BEFORE INDEPENDENT HEARING COMMISSIONERS
IN CHRISTCHURCH

TE MAHERE Ā-ROHE I TŪTOHUA MŌ TE TĀONE O ŌTAUTAHI

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of the hearing of submissions on Plan Change 14 (Housing and Business Choice) to the Christchurch District Plan

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STATEMENT OF PRIMARY EVIDENCE OF MICHAEL (MIKE) PAUL GREEN ON BEHALF OF CHRISTCHURCH CITY COUNCIL

METEOROLOGY / WIND EFFECTS

Dated: 11 August 2023

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. My full name is **Michael (Mike) Paul Green**. I am employed as an Engineering Meteorologist at Meteorology Solutions Ltd.

2. I have prepared this statement of evidence on behalf of the Christchurch City Council (the **Council**) in respect of matters arising from the submissions and further submissions on Plan Change 14 to the Christchurch District Plan (the **District Plan**; **PC14**).

3. My expertise is in meteorology in an engineering/applied context, which include impacts of wind in urban environments.

4. The key points from my evidence are:

   (a) Wind can negatively affect outdoor pedestrian comfort and safety at street level (which is normally at 1.5 m above ground level), especially for a relatively windy city such as Christchurch.

   (b) Increasingly tall buildings can increase street level wind speeds and may adversely affect the comfort and safety of pedestrians and those sitting outside / using public spaces.

   (c) Wind impact assessments are required in many cities in the world; including Auckland, Wellington, and Dunedin in New Zealand.

   (d) Computational Fluid Dynamics (**CFD**), or a wind tunnel, can be used to assess spatial wind impacts at pedestrian level.

   (e) Wind standards and associated assessment criteria are well developed around the world and can be used determine wind speed changes at street level (1.5 m above ground) because of a new building, and whether those wind speeds may result in adverse effects on public and pedestrian amenity and safety.

   (f) If potential adverse wind effects are identified, wind assessments can test mitigation options to determine if those effects can be reduced or avoided.

   (g) In my opinion wind assessments for Christchurch City need to address both wind comfort and wind safety. I consider that:

   (h) the London LDDC standard (see **Table 1**) is used to assess comfort; and

(i) the NEN 8100 Danger standard is used to assess safety (see **Table 3** below).

5. The comfort standards should use:

(a) a 5% exceedance wind speed criteria (wind speed categories are not exceeded more than 5% of the time);

(b) the maximum of the mean and GEM (gust equivalent mean) wind speeds; and

(c) background wind data covering a 24-hour period.

INTRODUCTION

6. My name is **Michael (Mike) Paul Green**. I am an engineering meteorologist with 20+ years' experience in applied meteorology. I have applied meteorology, and climatology, across a range of engineering disciplines including renewable energy, expert witness work, urban design, customised weather forecasting for decision-making and risk mitigation, and climate change impacts.

7. As a meteorologist working in the engineering environment, I have been a wind expert in different contexts such as for wind energy applications, extreme wind gusts assessments, including in as in urban, remote, and mountain environments.

8. In preparing this evidence I have:

(a) Completed an assessment and report[1] *Technical Advice for Wind for Christchurch City* (**Report**) for Christchurch City Council (**CCC**) on assessing wind impacts with increasing building height;

(b) Reviewed relevant submissions relating to wind impacts and discussed these with David Hattam (Planner for CCC); and

(c) Read through relevant documentation relating to PC14 and wind impacts such as in 'Briefing letter to Council witnesses(63844002.8.pdf)' as received from CCC/Buddle Findlay.

9. I am authorised to provide this evidence on behalf of the Council.

[1] Technical Advice for Wind for Christchurch City

QUALIFICATIONS AND EXPERIENCE

10. I hold the qualifications of Master of Science (with distinction), and Class 1 Meteorologist qualification. I have 20+ years' experience in applied meteorology.

11. My experience as an engineering meteorologist includes:

    (a) Urban wind impact assessments involving CFD in Christchurch, including for Metro Sports, Convention Centre, Christchurch Hospital Acute Service building, Bus Interchange, Fletcher Living urban residential project (Manchester St. area), and various new school developments.

    (b) Urban wind impact assessments for other locations in New Zealand including for the New Dunedin Hospital, and for outdoor urban areas in Australia and Middle East.

    (c) CFD modelling for thermal plume modelling for natural ventilation systems for a new data centre in the North Island.

    (d) Extreme wind gust assessments for telecommunication tower structures in New in Zealand and Australia.

