THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

CFD PEDESTRIAN LEVEL WIND STUDY

Heron Gate Masterplan

Ottawa, Ontario

Hazelview Developments

REPORT NO. 24168wind **May 21, 2025**

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1. EXECUTIVE SUMMARY

The Heron Gate Village Development proposed by Hazelview Developments in the City of Ottawa has been assessed for environmental standards with regard to pedestrian level wind velocities relative to comfort and safety. Based upon our analysis, wind conditions in the existing setting are considered mainly suitable for sitting or standing year-round, with localised strolling and walking conditions proximate to corners and gaps between high-rise buildings.

The proposed Development involves construction of 37 buildings ranging in height from 3 to 25 storeys. A Park is proposed central to the site, and POPS are proposed in various areas throughout the site.

The Development site is, for all intents and purposes, surrounded by a suburban mix of low through high-rise residential buildings, low-rise commercial buildings, mature vegetation, and open spaces. The proposed Development will have a sympathetic relationship with the pending wind climate. Urban development provides turbulence inducing surface roughness that can be wind friendly, while open, and to a lesser degree, suburban settings afford wind the opportunity to accelerate as the wind's boundary layer profile thickens at the pedestrian level, owing to lack of surface roughness. Transition zones from open and/or suburban to urban settings can prove problematic, as winds exacerbated by relatively more open settings are redirected to flow over, around, down, and between buildings.

The proposed Development redirects winds that formerly flowed over the site, the increased blockage relative to the existing setting causing wind to redirect to flow over the buildings without consequence, and/or, depending upon the angle of incidence, around, or down the façades towards the pedestrian level, as downwash. The Development features stepped podiums that intercept downwash, deflecting a portion of said flows around the buildings at elevations above the pedestrian level.

Once the subject site is developed, ground level wind conditions remain relatively similar to the existing setting. The proposed Development provides blockage to winds from some directions, resulting in localised improvements, and conversely the proposed buildings redirect winds to flow down and around the façades, resulting in localised increases in winds. This results in wind conditions that are predicted suitable for sitting or standing through the majority of the year, with localised strolling conditions in the winter and spring. The site and surrounds generally remain comfortable and appropriate to the areas' intended purposes throughout the year, and consideration of fine design details and mitigative landscape features will result in more comfortable conditions than reported.

Mitigation plans may be explored through future submissions for the Entrances to Buildings 3.1, 4.6, 7.4, and 9.1, as well as the proposed Parks and POPS throughout the site if more comfortable conditions than reported are desired.

The proposed Development is predicted to realise wind conditions acceptable to a typical suburban context, based on this preliminary Computational Fluid Dynamics analysis.

Respectfully submitted,

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2. INTRODUCTION

Hazelview Developments retained Theakston Environmental to study the pedestrian level wind environment for the proposed Heron Gate Village Development, in the City of Ottawa, as shown in Figure 1. The Development involves a proposal to construct 37 buildings ranging in height from 3 to 25 storeys, in the configuration shown in Figure 2. Figurr Architects Collective provided architectural drawings. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

The specific objective of the study is to determine areas of higher-than-normal wind velocities induced by the shape and orientation of the proposed Development and surroundings. The wind velocities are rated in accordance with the safety and comfort of pedestrians, notably at entrances to the buildings, sidewalks, courtyards on the property, as well as in the immediate vicinity.

To obtain an objective analysis of the wind conditions for the property, the wind environment was tested in two configurations. The existing configuration included the current site as well as the approved neighbouring proposed developments in the surrounding area. The proposed configuration included the subject development.

The computational studies used in this Pedestrian Level Wind Study are established procedures that have been developed specifically for analyses of this kind. The methodology, summarized herein, describes criteria used in the determination of pedestrian level wind conditions.

3. OBJECTIVES OF THE STUDY

1. To quantitatively assess, by computational fluid dynamic (CFD) simulation, the pedestrian level wind environment under existing conditions and proposed conditions with the Development in accordance with the City of Ottawa's Terms of Reference.

2. To assess mitigative solutions in necessary cases.

3. To publish a Consultant's report documenting the findings and recommendations.

4. METHOD OF STUDY

4.1 General

The Theakston Environmental wind engineering facility was developed for the study of, among other sciences, the pedestrian level wind environment occurring around buildings, with focus on the safety and comfort of pedestrians. Accurate digital models of the proposed Development site, and the immediate surroundings are built, and studied computationally using the software SimScale, with resulting wind speeds stored for a surface spanning the areas likely to be frequented by pedestrians. This qualitative analysis provides predictions of wind speeds for various probabilities of occurrence and for various percentages of time that are ultimately weighted relative to a historical range of wind conditions and provided to the client.

The techniques, applied to wind and other studies carried out using this method, utilise the computational fluid dynamics (CFD) program. The testing method has been developed for these kinds of environmental studies, and has been adapted with specific settings, testing procedures and protocols, accordingly.

The purpose of this Pedestrian Level Wind Study is to evaluate the pedestrian level wind speeds for a full range of wind directions. To accomplish this, the wind's mean speed boundary layer profiles are simulated and applied to a site-specific model under test. Gust Equivalent Mean (GEM) values are extracted from the software for existing and proposed built scenarios, which accounts for sixteen (16) wind directions, at a surface that is uniformly at 1.5 m level above the ground in the entire field.

The wind speeds at the areas of interest were subsequently combined with the design probability distribution of gradient wind speed and direction (wind statistics) recorded at Ottawa International Airport, to provide predictions of the full-scale pedestrian level wind environment. Predictions of the full-scale pedestrian level wind environment are presented as the GEM wind speed exceeded 20% of the time, based on the four seasons, which can be found in Figures 5a – 5h.

4.2 Meteorological Data

The wind climate for the Ottawa region that was used in the analysis was based on historical records of wind speed and direction measured at Ottawa International Airport for the period between 1992 and 2022. The meteorological data includes hourly wind records and annual extremes. The analysis of the hourly wind records provides information to develop the statistical climate model of wind speed and direction.

4.3 Statistical Wind Climate Model

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Ottawa International Airport in Figure 4. Seasonal distributions are shown for the four seasons from the hours of 6:00 to 23:00 (Figures 4a – 4d). From this, it is apparent that winds can occur from any direction; however, historical data indicates the directional characteristics of strong winds are northwest through west to southwest with additional significant components from the northeast, and said winds are most likely to occur through the winter and spring.

4.4 Pedestrian Level Wind Velocity Study and Computational Setup

A digital model was created of the proposed Development and pertinent surroundings, including the existing buildings. The model is based upon information gathered from client drawings and Google Earth. Figurr Architects Collective provided the architectural drawings. The structures and features that would have an impact on the wind flows are included in the digital model. The existing and proposed scenarios have both been simulated in the commercially available SimScale wind simulation software.

A three dimensional 'mesh' is created of varying size, appropriate to the distance from the study area. In these studies, a section plane was placed at a height of 1.5m from the ground (typical level of pedestrian activity) to extract simulated GEM wind speeds. These wind speeds are an ensemble average wind speed and hence more representative of the wind microclimate in the study area. The velocities obtained from the simulation are recorded and combined with historical meteorological data via post-processing.

4.5 Pedestrian Comfort Criteria

The assignment of pedestrian comfort takes into consideration pedestrian safety and comfort attributable to mean and gust wind speeds. Gusts have a significant bearing on safety, as they can affect a person's balance, while winds flowing at or near mean velocities have a greater influence upon comfort.

Figure 5 presents results for the Comfort Categories, which are based upon the four seasons and calculated at the Gust Equivalent Mean (GEM) wind speed that is exceeded 20% of the time, based upon wind events occurring between 6:00 and 23:00. The GEM wind speed is the greater of the mean wind speed or the gust wind speed divided by 1.85. The gust wind speed is obtained as the sum of the local mean speed and the product of the peak factor and rms (i.e. mean + peak factor * rms). The peak factor is assumed to be 3.0 following the Gaussian distribution assumption and the rms was recalculated from the local turbulent kinetic energy obtained from the CFD simulation. These speeds are directly related to the pedestrian comfort at a particular point. Table 1, below, summarizes the comfort criteria used in the presentation of the results depicted in Figure 5. The comfort criteria are based on those prescribed in the City of Ottawa's Terms of Reference for Wind.

Table 1: Comfort Criteria

ACTIVITY	Gust Equivalent Mean Wind Speed Exceeded 20% of the Time	Description
COMFORT	***km/h***	
Sitting	0-10	Calm or light breezes desired for outdoor restaurants, seating areas and other amenity spaces.
Standing	0-14	Gentle breezes suitable for main building entrances and bus stops.
Strolling	0-17	Moderate winds that would be appropriate for window shopping and strolling along a downtown street, plaza or park.
Walking	0-20	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>20	Strong winds of this magnitude are considered unacceptable for most activities, and wind mitigation is typically recommended.

The effects of mean and gust wind conditions are described as suitable for sitting, standing, strolling, or walking when said categories are realised 80% of the time, or greater. The uncomfortable category encompasses wind conditions that exceed walking criteria. For a point to be rated as suitable for sitting, for example, the wind conditions must not exceed 10km/h, more than 20% of the time. For sitting, the rating would include conditions ranging from calm up to wind speeds that would rustle tree leaves or wave flags slightly, as presented in the Beaufort Scale included in the Background and Theory of Wind Movement section. As the name infers, the category is recommended for outdoor space where people might sit for extended periods.

The standing category is slightly more tolerant of wind, including wind speeds from calm up to 14km/h, occurring at least 80% of the time. In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Strolling category includes wind speeds from calm up to 17km/h, occurring at least 80% of the time, and is considered appropriate for strolling along a street, plaza or park. The Walking category includes wind speeds from calm up to 20km/h, occurring at least 80% of the time. These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Uncomfortable category covers a broad range of wind conditions that are generally a nuisance for most activities, including wind speeds above 20km/h occurring more than 20% of the time.

The figures represent the average person's response to wind force for the four seasons. Effects such as wind chill and humidex (based on perception) are not considered. Clothing is not considered since clothing and perceived comfort varies greatly among the population. There are many variables that contribute to a person's perception of the wind environment beyond the seasonal variations presented. While people are generally more tolerant of wind during the summer months than during the winter, due to the wind cooling effect, people become acclimatized to a particular wind environment. People dwelling near the shore of an ocean, large lake or open field are more tolerant of wind than people residing in a sheltered wind environment.

4.6 Pedestrian Safety Criteria

An estimate of safety criteria exceedances are also included in the analysis to predict areas where strong wind gusts may occur. The estimate is based upon the gust wind speed exceeded nine times per year, or 0.1% of the time annually, based on 24 hour a day weather data. The safety criteria are shown below in Table 2. CFD modelling is limited in its ability to predict gust wind speeds and areas of concern, should they arise, may require further wind tunnel analysis. The estimated safety ratings for the existing and proposed settings are depicted in Figure 6.

Table 2: Safety Criteria

ACTIVITY	**Gust Wind Speed Exceeded 9 Times per year**	**Description**
SAFETY	***km/h***	
Passing	0-90	Acceptable gust speeds that will not adversely affect a pedestrian's balance and footing.
Exceeded	>90	Excessive gust speeds that can adversely affect safety and a pedestrian's balance and footing. Wind mitigation is typically required.

4.7 Pedestrian Comfort Criteria – Seasonal Variation

The level of comfort perceived by an individual is highly dependent on seasonal variations of climate. Perceived comfort is also specific to each individual and depends on clothing choices. The comfort criterion used averages the results across the general population to remove effects of individuals and clothing choices, however, seasonal effects are important. For instance, a terrace or outdoor amenity space may have limited use during the winter season but require acceptable comfort during the summer.

