WIND DESIGN

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1.0 SCOPE

This data sheet provides general guidance to building designers regarding wind considerations with regard to property protection at highly protected buildings. This includes recommended wind pressures for common building shapes for the following:

A. Building components and cladding (e.g., roofs and walls), and the securement to their immediate supports. The design of the supports themselves, such as girts, studs, mullions (unless part of a tested window assembly), joists, purlins and their primary supports, are not included.

B. Opening protection (doors, windows, skylights, etc.).

C. Wind forces for anchorage of roof-mounted equipment (for equipment other than roof-mounted solar panels). For securement of roof-mounted solar panels, see DS 1-15..

For main wind force-resisting systems (MWFRS) and other structures, such as chimneys, tanks, signs, and open frameworks, refer to the American Society of Civil Engineers (ASCE) standard ASCE 7, *Minimum Design Loads for Buildings and Other Structures* (2005, 2010, or 2016 as required by local code), or other local code.

Optional guidance for tornado-resistant design can be found in Appendix D.

Open buildings are not covered by this data sheet. However, a conservative approach for these roof pressures can be achieved by following the guidelines in this data sheet for enclosed buildings.

Only enclosed buildings are recommended for new construction; however, guidance is also provided for partially enclosed buildings because they may be encountered during renovations of existing structures.

Guidance in determining proper construction to resist the recommended loads in this document is included in other documents listed in Section 4.0.

Guidance related to other types of loads; such as snow, ice and rain,can be found in Data Sheet 1-54.

1.1 Changes

July 2022. The wind speed information for Australia (Figure 5 and Table AC 1.1.1) has been updated based on the latest Australian Code (see Section 4.2). Wind speeds were reduced to equivalent 3-second gusts based on Australian measurements of 0.2 second gusts. That was done by multiplying the previous wind speed by a 0.89 adjustment factor. In Regions D, C and B2, as defined in the Australian Code, a 1.05 climate change multiplier (MC, to account for climate uncertainty) was applied to the wind speed. On the east coast, Region B1 was expanded and split into two parts. The first 100 km (62 miles) inland (which includes Brisbane) is considered cyclonic based on the guidance in this document. Region B1 between 100 and 200 km (62 and 124 miles) inland is not considered cyclonic. The result of these adjustments are as follows:

Region D (cyclonic), which was 66 m/s (148 mph) is now 62 m/s (138 mph).
Region C (cyclonic), which was 56 m/s (125 mph) is now 52 m/s (117 mph).
Region B2 (cyclonic), which was 48 m/s (107 mph) is now 45 m/s (100 mph).
Region B1 (cyclonic), east coast for 100 km (62 miles) inland (including Brisbane), which was 48 m/s (107 mph) is now 43 m/s (96 mph).
Region B1 (non-cyclonic), on the east coast between 100 and 200 km (62 and 124 miles) inland, which was 41 m/s (92 mph) is now 43 m/s (96 mph).
Regions A0 to A5 (non-cyclonic), which was 41 m/s (92 mph) is now 36 m/s (82 mph).

Regarding Table AC1.1.1, there will be no change to the wind speeds in Fiji and Tonga as they are not part of Australia. For the other 4 islands:

Christmas Island is in Region B2 (cyclonic), which was 48 m/s (107 mph) is now 45 m/s (100 mph).
Cocos Islands is in Region C (cyclonic), which was 56 m/s (125 mph) is now 52 m/s (117 mph).
Norfolk Island is in Region B1, which was 48 m/s (107 mph) is now 43 m/s (96 mph).
Lord Howe Island is in Region A2 (non-cyclonic), which was 41 m/s (92 mph) is now 36 m/s (82 mph).

1.2 Hazard

Buildings are constructed with the purpose of protecting their contents from the elements. The goal of this data sheet is to prevent any breach of the building envelope that could let rain, wind-driven rain, or debris enter. The envelope can be breached for many reasons, including the following:

- Windows, doors, and lightweight wall cladding can be broken by windborne debris, such as tree branches, parts of wood-framed structures, and roof tiles or gravel from nearby roofs.
- Windows and doors and lightweight wall cladding can be blown in or out by the pressures exerted on the building.
- Roofing and roof deck materials can be torn and/or peeled off structures.
- Inadequately secured roof-mounted equipment can be blown out of place, damaging the roof cover.

The total wind load (exterior and interior) acts on components and cladding, creating load paths through the various components and back to the supporting members (beams, joists, purlins, girts, studs, etc.). The ability of the components and cladding to resist this wind load is based on the “weakest link” in this load path. Determining the proper design load is critical before the process of selecting an adequate roof assembly, doors, window protection, wall cladding, etc.

Several factors need to be considered, including the following:

A. Water infiltration into the building can and often does affect production operations negatively. Operations downtime results in loss of business revenue and adds to the total loss. Other facilities that depend on product flow from an affected facility may also suffer business interruption.

B. Failure of a roof system (or portion of a roof system) from wind uplift forces eliminates the remainder of its expected life span and necessitates immediate repairs and/or replacement.

C. Wind events that can cause roof or wall failure are typically concurrent with rainfall, which can cause extensive water damage to the building and contents. If rainfall does not occur during the failure, the possibility of such damage remains until the roof system is repaired or replaced.

D. It is more economical (over the expected life span of a roof system) to construct a roof and wall cladding system that will withstand anticipated wind forces than to build something less expensive that may require future repair or replacement of building components and contents.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Design Wind Pressures

Ratings Calculator in RoofNav calculates the roof wind pressures and the corresponding roof uplift ratings needed for various roof zones for the following conditions:

A. Gabled roofs for roof slopes up to 22.6° (5 per 12)

B. Other common roof shapes (as described in Section 3.2)

Ratings Calculator assumes a directionality factor (K_D) = 0.85, which is appropriate for most building shapes (for exceptions see Section 2.1.8), and an elevation factor (Ke) of 1.0.

When using Ratings Calculator, ensure the proper variables are input as described below including; the design wind speed (see Appendix C), surface roughness exposure (see Section 2.1.2 and Section 3.0), and potential exposure to windborne debris (see Section 2.4). For additional guidance regarding input required for internal and external fire ratings, see DS 1-29. For additional guidance regarding input required for hail ratings, see DS 1-34.

2.1.1 Select the design wind speed from the respective map or table in Appendix C. This wind speed is a 3-second gust wind speed representative of an open terrain (Surface Roughness Exposure C, see Section 3.2.2) at an elevation of 33 ft (10 m). Factors within this document are applied to adjust for other building heights and terrains.

For enhanced design for locations in regions that are prone to tropical cyclones (see Appendix A) including hurricanes, typhoons, and cyclones, consider guidance in 3.1.3 and Tables 3.1.3.1 and 3.1.3.2, before selecting the design wind speed.

For locations where the building owner or occupant is concerned about potential tornado exposure, see Appendix D for optional guidance.

2.1.2 Determine the Surface Roughness Exposure using guidance in Section 3.2.3.

2.1.3 Determine the roof height as follows:

A. Use the eave height for roof slopes ≤ 10°.

B. Use the mean roof height for roof slopes >10°.

C. Use guidance in Section 3.4 for less common roof shapes.

2.1.4 Design new buildings in their entirety to be enclosed. For existing buildings where cladding is to be replaced, determine the enclosure classification as either "enclosed," "partially enclosed," or "open" using guidance in Section 3.2.3.

For new construction, before the roof assembly is designed, the building designer should verify that:

A. All walls are adequate for the design wind pressure (see 2.2, 3.2 and 3.5), and

B. All wall opening protectives (e.g., dock and personnel doors, windows, louvers) are adequate for the design wind pressures and windborne debris, if applicable (see Section 2.4), and

C. Openings in exterior walls are limited, protected or distributed such that the criteria in 3.2.4 is met for an enclosed building.

2.1.5 Use a topographic factor (K_{ZT}) of 1.0 for ground slopes < 10% (6°). For steeper ground slopes, refer to DS 1-8. For locations in Hawaii, a topographic factor of 1.0 may be assumed for all installations as this is already considered in the Hawaii wind speed maps in this document. This exception applies only to Hawaii wind maps in this document. For other locations, a K_{ZT} greater than 1.0 may be required.

2.1.6 As an alternative to using Ratings Calculator, the ultimate pressure ratings for walls and roofs can be calculated using guidance in Section 3.2.

The pressure coefficients in Table 3.2.2a for low-slope (≤7º), gabled roofs should also be used for mono-slope roofs, with slopes ≤3º and saw-tooth roofs with slopes ≤10º.

NOTE: The pressure coefficients in Section 3.2 are intended for the design of components and cladding such as roof decks and their securement, above-deck roof components and wall panels, and assume an effective wind area (EWA) of ≤10 ft^2 (1 m^2).

For roof joists or purlins, or wall studs or girts, these design pressures may be reduced to account for their larger EWAs and lower wind pressure coefficients in accordance with ASCE 7 or similar standard outside the U.S. The primary building framing or MWFRS (main wind force resisting system) may be designed to ASCE 7 or other locally accepted code outside of the United States.

2.1.7 Use guidance in ASCE 7 or Section 3.4 to determine the design wind pressure for the following roofs:

A. Multi-gable roofs with slopes greater than 10°

B. Mono-slope roofs with slopes greater than 3°

C. Saw-tooth roofs with slopes greater than 10°

D. Arched roofs

2.1.8 Use a minimum directionality factor (K_D) of 0.85 for most commonly shaped buildings.

For circular domes and octagonal buildings, the building designer should use a minimum directionality factor (K_D) = 1.0 and calculate wind design pressures using wind speeds from this document and pressure coefficients from ASCE 7.

2.1.9 For roofs sloped greater than 45°(see Figures 3.4.6 A and B), including but not limited to mansard roofs (see Figure A2), use wind design pressures for the walls and roof as follows:

A. Use the external pressure coefficients for wall Zones 4 and 5 per Table 3.2.2e or Table 3.2.2f.

B. Use the peak roof height to determine q_z.

2.1.10 Use wind design pressures for circular cupola roofs (see Figures A1a. and A1b) based on wall Zone 4 per Table 3.2.2e or Table 3.2.2f. For other cupola roof shapes, such as hip-shaped, treat as a gabled roof.

2.1.11 For roof overhangs, do the following:

A. Design roof decks and above-deck components using ordinary roof design criteria.

B. Design soffits beneath the overhang using positive pressure criteria for walls.

C. Design the ends of the joists or purlins supporting the overhang for the combined loads per A and B, acting upward.

2.1.12 Multiply the wind pressure by an importance factor (I) of 1.15.

2.1.13 Multiply the design or allowable strength wind pressure by a safety factor of 2.0 to obtain the minimum ultimate wind rating for the assembly, except where noted with regard to use of the Eurocode. The intent is not to apply a safety factor of 2.0 to an ultimate wind pressure.

2.2 Exterior Walls

2.2.1 Design wall panels for wind pressures in accordance with section 3.0. Pressure coefficients used in this data sheet assume an effective wind area (EWA) of 10 ft^2 (1 m^2). Pressure coefficients may be reduced in accordance with ASCE 7-16, if a larger EWA can be substantiated.

2.2.2 When using panel walls, select FM Approved exterior wall panels listed in the *Approval* Guide for natural hazards exposure (FM 4881), where available. Select panels with wind pressure ratings that meet or exceed that needed based on Section 3.5, including a minimum safety factor of 2.0 and importance factor of 1.15 times the design wind pressures in accordance with this document. Refer to Sections 3.5.3, Windborne Debris Rating to identify the needed natural hazard ratings (NTC,TC, and TCM) and D.S. 1-34 for FM Approved Exterior Wall and Roof Hail Ratings.

In regions subject to windborne debris, provide panels that are also resistant to windborne debris.

2.3 Section Reserved for Future Use

2.4 Opening Protectives in Exterior Walls

2.4.1 Exterior Doors

2.4.1.1 Use Zone 4 or 5 wall pressures for exterior personnel doors and their hardware as recommended in this document, depending on the door location, using effective wind areas (EWA)as follows:

A. For walls ≤ 60 ft (18 m) high, use an EWAs = 10 ft^2 (1 m^2), or

B. For walls > 60 ft (18 m) high, use an EWA = 20 ft^2 (2 m^2).

Reductions for larger dock doors (not hardware) with larger EWA may be used as outlined in 2.4.1.2.

2.4.1.2 Use design pressures for dock doors based on the following:

A. For rolling steel dock doors, use a maximum EWA equal to the door width (up to a maximum of 20 ft [6.1 m]), times the door height (up to a maximum of 10 ft [3.05 m]). For larger doors, use ASCE 7.

B. For sectional dock doors (see Figure 2.4.1.2-1), use a maximum EWA = the door span (l) times the width of an individual door panel (w). For example, if the door has a span (l) of 8 ft (2.4 m), and the individual door panels have a width (w) of 2 ft (0.6 m), use an EWA = 16 ft^2 (1.8 m^2) for new construction. **EXCEPTION: If the door was satisfactorily tested as outlined in 2.4.1.3, the EWA may be based on guidance in 2.4.1.2A.**

2.4.1.3 Ensure sectional or rolling dock doors to be used in the following locations have been cycle pressure tested in accordance with the Florida Building Code Testing Application Standards (TAS) 201 and 203, ASTM standards E1886 and E1996, or ANSI/DASMA 115 where the design wind speed is at least 100 mph (45 m/s).

In addition conduct impact testing for the following locations:

- Where the design wind speed is at least 110 mph (49 m/s) within one mile of the coast

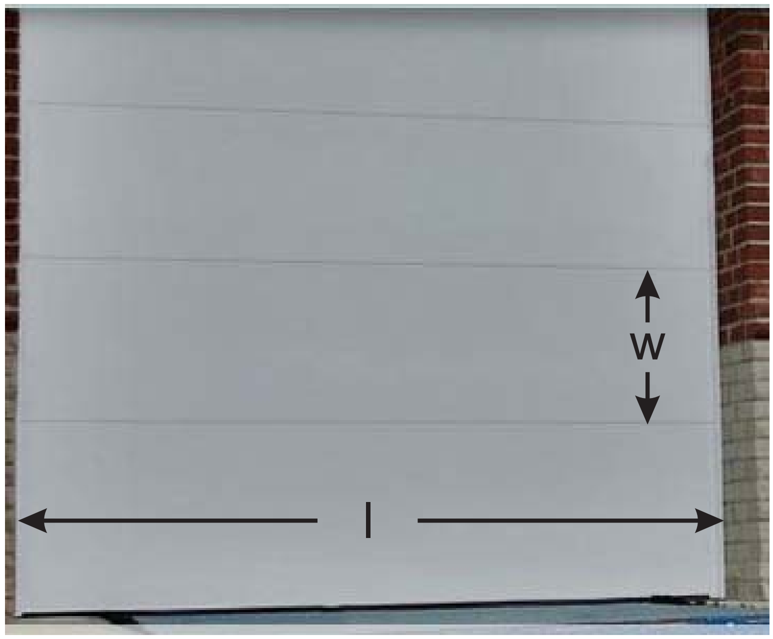


Fig. 2.4.1.2-1. Sectional dock door

- Where the design wind speed is at least 120 mph (54 m/s)

2.4.1.4 For locations not in tropical cyclone-prone regions, use dock doors that have either met the above criteria or passed uniform pressure tests using TAS 202, ASTM E330, ANSI/DASMA 108, or equivalent local test standard, if available.

2.4.1.5 Do not use sliding exterior doors in tropical cyclone-prone locations unless they have been satisfactorily tested for wind-driven rain in accordance with Section 2.4.2.4. Install sliding door latch mechanisms to release in an upward direction. Latches that release in a downward direction are prone to self-release from severe door vibrations during high wind pressure cyclic loading.

2.4.1.6 If existing dock doors are replaced with wind-rated doors, have the securement to and strength of the existing building framework analyzed by a licensed professional engineer practicing structural engineering (P.E. or S.E.), and have reinforcement provided as needed. If the original door was not properly wind rated, it is possible the framework it was secured to was not appropriate either.

2.4.2 Windows in Exterior Walls

2.4.2.1 Use ASTM E 1300 (or other comparable code or standard outside the United States) to ensure glass and glazing are resistant to the recommended allowable wind design pressures per this document. NOTE: This standard cannot analyze the effects of windborne debris, which must be determined by test as noted in Section 2.4.2.3.

2.4.2.2 Determine ultimate wind design pressures for windows based on the following:

A. For windows supported on only two opposite sides, determine the pressure based on an EWA = the window span between supports times the lesser of (a) the window width, or (b) 1/3 times the window span. For example, if a 3 ft (0.9 m) wide window spans 6 ft (1.8 m) to supports at its top and bottom, the EWA = 6 ft (1.8 m) times 2 ft (0.6 m) = 12 ft^2 (1.1 m^2).

B. For windows supported on all four sides determine the pressure based on an EWA = the total window area.

NOTE: ASTM E1300 determines the allowable wind pressure (AWP)for the glass, not the ultimate wind pressure (UWP). Aluminum mullions may be designed in accordance with Aluminum Design Manual (see Section 4.2), which requires a safety factor of 1.65 based on yield stress.

2.4.2.3 In the following locations, protect glazed openings exposed to potential windborne debris (small or large) with impact-resistant glazing system that has been satisfactorily tested per Florida Building Code Testing Application Standards (TAS) 201, 202, and 203, or ASTM standards E1886 and E1996 (for additional information, see Section 3.7).

A. For new installations in locations prone to tropical storms and where the design wind speed is ≥100 mph (45 m/s) on the wind maps or tables in Appendix C, and window openings are exposed to small windborne debris (such as roof aggregate including pea gravel or larger stone ballast), ensure the height of protection is in accordance with Section 3.7.

B. For new installations at locations prone to tropical storms where the design wind speed is ≥110 mph (49 m/s) on the wind maps or tables in Appendix C, and within 1 mile (1.6 km) from the coast or anywhere where the design wind speed is ≥120 mph (54 m/s) on the wind maps or tables in Appendix C, perform testing for large windborne debris:

1. within 30 ft (9.1 m) above grade, or

2. within 30 ft (9.1 m) above inadequately secured roofing materials or roof-mounted equipment on buildings within 100 ft (30 m) horizontally.

For more information, see the definitions of “**small windborne debris**” and “**large windborne debris**” in Appendix A.

Regardless of what design level is chosen for enhanced designs, use the guidance immediately above to determine the need for opening protection.

2.4.2.4 Use windows and related sealing systems for windows and wall penetrating air-conditioning units that meet the following criteria:

A. For non-tropical cyclone-prone regions, use systems that have been tested in accordance with ASTM E331 or ASTM E2268 (or other comparable test standard outside the United States).

B. For tropical cyclone-prone regions (A, B, and C), use systems that have been tested using the ASTM E2268 method, but using pressure levels in accordance with AAMA 520-12, where available. The pressure level listed in AAMA 520-12 to which the system should be tested is at least 85% of the allowable windward wall pressure, but need not exceed 42 psf (2.01 kPa). Also see Section 4.2, ASCE Pre-Standard for Performance-Based Wind Design.

2.4.3 Louvers in Exterior Walls

2.4.3.1 For exterior walls in locations in Tropical Cyclone Region A (based on applicable wind maps or tables in Appendix C)), use louvers tested to resist wind-driven rain in accordance with ANSI/AMCA 550-15 at the needed wind pressures based on this document.

2.4.3.2 In locations in Tropical Cyclone Region B (based on the applicable wind maps or tables in Appendix C) and within 1 mile of the coast; or in Tropical Cyclone Region C (based on the applicable wind maps or tables in Appendix C) where louvers are within 30 ft (9.1 m) above grade or within 30 ft (9.1 m) above inadequately secured roofing materials or roof-mounted equipment on buildings within 100 ft (30 m) horizontally, use louvers tested to resist large windborne debris in accordance with AMCA 540-13 or FBC PA 201; and cyclic pressure tested in accordance with FBC PA 203.

2.5 Width of Various Roof and Wall Corner Zones

2.5.1 Determine the plan dimensions for all of the roof and wall zones in accordance with Section 3.2. In addition, do the following:

A. Use Zone 3 for roof corners where the interior angle between exterior walls is <135º, such as for a pentagonal or hexagonal shaped building.

B. Use Zone 2 for roof corners where the interior angle between exterior walls is ≥135º, such as for an octagonal shaped building.

C. Use Zone 2 pressures for gabled roofs that would otherwise be in Zone 3, only if a minimum 3 ft (0.9 m) high parapet is provided throughout the entire perimeter of the roof. Partial parapets, such as those located at the corner areas only or those that are lower than 3 ft (0.9 m) in portions of the roof, do not qualify for this reduction.

D. Where roof elevation differences exist between abutting roofs, see Figures 3.2.2b and 3.2.2c.

2.6 Roof-Level Equipment and Surfacing

2.6.1 Have a licensed professional engineer practicing structural engineering (P.E. or S.E.) design anchorage and resistance to overturning for large roof-mounted equipment (e.g., HVAC unit) to withstand the wind speeds according to this data sheet acting on all exposed surfaces using the following equations for horizontal and vertical forces:

A. Horizontal forces: $F_H = q_H(GC_h)A_f$ (lb, N)

Where:

F_H = lateral force (lb, N) on rooftop structures and equipment located on buildings of any height and acting at the centroid of the equipment.

q_H = velocity pressure evaluated at mean roof height of the building per Equation 3.2.1a, psf (N/m^2). See Section 3.2.1.

(GC_h) = 1.9 for rooftop structures and equipment with A_f < (0.1BH) for rooftop equipment Otherwise, GC_h may be reduced linearly from 1.9 to 1.0 as the value of A_f is increased from (0.1 BH) to (BH).

B = width of the building (in the direction perpendicular to the wind direction) that equipment is on, ft or m.

H = height of the building roof, ft or m.

A_f = vertical projected area (wall area) of the rooftop structure or equipment on a plane normal to the wind direction, ft^2 (m^2).

B. Vertical forces: $F_V = q_H(GC_v)A_r$ (lb, N)

Where:

F_V = vertical uplift force on rooftop structures and equipment, lb (N).

q_H = velocity pressure evaluated at mean roof height of the building per Equation 3.2.1a, psf (N/m^2), see section 3.2.1.

(GC_v) = 1.5 for rooftop structures and equipment that are mounted flush with the roof surface, and 0.8 for equipment elevated above the roof between 0.5 and 1.5 times the height of the equipment with A_r < (0.1BL). GC_r may be reduced linearly from 1.5 to 1.0 as the value of Ar is increased from (0.1BL) to (BL).

A_r = horizontal projected area (roof area) of the rooftop structure or equipment, ft^2 (m^2).

L = horizontal dimension of the building measured parallel to the wind direction, ft, m.

Exception for elevated equipment meeting the following criteria:

When $0.5S \leq X \leq 1.5S$, use $GC_v = 0.8$

Where:

X = the height of a clear opening between the top of the roof and the underside of the equipment (ft, m).

S = the height of the equipment as measured from the bottom face of the equipment to the top face of the equipment (ft, m).

A_r = horizontal projected area (roof area) of the rooftop structure or equipment, ft^2 (m^2).

L = horizontal dimension of the building measured parallel to the wind direction, ft, m.

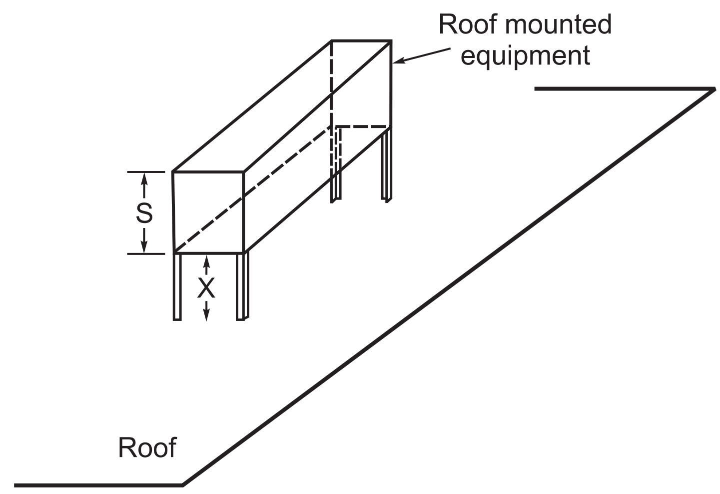


Fig. 2.6.1 Anchorage of roof-mounted equipment

2.6.2 Do not use gravel surfacing of any type on installations in Tropical Cyclone Regions A, B, or C (see Appendix A and the coastal portions of relevant wind maps in Appendix C) or where prohibited by Data Sheet 1-29. Use FM Approved roof covers that do not require gravel in these areas.

2.6.3 Use FM Approved skylights (see the *Approval Guide*). FM Approved skylights are rated in a similar manner as FM Approved roof systems. Ensure the rating of the skylight matches the rating required for the specific zone of the roof in which it will be installed. Do not install skylights where the uplift resistance of the skylight is less than the needed uplift pressure of the roof. Also, select FM Approved skylights that are rated for the needed hail exposure in accordance with Data Sheet 1-34.

2.6.4 For all new installations of piping and conduit located on top of a roof, have a licensed professional engineer practicing structural engineering (P.E. or S.E.) verify that adequate securement to the roof deck or framing is provided for wind resistance.

2.6.5 Secure appurtenances for roof-mounted equipment (e.g., intake and exhaust hoods, cowlings) in accordance with US Federal Emergency Management Association guidance (FEMA 549). For additional information, follow the link below or see Section 4.2:

https://www.fema.gov/

2.6.6 When maintenance is provided on roof-mounted equipment that requires removal of components, such as hoods and related fasteners, install all fasteners that were provided in the original installation after the work has been completed.

2.7 Wind Tunnel Tests

2.7.1 Use wind design pressures or pressure coefficients for tall (over 656 ft [200 m]) or unusually shaped buildings (those not covered in this document, ASCE 7, the Eurocode, or other local code or standard) based on atmospheric Boundary Layer Wind Tunnel (BLWT) tests in accordance with ASCE 49 or other similar local standard. Use other related design assumptions in this document. Aerospace wind tunnels should not be used. Design pressures based on BLWT tests should not be reduced below the following percentage of prescriptive pressures:

A. The design pressure for all roof zones **should be at least 80% of the Zone 1** prescriptive required pressure using pressure coefficients and wind speeds from this document.

B. The design pressure for all wall zones **should be at least 80% of the Zone 4** prescriptive required pressure using pressure coefficients and wind speeds from this document.

Where specific criteria in ASCE 7 has been met, the 80% minimum in A and B may be reduced to 65%.

Existing tests based on ASCE 7 may also be accepted.

2.8 Use of the Eurocode

Locations within European Committee for Standardization (CEN) member nations that have adopted and follow the Eurocode as their national standard may use Eurocode 1, *Actions on Structures*, Parts 1-4: General Actions-Wind Actions, in lieu of this data sheet to determine wind loads, with the following exceptions:

2.8.1 Do not use Eurocode Terrain IV. Conduct atmospheric boundary layer wind tunnel tests (BLWT) for tall buildings (>200 m, 656 ft high) in urban areas of Europe, or for buildings with irregular shapes.

For buildings less than 200 m or 656 ft high, use either a prescriptive design using whatever terrain (other than Eurocode Terrain IV) is appropriate, or wind tunnel modeling.

2.8.2 Use the external pressure coefficients for 1 m^2 (10 ft^2) for components and cladding (c_{PE}, 1).

2.8.3 Do not use a 10-minute mean wind speed of less than 22.5 m/s (50 mph), when using the EuroCode. Use an actual design wind speed reflecting a 10 minute mean wind speed, effective at 10 m (33 ft) in height, in open terrain with a minimum mean recurrence interval (MRI) of 50 years. The source for this information can be one of the following:

A. The Annex to the Eurocode for the country in question, if it is available, or

B. The wind map for Europe in this document represents fastest mile wind speeds as adjusted to a 10-minute mean wind speed using Table AC1.3.

2.8.4 Use a minimum resultant safety factor (or net load factor, ultimate resistance divided by the design pressure) of 2.0 for the securement of the deck and above-deck roof components. Use a minimum safety factor or net load factor of 2.0 for failure modes related to the securement of metal wall panels.

2.8.5 One of the following may be done to account for the higher wind pressures in the perimeter and corner areas:

A. Use wind design pressures for the field, perimeter and corner areas based on the Eurocode, or

B. Use wind design pressures for the field-of-roof as determined by the Eurocode and provide prescriptive enhancements for the securement of above-deck roof components and metal deck securement for the perimeter and corner areas per DS 1-29 or DS 1-31.

2.8.6 Do not credit parapets for reducing roof design uplift pressures unless the parapet height (h_P) is at least 3 ft (0.9 m). In addition, use design pressures based on the Eurocode that are at least equal to that required for an h_P/h ratio of 0.025, regardless of the actual ratio.

2.8.7 Use Figure 30.3-7 of ASCE 7-16 for external pressure coefficients (GC_P) for domed roofs with an EWA of 10 ft^2 or 1 m^2 (CPE,1).

2.8.8 Design all structural framing, including beams, columns, trusses, purlins, and girts, using load factors and capacity-reduction factors specified in the Eurocode.

2.8.9 Use Eurocode factors that are modified by National Annexes only if they make the design more conservative.

2.9 Emergency Power Systems

2.9.1 Provide emergency power systems and fuel supplies in tropical cyclone-prone areas adequate to fully power both of the following:

A. All equipment required for refrigeration or climate control of valuable perishable items, and

B. All equipment important for vital operations.

For details regarding the design and installation of generators and fuel supplies, see DS 5-23.

2.9.2 Design the equipment or structures housing emergency power systems to resist wind pressures in accordance with this document.

2.9.3 Ensure emergency power systems can provide service for the extent of the power loss. Size diesel fuel tanks assuming one pint per horsepower (1/3 L per kW) per hour of expected operation.

2.9.4 Follow guidance in Data Sheet 5-23 with regard to the following:

A. The operation and protection of emergency power systems

B. The arrangement and protection of fuel supplies feeding emergency power systems

2.9.5 Provide protection and fire separation for equipment and fuel supplies in accordance with DS 7-88, *Ignitable Liquid Storage Tanks*.

2.10 Wind Emergency Procedures

2.10.1 Develop a wind emergency response plan (WERP) in accordance with DS 10-1.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Wind Forces

The wind uplift forces on roofs and walls vary, depending on many factors, including wind speed, building geometry, surrounding ground terrain, topographic effects and enclosure classification. These factors are considered in this document.

When the wind strikes a building, the resultant uplift force acting on the roof system is the sum of the negative pressure above the roof and the positive internal building pressure (Figure 3.1). For buildings with large or inadequately protected openings, the internal pressure is considerably higher. For a given building and wind speed, the internal pressure is considered constant across the entire roof. External pressure components vary significantly for different areas of the roof or wall.

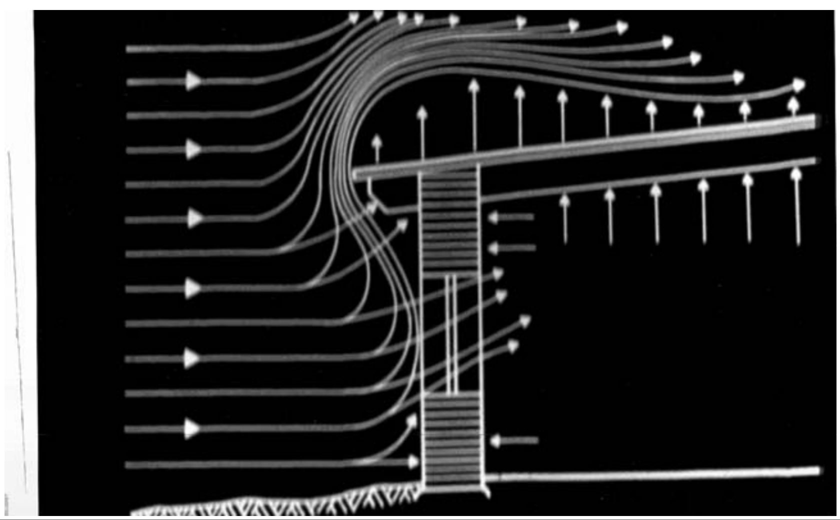


Fig. 3.1 Section view, wind acting on a roof

The wind exerts varying negative (suction) forces on different areas of the roof (Figures 3.2.2a through f). For simplicity, the roof can be divided into three areas: corners, perimeter, and roof field. The perimeter and corners are exposed to higher uplift forces than the roof field. The maximum uplift force occurs at the corners when the wind blows at an angle of about 45° to the roof. The maximum uplift force at the windward roof perimeter occurs when the wind blows at 90° to the perimeter. Actual pressure coefficients for the corners and perimeter vary depending opening protection and building geometry. The reason for the higher forces in these areas is the wind speed increases at the building edge as the wind flows over the structure.

To compensate for the increased pressures at the roof corners and perimeter, additional roof component fastening over the FM Approval requirements is recommended in these areas.

Wind can damage roofs in a number of ways. Types of damage include the following:

- perimeter flashing removed or loosened
- roof covering and/or insulation removed

- roof covering and/or insulation lifted and dropped back into place
- structural roof deck panels dislodged or lifted
- roof covering damaged by impact from wind blown objects
- dislodged roof protrusions, such as vents, skylights and pipes
- roof deck delamination within itself such as can occur with improperly installed lightweight insulating concrete.

Uplift damage to the roof deck usually results in significant additional damage to above-deck components. This damage can spread a considerable distance beyond the damaged deck even if the above-deck components are properly secured. After a small area of deck becomes dislodged, wind can act on the loose edges of the roof cover and insulation. The wind can then peel the cover from the deck.

Other damage that can result are windows, doors, wall cladding blown in or out, and windows broken from windborne debris. When wall openings exist or are created during the windstorm, higher internal building pressures can result. Rain infiltration into the building also occurs. Any or all of these kinds of damage can occur in one windstorm. Even if windows remain intact, wind-driven rain around windows can cause extensive damage to the building's interior and contents. This is particularly true with sliding patio doors found in hotels, apartments, and condominiums.

Damage to the structural frame of a building seldom occurs during a windstorm. Yet, a very small breach in the building envelope can destroy a large area of the interior. For this reason, keeping the building envelopesealed is one of the most effective ways of preventing windstorm damage to a facility.

3.1.2 Design Wind Speeds

The design wind speed used should be based on the greater of that from the applicable wind map or table in Appendix C, or selected from Section 3.1.3 considering Table 3.1.3.1 or Table 3.1.3.2. When using the wind maps, use the exact wind speed for the band within which the building is located; do not interpolate.

The use of safety factors and importance factors helps account for the following:

- Actual wind speeds in excess of the design wind speeds
- Design errors
- Defects in material or workmanship
- Adverse effects due to aging of cladding materials

The basic wind speed has been increased over neighboring regions by approximately 10% (4.5 m/s) in areas exposed to extreme local winds. In the United States and Canada this would include such effects as the Santa Ana, Chinook, Columbia River Gorge, and Wasatch Mountain winds. Applicable areas include the Special Wind Regions shown on some of the wind speed maps. Where local jurisdictions require higher design wind speeds, use those. Make appropriate increases for other areas exposed by high local winds if justified by local records.

3.1.3 Enhanced Designs for Regions Prone to Tropical Storms Including Hurricanes, Typhoons and Cyclones

Select a building design level in Table 3.1.3.1 that reflects the importance of the building. Consider the value of the building and its contents and the value of preventing an interruption to activities inside the building. Consider using an Enhanced Design I or II for buildings in hurricane, tropical cyclone or typhoon-prone regions. These designs can greatly reduce damage allowing earlier resumption of operations, often as soon as employees return and utilities are restored.

Table 3.1.3.1 Optional Building Wind Design - Enhanced Design I and II

Design Level	*Design Criteria*	*Expected Hurricane Damage*
Minimum Acceptable Design	Design the entire building[1] and important structures for the basic wind speeds and other related guidance per this document.	Negligible damage from winds that do not exceed the basic wind speed. Extensive damage and delay before building is functional from winds that considerably exceed the basic wind speed.
Enhanced Design I	Enhance the components that are more vulnerable to wind damage[2] to resist design pressures that are higher than the basic wind design. See Table 3.1.3.2. Ensure other components meet local code.	Negligible damage from winds that do not exceed the basic wind speed. Moderate to severe damage to components that are unimproved, or supported by unimproved components, and moderate to severe delay before building is functional from winds that do not exceed the actual design wind speed.
Enchanced Design II	Design the entire building[1] and important structures for wind pressures that are higher than the basic wind pressures. See Table 3.1.3.2.	Negligible damage from winds that do not exceed the basic wind speed. Minimal damage and delay before building is functional from winds that do not exceed the actual design wind speed.

[1] This includes above-deck roof components, perimeter flashing, roof deck span and securement, wall cladding and opening protectives,and roof mounted equipment. All framing and foundations should be designed per local code, but using wind speeds from this document. Refer to D.S 1-29 for additional information on roof design.
[2] This includes above-deck roof components, perimeter flashing, roof deck span and securement, wall claddings, opening protectives.

Wind maps in Appendix C provide the minimum acceptable wind design criteria. Those for the United States are based on the American Society of Civil Engineers (ASCE) 7-05, *Minimum Design Loads for Buildings and Structures*. These minimum wind speeds as elsewhere in the world, provide a basic level of protection to all buildings and have protected most buildings from collapse and major structural damage.

However, the wind speeds of some historical hurricanes have exceeded these minimum design wind speeds in some areas, leading to severely damaged buildings that are not useable for many months. Typically, observed damages are failures of the building envelope: roof flashings and coverings, roof decks, wall claddings, doors, and windows.

Table 3.1.3.2 Wind Speeds Associated with Various Hurricane Categories as Used by the U.S. National Weather Service

Saffir-Simpson Hurricane Category	*One Minute Sustained Wind Speed,[1]mph (m/s)*	*Basic 3 – sec gust wind speed,[2] mph (m/s)*	*Average or Recommended Design Speed, mph (m/s)*
Category 1	74-95 (33.1-42.5)	82-108 (37-48)	108 (48)
Category 2	96-110 (42.6-49.2)	108-130 (48-58)	120 (54)
Category 3	111-130 (49.3-58.1)	130-156 (56-70)	145 (65)
Category 4	131-155 (58.2-69.3)	156-191 (70-85)	170 (78)
Category 5	> 155 (> 69.3)	> 191 (> 85)	200 (90)

[1] Over open water.
[2] Over land.

3.2 Wind Pressure Determination

3.2.1 Calculating Basic Wind Pressure

The roof perimeter and corners are exposed to higher uplift forces than the field of the roof. The maximum uplift force occurs at the corners when the wind blows at an angle of about 45° to the roof (roughly along the diagonal). The maximum uplift force along the windward roof perimeter occurs when the wind blows at 90° to the perimeter. Actual pressure coefficients for the corners and perimeter vary depending on the building height, parapet height, roof slope, etc.

Use Equation 3.2.1a to determine the basic wind velocity pressure at a given height.

$q_h = 0.00256 K_Z K_{ZT} K_D K_E V^2 I$ (Eqn. 3.2.1a)
$q_h = 0.613 K_Z K_{ZT} K_D K_E V^2 I$ (Eqn. 3.2.1a, metric)

Where:

q_h = the basic velocity pressure calculated at height h, psf (N/m^2).

K_Z = velocity pressure coefficient (see **Table 3.2.2g** or ASCE 7)

K_{ZT} = topographic factor, use 1.0 for all flat terrains with ground slopes <10°. For steeper terrains, use DS 1-8 or ASCE 7.

K_D = directionality factor, use 0.85, except use 1.0 for cylindrical structures.

K_E = elevation factor, use 1.0 for locations near sea level, or conservatively use 1.0 for other locations. For higher elevations, see Table 3.2.2h or ASCE 7-16.

V = design wind speed per the respective wind map in Appendix C at 33 ft (10 m) above grade in Exposure C (open terrain), mph (m/s).

I = importance factor of 1.15.

Use Equation 3.2.1b to determine the design pressure for the specific zone of the building.

$p = [(GC_P) - GC_{Pi}]\ q_h$ (Eqn. 3.2.1b)
$p_u = p(SF)$

Where:

GC_P = external pressure coefficient. This value will vary depending on the roof area in question and its slope, the wall area in question and the height. For values, see Section 3.2.2 and referenced tables and figures.

