RESEARCH HIGHLIGHT

June 2007 Technical Series 07-114

Wind-Rain Relationships in Southwestern British Columbia

INTRODUCTION

Building envelope failures in southwestern British Columbia has brought to light the strong influence of wind-driven rain on building envelopes.

There are, however, no specific design tools to determine exposure to wind-driven rain for specific locations and orientations in the region. The closest design data are the DRWP (driven-rain wind pressure) values in the CSA A440 standard, but these are non-directional.

This study examines the relationship between wind and rain for all seasons of the year. Wind and rainfall data are from 12 meteorological stations on Vancouver Island and in B.C.'s Lower Mainland.

METHODOLOGY

Twelve meteorological stations were determined to be suitable for the analysis: four on Vancouver Island (*see* figure 1) and eight in the Lower Mainland (*see* figure 2).

These 12 stations provide a statistically valid sample of:

1. Hourly wind speeds and directions at 10 m (33 ft.) above ground.
2. Hourly rainfall rates in millimetres per hour.

Figure 1 Vancouver Island meteorological stations

The five Environment Canada (EC) stations collected mean wind speed and direction for two minutes at the top of each hour. Wind direction is given in tens of degrees. One-hour mean wind speed and direction are computed at the seven Greater Vancouver Regional District (GVRD) stations. There may be differences between top-of-the-hour data and hourly averages, but this study indicates trends, even accounting for that difference.

Using this hourly weather data, statistics such as averages, standard deviations and maximum and minimum values were calculated and various data subsets were plotted. Wind pressures were calculated using the classic formula:

$$P = 0.04991 \times (\text{wind speed})^2$$

for P in pascal (Pa) and wind speed in kilometres per hour (km/h). This equation assumes a 0°C (32°F) air temperature with an atmospheric pressure of 101.325 kPa (14.6 PSI).

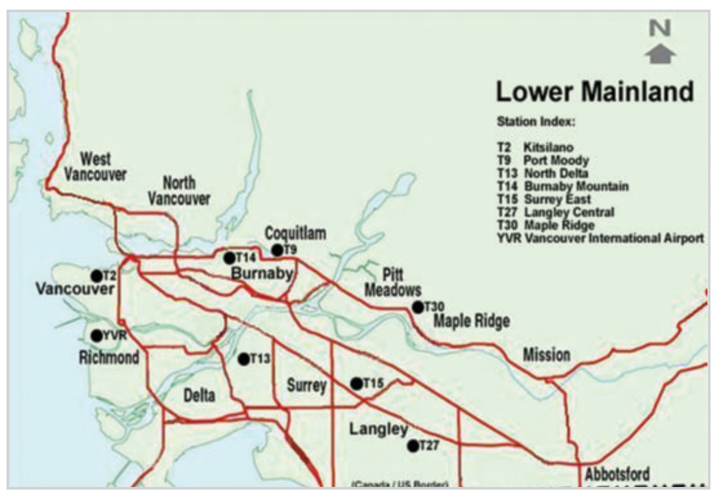

Figure 2 Lower Mainland meteorological stations

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The driving-rain wind pressure (DRWP) is calculated for the 5- and 10-year return periods using the wind pressure, P, for hours when the rainfall exceeds a threshold of 1.8 mm/h. (0.07 in./h).

The DRWP values in the CSA A440 standard for windows are based on the 5-year and 10-year return periods for use with window systems identified in the CSA A440 standard. Because the data set used in this study covered less than 10 years, the 5-year and 10-year extremes could not be generated. Instead, the wind pressure was calculated for all hours when the rainfall threshold of 1.8 mm/h. was met.

DATA ANALYSIS

Table 1 shows the average annual rainfall amount at each of the 12 stations, as well as a breakdown of rainfall amounts by season. As shown in the table, Victoria International Airport measured the least amount of annual rainfall at 861 mm (33.8 in.), almost one metre (3.2 ft.) less than the highest observed annual rainfall amount (1,858 mm [73.1 in.]), recorded on Burnaby Mountain.

In general, a consistent gradient in annual rainfall is observed, with values increasing from south to north (either on Vancouver Island or on the mainland), and from west to east for stations in the Fraser River valley.