5. RESULTS

5.1 Study Site and Test Conditions

Proposed Development

The proposed Heron Gate Village Development is located in the City of Ottawa and bounded to the north by Heron Road, to the west by Heron-Walkley Park, to the east by the recently redeveloped Heron Gate shopping plaza, and to the south by Walkley Road. The proposed Development site is currently occupied by various low-rise residential buildings that will be removed. Six low through high-rise buildings, denoted Buildings 3.9, 3.10, 4.7, 5.3, 5.4, and 5.5 will be retained.

The Masterplan of the proposed Development includes lots 2 through 9. Lot 1, consisting of three 6 storey buildings, and part of Lot 2, consisting of two 6 storey buildings and one 7 storey building, located at the northeast corner of the site, are approved and/or under a separate application.

The proposal for Lot 2 includes a 6 storey building, as well as two 18 storey buildings with 6 storey podiums. Lot 3 includes three 25 storey buildings with 4, 6, and 8 storey podiums, as well as 4, 6, and 10 storey buildings. Lot 4 consists of two 25 storey buildings with 4 and 8 storey podiums, as well as one 6 storey townhouse block and three 4 storey townhouse blocks. Lot 5 includes a 4 storey and a 3 storey townhouse block, and Lot 6 includes a 6 storey building and a 25 storey building with a 6 storey podium. Lot 7 consists of 25, 15, and 9 storey buildings with 6 storey podiums, as well as an 8 storey building. Lot 8 includes four 25 storey buildings with 6 storey podiums, as well as 10, two 9, and 6 storey buildings. Lot 9 consists of two 25 storey buildings with 10 and 6 storey podiums, as well as four 6 storey buildings.

A Public Park is proposed central to the site, and POPS spaces are proposed to the northeast of Lot 8, north of Lot 9, and central to Lot 2.

The proposed Development is in a configuration as shown in Figure 2.

Surrounding Area

The proposed Development site is surrounded by a mix of low through high-rise residential, commercial, and institutional buildings, mature vegetation, and open spaces, as indicated in Figure 1.

Immediately northeast of the site are the previously approved phases of the development consisting of the three 6 storey buildings of Lot 1 which have been built, and two 6 storey buildings and one 7 storey building of Lot 2. To the immediate northwest of the site are low through mid-rise residential buildings and the low-rise Heron Road Community Centre building. Lands north of the site beyond Heron Road are mainly occupied by low-rise residential buildings, with low-rise institutional buildings and related open parkland located to the northwest. Lands to the south through southeast of the site are occupied by a mix of mainly low-rise residential, institutional, and commercial buildings intermixed with a few high-rise residential buildings and related open lands. Low-rise commercial buildings and related open parking areas occupy lands to the immediate east of the site.

Urban developments present relatively coarse terrain that moderate pedestrian level winds, whereas low-rise buildings and open spaces allow wind the opportunity to accelerate on approach. Transition zones from more open to urban settings often prove problematic, as winds exacerbated by relatively more open settings are redirected to flow over, around, down, and between buildings. Figure 1 depicts the site and its immediate surrounds. The site plan is shown in Figure 2 and the computational geometry model is shown in Figure 3.

Macroclimate

For the proposed Development, the upstream wind flow during calculation was conditioned to simulate an atmospheric boundary layer passing over suburban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical meteorological data recorded at Ottawa International Airport was used in this analysis. The data is split up into four seasons, winter, spring, summer, and fall, and the resulting wind roses are presented as mean velocity and percent frequency in Figures 4a- 4d. The mean velocities presented in the wind roses are measured at an elevation of 10*m*. Thus, representative ground level velocities at a height of 1.5*m*, for an urban macroclimate, are 52% of the mean values indicated on the wind rose, (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for this area is predominantly suburban.

Winter (December through February) and spring (March through May) have the highest mean wind velocities of the seasons with prevailing winds from the northwest quadrant and additional significant components from the southwest and northeast. Summer (June through August) has the lowest mean wind velocities of the seasons with prevailing winds from the northwest through west to south, as indicated in Figure 5c. During the fall (September through November), prevailing winds include the northwest quadrant, southwest through south, and the northeast through east directions. Reported pedestrian comfort conditions pertain to the winter season, unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

In the computational model, the full wind field measuring 480m in radius was studied to determine conditions related to comfort and safety. For the existing setting, the subject buildings were removed, and the "existing" site model recalculated with the current site.

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (see Figure 4) was combined with pedestrian level mean and gust wind speeds measured at each point to provide predictions of the percentage of time a point will be comfortable for a given activity. These predictions of mean and maximum or "gust" wind speeds are provided on a seasonal basis in Figures 5a – 5h.

The ratings for a given location are conservative by design; when the existing surroundings and proposed buildings' fine massing details and actual landscaping are taken into consideration, the results tend toward a more comfortable site than testing alone would indicate.

Venturi action, scour action, downwash and other factors, as discussed in the Background and Theory of Wind Movement section, can be associated with large buildings, depending on their orientation and configuration. These serve to increase wind velocities. Open areas within a heavily developed area may also encounter high wind velocities. Consequently, wind force effects are common in heavily built-up areas. The Development site is exposed to a predominantly suburban setting to prevailing and remaining compass points with winds flowing over and between low through high-rise buildings, mature vegetation, and open spaces. As such, the surroundings can be expected to influence wind at the site to varying degrees.

5.3 Review of CFD Results

The areas of interest are areas surrounding the proposed Development, mainly public streets, neighbouring sites, interior site and activity areas, and pedestrian entrances. The pedestrian level comfort results are graphically depicted for the four seasons in Figures 5a – 5h and estimated safety results are graphically depicted in Figures 6a and 6b. The following discusses anticipated wind conditions and suitability for the areas' intended uses.

Public Street Conditions

Walkley Road

In the existing setting, the contour results along Walkley Road within the zone of influence of the proposed Development site indicate wind conditions that are mainly suitable for standing with localised sitting areas in the winter and spring, and sitting with localised standing areas in the summer and fall. The fairly comfortable conditions can be attributed to the predominantly low-rise surrounds that deflect winds to flow up and over the pedestrian level.

With inclusion of the proposed Development, a realignment of winds was noted along Walkley Road. Increases in winds were realised whereby the street becomes mainly rated for standing in the winter and spring, with localised strolling areas proximate to the intersections with Cedarwood Drive and Baycrest Drive. The street also becomes mainly suitable for standing in the fall, with localised sitting areas, and remains suitable for sitting in the summer with localised standing areas proximate to intersections. The general increases in winds can be attributed to the proposed mid to high-rise buildings fronting Walkley Road redirecting winds that formerly flowed over the existing low-rise buildings, to flow down and around the proposed buildings. The proposed Development incorporates wind-friendly design components including stepped conditions, which will reduce the propensity for downwash.

As such, inclusion of the proposed Development will result in a realignment of winds along Walkley Road, resulting in slightly windier conditions, however the street will remain suitable for its intended purpose throughout the year. Consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

With inclusion of the proposed Development, Walkey Road remains within the pedestrian level wind velocity safety criteria, as depicted in Figures 6a and 6b.

Heron Road

In the existing setting, areas of Heron Road adjacent to the proposed site are mainly suitable for sitting throughout the year, with localised standing areas in the winter and spring. The fairly comfortable conditions can be attributed to the predominantly low-rise surrounds that deflect winds to flow up and over the pedestrian level. In the proposed setting, the street realises fairly similar conditions throughout the year, with localised windier conditions, rated for standing, adjacent to the site.

As such, Heron Road will realise similar conditions with inclusion of the proposed Development, and will remain suitable for its intended purpose throughout the year. Consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

With inclusion of the proposed Development, Heron Road remains within the pedestrian level wind velocity safety criteria, as depicted in Figures 6a and 6b.

Baycrest Drive

In the existing setting, Baycrest Drive is mainly rated for standing in the winter and spring, with localised sitting conditions near the intersection with Heron Road, and localised strolling conditions near the existing high-rise buildings on site. Very localised walking conditions are also noted in the winter and spring near the intersection with Sandalwood Drive. More comfortable conditions, rated for sitting or standing, are noted through the summer and fall in the existing setting.

In the proposed setting, the street realises increases in winds whereby winds are deflected to flow down and around the proposed buildings, and through the gaps between, resulting in the strolling ratings extending along larger portions of the street through the winter and spring seasons. The street also becomes mainly rated for standing through the fall. Conversely, the proposed Development provides blockage from portions of the wind climate for internal areas of the site. This improves the localised walking conditions to strolling ratings through the winter and spring, and the street becomes mainly rated for sitting through the summer season.

Baycrest Drive will remain suitable for its intended purpose throughout the year, and consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

With inclusion of the proposed Development, Baycrest Drive remains within the pedestrian level wind velocity safety criteria, as depicted in Figures 6a and 6b.

Cedarwood Drive

In the existing setting, Cedarwood Drive is mainly rated for standing in the winter and spring, with localised sitting conditions near the northern portion of the street, and localised strolling and walking conditions near the existing cruciform high-rise buildings on site. In the summer and fall the street is mainly rated for sitting in the existing setting, with localised standing and strolling conditions adjacent to the existing high-rise buildings.

With inclusion of the proposed buildings, localised areas along the northern portion of the road and proximate to the intersection with Walkley Road realise increases in winds, sufficient to change the sitting/standing ratings in the winter and spring to mainly suitable for strolling, and the fall sitting ratings to standing. This can be attributed to winds flowing down and around the proposed buildings and through the gaps in between. Conversely, localised improvements were realised proximate to the existing cruciform buildings, whereby the proposed buildings provide blockage to easterly/westerly winds, improving the winter and spring ratings from strolling/walking to mainly standing, the summer ratings from standing to sitting, and the localised strolling ratings in the fall to standing.

As such, Cedarwood Drive will remain suitable for its intended purpose throughout the year. Consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

With inclusion of the proposed Development, Cedarwood Drive remains within the pedestrian level wind velocity safety criteria, as depicted in Figures 6a and 6b.

Sandalwood Drive

Sandalwood Drive is similarly suitable for sitting or standing throughout the majority of the year in the existing setting, with strolling areas in the winter and shoulder seasons proximate to the existing high-rise building at the intersection with Baycrest Drive. Localised walking conditions are similarly located in this area in the winter and spring.

In the proposed setting, improvements are noted whereby the localised walking conditions in the winter and spring are improved to strolling conditions. The strolling ratings in the fall proximate to the intersection with Baycrest Drive are similarly improved to standing, and the summer standing conditions in this area are improved to sitting. Conversely, the strolling conditions in the winter and spring, and the standing conditions in the fall, extend along larger portions of Sandalwood Drive to the north.

As such, Sandalwood Drive will remain suitable for its intended purpose throughout the year. Consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

With inclusion of the proposed Development, Sandalwood Drive remains within the pedestrian level wind velocity safety criteria, as depicted in Figures 6a and 6b.

Neighbouring Site Conditions

Areas surrounding the site realise generally similar conditions in the existing and proposed settings that are mainly suitable for sitting or standing throughout the year, with localised strolling conditions to the south of Walkley Road.

In the existing setting, Sandalwood Park is rated for sitting in the summer and fall and sitting or standing through the winter and spring. In the proposed setting, the area realises increases in winds resulting in conditions mainly rated for standing through the winter and spring, with localised strolling areas proximate to Sandalwood Drive, as well as localised standing areas through the fall. The increase in winds in Sandalwood Park is a reasonable expectation given the introduction of a large development in the area, and the area remains generally suitable for the intended use throughout the year. Consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

The neighbouring site conditions remain within the pedestrian level wind velocity safety criteria as depicted in Figures 6a and 6b.

