Evaluation of the Checkwind Application Methods for Wind Profile Determination

What is Checkwind?

Checkwind (https://www.revolutio.com.au/software/checkwind/) is a web-based facility for performing the wind profile calculations required by the Building Codes in Australia, Europe, The US and Canada among others. It claims to be a site-specific response to the Code requirements for producing the wind profiles at a specified site.

I obtained a two week trial version of the Checkwind App in order to explore the facilities used by the program and supplied to the user by Checkwind, and to determine the congruence of the results to the code for which they were derived.

What does it do?

In addition to the calculation of the profile as per code, the app automates specification of three key input parameters required by the calculation, namely the basic wind speed for available MRI for the location, the exposure category, and the topographic parameters of shape and slope.

For the US codes the app retrieves the wind data from the ASCE 7 Hazard Tool available on the web. For the Canadian CSA it obtains the NBCC table data. For a number of other countries which publish their wind speed maps on-line the app obtains this information as well.

To derive the exposure category the app detects several different landscape categories which it classifies as open, water, urban on Google Earth satellite images of the area surrounding the site and determines the percentage of the area in each sector at the location of interest. Using this data the sector is classified as C or B or D for the US codes and as roughness length for the Canadian CSA S37 code.

For topography determination the app uses digital elevation data to evaluate transects of the terrain in order to calculate the isolated topographic feature’s crest and lowest point on the transect and then establish the distance at the half-height of the feature. The app seems to use some heuristics to establish the shape of the topographic feature as well as the height and length measurements.

The input required from the user is the type, shape and height of the structure and the location of the structure.

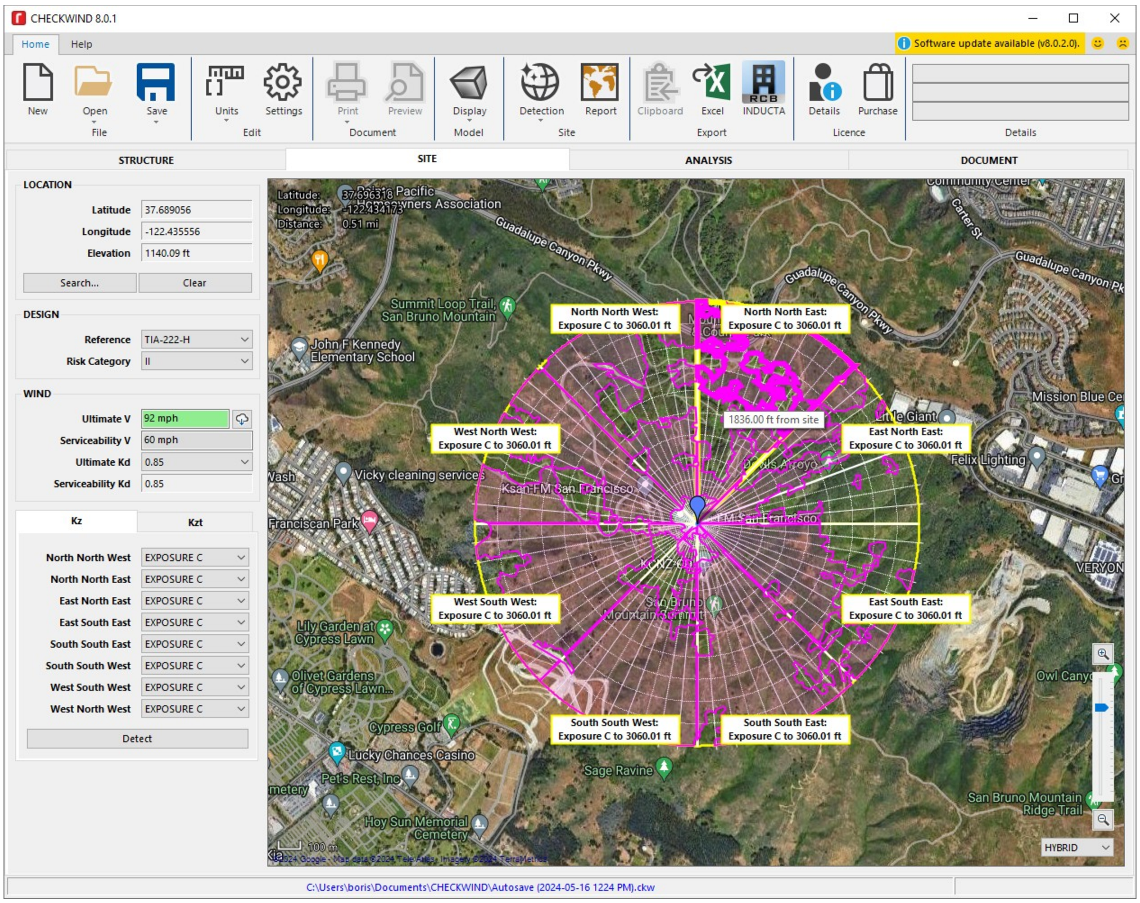
How well does it function?