    (e) Wind farm energy potential and extreme wind risk.

    (f) Assessing risk of roll-over of vehicles from extreme wind gusts for the KiwiRail network.

    (g) Wind mitigation work for Mt Hutt for the Northwest chair lift off load area (using CFD).

    (h) Expert witness and forensic meteorology work such as for wildfires, car accidents, and damage to property.

    (i) Extreme weather/wind forecasting for many contexts such as for KiwiRail operations, CCC, and large infrastructure projects around New Zealand.

12. I have been a member of the New Zealand Meteorological Society for 20+ years.

CODE OF CONDUCT

13. While this is a Council hearing, I have read the Code of Conduct for Expert Witnesses (contained in the 2023 Practice Note) and agree to comply with it. Except where I state I rely on the evidence of another person, I confirm that the issues addressed in this statement of evidence are within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

SCOPE OF EVIDENCE

14. My statement of evidence addresses the following matters:

    (a) Why wind impacts are important to consider in urban environments;

    (b) The impacts of different wind speeds in urban environments;

    (c) The effects of taller buildings on the wind environment in Christchurch;

    (d) Wind impact assessment requirements used for other cities;

    (e) Wind assessment methodology, input and output requirements, and cost;

    (f) Wind impact standards and associated assessment criteria;

    (g) Wind mitigation.

15. I address each of these points in my evidence below.

WHY ARE WIND IMPACTS IMPORTANT TO CONSIDER IN URBAN ENVIRONMENTS

16. Comfort and safety in relation to urban wind conditions are becoming increasingly important as pressure on land forces new developments to be built higher and larger. Higher and larger buildings can increase wind speeds near ground level, and negatively affect the surrounding pedestrian amenity. Knowing how new buildings affect the wind environment provides key information for planners and developers so to assess the effects in key areas[2]. If there are negative wind effects from a new building that require

[2] https://www.simscale.com/blog/pedestrian-wind-comfort-assessment/

mitigation, then the wind assessment can investigate if and how that can occur.

17. In urban environments wind speeds vary a lot over short distances. While light wind locations are caused by sheltering from buildings and vegetation, the interaction of wind and buildings creates wind tunnels and downwash off building facades that can manifest to create strong winds. Such conditions can potentially adversely affect both the comfort and safety of people. This is especially so as wind characteristics in urban areas are gusty in nature due to the interaction of buildings and background winds.

18. Levels of tolerance to wind in urban environments is usually linked to how people use different locations. For example, areas that people move through (and don't linger), such as streets and open footpaths can tolerate higher wind speeds more often, while outdoor alleyways/café areas, and urban parks and gathering areas etc., tolerate less wind. While there are general wind speed pedestrian safety levels, more sensitive environments, such as around hospitals, where there is more likely to be 'vulnerable' people, can require additional safety protection from the potential of strong wind gusts.

THE EFFECT OF TALLER BUILDINGS ON THE WIND ENVIRONMENT IN CHRISTCHURCH

19. Introducing taller buildings in Christchurch city could potentially negatively affect outdoor comfort and safety levels of the surrounding pedestrian amenity.

20. Long term wind data in the Christchurch area indicates a relatively windy climate. Based on 10 years of hourly wind data from Christchurch Airport, the mean wind speed exceeds 6 m/s (22 km/h) about 21% of the time, and 8 m/s (29 km/h) about 11% of the time. These wind speed categories are often used in wind comfort standards and so provide some context of the background wind climate. Due to the 'roughness' of the city environment, mean wind speeds in urban Christchurch are generally lower compared to areas surrounding the city. However, more taller buildings create the potential for the current position to deteriorate, resulting in (without considering wind mitigation) the potential deterioration of outdoor comfort in, and safety of, pedestrian and public spaces.

21. Wind modelling done for my Report indicates that wind effects near ground level increase for building heights above around 30 m. This is caused by taller buildings intercepting and deflecting stronger winds towards street level, while buildings with larger footprints can create wind tunnel effects at street level.

22. The effect of taller buildings on wind speeds at pedestrian level is complex and will vary depending on surrounding buildings and on the orientation of the new building, and surrounding buildings. For Christchurch urban residential areas, wind modelling results in my Report indicated an increase in wind speeds near ground level when building heights increase from 6-storeys (or around 18 m height) to 10-storey buildings (or around 30 m height). Increased wind impacts for lower building heights in urban residential areas, compared to the CBD area, is due to less sheltering from background winds from surrounding buildings. Considering the above, in my opinion wind assessment be completed for new buildings above 30 m for the CBD area, and above 20 m for residential urban developments.