Internal Site and Activity Space Conditions

Internal site conditions are generally predicted to be suitable for sitting in the summer, and sitting or standing through the remainder of the year, with localized strolling areas proximate to high-rise buildings. Improvements are noted proximate to the existing high-rise buildings on site, whereby localised walking conditions were noted through the winter and spring in the existing setting that were improved to strolling.

The central Park area to the south of the intersection of Baycrest Drive and Cedarwood Drive is rated generally suitable for sitting in the summer and standing through the remainder of the year. Localised strolling conditions are predicted proximate to the streets in the winter and spring. POPS are similarly proposed to the immediate north of the proposed Buildings 8.5, 8.8, 9.1, and 9.4, as well as between Buildings 2.3 and 2.6. The areas are generally suitable for sitting in the summer, sitting or standing in the fall, and standing or strolling in the winter and spring. If more comfortable conditions are desired within the Park and POPS areas, mitigation features may be applied such as berms, fencing, wind screens, coniferous plantings, raised planters, trellises, recessed seating areas, etc. situated throughout the spaces.

If future Outdoor Amenity Spaces are proposed atop the buildings, these areas will likely require mitigation plans in order to achieve conditions that are suitable for the intended uses. Mitigation plans may include perimeter wind screens, trellises, raised planters, coniferous trees, etc. in order to achieve appropriate conditions.

As such, the internal site areas and activity spaces are predicted to be generally comfortable and suitable for their intended uses, and consideration of fine design and landscape elements will result in more comfortable conditions than reported. With the inclusion of the proposed Development, these areas remain within the pedestrian level wind velocity safety criteria as depicted in Figure 6a and 6b.

Pedestrian Entrance Conditions

The Entrances to the proposed buildings are noted by arrows on the figures. These areas along the building façades are generally rated suitable for sitting throughout the year, with standing conditions just beyond, and will be suitable for the intended uses year-round. Areas proximate to Entrances to Buildings 3.1, 4.6, 7.4, and 9.1 are predicted to realise slightly windier conditions in the winter and spring, suitable for strolling, and mitigation may be explored for these entrances such as removing the entrances from building corners and/or gaps in between and/or recessing the entrances into the building façades.

The Entrances to the proposed Buildings remain within the pedestrian level wind velocity safety criteria as depicted in Figures 6a and 6b.

5.4 Summary

The observed wind velocity and flow patterns at the proposed Development site are largely influenced by approach wind characteristics that are dictated by the surrounding areas to prevailing and less dominant wind directions. These surroundings present a suburban terrain to prevailing winds, mitigating winds from some directions and affording wind opportunity to accelerate from others, resulting in generally comfortable conditions in the existing setting, with localised windy conditions near corners of high-rise buildings and in gaps between.

Once the subject site is developed, ground level wind conditions remain relatively similar to the existing setting. The proposed Development provides blockage to winds from some directions, resulting in localised improvements, and conversely the proposed buildings redirect winds to flow down and around the façades, resulting in localised increases in winds. This results in wind conditions that are predicted suitable for sitting or standing through the majority of the year, with localised strolling conditions in the winter and spring. The site and surrounds generally remain comfortable and appropriate to the areas' intended purposes throughout the year, and consideration of fine design details and mitigative landscape features will result in more comfortable conditions than reported. The relationship between surface roughness and wind is discussed in the Background and Theory of Wind Movement section and shown graphically in Figure A of the same section.

Mitigation plans may be explored through future submissions for the Entrances to Buildings 3.1, 4.6, 7.4, and 9.1, as well as the proposed Parks and POPS throughout the site if more comfortable conditions than reported are desired.

The proposed Development is predicted to realise wind conditions acceptable to a typical suburban context, based on this preliminary Computational Fluid Dynamics analysis.

6. FIGURES

Figure 1: Site Aerial Photo

Figure 2: Site Plan

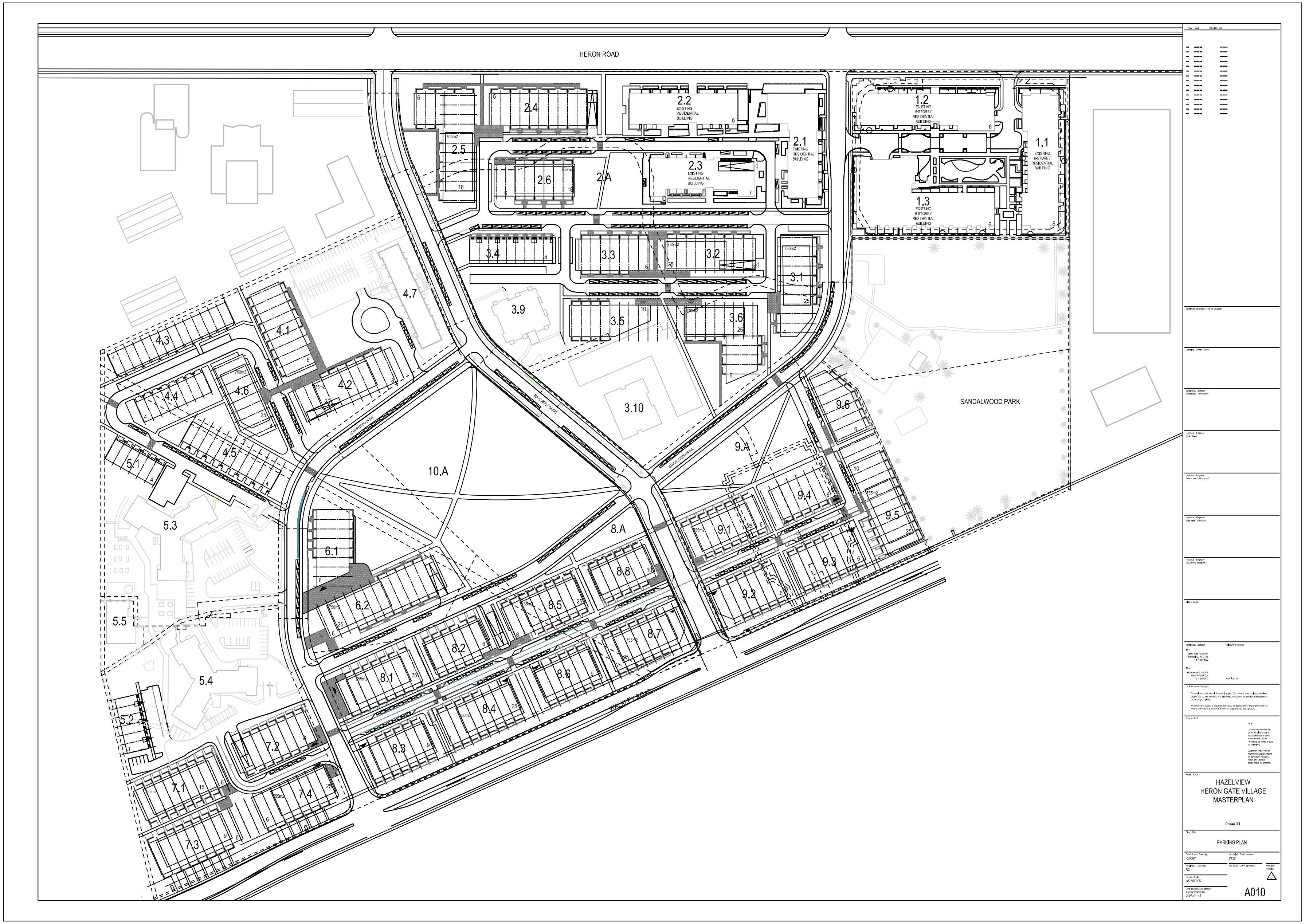

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Figure 3: Computational Geometry

a) Existing Setting

b) Proposed Setting

Figure 4a: Winter Wind Rose - Ottawa International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
December through February (1992 - 2022)