GC_{Pi} = internal pressure coefficient = +/- 0.18 for enclosed buildings and +/- 0.55 for partially enclosed buildings. For differentiation, see Section 3.2.4.

p_u = the nominal ultimate rating of the cladding (round up for assembly selection) considering the importance factor and safety factor.

SF = safety factor of 2.0.

NOTE: The +/-signs for GC_{Pi} are directional. The values are summed so as to result in the largest numerical value.

3.2.2 Wind Zones of Buildings

This document provides calculation methods for wind loads on roofs and walls. It is extremely important to recognize that wind blowing over a roof exerts varying uplift forces on different areas of the roof and walls.

For low-slope roofs (≤7° and h ≤ 60 ft (18 m), or h < 90 ft (27 m) and h/w ≤1.0), the roof can be divided into four zones as a function of h, where h = the mean roof height. See Figure 3.2.2a and Table 3.2.2a for dimensions and coefficients.

Zone 3: The roof corners, with L-shaped dimension = 0.6h by 0.6h by 0.2h.

Zone 2: The roof perimeter, between the corners, with rectangular dimension and width = 0.6h from roof edges.

Zone 1: The field-of-roof (area inside corners and perimeter corners) up to a distance of 1.2h from the edge of the roof.

Zone 1’: Applies to relatively wide buildings (>2.4h) and covers the remaining roof area inward from Zone 1.

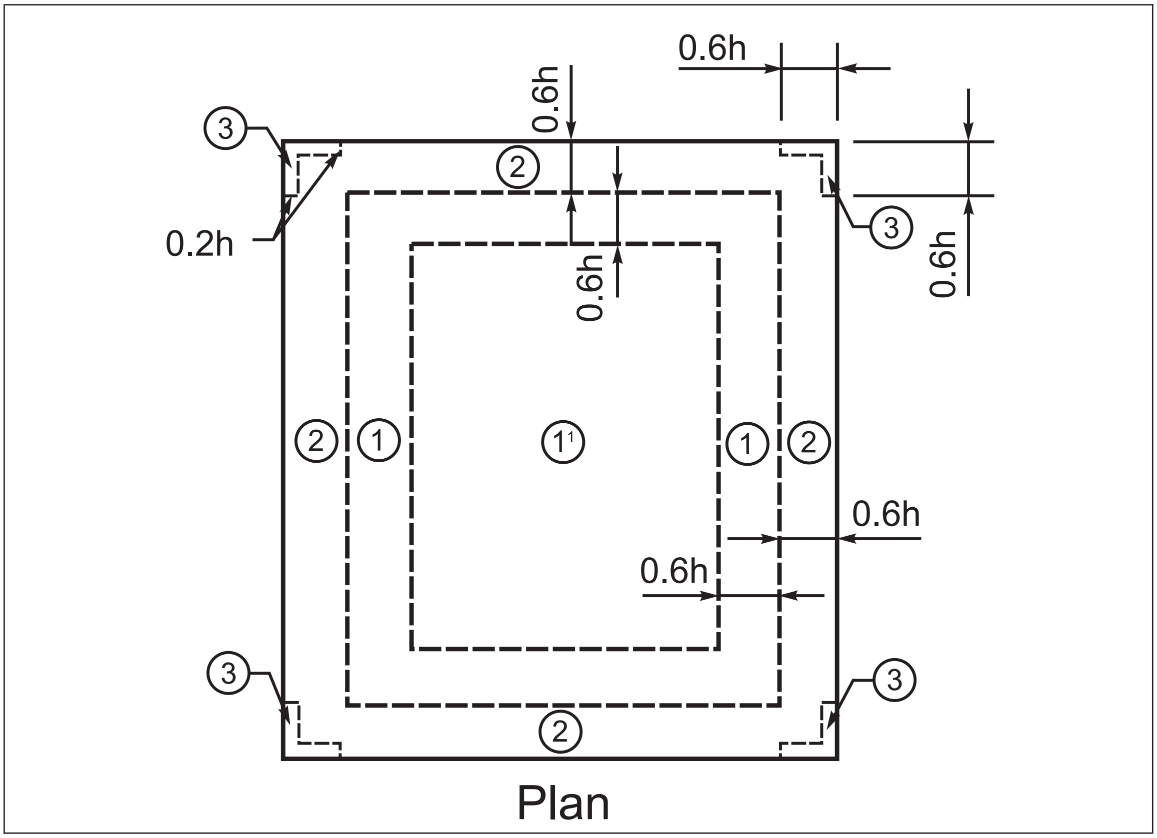


Fig. 3.2.2a Roof zones for roof slopes ≤7°

Table 3.2.2a. GC_p for Roof Slopes ≤7° [1, 2]

Zone	GC_P
3	- 3.2
2	- 2.3
1	- 1.7
1'	- 0.9

1. For all roofs ≤60ft (18 m) high, or roofs <90 ft (27 m) high where h/w ≤1

2. If a parapet with a minimum height of 3 ft (0.9 m) is provided around the entire perimeter, Zone 2 values for GC_P may be used in Zone 3.

NOTE: Where the difference in roof elevations between abutting buildings or building sections is greater than or equal to 10 ft (3.0 m), treat abutting areas of the higher building as perimeter and corner areas in accordance with Figure 3.2.2b. If the difference in roof elevations between abutting buildings is less than 10 ft (3.0 m), follow guidance in Figure 3.2.2c. The buildings have to be abutting for Figure 3.2.2c to apply, and they do not abut if there is any horizontal separation.

Table 3.2.2b. GC_p for Roof Slopes >7°, ≤ 20°

Zone	GC_p
3r	- 3.6
2n,2r,3e	- 3
1,2e	- 2.0

Walls are divided into two zones:

Zone 5: Wall corner strips.

Zone 4: The wall area between corner strips.

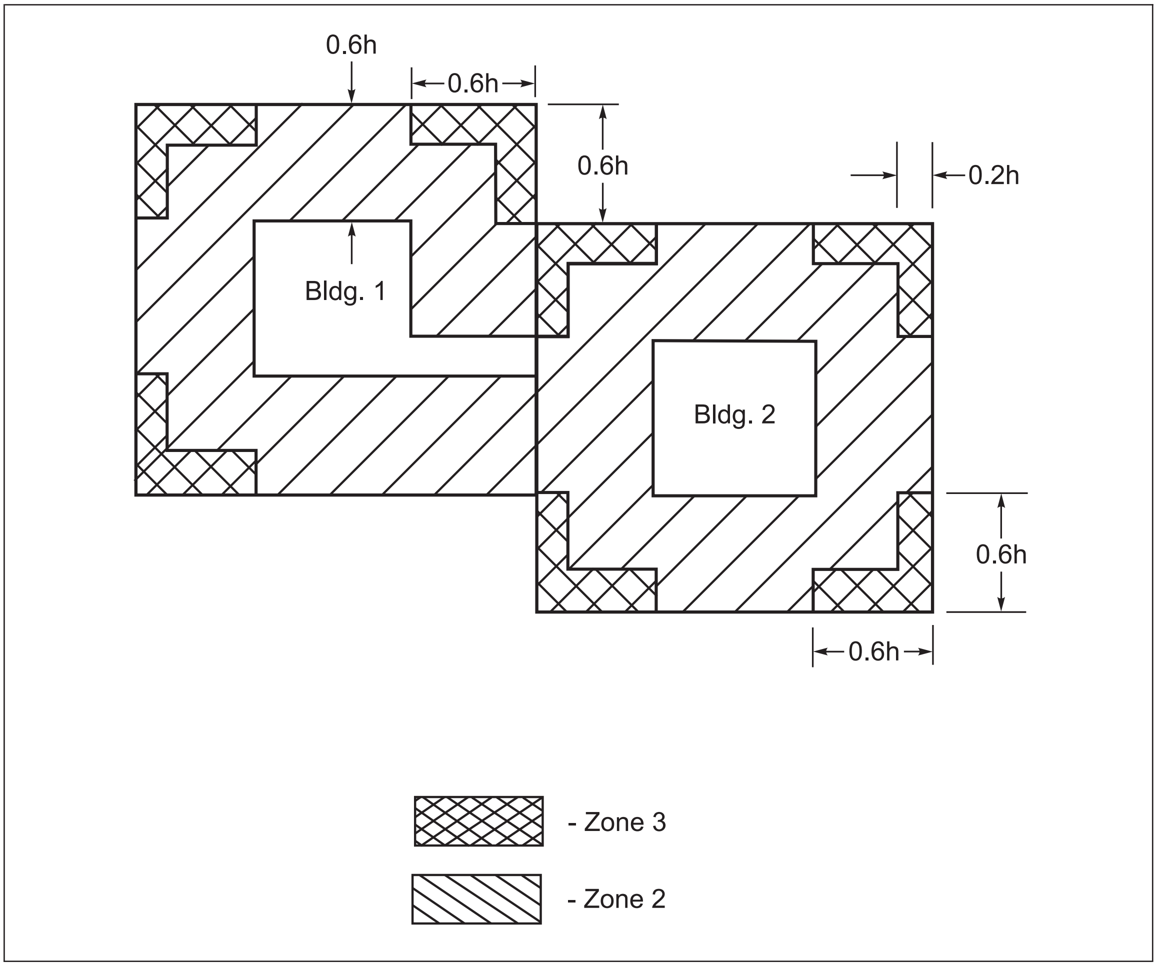


Fig. 3.2.2b. Adjoining low-sloped roofs where height of building 2 is greater than or equal to 10 ft (3 m) higher than Building 1 (NOTE: For roof slopes ≤7, Zone 3 is L-shaped.)

Table 3.2.2c. GC_p for Roof Slopes >20°, ≤27°

Zone	*GC_p*
3r*	- 2.75
2n,2r,3e	- 2.5
1,2e	- 1.5

* GC_p = - 3.6 @ EWA = 4 ft^2. For Zone 3r.
For EWA = 10 ft^2., GC_p = - 2.75.

See Figure 3.2.2e and Table 3.2.2e, for pressure coefficients, which depend on roof height and height to width ratio.

For roof slopes >7°, see Figure 3.2.2d and Tables 3.2.2b, 3.2.2c, or 3.2.2d, depending on the slope. The width (a) of the various perimeter and corner zones for these steeper sloped roofs equals the lesser of 10% of the building width or 0.4h, but not less than 4% of the width or 3 ft (0.9 m).

Table 3.2.2d. GC_p for Roof Slopes >27°, ≤45°

Zone	*GC_p*
3e*	- 2.5
2n,3r	- 2
1,2e,2r	- 1.8

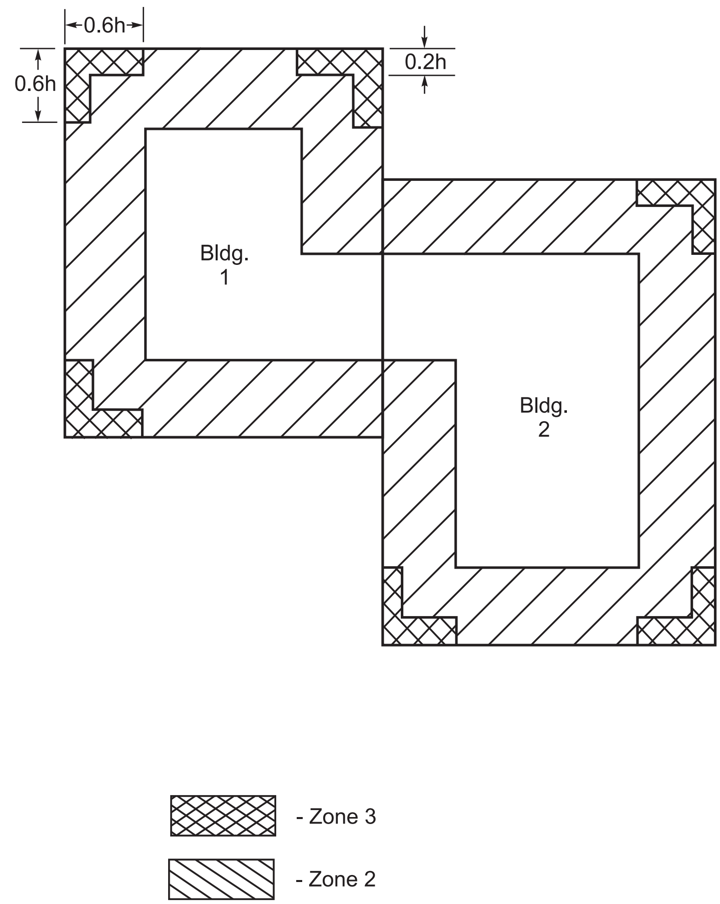


Fig. 3.2.2c. Adjoining low-sloped roofs where height of building 2 is less than 10 ft (3 m) higher than building 1 (NOTE: For roof slopes ≤7, Zone 3 is L-shaped.)

* For Zone 3e, GC_p = - 3.2 for EWA = 2 ft^2. For EWA = 10 ft^2, GC_p = -2.5. These larger GC_p values should be used for steep sloped roofing materials such as concrete or clay tile, asphalt shingles, or slate.

3.2.2.1 Determining Wall Pressures

Determine wall pressures for buildings as follows:

A. Determine the individual internal pressure coefficient based on the enclosure classification.

B. Determine the external pressure coefficient from Table 3.2.2e and Table 3.2.2f, using the building height, plan dimensions (if applicable), and roof slope.

C. Multiply the sum of those coefficients by the basic pressure (q_h). The signs for the coefficients should result in the highest possible total value. A negative sign means the force is outward. A positive sign means the force is inward.

D. Note that negative wall pressure (also known as outward or suction pressure) is a function of the mean roof height of the building. Negative pressures will always be higher than positive pressures.

E. Positive or inward pressure increases with building height, although for design simplicity the mean roof height is typically used. For buildings that are partially enclosed, the height of the highest opening will influence the internal pressure component.

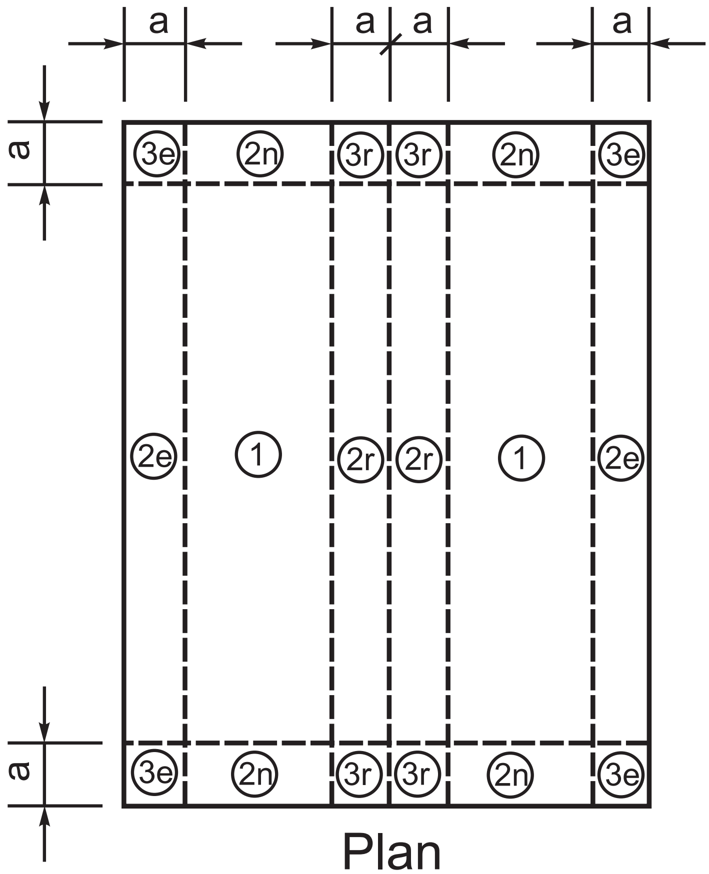


Fig. 3.2.2d Roof Zones for Roof Slopes >7°

Table 3.2.2e. Values of GC_P for Wall Zones 4 and 5

Building Height	*Roof Slope*	*Zone 4*	*Zone 5*
H ≤ 60 ft (18 m); or 60 ft <H <90 ft (27.4 m) for h/w ≤ 1.0	≤10°	-0.99	-1.26
		+0.9	+0.9
	>10°	-1.1	-1.4
		+1.0	+1.0
H > 60 ft (18 m) for h/w >1.0; or H ≥ 90 ft (27.4 m) for h/w ≤1.0	All slopes	-0.9	-1.8
		+0.9	+0.9

Note: The width (a) of Zone 5 is the lesser of 10% of the lesser plan dimension, or 0.4h, but not less than 4% of the lesser plan dimension or 3 ft (0.9 m).

Table 3.2.2f. Values of GC_P for Roofs (Θ ≤ 7°) on Tall Buildings

Building Height	*Zone 1*	*Zone 2*	*Zone 3*
H > 60 ft (18 m) for h/w > 1.0; or H ≥ 90 ft (27.4 m) for h/w ≤ 1.0	-1.4	-2.3	-3.2

1. For roofs with greater slopes, use GC_P values for low or mid-rise buildings in Tables 3.2.2b through d. Zone 3 dimensions = 2a x 2a x a, where a = 10% of the lesser plan dimension, but not less than 3 ft (0.9 m). Zone 2 width = a.
2. If a parapet with a minimum height of 3 ft (0.9 m) is provided around the entire perimeter, Zone 2 values for GC_P may be used in Zone 3.

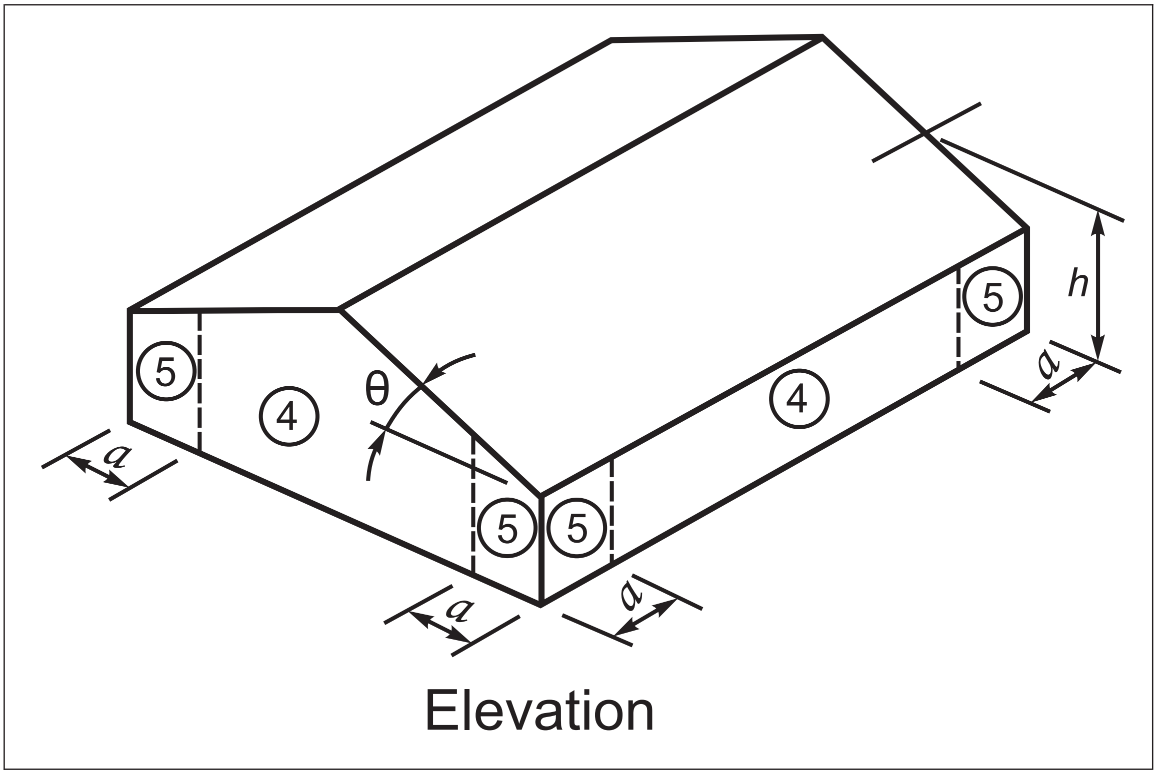


Fig. 3.2.2e. Wall zones for buildings ≤60 ft (18 m) high, or Buildings <90 ft (27 m) where h/w ≤ 1

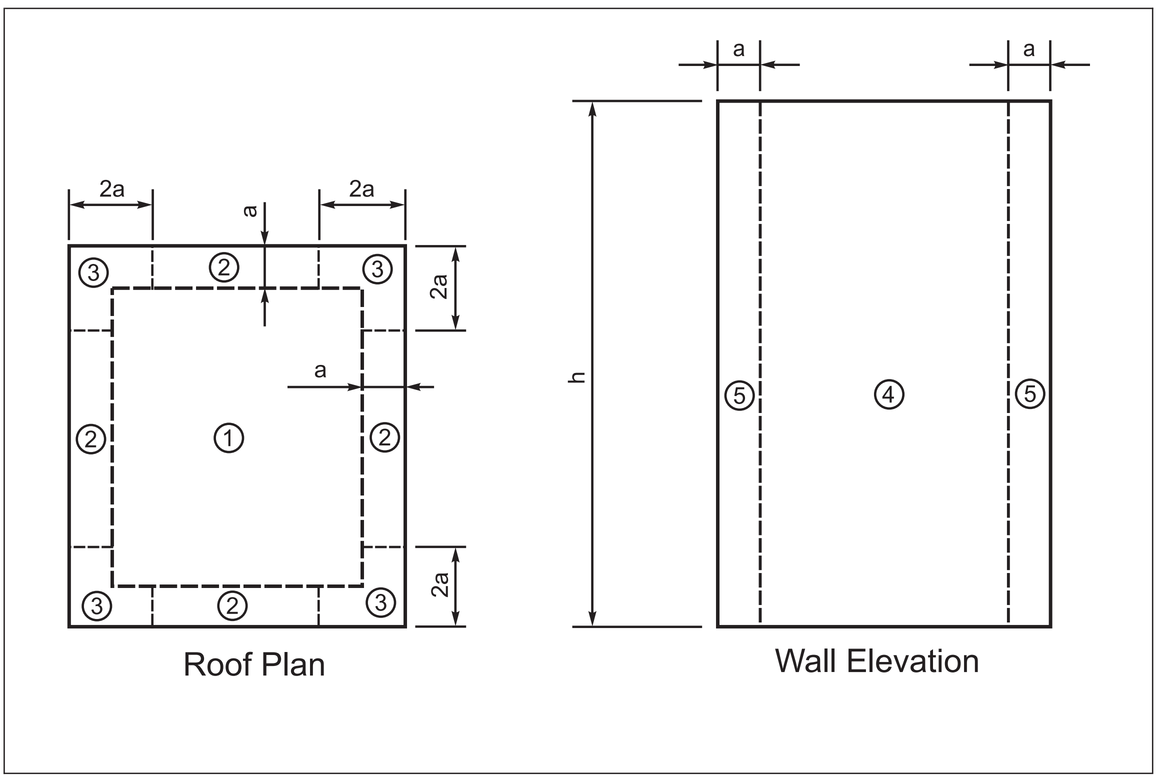


Fig. 3.2.2f. Roof and wall zones for buildings ≥90 ft (27 m) high, or buildings >60 ft (18 m) where h/w > 1

Table 3.2.2g. Velocity Pressure Coefficient, K_Z

Height Above Ground Level, z		*Exposure*		
ft	m	B	C	D
0-15	0-4.6	0.57	0.85	1.03
20	6.1	0.62	0.90	1.08
25	7.6	0.66	0.94	1.12
30	9.1	0.70	0.98	1.16
40	12.2	0.76	1.04	1.22
50	15.2	0.81	1.09	1.27
60	18	0.85	1.13	1.31
70	21.3	0.89	1.17	1.34
80	24.4	0.93	1.21	1.38
90	27.4	0.96	1.24	1.40
120	36.6	1.04	1.31	1.48
140	42.7	1.09	1.36	1.52
160	48.8	1.13	1.39	1.55
180	54.9	1.17	1.43	1.58
200	61	1.20	1.46	1.61
250	76.2	1.28	1.53	1.68
300	91.4	1.35	1.59	1.73
400	121.9	1.47	1.69	1.82
450	137.2	1.52	1.73	1.86
500	152.4	1.56	1.77	1.89

Table 3.2.2h. Ground Elevation Factor (K_E)

Elevation of Ground Above Mean Sea Level, ft	*Elevation of Ground Above Mean Sea Level, m*	*K_E*
≤0	≤0	1.0
1000	305	0.96
2000	610	0.93
3000	014	0.90
4000	1219	0.86
5000	1524	0.83
≥6000	≥1829	0.80

Note: K_E can be interpolated for intermediate elevations or can be determined using the formulae in ASCE 7-16.

Example 3.2.2

A proposed building in the United States is to have a 1.2° roof slope and is to be 200 ft by 300 ft by 30 ft high. The building is to be located **near sea level, on flat terrain** (<6° ground slope) in **Exposure C**. This location is in a **tropical cyclone-prone region (TC)**. All wall panels, doors, and windows will be protected against all recommended wind exposures to this site, so the building can be considered “enclosed.” This area has a design wind speed of 110 mph (49 m/s). Determine the ultimate pressure ratings needed for all four roof zones and the two wall zones, as well as the dimensions for each zone.

Solution 3.2.2

First, determine the basic wind pressure, q_h, using Equation 3.2.1a.

$q_h = 0.00256 K_Z K_{ZT} K_D K_E V^2 I$

Where:

K_Z = 0.98 (from Table 3.2.2g, Exposure C), K_{ZT} = 1.0 (flat terrain), K_D = 0.85 (rectangular building), K_E = 1.0 (near sea level), V = 110 mph, I = 1.15.

q_h = 0.00256(0.98)(1.0)(0.85)(1.0)(110)2(1.15) = 29.7 psf.

GC_{pi} = +/-0.18 (enclosed, same throughout all zones). NOTE: this is added to GC_P to create maximum inward or outward load conditions.

GC_p (roof areas from Table 3.2.2a) = -3.2 (Zone 3), -2.3 (Zone 2), -1.7 (Zone 1), -0.9 (Zone 1').

GC_p (wall areas from Table 3.2.2e) = -0.99 (Zone 4) and -1.26 (Zone 5).

Using Equation 3.2.1b, determine the maximum negative (upward or outward) pressures for each zone. Answers are summarized in Table 3.2.2i; needed wind ratings are rounded up based on rated pressure levels available.

$R_{NA} \geq R_{NR}$ nominal ultimate resistance, which is R_{NR} rounded up to the next highest 15 psf for roofs and 5 psf for walls, for comparison to wind-rated assemblies in Roof*Nav* (for roofs) or the *Approval Guide* (for walls).

Table 3.2.2i. Summary for Example 3.2.2

Zone	*q_h, psf*	*GC_{Pi}*	*GC_p*	*(GC_p − GC_{Pi})*	*SF*	*p, psf*	*R_{NA}, psf*[1]	*Zone Dimensions from edge, ft (m)*
3	29.7	+0.18	−3.2	−3.38	2.0	201	210	18 x 18 x 6 ft (5.5 x 5.5 x 1.8)
2	29.7	+0.18	−2.3	−2.48	2.0	147	150	0 − 18 (0 − 5.5)
1	29.7	+0.18	−1.7	−1.88	2.0	112	120	18 − 36 (5.5 − 11)
1'	29.7	+0.18	−0.9	−1.08	2.0	64	75	> 36 (> 11)
5	29.7	+0.18	−1.26	−1.44	2.0	86	90	0 − 12 (0 − 3.7)
4	29.7	+0.18	−0.99	−1.17	2.0	69.5	70	>12 (>3.7)

[1]R_{NA} = p rounded up to the next highest 15 psf for roofs and 5 psf for walls, for comparison to wind rated assemblies in Roof*Nav* or the *Approval Guide*, for roofs and walls, respectively.

3.2.3 Determining Surface Roughness Exposure

The descriptions below are based on information in ASCE 7. While information on this subject in the "Provisions" of ASCE 7 is relatively brief, the designer must refer to the additional information provided in the "Commentary" of that document. This is particularly important when the localized exposure is not obvious or may be interpreted as more than one of the following exposure categories (such as B or C).

3.2.3.1 Exposure Category B

For Exposure Category B to be used:

A. The exposing terrain should include urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

B. Use of this exposure category should be limited to those areas for which the above terrain prevails in all directions for a distance of at least 2600 ft (800 m) or 20 times the height of the building or other structure, whichever is greater.

C. Limited openings in this terrain, such as small parking lots, roads, road intersections, playing fields, underdeveloped lots, and tree clearings can be tolerated. For openings that exceed 600 ft (180 m) in total length measured radially from the building and 165 ft [50 m] in width, use surface roughness exposure C.

D. For buildings whose height is less than or equal to 30 ft (9.1 m), the prevailing exposure B distance may be reduced to 1500 ft (460 m).

E. In cases where the difference between exposures B and C is not obvious, use exposure C.

3.2.3.2 Exposure Category C

NOTE: In cases where the difference between exposure B and C is not obvious, use exposure C.

For Exposure Category C to be used:

A. The exposing terrain should be open with scattered obstructions having heights generally less than 30 ft (9 m), such as flat, open country and grasslands, and in all cases where exposures B and D do not apply.

B. This also includes where surface roughness exposure B terrain is interrupted by clearings (parking lots, wide roads, road intersections, playing fields, underdeveloped lots, tree clearings, etc.) of greater than 600 ft (180 m) in total length measured radially from the building and exceeding 165 ft (50 m) in width.

3.2.3.3 Exposure Category D

For Exposure Category D to be used in determining the design wind pressure, all of the following must be met:

A. The terrain upwind of the structure must be flat, unobstructed areas or water surfaces including smooth mud flats, salt flats, and unbroken ice and is present in the upwind direction for a distance greater than approximately 5000 ft (1500 m) or 20 times the building height, and

B. The building must be within the greater of 600 ft (180 m) or 20 times the building or structure height from the terrain, even if the terrain between the building and the terrain described in 2. above would otherwise be considered B or C.

Some examples of D exposures include inland waterways, the Great Lakes, and coastal areas.

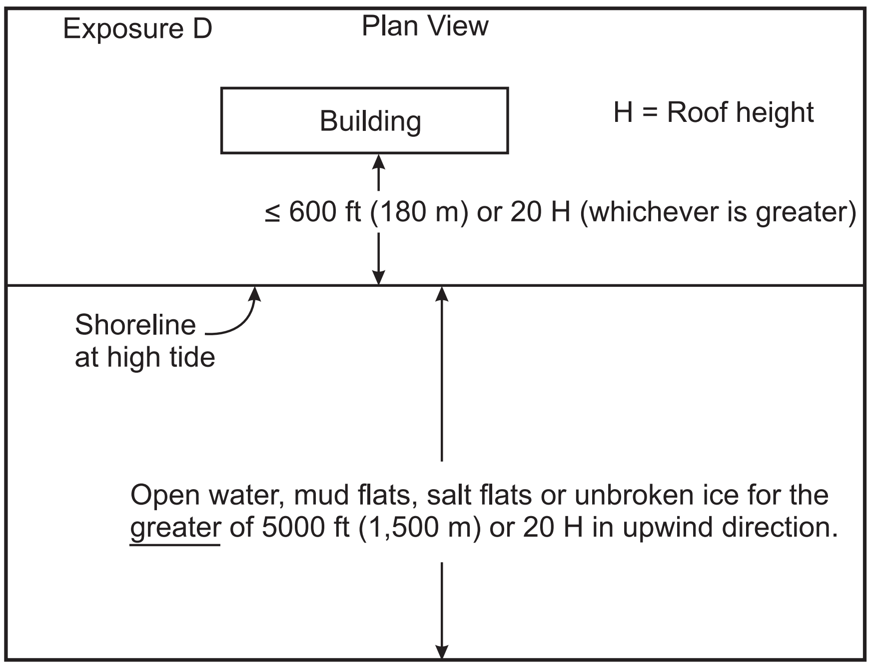


Fig. 3.2.3.3 Exposure D requirements

3.2.4 Building Enclosure Classification

Wind loads on a building are a result of internal and external pressure. In all cases, the external pressure component is larger and some minimal internal pressure component is always considered. Roof design loads cannot be considered in isolation from the walls. Failure of walls or opening protectives from pressure or windborne debris (where applicable) leads to a significant increase in internal pressurization and can result in direct water damage to building contents as well as an increase in design loads for the roof and remaining walls. Consequently, the design of new buildings should include adequate resistance of walls and wall opening protectives to wind pressure and windborne debris (where applicable) such that it need not be designed as a partially enclosed building. In cases where renovations are being made on an existing building that is partially enclosed, and it is not practical to make changes that would allow it to be considered enclosed, the new components should be designed for partially enclosed wind pressures.

The following criteria is in accordance with ASCE 7 and should be considered in new building designs:

A building that complies with both of the following conditions is considered a partially enclosed building:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the area of openings in the balance of the building envelope (walls and roof) by more than 10%, and

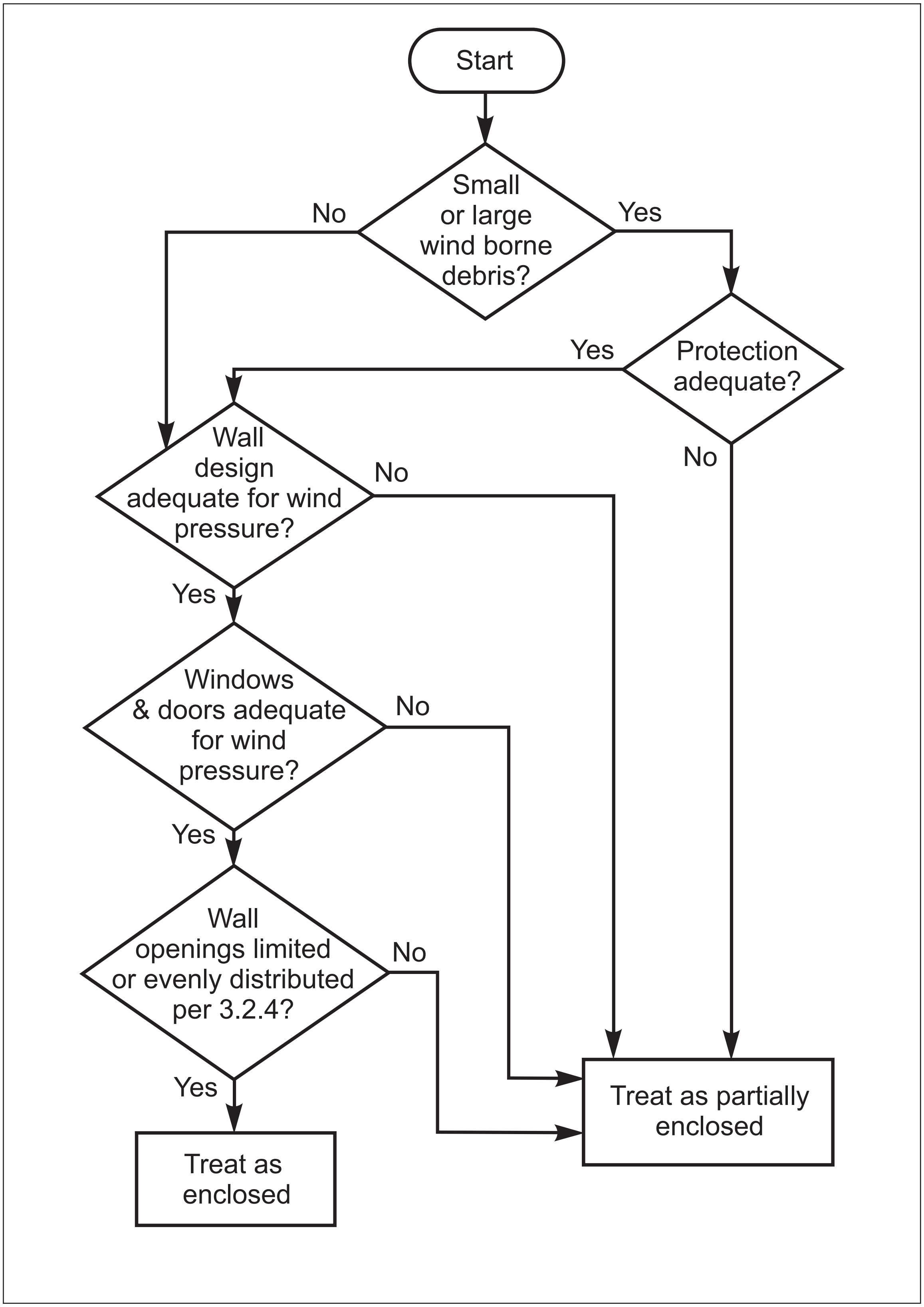
2. The total area of openings in a wall that receives positive external pressure exceeds 4 ft^2 (0.37 m^2) or 1% of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20%.

Buildings in a tropical storm-prone region that either meet criteria 1 and 2 above, or have wall cladding, or wall opening protectives that are inadequate for design wind pressures or windborne debris exposure (if applicable), are also considered partially enclosed.

For new construction, the building designer should verify that:

- All walls are adequate for the design wind pressure, and
- All opening protectives are adequate for the design wind pressures and windborne debris, if applicable, and
- Openings in exterior walls are limited, protected, or distributed so the criteria for an enclosed building is met.

To summarize all considerations for the determination of the enclosure type, see Flowchart A.



Flow Chart A. Enclosed building vs. partially enclosed building

3.2.5 Topographic Factor (K_{ZT})

The topographic factor is used to quantify the effects of wind speed up over hills, ridges and escarpments. This factor is multiplied by the wind velocity pressure, and has a minimum value of 1.0 for relatively flat (<6° or 10% ground slope) terrain. Additional information can be found in ASCE 7 or FM Global Data Sheet 1-8 (which includes tables that help simplify the quantification of this factor).

Wind maps for Hawaii reflect the wind speed-up effect over the steeply inclined inland terrain. Consequently, assume K_{ZT} = 1.0 for all locations in Hawaii. Other wind maps do not include this and the actual K_{ZT} value must be determined for ground slopes ≥6° or 10%.

3.2.6 Velocity Pressure Coefficient (K_Z)

The velocity pressure coefficient (K_Z) is multiplied by the basic wind pressure and quantifies how the pressure changes for various building heights and ground terrain exposures, as compared to the wind maps, which are effective at 33 ft (10 m) and open terrain (Exposure C). This variable factor may be determined from Table 3.2.2g.

3.2.7 Importance Factor

An importance factor (I) of 1.15 is recommended in this document and is multiplied by the basic velocity pressure. This reflects that buildings being designed are highly protected risks and are important from a property loss prevention standpoint.

3.3 Section Reserved for Future Use

3.4 Wind Design Pressures for Less-Common Roof Shapes

3.4.1 Steep-Slope, Mono-Slope, and Shed Roofs

A. Mono-slope roofs with slopes of 3º or less should be treated the same as low-slope gable roofs.

B. **For mono-slope roofs with slopes of more than 3º but not more than 30º**, use the external pressure coefficients (GC_p) in Table 3.4.1a. See Figure 3.4.1a for zone dimensions for slopes **of more than 3º but not more than 10º**. See Figure 3.4.1b for zone dimensions for slopes **of more than 10º but not more than 30º**.

Define “a” as the lesser of 10% of the lesser plan dimension or 40% of the roof height, but not less than 4% of the least horizontal dimension or 3 ft (0.9 m). As the roof slope is not more than 10°, use h = the eave height.

For example, for a mono-slope roof of more than 3º but not more than 10º, and the roof area is Zone 3, GC_P = -1.8. If the building is partially enclosed (GC_{PI} = 0.55), the total value of (GC_P - GC_{Pi}) is -1.8 - 0.55 = −2.35.