The first observation I would make is that the Checkwind App is not providing a “Site-Specific” assessment of the situation as prescribed in the codes. It is using a mapped wind which is based on a limited number of observing sites and where the mapping process of necessity glosses over the local variations in weather systems and orography, and over-rides the variability of the wind speed statistics which is location dependent. The suggested approach in the codes for a site-specific assessment is to use local observations and perform the statistics over a long period of record to derive the return period winds. If you want to get the full benefit of site specific assessment you would need to obtain directional exposure and the corresponding directional extreme wind speed.

The app does provide the calculation which the specific code requires using automation of the input parameter determination. The author seems to acknowledge that this automated derivation is not foolproof as he suggests that the app must be used by a knowledgeable professional.

To get a feel of the automation aspect I tested the app for the San Bruno Mountain in North San Francisco. This is an irregular terrain of rolling hills bordering on dense residential and recreational built up areas. The hill heights range up to 300 m.

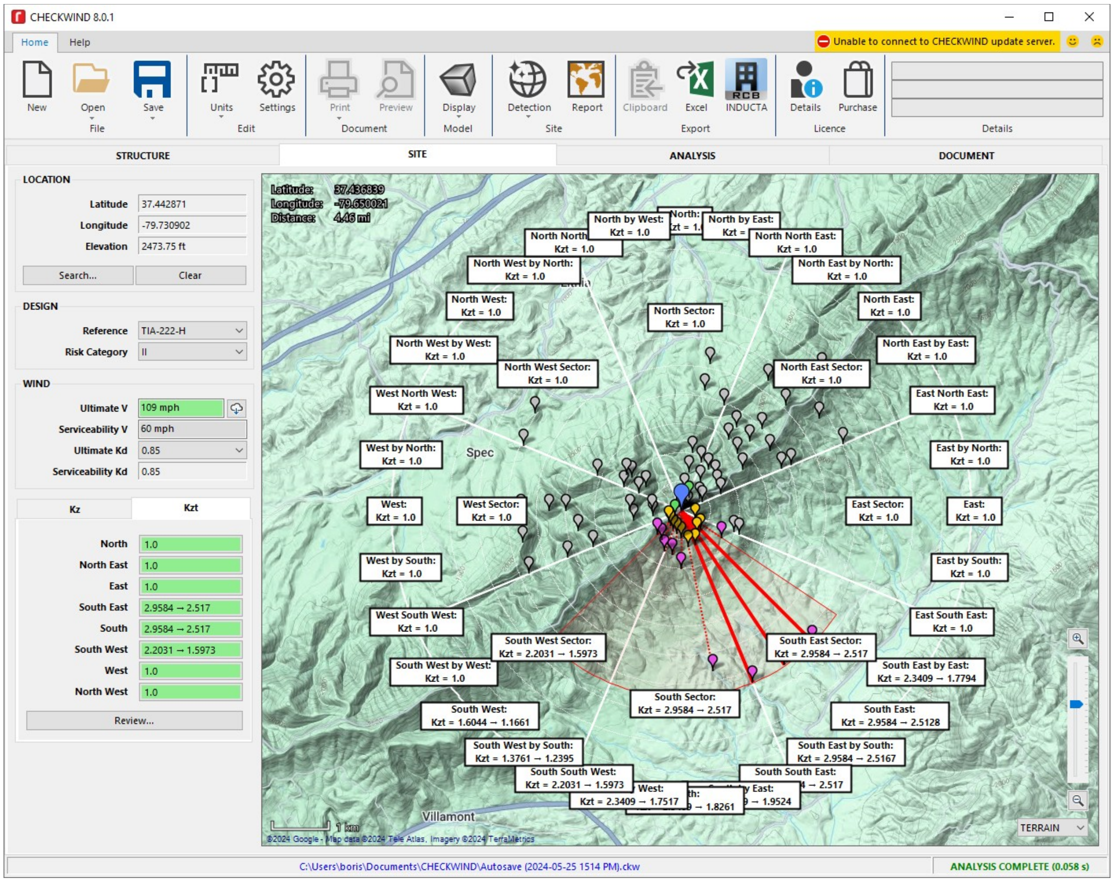
The exposure category determination derived by the app for the TIA 222 H Code is shown in the following figure.

