TERM CONSULTANCY FOR AIR VENTILATION ASSESSMENT SERVICES

Cat. A1– Term Consultancy for Expert Evaluation and Advisory Services on Air Ventilation Assessment (PLNQ 37/2007)

Final Report

Wang Tau Hom & Tung Tau Area

August 2010

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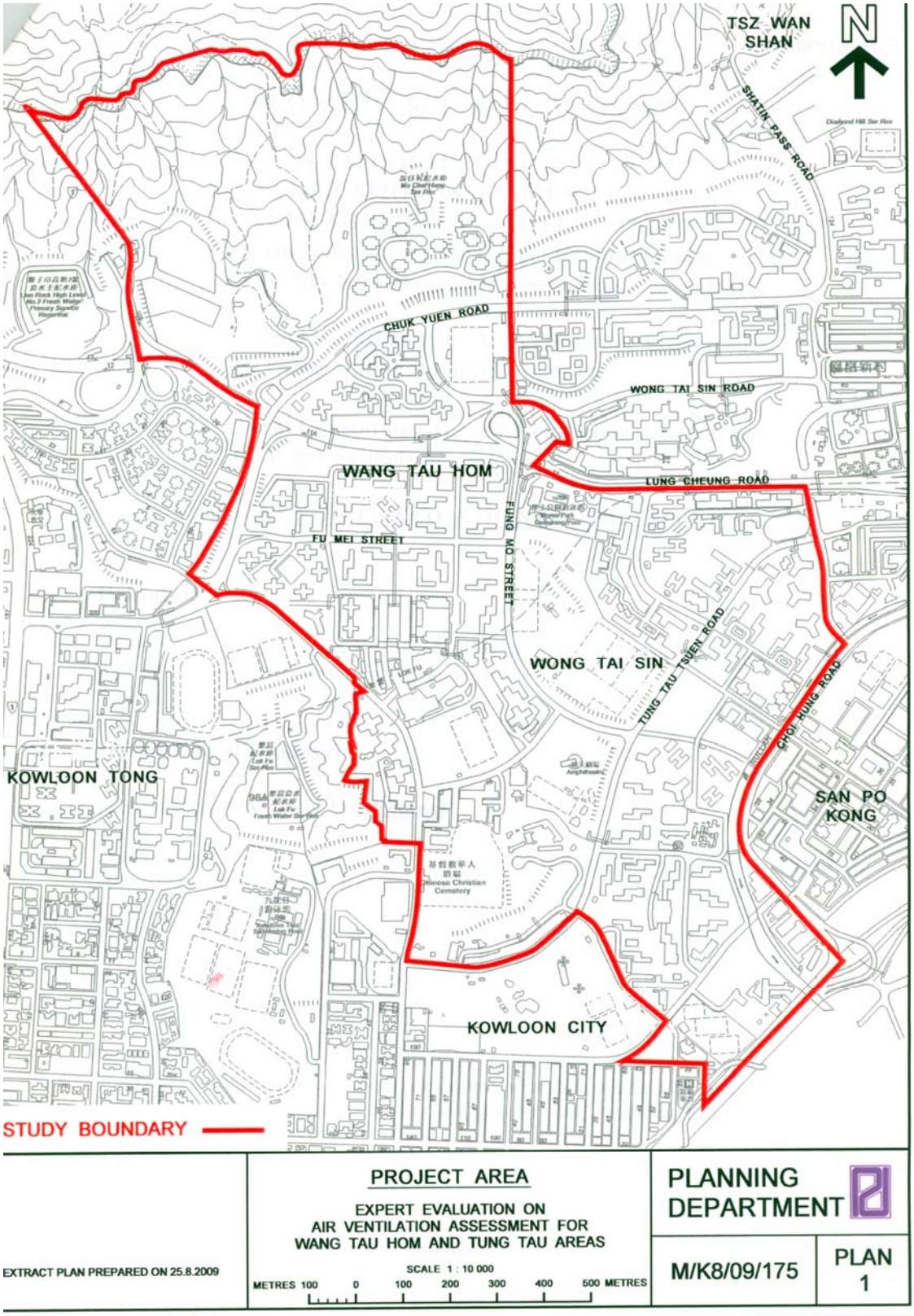
The Study Area



Expert Evaluation Report
of Wang Tau Hom & Tung Tau Area

Executive summary

0.1 Wind Availability

(a) Based on the available wind data, the annual wind of the study area is mainly from the East and North-East. The summer wind is mainly coming from the East, the West and the Southerly quarters.

(b) The Area is exposed to the empty site of the former Kai Tak Airport, which is further open to the Victoria Harbor in the south. It rises from the sea level to 240 mPD of Lion Rock at the north boundary over a distance of about 2 km. The ground rises gently northwards until Lung Cheung Road and then it goes steeper. For the purpose of air ventilation assessment, when wind is from the south to the north, the compression of air volume due to the sloping ground is insignificant. The overall ground can be assumed reasonably flat with the west side being a little higher when air paths of the study area are later assessed.

(c) For wind coming from the north and northeast over the hills, the wind profiles characteristics will be affected by hills. Turbulence and re-circulation of wind when it moves downhill towards the study area is expected (Figure 4.2). In general, the northerly wind arriving at the study area will be slowed and weakened by the shielding effects of the hills.

0.2 Existing conditions

(a) The existing building heights in mPD are ranging from 20mPD on the flat land to 190mPD on the northern slope. They mainly follow a stepped height profile.

(b) The study area has extensive open green spaces as “air spaces” both on slopes and flat ground where air ventilation can be relieved. There are: Lion Rock Park, Ma Chai Hang Playground, Morse Park (I) to (IV), Lok Fu Recreation Ground, Shek Ku Lung Road Playground. Especially because they are well distributed as well as linked, they are very useful to the Area.

(c) Due to the fact that the greenery coverage of the Area is mid to high; the corresponding Ground Coverage (GC) of buildings is low to mid. On the whole, the building volume density of the study area is not high. Properly and strategically located air paths should be able to address some of the urban thermal comfort concerns in the summer months.

0.3 The Existing Conditions with Committed Projects

(a) There are a few committed redevelopment projects scattered in the study area. One site is on the current Nga Tsin Wai Village to be redeveloped by Urban Renewal Authority. There will be a group of two separate high buildings (about 100mPD) with a horizontal distance of 40m from each other. These two buildings are designed with a vertical clearance and elevated to 15m above ground. The space between two buildings and on pedestrian level will let wind penetrate through.

(b) Another committed development is in Tung Tau Cottage Area East. Wind will not decrease much due to a single high-rise building so long as its surrounded buildings are not high on the whole.

(c) Tung Tau Estate Phase 9 will be developed to 2 buildings with a distance of about 10m in between. Its building width is about 40m for each. The permeability is acceptable.

0.4 The Initial Planned Scenario

(a) The proposed building height restrictions for “R(A)”, “C” “G/IC” and “OU” zones mainly reflect the existing conditions.

(b) In the initial planned scenario, It can be seen that some big roads are extracted from “R(A)” zone and rezoned to ROAD. It is good to ensure that the roads stay as air paths.

(c) In the initial planned scenario, some useful and important non-building areas are designated. The positions of the non-building areas are appropriate in terms of air ventilation.

(d) In addition, to further improve air ventilation connectivity of the area, more recommendations are made on NBA.

(e) The initial planned scenario keeps most of the existing “G/IC” sites as low-rise buildings and “O” sites. “G/IC” sites connected to or next to the main air paths are particularly useful. Further greening on these sites is recommended.

(f) Besides the non-building areas within the public housing estates, it is expected that Housing Department will conduct its own detail air ventilation assessment to further optimize their local air ventilation designs upon redevelopment.

0.5 The Recommended Scenario

(a) There is no focus area of concern in the study area. Further study will not be necessary.

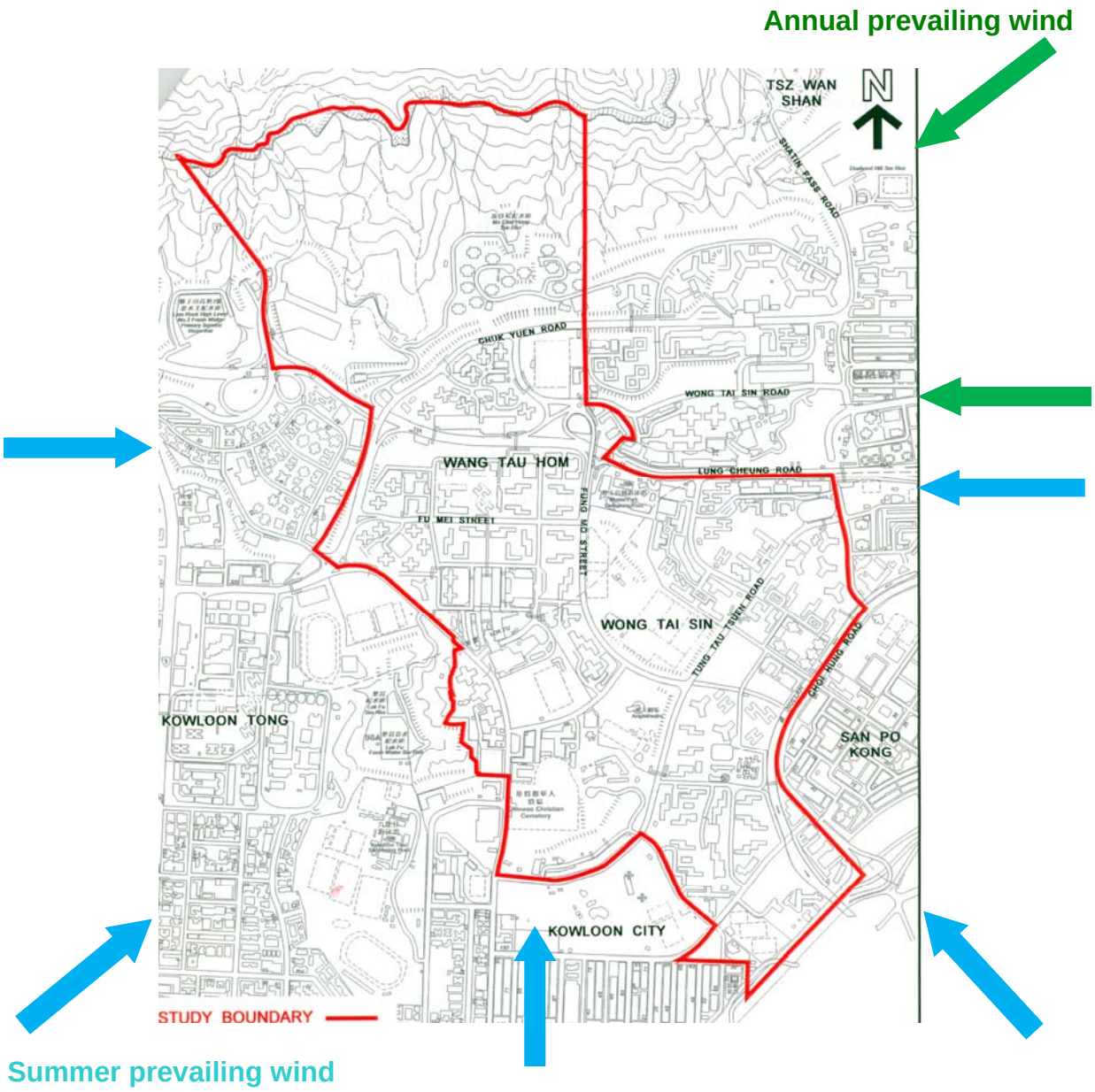


Figure 0.1 A summary of the prevailing winds of the Area

Expert Evaluation Report of **Wang Tau Hom & Tung Tau Area**

1.0 The Assignment

1.1 In order to provide better planning control on the building height upon development/redevelopment, the approved Wang Tau Hom & Tung Tau Outline Zoning plan (OZP) No. S/K8/19 (the Plan) is being reviewed with a view to incorporating appropriate development restrictions for various development zones of the OZP to guide future development/redevelopment. It is considered necessary to conduct an expert evaluation to assess the preliminary Air Ventilation impacts of the proposed building height restrictions.

1.2 This expert evaluation report is based on the materials given by Planning Department on 28th October and 3rd December 2009 to the Consultant including:

-	existing building height (in mPD) for Wang Tau Hom & Tung Tau Area
-	proposed building height restrictions (in mPD) for "R(A)" and "C" zones in Wa Tau Hom & Tung Tau Area
-	proposed building height restrictions (mainly in number of storeys) for "G/IC" and "OU" zones in Wang Tau Hom & Tung Tau Area
-	spot heights in Wang Tau Hom & Tung Tau Area
-	building age profile in Wang Tau Hom & Tung Tau Area
-	committed projects

1.3 The consultant has studied the above mentioned materials, and has conducted site inspection on 5th December 2009. During the writing of the report, the consultant has working sessions with colleagues on 28th October 2009 and 29th December 2009 at Planning Department.

2.0 Background

2.1 Planning Department's study: "Feasibility Study for Establishment of Air Ventilation Assessment System" has recommended that it is important to allow adequate air ventilation through the built environment for pedestrian comfort.

2.2 Given Hong Kong's high density urban development, the study opines that: "more air ventilation, the better" is the useful design guideline.

2.3 The study summarizes 10 qualitative guidelines for planners and designers. For the OZP level of consideration, breezeways/air paths, street grids and orientations, open spaces, non-building areas, waterfront sites, scales of podium, building heights, building dispositions, and greeneries are all important strategic considerations.

2.4 The study also suggests that Air Ventilation Assessment (AVA) be conducted in 3 stages: Expert Evaluation, Initial Studies, and Detailed Studies. The suggestion have been adopted and incorporated into HPLB and ETWB Technical Circular no. 1/06. The key purposes of Expert Evaluation are to:

(a) Identify good design features.
(b) Identify obvious problem areas and propose some mitigation measures.
(c) Define “focuses” and methodologies of the Initial and/or Detailed studies.
(d) Determine if further study should be staged into Initial Study and Detailed Study, or Detailed Study alone.