Table 3.4.1a. External Pressure Coefficients (GC_p) for Mono-Slope Roofs with Slopes of More Than 3º but Not More Than 10º

Roof Zone (see Fig. 3.10.1a)	*GC_p, Roof Slope > 3º but ≤ 10º*	*GC_p, Roof Slope > 10º but ≤ 30º*
1	-1.1	-1.3
2	-1.3	-1.6
2’	-1.6	DNA
3	-1.8	-2.9
3’	-2.6	DNA

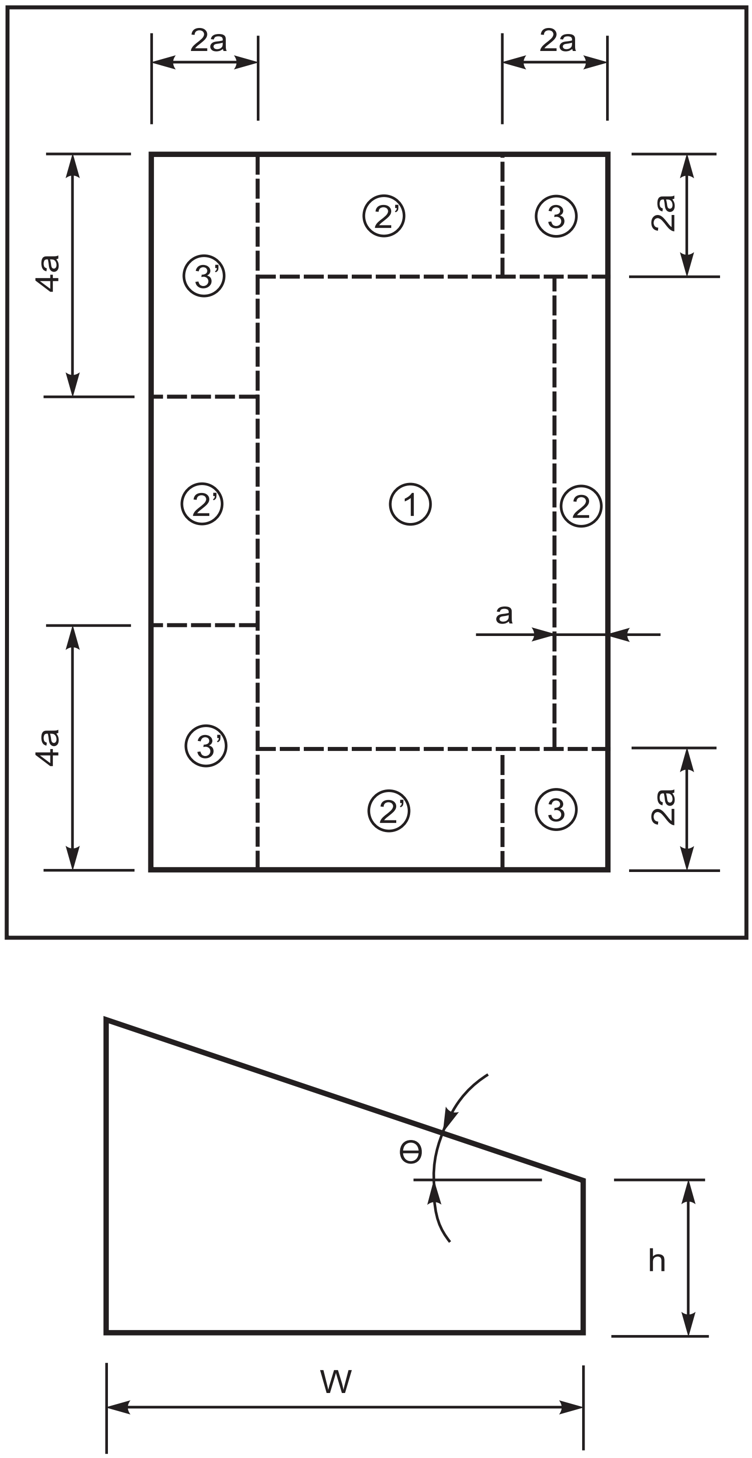


Fig. 3.4.1a. Zone 2 and 3 dimensions for mono-slope or shed-type roofs with slopes of more than 3° but not more than 10º (top: plan view; bottom: elevation view)

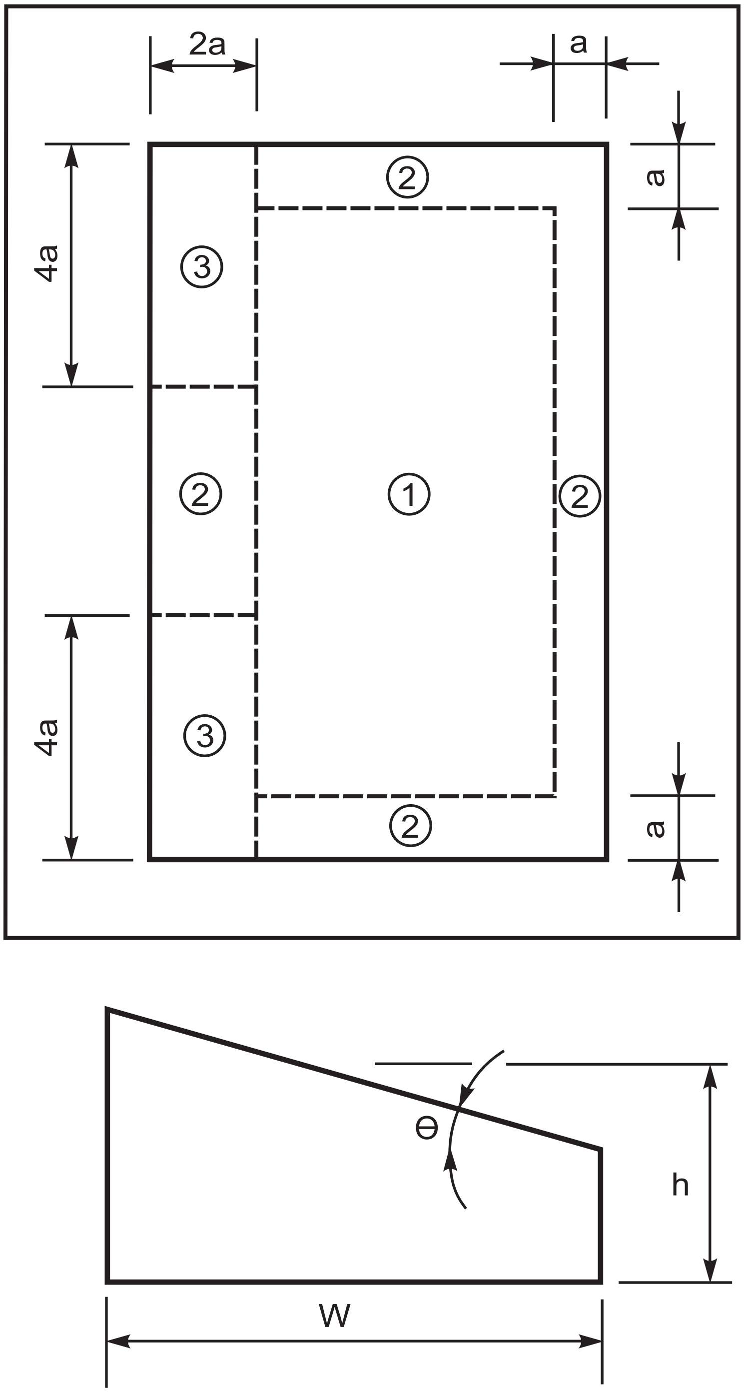


Fig. 3.4.1b. Zone 2 and 3 dimensions for mono-slope or shed-type roofs with slopes of more than 10° but not more than 30° (top: plan view; bottom: elevation view)

3.4.2 Steep-Slope Saw-Tooth Roofs

A. Saw-tooth roofs with roof slopes of 10º or less should be treated as low-slope gable roofs.

B. **For saw-tooth roofs with roof slopes of more than 10°**, use the external pressure coefficients GC_p in Table 3.4.2a. See Figures 3.4.2a and 3.4.2b for zone dimensions. Define “a” as the lesser of 10% of the lesser plan dimension or 40% of the roof height, but not less than 4% of the least horizontal dimension or 3 ft (0.9 m). As the roof slope is more than 10°, use h = the mean roof height.

Note that Zone 3, where the peak occurs, is rectangular with dimensions 2a x a, with the long dimension running along the roof peak, and that the Zone 3 pressures are higher for the first saw-tooth (span A) than for the remaining ones (spans B, C, D, etc.).

Table 3.4.2a. External Pressure Coefficients (GC_p) for Saw-Tooth Roofs with Slopes of More Than 10°

Zone	GC_p
1 (all spans)	-2.2
2 (all spans)	-3.2
3 (spans B, C, D, etc.)	-2.6
3 (span A only)	-4.1

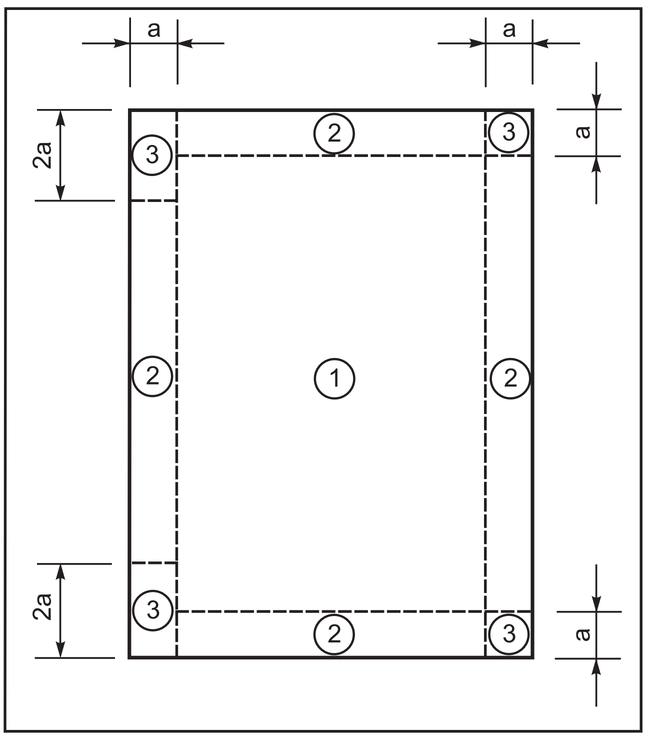


Fig. 3.4.2a. Zone 2 and 3 dimensions for saw-tooth roofs with slopes of more than 10°

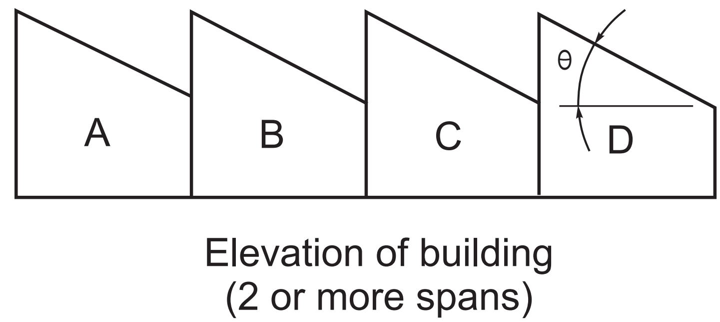


Fig. 3.4.2b. Elevation view for saw-tooth roofs with slopes of more than 10°

3.4.3 Arched Roofs

Arched roofs curve in one direction between parallel eaves (see Figure 3.4.3a), which provides somewhat favorable wind flow characteristics as represented in Figure 3.4.3b. Those areas are divided into 3 wind zones, two outer and one inner zone.

On the other two ends that resemble a gabled end, treat them as a gabled roof to determine wind pressure coefficients when the wind is parallel to the peak of the arch and perpendicular to the gabled ends. All together, this results in 4 wind zones for the entire roof.

To determine the wind loads on the roof:

A. Calculate the rise-to-span ratio, r (see Figure 3.4.3b.). The rise is measured from the top of the wall to the peak of the roof (for roofs on elevated structures) or from grade level to the peak of the roof (for roofs springing from ground level). The span is the building width from eave to eave.

B. Calculate the external pressure coefficient (C_P) based on r and Table 3.4.3a for each respective roof section. Since one must consider wind from all directions, the outer two zones (windward and leeward quarter) should be both be designed for the same worst case. For simplicity, consider the windward and leeward quarters to end at a distance equal to 25% of the building width in from the respective eave (see Figure 3.4.3b).

C. Add the pressure coefficients in Table 3.4.3a to the internal pressure coefficient. Multiply the sum of the external and internal pressure coefficient by the basic wind pressure (q).

D. The building designer should provide the spring line slope (see Figure 3.4.3 A). That equals the angle between the horizontal and a line tangent to the curve near the roof eave. Use that angle as if it were a gabled roof to determine the pressures near the gabled end.

Table 3.4.3a. External Pressure Coefficients (GC_p) for Arched Roofs

Roof Configuration	*RisetoSpan Ratio, r*	*CP*		
		WindwardQuarter	CenterHalf	Leeward Quarter
Roof on elevated structure	$0 < r < 0.2$	-1.08	-0.84 - 1.2r	-0.6
	$0.2 \leq r < 0.3$	Greater of 1.8r - 0.36, or 7.2r - 2.52	-0.84 - 1.2r	-0.6
	$0.3 \leq r \leq 0.6$	3.3r - 0.84	-0.84 - 1.2r	-0.6
Roof springing from ground level	$0 < r \leq 0.6$	1.68r	-0.84 - 1.2r	-0.6

Note: Minus sign indicates wind force away from surface, or uplift on roof.

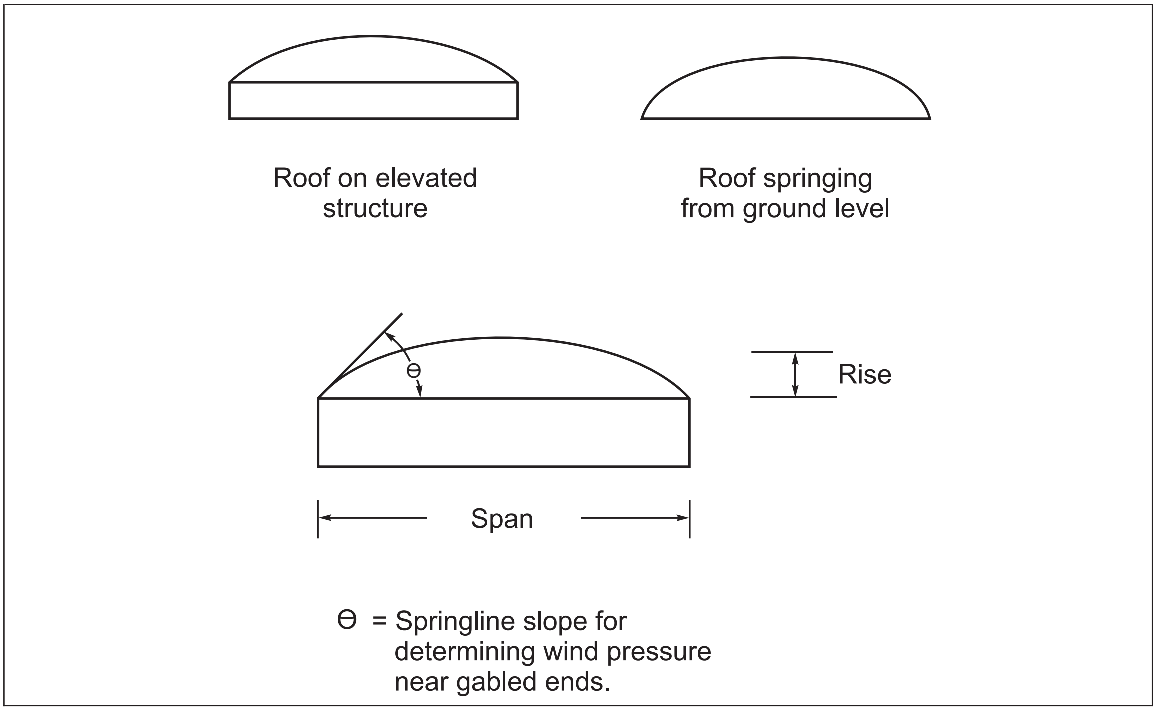


Fig. 3.4.3a. Elevation view of arched roof showing two different types and springline slope (provided by designer)

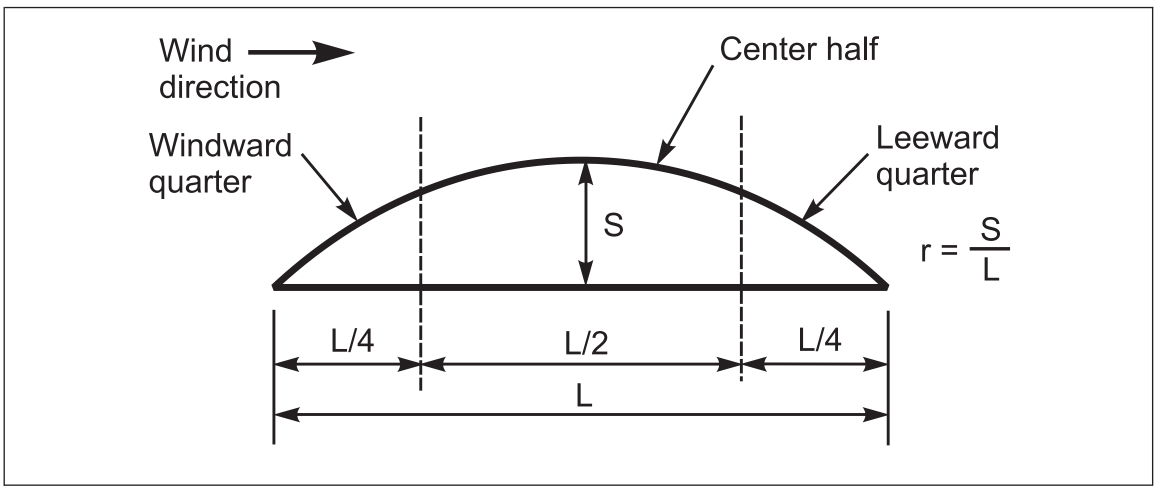


Fig. 3.4.3b. Elevation view of arched roof showing various wind zones (see Fig. 3.4.3c for a plan view)

3.4.3.1 Example Problem

An arched roof is to be constructed near sea level and have a spring-line slope of <7º. The roof eave height is 60 ft (18 m). The design wind speed is 130 mph (58 m/s). The location is prone to tropical cyclones. The exposure is C. The terrain is flat (<10º, so K_{ZT} = 1.0). The building is to be 230 ft (70 m) wide, walls and opening protectives will be designed for all expected exposures, and the building is considered enclosed.

1. Determine the rise-to-span ratio (r). The span is 230 ft (70 m) and the rise is 10 ft (3.0 m), so r = 0.04.

2. Use the external pressure coefficients (GC_P) from Table 3.4.3a for 0 < r < 0.2. As the building is “enclosed,” use an internal pressure coefficient of 0.18.

3. Windward quarter = **-1.08 (Zone 2E** of Example Plan Drawing).

4. Since the windward quarter governs, use the same design for the leeward quarter = -1.08 (Zone 2E of Example Plan Drawing).

5. Center half = [-0.84- 1.2(0.04)] = -0.89 (**Zone 1** of Example Plan Drawing).

6. Treat the spring-line slope of <7º as a gable roof slope to determine the external pressure coefficient from Table 3.2.2a of Section 3.3. GC_p = -3.2 and -2.3 for Zones 3 and 2, respectively.

7. Determine the basic wind pressure (q) using Equation 3.2.1a, a roof height of 60 ft (18 m)and a 125 mph (56 m/s) wind speed. That pressure is 44.2 psf (1.84 kPa).

$$\mathbf{q_h = 0.00256K_ZK_{ZT}K_DK_EV^2I}$$

$\mathbf{q_h}$ = (0.00256)(1.13)(1.0)(0.85)(1.0)(125)2(1.15) = 44.2 psf (2.12 kPa)

8. Multiply $\mathbf{q_h}$ by the sum of the external and internal pressure coefficients by a safety factor of 2.0. Round up to the next highest 15 psf for selection of Roof*Nav* listings.

Table 3.4.3b summarizes various pressures, including those needed if the building were partially enclosed. Figure 3.4.3c denotes the dimensions of the various zones. Zone 3 is L-shaped (36 by 36 by 12 ft; 11 by 11 by 3.7 m), Zone 2 is 36 ft (11 m) wide.

Table 3.4.3b. Arched Roof Example: Pressure Coefficients and Design Pressures

Zone(1)	*Pressure Coefficients[1] (2)*	*q_h, psf (kPa)(3)*	*Factored Wind Pressure(2)x(3)(2.0), psf (kPa)*	*Recommended Ratings,[2] psf (kPa)*
1	-1.07	44.2 psf (2.12 kPa)	94.5 (4.5)	105 (5.0)
2E	-1.26	44.2 psf (2.12 kPa)	112.3 (5.3)	120 (5.7)
2	-2.48	44.2 psf (2.12 kPa)	219 (10.5)	225 (10.8)
3	-3.38	44.2 psf (2.12 kPa)	299 (14.3)	300(14.4)

[1]Includes internal and external effects.
[2]Ratings are rounded up to next highest 15 psf (0.7 kPa) increment.

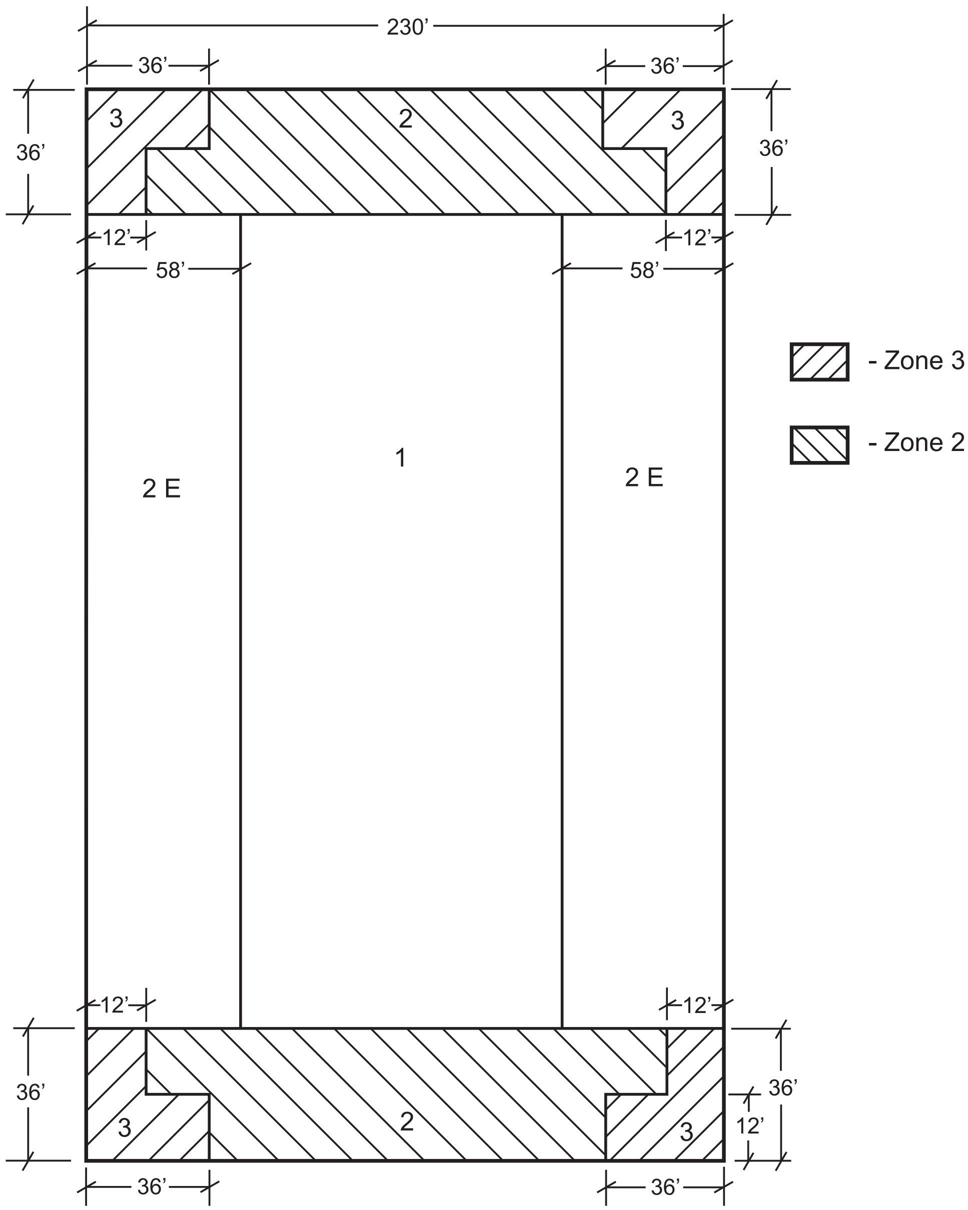


Fig. 3.4.3c. Plan view for arched roof example

3.4.4 Domed Roofs

Domed roofs are typically used on buildings with circular or approximately circular plan dimensions, and are curved in all directions. See Figure 3.4.4a.

Key variables:

f = height of the dome from the top of the wall to the roof peak, ft (m)

h_D = height of the wall from grade level to the roof eave, ft (m)

D = the diameter of the dome, ft (m)

A maximum uplift or negative pressure coefficient of -0.9 should be used for building dimension ratios of:

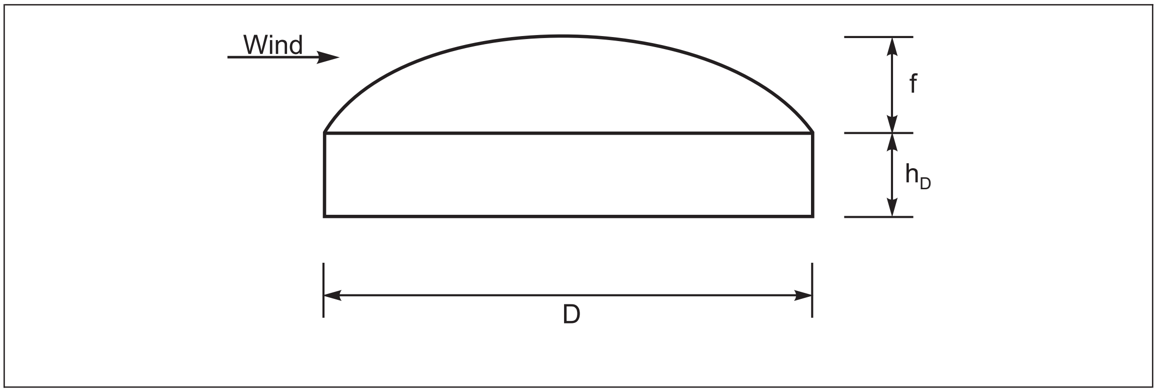


Fig. 3.4.4a. Elevation view of a domed roof

$0 \le h_D/D \le 0.5$, and $0.2 \le f/D \le 0.5$

Using the same units for the three variables, these ratios become dimensionless.

The external wind pressure coefficients will vary at different areas on the roof, depending on the ratio of the wall height to the dome diameter. As such structures are not that common (typically used for stadiums and arenas), and their design is beyond the scope of this document, the designer should refer to ASCE 7, the EuroCode, or other local standard for additional guidance.

3.4.5 Steep-Slope Multi-Span Gabled Roofs

A. Multi-span gabled roofs with roof slopes of 10º or less should be treated as low-slope gabled roofs.

B. **For multi-span gabled roofs with roof slopes >10° and ≤45°**, multiply q_h by the sum of the external pressure coefficient in Table 3.4.5a (for the specific roof slope) and the internal pressure coefficient. See Figure 3.4.5a for zone dimensions. Define “a” as the lesser of 10% of the lesser plan dimension **of the individual span** or 40% of the roof height, but not less than 4% of the least horizontal dimension or 3 ft (0.9 m). As the roof slope is >10°, use h = the mean roof height.

Table 3.4.5a. External Pressure Coefficients for Steep-Slope, Multi-Gable Roofs

Zone	*10° Θ ≤ 30°*	*30° Θ ≤ 45°*
1	-1.6	-2.0
2	-2.2	-2.5
3	-2.7	-2.6

3.4.6 Gabled Roofs with Slopes Greater than 45°

For gabled roofs with slopes greater than 45°, see Figures 3.4.5a and 3.4.6b. Treat the areas shown as either Zone 4 or 5 wall construction as noted in the figures.

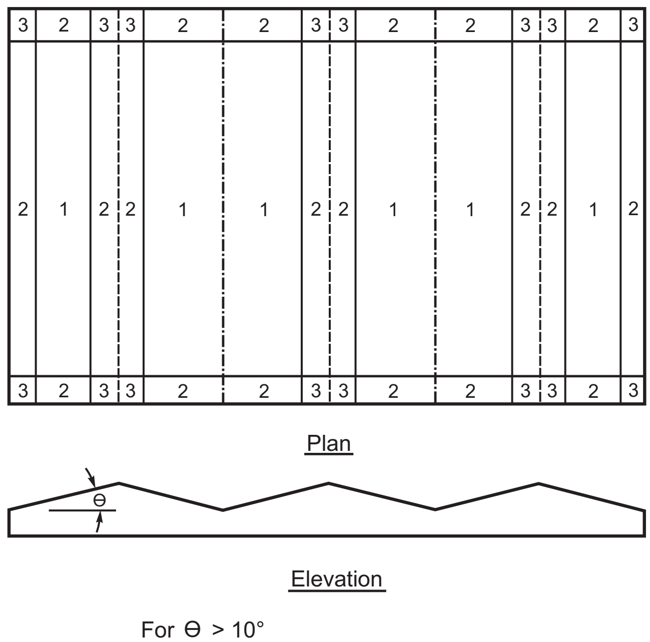


Fig. 3.4.5a. Zone dimensions for steep-slope multi-span gabled roofs

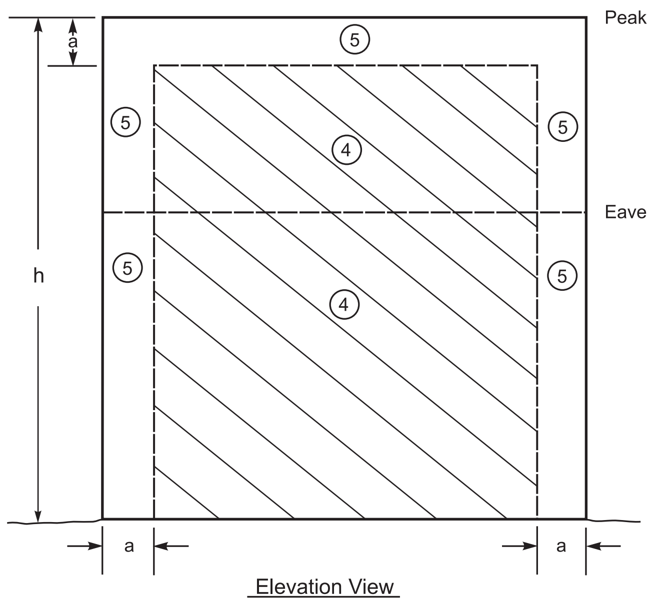


Fig. 3.4.6a. Gabled roofs with slopes >45.°

3.5 Wind Ratings for FM Approved Roof and Wall Assemblies

3.5.1 FM Approved Roof Assemblies

FM Approved roof assemblies and their wind ratings can be found using Roof*Nav*. The minimum pressure rating available for roofs is 60 psf. Higher rated assemblies are listed in 15 psf intervals. Depending on specific construction details, assemblies are available that are rated for up to several hundred psf.

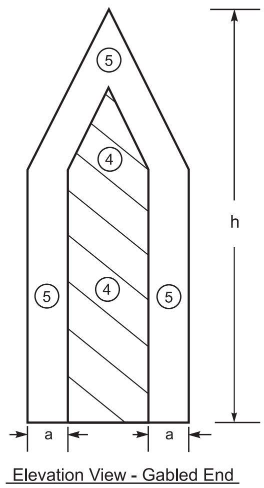


Fig. 3.4.6b. Gabled roofs with slopes >45°.

For **non-tropical cyclone prone regions**, Zone 1 may be limited to a **90 psf** wind rating provided:

- H< 90 ft, h/w ≤ 1.0
- Enclosed building
- V ≤ 90 mph, Exposure C or B
- Low sloped ground (< 6° or 10%), K_{ZT} = 1.0

3.5.2 FM Approved Exterior Wall Assemblies

3.5.2.1 Fire Rating

Wall panels can be FM Approved for interior use only (per FM 4880) or exterior use (per FM 4881). FM 4880 is for fire classification only and must be passed before being tested to FM 4881. The Approval height limitations are dependent on fire rating and are not related to wind rating.

3.5.2.2 Wind Pressure

FM Approved exterior wall assemblies and their wind ratings can be found in the *Approval Guide*. The minimum and maximum wind ratings and descriptions are noted in Table 3.5.2.2.

Table 3.5.2.2 Wind Categories and Ratings for FM Approved Wall Assemblies

*Wind Zone Category**	*Minimum Wind Pressure Rating*, +P, -P (psf)*	*Maximum Wind Pressure Rating*, +P, -P (psf)*
NTC	+40/-40	+75/-75
TC	+45/-45	No limit
TCM	+60/-60	No limit

*NTC = Non-tropical cyclone-prone region.
TC = Tropical cyclone-prone region, but not exposed to windborne debris.
TCM = Tropical cyclone prone region exposed to windborne debris (missiles).

The maximum spacing and minimum thickness of supporting steel (girts and studs) are dependent on wind rating and are not related to fire rating. The thickness of the supporting steel affects the pullout resistance of the screws. The listed panel width should not be exceeded. The minimum number and size of screws, and clip type if applicable, are critical with regard to wind rating.

Use this document to determine the minimum wind load ratings needed based on the building's geometry and geographic location. All FM Approved Class 1 exterior wall assemblies have a wind load rating. The rating describes inward and outward acting pressures (P_{inward} and $P_{outward}$) using a static pressure test and a cyclic pressure test. The FM Approval rating provided should be adequate for the maximum ultimate inward and outward pressures needed per this document. The ratings are usually given in increments of 5 lb/ft^2 (0.25 kPa) based on the inward pressure.

The outward magnitude of the pressure on the leeward side is equal to or higher than the pressure on the windward side. Depending on the building height and enclosure classification, and panel location (Zone 4 vs. 5), the design pressure will vary. The total outward pressure can be about one-third higher in Zone 5 than in Zone 4 for buildings less than 60 ft (18 m) high, and about twice as high in Zone 5 than Zone 4 for buildings over 60 ft (18 m). The positive sign is used to signify the fact that P_{inward} applies forces toward the wall. The negative sign is used to signify that $P_{outward}$ draws forces away from the wall (suction). **An importance factor of 1.15 and a safety factor of 2.0 should be applied to the inward and outward design pressures obtained from this document prior to selecting the rated panel.**

As the outward pressures in Zone 5 are always considerably higher than for Zone 4, and the building owner will desire to use the same type panel (thickness, panel width), it may be most practical to use the same FM Approved panel, but one that has a higher wind rating for a shorter span. In that way, the spacing between studs or girts at exterior walls may be reduced in Zone 5, depending on whether the wall panels span horizontally or vertically.

3.5.3 Windborne Debris Ratings

Use exterior wall assemblies rated for **Zone TCM** for sites located in tropical-cyclone-prone regions and subject to impact from windborne debris (see Section 2.4 and 3.7). The ratings are determined from static and cyclic pressure tests and the debris impact test(s). Such assemblies may meet the requirements of either the large missile (LM) or the small debris (SM) impact test.

Use exterior wall assemblies rated for **Zone TC** for sites **located in tropical cyclone-prone regions**, but not subject to impact from windborne debris. The ratings are determined from static and cyclic pressure tests.

Use exterior wall assemblies rated for **Zone NTC in non-tropical cyclone-prone regions** that are not subject to either hurricane force winds or impacts from windborne debris. The ratings are determined from static pressure tests. Cyclic pressure tests are also conducted, but with considerably less cycles than for a Zone TC or TCM rated system.

Whether or not there is exposure to tropical cyclones (see Appendix A) or windborne debris defines the required test details. For additional information, see FM 4881 and the *Approval Guide*.

3.6 FM Approved Exterior Wall and Roof Hail Ratings

All FM Approved Class 1 exterior wall and roof assemblies have a hail resistance rating. This rating simulates the expected impact of hail. For additional information on hail, see Data Sheet 1-34.

3.7 Designing for Windborne Debris

3.7.1 Designing for Small Windborne Debris

To determine the needed separation distance to prevent damage, use Equation 3.7.1. To determine the height above grade that needs protection, use Equation 3.7.2.

EQ. 3.7.1 $X_N = 0.37V[2.01(H/1200)^{0.2857}]^{1/2}\ (H_T)^{1/2}$

EQ. 3.7.1 (metric) $X_N = 0.45V[2.01(H/366)^{0.2857}]^{1/2}\ (H_T)^{1/2}$

where:

X_N = needed separation to prevent exposure (ft, m), not to exceed 1500 ft (457 m).

$V = V_{ASD}$ = allowable wind speed, mph (m/s).

H = height of source roof with aggregate, (ft, m).

H_T = height of trajectory of the aggregate = H + 30 ft (9.1 m) for new construction.

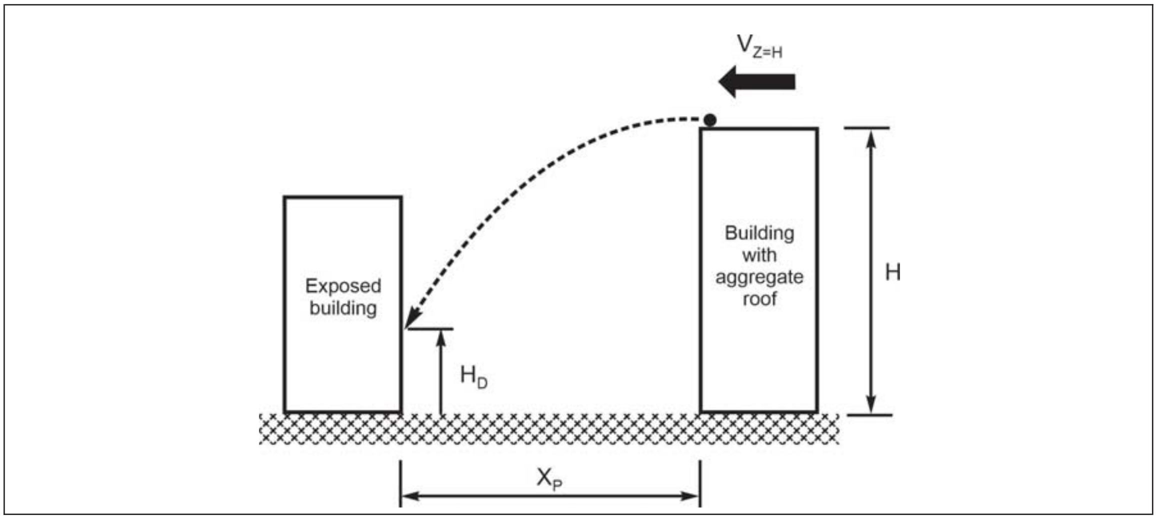


Fig. 3.7.1. Exposure from small windborne debris

Where the recommended separation is more than the separation provided (XP), the height of the exposed windows above the grade of the source building that are expected to be damaged and that need protection for small windborne debris exposure (HD), can be determined using Equation 3.9.2:

EQ. 3.7.2 $H_D = (H_T) - [28.2\ X_P\ ^2/\{(H)^{0.2857})(V)^2\}]$

EQ. 3.7.2 (metric) $H_D = (H_T) - [13.2\ X_P\ ^2/\{(H)^{0.2857})(V)^2\}]$

where:

H_D = height of the exposed wall, with respect to the base of the source building, for which damage is expected and protection is needed for (ft, m).

X_P = separation distance provided (ft, m).

3.7.2 Design for Large Windborne Debris

Tropical cyclone-prone (hurricane-, cyclone- or typhoon-prone) regions B and C are those for which designing for large windborne debris is recommended. Wall heights requiring protection are addressed in Section 2.0. Large windborne debris is considered to be considerably larger than roof aggregate (small debris) and its source is often closer to ground level than roof aggregate. Large debris can include, but is not limited to, wood framing from adjacent poorly constructed buildings; tree limbs; and inadequately secured clay, concrete, or slate roof tiles.

3.8 Roof-Mounted Equipment

3.8.1 Anchorage of Roof-Mounted Equipment

Calculations in Section 2.6.1 to determine resistance to uplift, sliding, and overturning of roof-mounted equipment are based on equations in ASCE 7-10 and ASCE 7-16. A reduced horizontal force coefficient, where sufficient space (as defined in 2.6.1) is provided between the underside of the equipment and the roof surface, has been provided based on more recent test data. Due to other factors, elevating the equipment to reduce wind forces alone is not likely to result in cost savings.

