STUDY REPORT

SR 300 (2013)

An Analysis of Wind-Driven Rain in New Zealand

GE Overton

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Preface

This report contains data generated for use in BRANZ's Weathertightness, Air Quality and Ventilation Engineering (WAVE) Programme. Although the data in this report does not target an industry need in itself, it is felt that it is of sufficient interest to the industry and the wider public to warrant publication.

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Abstract

This paper presents an analysis of wind-driven rain across 34 sites in New Zealand and the results are compared with selected data from other countries. The results are also compared to the test parameters in E2/VM1 (DBH 2011), the current verification method for demonstrating weathertightness of residential cladding systems in New Zealand.

Urban areas in New Zealand were found to experience high levels of wind-driven rain compared with other countries, although it is not always straightforward to make direct comparisons with other data.

The pressures from E2/VM1 exceed the five-year wind-driven rain rates and wind pressures for the vast majority of locations in New Zealand. If it was desired to base a water penetration tests on the interaction of wind and rain in New Zealand, the test pressures could be lower than what is currently in E2/VM1. However, it is not recommended to alter E2/VM1 in light of this study. This is because of the arbitrary nature of any choice about suitable return periods for water penetration and the fact that E2/VM1 has proven itself to be a successful procedure over the years.

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1. INTRODUCTION

Wind driven rain (WDR) is the term used to describe how much rain hits a vertical surface, for example, the wall of a building. Without the presence of wind, raindrops would fall vertically and a roof with eaves would be all that was needed to protect windows and other sensitive building elements in the wall from getting wet. The wind however, causes raindrops to deviate from a vertical trajectory so they can strike a wall, typically forming a film of water on the surface.

The presence of water on the surface of a wall is one of the three things needed for a leak to occur; the other two being a pathway for the water to follow and a force to drive the water along the pathway. As well as causing the raindrops to strike the wall, the wind pressure is related to the pressure difference across a cladding, one of the forces that can drive water into the wall. In most cases however, the pressure difference across the cladding will be substantially less than the wind pressure acting on the surface.

Quantifying the amount of water that strikes a wall cladding and the accompanying wind pressure is a key step in deriving a true performance basis for weathertight design. Other steps include calculating how much of this water penetrates the cladding and investigating what subsequently happens to that water. Previous work at BRANZ (Bassett et al, 2009) has established the potential for ventilation drying in walls and investigated leakage characteristics for claddings, while current work involves measuring the leakage through various joints.

It is therefore useful to look at the amount of WDR that actually occurs in New Zealand. This paper presents an analysis of WDR across 34 sites and the results are compared with selected data from other countries. The results are also compared to the test parameters in E2/VM1 (DBH 2011), the current verification method for demonstrating weathertightness of residential cladding systems in New Zealand.

2. CALCULATION METHOD

WDR is not typically measured at weather stations. Instead, semi-empirical relationships are used to relate the measurements available to the amount of WDR. The measurements available are typically the total rainfall per hour (mm), the hourly average wind speed (m/s) and the maximum three-second gust speed (m/s). For a detailed review of the measurement of WDR and various semi-empirical methods, the reader is referred to the extensive review performed by Blocken and Carmeliat (2010).

The calculation method used in this study was that described by Sahal and Lacasse (2008). Sahal and Lacasse essentially reviewed various methods for quantifying driving rain and then combined a number of these methods to form a step-by-step procedure for calculating test parameters (spray rates and pressures) that would represent the WDR for a given geographic location.

The calculation steps can be grouped into the following stages:

- gathering the climate data – this preliminary step includes correcting for averaging time and local terrain effects
- estimating the intensity of wind-driven rain – using empirical methods to calculate the rate at which rainfall hits a wall
- an analysis of extremes – using the peak WDR and wind events each year to assess the probability of exceeding a certain WDR rate or wind pressure

2.1 Gathering the Climate Data

The source weather data used in this analysis came from the NIWA National Climate Database. Hourly rainfall, average wind speed and maximum gust data were obtained for 34 locations across the country covering a 15-year period (1997-2011). These locations were chosen primarily for the completeness of the data available, i.e. rainfall, average wind speed and gust data were available for at least 95% of the hours in the 15-year period.

2.1.1 Selecting a Suitable Averaging Time

Wind and rain data is typically available in hourly form, i.e. the total rainfall for each hour and the average wind speed over each hour. When considering driving rain, an hour may not be the most suitable time period to consider. Mayo (1998) proposed that the maximum rainwater runoff from a wall is associated with an averaging time of five minutes and this averaging time was used in this study.

2.1.2 Five-Minute Rainfall Rate

The five-minute rainfall rate can be estimated from the hourly rainfall rate as follows (Choi, 1998):

$$r_{h(300)} = r_{h(3600)} \times \left(\frac{3600}{300}\right)^{0.42} \qquad (1)$$

Where r_h is the rainfall rate (mm/min).

The hourly rainfall data available from the weather stations was simply divided by 60 to give $r_{h(3600)}$, the hourly rainfall rate (mm/min).