2.5 To conduct the Expert Evaluation systematically and methodologically, it is necessary to undertake the following information analyses:

(a) Analyse relevant wind data as the input conditions to understand the wind environment of the Area.
(b) Analyse the topographical features of the Area, as well as the surrounding areas.
(c) Analyse the greenery/landscape characteristics of the Area, as well as the surrounding areas.
(d) Analyse the land use and built form of the Area, as well as the surrounding areas.

Based on the analyses:

(e) Estimate the characteristics of the input wind conditions of the Area.
(f) Identify the wind paths and wind flow characteristics of the Area through slopes, open spaces, streets, gaps and non building areas between buildings, and low rise buildings; also identify stagnant/problem areas, if any.
(g) Estimate the need of wind for pedestrian comfort.

Based on the analyses of the EXISTING urban conditions:

(h) Evaluate the strategic role of the Area in air ventilation term.
(i) Identify problematic areas which warrant attention.
(j) Identify existing “good features” that needs to be kept or strengthened.

Based on an understanding of the EXISTING urban conditions:

(k) Compare the prima facie impact, merits or demerits of the building height restrictions as proposed by Planning Department on Air Ventilation.
(l) Highlight problem areas, if any. Recommend improvements and mitigation measures if possible.
(m) Identify focus areas or issues that may need further studies. Recommend appropriate technical methodologies for the study if needed.

3.0 The Wind Environment

3.1 Hong Kong Observatory (HKO) stations provide useful and reliable data of the wind environment in Hong Kong (Figure 3.1). There are some 46 stations operated by HKO in Hong Kong. Together, they allow a very good general understanding of the wind environment especially close to ground level.

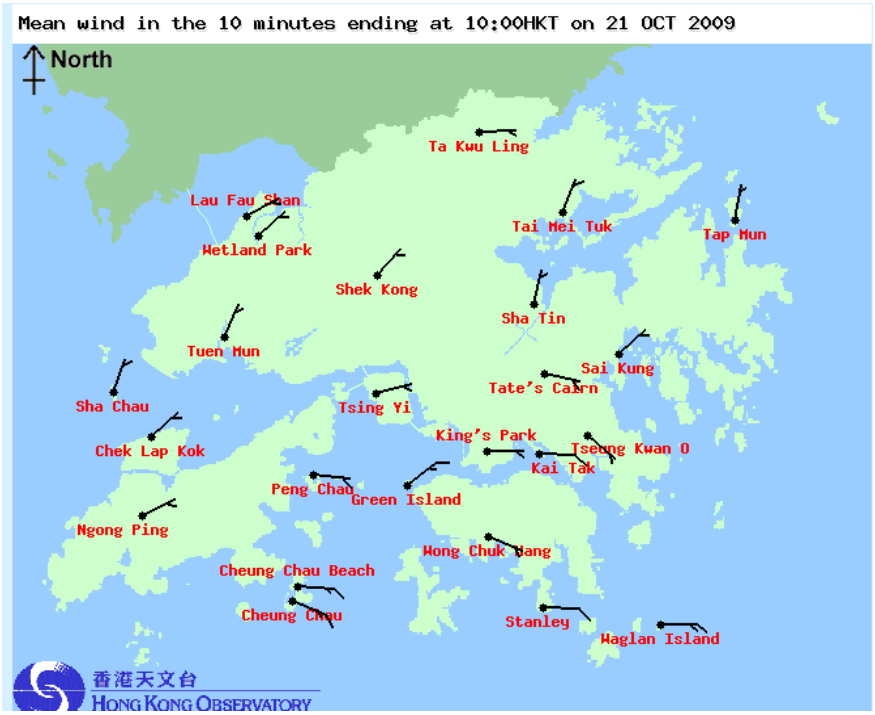


Figure 3.1 Some of the HKO stations in Hong Kong. This is a screen capture at 10:00 on 21 Oct 2009 from the HKO website. The arrows show the wind directions and speeds of the time.

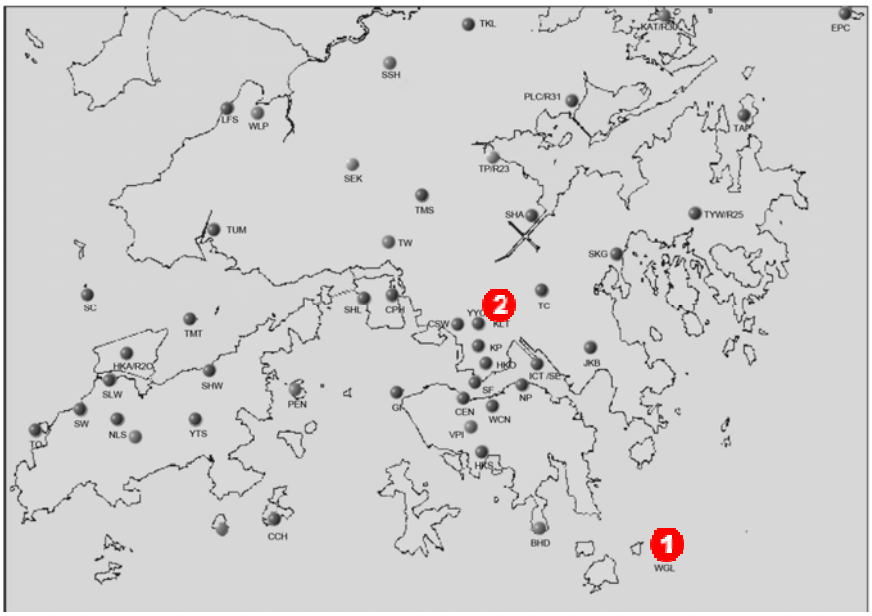


Figure 3.2 The HKO stations at 1: Waglan Island (WGL), 2: Kowloon Tsai (KLT),

3.2 The HKO station at Waglan Island (WGL) is normally regarded by wind engineers as the reference station for wind related studies (Figure 3.3). The station has a very long measuring record, and it is unaffected by Hong Kong's complex topography [unfortunately, it is known not to be able to capture the thermally induced local wind circulation like sea breezes too well]. Based on WGL wind data, studies are typically employed to estimate the site wind availability taking into account the topographical features around the site.

3.3 Examining the annual wind rose of WGL, it is apparent that the annual prevailing wind in Hong Kong is from the East. There is also a major component of wind coming from the North-East; and there is a minor, but nonetheless observable component from the South-West. Around 70% of the time, WGL has weak to moderate wind (0.1m/s to 8.2 m/s).

3.4 For the study, it is important to understand the wind environment seasonally or monthly (Figure 3.4 and 3.5). In the winter months of Hong Kong, the prevailing wind comes from the North-East. In the summer months, they come from the South-West. As far as AVA is concerned, in Hong Kong, the summer wind is very important and beneficial to thermal comfort. Hence, based on WGL data, it is very important to plan our city, on the one hand, to capture the annual wind characteristics, and on the other hand, to maximize the penetration of the summer winds (mainly from the South-West) into the urban fabric.

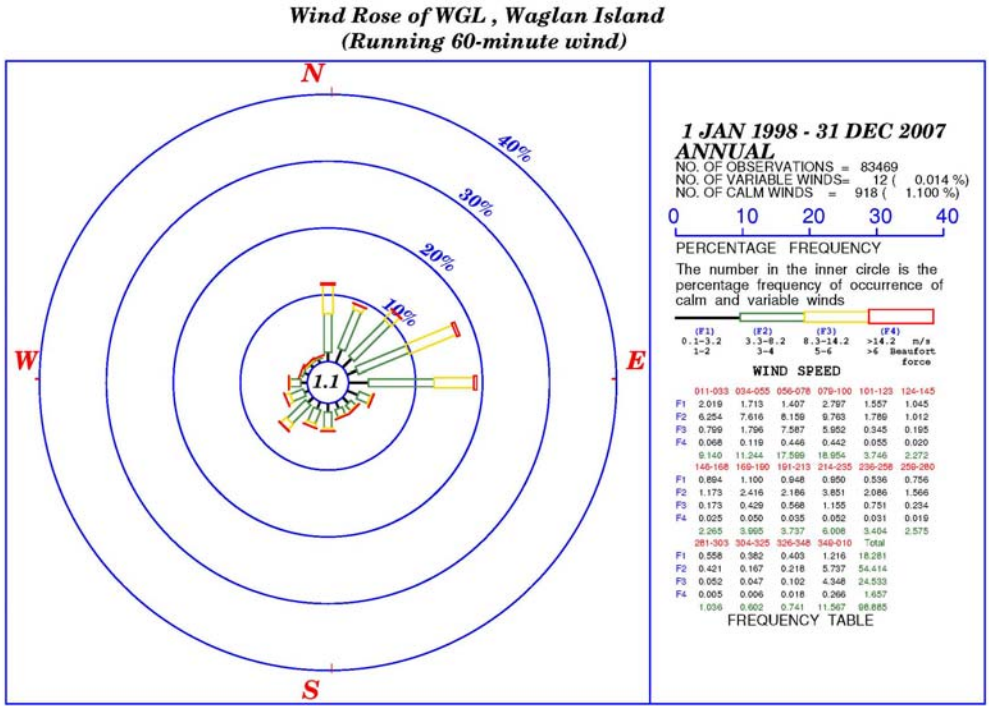


Figure 3.3 Wind rose of WGL 1998 – 2007[1] (annual)

[1] Wind data in 1998 – 2007 are the latest available 10-year data from HKO to the consultant.

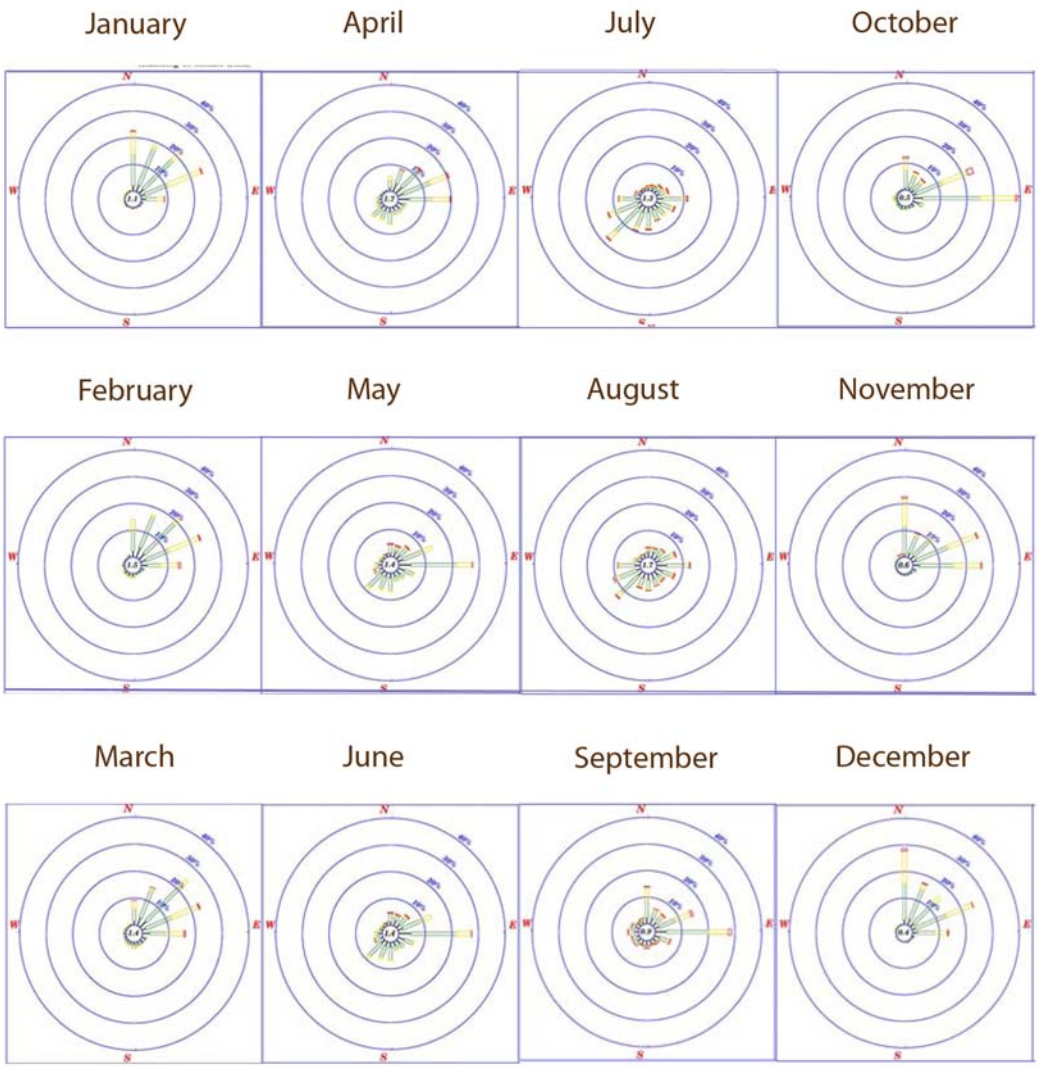


Figure 3.4 monthly wind roses of WGL 1998 – 2007

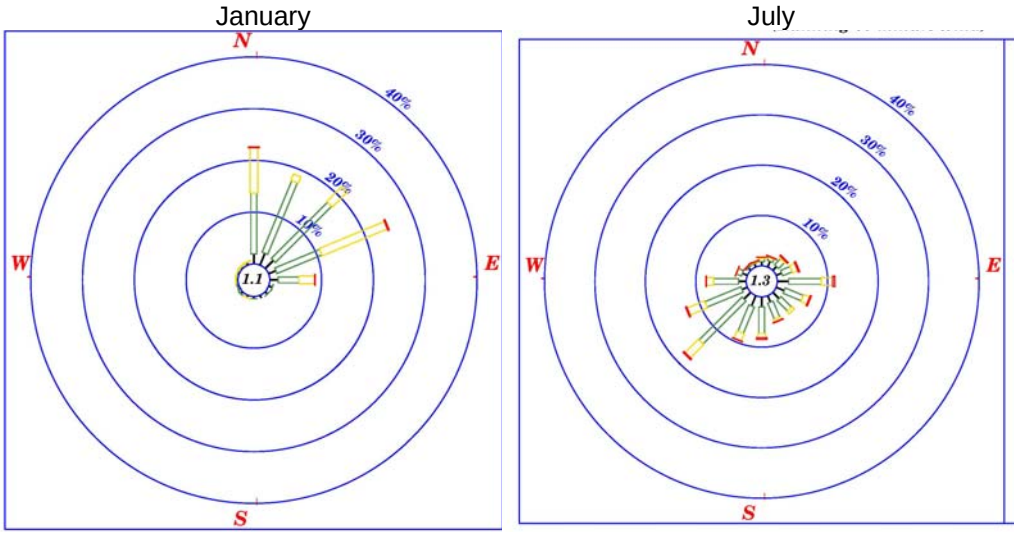


Figure 3.5 Wind roses of WGL 1998 – 2007 (Jan and July)