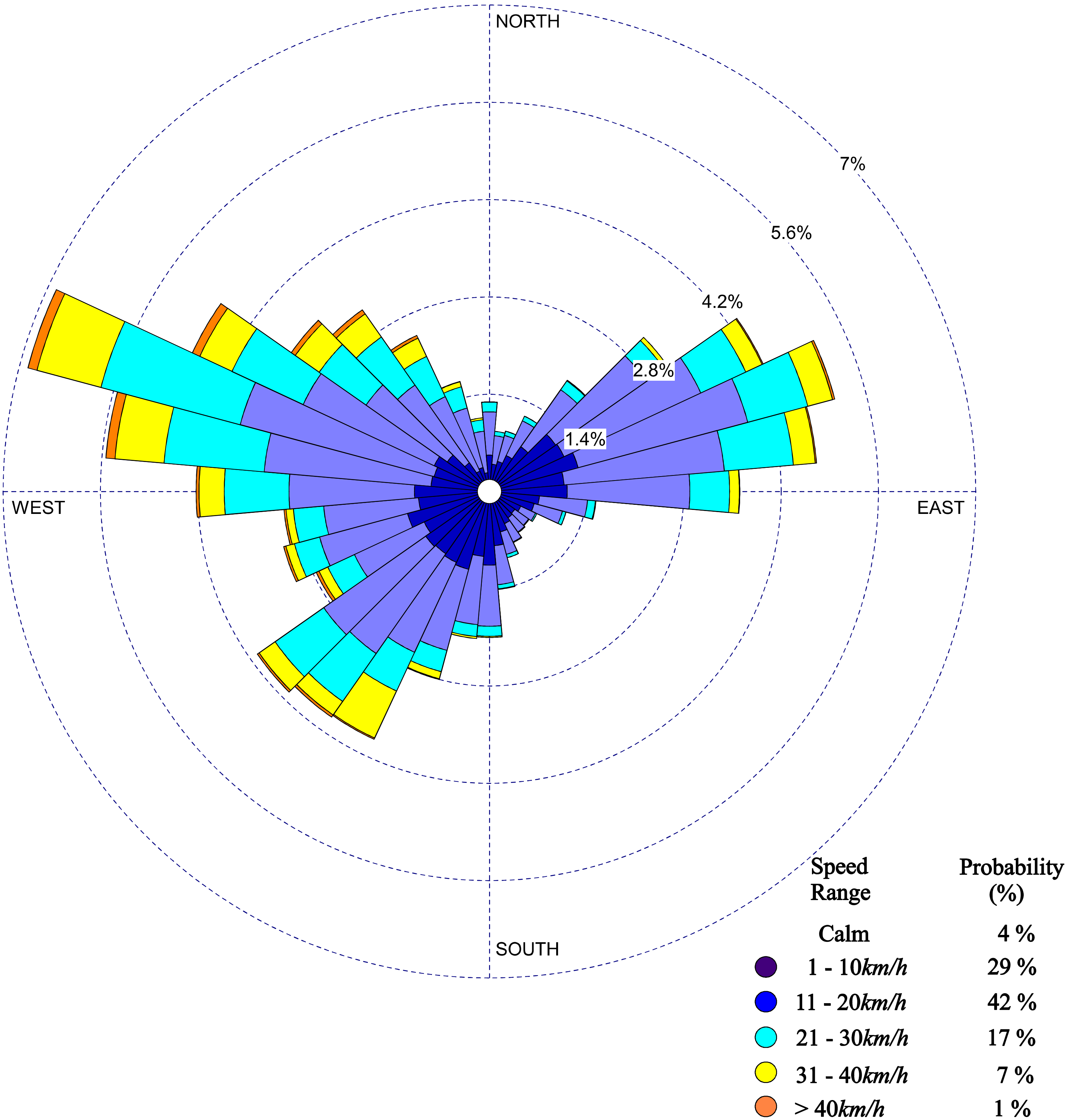

Figure 4b: Spring Wind Rose - Ottawa International Airport

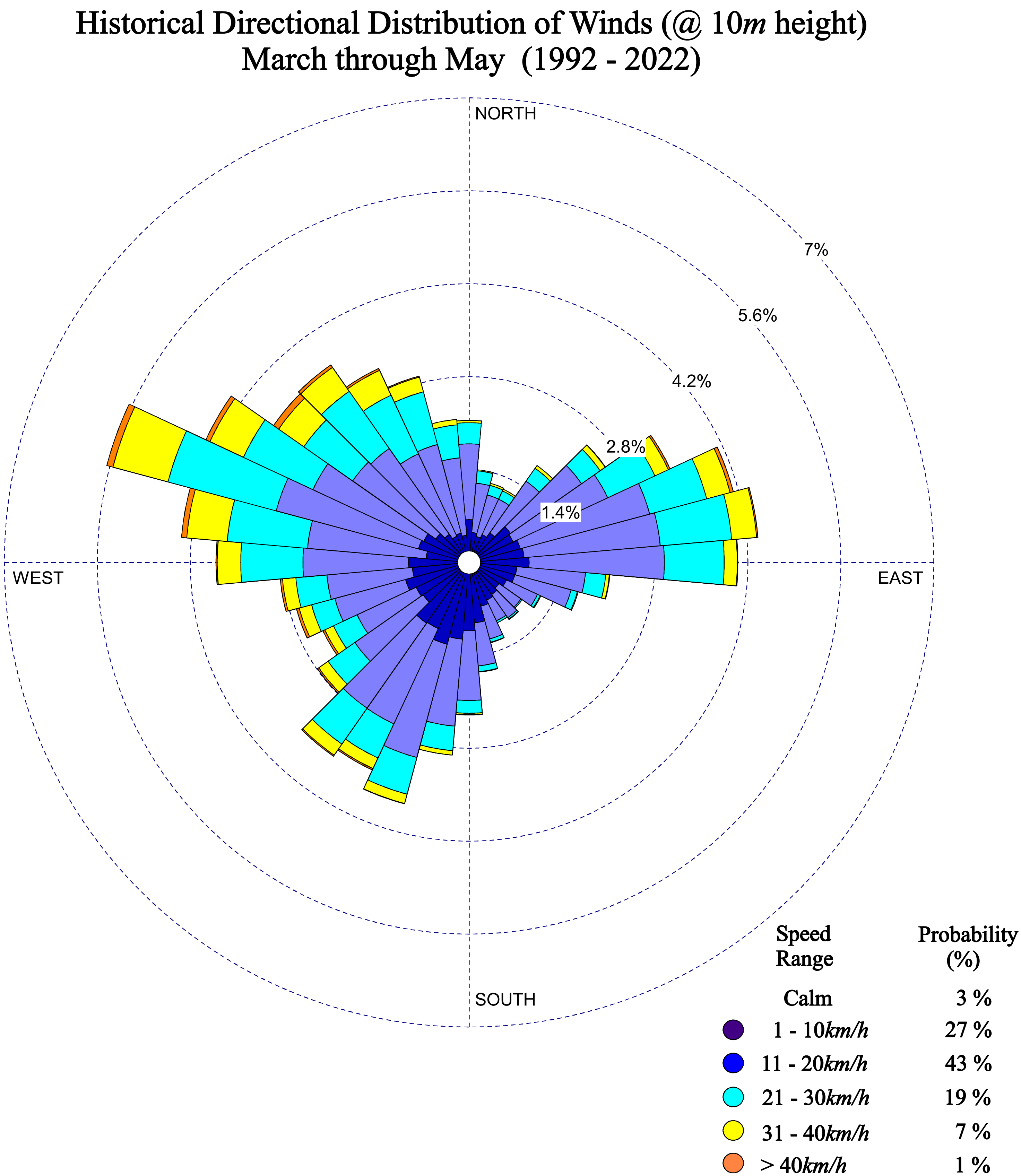

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Figure 4c: Summer Wind Rose - Ottawa International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
June through August (1992 - 2022)

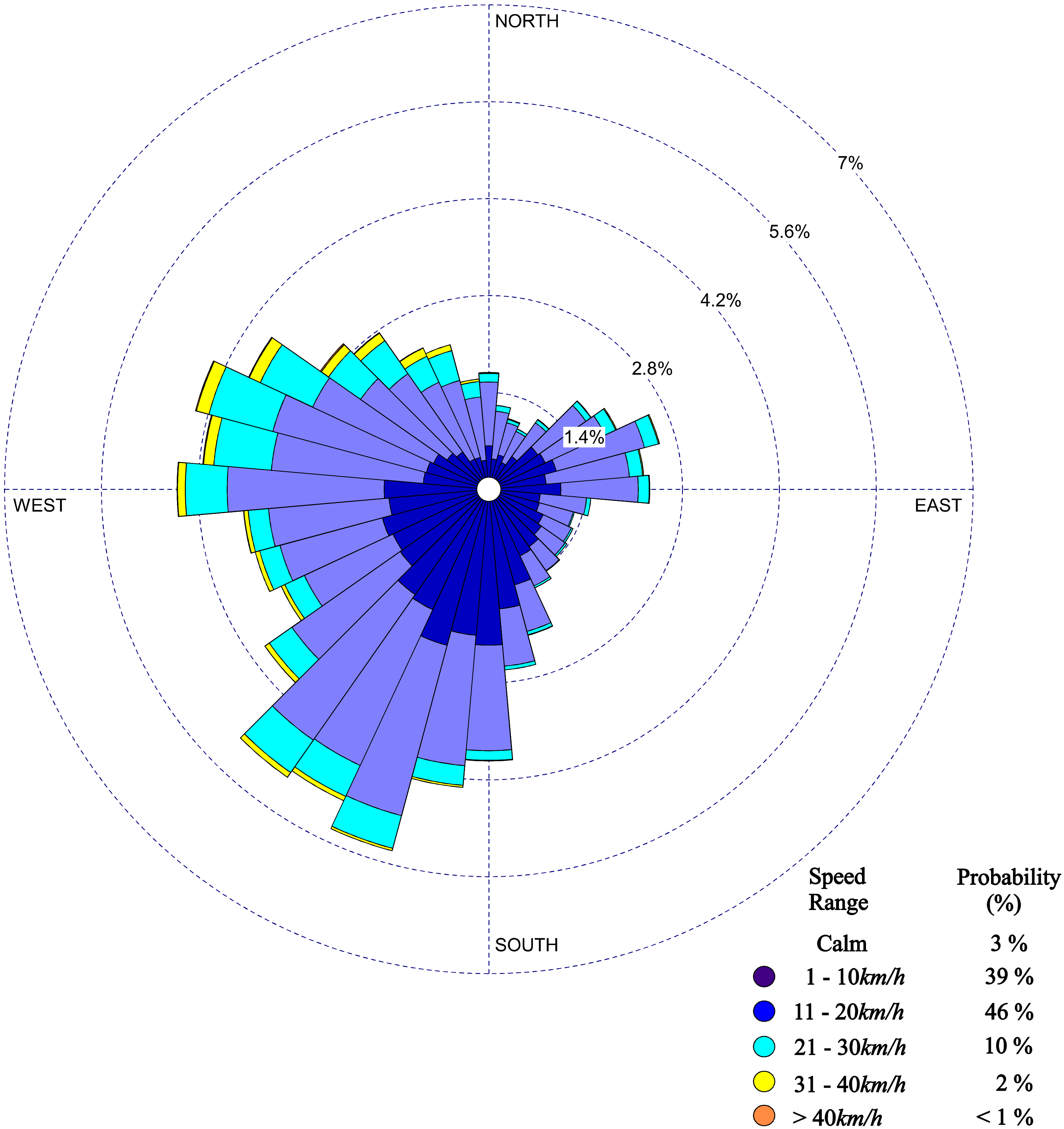
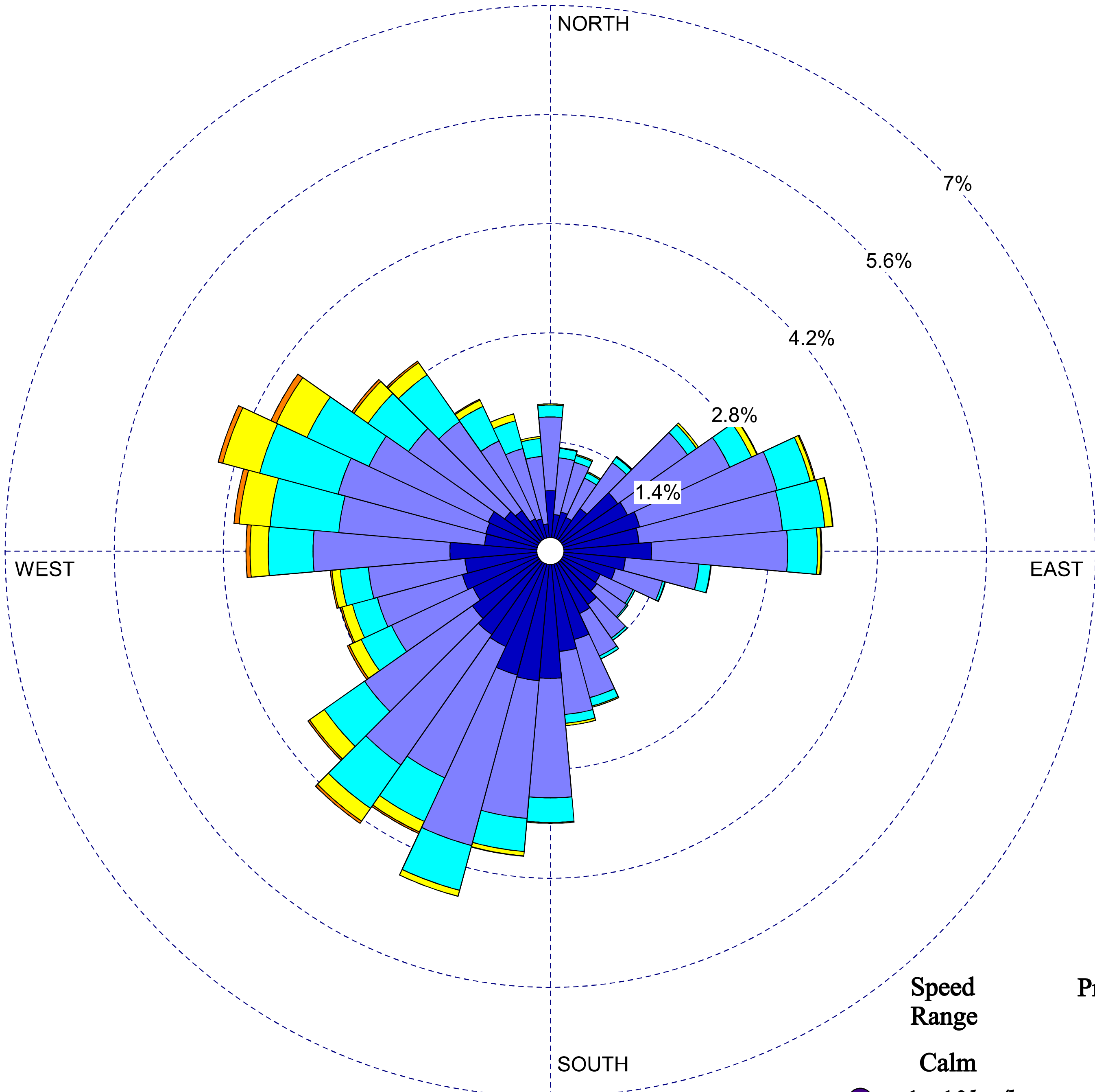