2.1.3 Five-Minute Wind Speed

The calculation of a five-minute wind speed is more complicated than the corresponding rainfall calculation. One complication is the fact that the anemometers at the various weather stations are not necessarily at the same height nor do they have the same surrounding terrain as each other. Therefore wind speed modifiers for both height and terrain were used to normalise the data.

The connection between the meteorological wind velocities and the normalised wind velocities is given by (2):

$$\frac{V_{norm}}{V_{met}} = \frac{T_{norm}\alpha_{norm}\left(z_{norm}/10\right)^{\gamma_{norm}}}{T_{met}\alpha_{met}\left(z_{met}/10\right)^{\gamma_{met}}} \qquad (2)$$

Where V is the wind velocity, z the anemometer mast height, T is a topographical factor that accounts for wind acceleration over topographical features (see Table 1), α is a surface roughness factor (see Table 2, drawn from Grimnrud et all [1981]) and γ scales the height variation of wind velocity according to surface roughness (also see Table 2).

Table 2-1 Topography Factor (from NZS 4203 – Now Superseded)

Topography	T_1
Valleys and gorges shaped to produce funnelling of the wind; exposed hillsides, peaks and ridges where acceleration of the wind is known to occur; especially abnormal sites	1.2 to 1.3
All other	1.0

Table 2-2 Coefficients of the Ground Roughness Function

Ground Roughness Category	Terrain Description	γ	α
1	Ocean or other body of water with at least five kilometres of unrestricted expanse	0.10	1.3
2	Flat terrain with some isolated obstacles, e.g. buildings or trees well separated from each other	0.15	1
3	Rural areas with low buildings, trees, etc.	0.20	0.85
4	Urban, industrial or forest areas	0.25	0.67
5	Centre of large city	0.35	0.47

The various factors in Table 2-1 and Table 2-2 were assessed for each weather station during earlier work at BRANZ. The old loadings code, NZS 4203 – *General Structural Design and Design Loadings for Buildings* (New Zealand Standards 1992) has now been superseded by NZS 1170 – *General Structural Design and Design Loadings for Buildings* (New Zealand Standards 2002) but it is considered the calculation would be largely unaffected and so the wind speed modifiers from this earlier work were used in this study.

The wind speed data from each station was normalised to a height of 10 m, a topographical factor of 1.0 and a ground roughness category of 1. Once the normalised wind speeds had been derived, the short-duration (five-minute) wind speed $V_{(300)}$ was calculated using the following equation (Choi, 1998):

$$V_{(300)} = \left(V_{(3)} - V_{(3600)}\right) \times \left(\frac{\ln(300/3600)}{\ln(3/3600)}\right) + V_{(3600)} \qquad (3)$$

Where $v_{(3600)}$ is the hourly wind speed and $v_{(3)}$ is the three-second gust speed in m/s.

2.2 Estimating Driving Rain Intensity on a Wall

The five-minute wind speed and rainfall rate were then used to calculate the WDR rate (mm/min) using equations given by Straube and Burnett (2000):

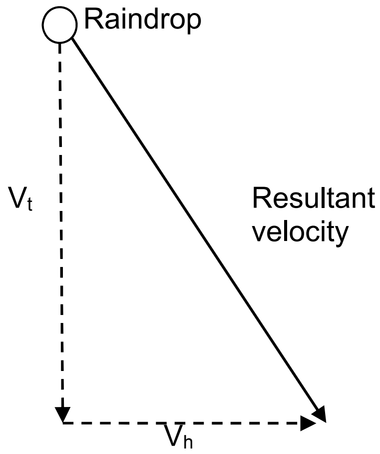
$$WDR = RAF \times DRF \times cos\theta \times V_h \times r_h \qquad (4)$$

Where RAF is a rain admittance factor (proposed by Straube to be 0.9), DRF(r_h) is the driving rain factor, r_h is the rainfall rate (mm/min), θ is the direction of the wind (relative to the wall, chosen here to be 90°, i.e. normal) and V_h (m/s) is the wind speed at the height of interest (left at 10 m standard wind probe height).

The driving rain factor is the proportionality constant that relates rain falling on a horizontal plane to that falling on a vertical plane:

$$WDR = DRF(r_h) \times V_h \times r_h \qquad (5)$$

The driving rain factor is a function of the rainfall rate. If we assume the raindrops are at their terminal velocity (V_t) in the vertical direction (normally reached after falling approximately 12 m [Wang 1977]) and are small enough that they have a horizontal velocity equal to that of the wind, we have the following situation:



$$\frac{r_h}{WDR} = \frac{V_t}{V_h}$$

$$WDR = r_h \times \frac{V_h}{V_t}$$

Figure 1 Resultant Velocity Vector for a Raindrop

From Figure 1, we can see that the DRF is simply the inverse of the terminal velocity of the raindrops:

$$DRF = \frac{1}{V_t} \qquad (6)$$

The terminal velocity of the raindrops is a function of the raindrop diameter, which is in turn a function of the rainfall rate.