3.8.2 Design of HVACR Equipment Exposed to Wind

The design of roof mounted heating, ventilating, air-conditioning and refrigeration equipment (HVACR)should prevent catastrophic failure of equipment, which could result in windborne debris. In some cases, wind designs or impact from windborne debris could result in large deformations which could adversely affect equipment function after a design wind event. If the equipment performance is critical to the operations of the facility, one of the following should be considered:

A. The equipment manufacturer should be instructed to design the equipment to limit deformation of exposed components caused by wind pressures to allow the equipment to be fully functional after a design wind event. If there is exposure to windborne debris and that is a concern, testing as noted in Section 4.0 would be needed to assure proper performance, or

B. Spare parts should be kept on hand to replace those that are both vulnerable to wind damage and critical to the function of the equipment.

3.9 Wind Tunnel Tests

Atmospheric Boundary Layer Wind Tunnel (BLWT) testing should be conducted, when required, to determine wind design information. This would be needed for tall buildings (over 656 ft [200 m]); unusually shaped buildings; or, in some cases, to determine wind loads on roof-mounted equipment. Such equipment is capable of providing obstructions within the tunnel's wind flow path that create sufficient turbulence to reflect atmospheric boundary conditions. Scale models of buildings are used within such equipment to simulate wind flow around the building, creating varied forces on portions of the structure and any equipment on top of it.

Aerospace wind tunnels do not create sufficient atmospheric boundary conditions and turbulence and do not accurately quantify wind effects on buildings or rooftop equipment.

3.10 Eurocode

Using Terrain IV of the Eurocode may result in velocity pressures that are 5% to 10% lower than those based on exposure B of ASCE 7. Eurocode Terrain IV is, by definition, similar to the former exposure A of ASCE 7. Exposure A, though no longer used, was generally applied to urban areas where localized effects could considerably change the wind pressures and where many tall buildings are built, which are best modeled in a wind tunnel. The coefficients used in ASCE 7 for roof corners and negative pressures for vertical corner strips of walls for tall buildings are more conservative than the Eurocode. This concern applies mainly to buildings between 90 ft and 656 ft (27.4 m and 200 m) in height because wind tunnel modeling is required by the Eurocode for buildings taller than that. The use of Eurocode Terrain III results in higher velocity pressures, which offsets the higher pressure coefficients for ASCE 7.

Wind speeds used based on the EuroCode method will appear low because they are 10-minute wind speeds as opposed to 3-second gust wind speeds as used elsewhere in this document. However, coefficients used in the EuroCode pressure calculations account for this, so the resultant pressures are similar to that using this document for an equivalent 3-second gust wind speed. Conversions between 3-second gust and 10-minute wind speeds can be made using Table AC1.3 in Appendix C. For example, calculations based on a 100 mph (45 m/s), 3-second gust wind speed should result in wind pressures similar to that using a 69 mph (31 m/s), 10-minute wind speed based on the EuroCode method.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-8, *Antenna Towers and Signs*
Data Sheet 1-15, *Roof-Mounted Solar Photovoltaic Panels*
Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
Data Sheet 1-34, *Hail Damage*
Data Sheet 1-54, *Roof Loads for New Construction*
Data Sheet 5-23, *Design and Protection for Emergency and Standby Power Systems*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 10-1, Pre-Incident Planning

RoofNav, an online resource of FM Approvals for roofing professionals
The *Approval Guide*, an online resource of FM Approvals

FM Approval Standard 4350, *Approval Standard for Windstorm Resistant Fenestrations*
FM Approval Standard 4431, *Approval Standard for Skylights*
FM Approval Standard 4481, *Approval Standard for Exterior Walls*

4.2 Other

Air Movement and Control Association. *Test Method for Louvers Impacted by Wind Borne Debris*, AMCA Standard 540-13.

Air Movement and Control Association. *Test Method for High Velocity Wind Driven Rain Resistant Louvers*, AMCA Standard 550-15.

The Aluminum Association. *Aluminum Design Manual.* 2015 Edition.

American Architectural Manufacturer's Association (AAMA). *Voluntary Specification for Rating the Severe Wind-Driven Rain Resistance of Windows, Doors and Unit Skylights*, AAMA 520-12.

American National Standards Institute/Air Movement and Control Association. *Test Method for High Velocity Wind Driven Rain Resistant Louvers*, ANSI/AMCA Standard 550-09.

American National Standards Institute/Door and Access Systems Manufacturers Association, International (ANSI/DASMA). *Standard Method for Testing Sectional Garage Doors and Rolling Doors: Determination of Structural Performance Under Missile Impact and Cyclic Wind Pressure*. ANSI/DASMA 115-2005.

American National Standards Institute/Door and Access Systems Manufacturers Association, International (ANSI/DASMA). *Standard Method for Testing Sectional Garage Doors and Rolling Doors: Determination of Structural Performance Under Uniform Static Air Pressure Difference*. ANSI/DASMA 108-2012.

American Society of Civil Engineers (ASCE). *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-05.

American Society of Civil Engineers (ASCE). *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-10.

American Society of Civil Engineers (ASCE). *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, ASCE 7-16.

American Society of Citil Engineers (ASCE). *Pre-Standard for Performance-Based Wind Design*, 2019.

American Society of Civil Engineers (ASCE). *Wind Tunnel Testing for Buildings and Other Structures*. ASCE 49-12.

American Society of Testing and Materials (ASTM) International. *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference*. ASTM E 330/E330M-14.

American Society of Testing and Materials (ASTM) International. *Standard Test Method for Water Penetration of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference*. ASTM E 331-00 (Reapproved 2009).

American Society of Testing and Materials (ASTM) International. *Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls and Doors by Cyclic Air Pressure Differential*. ASTM E 1233/1233M-14.

American Society of Testing and Materials (ASTM) International. *Standard Practice for Determining Load Resistance of Glass in Buildings*. ASTM E 1300-09.

American Society of Testing and Materials (ASTM) International. *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*. ASTM E 1886-13a.

American Society of Testing and Materials (ASTM) International. *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*. ASTM E 1996-14a.

American Society of Testing and Materials (ASTM) International. *Standard Test Method for Water Penetration of Exterior Windows, Skylights and Doors by Rapid Pulsed Air Pressure Difference*. ASTM E E2268-04 (Reapproved 2016).

British Standards Institute. *BS EN 1991-1-4,Eurocode 1, Actions on structures, General actions, Wind actions*, 2005+A1:2010.

DASMA 115.

Federal Emergency Management Association (FEMA). *Attachment of Roof-top Equipment in High-Wind Regions*. May 2006, Revised July 2006.

Florida Building Code. *Impact Test Procedures*. Testing Application Standard (TAS) 201-94

Florida Building Code. *Criteria for Testing Impact & Non-impact Resistant Building Envelope Components Using Uniform Static Air Pressure*. Testing Application Standard (TAS) 202-94.

Florida Building Code. *Criteria for Testing Products Subject to Cyclic Wind Pressure Loading*. Testing Application Standard (TAS) 203-94.

General Design Requirements and Loading on Structures Joint Technical Committee BD-006, ″Structural design actions PART 2 Windl actions AS/NZS 1170.2:2002,″ Standards Australia, Sydney, Australia, Standard ISBN 0 7337 4473 7, 2002.

4.3 Bibliography

4.3.1 FM Global

Data Sheet 1-31, *Metal Roof Systems*
Data Sheet 1-32, *Inspection and Maintenance of Roof Assemblies*
Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installation*
Data Sheet 1-49, *Perimeter Flashing*
Data Sheet 1-52, *Field Verification of Roof Wind Uplift Resistance*

4.3.2 Other

Door and Access Systems Manufacturers' Association International (DASMA), Technical Data Sheet #182.

APPENDIX A GLOSSARY OF TERMS

Arched Roof: A roof that is curved in one direction from one eave to the opposite eave, but has gables on the other two ends. See Fig. 3-4a, b and c.

Building, enclosed: A building that does not meet the criteria for open or partially enclosed buildings (see Flow Chart A and Section 3.2.3).

Building, open: A building having each wall at least 80% open.

Building, partially enclosed: A building in which there are sufficient openings to increase the internal pressure beyond that considered for an enclosed building (see Flow Chart A and Section 3.2.3).

Building width, W: The lesser plan dimension.

Cupola Roof: A small, steeply sloped structure, often found at the top of a larger structure. See Figures 1a and 1b.

Fig. 1a. Circular cupola roof; Fig. 1b. Hip-shaped cupola roof

Directionality factor (K_D): This factor accounts for(a) The reduced probability of maximum winds coming from any given direction, and (b) The reduced probability of the maximum pressure coefficient occurring for any given wind direction.

Dock door: A door serving a loading dock. The door allows access to a transport vehicle for loading and unloading operations.

Domed Roof: A roof which is circular in plan dimension, completely rounded in the vertical direction and slopes either to grade level or to the top of circular walls. See Fig. 3.4.4a.

Effective wind area (EWA): The area assumed to be supported by a construction component for the purpose of wind load transfer. For roof cover, roof deck, or wall panel fastening, the effective wind area should not exceed that supported by the fastener or clip (generally reflected in the tables in this document).

Escarpment: A cliff or steep slope, usually separating two levels or gently sloping areas.

FM Approved: Product or services that have satisfied the criteria for Approval by FM Approvals. Refer to RoofNav or the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Gable: A triangular shaped, upper portion of a building end wall that is formed by a sloping roof on either side of the ridge.

Gabled Roof: A roof with a peak in the interior part of the roof that slopes downward in two opposite directions towards lower eaves. Also, see Tables 6 and 12 in Section 3.0.

Girts: Wall-framing members that immediately support the wall panels.

h_p (Eurocode definition): Height of the parapet as measured from the top of the adjacent roof to the top of the parapet (m).

h (Eurocode definition): Height of the roof as measured from grade to the roof peak, regardless of roof slope (m).

Hill: A land surface characterized by strong relief in any horizontal direction.

Hurricane-prone regions: See “tropical cyclone-prone locations.”

Importance factor: A factor that accounts for the importance of the building. In applying this data sheet, the value of the importance factor is taken as 1.15 for all locations.

Inward wind pressure: A condition created on the windward side of a building. It is caused by wind forces and places forces toward the wall. It is sometimes referred to as positive pressure.

Mansard Roof: A steeply sloped roof usually found at the perimeter of a rectangular building. See Figure 2.

Fig. 2. Steep sloped mansard roof

Main Wind Force Resisting System (MWFRS): connected structural members that provide support and stability for the overall structure and that generally receive wind load from more than one surface.

Mean roof height (h): The average of the roof eave height and the height to the highest point on the roof surface, except for roof angles of less than or equal to 7°, where the mean roof height is the roof eave height.

Multi-gabled Roof: Two or more gabled roofs in parallel, abutting at their eaves on the same building or two abutting buildings. See Figure 3.4.5a.

Openings: Apertures or holes in the building envelope that allow air to flow through the building envelope and that are designed as "open" during design winds as defined by these provisions. Glass area, doors and louvers that are insufficiently designed to resist design wind pressures per this data sheet, and/or wind-borne debris as defined in Appendix A of this data sheet, are considered openings. (Make the glazing in the wind-borne debris regions impact-resistant glazing or protected with an impact resistant covering or assume such glazing that receives positive external pressure to be openings). For roof design pressures, openings are only considered when located on the story immediately below the roof.

Outward wind pressure: A condition created on the leeward side of a building. It is caused by wind forces and places forces away from the wall. It is sometimes referred to as negative pressure.

Pressure coefficient: A factor accounting for variations in inward and outward wind pressure on walls at different locations and elevations of the same building.

Ridge: An elongated crest of a hill characterized by strong relief in two directions.

Saw Tooth Roof: A roof with a series of ridges, usually with different pitches on either side of the roof. Often one side may contain glazing to allow indirect sunlight. See Fig. 3.4.2b.

Secondary roof framing: Structural framing, such as joists or purlins, that immediately supports the roof deck.

Shed or mono-slope roof: A roof that is sloped in one direction only. See Fig. 3.4.1a. and b.

Tropical cyclone-prone region: An area prone to tropical storms in which winds rotate about a center of low atmospheric pressure, clockwise in the southern hemisphere and counter-clockwise in the northern hemisphere. This includes locations prone to hurricanes, typhoons and cyclones and includes the following regions:

1. The U.S. Atlantic Coast and Gulf of Mexico Coast, including parts of Mexico (Eastern Mexico, the southern end of the Baja Peninsula and the southwest coast of Mexico) and Central America, within and on the coastal side of the 100 mph (45 m/s) wind zone.

2. Hawaii, Puerto Rico, Guam, U.S. Virgin Islands, St. Croix, St. John, St. Thomas and American Samoa.

For locations outside the United States, any areas that are in a "tropical cyclone" region or "typhoon-prone" region. This includes, but is not limited to, eastern Mexico and the southern coastal areas of western Mexico, parts of Australia (green, blue, and red banded areas in the map in Appendix C, as well as islands noted in Table AC1.1.1) and northern part of the North Island of New Zealand, Bermuda, all the countries and territories of the Caribbean (also see Table AC1.4), Bangladesh, India, the Philippines, Japan, South Korea, Hong Kong, Macau, Vietnam, Burma (Miramar), China, Sri Lanka, Cambodia, Taiwan, Madagascar, and the southeast coast of Brazil within and on the coastal side of the 100 mph (45 m/s) wind zone.

−Tropical Cyclone Region A is where the design wind speed is at least 100 mph (45 m/s).
− Tropical Cyclone Region B is where the design wind speed is at least 110 mph (49 m/s) within one mile of the coast.
− Tropical Cyclone Region C is where the design wind speed is at least 120 mph (54 m/s).

Typhoon-prone region: See "tropical cyclone-prone locations."

Wind Speed (design or allowable), V: The 3-second gust wind speed at 33 ft (10 m) above the ground in Surface Roughness Exposure C, as provided in the wind speed information of this data sheet. Except where otherwise noted, a 100-year mean recurrence interval (MRI) is used.

Windborne debris, large: Pieces of broken material and other objects that have become airborne projectiles due to the high winds.

Windborne debris, small: Any roof aggregate (including gravel and slag as used on multi-ply roof covers, and larger stone as used on ballasted roof covers) that become airborne projectiles due to the high winds.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

July 2022. The wind speed information for Australia (Figure 5 and Table AC 1.1.1) has been updated based on the latest Australian Code (see Section 4.2). Wind speeds were reduced to equivalent 3-second gusts based on Australian measurements of 0.2 second gusts. That was done by multiplying the previous wind speed by a 0.89 adjustment factor. In Regions D, C and B2, as defined in the Australian Code, a 1.05 climate change multiplier (MC, to account for climate uncertainty) was applied to the wind speed. On the east coast, Region B1 was expanded and split into two parts. The first 100 km (62 miles) inland (which includes Brisbane) is considered cyclonic based on the guidance in this document. Region B1 between 100 and 200 km (62 and 124 miles) inland is not considered cyclonic. The result of these adjustments are as follows:

Region D (cyclonic), which was 66 m/s (148 mph) is now 62 m/s (138 mph).
Region C (cyclonic), which was 56 m/s (125 mph) is now 52 m/s (117 mph).
Region B2 (cyclonic), which was 48 m/s (107 mph) is now 45 m/s (100 mph).
Region B1 (cyclonic), east coast for 100 km (62 miles) inland (including Brisbane), which was 48 m/s (107 mph) is now 43 m/s (96 mph).
Region B1 (non-cyclonic), on the east coast between 100 and 200 km (62 and 124 miles) inland, which was 41 m/s (92 mph) is now 43 m/s (96 mph).
Regions A0 to A5 (non-cyclonic), which was 41 m/s (92 mph) is now 36 m/s (82 mph).

Regarding Table AC1.1.1, there will be no change to the wind speeds in Fiji and Tonga as they are not part of Australia. For the other 4 islands:

Christmas Island is in Region B2 (cyclonic), which was 48 m/s (107 mph) is now 45 m/s (100 mph).
Cocos Islands is in Region C (cyclonic), which was 56 m/s (125 mph) is now 52 m/s (117 mph).
Norfolk Island is in Region B1, which was 48 m/s (107 mph) is now 43 m/s (96 mph).
Lord Howe Island is in Region A2 (non-cyclonic), which was 41 m/s (92 mph) is now 36 m/s (82 mph).

April 2021. The wind map in Figure 12 for South Korea has been updated. Wind speed information for Japan has not changed.

October 2020. Interim revision. Wind speed information for China and Vietnam has been revised.Editorial changes were made to Table 3.2.2, Summary for Example 3.2.2.

February 2020. Interim revision. Significant changes include the following:

A. Revised design wind guidance to reflect changes in pressure coefficients and zone dimensions in ASCE 7-16. In some cases, roof wind pressures have increased considerably based on an updated review of boundary layer wind tunnel (BLWT) test data. This document uses allowable strength design (ASD) for wind design guidance. More specific changes are noted below.

B. The basic design wind speed maps for the continental United States and Alaska remain unchanged. They are still based on ASCE 7-05. Optional design wind guidance for tornadoes is contained in Appendix D.

Instead of using wind isolines subject to interpolation, wind zones (polygons) are provided. For locations that fall anywhere within a given zone, the wind speed for that zone should be used without interpolation.

C. A separate 100-year MRI wind map is provided for each of the islands of Hawaii, instead of using one wind speed for all the islands. Also, because of the steep terrain on much of the islands, wind speeds on the map increase with elevation to reflect the topographic effect. So a determination of K_{ZT}, which can be somewhat complicated, is not needed for Hawaii (assume 1.0).

D. Deleted wind pressure tables for walls and roofs. Roof pressures can be determined using Ratings Calculator in RooofNav. Also, pressure equations with various pressure coefficients are provided in Section 3.0 of this document.

E. Incorporated relevant content from DS 1-28R/1-29R into this document (DS 1-28) or DS 1-29. DS 1-28R/1-29R has been made obsolete.

October 2016. Interim revision. Additional comments were added in section 3.4.3, Arched Roofs, to clarify how pressures are determined.

October 2015. This document was completely revised and reformatted. The following major changes were made:

A. Added optional guidance for tornado-resistant design.

B. Clarified guidance on surface roughness and roof overhangs.

C. Added an explanation of the wind speed design for ASCE 7-10.

D. Updated guidance for the anchorage of roof-mounted equipment.

E. Added guidance for less-common roof shapes.

F. Added design wind speeds for the four islands of Australia.

G. Added an explanation of “lee zones” in New Zealand.

H. Added further guidance on topographic factors.

I. Revised the formulae for small windborne debris.

J. Added guidance regarding emergency power systems.

K. Deleted the use of Ground Roughness Exposure C in coastal areas where v ≥ 120 mph (54 m/s) for new construction, to be consistent with ASCE 7.

L. Increased (from 3 ft [0.9 m] to 10 ft [3 m]) the minimum roof elevation required to treat abutting buildings differently with regard to various wind zones, for consistency with ASCE 7.

M. Updated the wind map for Western Mexico.

January 2012. Minor editorial changes were made to the caption for Figure 12 and Indonesia was removed from the list of hurricane-prone regions in Appendix A.

April 2011. Clarification was added to Table 6, Roof Design Outward Pressure Multipliers for Roof Zones 1, 2, and 3. Minor editorial changes were made.

September 2009. The following changes were made:

- Recommendations were added to enable the use of the Eurocode for wind design.
- Various wind maps and tables were added or updated.
  The format of the wind maps was changed from iso-lines, which are typically shown in 10 mph (4.5 m/s) increments, to colored bands using 5 mph (2.3 m/s) increments. This change eliminates interpolation.
- The cutoff for roof slope as it relates to the definition of roof height was changed from 7 to 10 degrees, to be consistent with ASCE 7.
- Addition guidance was added regarding the effective wind area for new doors on exterior vehicle openings. Additions and clarifications were made to Appendix A, Glossary of Terms.
- Minor editorial changes were made.

September 2007. Minor corrections were made to Tables 3, 4, 5 and 6.

February 2007. The following changes were done for this revision:

- Guidelines were added regarding the use of higher design levels to facilitate part or all of the building design to meet winds that exceed the basic wind speed.
- Information was added regarding the new category of approved exterior wall panels (per FM Approvals Standard 4881) for natural hazards exposures, including respective ratings which are appropriate for various exposures.
- Example problems were edited to reflect optional design pressures that are higher than that for the basic wind speed. Guidance on door and window design, and building frame design was clarified.

- Some additions and revisions were made to the Appendix A, in part, to be consistent with changes to ASCE 7-05. This includes the deletion of Surface Roughness Exposure A, changes to the definitions of Surface Roughness Exposure B, C, and D, and a change in the cutoff for low-slope and moderate slope roofs from **10° to 7° and from 30° to 27° respectively, for some situations.**
- Flow Chart A was modified.
- Table 8 was revised to be consistent with changes in DS 1-29.

September 2005. Clarification was made to Flow Chart A, Enclosed building vs. partially enclosed buildings.

January 2002. This revision includes a complete reformatting of wind design guidance. Wind loading requirements from the previous Data Sheet 1-7 and 1-28 have been combined into this single wind load data sheet. Load resistance issues are provided in the other data sheets listed above. Also, roof deck securement issues are now in Data Sheet 1-29.

This revision of the document includes a ''3-sec gust averaged time'' unit of wind speed, rather than the former ''fastest-mile'' unit of wind speed. Also, design pressures are now derived directly from the American Society of Civil Engineers (ASCE) Standard 7-98, *Minimum Design Loads for Buildings and Other Structures*. This encompasses some of the latest available technology for determining wind design pressures.

Inward and outward wall design pressures can be determined, as well as roof outward design pressures. These are a combination of internal and external pressures. Outward wall design pressures are uniform for the full wall height. Inward wall design pressures vary with height of the wall.

The term ''partially enclosed'' was previously addressed by the term ''large openings''. The adjustments to pressure are somewhat different than the previous adjustments.

September 2000. This revision of the document has been reorganized to provide a consistent format.

August 1998. Major revisions were made.

APPENDIX C WIND SPEED MAPS AND TABLES

C.1 Wind Speed

All wind speed maps and tables are representative at 33 ft (10 m) above grade in open terrain or Exposure C. All represent 3-second gust wind speeds, except where otherwise noted.

See Figures 3 (five parts) through 4 for the 100-year MRI wind maps for the continental United States and Alaska. For Hawaii, see Figures C-1A through C-1F. For other US territories outside the continental United States, use the wind speeds shown in Table AC1.1.

Table AC1.1. Design Wind Speeds for US Territories

Island	*3-second gust wind speed, mph (m/s)*
Guam and Northern Mariana Islands	170 (76)
Puerto Rico	175 (78)
Virgin Islands	145 (65)
American Samoa	145 (65)

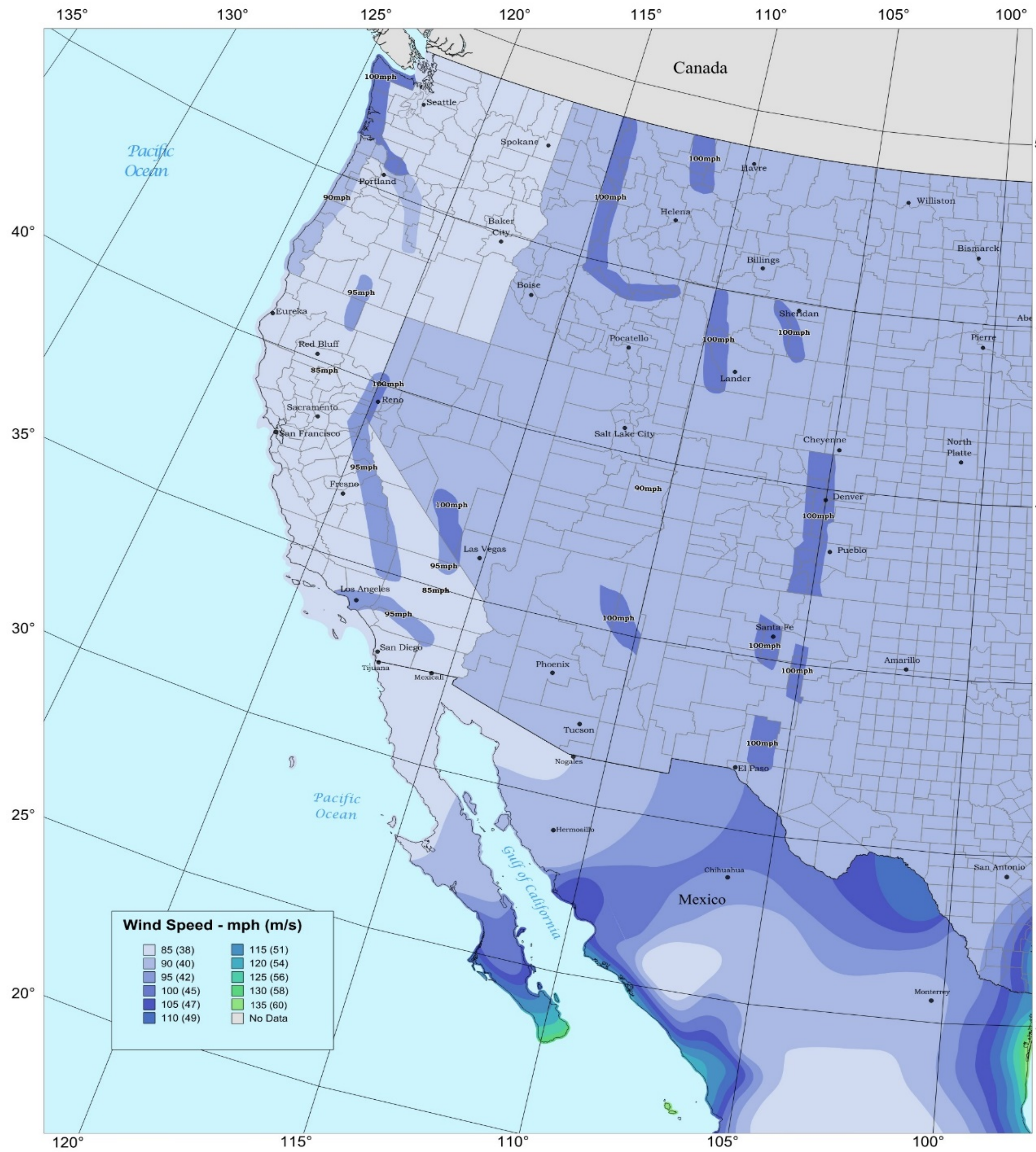
C.1.1 Regions Prone to Tropical Cyclones

Special attention should be paid to various construction details in tropical cyclone prone regions, as described in Section 2. There are 3 separate triggers for such details as follows:

Tropical Cyclone Region A − this includes all locations where the design wind speed is ≥ 100 mph (45 m/s), which should be designed to prevent damage from small windborne debris.

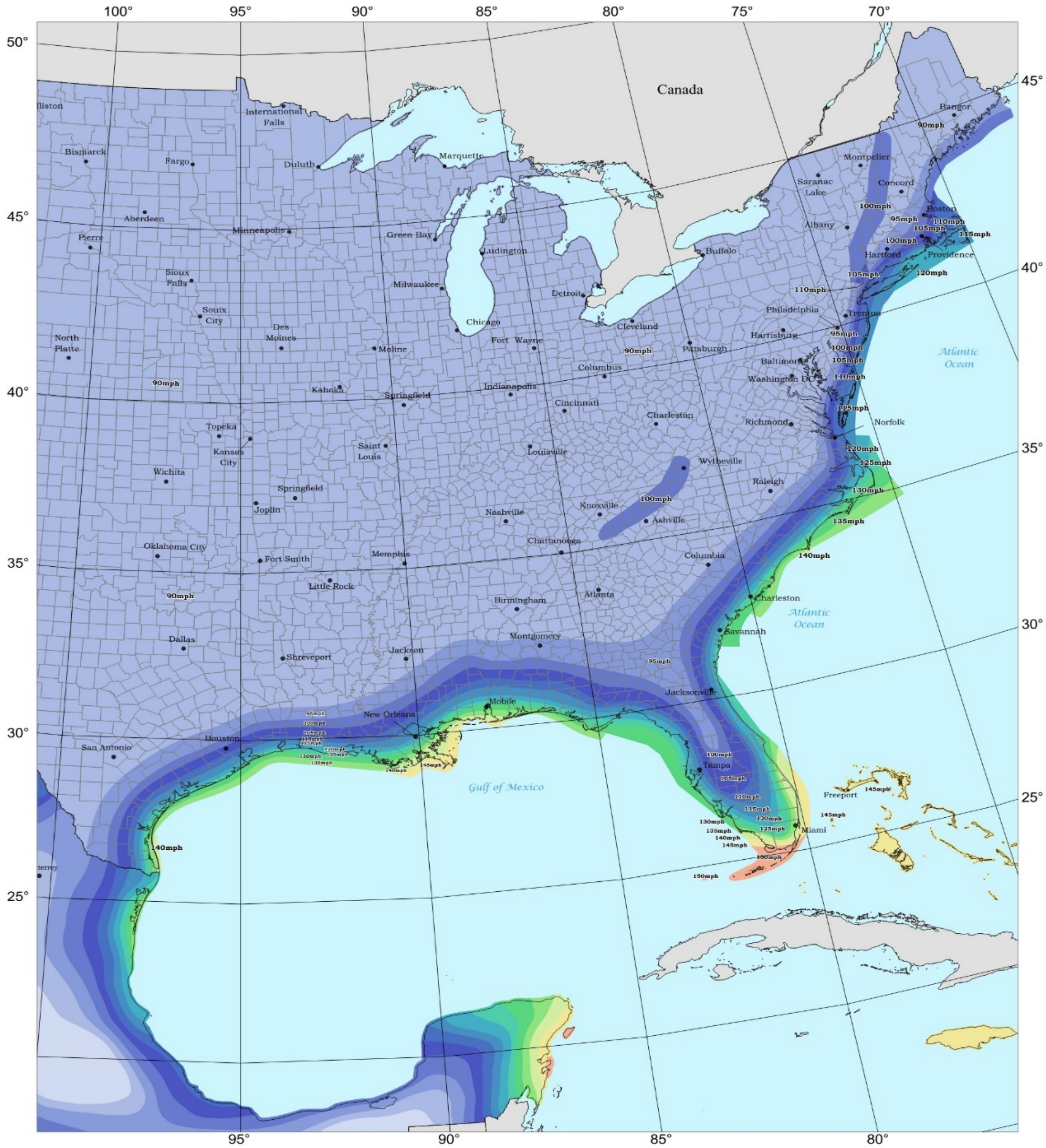
Tropical Cyclone Region B − this includes all locations where the design wind speed is ≥ 110 mph (49 m/s), which should be designed to prevent damage from small windborne debris throughout, or large windborne debris within 1 mile of the coast.

Tropical Cyclone Region C − this includes all locations where the design wind speed is ≥ 120 mph (54 m/s), which should be designed to prevent damage from small windborne debris throughout, or large windborne debris throughout.

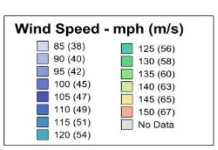


Notes: 1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33ft (10m) above ground for Exposure C category.
2. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.

Fig. 3. Basic Wind Speeds - Western United States (3/2020)



Notes: 1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33ft (10m) above ground for Exposure C category.
2. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.



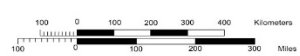
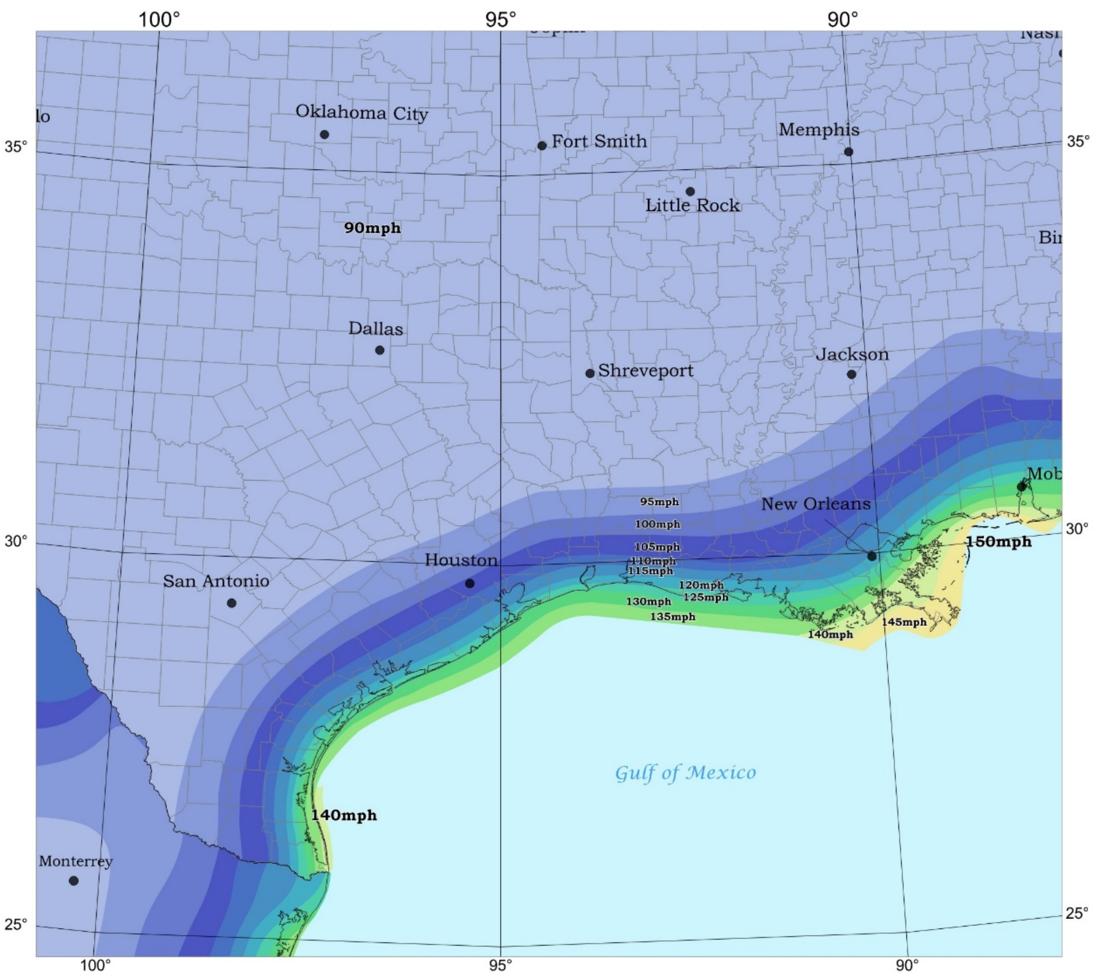


Fig. 3 (part 2). Basic Wind Speeds – Central & Eastern United States (3/2020)



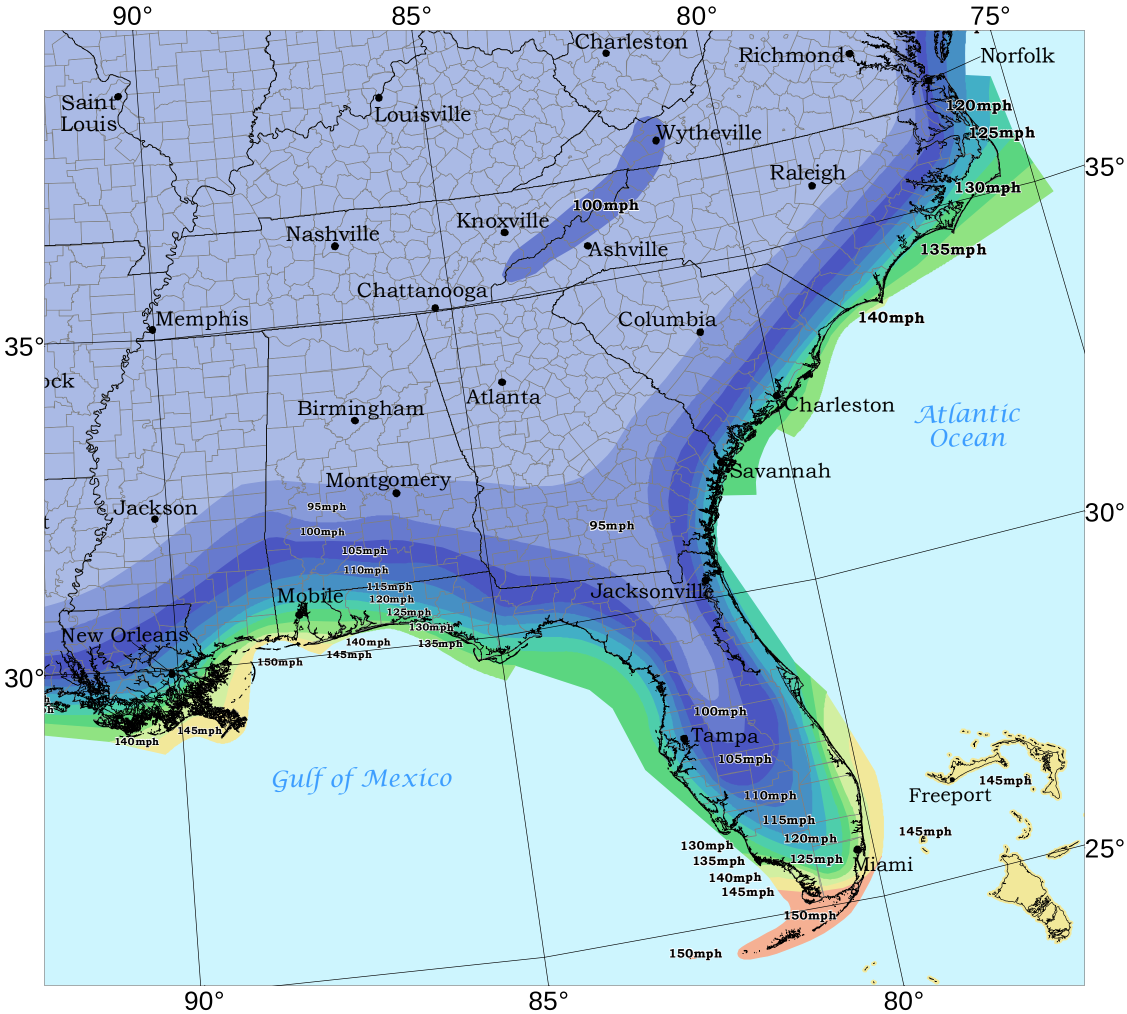
Notes: 1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33ft (10m) above ground for Exposure C category.
2. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.

Wind Speed - mph (m/s)

85 (38)	120 (54)
90 (40)	125 (56)
95 (42)	130 (58)
100 (45)	135 (60)
105 (47)	140 (63)
110 (49)	145 (65)
115 (51)	150 (67)

80 0 80 160 240 Kilometers
40 0 40 80 120 160 Miles

Fig. 3 (part 3) Basic Wind Speeds - Western Gulf of Mexico Coastline of United States (3/2020)



Notes: 1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33ft (10m) above ground for Exposure C category.
2. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.