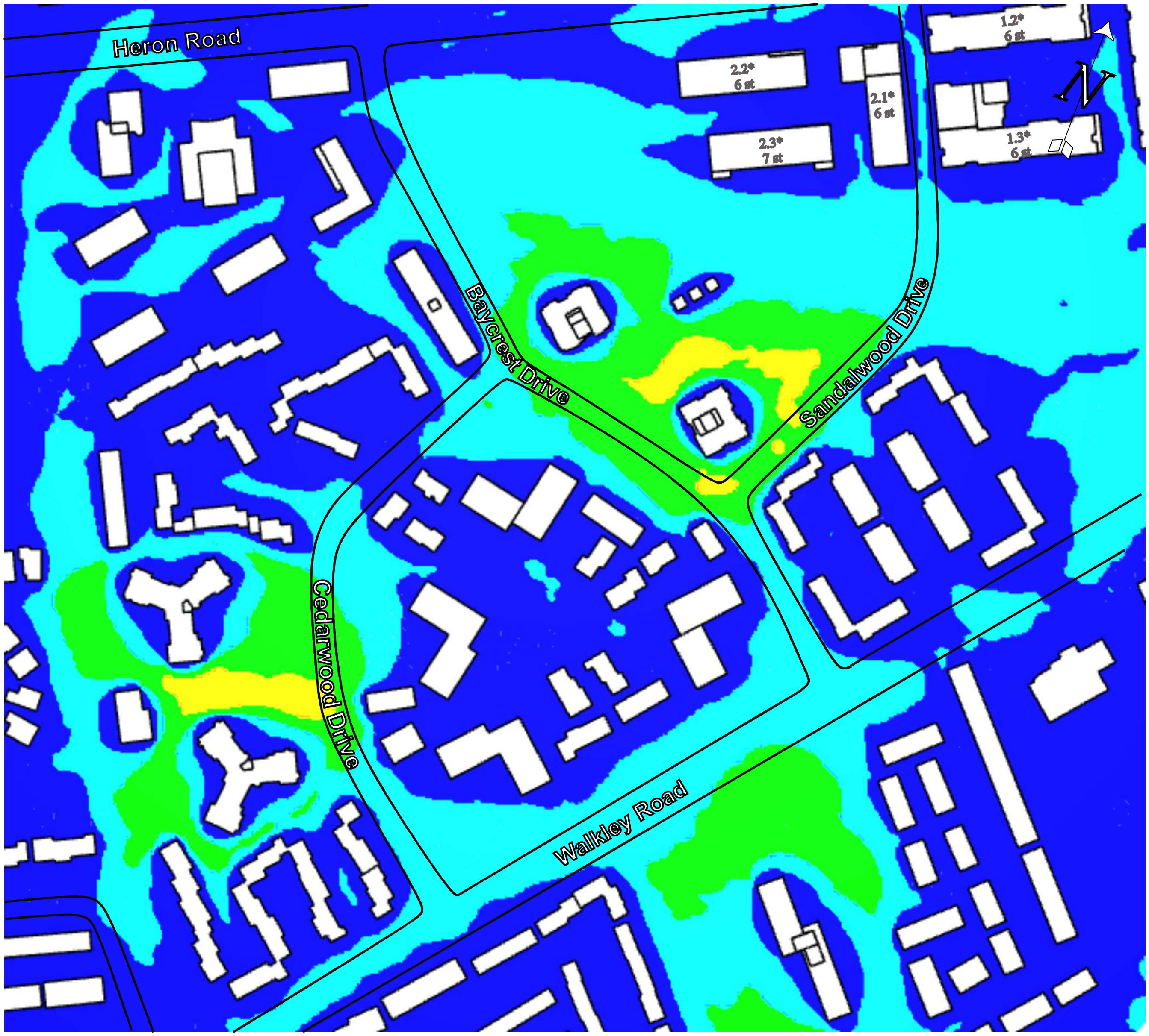
Figure 4d: Fall Wind Rose - Ottawa International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
September through November (1992 - 2022)



Speed Range	Probability (%)
Calm	3 %
1 - 10*km/h*	35 %
11 - 20*km/h*	44 %
21 - 30*km/h*	13 %
31 - 40*km/h*	4 %
> 40*km/h*	<1 %

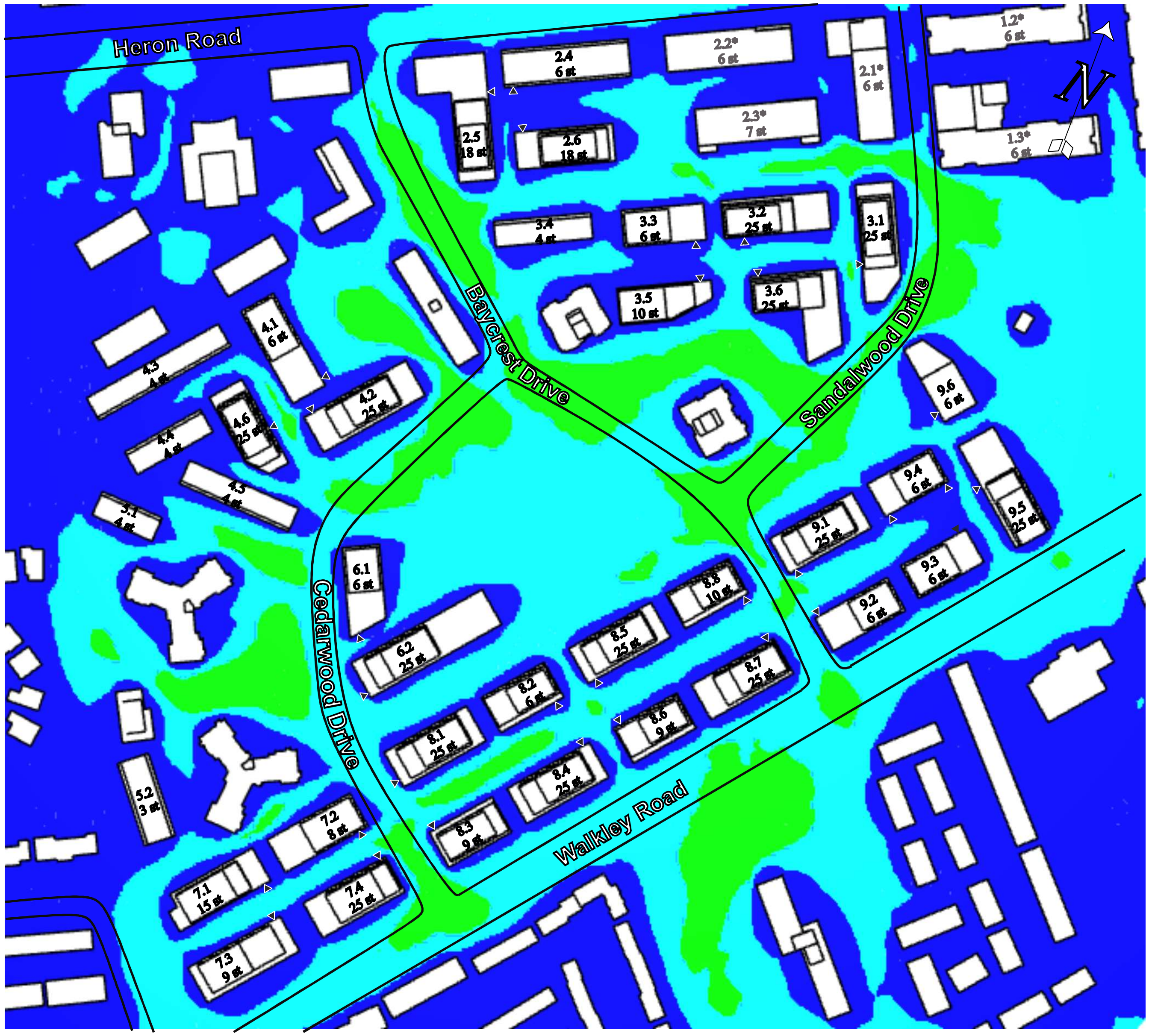
Figure 5a: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Existing