There are several options for calculating raindrop diameter. The one used in this study was the formula for predominant drop size, D_{pred} (Cornick et al, 2002):

$$D_{pred} = a \times \left(\frac{n-1}{n}\right)^{1/n} \qquad (7)$$

Where a = 1.30 x r_h^p, p = 0.232, n = 2.25.

Then, the terminal velocity can be calculated as follows (Dingle and Lee, 1972):

$$V_t = -0.16603 + 4.91884D - 0.888016D^2 + 0.054888D^3 \qquad (8)$$

In summary, for a particular rainfall rate the predominant drop size can be estimated, then the corresponding terminal velocity is calculated and finally the inverse of this is taken as the driving rain factor, DRF.

The DRF is then multiplied by the normalised wind speed and the rainfall rate to get the *free stream* wind-driven rain. Finally we use a rain admittance factor (0.9 in this study) to account for the presence of the building and calculate the rate at which rain hits a vertical wall.

2.3 Analysis of Extreme Values

To calculate the chances of exceeding a given WDR rate and wind speed in any given year, an analysis of extremes was used. The method employed in this study was that of Gumbel (1954) and is summarised below (Holmes, 2001):

- the largest value (WDR or wind speed) in each calendar year was extracted
- the values were ranked from smallest to largest: 1, 2, ... m ... to N
- each value was assigned a probability (p) of exceedance, where –

$$p = \frac{m}{N+1} \qquad (8)$$

- a reduced variate (y) was formed from –

$$y = -\ln(-\ln(p)) \qquad (9)$$

- the values (WDR or wind speed) were then plotted against y and a linear regression was used to draw a line of best fit, having an intercept, c, and a gradient, m
- the value for a given return period X_R (where X is the WDR or the wind speed) was then calculated as –

$$X_R = c + m\left\{-log_e\left[-log_e\left(1 - \frac{1}{R}\right)\right]\right\} \qquad (10)$$

Where R is the return period in years.

It should be noted that a 50-year return period, for example, has a probability of exceedance of 0.02 (1/50) in any one year. It should not be interpreted as recurring regularly every 50 years.

When considering the wind speed, the coincidence of wind and rain was accounted for by analysing only those wind speeds when the WDR rate was above a certain threshold. Choi (1998) chose to use 5 mm/hr of driving rain as a threshold and this was the practice followed here.

Wind speeds and WDR rates were calculated for return periods of five, ten, 25 and 50 years.

The resultant wind speeds were then converted to a pressure using the relationship:

$$P = \frac{1}{2}\rho V^2 \qquad (11)$$

Where P is the pressure (Pa), V is the wind speed (m/s) and ρ is the density of the air, taken to be 1.2 kg/m^3.

3. RESULTS

Table 3-1 shows the results from the analysis for 34 locations (sorted alphabetically), using the five-minute wind and rain data.

Table 3-1 Normalised Driving Rain in New Zealand Based on Five-Minute Rain and Wind Data

Five-Minute Data	Driving Rain Level (mm/min)				Wind Pressure (Pa) (≥5 mm/hr Driving Rain)			
	Return Period (Years)				Return Period (Years)			
Location	5	10	25	50	5	10	25	50
Auckland	2.84	3.37	4.03	4.52	284	313	352	383
Blenheim	1.77	2.24	2.84	3.28	267	310	368	415
Castlepoint	3.95	4.87	6.03	6.89	373	429	506	568
Christchurch	1.45	1.68	1.97	2.18	208	240	282	317
Dunedin	1.36	1.58	1.86	2.07	255	300	361	410
Gisborne	2.25	2.54	2.91	3.18	229	275	340	392
Gore	2.02	2.46	3.02	3.44	307	364	444	508
Hamilton	3.19	3.79	4.55	5.12	233	267	313	349
Hicks Bay	3.61	4.25	5.07	5.67	310	351	405	448
Hokitika	3.53	4.11	4.84	5.38	258	291	336	371
Invercargill	1.77	1.90	2.07	2.19	423	487	575	645
Kaikoura	2.18	2.57	3.07	3.44	390	436	498	546
Mahia	3.33	4.17	5.23	6.01	343	424	538	631
Manapouri	1.03	1.14	1.27	1.37	173	201	240	271
Napier	2.09	2.42	2.84	3.15	220	261	317	363
Nelson	2.81	3.36	4.06	4.58	255	287	331	366
New Plymouth	3.37	3.91	4.58	5.09	304	336	377	410
Paeroa	3.13	3.78	4.61	5.22	256	292	340	378
Palmerston North	2.08	2.49	3.00	3.38	204	220	241	257
Paraparaumu	2.43	2.87	3.42	3.83	253	277	309	333
Puysegur Point	4.90	5.55	6.38	6.99	518	563	623	669
Queenstown	1.61	1.89	2.25	2.51	219	248	286	317
Rotorua	3.03	3.48	4.06	4.49	231	256	290	316
Secretary Island	4.05	4.53	5.14	5.59	369	422	494	551
South West Cape	2.50	2.79	3.15	3.43	640	692	761	813
Tara Hills	2.37	3.26	4.38	5.22	164	201	253	296
Taupo	1.77	2.11	2.53	2.85	170	194	225	250
Tauranga	4.15	5.05	6.19	7.03	278	310	353	386
Timaru	1.64	1.99	2.43	2.76	165	190	226	254
Wanaka	0.83	0.94	1.07	1.16	121	135	154	168
Wellington	2.75	3.21	3.78	4.21	377	466	591	693
Westport	3.19	3.56	4.04	4.39	406	463	541	602
Whakatane	4.92	6.11	7.63	8.75	344	383	434	475
Whangarei	4.71	5.81	7.21	8.25	338	394	472	533

Table 3-2 shows the results from using hourly weather data as opposed to five-minute data. Also included in this table is the Driven Rain Index, which is simply the product of the mean annual wind speed (m/s) and the mean annual rainfall (m/yr) (Lacy, 1965).