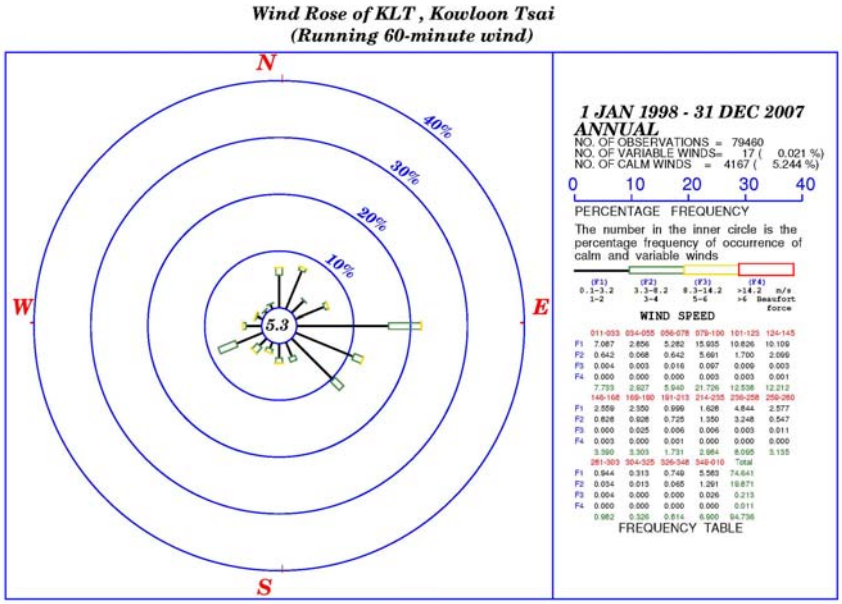


Figure 3.6 Wind rose of Kowloon Tsai 1998-2007 (annual)

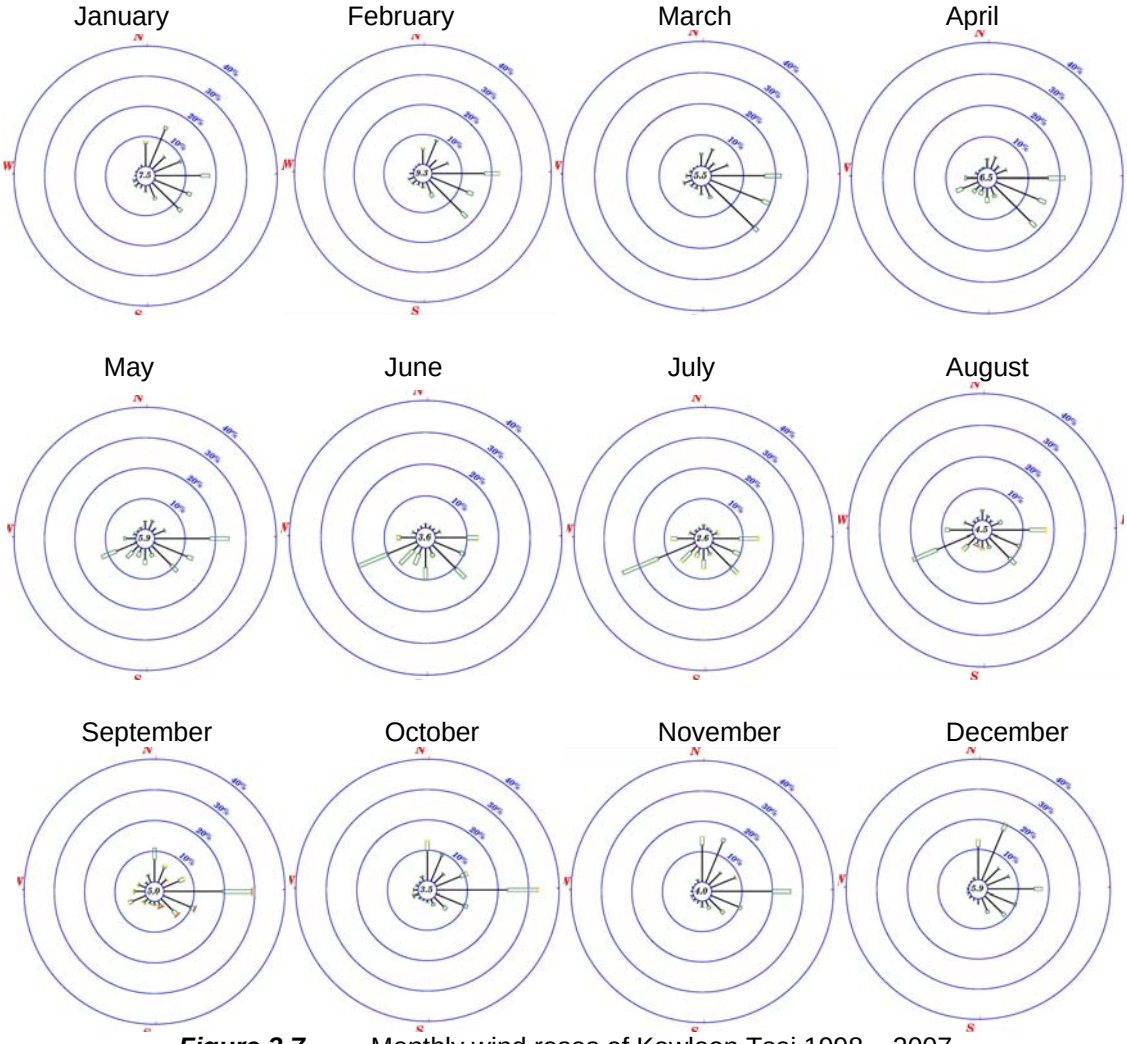


Figure 3.7 Monthly wind roses of Kowloon Tsai 1998 – 2007

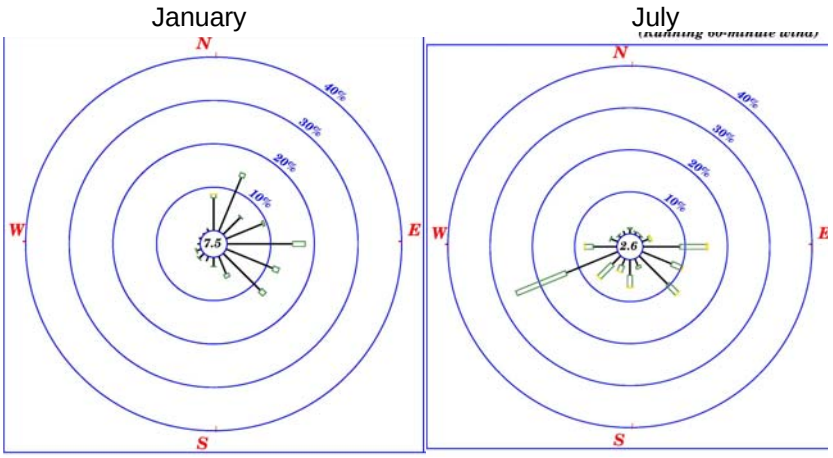


Figure 3.8 Wind roses of Kowloon Tsai 1998 – 2007 (Jan and July)

3.5 Apart from Waglan Island, wind data at Kowloon Tsai station have been extracted from HKO for reference (Figure 3.6 – 3.8) as the nearest stations measuring wind. It is located between Lok Fu Park and Kowloon Tsai Park. Kowloon Tsai's annual wind rose shows a prevailing wind direction of East, South-East and North-East. Kowloon Tsai's summer wind rose shows a prevailing wind direction of South-West, East and South-East. The eastern component benefits from sea breeze of the air channel over the old Kai Tak Airport. The western component comes from the same channeling effect from the Harbor west of the study area.

3.6 Researchers at Hong Kong University of Science and Technology (HKUST), Prof Alexis Lau and Prof Jimmy Fung, have simulated a set of wind data using MM5. The data period cover the whole year of 2004. Based on this dataset, 4 locations of the Area are extracted at 120m and 450m above ground (Figures 3.9 to 3.17).

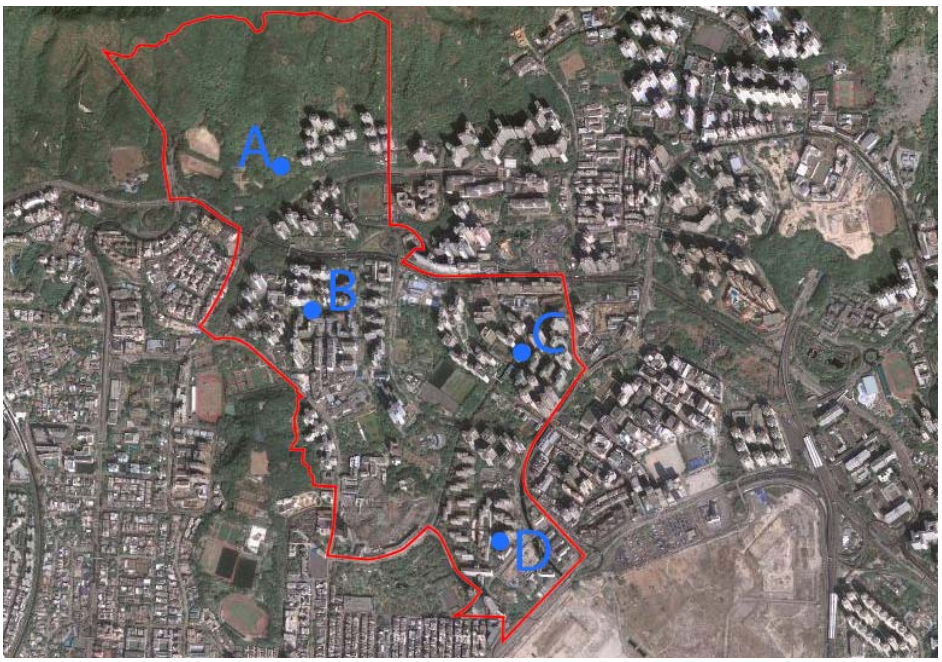


Figure 3.9 The 4 locations of MM5 extracted data

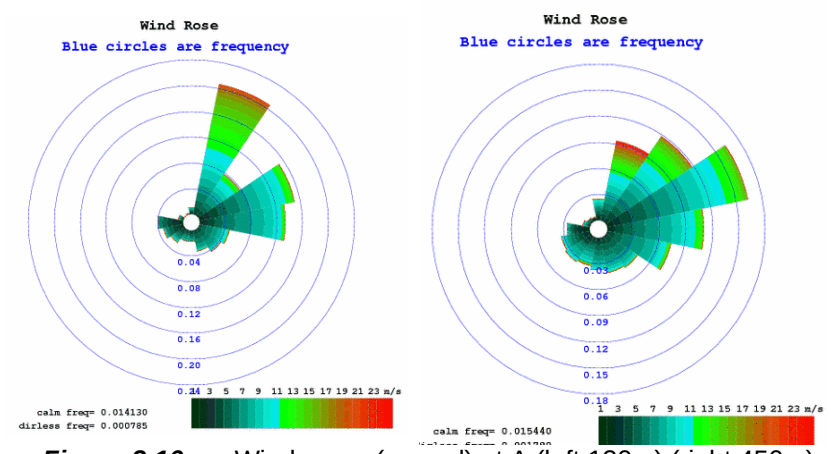


Figure 3.10 Wind roses (annual) at A (left:120m) (right:450m)

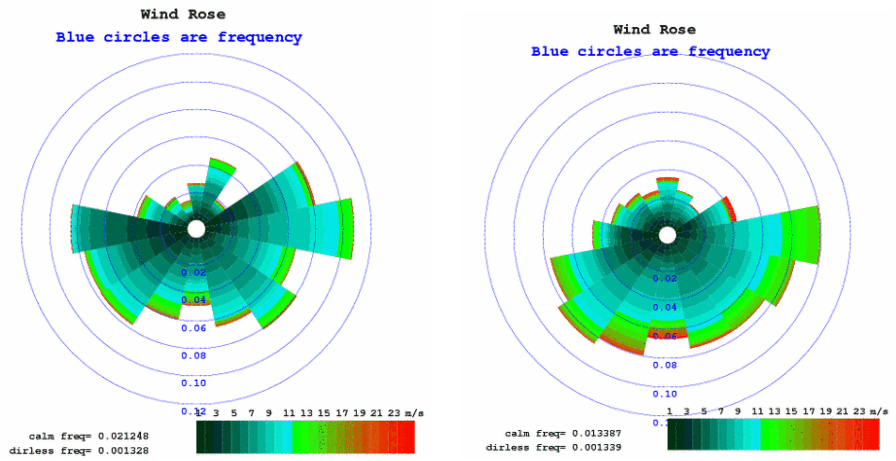


Figure 3.11 Wind roses (summer) at A (left:120m) (right:450m)