In the Lower Mainland, the high annual rainfall on Burnaby Mountain and in Port Moody is probably because the stations are close to elevated terrain.

All stations observed the highest rainfall in the winter—December–February—except Port Hardy Airport, where the highest rainfall was in the fall—September–November. Fall and winter months combined accounted for between 64 per cent and 72 per cent of the annual rainfall at the 12 stations.

Previous studies of wind-driven rain in Canada have ignored the winter months, as most precipitation in winter in most parts of Canada is snow. Also, those studies tended to use Victoria to represent British Columbia: as this study shows, these assumptions are erroneous.

Other statistical data analyzed in this report include rainfall frequency, seasonal distribution of wet hours, correlation between rainfall and wind speed and between rainfall and wind direction, and local variability in DRWP.

The study of rainfall and wind direction provides some interesting results, provided as wind roses for the 12 stations. Figure 3 is an example for Nanaimo Airport. The wind rose at the top of figure 3 shows direction and intensity of wind at the airport, expressed as a frequency in terms of the percentage of ALL hours for which data are recorded. The lower wind rose in figure 3 shows the same results, except that the frequency is a percentage of wet hours (that is, when more than 1.8 mm [0.07 in.] of rainfall falls within the hour).

Table 1 Average rainfall amounts by season at 12 stations

Station*	Average seasonal rainfall mm (in.)				Average annual rainfall mm (in.)
	Spring	Summer	Fall	Winter	
Port Hardy Airport	290 (11.4)	212 (8.35)	691 (27.20)	614 (24.17)	1,807 (71.14)
Comox Airport	204 (8)	125 (4.92)	340 (13.39)	421 (16.57)	1,089 (42.87)
Nanaimo Airport	205 (8)	107 (4.21)	304 (11.97)	421 (16.57)	1,037 (40.83)
Victoria Int'l Airport	159 (6.26)	88 (3.46)	275 (10.83)	340 (13.39)	861 (33.90)
Vancouver Int'l Airport	242 (9.53)	146 (5.75)	349 (13.74)	412 (16.22)	1,150 (45.28)
Kitsilano	277 (10.91)	140 (5.51)	366 (14.41)	510 (20.08)	1,293 (50.91)
Burnaby Mountain	420 (16.54)	241 (9.49)	511 (20.12)	685 (26.97)	1,858 (73.15)
North Delta	271 (10.67)	164 (6.46)	407 (16.02)	499 (19.65)	1,342 (52.83)
Port Moody	397 (15.63)	182 (7.17)	522 (20.55)	667 (26.26)	1,767 (69.57)
Surrey East	284 (11.18)	146 (5.75)	341 (13.43)	494 (19.45)	1,265 (49.80)
Maple Ridge	337 (13.27)	186 (7.32)	468 (18.43)	476 (18.74)	1,466 (57.72)
Langley Central	269 (10.59)	119 (4.69)	347 (13.66)	585 (23.03)	1,320 (51.97)

* Listed in geographical order from west to east.

Two differences are immediately evident.

First, the direction of wind changes when it rains. The wind direction for ALL hours is approximately evenly distributed from the four cardinal directions, with some wind recorded from the southeast.

During wet hours, the wind is predominantly from the east-southeast, southeast and south-southeast. Very little wind-driven rain from the north or southwest would be anticipated in Nanaimo, based on these figures. This suggests that the southeast face of a building would be more vulnerable to driving rain conditions in Nanaimo. This is not to say that one should design the wall assembly on this facade differently from the other elevations (for example, rainscreen walls facing southeast and face-sealed stucco everywhere else), but it does provide guidance as to locating vulnerable details. In this case, low-threshold entrance doors for accessibility should not face southeast in Nanaimo, as it will be difficult to prevent water ingress due to prevailing wind-driven rain from this direction.

Second, the magnitude of the wind speed shows significant variation when considering wet hours, as opposed to all hours. The wind is calm for almost 52 per cent of all hours, but only for approximately 25 per cent of the wet hours, and the wind speed is more often in the range of 6–9 m/s (19.69 – 29.53 ft./s) (22–32 km/h [13.67– 19.88 mph]) during wet weather, as opposed to 4–6 m/s (13.12 – 19.69 ft./s) (14 – 22 km/h [8.70–19.88 mph]) for all hours.