Sitting Standing Strolling Walking Uncomfortable

Figure 5b: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Proposed

Sitting Standing Strolling Walking Uncomfortable

Figure 5c: Pedestrian Level Wind Velocity Comfort Categories

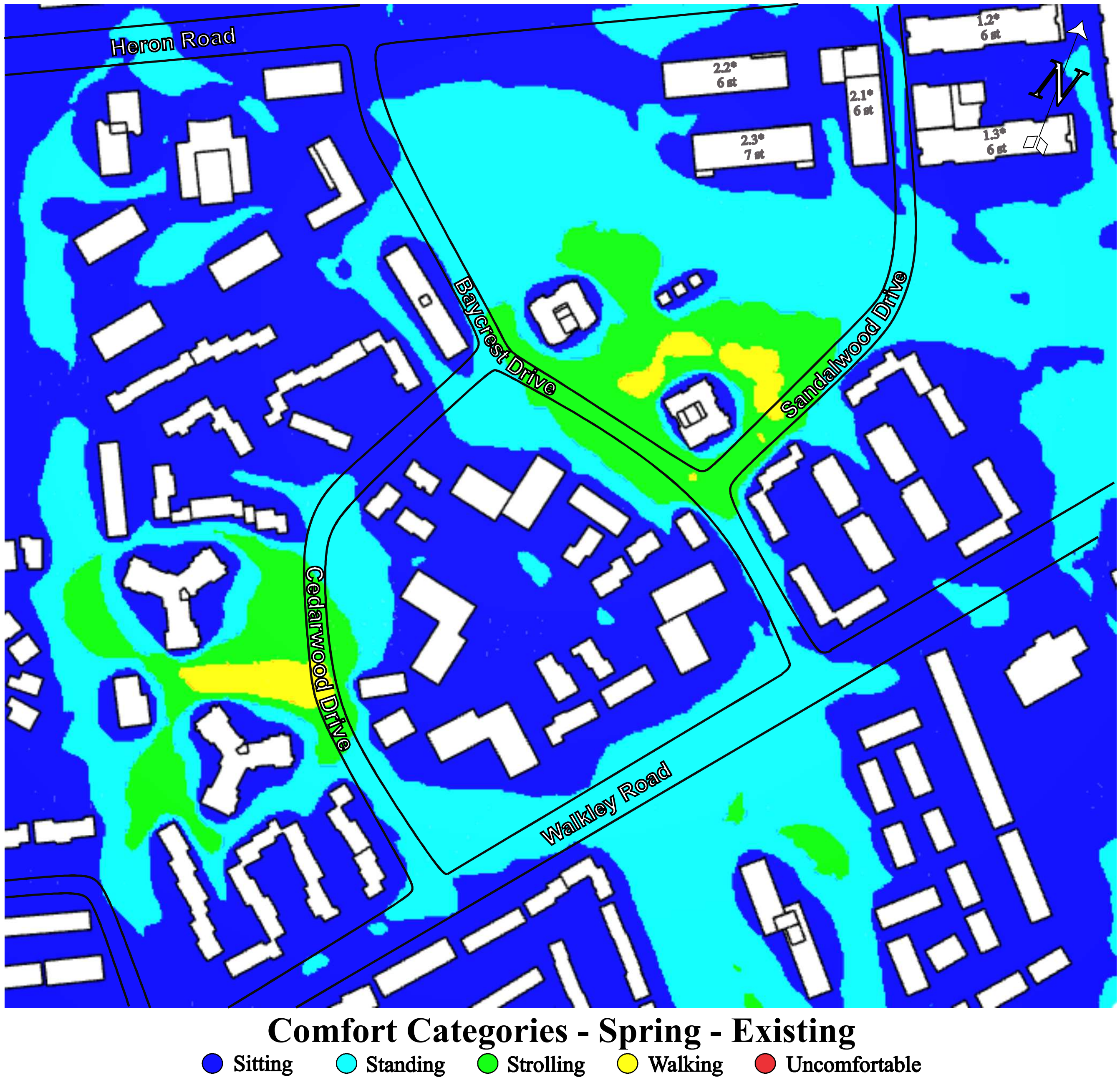
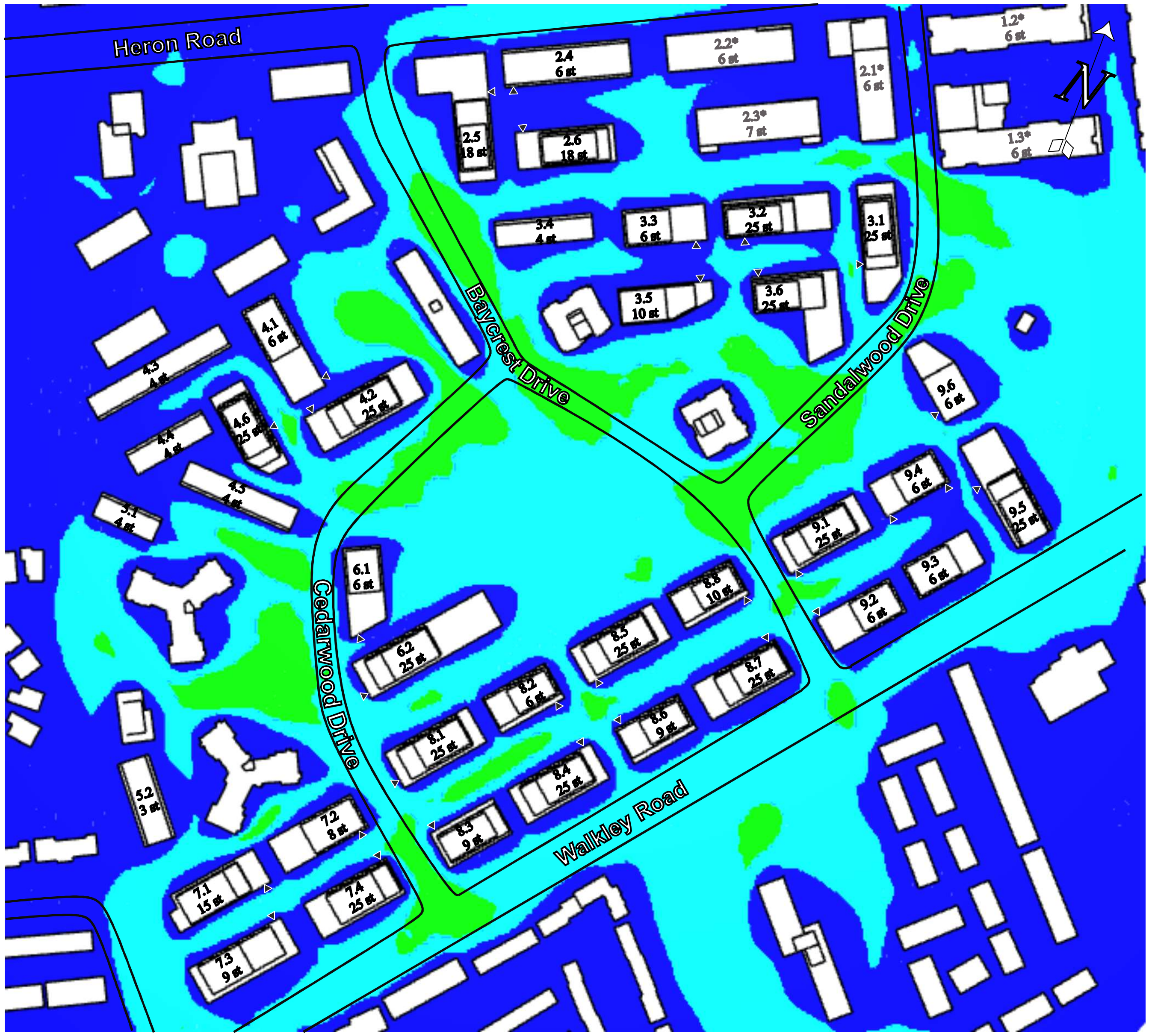


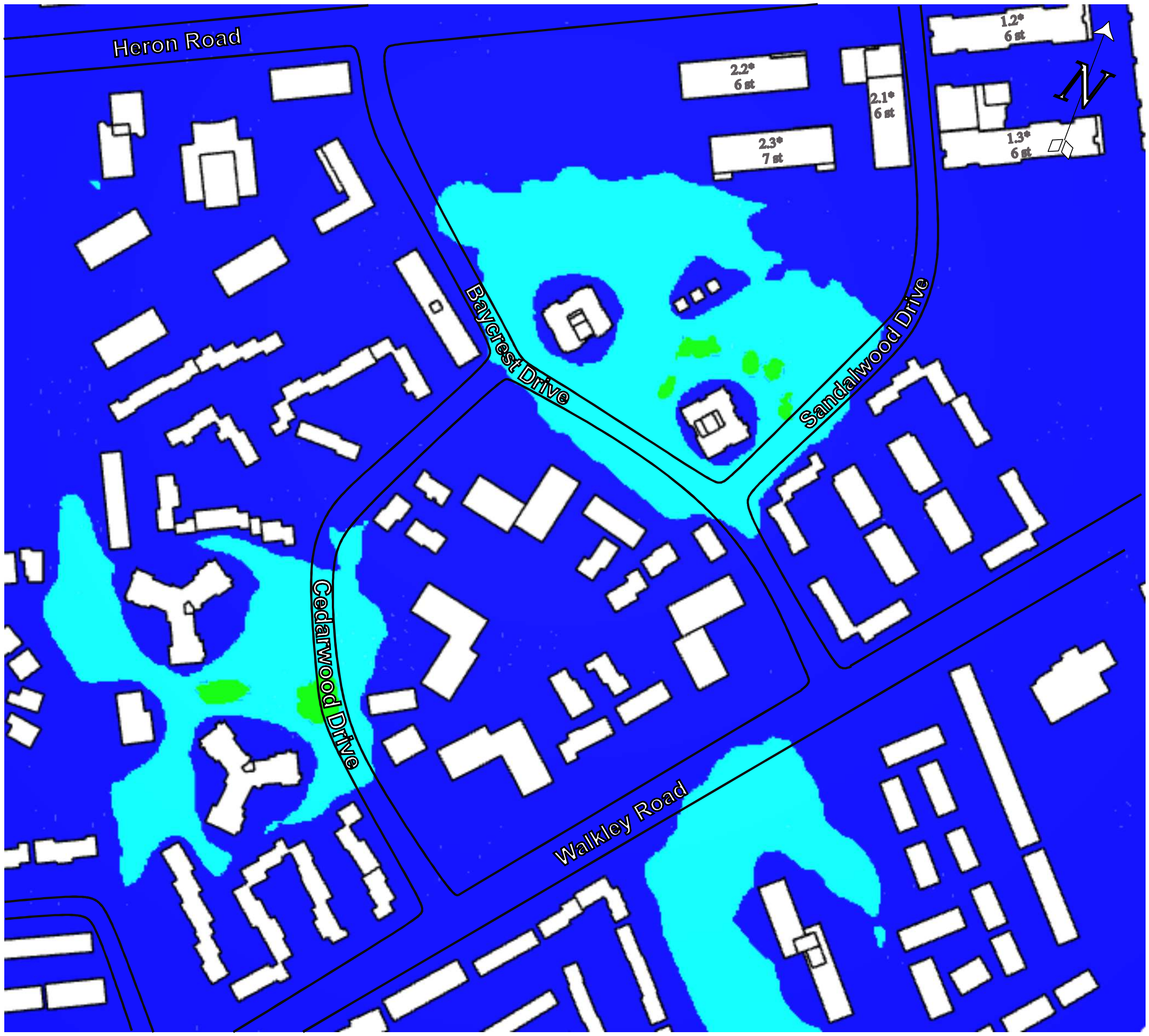
Figure 5d: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Spring - Proposed

Sitting   Standing   Strolling   Walking   Uncomfortable

Figure 5e: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Existing

Sitting Standing Strolling Walking Uncomfortable

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Figure 5f: Pedestrian Level Wind Velocity Comfort Categories

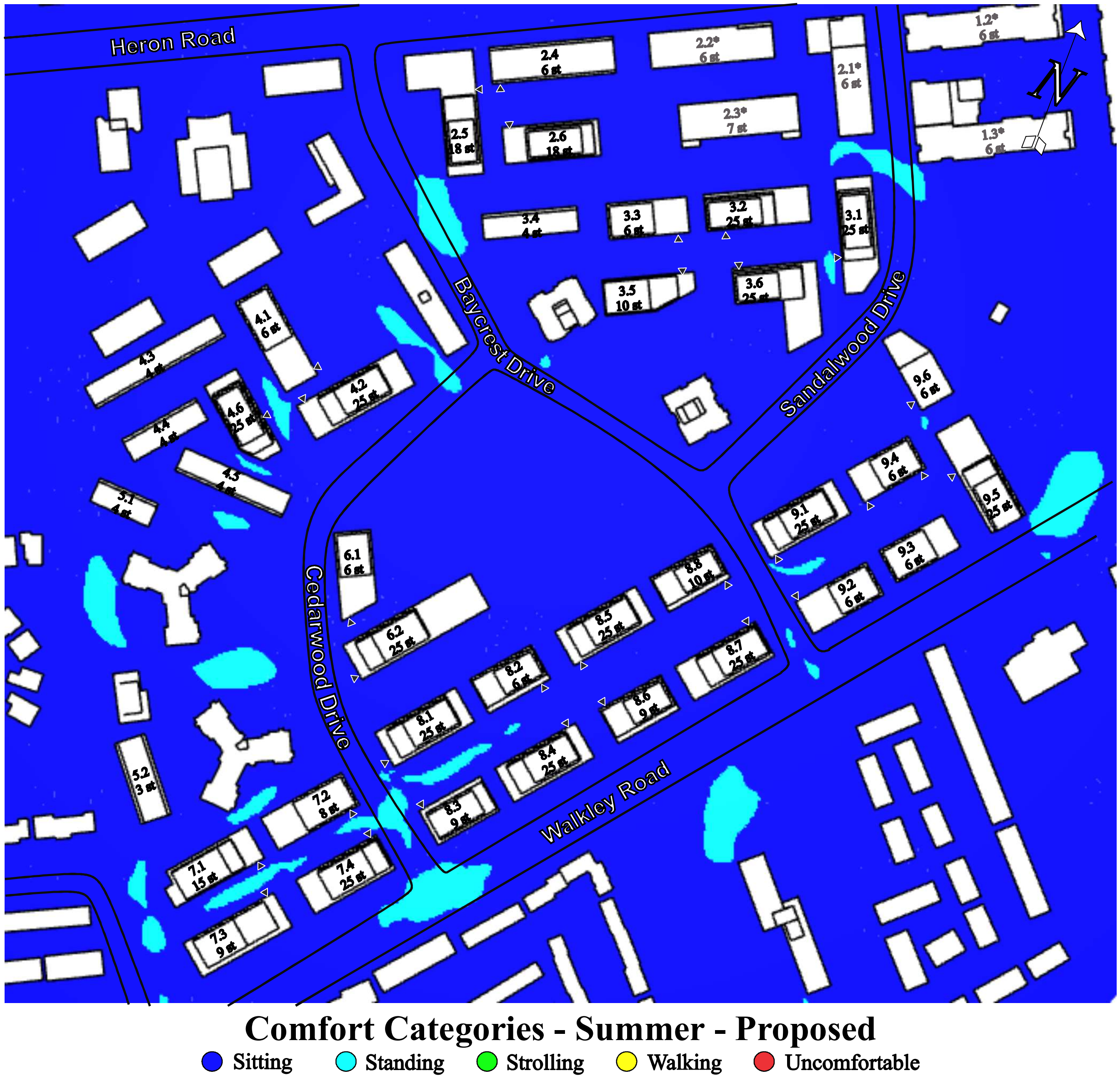

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Figure 5g: Pedestrian Level Wind Velocity Comfort Categories