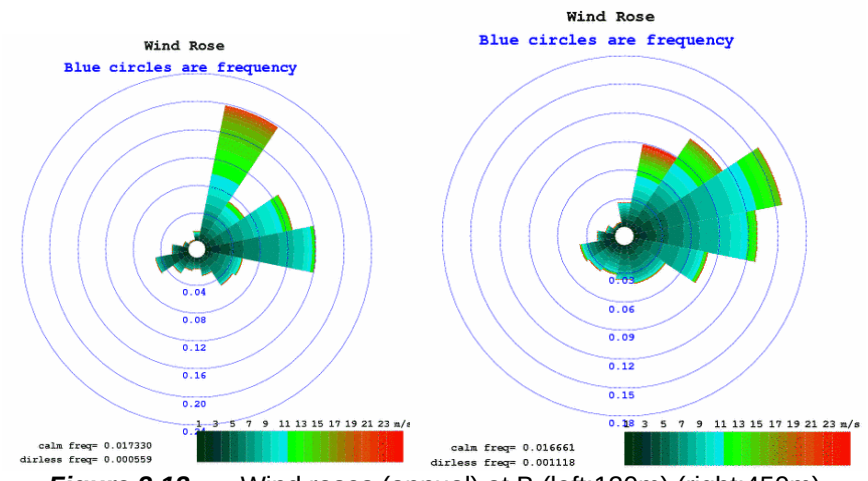


Figure 3.12 Wind roses (annual) at B (left:120m) (right:450m)

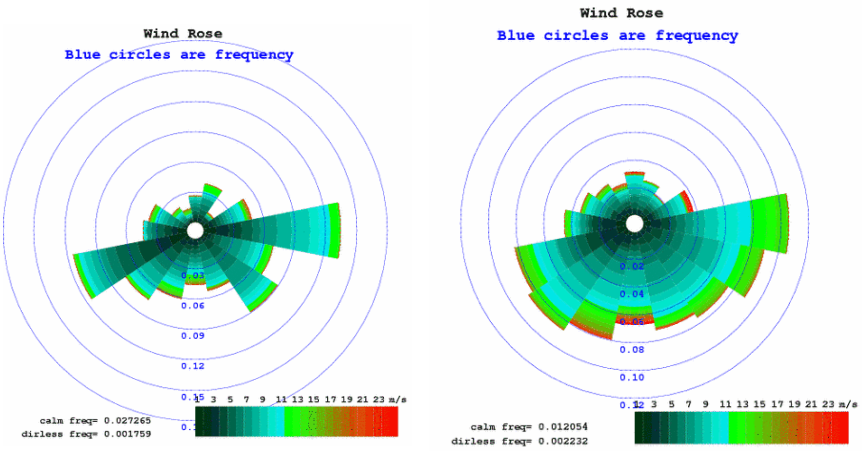


Figure 3.13 Wind roses (summer) at B (left:120m) (right:450m)

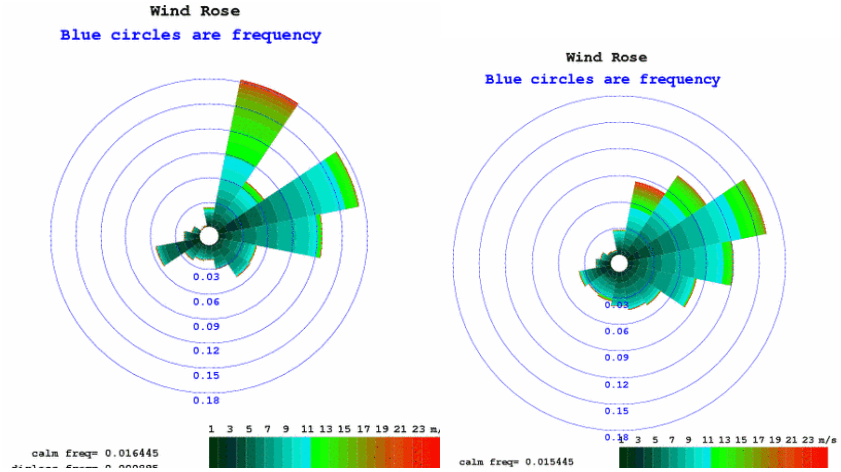


Figure 3.14 Wind roses (annual) at C (left:120m) (right:450m)

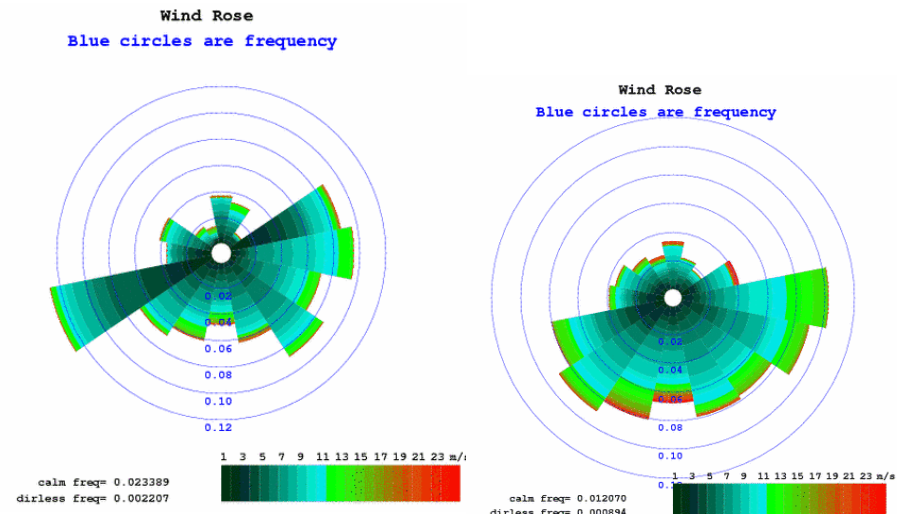


Figure 3.15 Wind roses (summer) at C (left:120m) (right:450m)

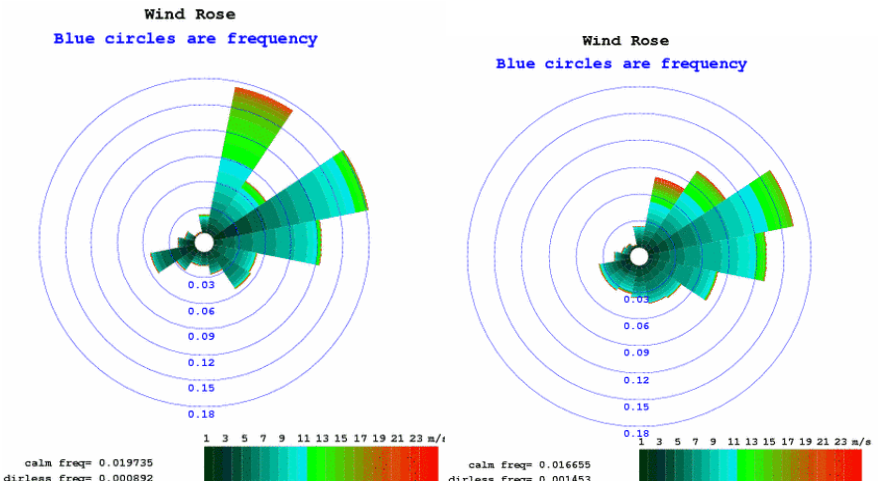


Figure 3.16 Wind roses (annual) at D (left:120m) (right:450m)

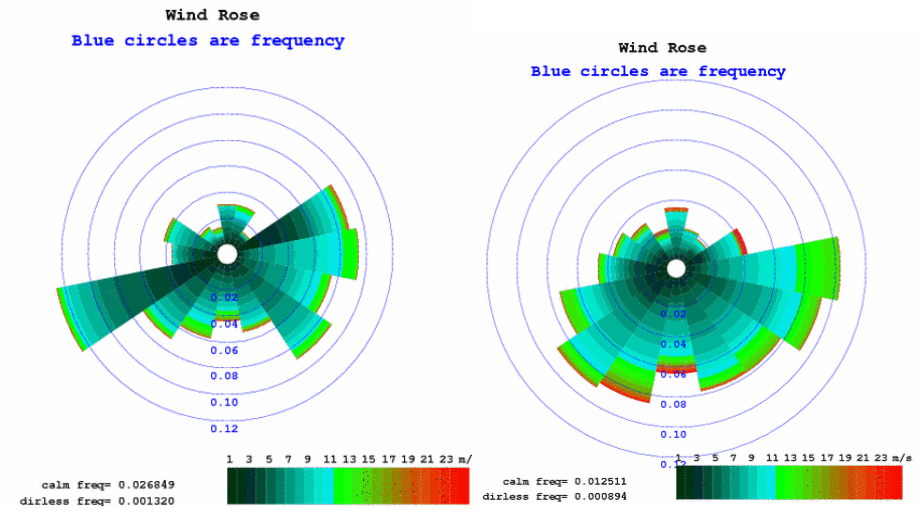


Figure 3.17 Wind roses (summer) at D (left:120m) (right:450m)

3.7 Extracted from the simulated MM5 data, a general understanding of the summer and the annual prevailing wind directions of the Study Area and the surroundings are indicated in Figure 3.18 and 3.19.

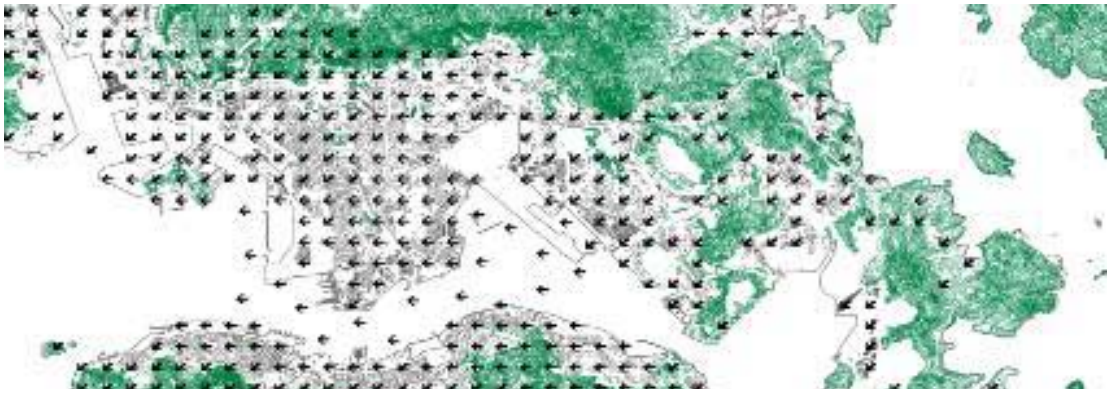


Figure 3.18 Prevailing wind directions (annual) based on MM5 (60mPD).

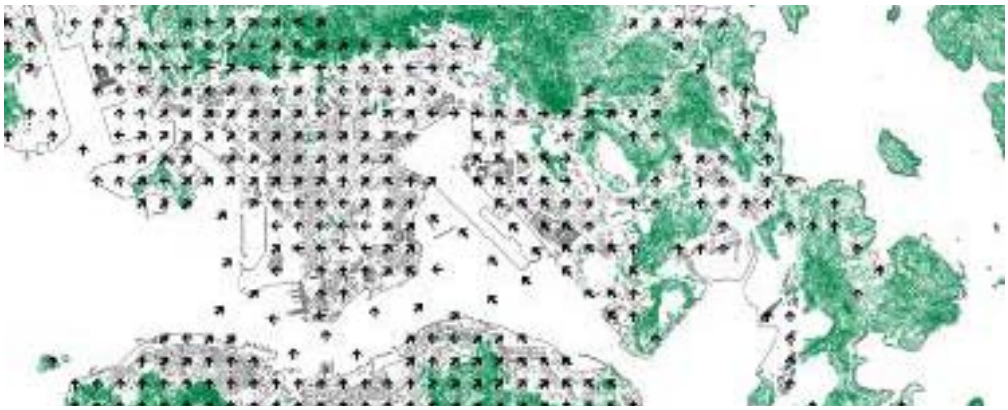


Figure 3.19 Prevailing wind directions of the summer months (Jun-Aug) based on MM5 (60mPD).

3.8 Based on the MM5 simulated wind roses of the 4 locations extracted, one can evaluate that there are little differences among them (Table 1) in terms of prevailing wind directions.

Table 1 Evaluated prevailing directions of the 4 locations

	Annual	Summer
A	NE, E	E, W, SE, SW
B	NE,E	E, W, SE
C	NE,E	W, E, SE
D	NE,E	W, E, SE

3.9 In summary, based on the available wind data shown in Figure 3.3 – 3.19, one may conclude that the annual wind of the study area is mainly from the East and North-East. The summer wind is mainly coming from the East, the West and the Southerly quarters (Figure 3.20).