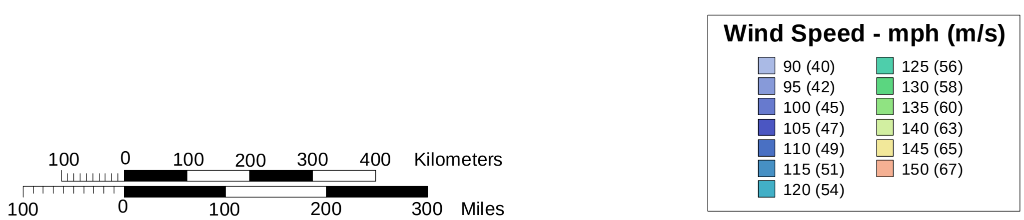
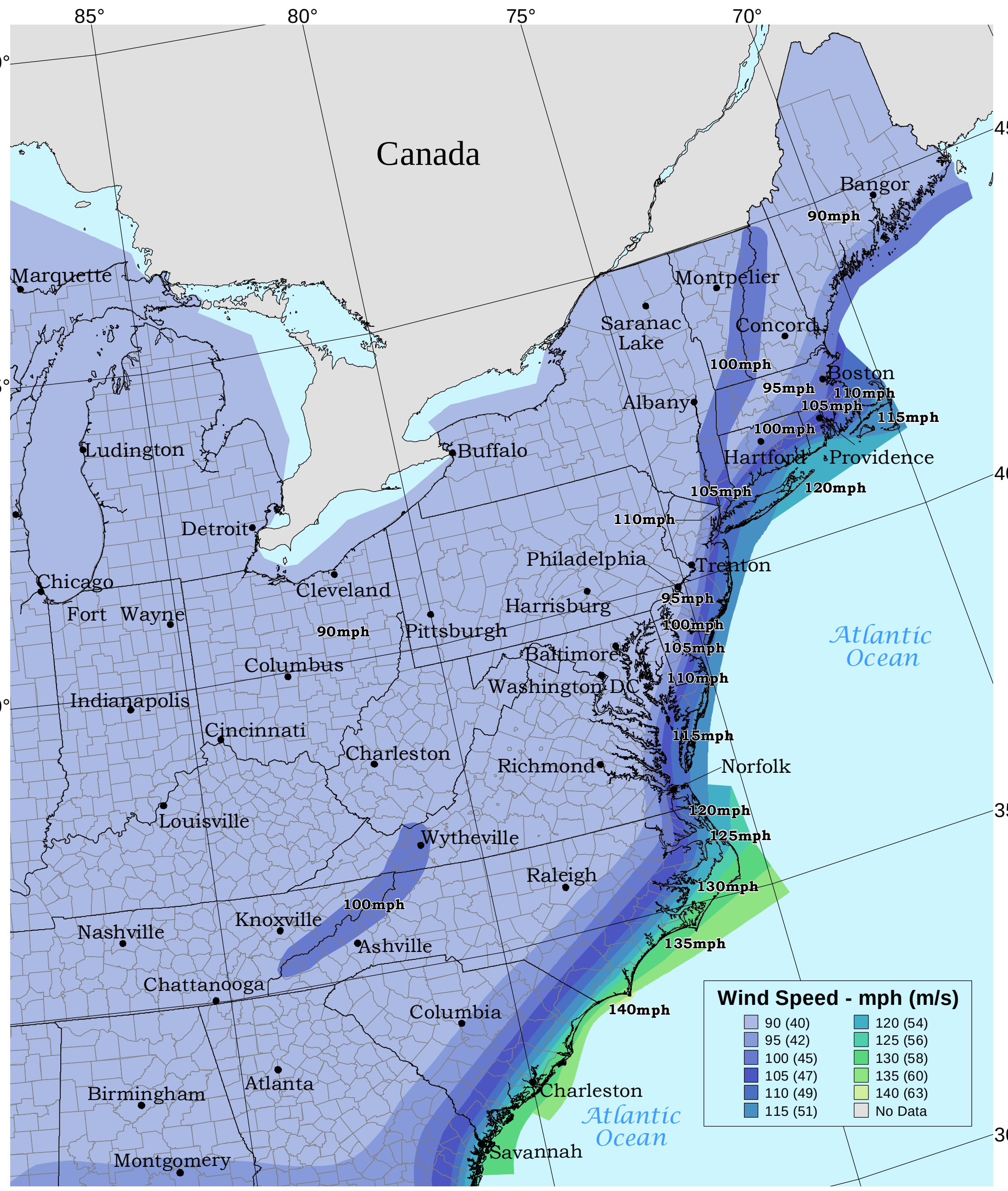


Fig. 3. (part 4). Basic Wind Speeds - Eastern Gulf of Mexico and Southern Atlantic Coastline of United States. (8/2001)



Notes: 1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33ft (10m) above ground for Exposure C category.
2. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.

Fig. 3. (part 5). Basic Wind Speeds - Mid-Atlantic and Northern Atlantic Coastline of United States. (8/2001)

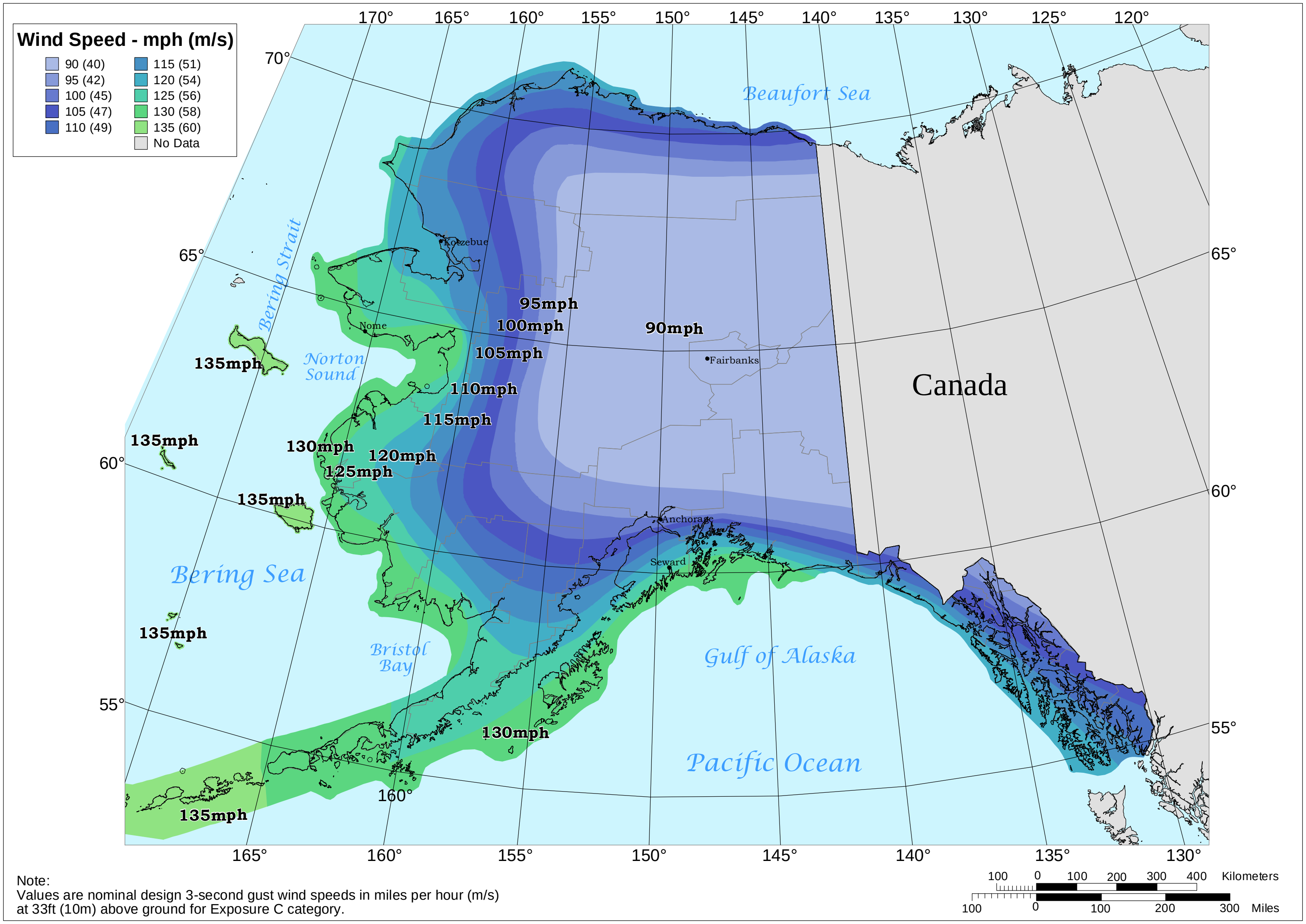


Fig. 4. Basic Wind Speeds - Alaska.

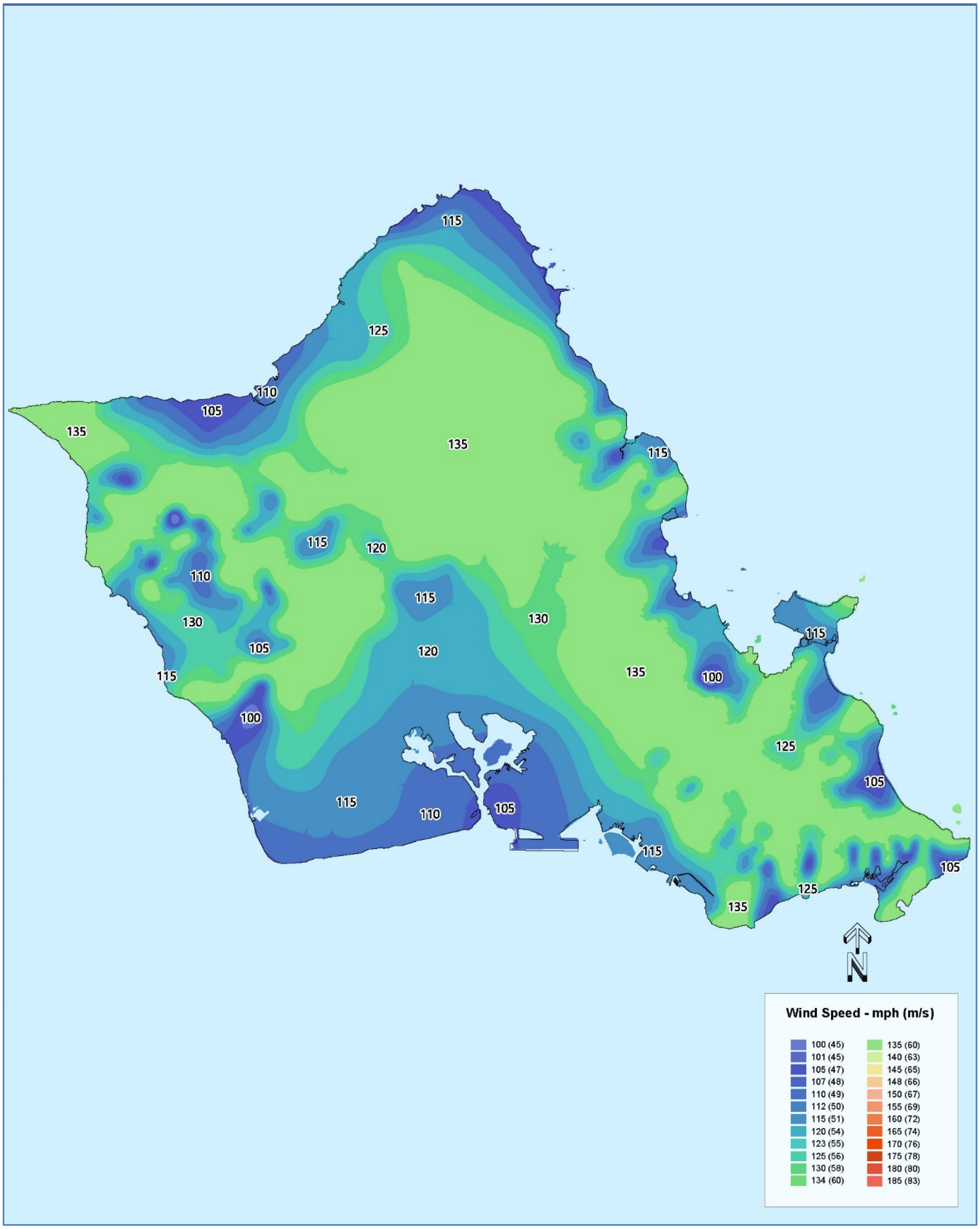


Fig. C-1a. 100-year MRI wind speeds for Oahu, HI, with topographic effects included.

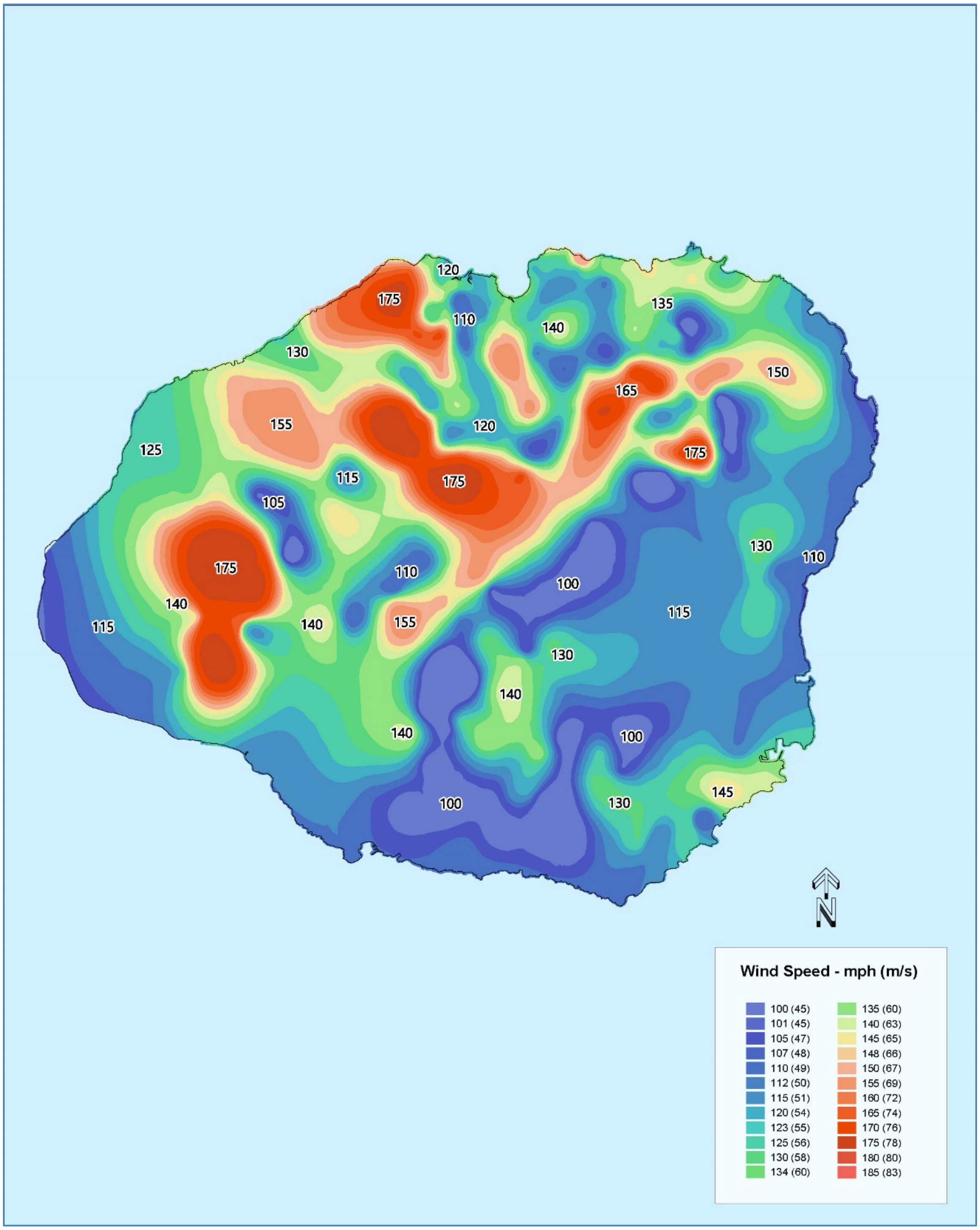


Fig. C-1b. 100-year MRI wind speeds for Kauai, HI, with topographic effects included

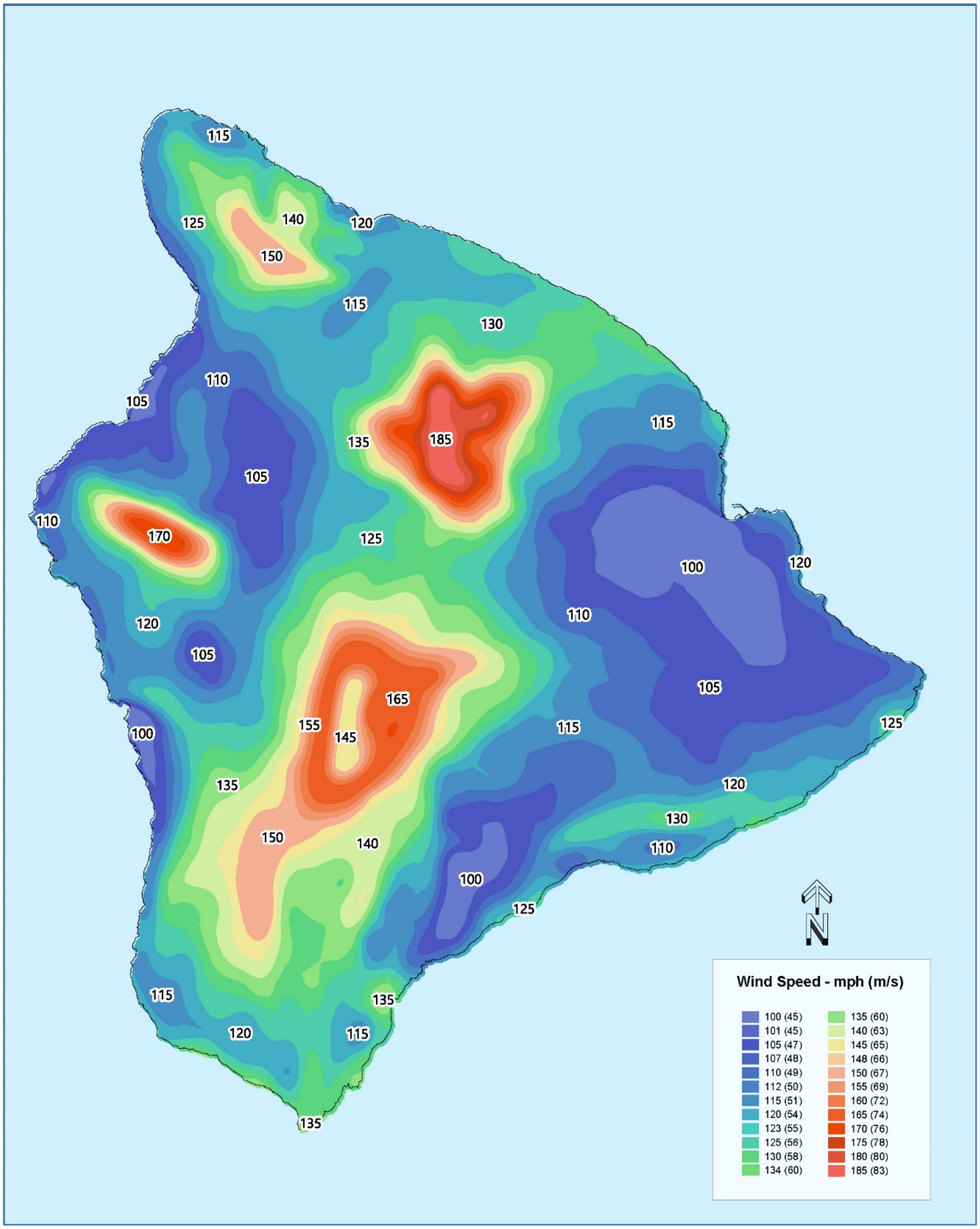


Fig. C-1c. 100-year MRI wind speeds for Hawaii, HI, with topographic effects included

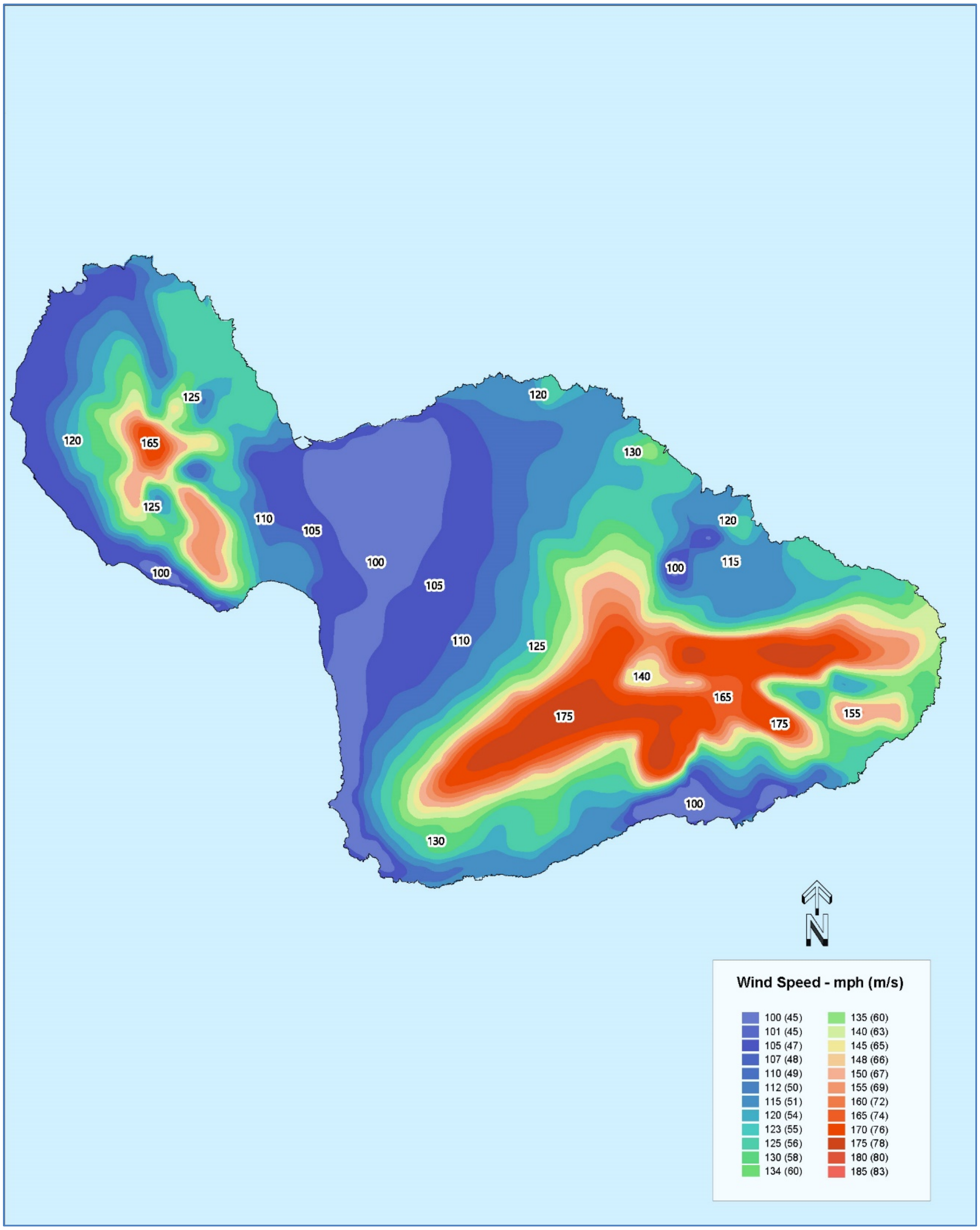


Fig. C-1d. 100-year MRI wind speeds for Maui, HI, with topographic effects included

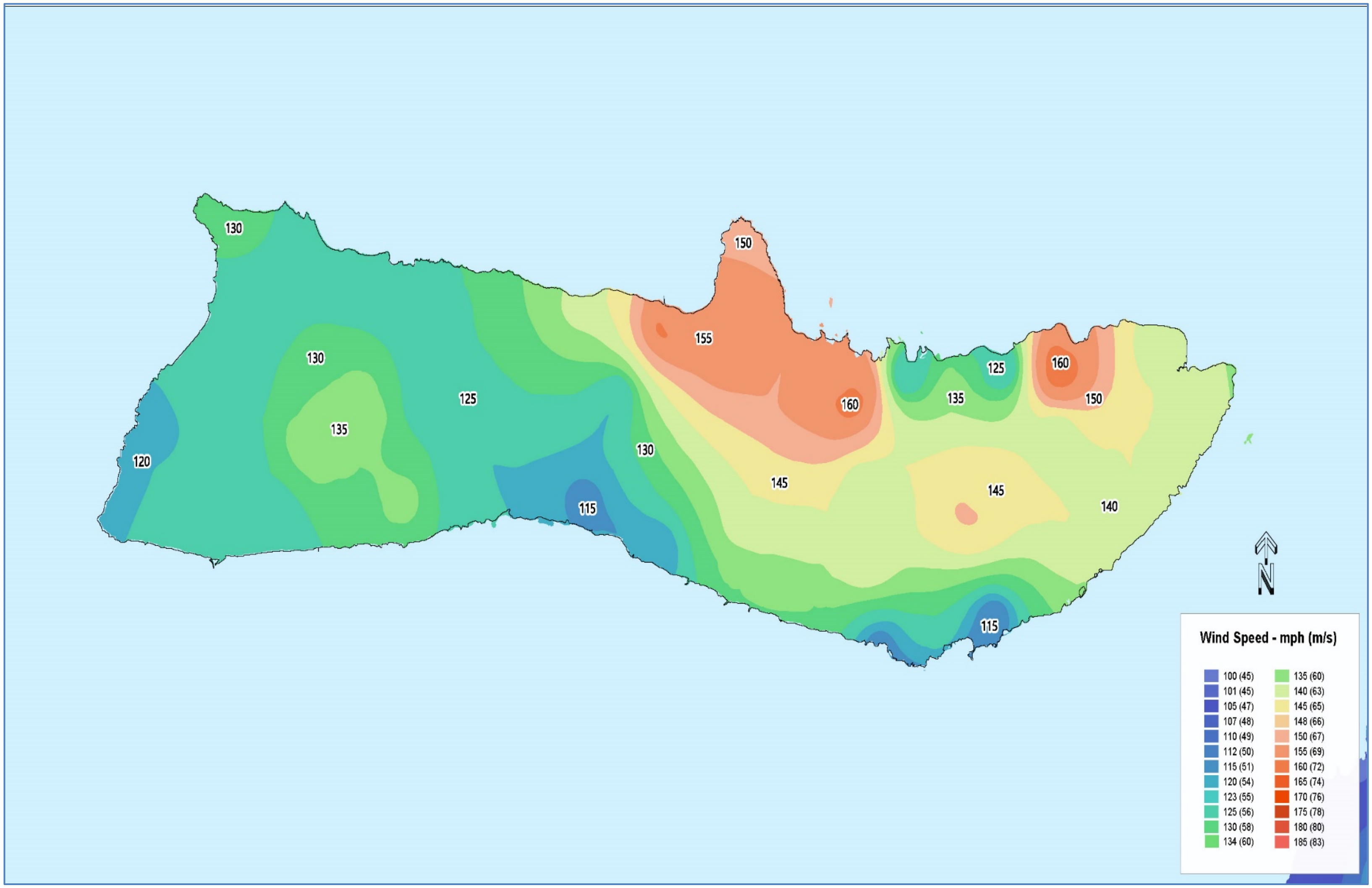


Fig. C-1e. 100-year MRI wind speeds for Molokai, HI, with topographic effects included

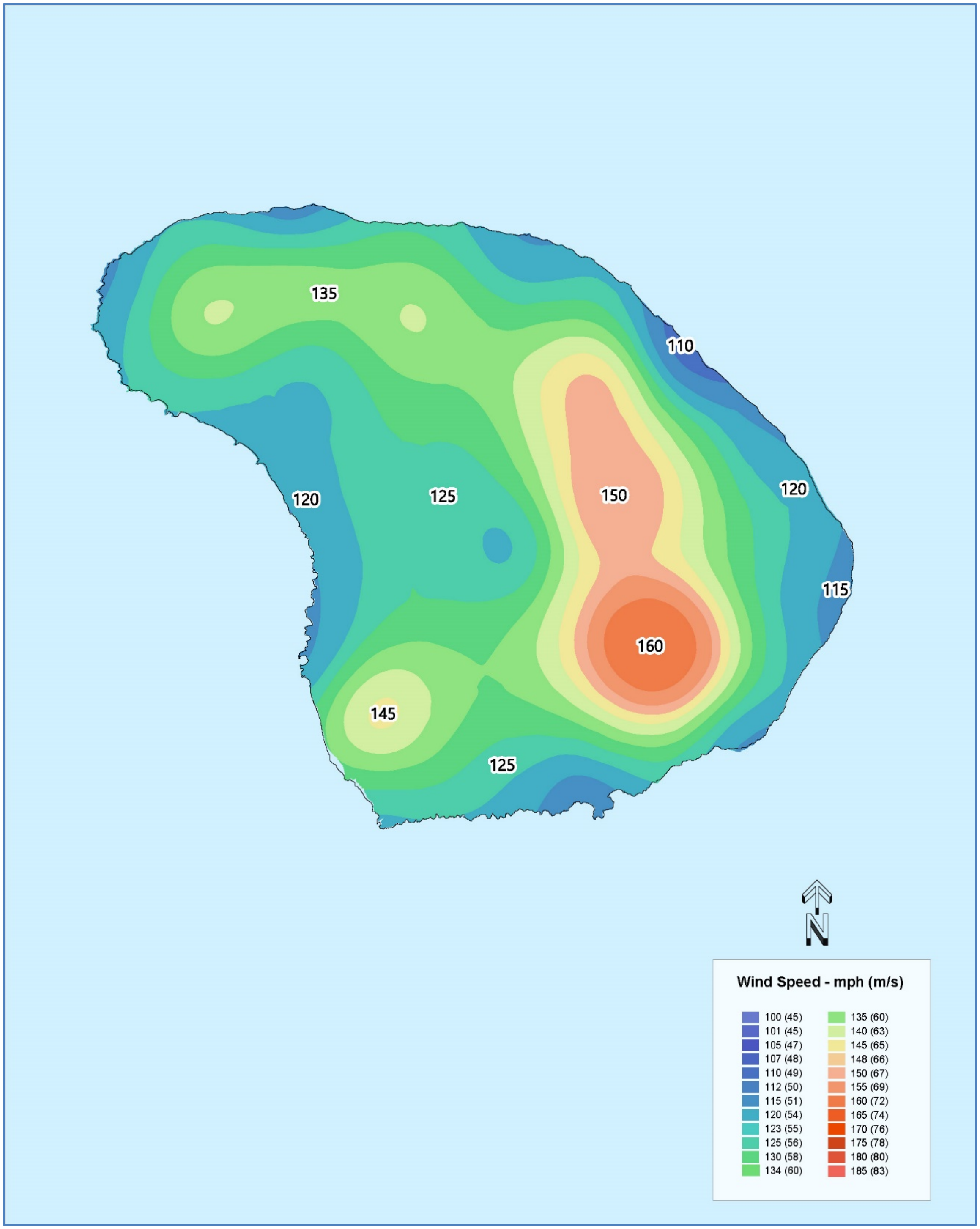


Fig. C-1f. 100-year MRI wind speeds for Lanai, HI, with topographic effects included

C.1.2 Wind Design for Australia and New Zealand

Use design wind speeds per Table AC1.1.1 for the four Australian islands noted.

Table AC1.1.1. Design Wind Speeds for Australian and Pacific Islands

Australian Island	*100-year MRI Wind Speed, mph (m/s)*	*Location*	*Tropical-Cyclone Prone Region*
Christmas Island	100 (45)	Well west of Darwin	Yes
Cocos Island	117 (52)	Well west of Darwin	Yes
Lord Howe Island	82 (36)	Well southeast of Brisbane	No
Norfolk Island	96 (43)	Well east of Brisbane	Yes
Fuji Islands	125 (56)	Well east of Townsville	Yes
Tonga	125 (56)	Well east of Townsville	Yes

C.1.2.1 New Zealand Wind Zone Topographic Effects

In the Australian/New Zealand Standard (AS/NZS 1170.2:2011), on the New Zealand wind map they note “lee” zones that are noted by various shading on the wind map and as listed in Table AC1.2. The total width of a wind zone (Southeast or Northwest) is 30 km (18.6 miles), of which 12 km (7.5 miles) is considered to be within the shadow lee zone and 18 km (11.2 miles) is considered to be within the outer lee zone. The wind zones are approximately centered on the mountain crests. The designer for any structures in these areas must increase the wind design pressures to account for the topographical effects (M) in these regions. Additional guidance is provided in the Australian/New Zealand Standard AS/NZS 1170.2:2011. Note that the presence of these lee zones should not be interpreted as being tropical cyclone prone.

Though calculated differently, similar guidance is provided in ASCE 7 (K_{ZT}). Using the New Zealand code, the designer multiplies M by the wind speed, which is then squared in determining the wind pressure. Per ASCE 7, K_{ZT} is multiplied by the wind pressure, so it is comparable to the square of M.

Table AC1.2. Location and Size of New Zealand Lee Zones

Location	*Horizontal Distance from Initiating Ridge, km (mi)*
Southeast Wind − Shadow Lee Zone	0 − 12 (0 − 7.5)
Southeast Wind − Outer Lee Zone	12 − 30 (7.5 − 18.6)
Northwest Wind − Shadow Lee Zone	0 − 12 (0 − 7.5)
Northwest Wind - Outer Lee Zone	12 − 30 (0 − 18.6)

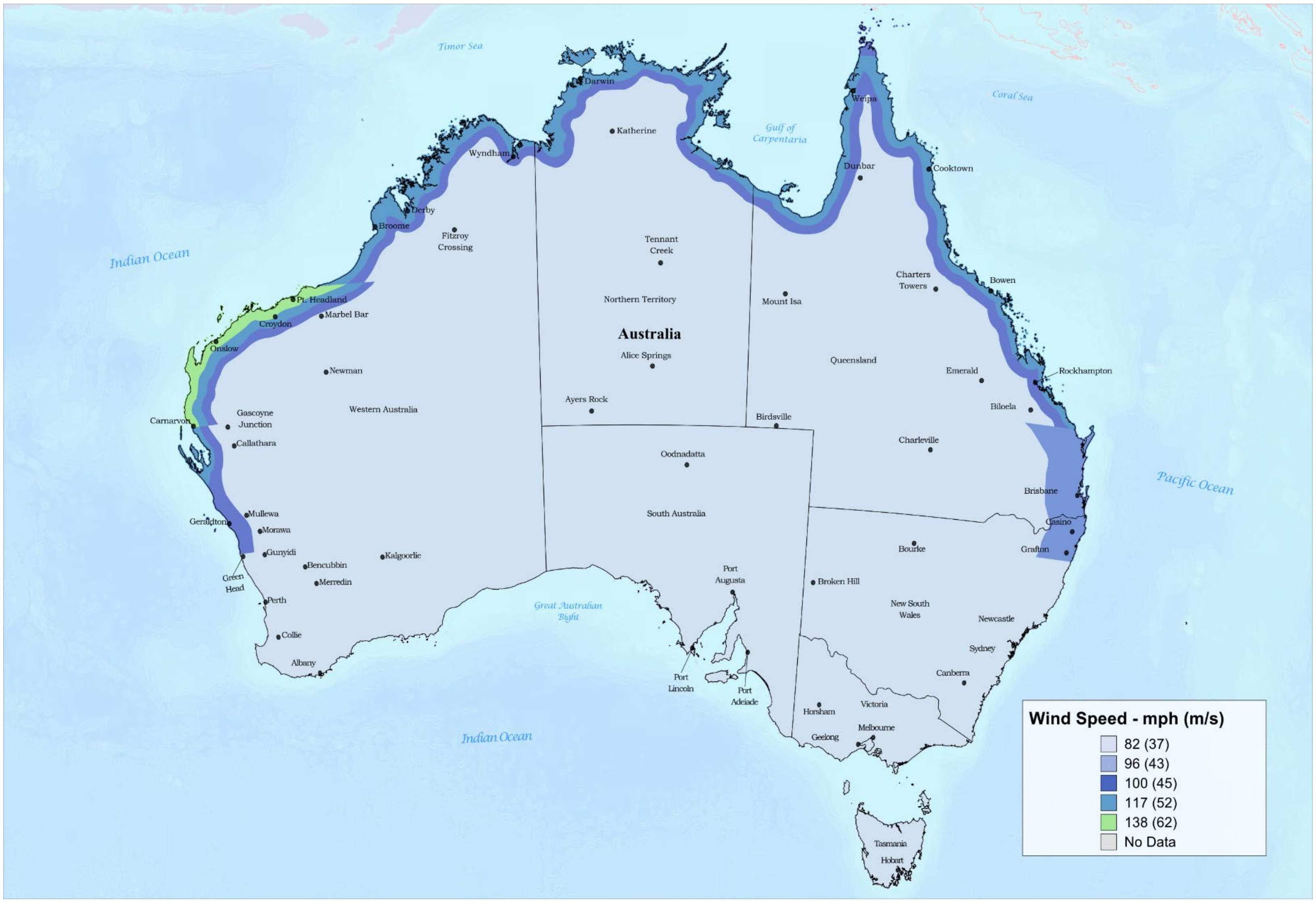


Fig. 5. Basic Wind Speeds - Australia, 3-sec gust in miles per hour (m/s).