Table 3-2 Normalised Driving Rain in New Zealand Based on 60-Minute Rain and Wind Data

Hourly Data	Driving Rain Level (mm/min)				Wind Pressure (Pa) (≥5 mm/hr Driving Rain)				Driven Rain Index (m^2/s.yr)
	Return Period (Years)				Return Period (Years)				
Location	5	10	25	50	5	10	25	50	
Auckland	1.04	1.24	1.50	1.69	208	235	272	301	5.0
Blenheim	0.61	0.77	0.98	1.14	190	236	301	355	2.6
Castlepoint	1.50	1.85	2.29	2.62	311	367	445	508	8.4
Christchurch	0.52	0.60	0.70	0.77	141	164	195	220	2.3
Dunedin	0.44	0.51	0.60	0.66	144	167	199	225	2.1
Gisborne	0.75	0.85	0.98	1.07	149	189	245	292	3.1
Gore	0.66	0.79	0.96	1.08	218	270	344	404	3.3
Hamilton	0.98	1.16	1.38	1.54	155	182	219	249	3.5
Hicks Bay	1.32	1.56	1.85	2.07	252	288	338	377	9.3
Hokitika	1.23	1.41	1.65	1.83	183	209	244	271	8.2
Invercargill	0.64	0.68	0.74	0.78	299	351	422	479	5.3
Kaikoura	0.81	0.95	1.14	1.27	277	305	343	372	3.1
Mahia	1.17	1.48	1.86	2.14	243	306	396	471	5.1
Manapouri	0.36	0.40	0.46	0.49	116	137	167	191	2.9
Napier	0.73	0.85	1.01	1.12	153	184	227	263	3.2
Nelson	0.89	1.02	1.18	1.30	188	210	239	262	2.9
New Plymouth	1.25	1.47	1.75	1.95	219	244	277	303	7.2
Paeroa	1.05	1.29	1.59	1.81	172	201	242	275	2.9
Palmerston North	0.72	0.87	1.06	1.20	135	150	172	188	3.8
Paraparaumu	0.87	1.03	1.24	1.40	151	169	192	211	4.0
Puysegur Point	1.78	2.01	2.31	2.53	500	591	717	818	20.0
Queenstown	0.60	0.71	0.85	0.96	153	177	209	235	2.3
Rotorua	1.07	1.24	1.44	1.60	167	186	212	232	4.9
Secretary Island	1.26	1.38	1.52	1.64	322	422	567	689	17.1
South West Cape	0.91	1.03	1.18	1.29	507	556	620	670	13.6
Tara Hills	1.08	1.52	2.07	2.49	85	106	135	159	1.3
Taupo	0.58	0.71	0.86	0.98	109	126	148	166	3.4
Tauranga	1.32	1.57	1.90	2.14	179	207	246	276	4.8
Timaru	0.54	0.66	0.80	0.91	102	118	140	157	1.4
Wanaka	0.30	0.34	0.39	0.43	72	81	95	105	1.9
Wellington	1.00	1.17	1.38	1.54	293	368	474	561	6.1
Westport	1.17	1.30	1.48	1.61	305	355	424	480	7.2
Whakatane	1.56	1.88	2.29	2.59	263	296	340	374	4.5
Whangarei	1.54	1.88	2.32	2.63	220	262	321	368	4.2

Figure 2 shows the five-year return values as a column chart sorted in order of decreasing wind pressure. For comparison, the annual average wind pressure and average annual rainfall are shown in Figure 3.