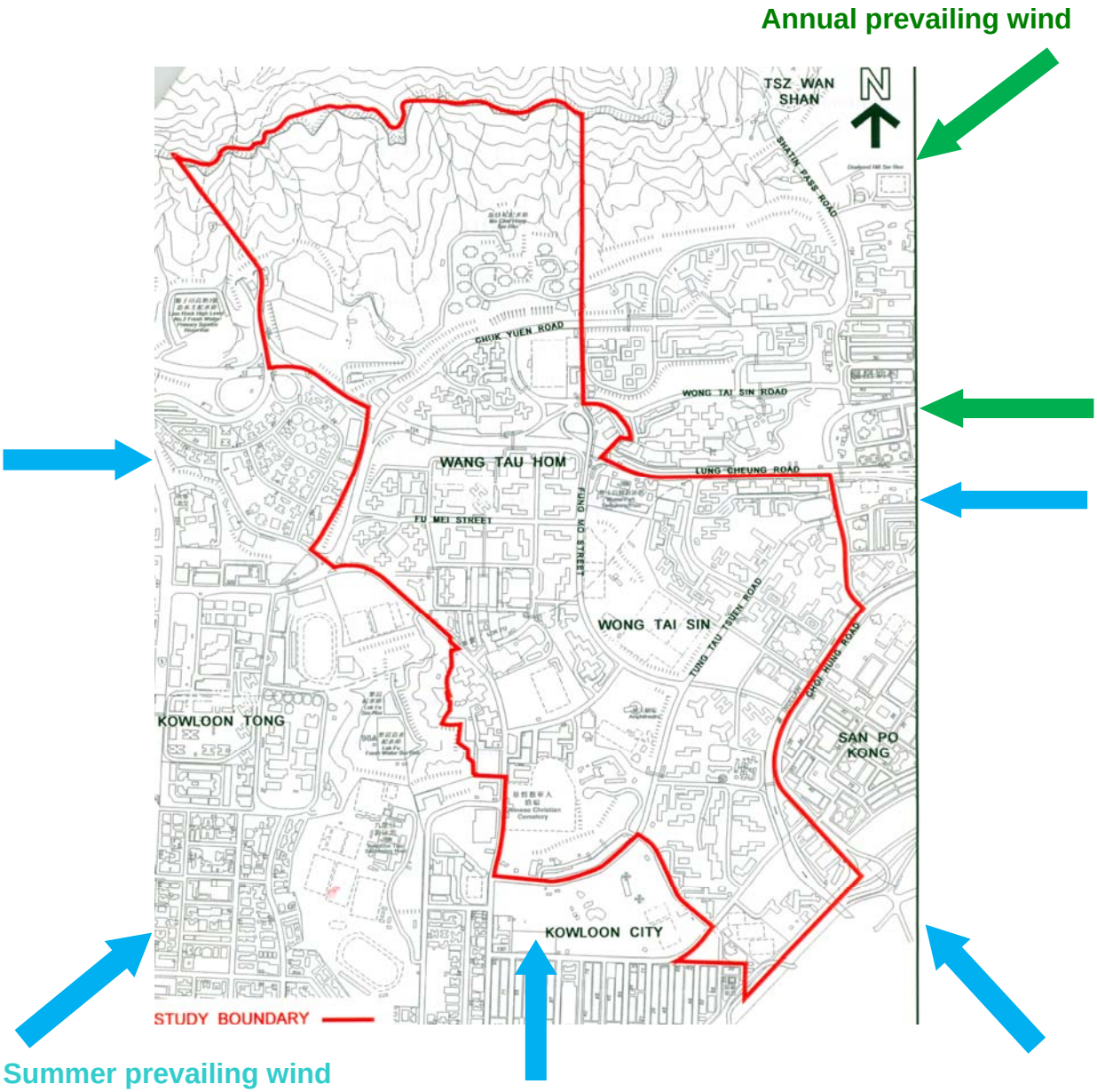


Figure 3.20 A summary of the prevailing winds of the Area

4.0 Topography, Land-Sea Breezes and the Urban Wind Environment

4.1 The Area is exposed to the empty site of the former Kai Tak Airport, which is further open to the Victoria Harbor in the south. It rises from the sea level to 240 mPD of Lion Rock at the north boundary (Figure 4.1).

Figure 4.1 A digital elevation map of the Area

4.2 For wind coming from the north and northeast over the hills, the wind profiles characteristics will be affected by hills. Turbulence and re-circulation of wind when it moves downhill towards the study area is expected (Figure 4.2). In general, the northerly wind arriving at the study area will be slowed and weakened by the shielding effects of the hills.

4.3 The 3 dimensional flow patterns of wind crossing the hills can be very complicated depending on a number of factors, e.g. the speed of the incoming wind [Appendix A]. In moderate wind conditions, it is predicted that a lee-wave will be generated, a number of eddies will form, and some re-circulation will be expected when the northerly wind arrives at the study area.

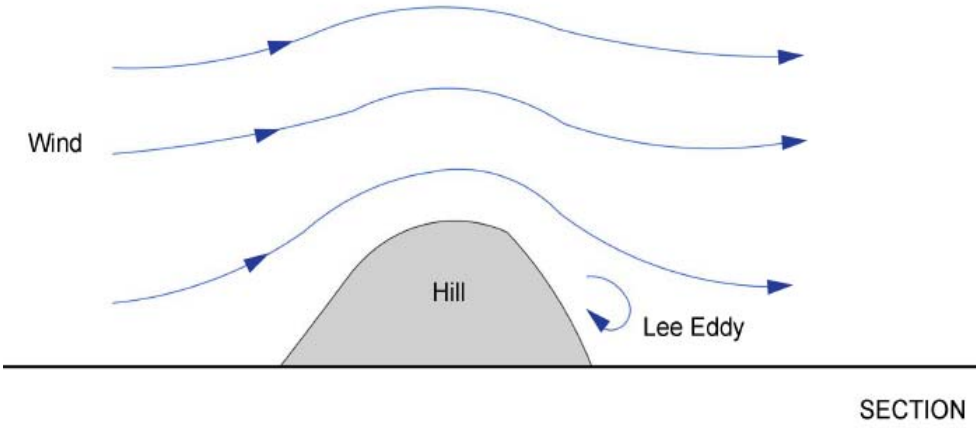


Figure 4.2 An example of wind flow across hills under moderate wind.

4.4 According to the digital elevation map in Figure 4.1, there is an increase of the ground level from the south towards the north of about 240mPD over a distance of about 2 km. The ground rises gently northwards until Lung Cheung Road and then it goes steeper. For the purpose of air ventilation assessment, when wind is from the south to the north, the compression of air volume due to the sloping ground is insignificant. The overall ground can be assumed reasonably flat with the west side being a little higher when air paths of the study area are later assessed .There is a small hill of around 80mPD at the south of the study area. Areas to its wakes can have marginally weaker air ventilation, but on the whole the hills are small and isolated, and air ventilation can find ways to pass around it.

5.0 The Existing Conditions

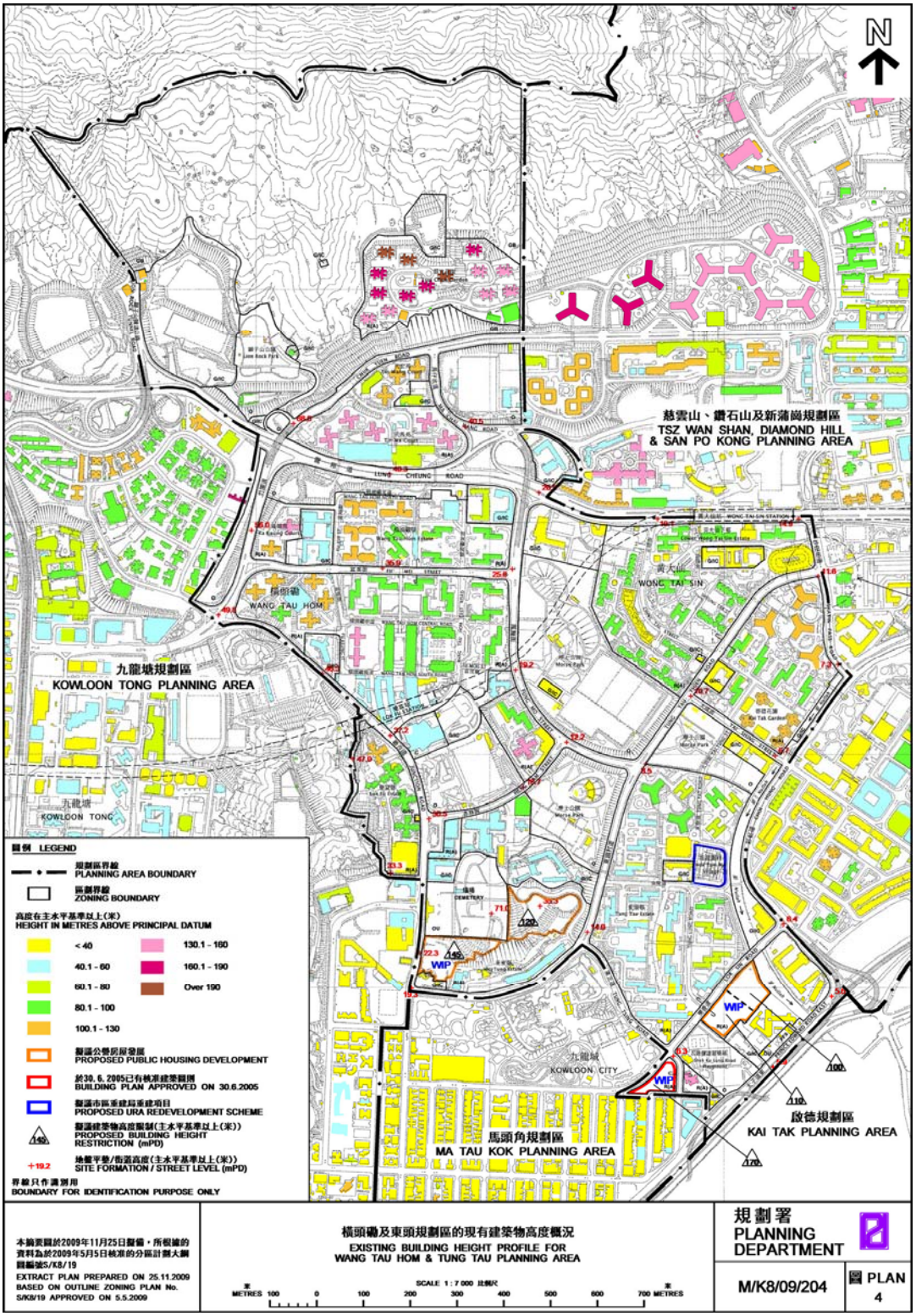


Figure 5.1 The existing building height profile of the study area in meters above principal datum (mPD)

5.0.1 The existing building heights in mPD are shown in Figure 5.1, ranging from 20mPD on the flat land to 190mPD on the northern slope. They mainly follow a stepped height profile.

5.0.2 The Area has a mixture of three zones – mostly "R(A)" and "G/IC", and with a small "C" zone. There are several large public housing estates in this study area, such as Tung Tau Estate, Lower Wong Tai Sin Estate, Lok Fu Estate and Wang Tau Hom Estate. Remaining are Home Ownership Scheme developments and Private Sector Participation Scheme development on the northern slope.

5.0.3 Besides residential buildings, there is a considerable amount of "G/IC" sites in the study area. Please refer to section 5.1.1 for detailed review from the air ventilation perspective.

5.0.4 Besides residential buildings and "G/IC" site, there is only a small piece of land zoned as "Commercial" near Lok Fu MTR Station.

5.1 Greenery, Open Spaces and G/IC sites

5.1.1 The study area has extensive open green spaces as "air spaces" both on slopes and flat ground where air ventilation can be relieved. There are: Lion Rock Park, Ma Chai Hang Playground, Morse Park (I) to (IV), Lok Fu Recreation Ground, Shek Ku Lung Road Playground (Figure 5.2). Especially because they are well distributed as well as linked, they are very useful to the Area. Wake interference and isolated roughness flows (Figure 5.3) are possible to recover and bring air into the pedestrian.

5.2 Land Use and Urban Morphology

5.2.1 Refer to 5.1 above, the greenery coverage of the Area is mid to high; the corresponding Ground Coverage (GC) of buildings is low to mid.

5.2.2 Researchers at CUHK have earlier resolved a set of Ground Coverage Ratio [*](GC) understanding of Hong Kong. A relevant area is shown in Figure 5.4. High ground coverage reduces urban porosity at the pedestrian level and thus reduces the potentials of air ventilation. On the whole the GC of the study area is "low" to "mid". A cluster of High GC can be found close to Lok Fu MTR Station (Figure 5.4 dotted circle). Another cluster of high GC can also be found around Wong Tai Sin MTR Station. They, including the other single high GC along Tai Shing Street, are isolated and thus not a cause of concern.

[*] Ground Coverage Ratio (GC) is the ratio of total ground area (include roads and open spaces) and ground area covered by buildings and podiums in a 100m x 100m grid.

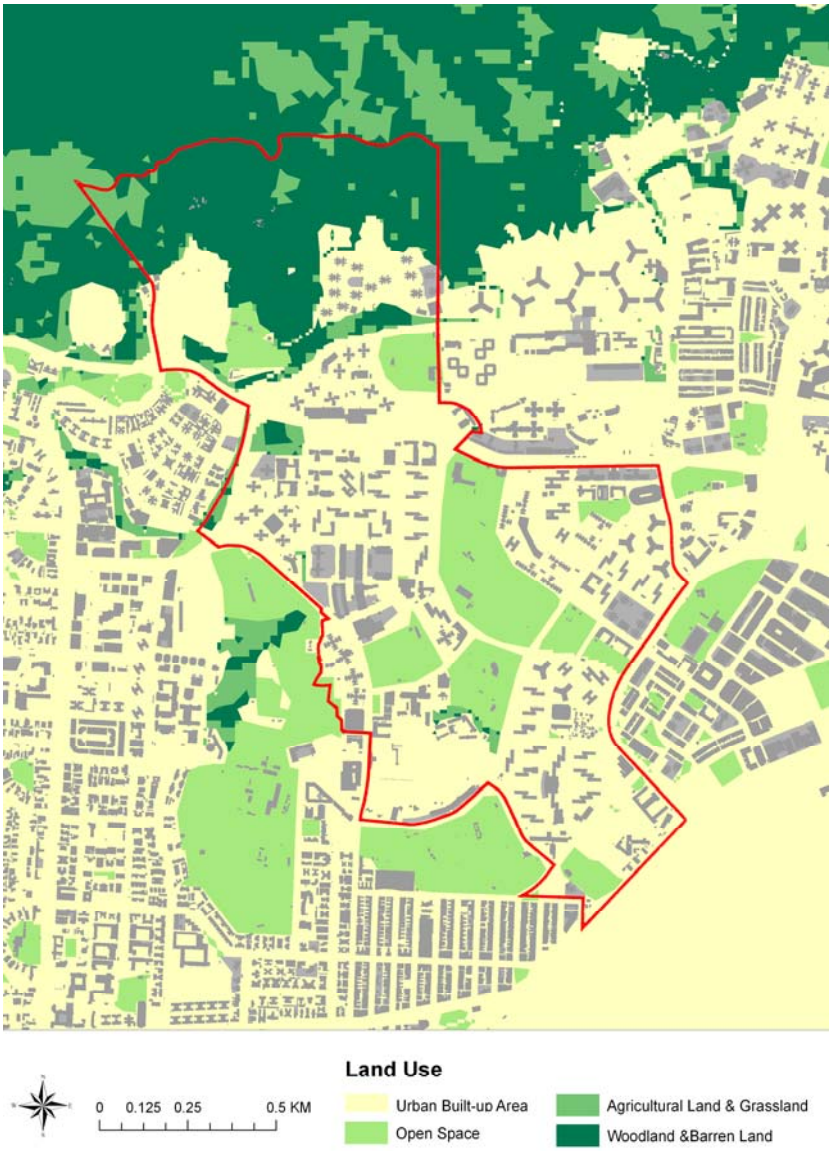


Figure 5.2 A greenery map of the Area based on land use data provided by Planning Department.