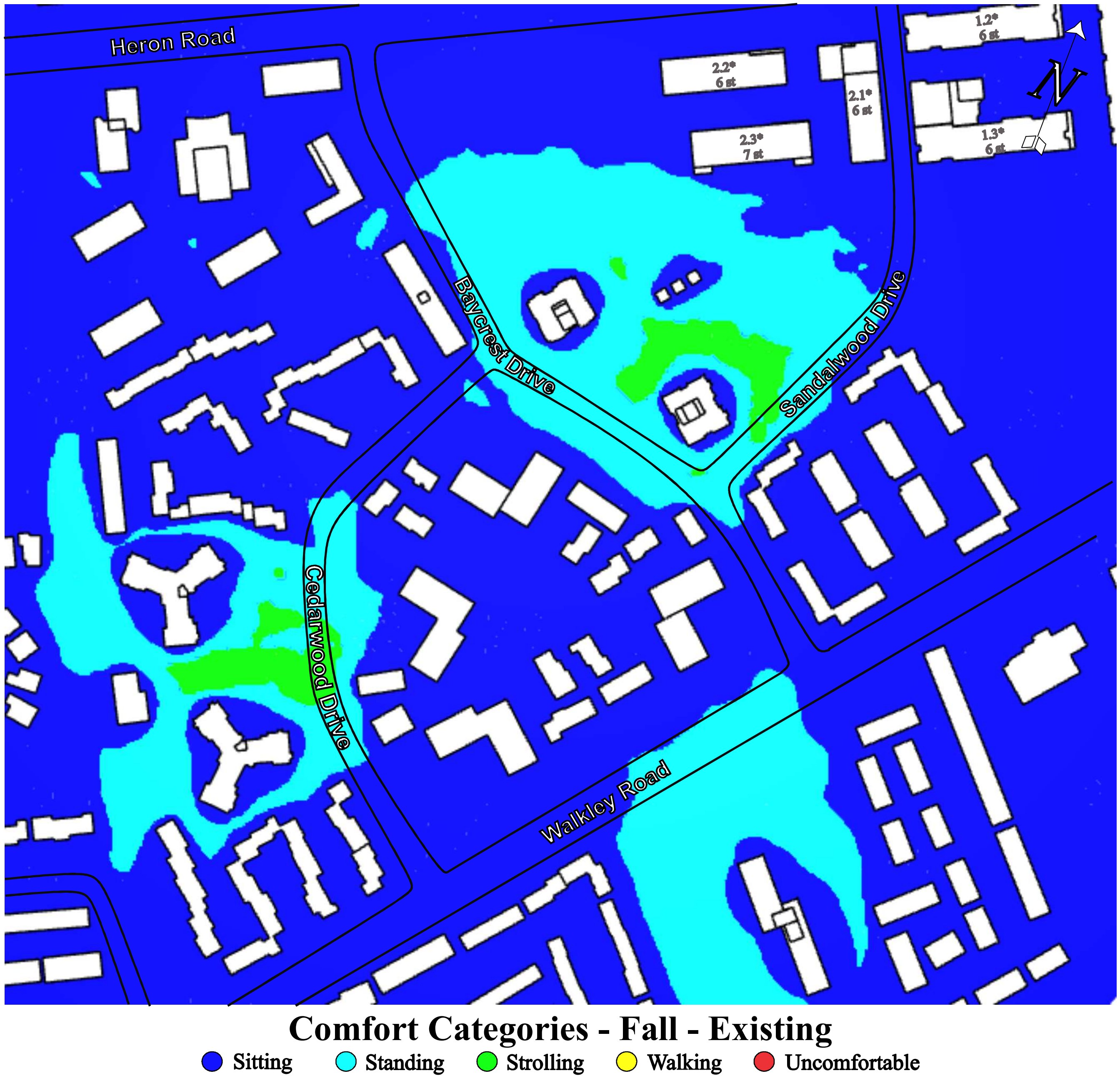

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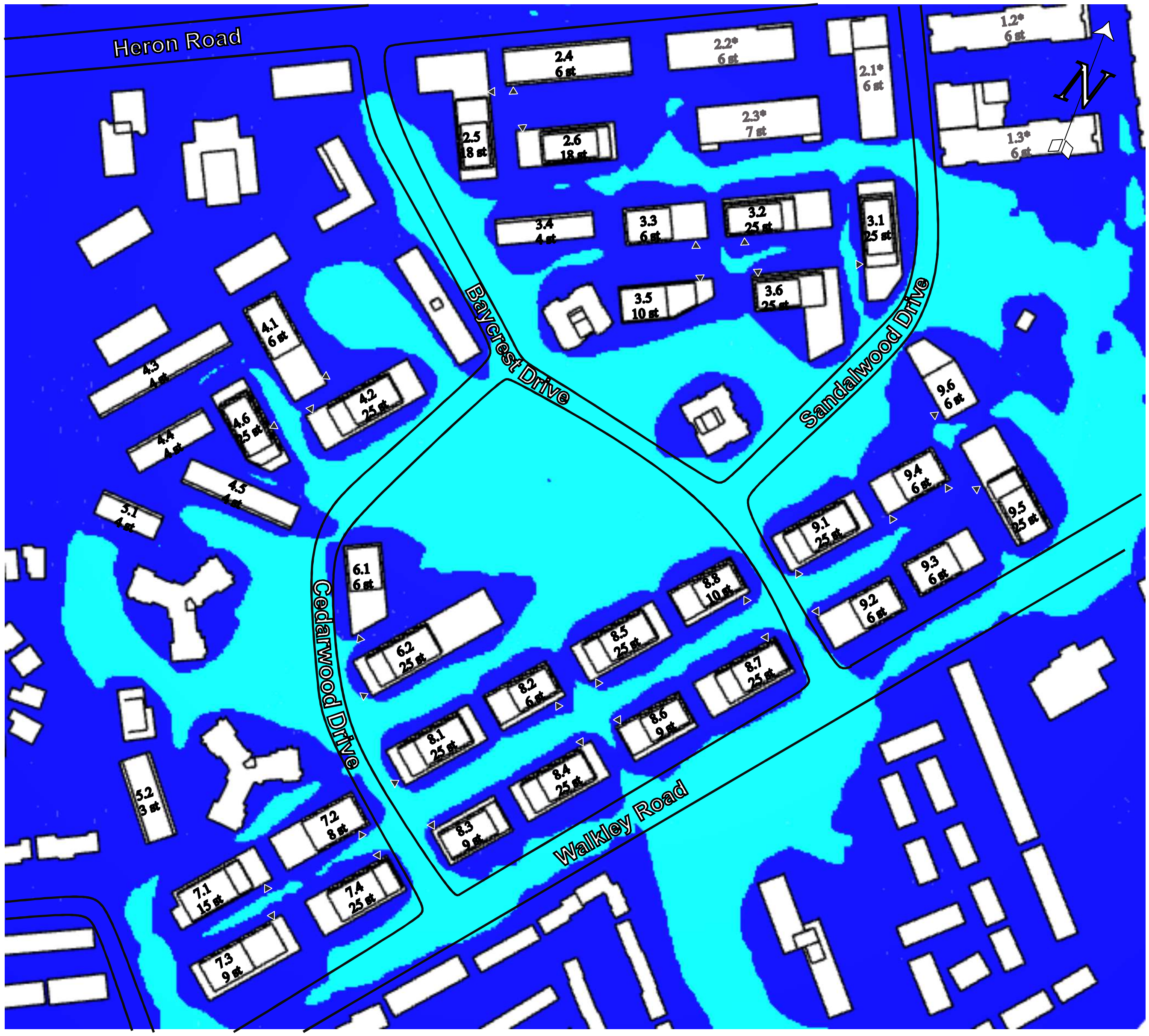
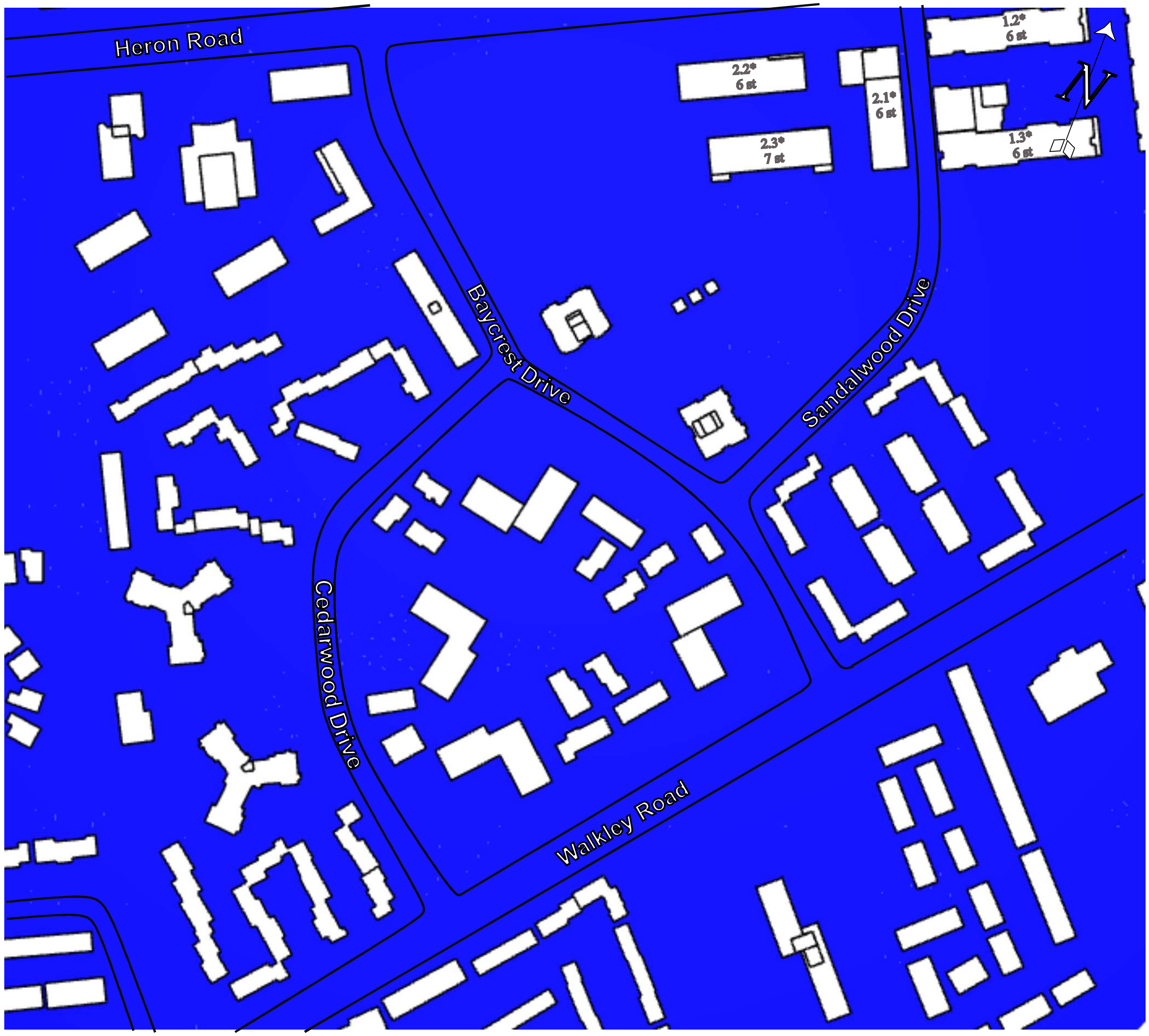
Figure 5h: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Fall - Proposed

Sitting Standing Strolling Walking Uncomfortable

Figure 6a: Pedestrian Level Wind Velocity Safety



Safety Criteria - Existing

Passing Safety Criteria Exceeding Safety Criteria *Estimated

Figure 6b: Pedestrian Level Wind Velocity Safety

Safety Criteria - Proposed

Passing Safety Criteria   Exceeding Safety Criteria   *Estimated

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7. BACKGROUND AND THEORY OF WIND MOVEMENT

During the course of a modular analysis of an existing or proposed site, pertinent wind directions must be analysed with regard to the macroclimate and microclimate. In order for the results of the study to be valid, the effects of both climates must be modelled in test procedures.