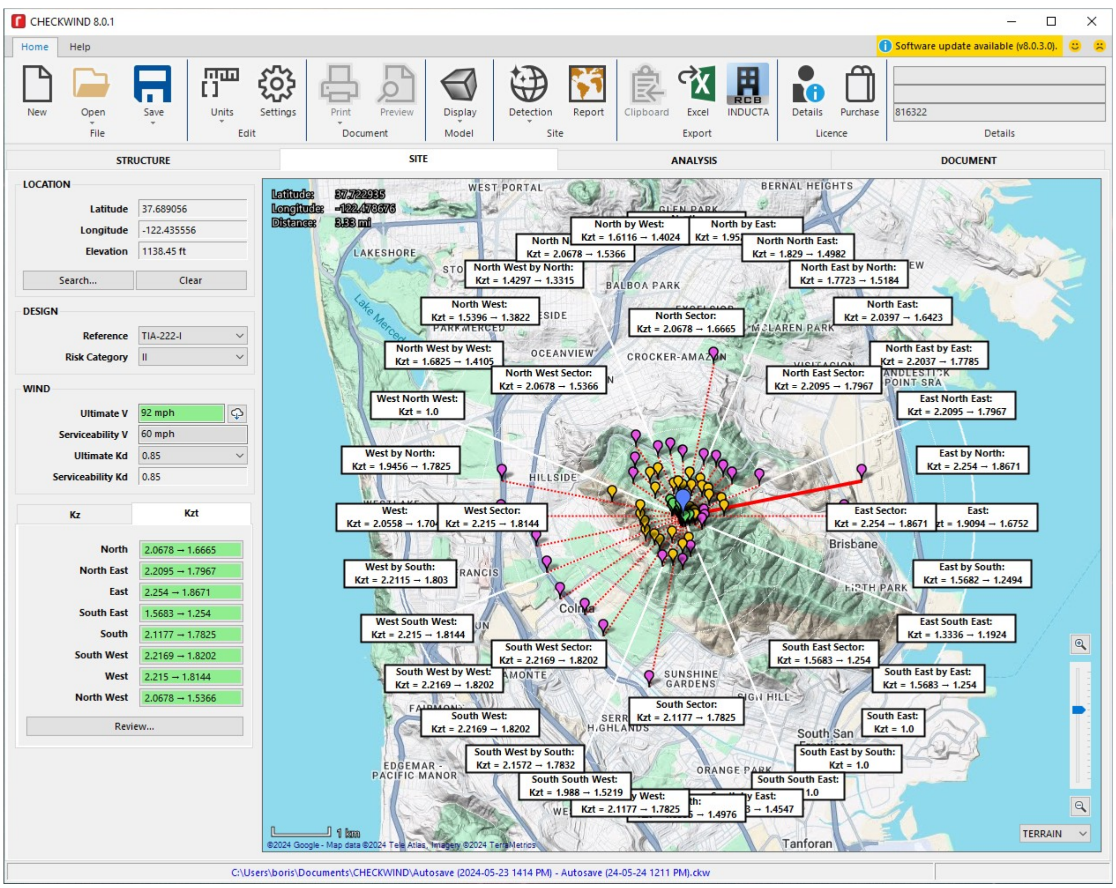


This derivation classified all sectors as C category, which is the open terrain category. The user has the option of changing the designation in order to get the calculation performed with a different exposure.

For the same site the ASCE7 22 chart classifies the WSW sector as B category, since it uses a larger radius to perform the classification. The algorithm seems to be designed to opt for the C classification unless there are clear reasons to designate a sector as having B exposure.

The topography characterization for the site is shown in the next screen shot. The figure shows that the calculated K_{zt} is equal to 1 for most sectors, meaning that no speed up calculations were required, in other words that there are no isolated hills. The version I of TIA, which has introduced the rolling terrain option, shown in the next chart shows that all hills and ridges now have terrain influences.