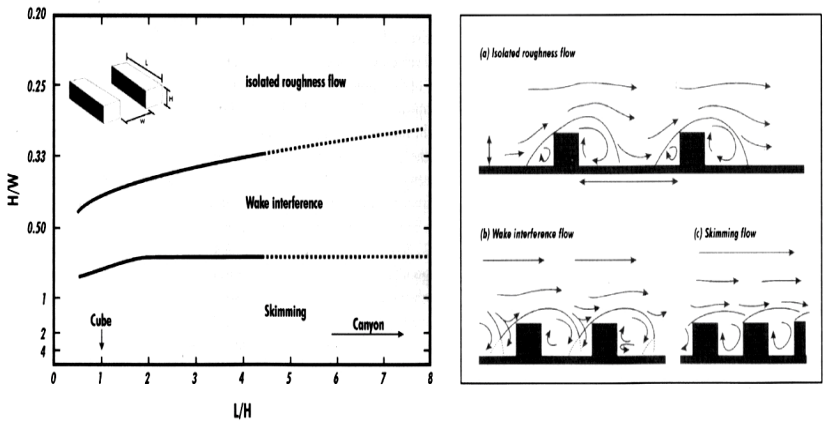


Figure 5.3 The relationship between building height and street width ratio and the possible flow regimes.

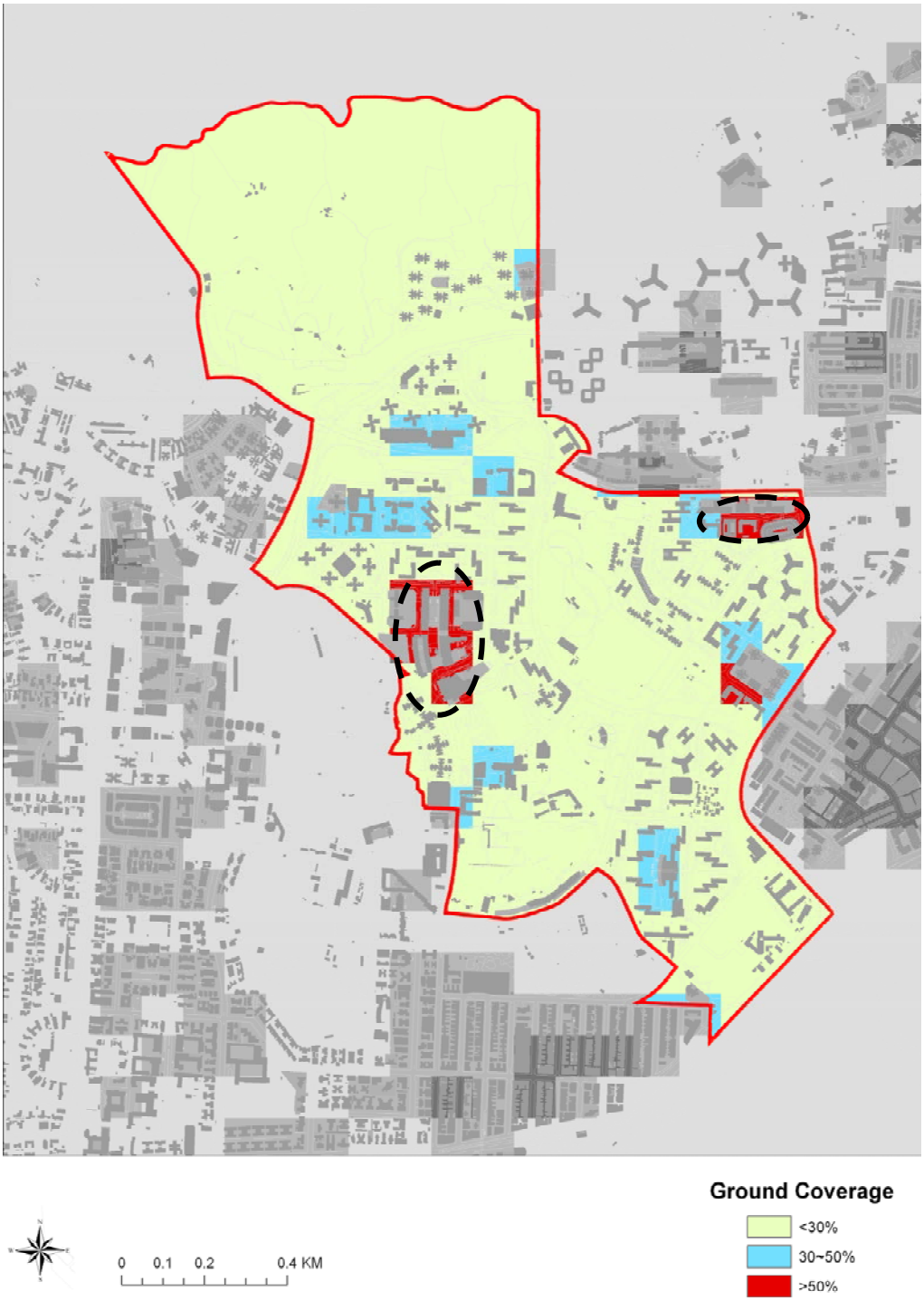


Figure 5.4 Ground Coverage Ratio map of the Area resolved to 100mx100m cell area (include roads, open spaces and ground area covered by buildings and podiums)

5.2.3 Higher building volume increases the urban thermal capability and reduces urban Sky View Factor (SVF), which reduces long wave radiation back to the sky causing urban heat island. This creates higher thermal stress in the summer months and the need for higher air ventilation to mitigate the negative thermal effects.

Researchers at CUHK have earlier resolved a set of Building Volume Density (BVD) understanding of Hong Kong. A relevant area is as shown in Figure 5.5. On the whole the building volume density of the study area is not high. Properly and strategically located air paths should be able to address some of the urban thermal comfort concerns in the summer months.

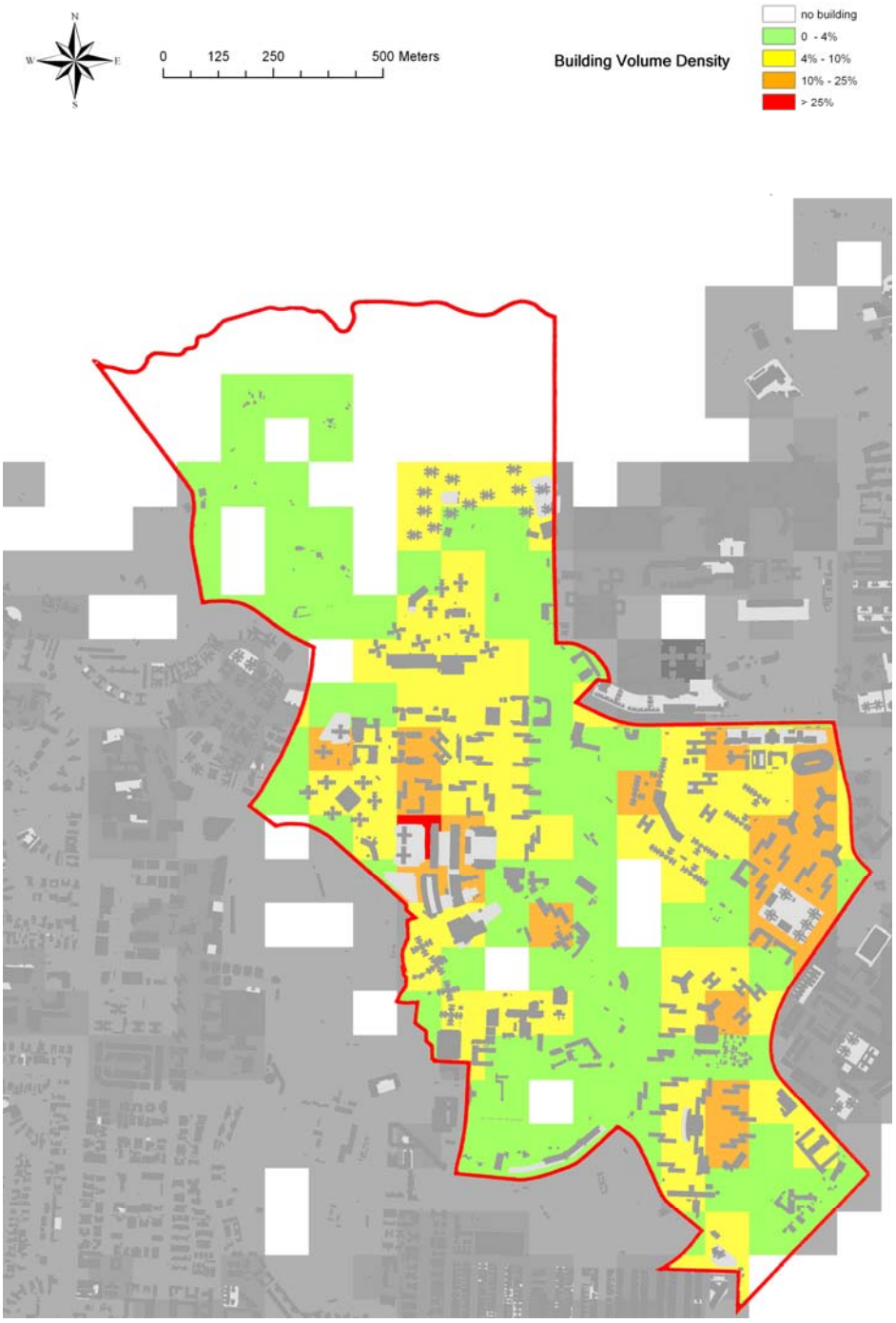


Figure 5.5 Building Volume Ratio map of the Area resolved to 100m x 100m grid. [For a site that occupies 100m x 100m, with a plot ratio of say 5, the building volume of the site will be about 150,000m^3. Building Volume Density in % (BVD) is building volume in m^3 of a 100m x 100m grid of land divided by a datum value of 1,200,000 m^3]

5.2.4 In Wong Tau Hom area, the north-south and east-west streets are 20-30m wide (building to building). Buildings on both sides of streets are 45-75m in absolute height. So the height to width ratio (building height over the street width) is about 1.5 – 4. In Wong Tai Sin area, roads and streets are 15-40m wide (building to building). Buildings are 70-90m absolute height. So the height to width ratio is about 1.5 – 2. In Tung Tau area, roads are 20-40m wide and buildings are 30-90m in absolute height. The height to width ratio is also a little higher than 1.5. Overall, according to the relationship of the height to width ratio with the possible flow regimes illustrated in Figure 5.3, mostly wake interference and sometimes skimming flow into the street canyon will occur in this study area. Currently, these street canyons are neither deep nor long.

5.3 Air Paths

5.3.1 Based on the understanding of building bulks in section 5.2 and the greenery areas in section 5.1, the air paths of the study area can be evaluated (Figure 5.6 and Figure 5.7). Figure 5.6 illustrates the air paths when wind comes from east (annual and summer) and west (summer). Figure 5.7 illustrates the air paths when wind comes from the northeast (annual) and southerly quarters (summer). They are not exclusive and would enhance each other when interlinked.

5.3.2 The main east-west roads in Wang Tau Hom, like Lung Cheung Road and Fu Mei Street, are main air paths for east prevailing wind, especially Lung Cheung Road. Lung Cheung Road is about 40m-50m wide and winds from the east can flow through it unobstructedly. Wang Tau Hom Central Road and Wang Tau Hom South Road are also its east-west air paths. In Tung Tau area, the main east-west air paths are Tung Tai Lane and Tung Lung Road. Well distributed and connected greeneries add to the efficacy of air paths. Please refer to blue arrows in Figure 5.6.

5.3.3 The main north-south air paths in the area include Fung Mo Street, Tung Tau Tsuen Road, Junction Road, Chuk Yuen Road and Shatin Pass Road. Choi Hung Road and adjacent Kai Tak Nullah together form a major breezeway. Please refer to purple arrows in Figure 5.7.

5.3.4 There are also southwest-northeast air paths in Tung Tau, like Lok Sin Road and Heng Lam Street. Southeast-northwest air path is Ching Tak Street. Please refer major air paths to purple arrows in Figure 5.7.

5.3.5 Most of these roads and streets, although extending in different directions, are connected with each other in all directions and also with greeneries and open spaces. But connected greeneries and open spaces can only form significant air paths as long as they are not obstructed at either ends. Long and deep canyons are rare in the study area. Weakened winds can recover in the green areas. Wind from east, northeast and south-quarter can easily find ways to penetrate through.