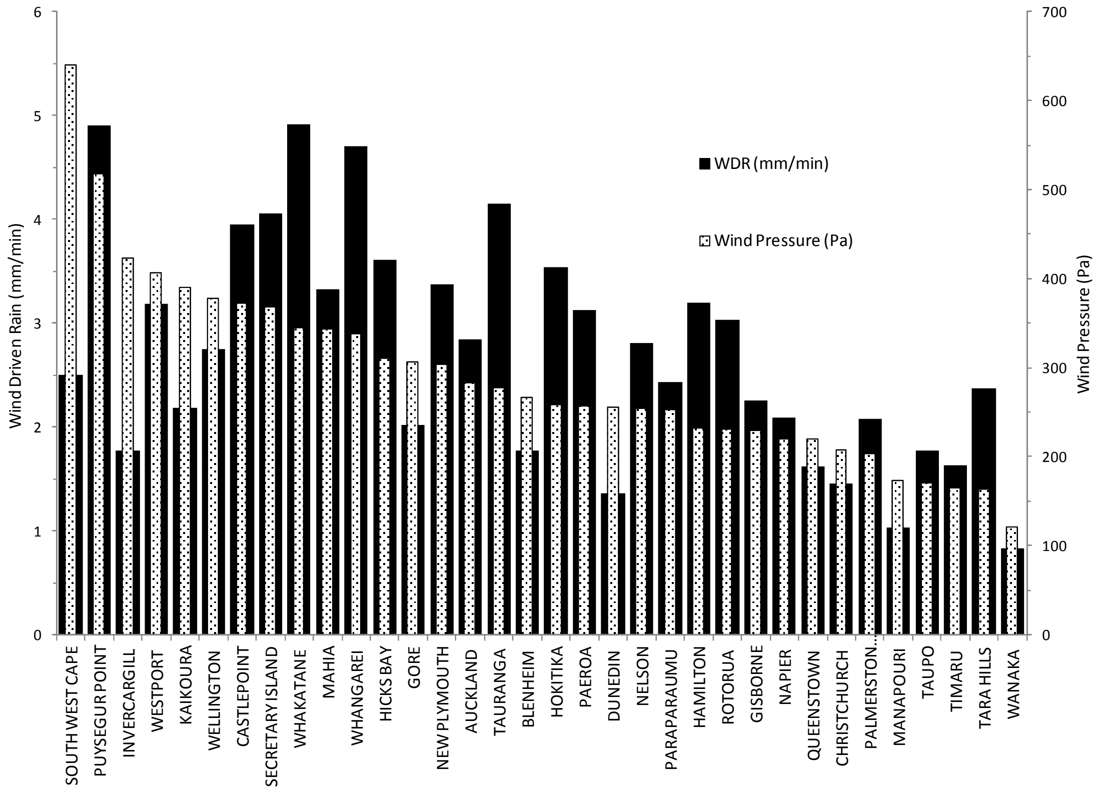


Figure 2 Five-Year Return WDR Rates and Free Wind Pressures for 34 Locations in NZ