The report includes wind roses for all 12 locations, for wet and total hours and seasonally. In all cases, the wet-hour wind roses for each season shows that the wind direction varies least during the winter and most during the summer. In addition, the frequency of high wind speeds (greater than 12 m/s [39.37 ft./s]) is greatest in the winter.

The Greater Vancouver Regional District shows a great variation in the all hours and wet hour wind roses as a function of location, and Vancouver Airport is not representative of all locations within the GVRD. Thus, design decisions based on information recorded at the Vancouver Airport would be quite incorrect for many other locations.

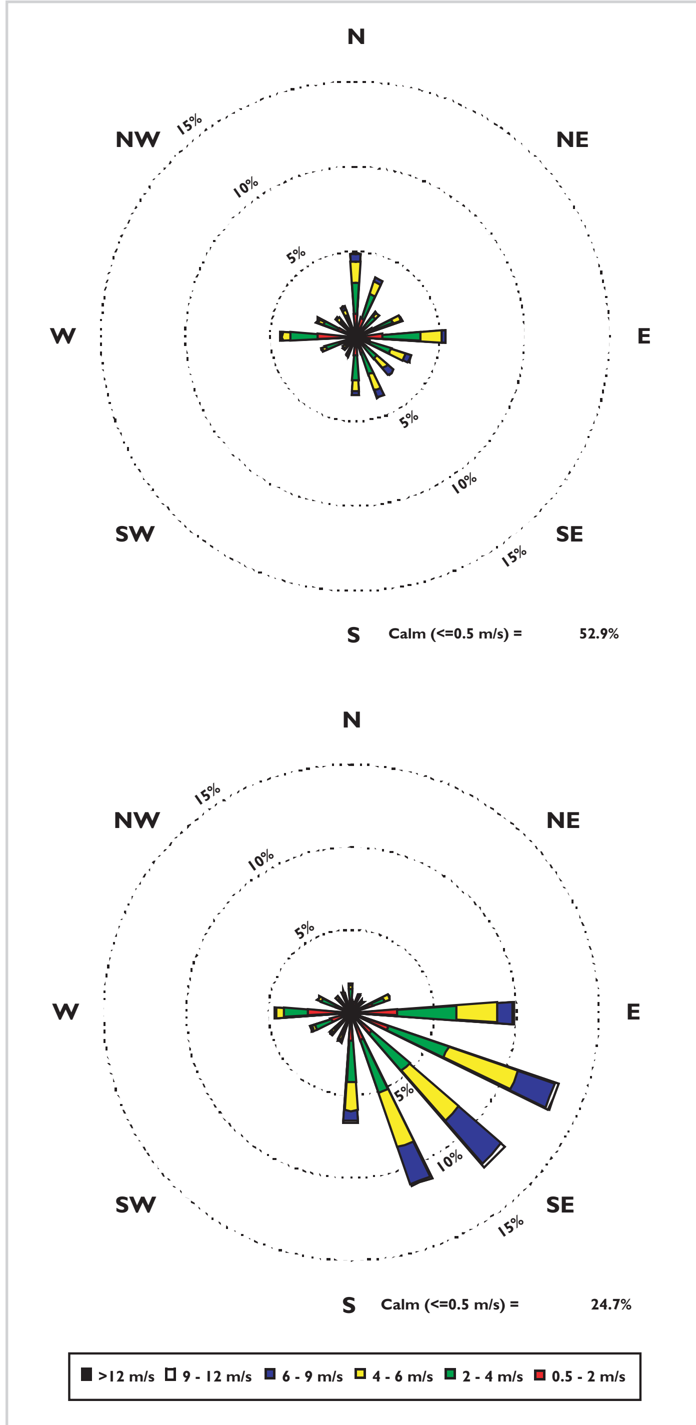

Figure 3 Nanaimo wind rose for all hours (top) and wet hours (bottom)

The report also provides seasonal wind roses for wet hours only for each station. In general, the variability of wind direction during wet hours increases over the seasons with minimum variability during winter and fall, and maximum variability during summer and spring. Thus, the highest frequency of a given wind direction during wet hours will likely occur in winter.