CHECKWIND 8.0.1
Home
Help
Unable to connect to CHECKWIND update server.
New
Open
Save
File
Units
Settings
Edit
Print
Preview
Document
Display
Model
Detection
Report
Site
Clipboard
Excel
INDUCTA
Export
Details
Purchase
Licence
Details
STRUCTURE
SITE
ANALYSIS
DOCUMENT
LOCATION
Latitude 37.442871
Longitude -79.730902
Elevation 2473.75 ft
Search...
Clear
DESIGN
Reference TIA-222-H
Risk Category II
WIND
Ultimate V 109 mph
Serviceability V 60 mph
Ultimate Kd 0.85
Serviceability Kd 0.85
Kz
Kzt
North 1.0
North East 1.0
East 1.0
South East 2.9584 → 2.517
South 2.9584 → 2.517
South West 2.2031 → 1.5973
West 1.0
North West 1.0
Review...
Latitude: 37.436839
Longitude: -79.650021
Distance: 4.46 mi
North by West: Kzt = 1.0
North by East: Kzt = 1.0
North North East: Kzt = 1.0
North East by North: Kzt = 1.0
North West by North: Kzt = 1.0
North West: Kzt = 1.0
North East: Kzt = 1.0
North Sector: Kzt = 1.0
North West by West: Kzt = 1.0
North East by East: Kzt = 1.0
North West Sector: Kzt = 1.0
North East Sector: Kzt = 1.0
West North West: Kzt = 1.0
East North East: Kzt = 1.0
West by North: Kzt = 1.0
East by North: Kzt = 1.0
West: Kzt = 1.0
West Sector: Kzt = 1.0
East Sector: Kzt = 1.0
East: Kzt = 1.0
West by South: Kzt = 1.0
East by South: Kzt = 1.0
West South West: Kzt = 1.0
East South East: Kzt = 1.0
South West Sector: Kzt = 2.2031 → 1.5973
South East Sector: Kzt = 2.9584 → 2.517
South West by West: Kzt = 1.0
South East by East: Kzt = 2.3409 → 1.7794
South Sector: Kzt = 2.9584 → 2.517
South West: Kzt = 1.6044 → 1.1661
South East: Kzt = 2.9584 → 2.5128
South West by South: Kzt = 1.3761 → 1.2395
South East by South: Kzt = 2.9584 → 2.5167
South South West: Kzt = 2.2031 → 1.5973
South South East: → 2.517
Kzt = 2.3409 → 1.7517
Spec
Villamont
1 km
TERRAIN
©2024 Google - Map data ©2024 Tele Atlas, Imagery ©2024 TerraMetrics
C:\Users\boris\Documents\CHECKWIND\Autosave (2024-05-25 1514 PM).ckw
ANALYSIS COMPLETE (0.058 s)