23. The complex nature of city environments mean that the effects of tall buildings can potentially reduce wind effects in some areas and increase them in others. CFD modelling is an objective and proven way to assess how a new building changes the wind environment by comparing with results with the pre-building wind scenario.

WIND IMPACT ASSESSMENT REQUIREMENTS FOR OTHER CITIES

24. Cities with windy climates often have regulations or guidelines that require wind impact assessments for new tall buildings with the aim to identify and mitigate deterioration of wind comfort levels.

25. Specific wind speed standards and associated assessment criteria for wind impact assessments vary from city to city, including around using mean wind speed and/or gust speed criteria, and around the proportion of time wind speeds can be exceeded. Cities requiring wind impact assessments would usually have a building height threshold for when it is required, such as a new building exceeding a certain number of stories, or reaching a certain height[3]. Other factors that can influence the requirement for a wind impact assessment can include the proximity to certain locations, or to other buildings/structures such as hospitals or key landmarks.

[3] London City wind guidelines

26. For New Zealand, Auckland and Wellington require wind impact assessments for tall new buildings. The Auckland height threshold is 25 m and Wellington is 18.6 m. The different heights for Auckland and Wellington, likely reflect the different wind climates of these cities.

27. For Wellington central city area for a new building, the wind speed criteria for safety is maximum wind speed not exceeding 20 m/s (gust speed), while for comfort it is based it is around a cumulative effect such as mean wind speeds above 2.5 m/s and 3.5 m/s not increasing more than 2% of the time. It should also be noted that for Wellington, the guide is not statutory but provides a way for demonstrating compliance.

28. Auckland City has more defined wind speed and time exceedance guides which are similar to a Davenport Standard[4] which is based on time of wind speed exceedance for different types of pedestrian areas, while for safety it is around annual peak gust speed not exceeding 25 m/s.

29. Dunedin requires wind impact assessments in the city area for new buildings above 20 m high. Dunedin assessment criteria is more general such as "limited to minimising as far as practicable adverse effects of wind".

WIND IMPACT ASSESSMENT METHODS, REQUIREMENTS, AND COST

30. Wind in city environments is complex and requires technical expertise to utilise and interpret results from sophisticated tools used such as Computational Fluid Dynamics models (CFD) and wind tunnels. CFD models are used in other applications such as for wind loading for building design, automotive and aerospace contexts, for energy generation, and for testing ventilation/cooling systems such as for data centres etc.

31. Depending on the height and extent of the new building, and on the complexity of the surroundings, the cost of a wind impact assessment would likely be in the $5,000 to $15,000 range.

32. In general, a wind impact assessment requires the following:

    (a) Analysis of representative long term background wind data (such as from Christchurch Airport). When using the wind data in the assessment, at least 8 direction sectors need to be considered.

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[4] Information on the Davenport wind standard

(b) A CFD or wind tunnel to assess:

(i) The current wind conditions at pedestrian level prior to a new building being established. The extent of the wind assessment should extend the maximum of either 100 m from the edge of the new building site, or to the end of the next main city block, and the 3D model should extend one block further out than the assessment area.

(ii) The potential wind conditions with the new building established. From these two sets of results, it can be shown if and where current wind conditions deteriorate (and/or improve), and if speed/frequency exceed the relevant wind standards. (There is more information on wind standards, effects, and assessment criteria below.)

(c) Using the wind standards (see below), identify locations where wind conditions have deteriorated (or improved), especially for pedestrian areas and public spaces, the predicted wind speeds, and the potential effects (adverse and positive).

(d) If existing wind conditions deteriorate and exceed the criteria given by the standards, then mitigation options (see below) can be tested to demonstrate how wind effects can be reduced.

WIND IMPACT ASSESSMENT STANDARDS AND ASSESSMENT CRITERIA

33. Wind discomfort and safety is somewhat subjective, in that people are impacted and tolerate wind individually, which is due to varying height, weight, age, health, and past experience in dealing with wind etc. Considering this wind standards, and associated wind speed and frequency criteria, have been developed considering a range of activities such as sitting for a long time, sitting for a short time, standing, and walking etc.

34. Wind speed is measured and assessed in two ways; using mean speed and/or gust speed. Mean wind speed is the average speed over a period of time which is usually ten minutes. Wind gust speed accounts for short-term fluctuations usually over a 3-second period. Urban wind comfort and safety can also be assessed using either mean wind speed or gust wind speed, or both.