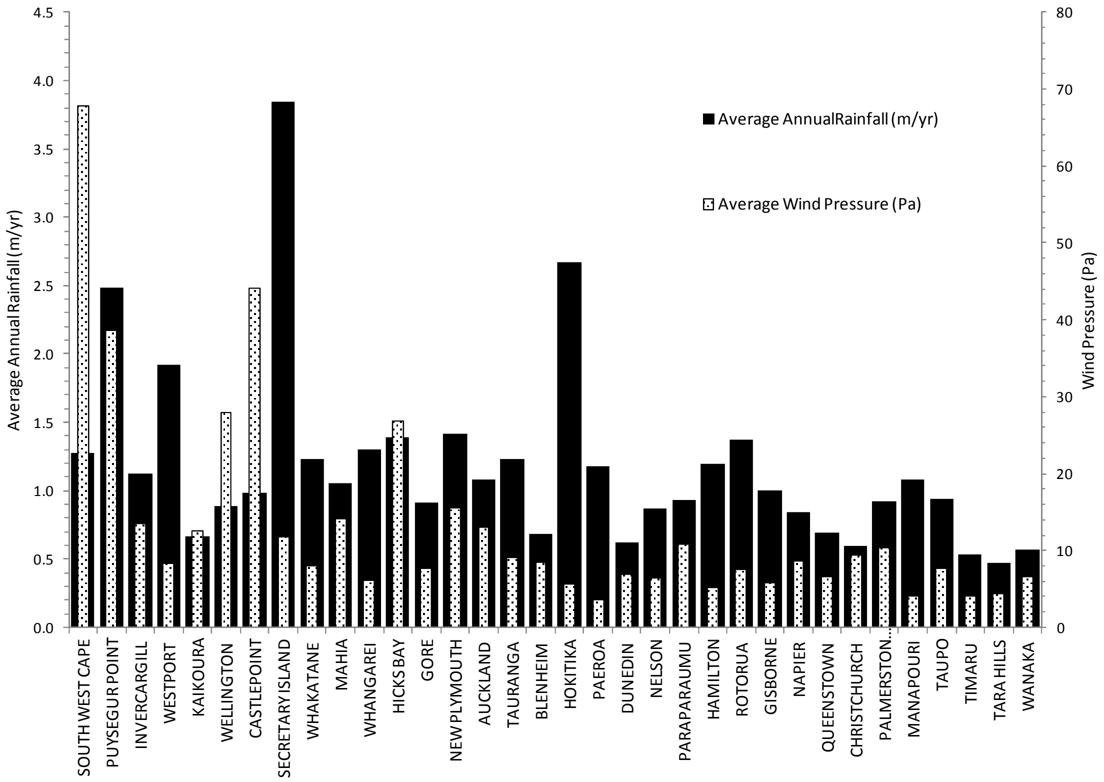


Figure 3 Average Yearly Rainfall and Wind Pressures for 34 Locations in NZ

4. DISCUSSION OF RESULTS

4.1 Selection of a Suitable Return Period

Table 3-1 and Table 3-2 contain data corresponding to return periods of five, ten, 25 and 50 years. When selecting a suitable return period, it may be argued that the return period for wind pressures and WDR rates should be linked to the service life of the structure, say 25 or 50 years. This should certainly be the case when considering the ultimate wind loads on a structure, for example, but the consequence of real WDR events exceeding the levels for a given return period should be considered. In a severe case, water penetration into the structure may occur, but the building is unlikely to be critically compromised. In addition, large sampling errors are introduced if the return period is far longer than the period that data is available. It is therefore considered that a five-year return period is a pragmatic choice when discussing WDR in New Zealand, noting that this represents a 20% chance of exceedance in any given year.

4.2 Variation in Wind-Driven Rain Across the Country

The analysis of wind-driven rain was performed using data from 34 locations, but not all of these locations are population centres. Unsurprisingly, some of the most severe conditions are observed at exposed coastal locations, such as the South West Cape on Stewart Island. However, other results are worthy of comment, especially because of how they compare with New Zealanders' typical opinions of the weather.

Wellington has a reputation as one of the windiest cities on Earth. This is borne out to some extent in the WDR rain analysis but places such as Invercargill, Westport and Kaikoura actually have a higher five-year return wind pressure. This is because the analysis only used the peak values in each year. Figure 3 shows that Wellington has easily the highest average wind pressure of any population centre in New Zealand.

4.3 Comparison with Other Countries

Driving rain analyses have been performed for numerous other countries, however it is difficult to compare these data because there are often differences in the method used. The most direct comparison can be made with Canada (Cornick and Lacasse, 2005), because of the similarity of the method used.

Table 4-1 shows some selected five-year return data from the two countries. One point of difference between the two sets of data is the threshold amount of wind-driven rain used to select wind records (1.8 mm/hr in the Canadian Study versus 5 mm/hr in this study). However, subsequent analysis showed that lowering the threshold for the New Zealand data had no effect for 29 of the locations and only altered the resultant wind pressures by a few pascals in the other five locations. Therefore this difference in the analysis method is considered negligible. Data for some of the largest cities (by population) for each country are shown along with the location corresponding to the highest wind pressure. Certainly, New Zealand's urban areas appear to experience severe driving rain compared with cities in Canada.

Table 4-1 Driving Rain Data for New Zealand and Canada (Cornick and Lacasse 2005)

New Zealand	**Wind-Driven Rain Rate (mm/min)**	**Wind Pressure (Pa)**
Auckland	2.8	282
Wellington	2.8	377
Christchurch	1.5	207
Hamilton	3.1	230
Dunedin	1.3	247
South West Cape	2.5	640
Canada		
Calgary	1.2	280
Toronto	1.0	180
Vancouver	0.6	150
Ottawa	1.3	190
Sandspit	2.8	630

Sahal and Lacasse (2008), whose method is used in this study, derived driving rain parameters for Istanbul (Turkey). Because of the lack of availability of climate records, the data was based on 30-minute averages; the five-year return WDR rate was 0.7 mm/min and the five-year wind pressure was 174 Pa. Comparing this to the hourly data for New Zealand would put Istanbul unsurprisingly towards the lower end of WDR severity.

The British Standard, BS8104 – *Assessing exposure of Walls to Wind Driven Rain* (BSI 1992) describes a local spell index method and a local annual index method for assessing WDR. The spell index is used when considering water penetration of a wall and the annual index is used when considering the moisture content of an exposed building material. Both of the methods correspond to a three-year return period. A spell is a variable time period that can include several WDR events interspersed with periods of up to 96 hours without appreciable WDR. The current method was developed from an earlier driven rain index, which originally took the form of the product of the annual rainfall (in m/yr) and the annual average wind speed (m/s). A value greater than seven was considered "severe", values between three and seven "moderate", while those below three were considered "sheltered". The current method relies on location-specific detail within the standard so is not directly transportable to New Zealand. For simplicity the old method was used for comparison with New Zealand and the annual driven rain index is shown in Table 3-2 for the 34 locations.

It can be seen that using the old annual driven rain index, Hokitika becomes the population centre with the most severe WDR, quite a different result to the main analysis in this paper. In particular, it could be expected that Wellington would fall into the "severe" category, but based on climate data from 1997-2011 that is not quite the case. Kaikoura also ends up with very different results based on the method used. It has one of the most severe five-year return wind pressures but is only just above the sheltered classification using the old annual driven rain index. For comparison, Figure 4 shows wind-driven rain maps based on BS8104 and the old annual driven rain index. There is a degree of similarity between the two; the "severe" category in the old map roughly aligns with "very severe" in the new map and the "moderate" category in the old map is similar to the combination of "moderate" and "severe" in the new map.