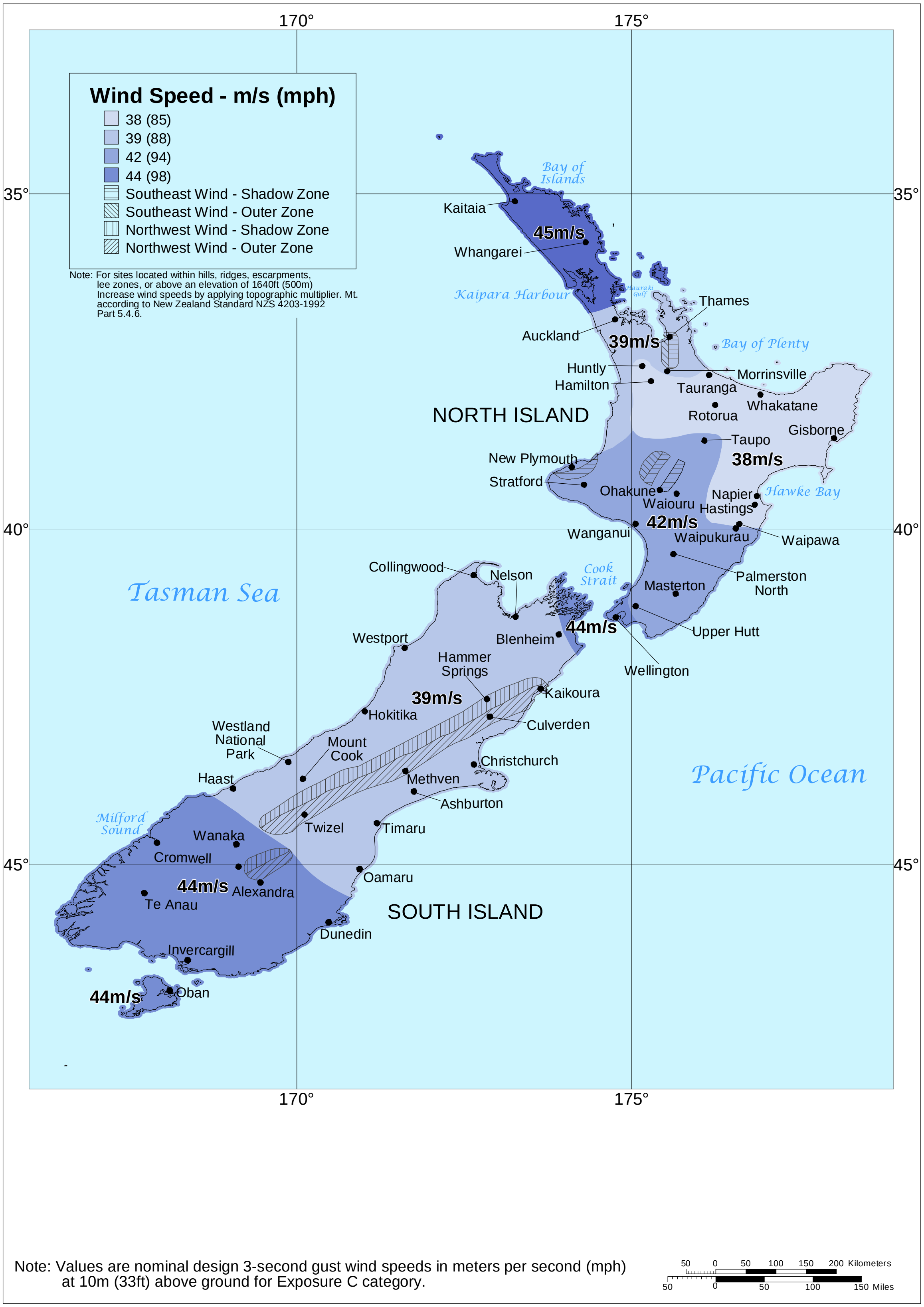
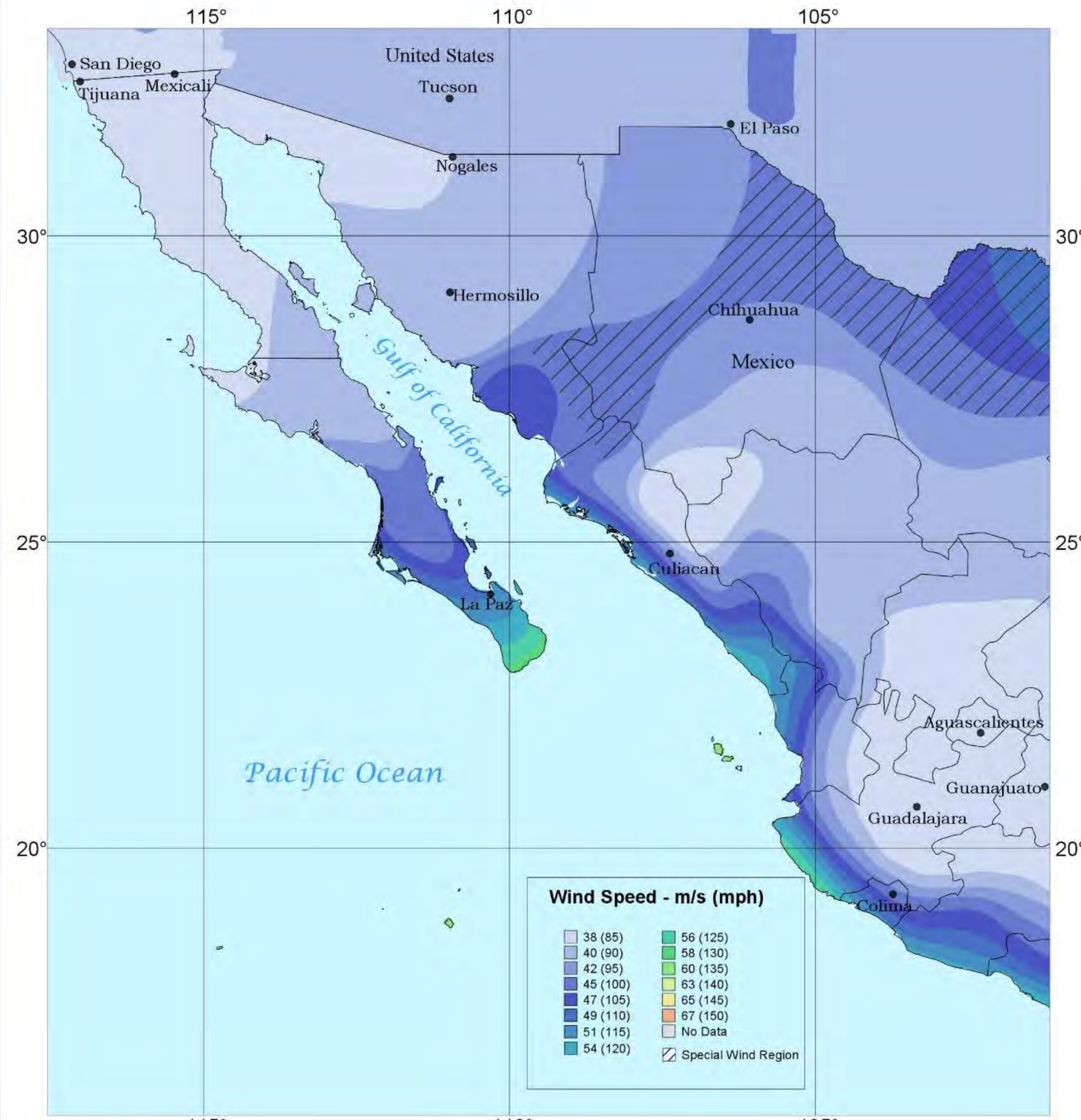


Fig. 6. Basic Wind Speeds - New Zealand, 3-sec gust in miles per hour (m/s). (8/2001)

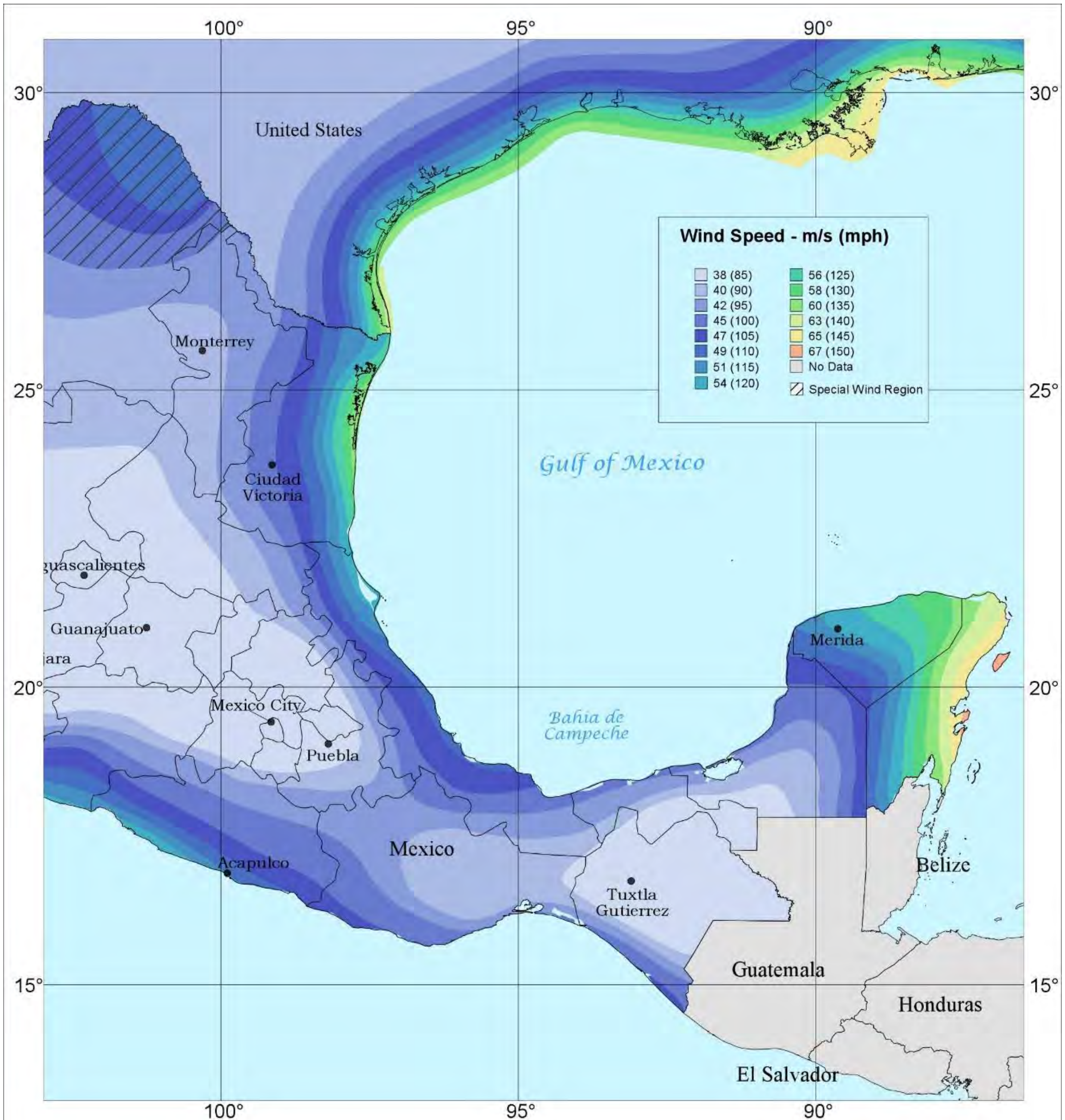


Notes: Values are nominal design 3-second gust wind speeds in meters per second (mph) at 10m (33ft) above ground for Exposure C category.

Consult local records in mountainous areas

To convert these basic wind speeds in m/s to mph multiply by 2.2369

Fig. 7 (Part 1) Basic Wind Speeds – Western Mexico, 3-sec gust in miles per hour

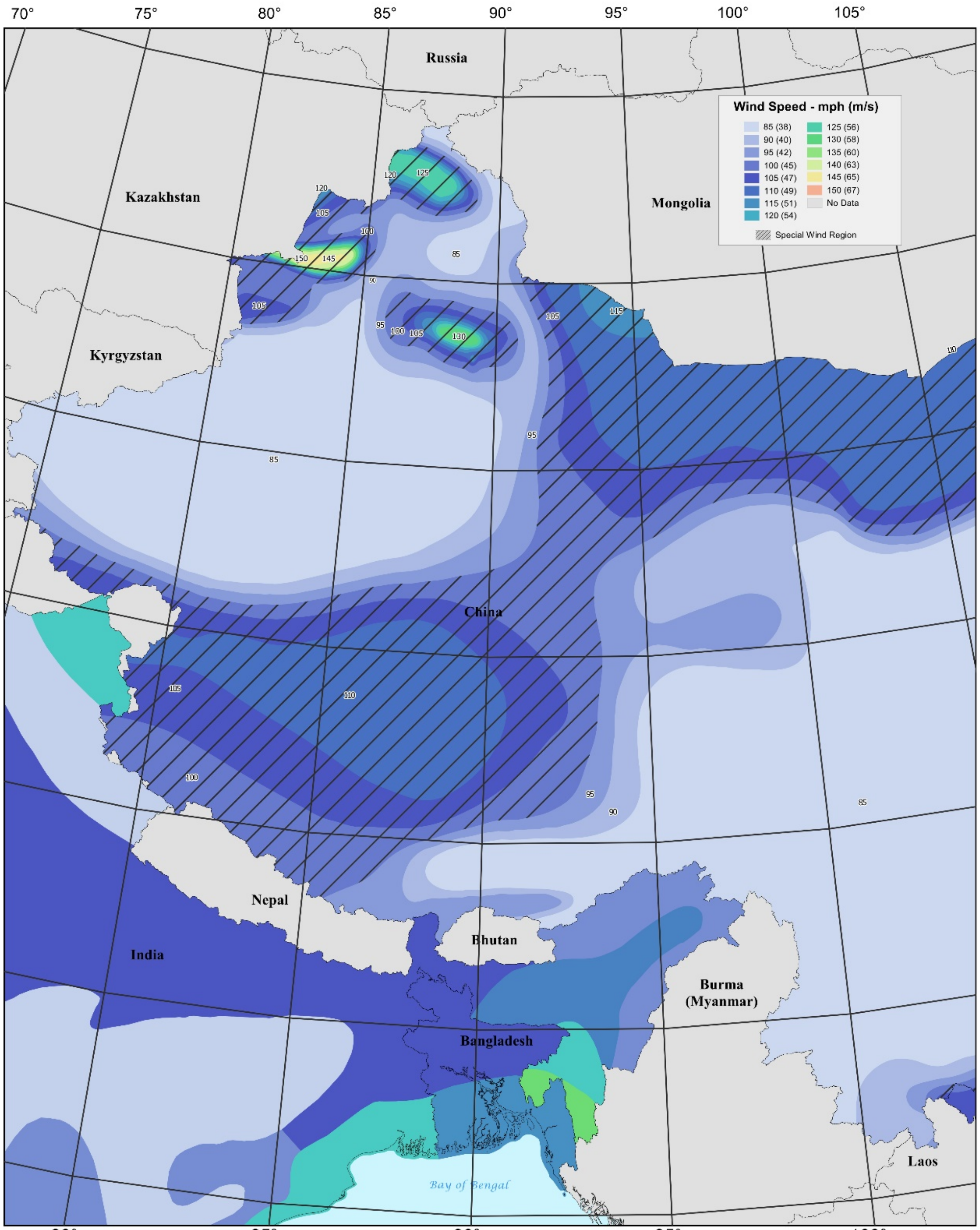


Notes: Values are nominal design 3-second gust wind speeds in meters per second (mph) at 10m (33ft) above ground for Exposure C category.

Consult local records in mountainous areas

To convert these basic wind speeds in m/s to mph multiply by 2.2369

Fig. 7. (Part 2) Basic Wind Speeds - Eastern Mexico, 3-sec gust in miles per hour.



Note: Values are nominal design 3-second gust wind speeds in meters per second (mph) at 10m (33ft) above ground for Exposure C category.

Fig. 8. Basic Wind Speeds for Western China, 3-sec. gust in m/s (mph)

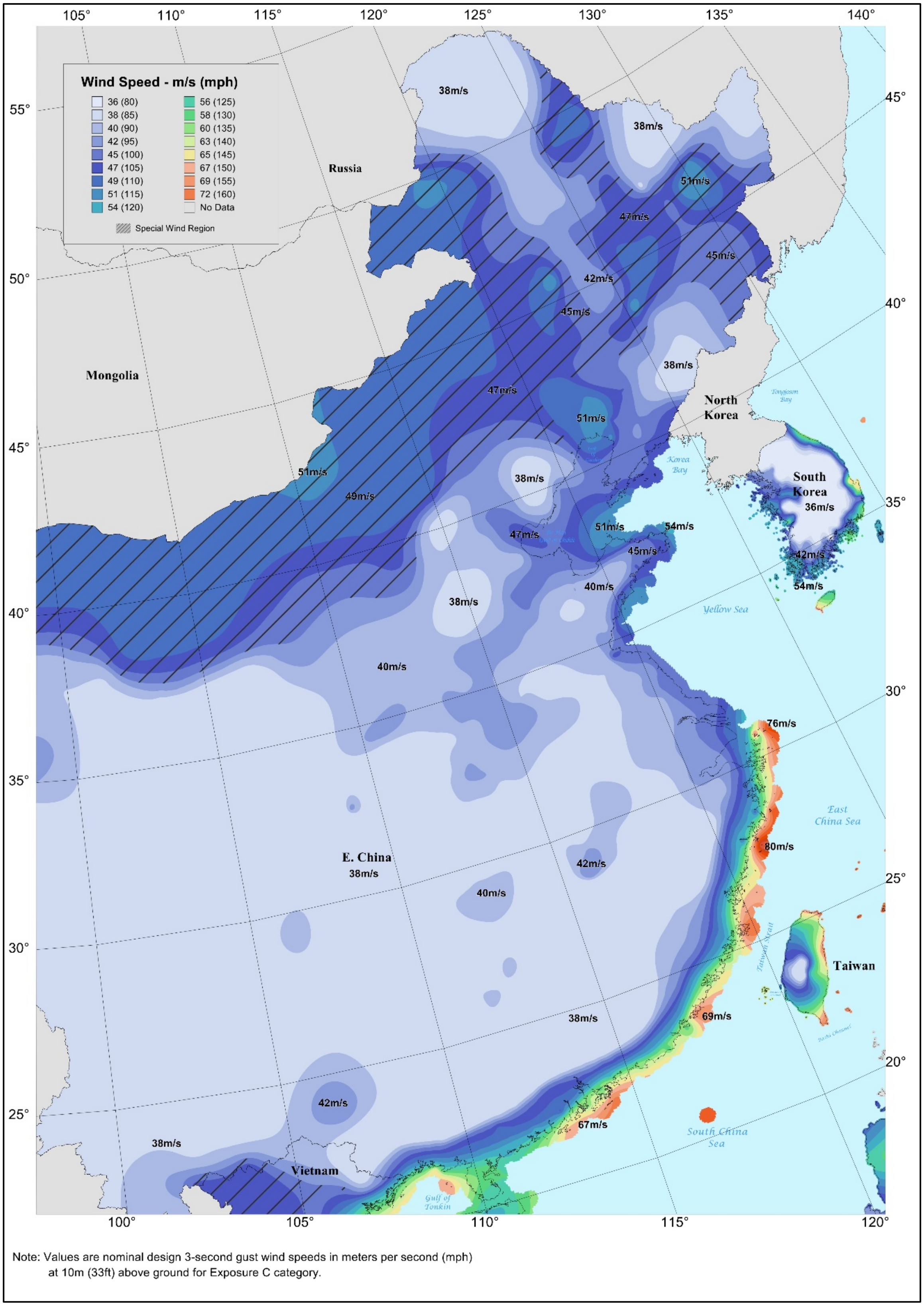


Fig. 8 (Part 2). Basic wind speeds: Eastern China, 3-sec gust in miles per hour

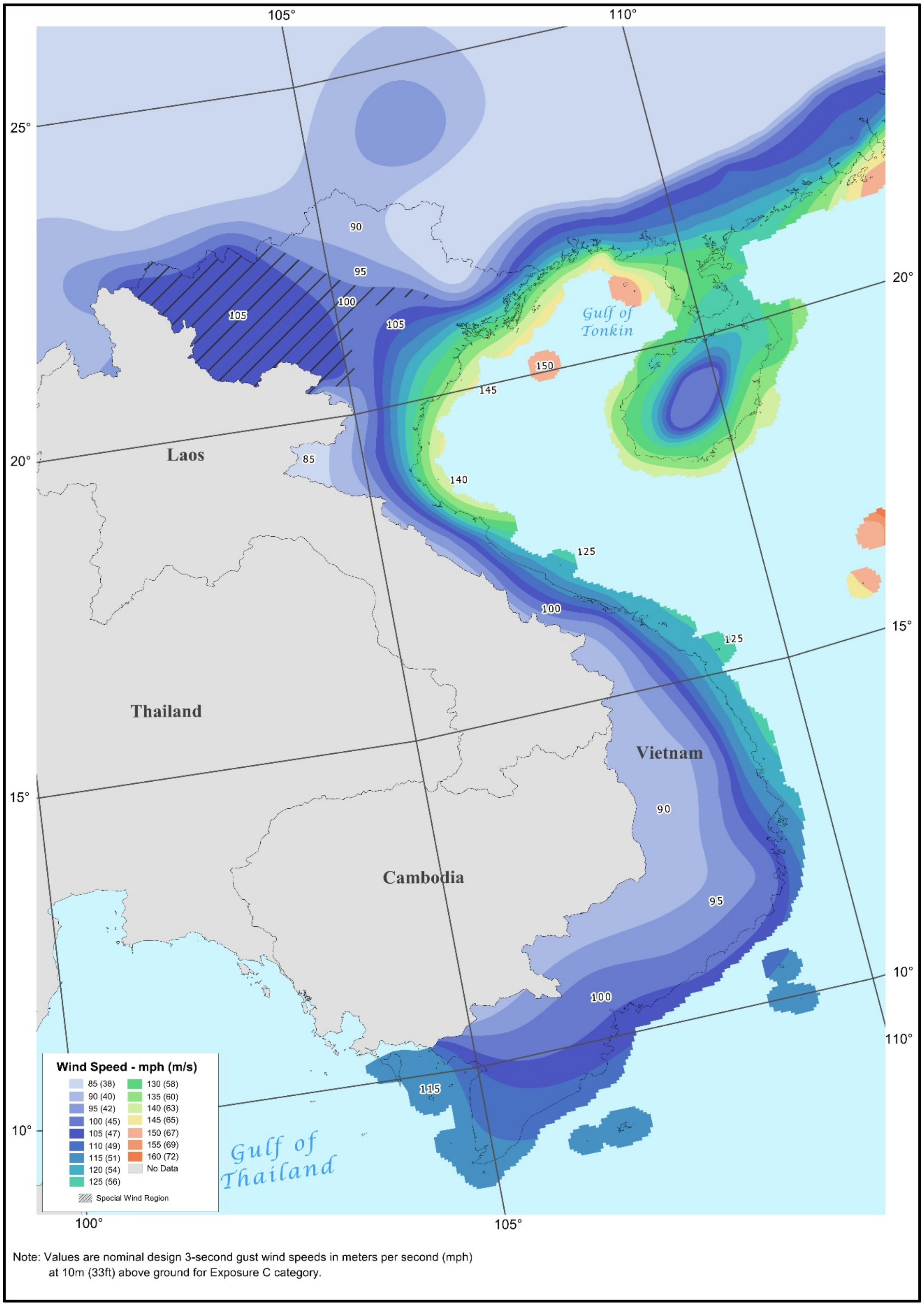
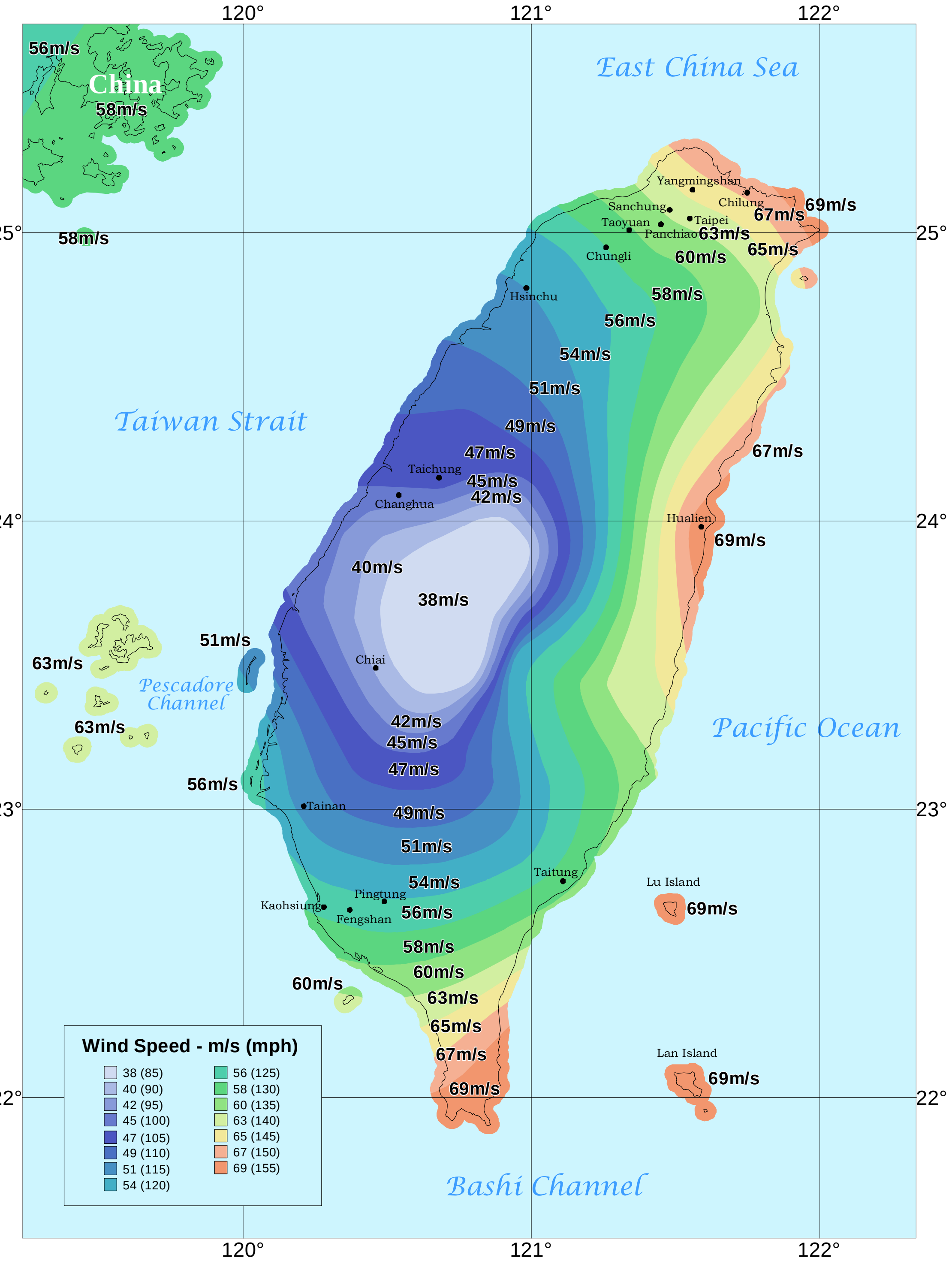


Fig. 8 (part 3) Basic Wind Speeds for Vietnam, 3-sec. gust in m/s (mph)



Note: Values are nominal design 3-second gust wind speeds in meters per second (mph) at 10m (33ft) above ground for Exposure C category.

20 0 20 40 60 Kilometers
10 0 10 20 30 40 Miles

Fig. 9. Basic Wind Speeds - Taiwan, 3 sec gust in m/s (mph). (8/2001)

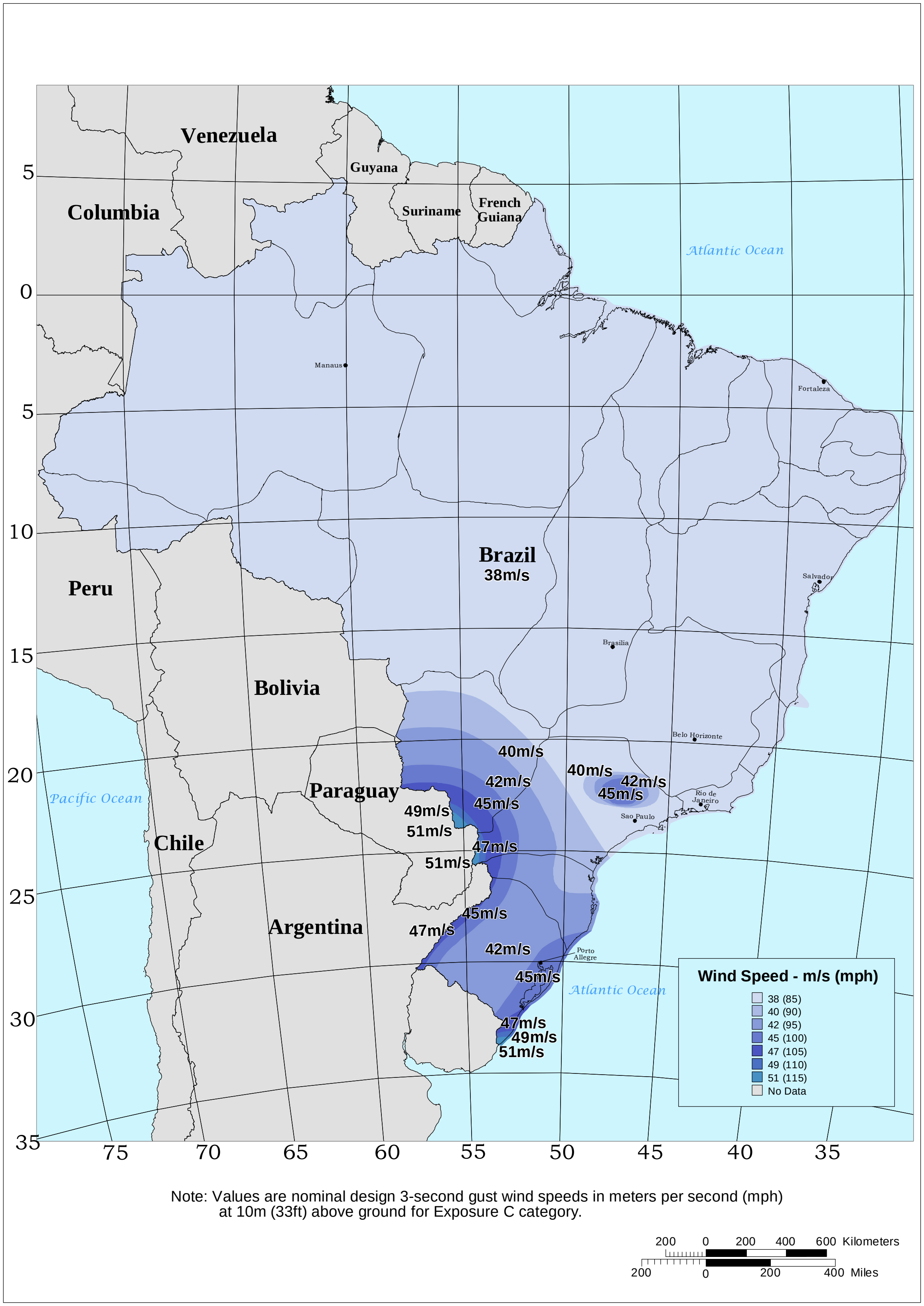


Fig. 10. Basic Wind Speeds - Brazil, 3-sec gust in miles per hour (m/s). (8/2001)

Table AC1.3. Wind Speed Conversions

Fastest Mile, mph	*Three-Second Gust, mph (m/s)*	*10-Minute Wind Speed, mph (m/s)*
70	84 (37)	58 (26)
75	88 (39)	61 (27)
80	94 (42)	65 (29)
85	100 (44)	69 (31)
90	104 (46)	72 (32)
95	111 (49)	77 ((34)
100	116 (52)	80 (36)
105	122 (54)	84 (37)
110	127 (56)	88 (39)
115	132 (59)	91 (40)
120	137 (61)	94 (42)
125	143 (64)	99 (44)
130	148 (66)	102 (45)
135	152 (68)	105 (47)
140	159 (71)	109 (48)
145	164 (73)	113 (50)
150	168 (75)	116 (52)
155	174 (77)	120 (53)
160	178 (78)	123 (55)

Table AC1.4. Basic Wind Speed for Selected Countries and Cities

Country/City	*Basic Wind Speed, 3-sec gust* [1]
Atlantic and Caribbean Sea Islands: Bermuda, Jamaica, Dominican Republic, Haiti, Bahamas, Virgin Islands, and the Leeward and Windward islands of the Caribbean Sea	145 mph (65 m/s)
Aruba	130 mph (58 m/s)
Trinidad and Tobago	120 mph (54 m/s)
Malaysia	Not a typhoon-prone region
Panama	72 mph (32 m/s) for the Pacific side; 87 mph (39 m/s) for the Caribbean side. Panama is not prone to tropical storms.[2]
Samoa Islands	135 mph (60 m/s)
Singapore	Not a typhoon-prone region

[1] Consult local records in mountainous areas.
[2] This is consistent with the Structural Design Code for the Republic of Panama.

Fig. 11. Basic Wind Speeds for Selected Cities: Canada, 3-sec gust in miles per hour (m/s) (8/2001)

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
100 Mile House	British Columbia	51.6475	-121.29	83
Abbotsford	British Columbia	49.0492	-122.331	103
Abbottsford	British Columbia	49.0492	-122.331	103
Acton Vale	Quebec	45.6483	-72.5659	74
Agassiz	British Columbia	49.2375	-121.77	115
Ailsa Craig	Ontario	43.1604	-81.6796	98
Aishihik	Yukon Territory	61.5942	-137.513	82
Ajax	Ontario	43.85087	-79.0203	100
Aklavik	Northwest Territories	68.2201	-140.367	100
Alberni	British Columbia	49.26557	-124.814	105
Alert	Northwest Territories	82.4243	-62.5671	115
Alexandria	Ontario	45.3084	-74.6277	84
Alliston	Ontario	44.1453	-79.8577	74
Alma	Quebec	48.5497	-71.6602	74

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Alma	New Brunswick	45.6074	-64.9386	98
Almonte	Ontario	45.2303	-76.1887	84
Amherst	Nova Scotia	45.8327	-64.2043	100
Amos	Quebec	48.5747	-78.1253	74
Amprior	Ontario	45.4409	-76.3612	81
Amqui	Quebec	48.4594	-67.4377	78
Anse Comeau	Quebec	49.2171	-68.1608	103
Antigonish	Nova Scotia	45.6231	-61.9897	98
Antigonishe	Nova Scotia	45.6231	-61.9897	98
Arctic Bay	Northwest Territories	73.0387	-85.1881	98
Argentia	Newfoundland	47.2836	-54.0105	115
Armstrong	Ontario	50.3057	-89.0605	69
Arnprior	Ontario	45.4409	-76.3612	81
Ashcroft	British Columbia	50.7256	-121.276	82
Assiniboia	Saskatchewan	49.6243	-105.963	100
Athabasca	Alberta	54.7133	-113.284	84
Athabaska	Alberta	54.7133	-113.284	84
Atikokan	Ontario	48.7572	-91.6158	69
Aurora	Ontario	44.00648	-79.4504	86
Aylmer	Quebec	45.3899	-75.8304	84
Bagotville	Quebec	48.3459	-70.8927	81
Baie-Comeau	Quebec	49.2171	-68.1608	103
Baker Lake	Northwest Territories	64.3235	-96.0323	98
Bancroft	Ontario	45.0524	-77.8509	74
Banff	Alberta	51.1772	-115.552	93
Barrhead	Alberta	54.1218	-114.397	86
Barrie	Ontario	44.3847	-79.6752	74
Barriefield	Ontario	44.2395	-76.4514	91
Bathurst	New Brunswick	47.612	-65.6466	91
Battrum	Saskatchewan	50.54834	-108.335	107
Beaconsfield	Quebec	45.42424	-73.8662	84
Beauport	Quebec	46.85944	-71.1932	96
Beauséjour	Manitoba	50.0606	-96.5254	84
Beaverlodge	Alberta	55.2069	-119.429	79
Beaverton	Ontario	44.4295	-79.1536	78
Bedford	Quebec	45.12055	-72.9865	84
Belleville	Ontario	44.1605	-77.3766	86
Belmont	Ontario	42.8814	-81.0875	93
Beloeil	Quebec	45.56699	-73.2024	81
Big Trout Lake	Ontario	53.81876	-89.8351	86
Biggar	Saskatchewan	52.0539	-107.976	107
Boissevain	Manitoba	49.2287	-100.057	100
Bonavista	Newfoundland	48.6541	-53.1205	110
Borden	Ontario	44.2901	-79.9127	74
Bracebridge	Ontario	45.0353	-79.3036	78
Bradford	Ontario	44.12022	-79.5619	78
Brampton	Ontario	43.6889	-79.7583	86
Brandon	Manitoba	49.8404	-99.958	93
Brantford	Ontario	43.1457	-80.2624	84
Bridgewater	Nova Scotia	44.3732	-64.5176	100
Brighton	Ontario	44.0351	-77.7281	98
Broadview	Saskatchewan	50.3796	-102.576	86
Brockville	Ontario	44.6011	-75.69	86
Brome	Quebec	45.19407	-72.5717	81
Brooks	Alberta	50.5676	-111.894	96
Brossard	Quebec	45.45715	-73.4922	84
Buchans	Newfoundland	48.8232	-56.8743	103
Buckingham	Quebec	45.5863	-75.4059	84
Burks Falls	Ontario	45.61988	-79.4087	78
Burlington	Ontario	43.3255	-79.7917	91
Burnaby	British Columbia	49.234	-122.953	92
Burns Lake	British Columbia	54.2327	-125.765	83
Cache Creek	British Columbia	50.8148	-121.322	82
Calgary	Alberta	51.0246	-114.102	94
Cambridge	Ontario	43.3559	-80.3035	78
Cambridge Bay	Northwest Territories	69.1122	-105.071	98
Campbell River	British Columbia	50.0307	-125.255	105
Campbellford	Ontario	44.3007	-77.7909	84

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Campbells Bay	Quebec	45.7324	-76.5875	74
Campbellton	New Brunswick	47.9988	-66.6763	96
Campbell-town	New Brunswick	47.9988	-66.6763	96
Campsie	Alberta	54.13735	-114.651	86
Camrose	Alberta	53.0198	-112.831	84
Cannington	Ontario	44.35018	-79.0386	78
Canso	Nova Scotia	45.3341	-61.0029	105
Cape Race	Newfoundland	46.665	-53.093	136
Cardston	Alberta	49.1909	-113.301	134
Carleton Place	Ontario	45.1432	-76.1412	84
Carmi	British Columbia	49.4973	-119.12	79
Castlegar	British Columbia	49.3147	-117.666	76
Cavan	Ontario	44.19967	-78.4687	86
Cayoosh Flat	British Columbia	50.6931	-121.929	86
Centralia	Ontario	43.2839	-81.4721	96
Chambly	Quebec	45.44906	-73.2918	84
Channel-port Aux Basqeus	Newfoundland	47.5851	-59.1657	110
Chapleau	Ontario	47.8504	-83.4079	69
Charlottetown	Prince Edward Island	46.239	-63.1333	103
Chatham	Ontario	42.4024	-82.185	86
Chatham	New Brunswick	47.0302	-65.4668	84
Chesley	Ontario	44.30272	-81.0966	91
Chesterfield	Northwest Territories	63.3437	-90.7414	100
Chesterfield Inlet	Northwest Territories	63.3437	-90.7414	100
Chetwynd	British Columbia	55.694	-121.619	84
Chicoutimi	Quebec	48.4294	-71.0424	78
Chilliwack	British Columbia	49.1432	-121.961	110
Churchill	Manitoba	58.7609	-94.0678	106
Claresholm	Alberta	50.0268	-113.579	124
Clinton	Ontario	43.6197	-81.5394	96
Cloverdale	British Columbia	49.10833	-122.725	91
Clyde	Northwest Territories	70.457	-68.6299	124
Clyde River	Northwest Territories	70.457	-68.6299	124
Coaticook	Quebec	45.1338	-71.8053	81
Coboconk	Ontario	44.65881	-78.7974	78
Cobourg	Ontario	43.96	-78.1574	103
Cochrane	Ontario	49.0639	-81.0466	78
Colbourne	Ontario	44.0051	-77.8877	100
Cold Lake	Alberta	54.4575	-110.189	84
Coleman	Alberta	49.6397	-114.497	115
Collingwood	Ontario	44.4957	-80.2116	81
Colvilletown	British Columbia	49.1253	-123.924	105
Comax	British Columbia	49.682	-124.942	105
Comeau Bay	Quebec	49.2171	-68.1608	103
Comox	British Columbia	49.682	-124.942	105
Comuck	British Columbia	49.682	-124.942	105
Contrecoeur	Quebec	45.85716	-73.2391	87
Coppermine	Northwest Territories	67.8717	-115.639	90
Coral Harbour	Northwest Territories	64.13374	-83.1669	132
Corner Brook	Newfoundland	48.9587	-57.9856	115
Cornwall	Ontario	45.0283	-74.7381	84
Coronation	Alberta	52.0902	-111.441	78
Coronation	Northwest Territories	67.8717	-115.639	90
Corunna	Ontario	42.8886	-82.4533	91
Courtenay	British Columbia	49.6803	-124.999	105
Cowansville	Quebec	45.2067	-72.7464	84
Cowley	Alberta	49.5733	-114.063	132
Cranbrook	British Columbia	49.5101	-115.768	74
Crescent Valley	British Columbia	49.45	-117.55	74
Crofton	British Columbia	48.8632	-123.647	105
Dafoe	Saskatchewan	51.749	-104.521	81
Dartmouth	Nova Scotia	44.6851	-63.5353	100
Dauphin	Manitoba	51.141	-100.049	84
Dawson	Yukon Territory	64.0428	-139.417	73
Dawson City	Yukon Territory	64.0428	-139.417	73
Dawson Creek	British Columbia	55.7542	-120.234	84
Debert	Nova Scotia	45.43808	-63.4599	98
Deep River	Ontario	46.09717	-77.4939	78