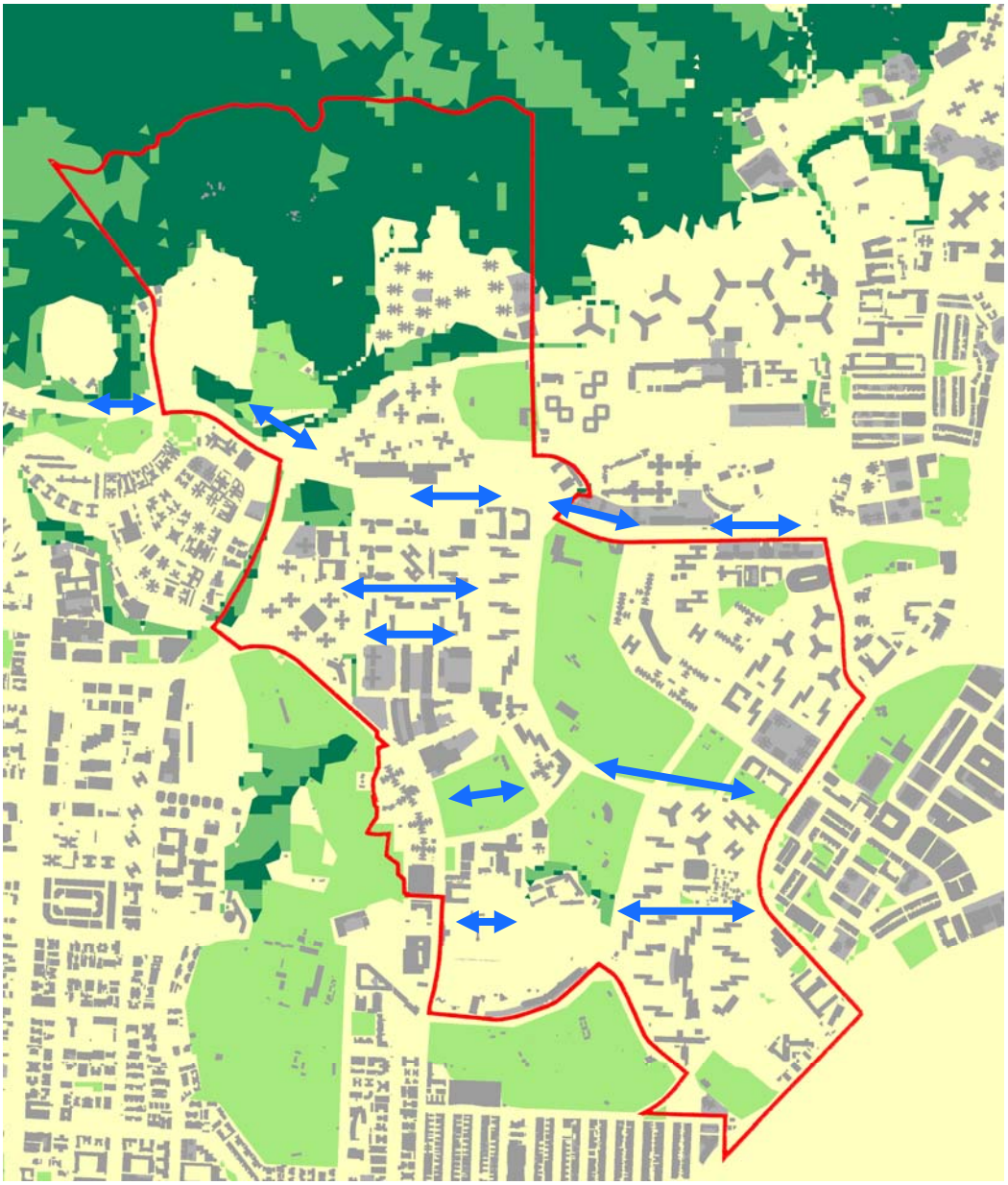


Figure 5.6 Air paths in the study area when wind comes from east (annual and summer) and west (summer)

Figure 5.7 Air paths in the study area when wind comes from the northeast (annual) and southerly quarters (summer)

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6.0 The Existing Conditions with Committed Projects

6.1 There are a few committed redevelopment projects scattered in the study area. One site is on the current Nga Tsin Wai Village to be redeveloped by Urban Renewal Authority (Figure 6.1). There will be a group of two separate high buildings (about 100mPD and 134mPD) with a horizontal distance of 40m from each other. These two buildings are designed with a vertical clearance and elevated to 15m above ground. The space between two buildings and on pedestrian level will let wind penetrate through.

Figure 6.1 The committed redevelopment project of Nga Tsin Wai Village

6.2 Tung Tau Cottage Area East (Figure 6.3) will be developed. A conceptual plan with a maximum building height of 120mPD has been provided by PlanD. The maximum height stipulated is similar to its surroundings. With the information provided, we do not see any issue. However, further evaluation could only be provided when more detailed building disposition information and podium extent.

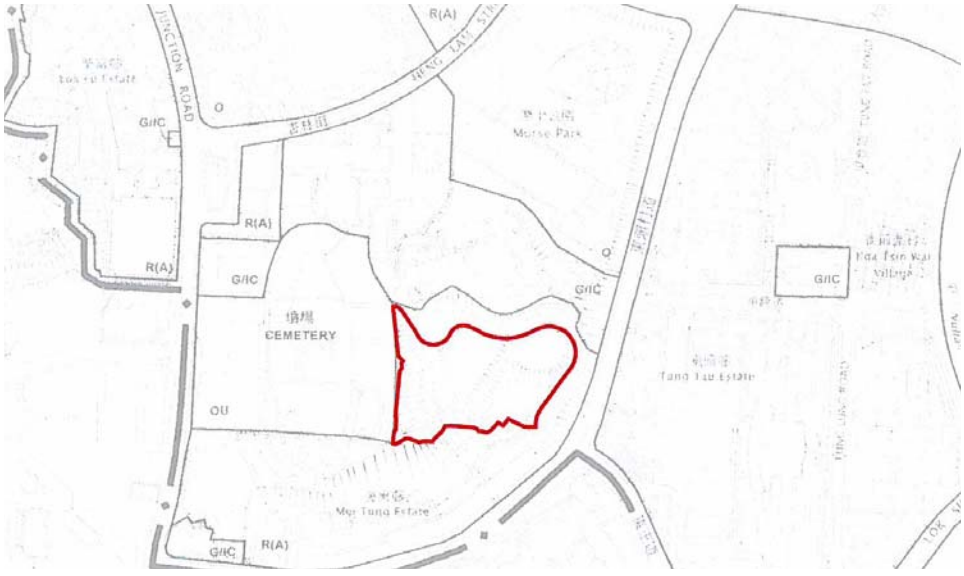


Figure 6.2 The Development Location of Tung Tau Cottage Area East

6.3 Tung Tau Estate Phase 9 (Figure 6.5) will be developed to 2 buildings ranging from 100mPD to 120mPD with a distance of about 10m in between. Its building width is about 40m for each. The permeability is acceptable.

Figure 6.3 The committed project of Tung Tau Estate Phase 9

7.0 The Initial Planned Scenario

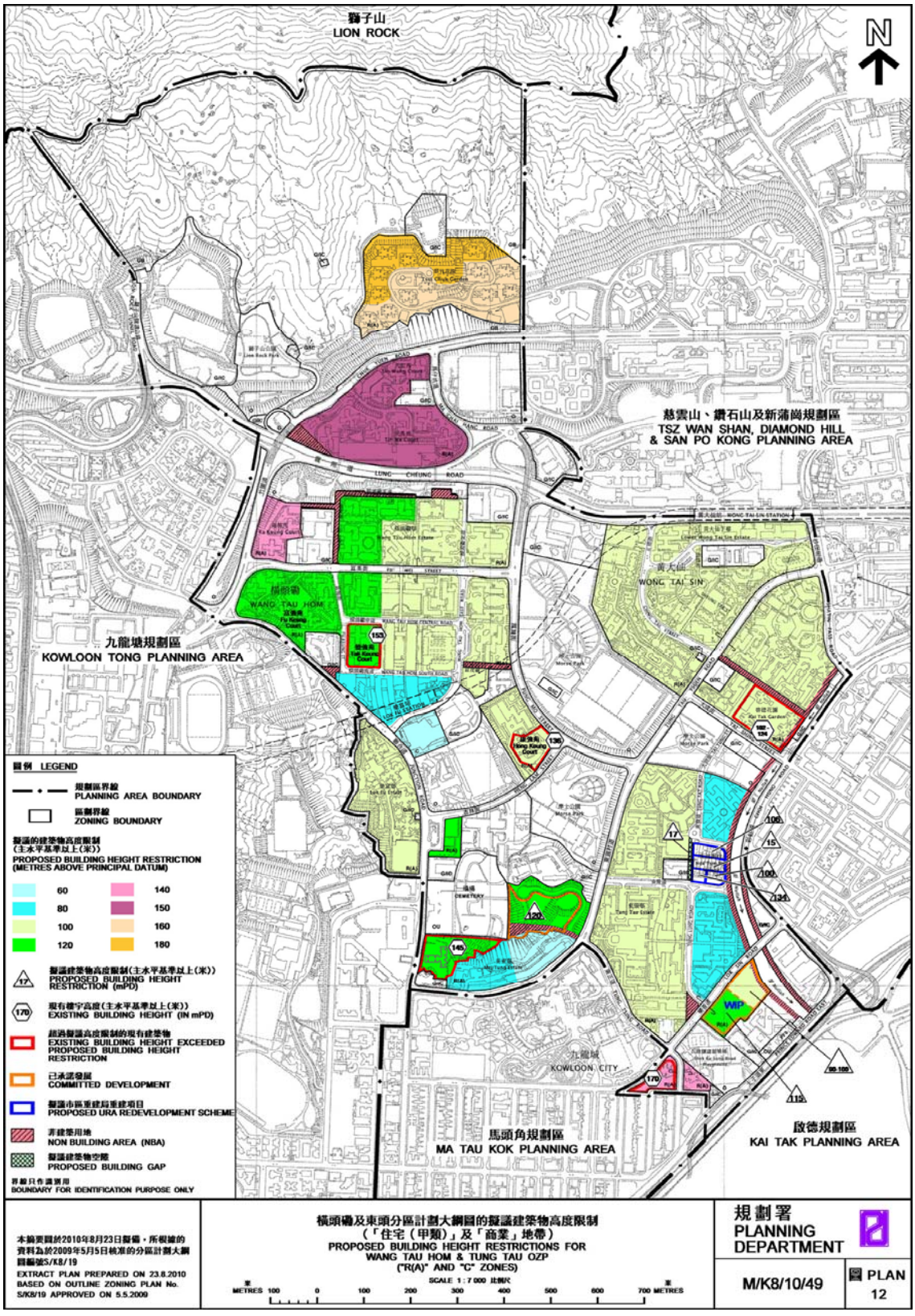


Figure 7.1 The Initial Planned Scenario of the Area (proposed building height restrictions for "R(A)" and "C" Zones).

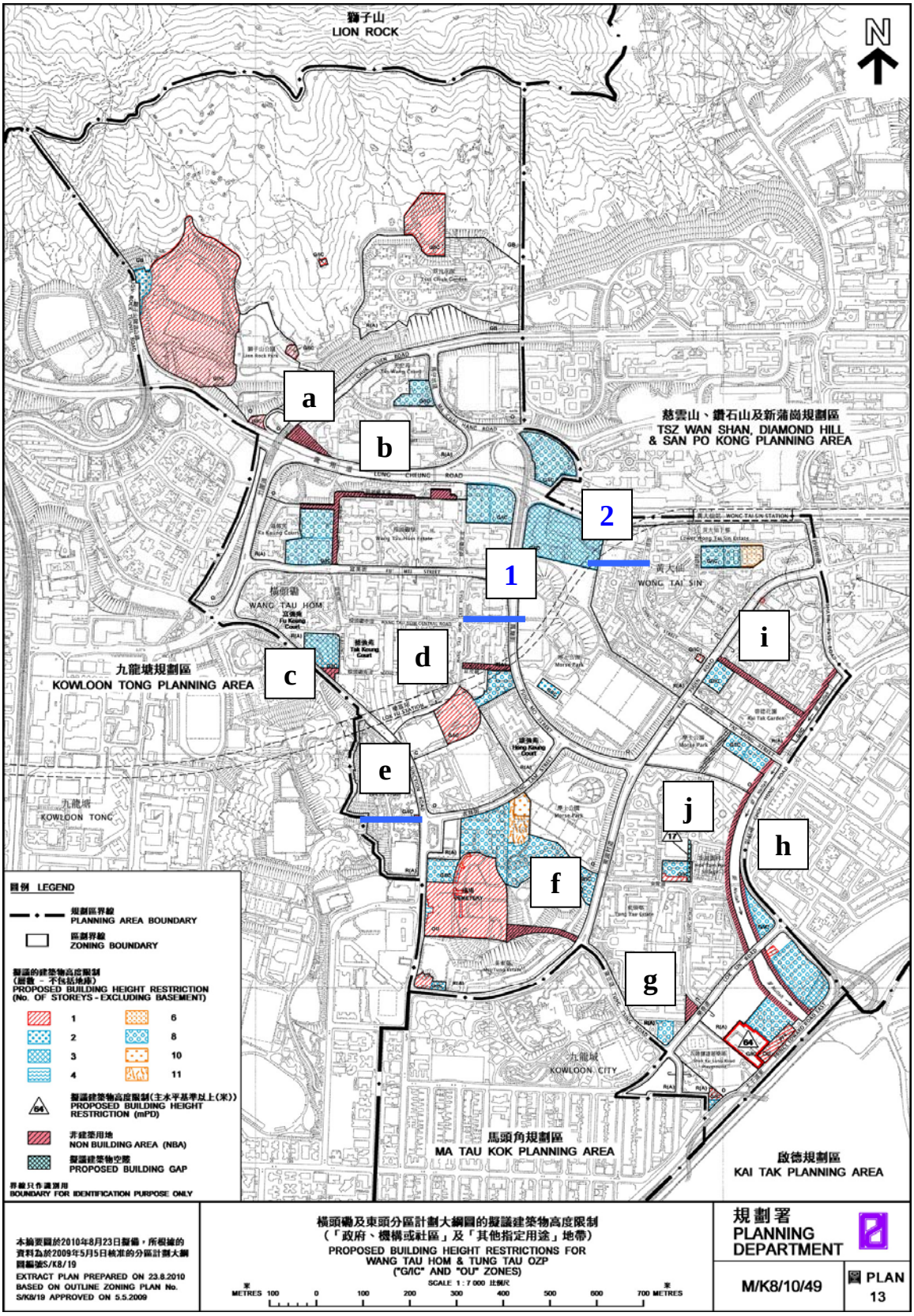


Figure 7.2 The Initial Planned Scenario of the Area (proposed building height restrictions for "G/IC" and "OU" Zones; non building area).