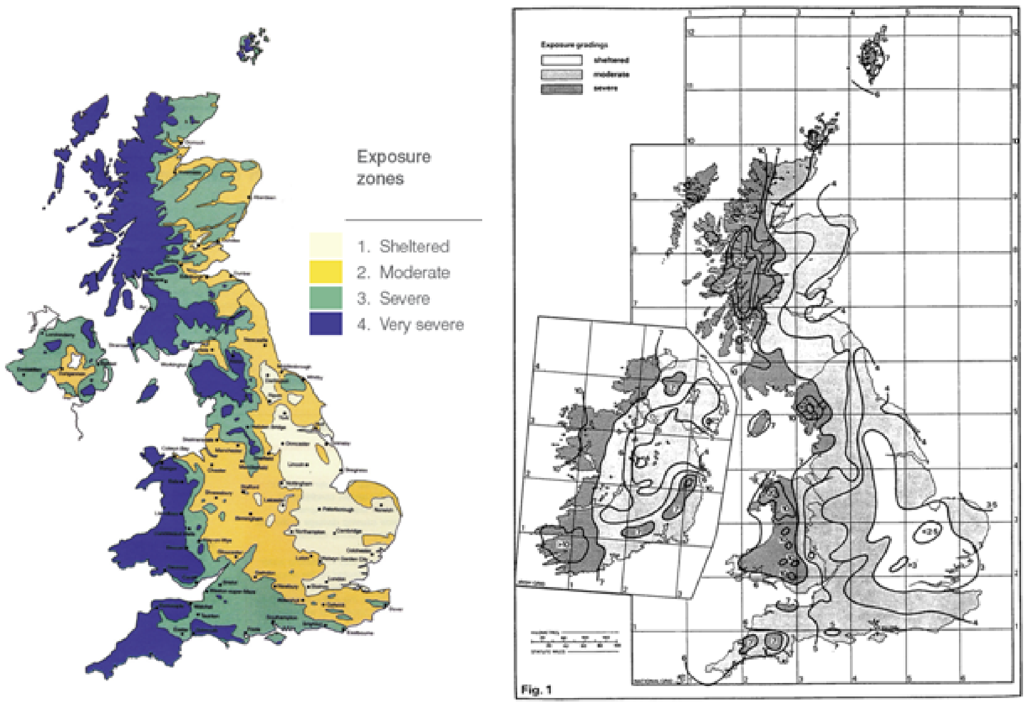


Figure 4 Spell Index Map (Technology Strategy Board [2010]) and the Earlier Annual Driven Rain Index Map for the UK (Lacy 1977)

If the rough assumption is made that values for the old annual driven rain index align with the spell index in the following way: >7 = very severe; >4 = severe; >3 = moderate; <3 = sheltered, the classification shown in Table 4-2 is obtained.

Table 4-2 Estimated BS8104 Spell Index Classifications for New Zealand

Very Severe	Severe	Moderate	Sheltered
Puysegur Point	Wellington	Paraparaumu	Paeroa
Secretary Island	Invercargill	Palmerston North	Manapouri
South West Cape	Mahia	Hamilton	Nelson
Hicks Bay	Auckland	Taupo	Blenheim
Castlepoint	Rotorua	Gore	Christchurch
Hokitika	Tauranga	Napier	Queenstown
New Plymouth	Whakatane	Gisborne	Dunedin
Westport	Whangarei	Kaikoura	Wanaka
			Timaru
			Tara Hills

In summary, there would likely be several differences in the results compared with the main analysis in this paper if the BS8104 method was used for New Zealand. If the BS8104 method was used, it is expected that the WDR levels would be similar to those in the UK, given the distribution of estimated spell indexes shown in Table 4-2.

4.4 Comparison with Existing Water Penetration Test Parameters

In New Zealand, E2/VM1 is typically used to test the weathertightness of residential cladding systems that include a cavity. E2/VM1 is a series of water penetration tests based on the procedure of NZS 4284 – *Testing of Building Facades* (Standards New Zealand, 2008).

The pressures in the E2/VM1 tests are derived from NZS 1170 – *General Structural Design and Design Loadings for Buildings* (Standards New Zealand, 2003), which describes the calculation of ultimate limit state and serviceability limit wind pressures. NZS 1170 also specifies the various factors that should be applied to the free wind speed to account for effects from topography, height and shielding etc. The final test pressures are 455 Pa for the static pressure tests (30% of the pressure arising from a 55 m/s wind) and 455-910 Pa for the cyclic pressure tests. The spray rate for the tests is specified as being not less than 3 L/m^2. Figure 5 shows these values plotted with the WDR data from this study.

