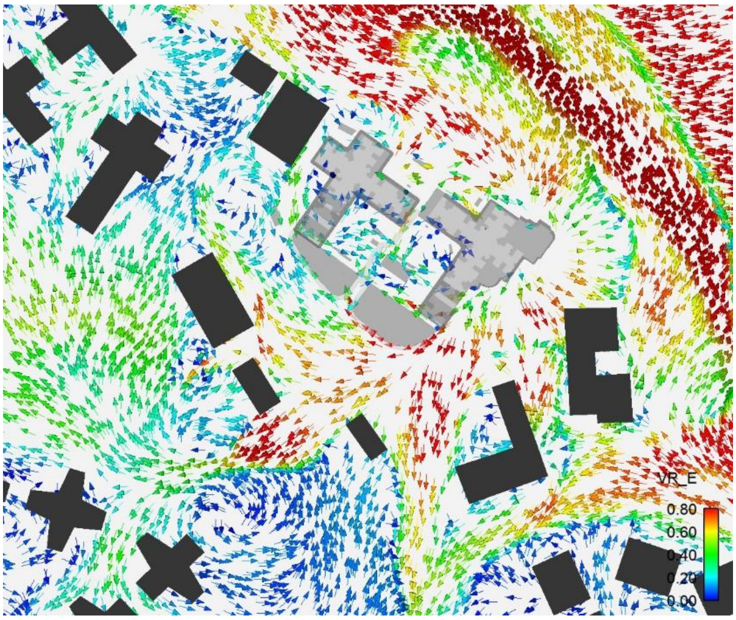



Figure 61  Velocity Vector Plot under E wind at Ground Level in Proposed Scheme

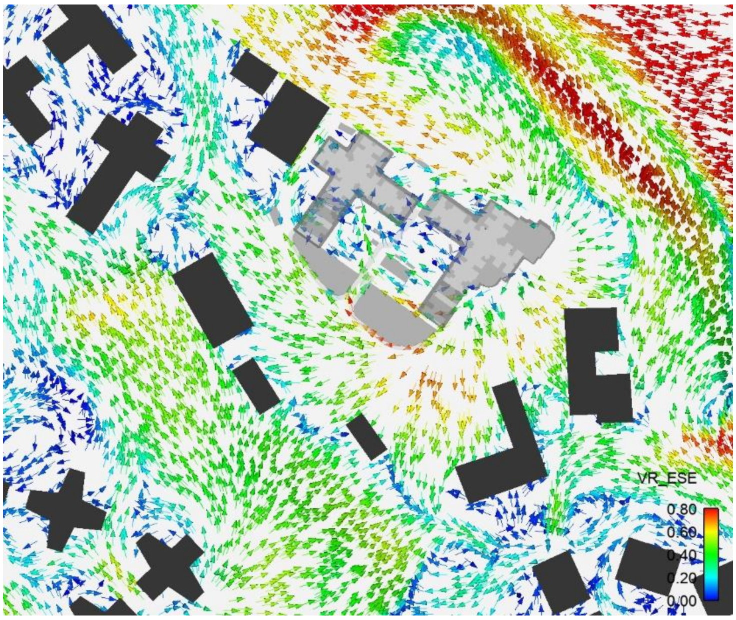



Figure 62 Velocity Vector Plot under ESE wind at Ground Level in Proposed Scheme

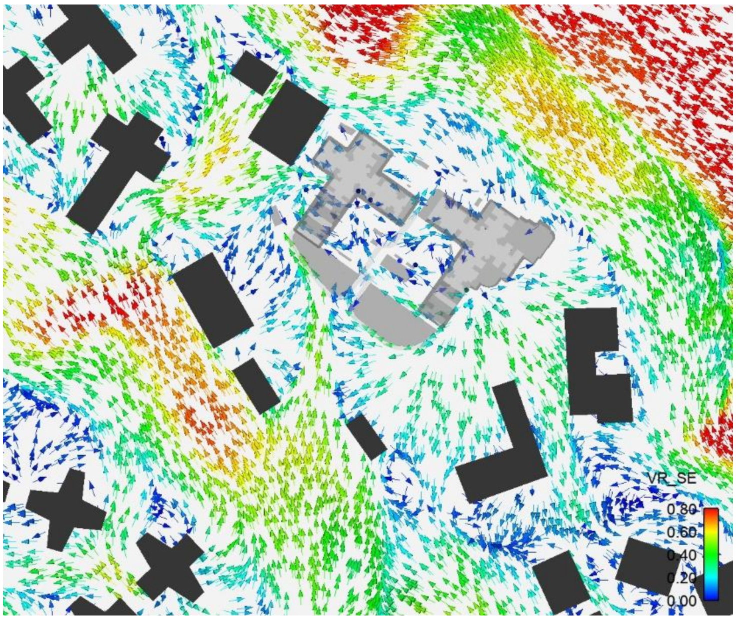