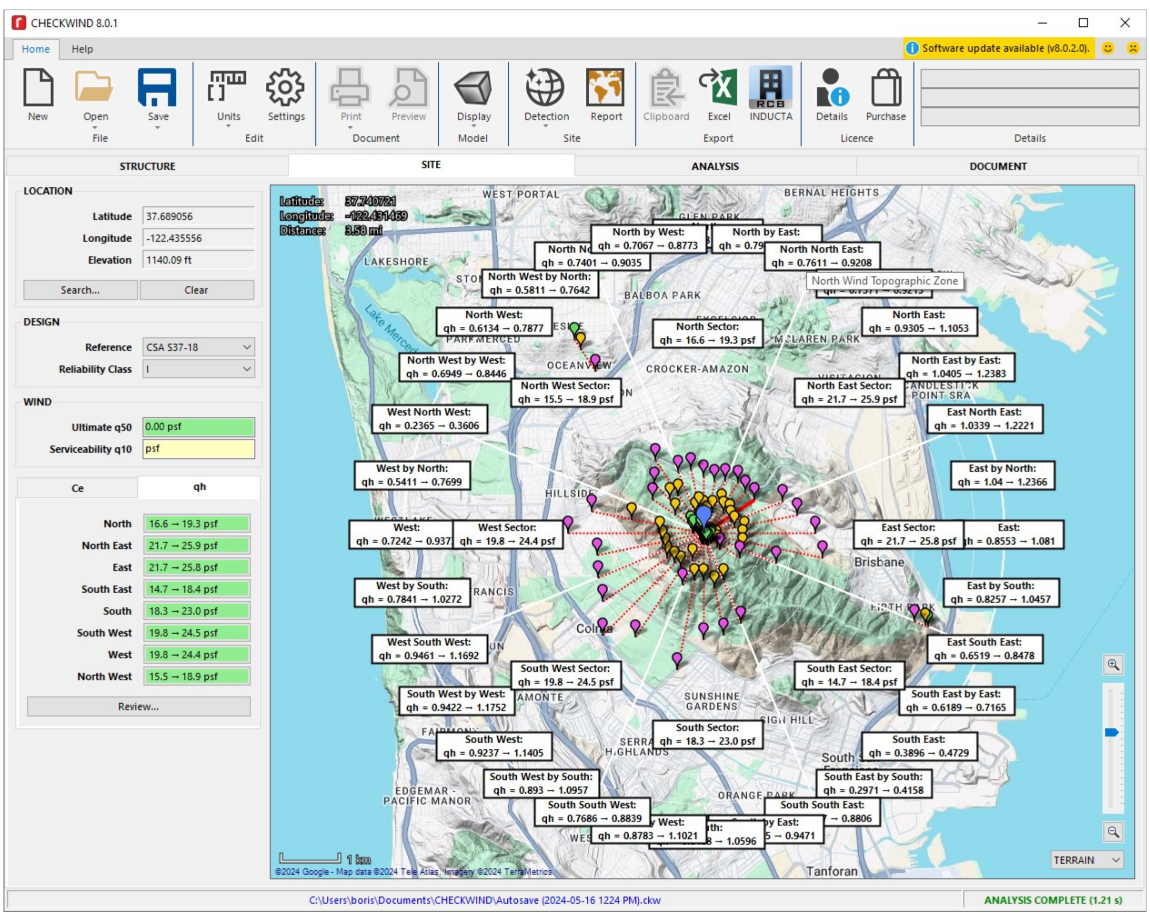

CHECKWIND 8.0.1
Home
Help
Software update available (v8.0.3.0).
New
Open
Save
File
Units
Settings
Edit
Print
Preview
Document
Display
Model
Detection
Report
Site
Clipboard
Excel
INDUCTA
Export
Details
Purchase
Licence
816322
Details
STRUCTURE
SITE
ANALYSIS
DOCUMENT
LOCATION
Latitude 37.689056
Longitude -122.435556
Elevation 1138.45 ft
Search...
Clear
DESIGN
Reference TIA-222-I
Risk Category II
WIND
Ultimate V 92 mph
Serviceability V 60 mph
Ultimate Kd 0.85
Serviceability Kd 0.85
Kz
Kzt
North 2.0678 → 1.6665
North East 2.2095 → 1.7967
East 2.254 → 1.8671
South East 1.5683 → 1.254
South 2.1177 → 1.7825
South West 2.2169 → 1.8202
West 2.215 → 1.8144
North West 2.0678 → 1.5366
Review...
Latitude: 37.722935
Longitude: -122.478676
Distance: 3.33 mi
WEST PORTAL
BERNAL HEIGHTS
North by West: Kzt = 1.6116 → 1.4024
North by East:
North North East: Kzt = 1.829 → 1.4982
Kzt = 2.0678 → 1.5366
North West by North: Kzt = 1.4297 → 1.3315
North East by North: Kzt = 1.7723 → 1.5184
LAKESHORE
BALBOA PARK
North West: Kzt = 1.5396 → 1.3822
North Sector: Kzt = 2.0678 → 1.6665
North East: Kzt = 2.0397 → 1.6423
North West by West: Kzt = 1.6825 → 1.4105
North East by East: Kzt = 2.2037 → 1.7785
OCEANVIEW
CROCKER-AMAZON
MCLAREN PARK
North West Sector: Kzt = 2.0678 → 1.5366
North East Sector: Kzt = 2.2095 → 1.7967
West North West: Kzt = 1.0
East North East: Kzt = 2.2095 → 1.7967
West by North: Kzt = 1.9456 → 1.7825
East by North: Kzt = 2.254 → 1.8671
HILLSIDE
West: Kzt = 2.0558 → 1.70
West Sector: Kzt = 2.215 → 1.8144
East Sector: Kzt = 2.254 → 1.8671
East: Kzt = 1.9094 → 1.6752
Brisbane
West by South: Kzt = 2.2115 → 1.803
East by South: Kzt = 1.5682 → 1.2494
Colma
West South West: Kzt = 2.215 → 1.8144
East South East: Kzt = 1.3336 → 1.1924
South West Sector: Kzt = 2.2169 → 1.8202
South East Sector: Kzt = 1.5683 → 1.254
South West by West: Kzt = 2.2169 → 1.8202
South East by East: Kzt = 1.5683 → 1.254
SUNSHINE GARDENS
South Sector: Kzt = 2.1177 → 1.7825
South West: Kzt = 2.2169 → 1.8202
South East: Kzt = 1.0
South San
South West by South: Kzt = 2.1572 → 1.7832
South East by South: Kzt = 1.0
EDGEMAR - PACIFIC MANOR
ORANGE PARK
South South West: Kzt = 1.988 → 1.5219
South South East: 1.0
Kzt = 2.1177 → 1.7825
→ 1.4976
→ 1.4547
Tanforan
1 km
TERRAIN
©2024 Google - Map data ©2024 Tele Atlas, Imagery ©2024 TerraMetrics
C:\Users\boris\Documents\CHECKWIND\Autosave (2024-05-23 1414 PM) - Autosave (24-05-24 1211 PM).ckw