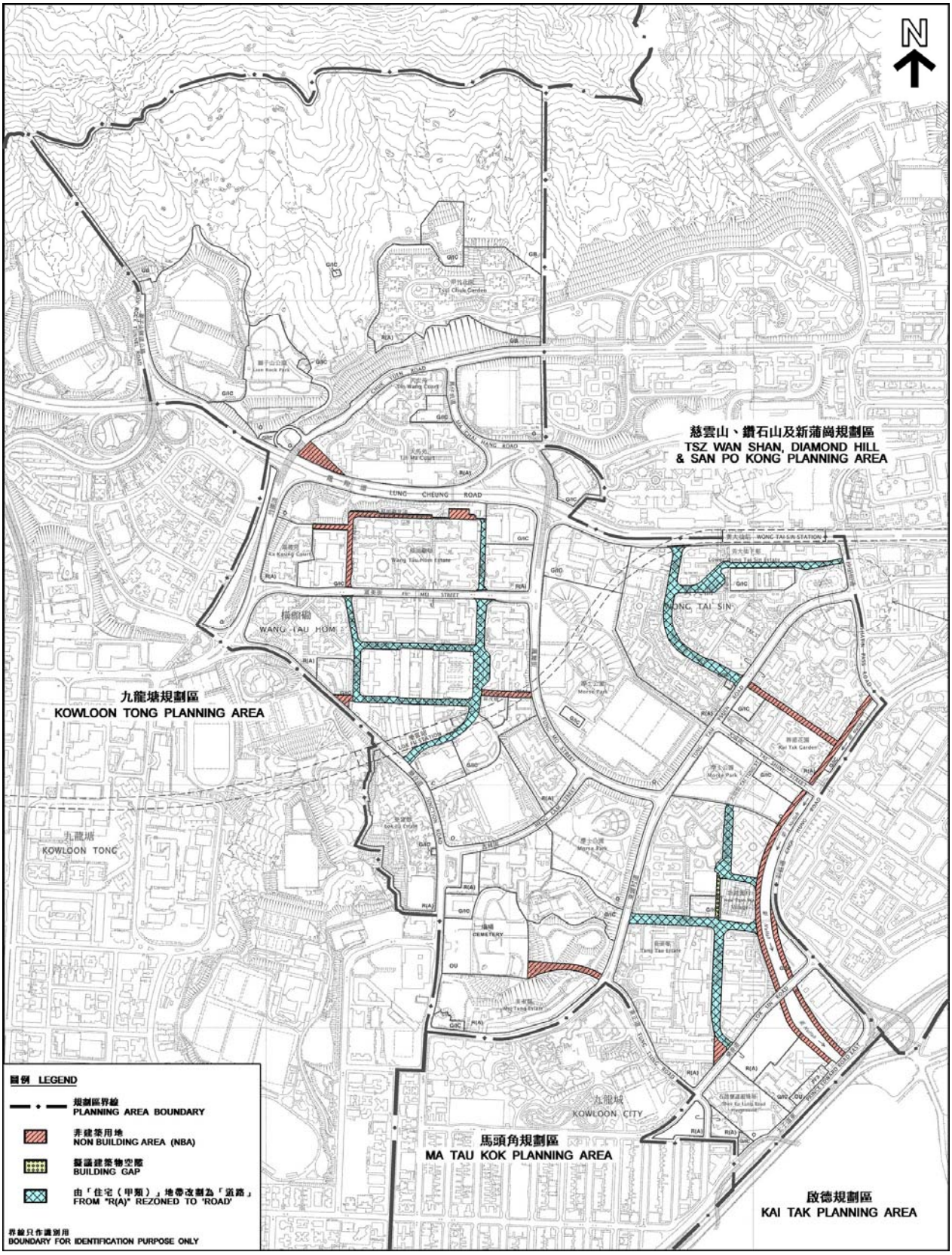


Figure 7.3 The Initial Planned Scenario of the Area (proposed zoning changed to "ROAD").

7.1.1 The proposed building height restrictions for "R(A)", "C" "G/IC" and "OU" Zones mainly reflect the existing conditions (Figure 7.1 – 7.2).

7.1.2 In general, a stepped building height concept has been adopted. This ranges from 80mPD along Choi Hung Road in the east to 120 mPD in the west, and further to 180mPD on the northern slope. This would transfer to a similar absolute height profile as the existing condition mostly. That is to say, given the same street width, the H/W ratios in both cases would be similar. Please refer to the section 5.2.4 for the H/W analysis of the existing condition.

7.1.3 In the initial planned scenario, It can be seen that some big roads are extracted from "R(A)" zone and rezoned to ROAD. It is good to ensure that the road stays as air paths (Figure 7.3).

7.1.4 In the initial planned scenario, some useful and important non-building areas are designated to improve both the local and district environment. The positions of the non-building areas are appropriate in terms of air ventilation (Figure 7.2 & 7.3). Also refer to the air path section of 5.3. They are concentrated in those areas with relatively high BV and supplement the existing air paths.

(a) The NBA allows better connection to the open spaces and downhill air movement from the north-west into Wang Tau Hom Estate areas. The triangular NBA shown on the plan is reasonable. However, preferably, it should be larger.

(b) The NBA along Lung Cheung Road enhances it as an air path and buffer. The space between Lung Cheung Road and Wang Tau Hom Estate should be greened with trees. The NBA west of Wang Tau Hom Estate is very useful extending the north-south air path of Fu Keung Street. It also opens up the current dead end of Wang Tau Hom South Road.

(c) A small portion of land at the southern corner of Wang Tau Hom Jockey Club Clinic abutting Fu Keung Street is designated as a NBA to extend the air path of Wang Tau Hom South Road westward to Junction Road and Lok Fu Park.

(d) The east-west orientated NBA east of of Wang Tau Hom South Road is very important as it provides very useful east-west air ventilation to the PTI. Preferably, the NBA's southern boundary should be further widened to provide a 20 to 30m wide NBA.

(e) The NBA extends Heng Lam Street enhances east-west air ventilation. Should sufficient gaps between buildings be maintained when Lok Fu Estate is re-developed, due to the Lok Fu Park and Lok Fu Recreation Ground, the position of this NBA highlighted in blue is not critical and does not need to straight line up with Heng Lam Street.

(f) The NBA extends Tung Tsing Road air path towards Lok Fu. Preferably, it should be wider and better connect Kowloon Walled Sity Park to the open space of Chinese Christian Cemetery.

(g) The NBA is important as it connects Tung Lung Road to the open space of Shek Ku Lung Road Playground providing useful air ventilation connectivity in the summer. Considering the summer south-western prevailing wind, preferably, the NBA's western boundary should spread outward to better taking advantage of Shek Ku Lung Road Playground. The proposed NBA that has its western boundary parallel to Tung Lung Road is an acceptable compromise.

(h) The NBAs are important to enhance the usefulness of the Nullah as an important north-south air path in the area. Please also refer to section 5.3.3 for more elaboration. The air paths also further benefit Diamond Hill areas. Preferably, this NBA should be wider. The NBAs proposed by the initial planning scenario along both sides of Kai Tak Nullah could serve the air ventilation function, as an enhancement to Choi Hung Road and Kai Tak Nullah. Together, a 30m-50m wide breezeway is formed in the area. They should not be development in the future.

(i) The NBA usefully connects Ching Tak Street to Choi Hung Road Playground providing useful air ventilation connectivity to San Po Kong.

(j) A strip of about 7-m wide land along the eastern side of multi-storey car parking building within Tung Tau (II) Estate and Chi Tak Public School is demarcated as a building gap and subject to a maximum BH restriction of 17mPD in order to better connect the existing air path and improve the air ventilation in the area.

In addition, to further improve air ventilation connectivity of the area and for better quality living environment, it is recommended upon redevelopment that:

(1) A NBA is created to extend Wang Tau Hom Central Road eastward to Morse Park to better improve the air ventilation potentials of the PTI.

(2) A NBA is created to extend Ching Tak Street westward to Morse Park to better improve the air ventilation potentials of Wong Tai Sin Estate.

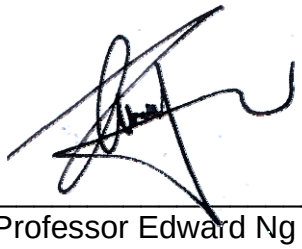
(3) All NBA so created should be properly greened with tree planting to enhance its usefulness for creating quality urban living spaces as much as possible.

7.1.5 The initial planned scenario keeps most of the existing "G/IC" (Figure 7.2) as low-rise buildings and "O" sites. "G/IC" sites connected to or next to the main air paths are particularly useful. Further greening on these sites is recommended.

7.1.6 Besides the above recommended non-building areas within the public housing estates, it is expected that Housing Department will conduct its own detail air ventilation assessment to further optimize their local air ventilation designs upon redevelopment.

8.0 The Recommended Scenario

8.1 There is no focus area of concern in the study area. Further study will not be necessary.



Date: 23 August 2010

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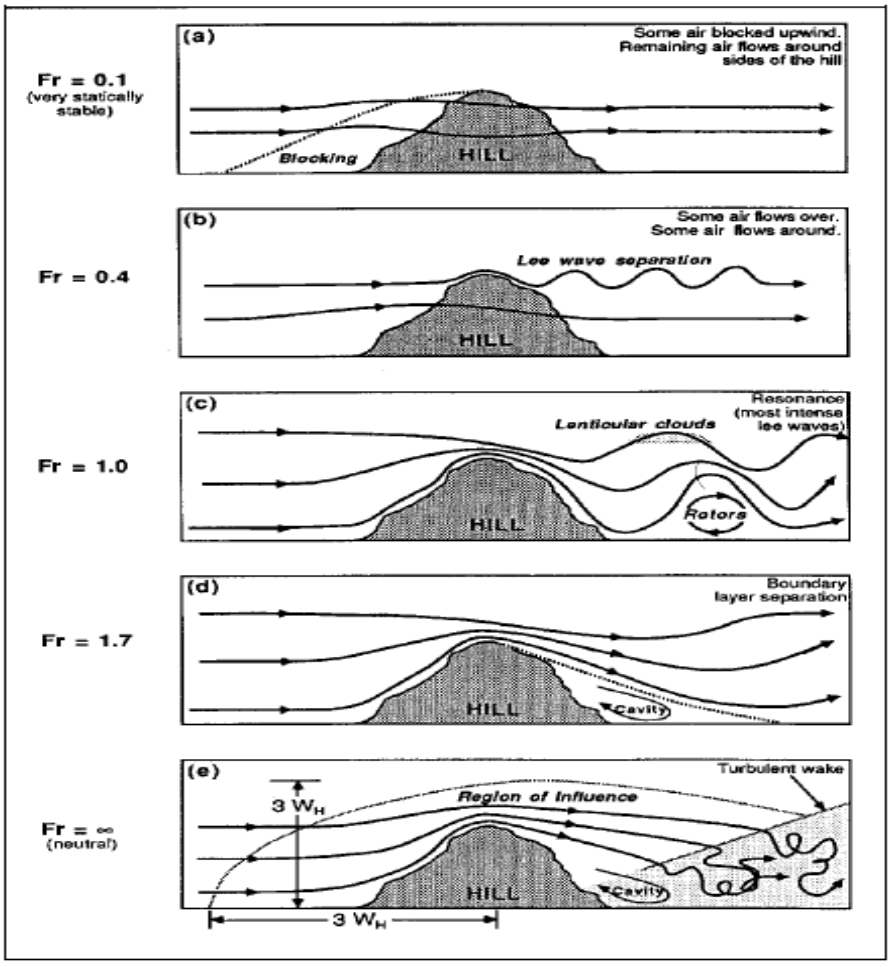
Appendix A: Wind over a small hill.



For a strongly stable environments, i.e. where the buoyancy affects are strong, and Fr ≈ 1, the air flows around the hill ((a)) and a stagnant mass of air builds up before the hill. **At a slightly faster wind** (Fr ≈ 0.4) some of the air flows over the hill ((b)) while the air at lower altitudes separate to flow around the hill. The natural wavelength of the air that flows over the top is much smaller than the hill size and the flow is perturbed by the hill to form lee waves. A lee wave separation occurs from the top and flows above the air that flows around the hill. A column of air with the same height as the hill approaches the hill and a fraction of it flows above the hill. **At higher wind speeds** and Fr ≈ 1.0, the stability is weaker and the wavelength of the gravity waves (lee waves) approaches the size of the hill ((c)). A natural resonance forms the large amplitude lee waves or mountain waves. If there is sufficient moisture, lenticular clouds can form along the crests of the waves downstream of the hill. **For stronger winds** with Fr ≈ 1.7 ((d)) the natural wavelength is longer than the hill dimensions, thus causing a boundary layer separation at the lee of the hill. **Neutral stratification** ((e)) occurs for strong winds with neutral stability (no convection) and Froude number approaching infinity. The streamlines are disturbed upwind and above the hill out to a distance of about 3 times the hill length WH. Near the top of the hill the streamlines are packed closer together, causing a speed-up of the wind. Immediately downwind of the hill is often a cavity associated with boundary layer separation. This is the start of a turbulent wake behind the hill. The height of the turbulent wake is initially the same order as the size of the hill and grows in size and diminishes in turbulent intensity downwind. Eventually the turbulence decays and the wind flow returns to its undisturbed state.

Froude number (Fr)

$$F_r^2 = \frac{\text{Inertial forces}}{\text{Bouyant forces}} \qquad F_r^2 = \frac{\bar{u}_0^2/W_h}{g\Delta\theta/\theta_0}$$

The inertial forces (order $\bar{u}_0^2/W_h$) act in the horizontal direction along the wind flow, and the buoyant forces (order $g\frac{\Delta\theta}{\theta_0}$ where $\Delta\theta$ is a typical temperature disturbance, g is gravitational acceleration, θ_0 is potential temperature) act in the vertical. The Froude number can be more elaborately defined as

[courtesy Sykes, R.I., 1980, "An asymptotic theory of incompressible turbulent boundary-layer flow over a small hump", J. Fluid Mech.101: 647-670.]