Figure 63 Velocity Vector Plot under SE wind at Ground Level in Proposed Scheme

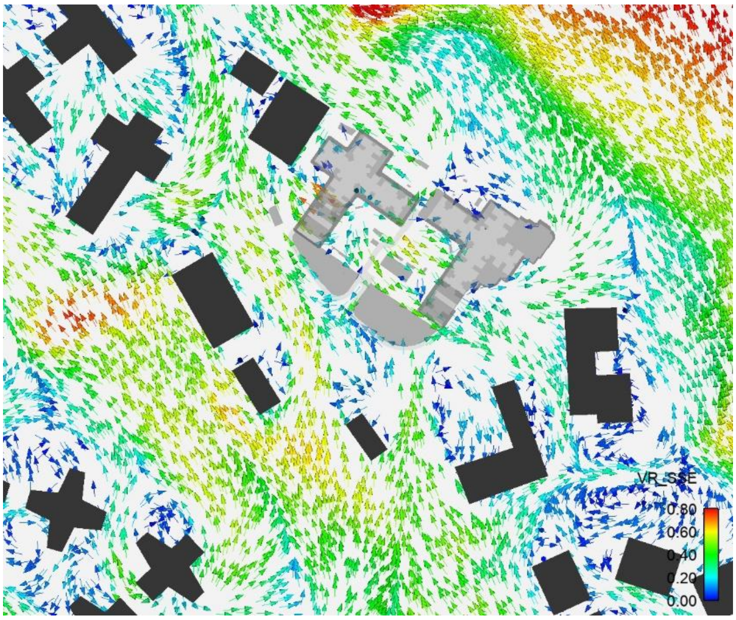



Figure 64 Velocity Vector Plot under SSE wind at Ground Level in Proposed Scheme

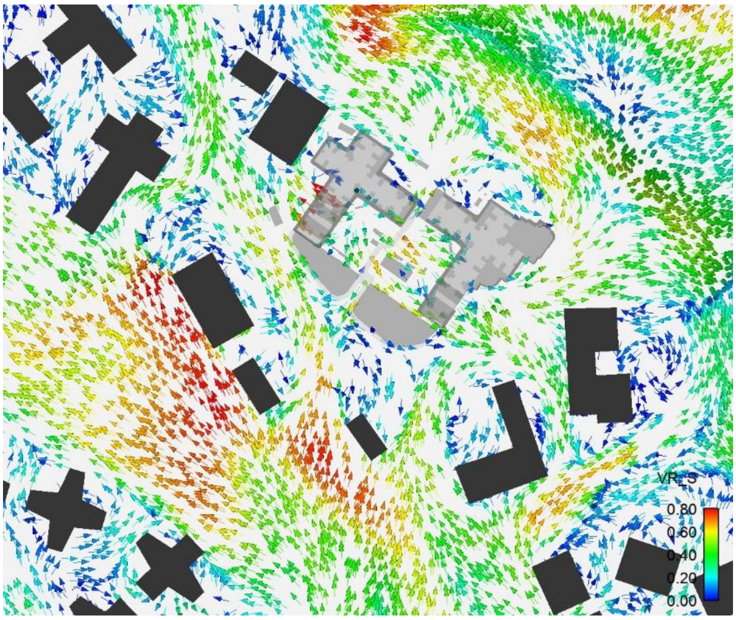



Figure 65 Velocity Vector Plot under S wind at Ground Level in Proposed Scheme

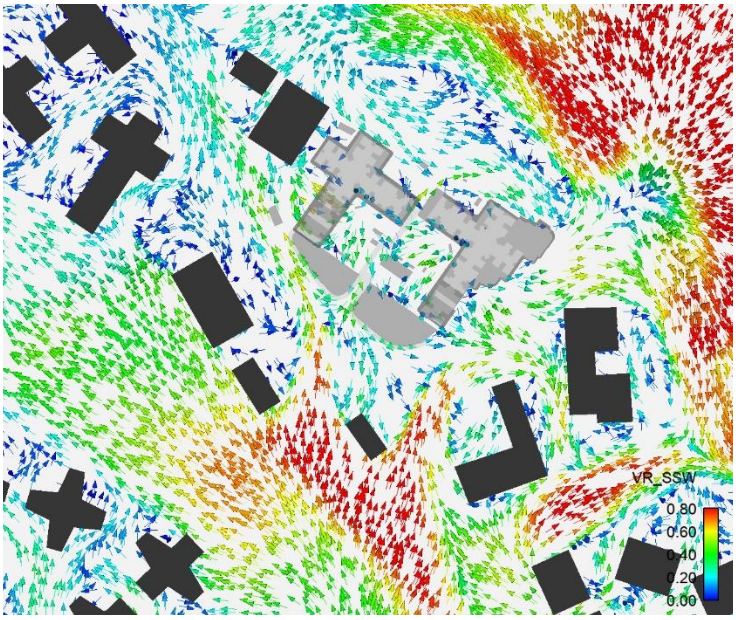