I have also examined some of the samples provided with the app to see how well the topography is represented. One of the samples shows the following:

WIND	CRITICAL	TOPOGRAPHY	H	Lh	x	SHIELDED	ISOLATED	Kzt
N	NNE	Ridge	907.15 ft	3202.40 ft	2034.12 ft	False	True	1.5337
NE	ENE	Ridge	1077.76 ft	1468.67 ft	-65.62 ft	False	True	2.9418
E	EbS	Ridge	1048.23 ft	1371.78 ft	0.00 ft	False	True	2.9584
SE	ESE	Ridge	1058.07 ft	1689.63 ft	0.00 ft	False	True	2.9584
S	SSE	Ridge	482.28 ft	793.96 ft	0.00 ft	True	False	1.0
SW	WSW	Flat	314.96 ft	2320.01 ft	65.62 ft	False	False	1.0
W	WNW	Flat	392.06 ft	2470.01 ft	65.62 ft	True	False	1.0
NW	NNW	Flat	396.98 ft	2566.34 ft	0.00 ft	True	False	1.0

This example shows the complexity of terrain categorization, and the need for extreme caution in automating highly variable 3 dimensional input variables. For example for the NE to SW transect, the northeasterly winds are represented as approaching a ridge but the southwesterly winds are not seeing the ridge at all for calculating purposes since it is not seen as isolated. In other words, the ridge is both isolated and not isolated.

While trying out the different codes, I set the code to the CSA S37-18 to see if the terrain would be detected. In this case the terrain was detected as shown in the following screen shot. This shows that the analysis was performed to calculate the Qh value and using the speed up by terrain.



The app does not explain what wind speed data was used for the analysis, since the NBCC table of winds is only available for locations in Canada. Nor is there an explanation of how the roughness lengths at the site were calculated by the app.

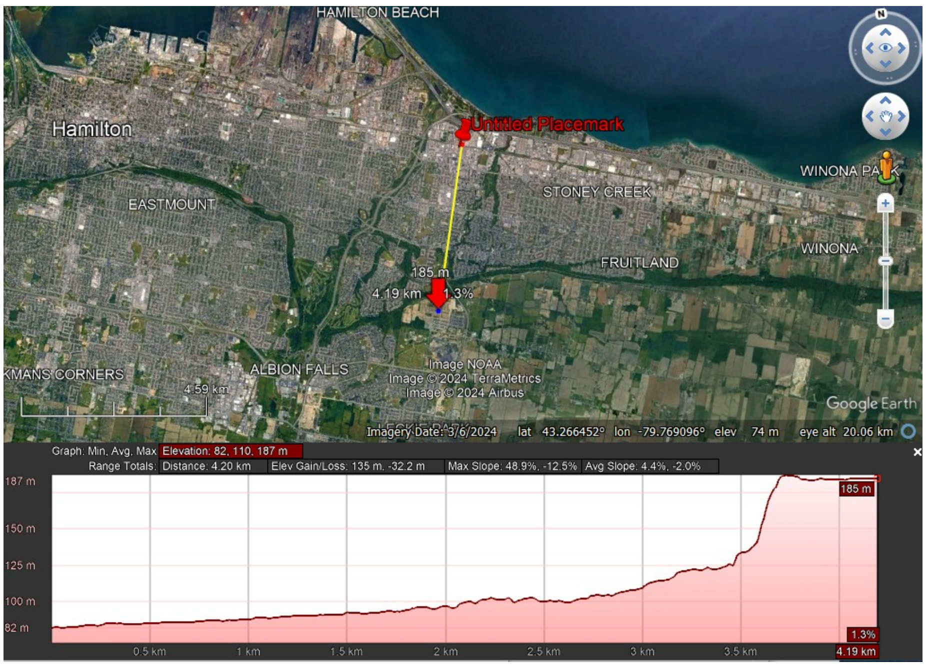
For the CSA S37 code which requires specification of the roughness length for the general area surrounding the site terminating at the base of the hill as well as the roughness on the slope of the topographic feature, Checkwind does allow for several zones for each sector, although the zones don't seem to be tied to the distance from the crest to the bottom of the hill, with many of the sectors having only a single sector defined.

Another run done for the S37–18 code shows the following topographic treatment by sector. This shows that the maximum loading is for winds from the North sector at 6.7 psf for the 10m level.