Macroclimate

Wind velocity, frequency and directions are used in tests with models to establish part of the macroclimate. These variables are determined from meteorological data collected at the closest weather monitoring station. This information is used in the analysis of the site to establish upstream (approach) wind and weather conditions.

When evaluating approach wind velocities and characteristic profiles in the field it is necessary to evaluate certain boundary conditions. At the earth's surface, "no slip" conditions require the wind speed to be zero. At an altitude of approximately one kilometre above the earth's surface, the motion of the wind is governed by pressure distributions associated with large-scale weather systems. Consequently, these winds, known as "geostrophic" or "freestream" winds, are independent of the surface topography. In model simulation, as in the field, the area of concern is the boundary layer between the earth's surface and the geostrophic winds. The term boundary layer is used to describe the velocity profile of wind currents as they increase from zero to the geostrophic velocity.

The approach boundary layer profile is affected by specific surface topography upstream of the test site. Over relatively rough terrain (urban) the boundary layer is thicker and the wind speed increases rather slowly with height. The opposite is true over open terrain (rural). The following power law equation is used to represent the mean velocity profile for any given topographic condition:

$$\frac{U}{U_F} = \left(\frac{z}{z_F}\right)^a$$

where U = wind velocity (m/s) at height z (m)
a = power law exponent
and subscript $_F$ refers to freestream conditions

Typical values for a and z_F are summarized below:

Terrain	a	z_F (m)
Rural	0.14 - 0.17	260 - 300
Suburban	0.20 - 0.28	300 - 420
Urban	0.28 - 0.40	420 - 550

Wind data is recorded at meteorological stations at a height z_{ref}, usually equal to about 10m above grade. This historical mean wind velocity and frequency data is often presented in the form of a wind rose. The mean wind velocity at z_{ref}, along with the appropriate constants based on terrain type, are used to determine the value for U_F, completing the definition of the boundary layer profile specific to the site. The following Figure shows representations of the boundary layer profile for each of the above terrain conditions:

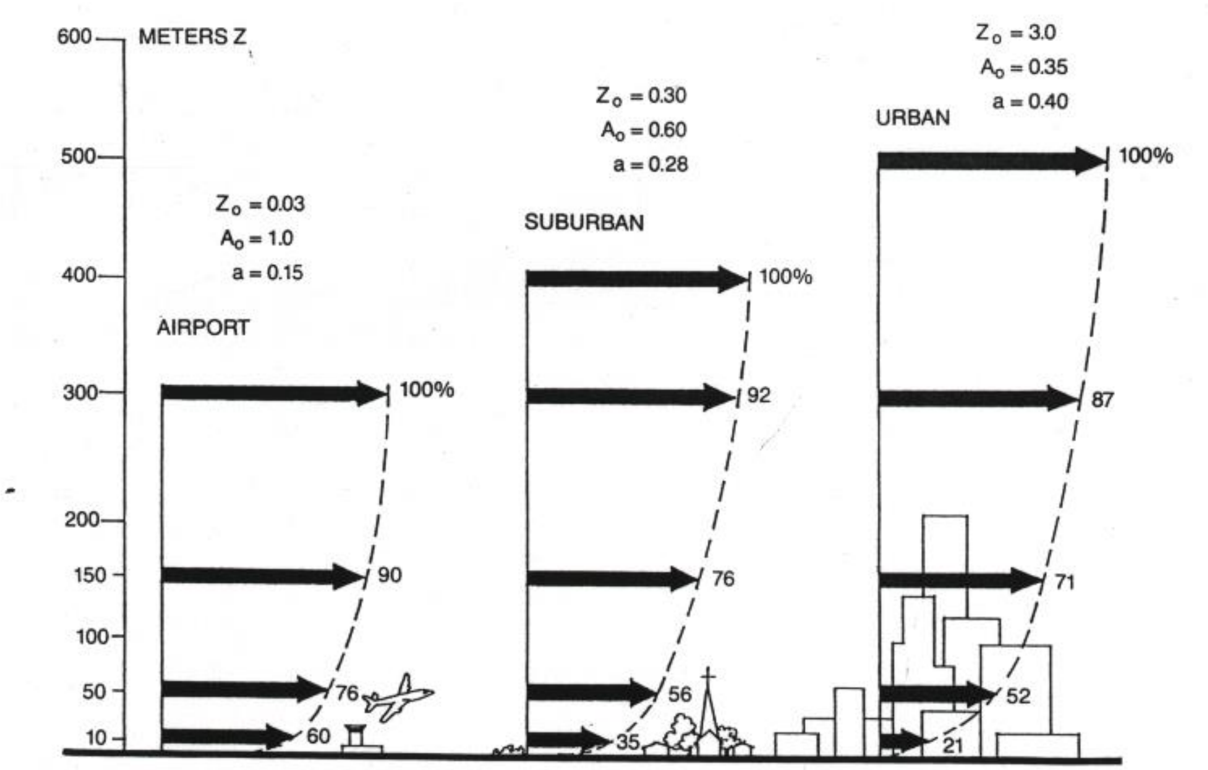

Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

For the above velocity profiles, ground level velocities at a height of $z = 2m$, for an urban macroclimate are approximately 52% of the mean values recorded at the meteorological station at a height equal to $z_{ref} = 10m$. For suburban and rural conditions, the values are 63% and 78% respectively. Thus, for a given wind speed at z_{ref} open terrain or fields (rural) will experience significantly higher ground level wind velocities than suburban or urban areas.

When a boundary layer wind flows over one terrain onto another, the boundary layer profile shape rapidly changes to that dictated by the new terrain. If the preceding wind flow is over rough suburban terrain and an open area is encountered a rapid increase in ground level winds will be realized. A similar effect will occur when large low-density residential areas are demolished to accommodate high-rise developments. The transitional open area will experience significantly higher pedestrian level winds than the previous suburban setting. Once the high-rise development is established, ground level winds will moderate with localized areas of higher pedestrian level winds likely to occur. Pedestrian level wind velocities respond to orientation and shape of the development and if the site is not appropriately engineered or mitigated, pedestrian level wind may be problematic.

<u>Microclimate</u>

The specific wind conditions related to the study site are known as the microclimate, which are dictated mainly by the following factors:

- The orientation and conformation of buildings within the vicinity of the site.
- The surrounding contours and pertinent landscape features.

The microclimate establishes the effect that surrounding buildings or landscape features have on the subject building and the effect the subject building has on the surrounds. For the majority of urban test sites the proper microclimate can be established by modelling an area of 300*m* in radius around the subject building. If extremely tall buildings are present then the study area must be larger, and if the building elevations are on the order of a few floors, smaller areas will suffice to establish the required microclimate.

General Wind Flow Phenomena

Wind flow across undulating terrain contains parallel streamlines with the lowest streamline adjacent to the surface. These conditions continue until the streamlines approach vertical objects. When this occurs there is a general movement of the streamlines upward ("Wind Velocity Gradient") and as they reach the top of the objects turbulence is generated on the lee side. This is one of the reasons for unexpected high wind velocities as this turbulent action moves to the base of the objects on the lee side.

Other fluid action occurs through narrow gaps between buildings (Venturi Action) and at sharp edges of a building or other vertical objects (Scour Action). These conditions are predictable at selected locations but do not conform to a set direction of wind as described by a macroclimate condition. In fact, the orientation and conformation of buildings, streets and landscaping establish a microclimate.

Because of the "Wind Velocity Gradient" phenomena, there is a "downwash" of wind at the face of buildings and this effect is felt at the pedestrian level. It may be experienced as high gusty winds or drifting snow. These effects can be obviated by windbreak devices on the windward side or by canopies over windows and doors on the lee side of the building.

The intersection of two streets or pedestrian walkways have funnelling effects of wind currents from any one of the four directions and is particularly severe at corners if the buildings project to the street line or are close to walkways.

Some high-rise buildings have gust effects as the wind velocities are generated suddenly due to the orientation and conformation of the site. Since wind velocities are the result of energy induced wind currents the solution to most problems is to reduce the wind energy at selected locations by carefully designed windbreak devices, often landscaping, to blend with the surrounds.

The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries in ships of the Royal Navy. The original scale was an association of integers from 0 to 12, with a description of the effect of wind on the behaviour of a full-rigged man-of-war. The lower Beaufort numbers described wind in terms of ship speed, mid-range numbers were related to her sail carrying ability and upper numbers were in terms of survival. The Beaufort Scale was adopted in 1874 by the International Meteorological Committee for international use in weather telegraphy and, with the advent of anemometers, the scale was eventually adopted for meteorological purposes. Eventually, a uniform set of equivalents that non-mariners could relate to was developed, and by 1955, wind velocities in knots had replaced Beaufort numbers on weather maps. While the Beaufort Scale lost ground to technology, there remains the need to relate wind speed to observable wind effects and the Beaufort Scale remains a useful tool.

Abbreviated Beaufort Scale

Beaufort Number	Description	Wind Speed			Observations
		km/h	*m/s*	h=2*m* for Urban *m/s*	
2	Slight Breeze	6-11	1.6-3.3	< ~2	Tree leaves rustle; flags wave slightly; vanes show wind direction; small wavelets or scale waves.
3	Gentle Breeze	12-19	3.4-5.4	< ~3	Leaves and twigs in constant motion; small flags extended; long unbreaking waves.
4	Moderate Breeze	20-28	5.5-7.9	< ~4	Small branches move; flags flap; waves with whitecaps.
5	Fresh Breeze	29-38	8.0-10.7	< ~6	Small trees sway; flags flap and ripple; moderate waves with many whitecaps.
6	Strong Breeze	39-49	10.8-13.8	< ~8	Large branches sway; umbrellas used with difficulty; flags beat and pop; larger waves with regular whitecaps.
7	Moderate Gale	50-61	13.9-17.1	< ~10	Sea heaps up, white foam streaks; whole trees sway; difficult to walk; large waves.
8	Fresh Gale	62-74	17.2-20.7	> ~10	Twigs break off trees; moderately high sea with blowing foam.
9	Strong Gale	75-88	20.8-24.4		Branches break off trees; tiles blown from roofs; high crested waves.

Wind speeds indicated above, in *km/h* and *m/s*, are at a reference height of 10 metres, as are the wind speeds indicated on the Figure 5 wind roses. The mean wind speeds at pedestrian level, for an urban climate, would be approximately 56% of these values. The 3rd column for wind speed is shown for reference, at a height of 2*m*, in an urban setting. The approximate Comfort Category Colours are shown above. The relationship between wind speed and height relative to terrain is discussed in the section above.

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