Figure 66  Velocity Vector Plot under SSW wind at Ground Level in Proposed Scheme

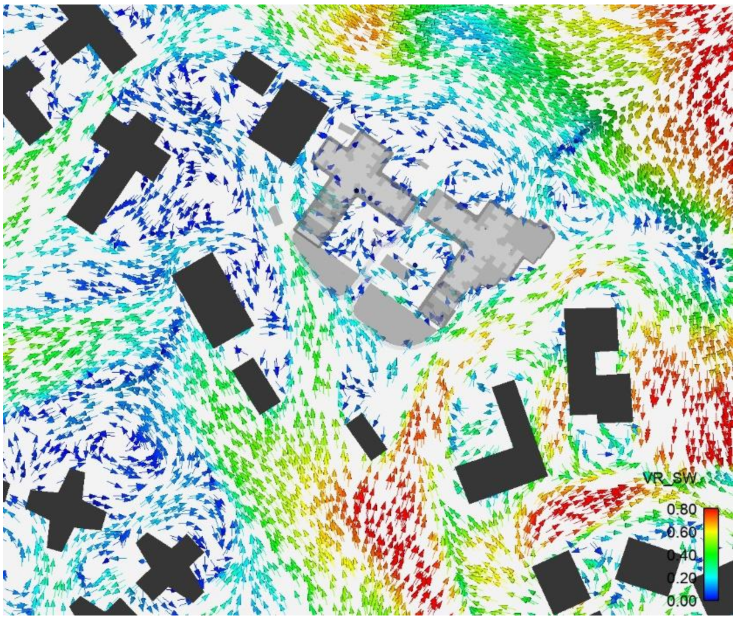



Figure 67  Velocity Vector Plot under SW wind at Ground Level in Proposed Scheme

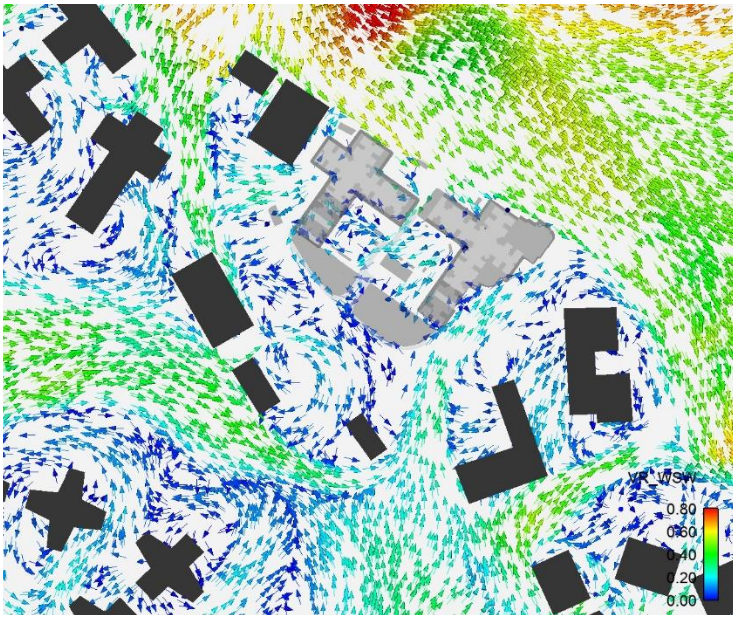



Figure 68 Velocity Vector Plot under WSW wind at Ground Level in Proposed Scheme