WIND	CRITICAL	TOPOGRAPHY	H (ft)	L (ft)	Lint (ft)	SLOPE	qh (psf)
N	NNW	Ridge	310.04	1842.75	-13320.18	0.1682	6.7→10.4
NE	NNE	Ridge	229.66	1238.52	-13910.73	0.1854	4.7→8.8
E	EbN	Flat	27.89	1138.19	-853.02	0.0245	4.9→9.1
SE	SSE	Flat	31.17	185.93	-8858.3	0.1676	4.9→9.1
S	S	Ridge	41.01	136.71	-2755.97	0.3	4.9→9.1
SW	WSW	Escarpment	36.09	446.19	4265.06	0.0809	4.9→9.1
W	WSW	Escarpment	36.09	446.19	4265.06	0.0809	4.9→9.1
NW	NWbN	Ridge	328.08	2110.7	-15616.8	0.1554	4.7→8.8

The value for Lint, which is the distance off the crest, is stated as -13320 ft which is downwind of the site and is much greater than 2 x L. The equations are set to limit the off-crest distance to 2xL, beyond which it is assumed that the influence of the hill or ridge is zero.

The map below shows the actual situation of the site and the escarpment showing that the site is not influenced by the escarpment at all.



The automated terrain detection has found elevated terrain along this transect, and in fact for most directions, but hasn't determined the likelihood that this elevation can have any influence at the location of the site. This was then coupled with an error in the Checkwind calculation procedure by not restricting it to the 2xL range of the site, in effect placing the site on top of a ridge (which is clearly an escarpment on the map) rather than four km distant from the site.

Conclusions and Recommendations

The ASCE 7 and TIA 222 codes provide the design engineer with the procedures for calculating the wind load on a structure, and provide the basic wind for a location on a national map through the Hazard Tool web site. The codes also recognize the limitations of the map particularly for mountainous terrain and provide the option to the engineer to avail himself of site specific determination of the wind which uses more local data and which uses recognized procedures for extreme wind determination for the local data.

Checkwind claims to provide a site specific assessment but using data and automated procedures rather than the local assessment envisaged by the Codes. When the engineer receives the results of the calculation he needs to determine if the correct situation has been calculated.

Because the codes still specify the requirement to select one of three terrain categories there is usually a big difference in the final results depending on the choice. Checkwind allows the user to over-ride its terrain code in order to determine the upper and lower bounds for the wind or pressure profiles, but the app does not provide all of the information needed to justify such interpolation. Nor is there the numerical data to justify the interpolation.

The estimation of hill (ridge) shape and slope parameters is the most critical part in the speed up calculation. Currently the best approach is the use of Google Earth Pro to visually examine the shape for all relevant directions and determine the steepest slope. Because in the real world the hills, ridges and escarpments seldom conform to the idealized mathematical description the reviewer has to make a best approximation which captures the real situation but in a mathematically measurable simplified form. Without taking this hard fact into account it is possible to go astray and depart from the most important elements of the actual situation.

This makes the automation of the topography classification process very difficult, and can lead to chasing down irrelevant minutiae of the terrain while losing the most salient bigger picture. This is graphically demonstrated by the last example above, where an escarpment 4 km from the site of a tower, which can have no influence on the speed up at the site, is nevertheless selected for consideration and produces the largest speed up.

A further complication in determining the hill parameters is that in a range of hills each hill can be independently affecting the speedup on the hill without the influence of other hills upwind and their speed up effect can be larger than the other hills would produce.

This was shown experimentally and by wind tunnel and numerical modeling by an Australian research team in the Belmont Hills of New Zealand.

Comparison of Wind Speed Hill-shape Multipliers Calculated by Seven Wind Loading Standards with Full-scale Measurements R.G.J. Flay, M. Nayyerloo, A.B. King, M. Revell, 17th Australian Wind Engineering Society Workshop, 2015)

The following graphic from their paper depicts the wind tunnel determined speed up factor.