35. Using mean wind speed on its own might not represent the effects of wind gusts, especially in urban areas where buildings create a turbulent environment. The gust equivalent mean wind speed (GEM) is a way to represent wind speed which is based on the gustiness of the wind, which is an important factor for comfort and safety. Since GEM is not necessarily higher than the mean wind speed, in my opinion using the maximum of both mean wind speed and GEM is the best way to assess the potential effects of urban wind speed on peoples' comfort and safety. The mathematics to derive GEM from CFD modelling is complex[5], but in summary, GEM equals the predicted maximum 3 second gust speed divided by 1.85.

Wind comfort levels

36. There is no one standard to assess wind comfort, but the Lawson wind comfort scale, and adaptions of it, are the most common standards for assessing comfort levels of urban wind. The Davenport standard is also well-known and is similar to the wind standard criteria used for Auckland[6]. London uses a variation of the Lawson criteria called the Lawson LLDC (London Docklands Development Corporation) criteria, and a more recent assessment criteria is the NEN 8100 Dutch wind nuisance standard[7]. These standards relate appropriate wind speeds to people activities as given in **Tables 1 and 2** and **Figure 1**. Exceedance levels (proportion of time wind speeds are reached/exceeded is usually at 2% or 5% for comfort level assessment, and lower occurrence percentages for safely levels.

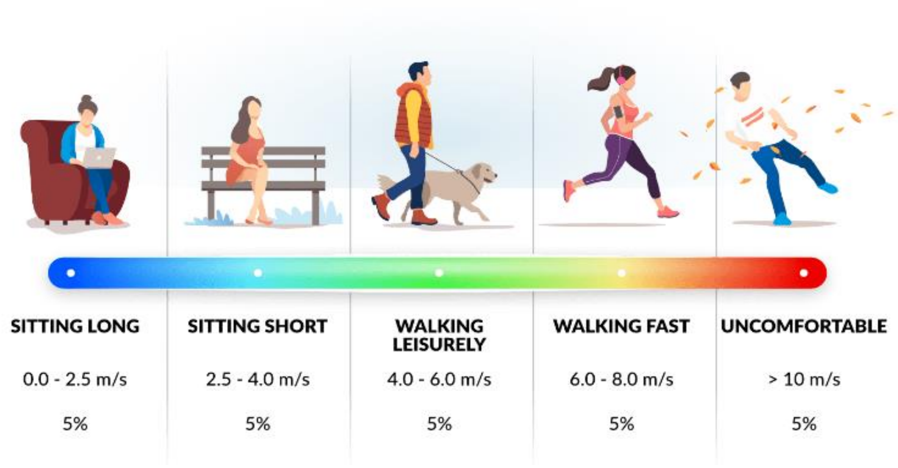

Figure 1: Lawson wind comfort standard relating wind speed criteria and time exceedance level with appropriate pedestrian activity

[5] Gust Equivalent Mean wind speed derivation note
[6] https://www.simscale.com/blog/wind-comfort-criteria/
[7] London City wind guidelines

37. In the technical **Report** completed for Christchurch, two assessment standards were considered; the London LDDC index (**Table 1**) and Lawson LDDC index (**Table 2**). Note that the London LDDC criteria are based on a version of Lawson wind comfort classification. Both of these standards utilise the maximum of the mean and GEM wind speeds with exceedance levels of 5% and use background wind data for all 24 hours in the day. In my opinion using background wind data for all 24 hours of the day and the 5% exceedance levels balances less rigorous criteria while maintaining good comfort and safety levels.

Table 1: London LDDC criteria to show spatial wind impacts

	Category	Maximum of mean and GEM wind speed (5% exceedance)	Possible adapted description for Christchurch
A	Frequent Sitting	2.5 m/s	Acceptable for frequent outdoor sitting use such as outdoor restaurants and cafés.
B	Occasional Sitting	4 m/s	Acceptable for occasional outdoor seating, such as general public outdoor spaces, balconies and terraces intended for occasional use.
C	Standing	6 m/s	Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.
D	Walking	8 m/s	Acceptable for external pavements and open walkways.
E	Uncomfortable	Greater than 8 m/s	Not comfortable for regular pedestrian access.
F	Pedestrian Safety Limit	15 m/s (0.022% exceedance)	Presents a safety risk for pedestrians, especially to the more vulnerable members of the public.