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Deseronto	Ontario	44.1926	-77.0469	86
Destruction Bay	Yukon Territory	61.2561	-138.803	103
Deux-Montagnes	Quebec	45.54176	-73.8932	81
Digby	Nova Scotia	44.6214	-65.7618	98
Dog Creek	British Columbia	51.584	-122.239	84
Dolbeau	Quebec	48.8794	-72.2323	78
Dorchester	Ontario	42.98522	-81.0491	91
Dorion	Ontario	48.78333	-88.5333	83
Dorval	Quebec	45.43896	-73.7332	84
Dresden	Ontario	42.58434	-82.1799	86
Drumheller	Alberta	51.4617	-112.703	86
Drummondville	Quebec	45.8821	-72.4953	74
Drummondville East	Quebec	45.8821	-72.4953	74
Dryden	Ontario	49.7817	-92.8476	69
Duncan	British Columbia	48.7648	-123.685	105
Dundurn	Saskatchewan	51.8036	-106.499	96
Dunnville	Ontario	42.9076	-79.6185	86
Durham	Ontario	44.1667	-80.8118	86
Dutton	Ontario	42.66379	-81.5027	91
Earlton	Ontario	47.7088	-79.8187	87
Earlton Junction	Ontario	47.7088	-79.8187	87
East Souris	Prince Edward Island	46.3542	-62.2507	98
Edmonton	Alberta	53.5556	-113.508	87
Edmundston	New Brunswick	47.381	-68.3294	86
Edson	Alberta	53.5835	-116.435	98
Elko	British Columbia	49.3007	-115.11	84
Elmvale	Ontario	44.58357	-79.8663	78
Embarras	Alberta	58.2086	-111.375	84
Embro	Ontario	43.15365	-80.9	91
Englehart	Ontario	47.8235	-79.8711	84
Eskimo Point	Northwest Territories	61.1877	-94.0963	106
Espanola	Ontario	46.2534	-81.7602	84
Estevan	Saskatchewan	49.1399	-102.999	99
Etobicoke	Ontario	43.65437	-79.5408	96
Eureka	Northwest Territories	79.9842	-85.8287	107
Exeter	Ontario	43.347	-81.4733	96
Fairview	Alberta	56.0717	-118.376	78
Farnham	Quebec	45.2853	-72.9793	84
Fenelon Falls	Ontario	44.5341	-78.726	78
Fergus	Ontario	43.707	-80.3696	78
Fernie	British Columbia	49.51	-115.065	91
Flin Flon	Manitoba	54.76849	-101.877	87
Fonthill	Ontario	43.04543	-79.2855	86
Forest	Ontario	43.0966	-81.996	96
Fort Erie	Ontario	42.9091	-78.9257	91
Fort Frances	Ontario	48.6145	-93.4165	73
Fort Good Hope	Northwest Territories	66.255	-128.621	105
Fort Macleod	Alberta	49.7164	-113.405	126
Fort McLeod	British Columbia	54.9934	-123.031	74
Fort McMurray	Alberta	56.7251	-111.366	78
Fort Nelson	British Columbia	58.8003	-122.702	70
Fort Providence	Northwest Territories	61.3547	-117.66	78
Fort Rae	Northwest Territories	62.8337	-116.036	91
Fort Resolution	Northwest Territories	61.1736	-113.663	83
Fort Saint John	British Columbia	56.2481	-120.854	83
Fort Saskatchewan	Alberta	53.7065	-113.216	86
Fort Simpson	Northwest Territories	61.8621	-121.361	84
Fort Smith	Northwest Territories	60.0125	-111.893	84
Fort Vermilion	Alberta	58.3898	-115.997	70
Fort Vermillion	Alberta	58.3898	-115.997	70
Fort William	Ontario	48.441	-89.2476	83
Fort-coulonge	Quebec	45.8425	-76.7342	74
Fredericton	New Brunswick	45.9493	-66.6543	84
Gagetown	New Brunswick	45.7786	-66.1487	96
Gananoque	Ontario	44.3311	-76.1673	91
Gander	Newfoundland	48.9508	-54.6277	103
Gaspé	Quebec	48.8286	-64.5025	117
Gatineau	Quebec	45.4942	-75.6607	84

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Geraldton	Ontario	49.7212	-86.9506	69
Gimli	Manitoba	50.633	-96.9852	84
Glacier	British Columbia	51.2658	-117.516	74
Glencoe	Ontario	42.7232	-81.7143	86
Goderich	Ontario	43.7457	-81.7053	98
Golden	British Columbia	51.2917	-116.959	78
Good Hope	Northwest Territories	66.255	-128.621	105
Gore Bay	Ontario	45.9115	-82.4634	83
Gracefield	Quebec	46.0942	-76.0587	74
Graham	Ontario	49.2395	-90.5866	69
Granby	Quebec	45.4025	-72.7221	78
Grand Bank	Newfoundland	47.0932	-55.7612	115
Grand Falls	New Brunswick	47.0502	-67.7341	84
Grand Falls	Newfoundland	48.929	-55.6505	103
Grand Forks	British Columbia	49.0342	-118.44	83
Grande Prairie	Alberta	55.1697	-118.796	92
Gravenhurst	Ontario	44.9171	-79.3674	78
Greenwood	British Columbia	49.0904	-118.671	86
Greenwood	Nova Scotia	44.9764	-64.9509	96
Grimsby	Ontario	43.1823	-79.557	91
Guelph	Ontario	43.5505	-80.2519	76
Guthrie	Ontario	44.4728	-79.55	74
Habay	Alberta	58.8088	-118.707	70
Haileybury	Ontario	47.4419	-79.6295	86
Haldimand-norfolk	Ontario	43.2263	-80.142	86
Haliburton	Ontario	45.045	-78.5085	78
Halifax	Nova Scotia	44.6539	-63.6075	100
Halleybury	Ontario	47.4419	-79.6295	86
Halton	Ontario	43.5809	-79.8591	81
Hamilton	Ontario	43.257	-79.8423	91
Haney	British Columbia	49.2198	-122.503	91
Hanover	Ontario	44.1465	-81.0194	91
Happy Valley	Newfoundland	53.2974	-60.28	81
Hardisty	Alberta	52.6734	-111.299	78
Harrington Harbour	Quebec	50.4975	-59.4709	127
Harve-st-pierre	Quebec	50.2434	-63.6032	117
Hastings	Ontario	44.30694	-77.9558	84
Hawkesbury	Ontario	45.6047	-74.6114	84
Hay River	Northwest Territories	60.8535	-115.749	78
Hearst	Ontario	49.6895	-83.6786	69
Hemmingford	Quebec	45.0504	-73.5868	84
High River	Alberta	50.5816	-113.869	107
Hinton	Alberta	53.3919	-117.596	91
Holman	Northwest Territories	70.7359	-117.746	122
Honey Harbour	Ontario	44.87107	-79.8171	81
Hope	British Columbia	49.3799	-121.438	103
Hornepayne	Ontario	49.21302	-84.7711	69
Hudson Bay	Saskatchewan	52.8573	-102.382	81
Hudson Bay Junction	Saskatchewan	52.8573	-102.382	81
Hull	Quebec	45.4362	-75.7255	84
Humboldt	Saskatchewan	52.2014	-105.119	83
Huntsville	Ontario	45.3197	-79.2096	78
Iberville	Quebec	45.3107	-73.2377	84
Ingersoll	Ontario	43.0423	-80.8802	91
Inuvik	Northwest Territories	68.3655	-133.706	103
Iqaluit	Northwest Territories	63.71104	-68.3275	103
Iroquois Falls	Ontario	48.7746	-80.6845	84
Isachsen	Northwest Territories	78.7723	-103.572	126
Island Falls	Saskatchewan	55.5041	-102.329	87
Island Lake	Manitoba	53.8666	-94.6407	87
Ivujivik	Quebec	62.4138	-77.9287	125
Jarvis	Ontario	42.88448	-80.1141	86
Jasper	Alberta	52.8785	-118.085	91
Jellicoe	Ontario	49.6848	-87.5479	69
Joliette	Quebec	46.0266	-73.4425	79
Jonquiere	Quebec	48.4239	-71.2445	78
Kamloops	British Columbia	50.7113	-120.386	84
Kamsack	Saskatchewan	51.5586	-101.897	84

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Kangerjuaq	Northwest Territories	64.3235	-96.0323	98
Kapuskasing	Ontario	49.4278	-82.429	73
Kaslo	British Columbia	49.9097	-116.911	73
Keg River	Alberta	57.7551	-117.6	70
Kelowna	British Columbia	49.8675	-119.449	91
Kemptville	Ontario	45.0205	-75.6332	84
Kenogami	Quebec	48.4282	-71.2307	78
Kenora	Ontario	49.7681	-94.4894	73
Kentville	Nova Scotia	45.0749	-64.5018	96
Killaloe Station	Ontario	45.5519	-77.4229	78
Kimberley	British Columbia	49.6827	-115.983	74
Kimberly	British Columbia	49.6827	-115.983	74
Kincardine	Ontario	44.1758	-81.6301	98
Kindersley	Saskatchewan	51.4675	-109.154	105
Kingston	Ontario	44.23	-76.4975	91
Kinmount	Ontario	44.7846	-78.6475	78
Kirkland Lake	Ontario	48.1596	-80.0281	84
Kitchener	Ontario	43.457	-80.4934	81
Knob Lake	Quebec	54.8007	-66.8108	86
Kogluktok	Northwest Territories	67.8717	-115.639	90
Komoux	British Columbia	49.682	-124.942	105
Kuujjuag	Quebec	58.1081	-68.4172	112
Kuujjuarapik	Quebec	55.28335	-77.7499	121
La Malbaie	Quebec	47.6569	-70.1608	98
La Tuque	Quebec	47.4432	-72.7774	78
Labrador City	Newfoundland	52.9396	-66.9201	84
Lac du Bonnet	Manitoba	50.255	-96.0745	81
Lac La Biche	Alberta	54.7675	-111.96	84
Lachute	Quebec	45.654	-74.3425	84
Lac-Mégantic	Quebec	45.5717	-70.8625	78
Lacombe	Alberta	52.46415	-113.734	84
Ladner	British Columbia	49.09013	-123.082	93
Lakefield	Ontario	44.4163	-78.2657	81
Langley	British Columbia	49.1009	-122.65	91
Lansdowne House	Ontario	52.2097	-87.9021	74
Laval	Quebec	45.5714	-73.6838	84
Le Pas	Manitoba	53.8164	-101.253	87
Leamington	Ontario	42.0504	-82.5992	91
Lennoxville	Quebec	45.3691	-71.8559	74
Lery	Quebec	45.34483	-73.8062	84
Lethbridge	Alberta	49.6908	-112.82	121
Levis	Quebec	46.80289	-71.1761	96
Lillooet	British Columbia	50.6931	-121.929	86
Lindsay	Ontario	44.3518	-78.7316	81
Lions Head	Ontario	44.98475	-81.2532	91
Listowel	Ontario	43.7331	-80.9452	91
Liverpool	Nova Scotia	44.0392	-64.7185	103
Lloydminster	Saskatchewan	53.28414	-110.003	84
Lockeport	Nova Scotia	43.6989	-65.1253	103
London	Ontario	42.9883	-81.2356	96
Loretteville	Quebec	46.8549	-71.3644	96
Louisbourg	Nova Scotia	45.925	-59.9684	107
Louisburg	Nova Scotia	45.925	-59.9684	107
Louisville	Quebec	46.2586	-72.9482	87
Lucan	Ontario	43.18781	-81.4028	98
Lunenburg	Nova Scotia	44.377	-64.3202	103
Lynn Lake	Manitoba	56.8558	-101.039	87
Lytton	British Columbia	50.2338	-121.577	86
Mackenzie	British Columbia	55.3298	-123.086	74
Macleod	Alberta	49.7164	-113.405	126
Magog	Quebec	45.2608	-72.1407	78
Maitland	Ontario	44.63513	-75.6133	86
Malartic	Quebec	48.1414	-78.1264	74
Maniwac	Quebec	46.3785	-75.9753	73
Maniwaki	Quebec	46.3785	-75.9753	73
Manning	Alberta	56.9148	-117.609	70
Maple Creek	Saskatchewan	49.896	-109.479	105
Markdale	Ontario	44.3285	-80.6633	84

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Markham	Ontario	43.85619	-79.3368	96
Martin	Ontario	49.2496	-91.1476	69
Masset	British Columbia	54.02278	-132.099	105
Masson	Quebec	45.5498	-75.4178	84
Matane	Quebec	48.8431	-67.5271	103
Matheson	Ontario	48.5367	-80.4691	84
Matheson Station	Ontario	48.5367	-80.4691	84
Mattawa	Ontario	46.31748	-78.7023	74
McBride	British Columbia	53.2998	-120.163	78
McLeod Lake	British Columbia	54.9934	-123.031	74
McMurray	Alberta	56.7251	-111.366	78
Meadow Lake	Saskatchewan	54.1351	-108.427	93
Medicine Hat	Alberta	50.0312	-110.682	97
Megantic	Quebec	45.5717	-70.8625	78
Melfort	Saskatchewan	52.8537	-104.606	78
Melville	Saskatchewan	50.9299	-102.795	84
Merrit	British Columbia	50.1073	-120.782	86
Merritt	British Columbia	50.1073	-120.782	86
Midland	Ontario	44.7446	-79.8771	81
Milton	Ontario	43.5127	-79.8787	86
Milton West	Ontario	43.5127	-79.8787	86
Milverton	Ontario	43.5658	-80.9221	86
Minden	Ontario	44.9279	-78.7254	78
Mississauga	Ontario	43.58873	-79.6444	93
Mitchell	Ontario	43.4673	-81.1955	93
Moncton	New Brunswick	46.098	-64.7889	105
Mont Jolie	Quebec	48.587	-68.1931	103
Mont-Joli	Quebec	48.587	-68.1931	103
Mont-Laurier	Quebec	46.5508	-75.496	73
Montmagny	Quebec	46.9791	-70.5598	98
Montreal	Quebec	45.5316	-73.6102	84
Montrose	British Columbia	49.0866	-117.574	76
Moose Harbor	Ontario	51.2729	-80.6725	78
Moose Jaw	Saskatchewan	50.39	-105.54	91
Moosonee	Ontario	51.2729	-80.6725	78
Morden	Manitoba	49.1885	-98.1051	96
Morrisburg	Ontario	44.9007	-75.1841	84
Mould Bay	Northwest Territories	76.2483	-119.35	107
Mount Forest	Ontario	43.984	-80.7306	84
Murray Bay	Quebec	47.6569	-70.1608	98
Nakina	Ontario	50.1637	-86.7131	69
Nakusp	British Columbia	50.2381	-117.794	76
Nanaimo	British Columbia	49.1253	-123.924	105
Nanymo	British Columbia	49.1253	-123.924	105
Napanee	Ontario	44.2728	-77.1146	86
Napanee	Ontario	44.2461	-76.952	86
Neepawa	Manitoba	50.2338	-99.4588	87
Nelson	British Columbia	49.4821	-117.296	74
New Glasgow	Nova Scotia	45.5926	-62.6589	98
New Liskeard	Ontario	47.5131	-79.6774	86
New Westminister	British Columbia	49.1802	-122.89	91
Newcastle	Ontario	43.9114	-78.6781	103
Newmarket	Ontario	44.0943	-79.4396	81
Niagara Falls	Ontario	43.0974	-79.0935	86
Nichikun	Quebec	53.1969	-70.883	81
Nicolet	Quebec	46.2342	-72.6069	86
Nipawin	Saskatchewan	53.3449	-104.02	81
Nitchequon	Quebec	53.1969	-70.883	81
Noranda	Quebec	48.2407	-79.029	78
Norman Wells	Northwest Territories	65.2784	-126.814	105
North Battleford	Saskatchewan	52.7735	-108.282	109
North Bay	Ontario	46.3093	-79.4533	77
North Burnaby	British Columbia	49.234	-122.953	92
North Sydney	Nova Scotia	46.148	-60.1893	103
North Vancouver	British Columbia	49.3356	-123.137	92
North York	Ontario	43.78347	-79.4078	96
Norwood	Ontario	44.3823	-77.9799	84
Nottingham Island	Northwest Territories	63.11667	-77.9333	132

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Oakville	Ontario	43.4437	-79.662	93
Ocean Falls	British Columbia	52.35402	-127.694	103
Orangeville	Ontario	43.9181	-80.0946	78
Orillia	Ontario	44.6016	-79.4179	78
Oromocto	New Brunswick	45.8435	-66.4628	93
Oshawa	Ontario	43.8992	-78.8526	100
Osoyoos	British Columbia	49.0343	-119.466	91
Ottawa	Ontario	45.4129	-75.6701	84
Outremont	Quebec	45.51452	-73.6111	84
Owen Sound	Ontario	44.5646	-80.9339	91
Pagwa River	Ontario	50.0093	-85.2128	69
Paris	Ontario	43.1963	-80.3792	84
Parkhill	Ontario	43.1623	-81.6842	98
Parry Sound	Ontario	45.3433	-80.0265	81
Peace River	Alberta	56.23386	-117.29	74
Pembroke	Ontario	45.8161	-77.106	78
Penetanguishene	Ontario	44.7628	-79.9288	81
Penticton	British Columbia	49.4902	-119.613	100
Perce	Quebec	48.5216	-64.234	122
Perth	Ontario	44.9082	-76.2508	84
Petawawa	Ontario	45.9061	-77.2736	78
Peterborough	Ontario	44.2958	-78.3296	84
Petewahweh	Ontario	45.9061	-77.2736	78
Petewawa	Ontario	45.9061	-77.2736	78
Petrolia	Ontario	42.8812	-82.1478	91
Pickering	Ontario	43.8568	-79.0122	100
Picton	Ontario	44.0011	-77.1376	93
Pictou	Nova Scotia	45.6778	-62.7106	98
Pierrefonds	Quebec	45.49402	-73.8494	84
Pincher	Alberta	49.4844	-113.947	130
Pincher Creek	Alberta	49.4844	-113.947	130
Pincourt	Quebec	45.35721	-73.9822	84
Pine Falls	Manitoba	50.5615	-96.2294	82
Plattsville	Ontario	43.30325	-80.6216	84
Plessisville	Quebec	46.224	-71.7843	78
Point Alexander	Ontario	46.13333	-77.5667	78
Port Alberni	British Columbia	49.2949	-124.854	105
Port Arthur	Ontario	48.441	-89.2476	83
Port Burwell	Ontario	42.64852	-80.8063	91
Port Colborne	Ontario	42.8895	-79.2517	91
Port Credit	Ontario	43.55334	-79.582	93
Port Dover	Ontario	42.78677	-80.203	91
Port Elgin	Ontario	44.4346	-81.392	98
Port Hardy	British Columbia	50.7264	-127.497	105
Port Hawkesbury	Nova Scotia	45.6198	-61.3633	115
Port Hope	Ontario	43.9499	-78.2935	103
Port McNeill	British Columbia	50.5847	-127.096	105
Port Perry	Ontario	44.1017	-78.9467	86
Port Radium	Northwest Territories	66.0892	-118.014	96
Port Stanley	Ontario	42.66468	-81.2147	91
Portage La Prairie	Manitoba	49.9693	-98.3052	91
Port-Cartier	Quebec	50.0279	-66.8558	110
Powell River	British Columbia	49.8389	-124.521	103
Prescott	Ontario	44.7165	-75.5219	86
Prince Albert	Saskatchewan	53.1926	-105.742	81
Prince George	British Columbia	53.9139	-122.768	81
Prince Rupert	British Columbia	54.3152	-130.308	98
Princeton	British Columbia	49.4563	-120.505	78
Princeton	Ontario	43.17005	-80.5267	84
Providence	Northwest Territories	61.3547	-117.66	78
Qualicum Beach	British Columbia	49.3511	-124.448	105
QuAppelle	Saskatchewan	50.54255	-103.878	86
Quebec	Quebec	46.8021	-71.2449	96
Quesnel	British Columbia	52.9816	-122.493	74
Rae	Northwest Territories	62.8337	-116.036	91
Ragged Island	Nova Scotia	43.6989	-65.1253	103
Raith	Ontario	48.8248	-89.9362	69
Ranfurly	Alberta	53.4063	-111.677	74

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Rankin Inlet	Northwest Territories	62.8177	-92.1133	103
Rayside-Balfour	Ontario	46.60648	-81.1921	86
Red Deer	Alberta	52.2632	-113.8	84
Red Lake Road	Ontario	49.9663	-93.3802	70
Regina	Saskatchewan	50.4478	-104.616	86
Renfrew	Ontario	45.4752	-76.6967	78
Resolute	Northwest Territories	74.6864	-94.9094	110
Resolution	Northwest Territories	61.1736	-113.663	83
Resolution Island	Northwest Territories	61.3151	-64.8355	145
Revelstoke	British Columbia	50.9949	-118.191	74
Richmond	Quebec	45.6619	-72.1414	74
Richmond	British Columbia	49.1579	-123.137	92
Richmond	Ontario	45.1963	-75.829	96
Rimouski	Quebec	48.4277	-68.5165	103
River Clyde	Northwest Territories	70.457	-68.6299	124
Rivers	Manitoba	50.0265	-100.235	91
Rivigere-du-Loup	Quebec	47.8311	-69.5352	100
Riviere-du-Loup-en-Bas	Quebec	47.8311	-69.5352	100
Roberval	Quebec	48.5178	-72.2337	78
Rock Island	Quebec	45.00766	-72.0985	84
Rockland	Ontario	45.5499	-75.2861	84
Rocky Mountain House	Alberta	52.3738	-114.914	87
Rosemere	Quebec	45.63899	-73.785	84
Rosetown	Saskatchewan	51.5495	-107.99	105
Rouyn	Quebec	48.2065	-79.0427	78
Rugged Island	Nova Scotia	43.6989	-65.1253	103
Sackville	New Brunswick	45.923	-64.3571	100
Saint John	New Brunswick	45.2823	-66.0715	96
Saint-Joseph-d'Alma	Quebec	48.5497	-71.6602	74
Salaberry-de-Valleyfield	Quebec	45.2633	-74.1329	84
Salmon Arm	British Columbia	50.6994	-119.283	82
Sandilands	Manitoba	49.32444	-96.2964	84
Sandspit	British Columbia	53.2331	-131.825	110
Sarnia	Ontario	42.9721	-82.3881	91
Saskatoon	Saskatchewan	52.1432	-106.653	92
Sault Ste Marie	Ontario	46.522	-84.3372	84
Scarborough	Ontario	43.793	-79.2747	96
Schefferville	Quebec	54.8007	-66.8108	86
Schreiber	Ontario	48.81331	-87.2665	83
Scott	Saskatchewan	52.3635	-108.818	105
Seaforth	Ontario	43.5562	-81.3842	96
Selkirk	Manitoba	50.1389	-96.8875	86
Senneterre	Quebec	48.3887	-77.2401	74
Sert-iles	Quebec	50.2081	-66.3731	110
Shafferville	Quebec	54.8007	-66.8108	86
Shawenegan	Quebec	46.5511	-72.7485	78
Shawinigan	Quebec	46.5511	-72.7485	78
Shawinigan Falls	Quebec	46.5511	-72.7485	78
Shawville	Quebec	45.60381	-76.4916	78
Shelter Bay	Quebec	50.0279	-66.8558	110
Sherbrook	Quebec	45.4044	-71.9	74
Sherbrooke	Quebec	45.4044	-71.9	74
Shewanegan	Quebec	46.5511	-72.7485	78
Shippegan	New Brunswick	47.7411	-64.715	110
Shippigan	New Brunswick	47.7411	-64.715	110
Sidney	British Columbia	48.6561	-123.4	103
Sillery	Quebec	46.77958	-71.2506	96
Simcoe	Ontario	42.8361	-80.3011	86
Simpson	Northwest Territories	61.8621	-121.361	84
Sioux Lookout	Ontario	50.0968	-91.9319	69
Slave Lake	Alberta	55.2792	-114.768	81
Smith River	British Columbia	59.8787	-126.442	70
Smithers	British Columbia	54.7805	-127.175	84
Smiths Falls	Ontario	44.9048	-76.0241	84
Smithville	Ontario	43.09469	-79.5486	86
Smooth Rock Falls	Ontario	49.27366	-81.6239	74
Snag	Yukon Territory	62.4	-140.367	73
Sorel	Quebec	46.0446	-73.1052	87

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Souris	Prince Edward Island	46.3542	-62.2507	98
South River	Ontario	45.8425	-79.3766	74
Southampton	Ontario	44.4919	-81.3648	96
Split Lake	Manitoba	56.0234	-95.8121	93
Springhill	Nova Scotia	45.6539	-64.0595	98
Spurell Harbour	Northwest Territories	63.3437	-90.7414	100
Spurrell Harbour	Northwest Territories	63.3437	-90.7414	100
Squamish	British Columbia	49.7009	-123.158	98
St Anthony	Newfoundland	51.3562	-55.5645	121
St Catharines	Ontario	43.1756	-79.2228	91
St John's	Newfoundland	47.5652	-52.7343	118
St Marys	Ontario	43.25975	-81.1406	93
St Stephen	New Brunswick	45.19229	-67.2772	103
St Thomas	Ontario	42.7731	-81.1808	91
Ste.-foy	Quebec	46.767	-71.2892	96
Ste-Agathe-des-Monts	Quebec	46.04802	-74.2841	78
Ste-Anne-de-Bellevue	Quebec	45.40393	-73.9523	84
Steinbach	Manitoba	49.5181	-96.697	84
Stephenville	Newfoundland	48.5497	-58.5872	117
Stettler	Alberta	52.3233	-112.695	78
Stewart	British Columbia	55.927	-130.01	86
Stewiacke	Nova Scotia	45.1377	-63.3491	98
St-Felicien	Quebec	48.65777	-72.451	78
St-Georges-de-Cacouna	Quebec	47.91694	-69.5006	100
St-Hubert	Quebec	45.49671	-73.4097	84
St-Hyacinthe	Quebec	45.62645	-72.9472	78
Stirling	Ontario	44.29614	-77.5475	83
St-jerome	Quebec	48.4234	-71.8756	81
St-Jovite	Quebec	46.11804	-74.6006	76
St-Lambert	Quebec	48.95169	-79.4583	84
St-Laurent	Quebec	45.50732	-73.6824	84
St-Nicolas	Quebec	46.67828	-71.3474	93
Stony	Saskatchewan	52.8537	-104.606	78
Stony Plain	Alberta	53.5276	-114.01	87
Strasbourg	Saskatchewan	51.0689	-104.943	86
Stratford	Ontario	43.3668	-80.9806	91
Strathroy	Ontario	42.9577	-81.6169	93
Sturgeon Falls	Ontario	46.3576	-79.9159	78
Sudbury	Ontario	46.485	-80.9848	87
Suffield	Alberta	50.2144	-111.176	100
Summerside	Prince Edward Island	46.3962	-63.7545	110
Sundridge	Ontario	45.7792	-79.3779	74
Surrey	British Columbia	49.10582	-122.828	91
Sutton	Quebec	45.1075	-72.6163	84
Swan River	Manitoba	52.0972	-101.271	82
Swift Current	Saskatchewan	50.285	-107.793	104
Sydney	British Columbia	48.6561	-123.4	103
Sydney	Nova Scotia	46.148	-60.1893	98
Taber	Alberta	49.7755	-112.128	115
Tadoussac	Quebec	48.1493	-69.7181	99
Ta-Tuque	Quebec	47.4432	-72.7774	78
Tavistock	Ontario	43.32096	-80.8362	91
Taylor	British Columbia	56.2191	-120.688	84
Temagami	Ontario	47.06667	-79.7833	81
Temiscaming	Quebec	46.7222	-79.0996	74
Terrace	British Columbia	54.5167	-128.608	79
Teslin	Yukon Territory	60.1727	-132.719	69
Thamesford	Ontario	43.059	-80.9962	91
The Pas	Manitoba	53.8164	-101.253	87
Thedford	Ontario	43.1631	-81.8571	98
Thetford	Quebec	46.0939	-71.3034	81
Thetford Mines	Quebec	46.0939	-71.3034	81
Thompson	Manitoba	55.7426	-97.858	93
Three Rivers	Quebec	46.3376	-72.6075	87
Thunder Bay	Ontario	48.441	-89.2476	83
Thurso	Quebec	45.6167	-75.3674	84
Tignish	Prince Edward Island	46.9608	-64.0224	117
Tillsonburg	Ontario	42.8613	-80.7229	86

Name	Province	Latitude	Longitude	Wind Speed 3 Sec mph
Tilsonburg	Ontario	42.8613	-80.7229	86
Timmins	Ontario	48.4836	-81.3437	81
Tofino	British Columbia	49.1469	-125.905	110
Toronto	Ontario	43.6871	-79.3893	96
Trafalgar	Nova Scotia	45.2898	-62.6652	96
Trail	British Columbia	49.0974	-117.693	78
Trenton	Ontario	44.0941	-77.5831	91
Trois-Rivieres	Quebec	46.3376	-72.6075	87
Trout Creek	Ontario	45.9851	-79.3549	74
Tukik	Northwest Territories	73.0387	-85.1881	98
Turner	Alberta	50.6763	-114.273	107
Turner Valley	Alberta	50.6763	-114.273	107
Twin Falls	Newfoundland	53.5008	-64.5285	84
Uranium City	Saskatchewan	59.5665	-108.619	87
Uxbridge	Ontario	44.10642	-79.1228	84
Val-dor	Quebec	48.1044	-77.7885	74
Valleyfield	Quebec	45.2633	-74.1329	84
Valleyview	Alberta	55.0701	-117.28	91
Vancouver	British Columbia	49.2575	-123.133	92
Varennes	Quebec	45.6826	-73.4409	84
Vegreville	Alberta	53.4936	-112.049	78
Vercheres	Quebec	45.7715	-73.3575	87
Verdun	Quebec	45.45899	-73.5722	84
Vermilion	Alberta	53.3541	-110.847	73
Vernon	British Columbia	50.2604	-119.265	86
Victoria	British Columbia	48.4467	-123.349	105
Victoriaville	Quebec	46.0582	-71.9645	78
Ville-Marie	Quebec	47.3318	-79.431	84
Virden	Manitoba	49.8434	-100.933	91
Vittoria	Ontario	42.76202	-80.3231	91
Wabana	Newfoundland	47.6442	-52.9544	115
Wabush	Newfoundland	52.9023	-66.8705	84
Wagner	Alberta	55.35	-114.983	81
Wainwright	Alberta	52.834	-110.858	78
Walkerton	Ontario	44.1237	-81.1451	93
Wallaceburg	Ontario	42.5903	-82.384	86
Waterloo	Ontario	43.5941	-80.5546	81
Waterloo	Quebec	45.3509	-72.5203	78
Watford	Ontario	42.94998	-81.88	91
Watson Lake	Yukon Territory	60.0689	-128.703	78
Wawa	Ontario	47.9933	-84.7737	83
Welland	Ontario	42.9962	-79.2545	86
West Lorne	Ontario	42.60378	-81.6067	91
West Vancouver	British Columbia	49.36667	-123.167	92
Wetaskiwin	Alberta	52.9672	-113.371	84
Weyburn	Saskatchewan	49.6664	-103.859	93
Whitby	Ontario	43.881	-78.9336	100
White River	Ontario	48.593	-85.3067	69
Whitecourt	Alberta	54.1449	-115.688	86
Whitehorse	Yukon Territory	60.7257	-135.044	81
Whycocomagh	Nova Scotia	45.9802	-61.131	96
Wiarton	Ontario	44.737	-81.1403	91
Williams Lake	British Columbia	52.1342	-122.139	82
Wimborne	Alberta	51.866	-113.587	84
Windsor	Nova Scotia	44.9939	-64.1428	99
Windsor	Ontario	42.3068	-82.9827	91
Windsor	Quebec	45.5689	-72.0055	74
Wingham	Ontario	43.8849	-81.3044	93
Winnipeg	Manitoba	49.9212	-97.1244	90
Woodbridge	Ontario	43.79665	-79.5883	96
Woodstock	New Brunswick	46.1486	-67.5786	81
Woodstock	Ontario	43.1292	-80.7566	86
Wyoming	Ontario	42.9553	-82.1185	91
Yellowknife	Northwest Territories	62.4738	-114.366	91
Yorkton	Saskatchewan	51.2092	-102.465	84
Youbou	British Columbia	48.87289	-124.199	103

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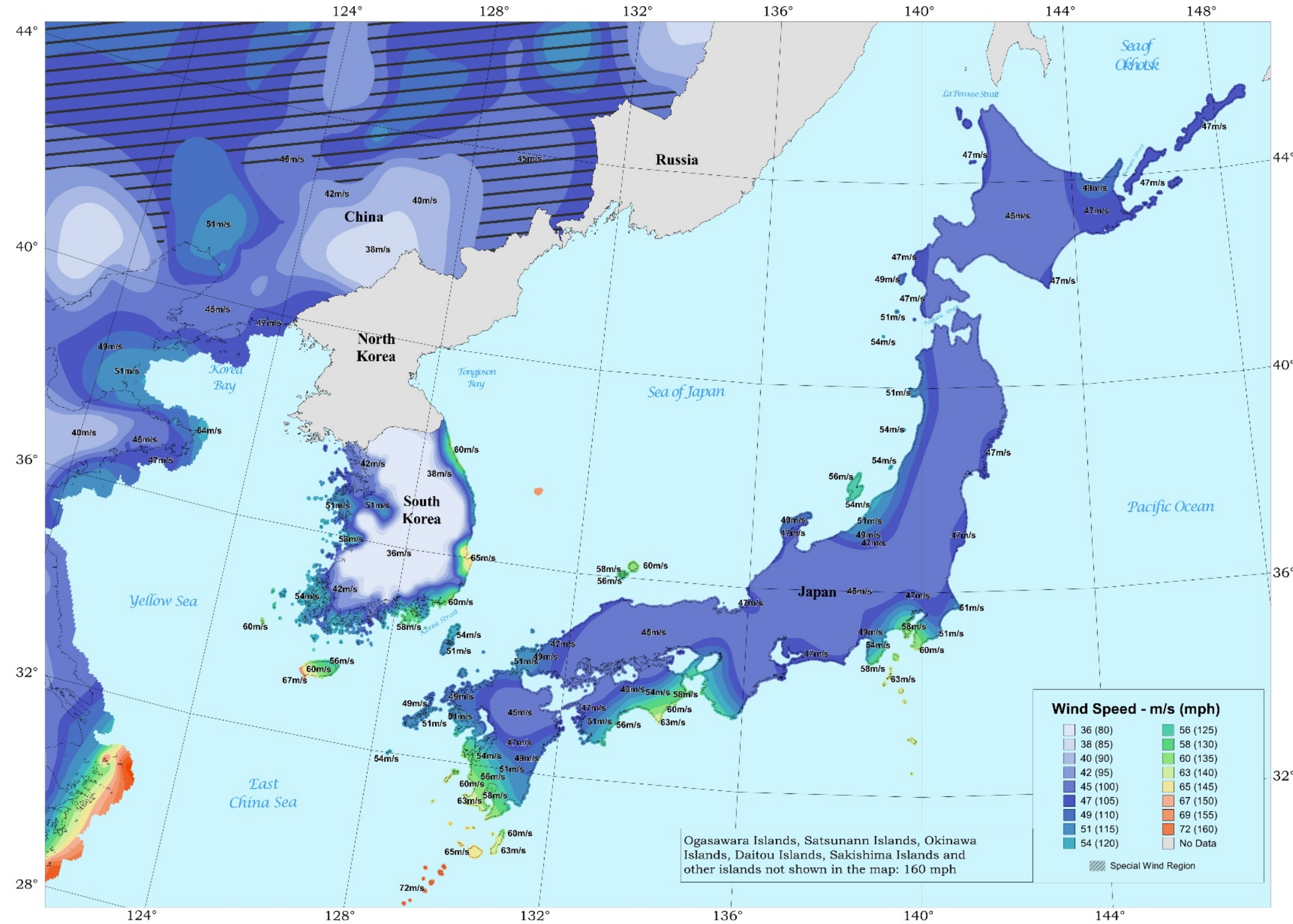


Note: Values are nominal design 3-second gust wind speeds in meters per second (mph) at 10m (33ft) above ground for Exposure C category.

Fig. 12. Basic Wind Speeds - Japan and South Korea, 3-sec gust in miles per hour (mph).

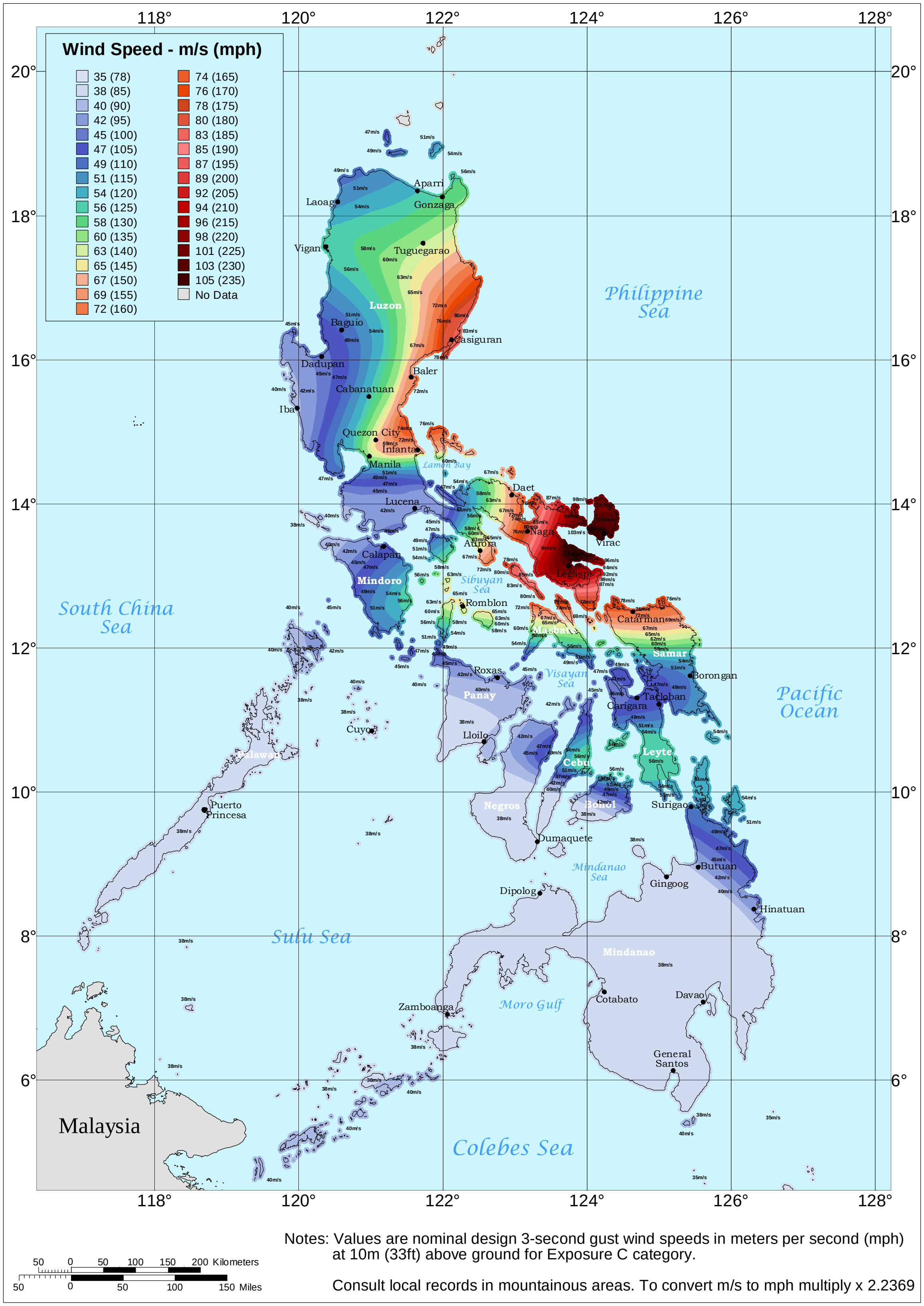
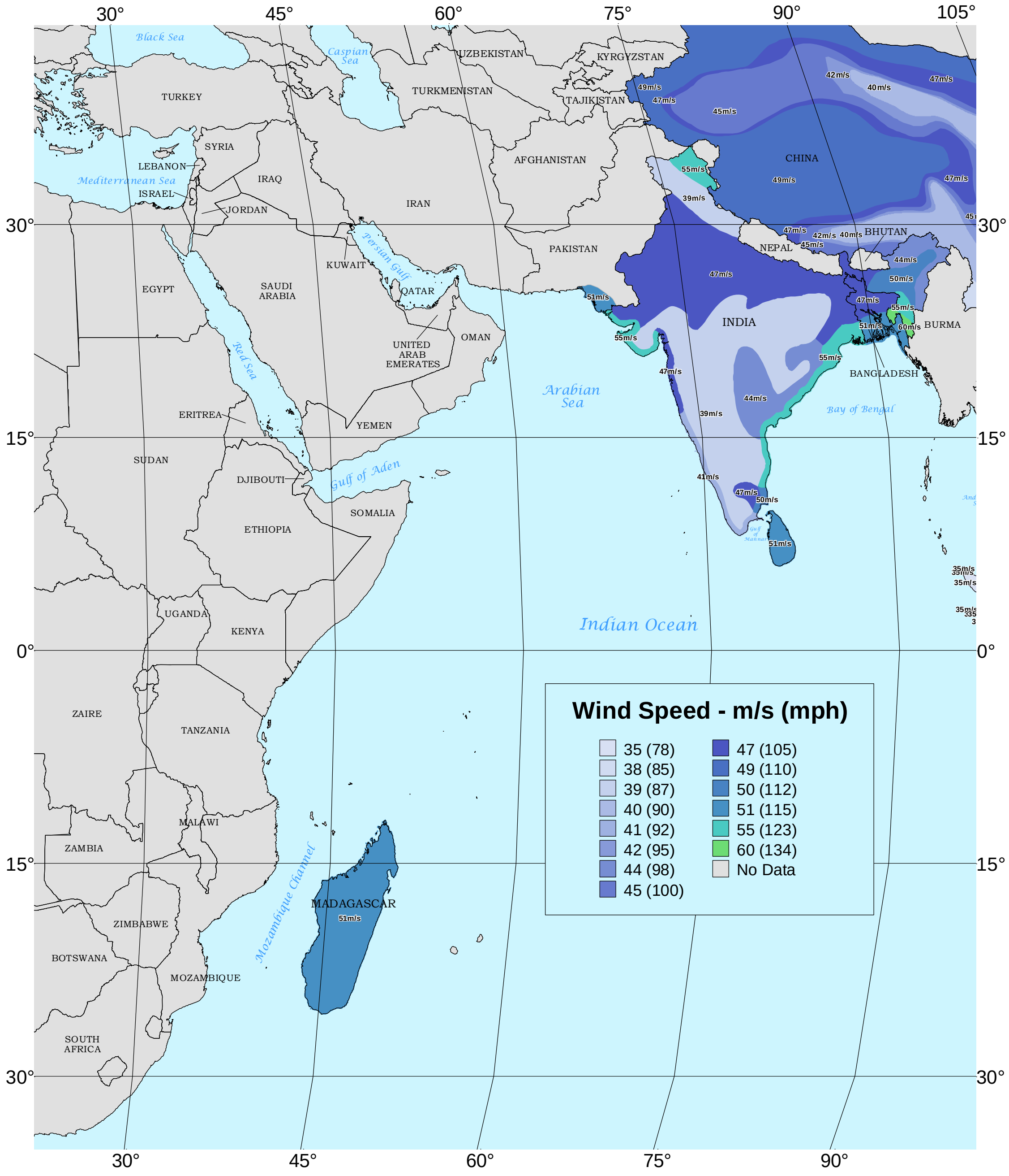


Fig. 13 Basic wind speeds - Philippines, 3-sec gust in miles per hour (8/2001)



Notes: Values are nominal design 3-second gust wind speeds in meters per second (mph) at 10m (33ft) above ground for Exposure C category.