Prominent wet-wind directions during winter will tend to be prominent wet-wind directions during all other seasons; however, the frequency of these wind directions will decrease as directional variability increases. The most frequent high-wind speeds at all stations occur during winter and are associated with the prominent wind direction(s). Wind speeds vary by season, with maximum values occuring during the fall and winter and minimum values in spring and summer.

In summary, this study has simply provided a statistical analysis of the coincidence of wind and rain over the available data for Vancouver Island and the Lower Mainland of British Columbia. An analysis of the temporal distribution of rainfall would be useful, as it would indicate whether wetting or drying predominates in a given location. If the wet hours occur all at once, the rest of the year acts as a drying period; in the worst case, wet hours are evenly distributed throughout the year, so that buildings never get a chance to completely dry out before the next rainfall. It would be possible to analyze the data for these trends, but such an analysis was not within the scope of this study.

IMPLICATIONS FOR THE HOUSING INDUSTRY

The topography and ocean influence greatly affect local weather conditions in the Lower Mainland and Vancouver Island, and building design decisions based on weather information from a single location such as the Vancouver Airport may be inappropriate for the location of the building. The data show that Vancouver Airport weather data do not represent wind-rain conditions over all locations within the lower Fraser Valley. Predominant wind directions during rain, as well as maximum wind speed, vary with location. Consequently, the DRWP varies with location.

For building envelopes, the findings indicate that using, for example, CSA-A440 DRWP values based on Vancouver Airport data could underestimate conditions in locations around Burnaby Mountain and overestimate conditions in many other locations, such as Kitsilano.

For those who are remediating a building envelope, cost considerations could mean that one wall, perceived to be most vulnerable to wind-driven rain, receives more work or attention than the other walls. If the wind direction during wet hours at the location of interest is significantly different than at the Vancouver Airport, the wrong wall could be upgraded.

These results also have implications for design of new construction. Knowing the prevailing directions for wind-driven rain in a given location can provide guidance in selecting appropriate facades for entrance doors or sliding patio doors, both of which are notoriously poor at resisting wind-driven rain. The wind roses of the type shown in Figure 3 can also provide some indication about the need for wider overhangs on a given elevation. Also, if (due to an unavoidable interior configuration) an entrance door must be located on an elevation with a high exposure to wind-driven rain, the designer can anticipate the need for a canopy or deep alcove to reduce the building's vulnerability to water ingress.

The analysis shows that all stations in this study exhibit a marked difference in the wind direction and frequency of higher wind speeds for wet hours versus all hours. In addition, the seasonal variation of the wind is such that the most frequent high-wind speeds at all stations occur during winter and are associated with the prominent wind direction(s). An early study (Surry et al., 1995) looked at wind-rain relations for several stations across Canada from April to September. This study shows that, for the southwest corner of B.C., wind-driven rain is just as important during the winter months when rain events are more common and wind speeds are typically higher.

The conclusions of the earlier study (Surry et al., 1995) are valid for this study:

> DRWP values derived for a range of directions could provide useful information to sophisticated design approaches. As some building surfaces will receive less wind-driven rain than others, depending on their orientation, it may be possible to design these favourably oriented facades in a more economical manner than the facades which face the prevailing direction of wind-driven rain.

The current study also adds to these conclusions, pointing out that in regions where topography and other factors such as the ocean influence the weather over a small regional scale, the local variation of wind-driven rain and wind direction should be taken into account. One possible outcome of this conclusion is that the "Exposure Nomograph" in *Best Practice Guide: Building Technology Wood-Frame Envelopes in the Coastal Climate of British Columbia* (CMHC, 2001) could be modified to reflect the difference in exposure categories for various directions. For example, Figure 3 indicates that southeast-facing walls receive the predominant exposure to wind-driven rain in Nanaimo, but it also shows that north-facing walls are only exposed to wind-driven rain for approximately one per cent of the hours in the year.

For many locations, the average wind speed increased as the rainfall rate increased. It would be preferred for wind speeds to be higher during non-wet hours, to promote drying of the building envelope, but such does not appear to be the case. Building designers should be aware that this emphasizes the need to prevent wetting of the walls during rain events and to promote drying during non-wet hours. Any design index used to provide guidance in this regard should highlight this important finding.

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Housing Research at CMHC

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