Table 2: Lawson LDDC criteria to show spatial wind impacts

		Category	Maximum of mean and GEM wind speed (5% exceedance)	Possible adapted description for Christchurch
	A	Outdoor dining	2 m/s	Acceptable for frequent outdoor sitting use such as outdoor restaurants and cafés.
	B	Pedestrian Sitting	4 m/s	Acceptable for occasional outdoor seating, such as general public outdoor spaces, balconies and terraces intended for occasional use.
	C	Pedestrian Standing	6 m/s	Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.
	D	Pedestrian Walking	8 m/s	Acceptable for external pavements and open walkways.
	E	Business walking	10 m/s (less than 5%)	Not comfortable for regular pedestrian access.
	U	Uncomfortable	10 m/s (more than 5%)	Not comfortable for regular pedestrian access (and potentially dangerous for some people)

38. In my opinion the London LDDC standard (which is a version of the Lawson standard) is the best standard to adopt for Christchurch because, based my assessment of wind impacts in Christchurch City, it provides a good balance between ensuring favourable wind conditions and ensuring that wind effects in key areas can be mitigated.

39. In my opinion the 2% exceedance level criteria (as used in some versions of Lawson standards) is less forgiving and could make achieving suitable wind levels challenging for higher new buildings, especially for a relatively windy city such as Christchurch. In my opinion the 5% of the time exceedance level will deliver an appropriate/better wind effects outcome and provides greater flexibility to developers compared to 2% of the time exceedance levels.

Safety

40. As for comfort there is also a variety of standards which address potential safety effects. Wind speeds above 15 m/s have been assessed as a threat to property and life, esp. in an urban environment.[8]

41. London LDDC Pedestrian Safety Limit uses a wind speed of 15m/s (see **Table 1**) and has a more conservative criteria compared to NEN 8100, which I consider less appropriate for Christchurch. The NEN 8100 Dutch

[8] https://www.weather.gov/mlb/seasonal_wind_threat

wind nuisance standard also advises on dangerous wind speeds based on the occurrence of wind gusts above 15 m/s (54 km/h or 34 mph) as shown in **Table 3**.

Table 3: NEN 8100 standard adapted to identify 'dangerous' locations

		Wind speed	Frequency	Description
(blue)	A	15 m/s	Less than 0.05%	No Risk
(yellow)	B	15 m/s	Less than 0.3%	Limited Risk
(red)	C	15 m/s	Greater than or equal to 0.3%	Dangerous

42. In my opinion based my assessment of wind impacts in Christchurch City the NEN 8100 Dutch wind nuisance standard, with Category C requirements for the general use and Category B for environments where there are more 'vulnerable' people, such as in the vicinity of the hospital, is more appropriate for use for identifying wind safety effects in Christchurch because it balances a good level of assurance for safety and ensuring a realistic level enabling potential adverse effects to be appropriately mitigated.

WIND MITIGATION

43. If a wind impact assessment identifies wind speed and frequency at street level (normally 1.5 m above ground level) that exceed the relevant standards, then there are many practical mitigation options available to developers to reduce wind effects. As above such assessments, and the development of mitigation as required, are commonplace in other New Zealand cities.

44. Examples of mitigation measures to reduce wind impacts include:

(a) Use of vegetation and other porous/mesh barriers strategically aligned to reduce wind speeds at street level.

(b) Use of vegetation next to or under building overhangs.

(c) Avoiding larger towers/slab structures facing into stronger wind regimes, such as for northeast, southwest and northwest winds in Christchurch.

(d) Use of wind canopies at street level for larger towers/slab structures, especially those facing into stronger wind regimes.

(e) Balconies and other ‘rough’ features on the building facades will reduce downwash, especially buildings facing into stronger wind regimes.

(f) Use of wind lobbies and revolving doors for laneways exposed to the stronger wind regimes.

CONCLUSION

45. Wind in Christchurch has the potential to adversely affect the comfort and safety of pedestrians and those sitting outside / using public spaces. The introduction of taller buildings will change wind speeds at street level, increasing them in some areas, potentially to a level that may result in adverse comfort and safety effects. This is why wind impact assessments (using wind tunnels or CFD models) are required for new tall buildings in cities around in the word, including Auckland, Wellington, and Dunedin in New Zealand.

46. To help determine if new taller buildings may create negative wind effects on the surrounding public and pedestrian amenity and safety, I have recommended wind standards (and associated assessment criteria), for Christchurch City. If a new building may create wind effects that exceed the standards a wind impact assessment can test mitigation options to reduce wind speeds to appropriate levels, especially in key pedestrian and public spaces.

Date: 11 August 2023

Mike Green, Meteorology Solutions Ltd.