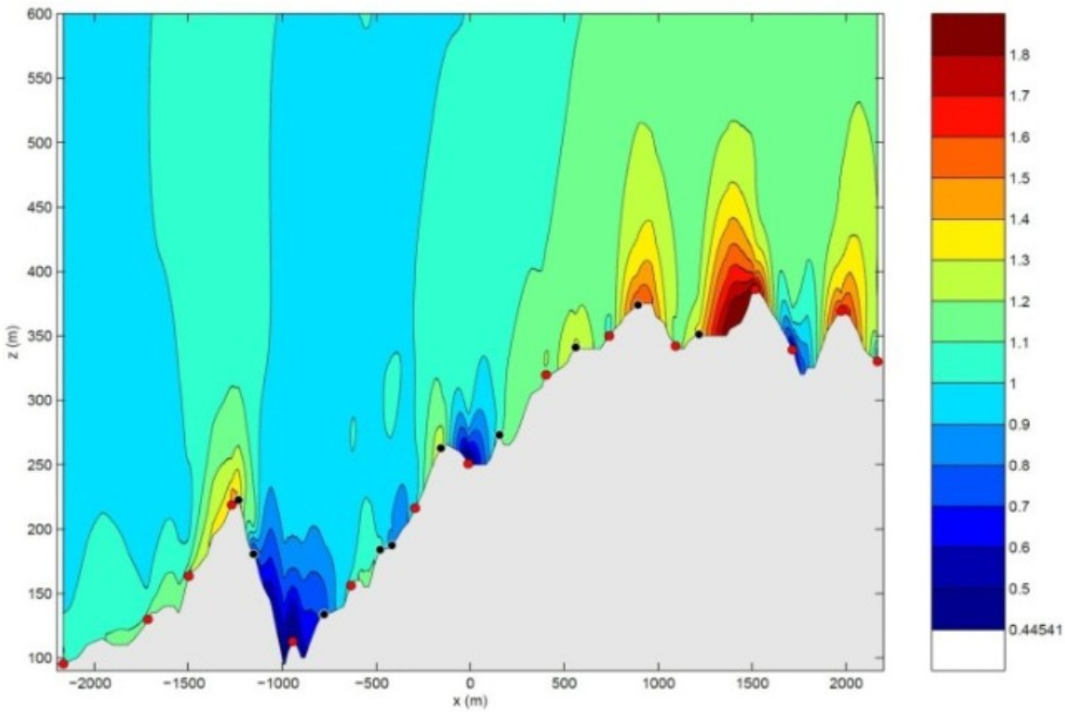


Figure 8 Cross section of the hill shape multipliers measured in the wind tunnel for wind direction 340. The wind is blowing from the left.

The authors compared the speed up factor as determined by the Australian, US, Canadian, Japanese, Korean standards and found that all were able to find the speed up at the crest of the leftmost hill (isolated), but all failed to show the much greater speed up on the three higher hills further downwind. The main reason for this failure of the codes is that they seem to all assume that the subsequent hills are part of a large hill encompassing the remaining hills and hence seen as one hill with large Length and hence shallow slope.

I have shown in a paper presented to the WG 4 of the IASS in Toronto in 2022 that if one treats each of the hills using the rolling terrain formulation derived by Taylor and Walmsley, each depicting the hill with the correct localized parameters then the peak speed up is correctly predicted for all the hills. This is the change that the TIA 222 I has implemented in the profile equation.

https://www.ice-inc.co/wp-content/uploads/2022/10/Wind-Speed-Up-Formulation-Testing-IASS.pdf

What this means for the automated topography derivation is that it is not sufficient to look for the global floor of the range of hills, because the local low can be more important for that direction.

The other issue critical to the determination of the maximum wind load is the requirement in the codes to use the greatest extreme wind over all directions for each approach direction. This will clearly tend to over-estimate the overall extreme wind speed up. The only way to avoid this assumption is to perform the wind statistics separately for each sector and then apply the appropriate wind for each of the sectors. This requires dealing with the hourly data for each direction and performing the statistics, which requires a proper site specific assessment.

The Directional Site Specific Procedure developed by ICE uses 40 to 50 years of hourly data from the nearest suitable meteorological observing station. Using the Generalized Extreme Value Statistics on monthly maxima by direction. These extreme winds are then standardized to create a basic wind for each direction by taking into account the terrain roughness for each sector at the station.

For the structure site the ICE procedure extracts the roughness length from land use/land cover data at 200 m intervals out to 5000 m. In the ICE procedure there is no need to classify the terrain into 3 classes since the wind profiles are determined using the roughness formulation including accounting for changes in roughness on the fetch to the bottom of the feature and on the slope of the feature.

Using Google Earth the shape and slope of the topographic feature is determined for each sector and used to set the fetch roughness on approach to the feature and on the slope. This approach allows us to accommodate complex situations such as a hill which is partly forested where the hill is surrounded by a town which is bordering a large lake. To reflect the correct profile for a tall tower or on a significant hill requires accounting for the over-water fetch which over a large enough body of water affects the profile in the upper part of the tower.

This approach allows us to also model the glaze and rime ice accretion on elevated terrain using the airport data and to provide a calculated profile of the ice accumulation on the tower.