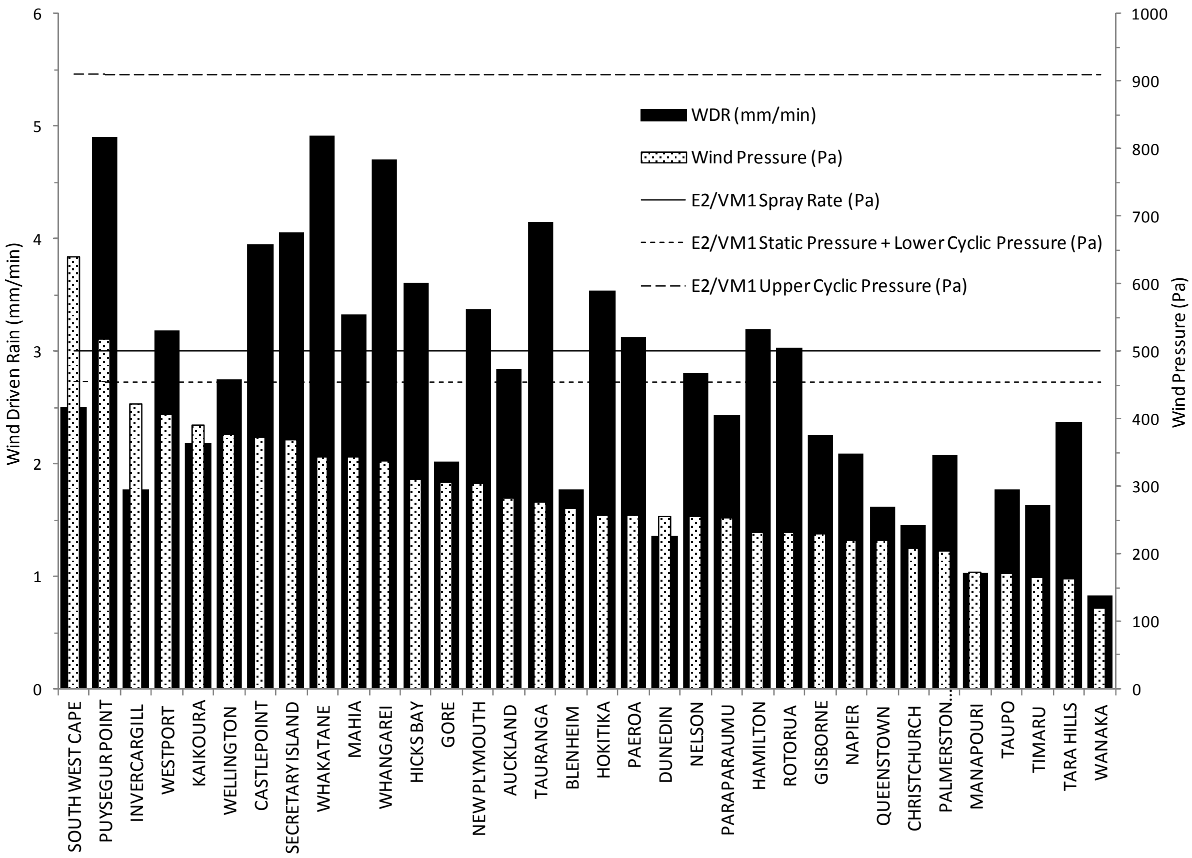


Figure 5 E2/VM1 Test Parameters Compared with Five-Year WDR Rates and Pressures in New Zealand

The pressures from E2/VM1 exceed the normalised five-year return wind pressures for the vast majority of locations in New Zealand and the spray rate from E2/VM1 is higher than the five-year return WDR rate for approximately half of the locations. However, the vast majority of site wind pressures (and hence WDR rates) are likely to be lower than normalised values because the sites will be in more sheltered locations than that assumed by the normalisation process.

In terms of the relative importance of the spray rate (WDR rate) and test pressure (wind pressure), it is likely that the pressure is the most important. Typically, as long as the spray rate is high enough to sustain a film of water on the surface of the wall, then it is likely to be sufficient. In E2/VM1 the concern is where the water goes rather than how much water penetrates so as long as there is free water in the vicinity of a defect, the spray rate is high enough.

Therefore the analysis performed in this study suggests that the parameters in E2/VM1 would exceed the five-year WDR rates and wind pressures for the vast majority of locations in New Zealand. If it was desired to base a water penetration test on the interaction of wind and rain in New Zealand, the test pressures could in theory be lower than what is currently in E2/VM1.

However, the choice of a five-year return period is somewhat arbitrary and E2/AS1 has proven itself to be an effective procedure over the years. Therefore it is not recommended to alter E2/VM1 in light of this study. The data in this study is likely to be most useful when deriving parameters for specific design or unusual situations, for example, where temporary weathertightness for a certain period is desired.

5. CONCLUSIONS

- wind-driven rain rates and accompanying wind pressures were calculated for 34 locations across New Zealand for the period 1995-2011
- urban areas in New Zealand appear to experience high levels of wind-driven rain compared with other countries, Canada in particular, although it is not always straightforward to make direct comparisons with other data. A rough comparison with data from the UK based on the BS8104 spell index method, suggests the WDR levels would be broadly similar in the two countries
- the pressures from E2/VM1 would exceed the five-year WDR rates and wind pressures for the vast majority of locations in New Zealand, because most site wind speeds would be lower than the normalised wind speeds used in this analysis. If it was desired to base water penetration tests on the interaction of wind and rain in New Zealand, the test pressures could in theory be lower than what is currently in E2/VM1
- it is not recommended to alter E2/VM1 in light of this study. This is because of the arbitrary nature of any choice about suitable return periods for water penetration and the fact that E2/VM1 has proven itself to be a successful procedure over the years

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