Consult local records in mountainous areas.

400 0 400 800 1200 Kilometers
200 0 200 400 600 800 Miles

Fig. 14. Basic wind speeds - cyclone-prone exposures from the Indian Ocean, 3-sec gust in miles per hour (8/2001)

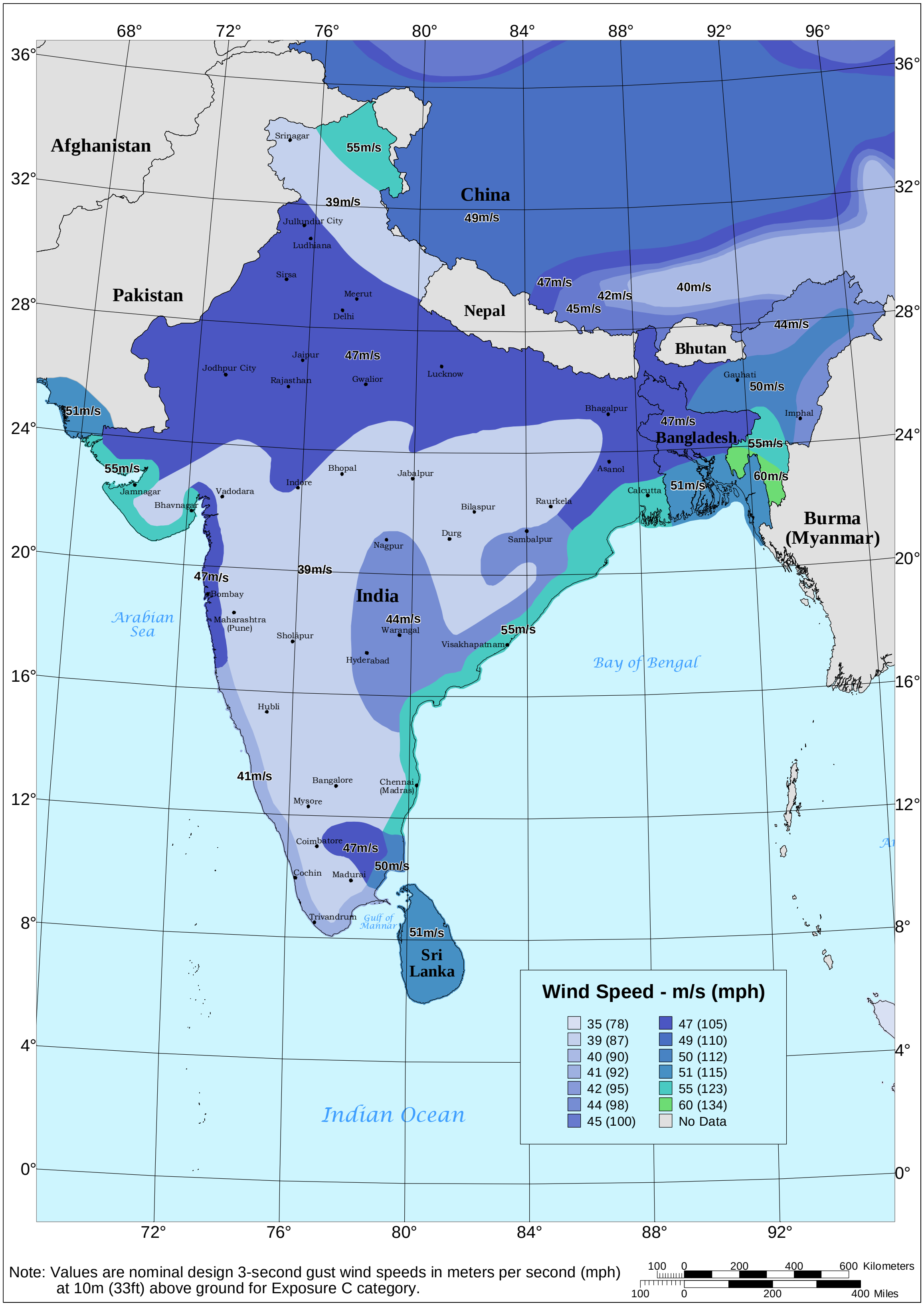


Fig. 15. Recommended basic wind speeds - India, in m/s (mph) (11/2006)

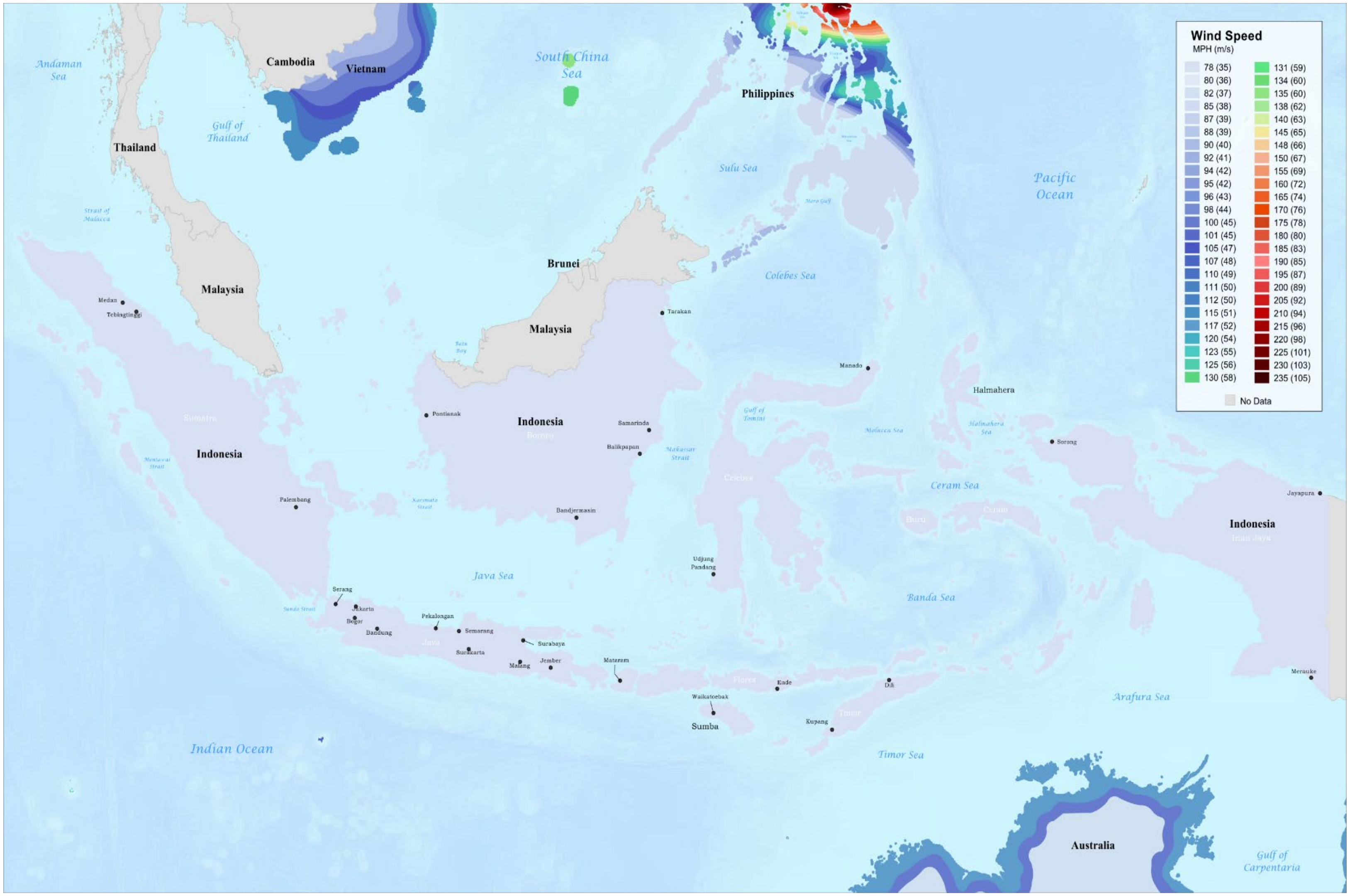
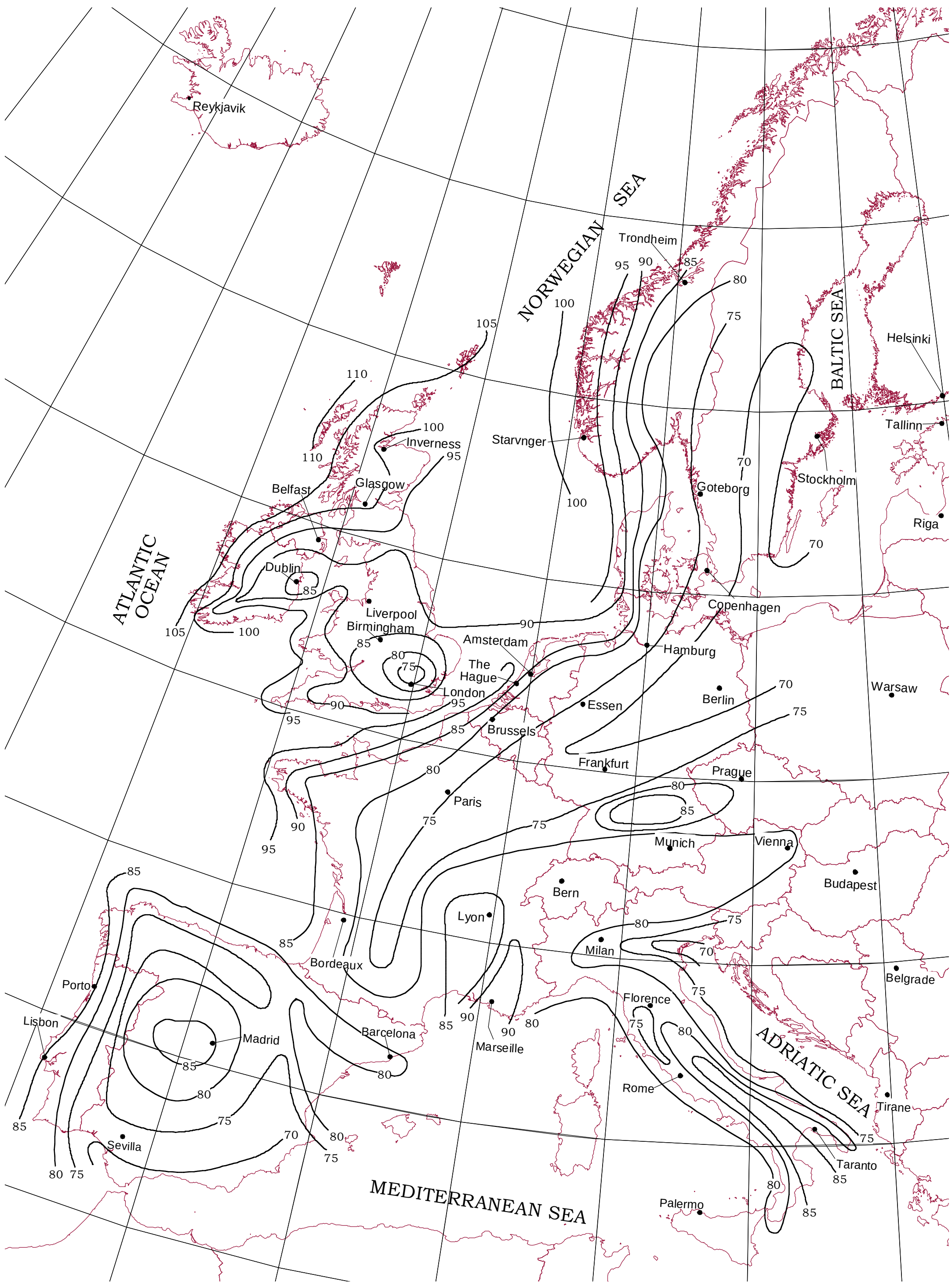


Fig. 16. Basic Wind Speeds - Indonesia, 3-sec gust in miles per hour (m/s).



Note: Consult local records in mountainous areas

Miles per hour	110	105	100	95	90	85	80	75	70
Meters per sec.	49	47	45	43	40	38	36	34	31

50 0 100 200 Kilometers
50 0 50 100 Miles

Fig. 17. Basic wind speed in miles per hour for Europe. Annual extreme-mile 30 ft (9 m) above ground, 100-year mean recurrence interval.
Note *Convert wind speed using Table AC1.3 and Section C-1.*

APPENDIX D OPTIONAL GUIDANCE FOR TORNADO-RESISTANT DESIGN AND CONSTRUCTION

D.1 Scope

This appendix provides optional guidance for building owners or occupants who have important facilities that warrant additional protection to reduce potential property damage and business interruption as a result of a tornado.

This appendix uses the allowable wind speed method of design, with other modifications as noted in this section.

D.1.1 General

While tornadoes can occur virtually anywhere, it is not economically practical to design all buildings and structures for tornadoes. Building codes typically do not require such a level of design. Some building owners or occupants with key facilities in areas prone to tornadoes sometimes desire to provide some additional level of protection against tornadoes. This appendix is advisory only and provides some general information to assist these owners.

Tornadoes have hit major urban areas including Fort Worth, Texas; Salt Lake City, Utah; Memphis, Tennessee; Atlanta, Georgia; and St. Louis, Missouri.

Tornadoes are categorized by wind speed ranges and potential damage using the Enhanced Fujita (EF) scale (see Table D-1). The probability of a strike from a tornado is greater in some locations than others (see Fig. D-1 and D-2). The minimum design wind speeds throughout the country are generally high enough that properly designed and constructed roof and wall assemblies should not be severely damaged during a low-end (EF0 or EF1) tornado. Locations prone to tropical storms are designed for higher wind speeds and in some cases windborne debris, and may be more resistant to somewhat more intense tornadoes. It is up to the individual building owner to decide if the importance of the building and/or occupancy justifies the design of a building to a higher level to reduce potential damage from a tornado. For additional information, see references in Section D 4.0.

The importance of the building along with the probability of a tornado impacting the building should be considered. The value of the building occupancy, effect on business continuity, and importance of company records can define the importance of a building with regard to property protection. Data is available for the United States that defines the probability of tornado occurrence in a given state. However, the size of the state can skew these figures, therefore maps that denote the probability of occurrence within a state per unit area are a more accurate reflection of tornado occurrence(see Fig. D-1).

Table D-1. Potential Damage and Wind Speeds Corresponding to the Enhanced Fujita Scale

Enhanced Fujita Scale	*Damage*	*Estimated 3-second Peak Gust (mph)*	*Estimated 3-second Peak Gust (m/s)*
EF0	**Light damage.** Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.	65 - 85	29 - 38
EF1	**Moderate damage.** Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.	86 - 110	39 - 49
EF2	**Considerable damage**. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.	111 - 135	50 - 60
EF3	**Severe damage**. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.	136 - 165	61- 74
EF4	**Devastating damage**. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.	166 - 200	75 - 90
EF5	**Incredible damage**. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur.	≥ 200	≥ 90

As with hurricanes, the magnitude of tornadoes varies considerably, from EF0 to EF5 (Enhanced Fujita Scale; see Table D-1). Between 2008 and 2013, about 97% of tornadoes had EF2 or lower intensity (see Table D-2). While EF5 tornadoes can have wind speeds of over 200 mph (90 m/s), such tornadoes are rare. Also, when an EF5 tornado occurs, the actual damage area within its path that is consistent with EF5 damage is relatively small. While a tornado may be classified as either an EF4 or EF5, not all the areas within its path experience such a magnitude of wind effects. As much as 80% of the damage within the path of an EF5 tornado is consistent with the damage of a tornado with a scale of EF3 or less. It is not generally considered practical to design for an EF5 tornado. With few exceptions, locations within the United States are required by code to have a minimum design wind speed (not ultimate) of 90 mph, 3-second gusts. Some damage caused by lower-scale tornadoes is likely attributable to poor design or construction practices.

In addition to deciding whether the probability of tornado exposure justifies more fortified construction, one must select the design wind speed for the facility. Such guidance is provided in this document and in FEMA 320 and FEMA 361 (see Appendix D, Section 4.0).

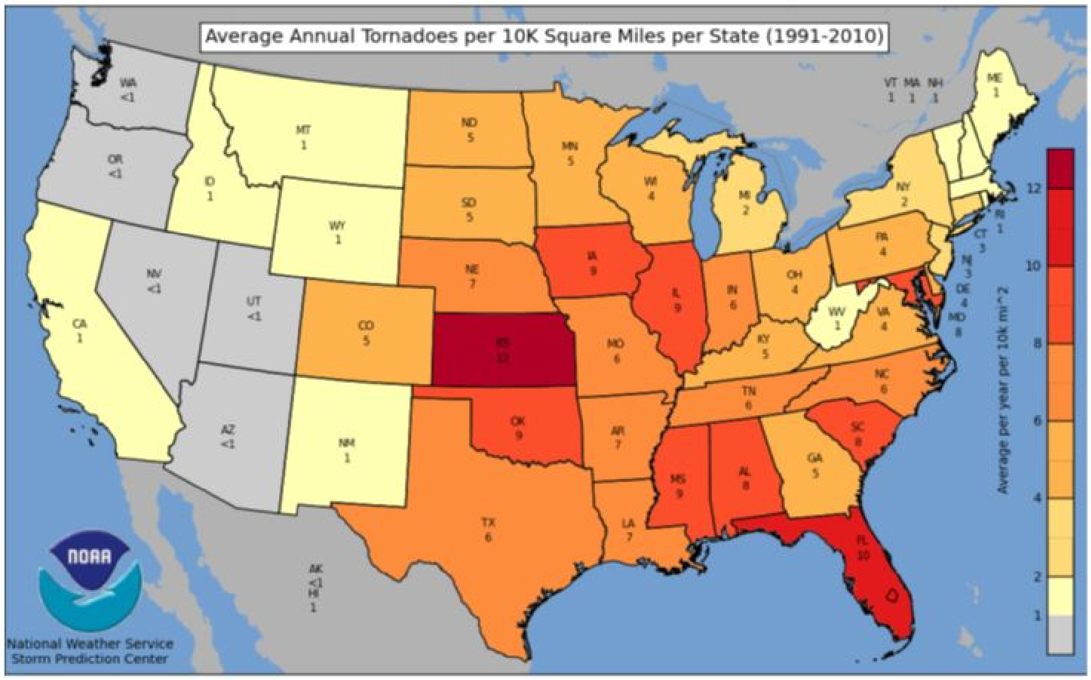


Fig. D-1. Average annual tornado counts per state and per 10,000 square miles between 1991 and 2010

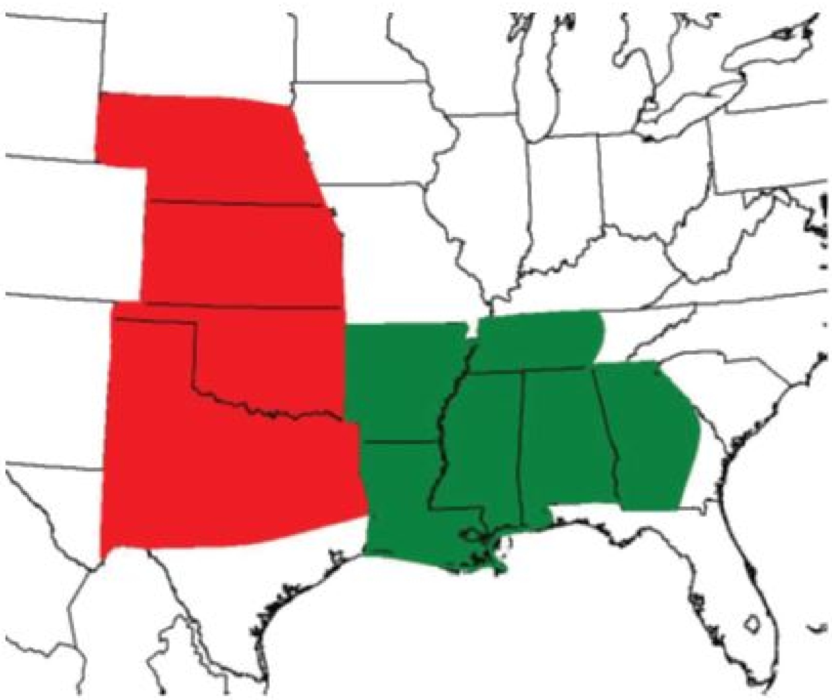


Fig. D-2. Areas covered by Tornado Alley (shown in red) and Dixie Alley (shown in green)

Table D-2. Tornado Frequency Based on Enhanced Fujita Scale

EF Scale	*Average Counts of 2008-2013*	*% of Total*
EF0/U	721	56.5%
EF1	390	30.6%
EF2	122	9.5%
EF3	34	2.7%
EF4	9	0.7%
EF5	1	0.1%
Total	1,277	100%

D.1.2 Tornado Shelters

If the goal is only to provide temporary shelter, construction of a safe room may be a practical solution. Design of such structures is beyond the scope of this data sheet, but guidance for the construction of safe rooms up to 14 by 14 ft (196 ft^2; 4.27 by 4.27 m; 18.2 m^2) and for up to 39 occupants can be found in FEMA 320. Where the facility is to serve a larger number of occupants, such as a community safe room, guidance for the construction of larger internal or stand alone safe rooms can be found in FEMA 361.

D.2 Recommendations

D.2.1 Design the building envelope, including walls, doors, windows, skylights, roof-mounted equipment, and roofs to resist wind speeds in accordance with Figure D-3 and Section D.3.0. Higher design wind speeds may also be used if desired.

D.2.2 Make the following assumptions in regard to wind design:

A. Base the design on a “partially enclosed building,” regardless of what efforts are made to maintain the building envelope. A breach of even limited size can compromise the integrity of a building envelope that might otherwise be considered “fully enclosed.”

B. Assume a Surface Roughness Exposure of “C,” even if the terrain conditions prior to the storm justify the use of a “B” exposure. The event may modify the surrounding terrain prior to impact by the tornado.

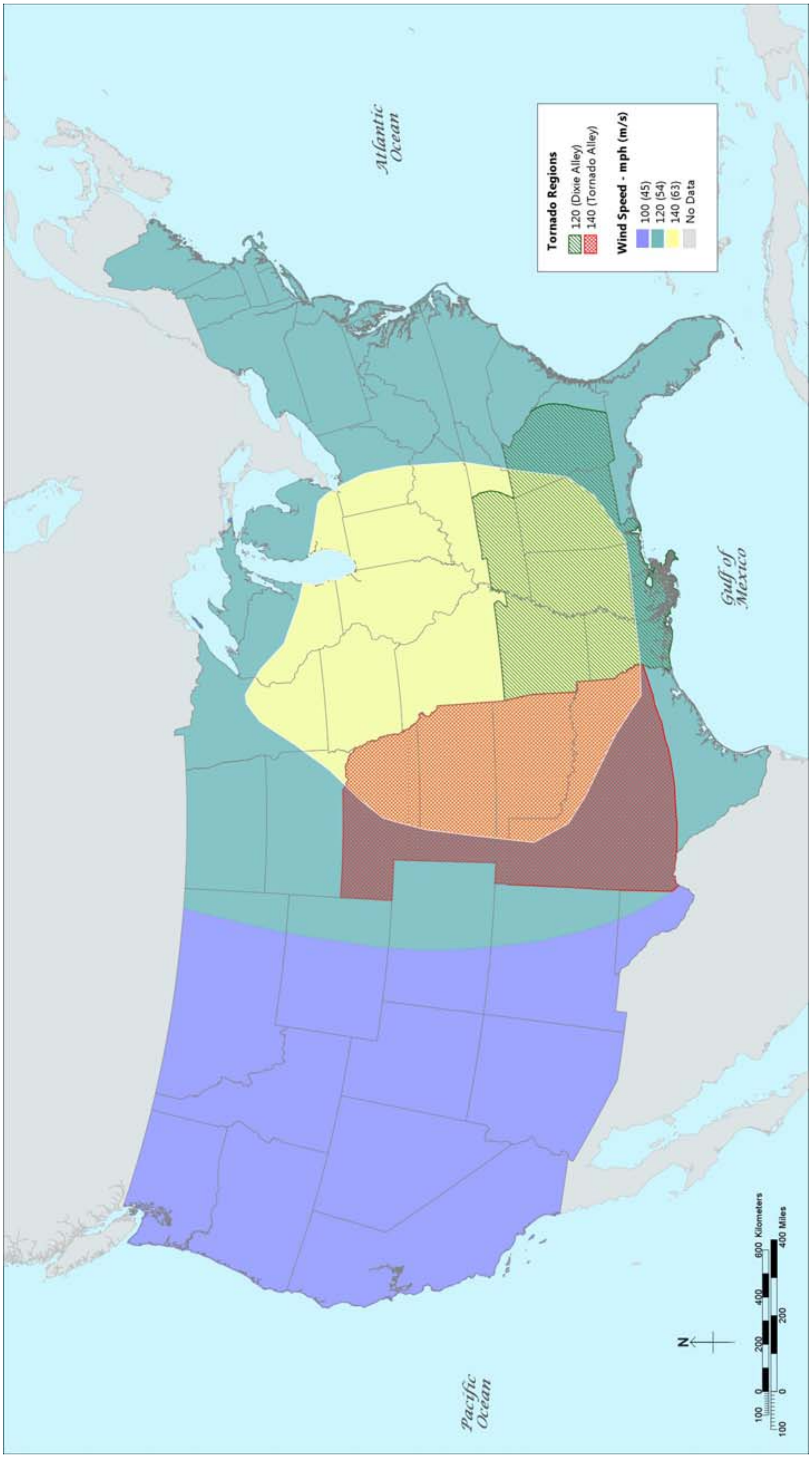


Fig. D-3. Recommended Property Protection Tornado Wind Speed Zones for the Mainland USA Based on a 10^{-4} Probability or 10,000-Year Mean Recurrence Interval (MRI)

Figure D-3 note: Hawaii, Alaska, Puerto Rico, and Guam are considered to have a very low probability of tornado occurrence. The non-tornado design wind speeds exceed 100 mph (45 m/s) for all of Hawaii, Puerto Rico and Guam, and much of Alaska. One difference is that Hawaii, Puerto Rico, and Guam are prone to tropical storms and should normally be designed for windborne debris; whereas that is not true for Alaska.

D.2.3 Avoid the use of windows. This will help prevent the compromise of the building envelope.

D.2.4 When avoiding windows in the exterior walls is not practical, use Level E (preferably) or Level D impact-resistant windows as tested in accordance with FM 4350 or other standards (such as TAS 201 and 203 or ASTM E 1886 and E 1996 noted in Section 4.0). See Table D-3 for specific test details.

Ideally, tornado-resistant windows should be able to withstand the impact from a 15 lb (6.8 kg), wood, nominal 2 x 4 in. (50 x 100 mm) member impacting at 100 mph (45 m/s). Windows that could pass such a test are not commonly available commercially and often would not be economically practical to use for buildings other than shelters. The weight and impact speed used in a tornado-resistant window test is considerably greater than that used in large windborne debris impact tests for windows in areas exposed to hurricanes and described in Table D-3 and in reference documents noted in Section D.4.0.

Despite all efforts to prevent it, some portions of the wall envelope can be breached, so the building envelope should be considered partially enclosed. Interior walls are normally designed to meet minimal interior lateral load requirements, not wind loads.

D.2.5 Do not use roof aggregate of any type or size, other than mineral surfacing such as for cap sheets.

D.2.6 Where practical, openings in exterior walls other than personnel doors should be limited. Doors should open outward and be provided with positive latching, both of which should be adequate for the wind design pressures used. Where large exterior doors are required, use doors that are rated for the needed design pressures, as well as windborne debris impact (Level E or D, see Table D-3). Avoid the use of all doors in corner areas (Zone 5), or design and test for increased pressures in this area.

D.2.7 Consideration should be given to the provision of full-time inspection during the installation of exterior wall and roof components. For more information on evaluation of roof components, refer to DS 1-52.

Table D-3. Test Criteria for Large Windborne Debris Tests

Windborne Debris Level	*Simulated Debris*	*Impact Speed*
D	9 lb +/-0.25 lb (4100 g +/- 100 g), nominal 2 x 4 in. x 8 ft +/- 4 in. (2.4 m +/- 100 mm) lumber	50 ft/s, 34 mph, 15.3 m/s
E	9 lb +/- 0.25 lb (4100 g +/- 100 g), nominal 2 x 4 in. x 8 ft +/- 4 in. (2.4 m +/- 100 mm) lumber	80 ft/s, 55 mph, 24.4 m/s

D.3 Support for Recommendations

D.3.1 General Design Considerations

In some cases, it may be desirable to construct large commercial, residential, health care, or industrial buildings to be resistant to tornadic wind speeds. It may not be economically practical to follow all the same guidelines as used for tornado shelters, however, construction considerations in this data sheet should improve the resistance to tornado winds.

D.3.2 Building Envelope Concerns

D.3.2.1 Building Shape and Specific Occupancy Concerns

Tornado damage is caused by both windborne debris and pressure. The building owner should consider both the size of the building in question, as well as its occupancy. A windowless, concrete dome may provide the best resistance. The curvature of the structure allows for lower pressures acting on the surface, and windows are a potential weak link in the wall envelope. However, it often may not meet the needs of the building function or the aesthetic concerns of the owner.

Interior partition walls are typically designed for only 5 to 10 psf (0.24 to 0.48 kPa) lateral loads, are not able to withstand high wind pressures, and may offer only limited protection if the building envelope is breached.

D.3.2.2 Windborne Debris and Glass Breakage

Annealed, heat-strengthened (partially tempered) or even fully tempered glass should not be used (while tempered glass may meet safety glass criteria, it is not adequately resistant to windborne debris). These glass types have the greatest potential to break, compromise the enclosure of the building, increase wind pressure on the structure, and directly expose the interior of the building to wind pressure, windborne debris, and rain.

Laminated glass can meet the requirements for safety glass and windborne debris resistance. The use of laminated glass or other material and associated framing that has passed a large windborne debris impact test is recommended for use in exterior walls designed to have some resistance to tornadoes. While the impact speed of windborne debris during a tornado may be up to 100 mph (45 m/s), it may not be economically practical to design for such a high level of impact. **Laminated glass that has been tested to a Type E large windborne debris test in accordance with ASTM E 1886 and ASTM E 1996** may maintain a reasonable level of integrity for the opening against windborne debris of moderate size and impact velocity, and may be cost effective to use. A less-desirable alternative would be to use laminated glass that has passed the Type D windborne debris level test per the same standards. For specific test details, see Table D-3.

Reducing the potential sources of windborne debris is important and can be cost effective. Gravel roof surfacing of any type should not be used. This includes large stone ballast such as used on loose-laid ballasted roofs, or pea gravel used on built-up-roofs (BUR) and modified-bitumen (mod-bit) types. While pea gravel is usually embedded into a full mop of hot bitumen, in practice only the bottom half of the pea gravel gets embedded and the top half remains loose and nested and is subject to becoming windborne debris in an extreme wind event. Stone ballast used for loose-laid roof systems may be larger, but it still contains a large percentage of stone small enough to become windborne debris (see report by Phalen).

D.3.2.3 Exterior Doors

Dock doors are the most vulnerable to wind damage and they are one of the building envelope components that receive the least attention, outside of hurricane-prone areas, with regard to wind design.

The use of wind-rated doors is critical in buildings designed for some level of tornado resistance. Normally the vertical guides and end-locks that attach the door slats to those guides are smooth and are designed to allow vertical movement of the door, but not resist considerable lateral forces. Such doors bow considerably under wind load and act like catenaries, thus allowing the door slats to pull out of the vertical guides. Wind-rated doors have guides and end-locks that are interlocked to resist such large lateral loads. For more information, see Section 4.0.

D.3.2.4 Design Wind Speeds and Wind Pressures

Recommended tornado design wind speeds for shelters can be found in FEMA 320 or FEMA 361. It should also be noted that other factors related to wind pressure may be greater than normally used for wind design.

When providing property protection, tornado design wind speeds for the United States may be selected from Figure D-3. This figure covers the entire mainland United States, subdividing it into three wind zones (100, 120, and 140 mph [45, 54, and 62 m/s]).

Similarly to what occurs in hurricanes, most tornado damage is much greater to the building envelope than to the building frame. For some larger structures designed for more typical code required wind speeds (≥90 mph [≥ 40 m/s]), using an importance factor of 1.15 (based on ASCE 7-05) have experienced considerable damage to the building envelope, yet limited damage to the structural frame. One cost-effective approach would be to provide limited increase in design strength for the building frame, but considerable increase in resistance for the building envelope.

D.3.2.5 Design Method

For the design of components and cladding, after selecting the design wind speed from Figure D-3, determine the design pressure using Equations D-1 and D-2 below.

$$q_h = 0.00256 K_Z K_{ZT} K_D I V^2 \qquad \text{(Eqn. D-1)}$$

Where:

q_h = the basic velocity pressure calculated at height h

K_Z = velocity pressure coefficient (see Table D-4 or ASCE 7) for Exposure C (unless Exposure D applies), even if the terrain is considered B now.

K_{ZT} = topographic factor, use 1.0 for all terrains

K_D = directionality factor, use 1.0 regardless of the shape of the structure

I = importance factor ≥1.0

V = allowable strength design wind speed per Figure D-3 at 33 ft (10 m) above grade in Exposure C (open terrain). As this design method does not use ultimate wind speeds, a 2.0 safety factor is applied to the calculated pressure.

$p = [(1.05GC_P) - GC_{Pi}]\, q_h$ (Eqn. D-2)

Where:

GC_P = external pressure coefficient. For a low slope, gabled roof ≤ 60 ft (18 m) tall, see Table D-5 for values for Zones 1, 2, 3, 4 and 5. For other geometries see ASCE 7.

GC_{Pi} = internal pressure coefficient = +/- 0.55, assumes that building is partially enclosed regardless of what assumptions would be made for other types of wind loading

Table D-4. Values of K_Z for Exposure C Tornado Design for Buildings Up To 200 ft (61 m) High*

Height Above Ground Level			*Height Above Ground Level*		
ft	m	K_Z	ft	m	K_Z
15	0-4.6	0.85	80	24.4	1.21
20	6.1	0.90	90	27.4	1.24
25	7.6	0.94	100	30.5	1.26
30	9.1	0.98	120	36.6	1.31
40	12.2	1.04	140	42.7	1.36
50	15.2	1.09	160	48.8	1.39
60	18	1.13	180	54.9	1.43
70	21.3	1.17	200	61.0	1.46

*** Do not use if Exposure D applies and do not use Exposure B in any case.**

Table D-5. Values of External Pressure Coefficient (GC_P) for Low-Slope (Θ ≤ 7°) Gabled Roofs ≤ 60 ft (18 m) High

Zone	GC_P
1	-1.7
2	-2.3
3	-3.2
4	+0.9/-1.0
5	+0.9/-1.26

+ inward pressure; - outward or upward pressure, which always governs for roofs

D.3.2.6 Example D-1

Given: A 50 ft (15.2 m) high building is proposed to be constructed at a Eastern Kansas and the building owner requires it to be designed for property protection against tornado winds. Using Fig. D-3, determine the recommended design wind speed and calculate the design wind pressures for all 5 roof and wall areas.

Solution: First determine which wind zone the proposed installation is in using Fig. D-3. For this location, use V = 140 mph (62 m/s) wind speed. Use Equations D-1 and D-2 to calculate the design pressures.

$q_h = 0.00256K_ZK_{ZT}K_DIV^2$ (Eqn. D-1)

From Table D-4, use 1.09 for K_Z. Use 1.0 for K_{ZT}, K_D and I.

$q_h = 0.00256(1.09)(1.0)(1.0)(1.0)(140)^2 = 54.7$ psf (2.6 kPa)

Use Equation D-2 and respective GC_P values from Table D-5 to determine the design pressures in respective zones.

$p = [(1.05GC_P) - GC_{Pi}]\, q_h$ (Eqn. D-2)

Use GC_{Pi} = +/- 0.55 for all zones, as partial enclosure must be assumed.

For Zones 1, 2, 3, 4, and 5, the respective values of GC_P = -1.0, -1.8, -2.8, +0.9/-1.0 and +1.0/-1.26. So for:

Zone 1: qh = [(1.05)(-1.7) − 0.55](54.7 psf) = −128 psf (−6.1 kPa)
Zone 2: qh = [(1.05)(-2.3) − 0.55](54.7 psf) = −162 psf (−7.8 kPa)
Zone 3: qh = [(1.05)(-3.2) − 0.55](54.7 psf) = −214 psf (−19.2 kPa) Zone 4: q_h = [(1.05)(+0.9) + 0.55](54.7psf) = +82 psf (+3.9 kPa)
Zone 4: q_h = [(1.05)(-1.0) - 0.55](54.7psf) = -87 psf (-4.2 kPa)
Zone 5: q_h = [(1.05)(+1.0) + 0.55](54.7psf) = +87 psf (+4.2 kPa)
Zone 5: q_h = [(1.05)(-1.26) - 0.55](54.7psf) = -102 psf (-4.9 kPa)

Table D-6. Summary for Example D-1

Zone	*Wind Design Pressure, psf (kPa)*	*Ultimate Assembly Rating w/Min. 2.0 SF, psf (kPa)*
1	-128 (-6.1)	270 (-12.9)
2	-162 (-7.8)	330 (-15.8)-
3	-214 (-10.2)	435 (-20.87)
4	+82/-87 (+3.9/-4.2)	+165/-175 (+7.9/-8.4)
5	+87/-102 (+4.2/-4.9)	+175/-205 (+8.4/-9.8)

D.3.2.8 Building Materials Used for Roof Construction

Wind loss experience has been more favorable with structural concrete roof decks than with steel deck. Steel deck may be used, but should be designed for higher pressures. This could involve the use of any or all of the following:

- Shorter deck spans
- Stiffer (deeper, thicker, etc.) deck
- Increased securement to joists/purlins

Experience has also shown that steel joists may buckle due to the transfer of lateral loads to them or compressive stresses that develop in their lower chords while uplift pressures are applied to the roof deck. This could be resolved by enhancing the joist resistance, improving the joist bridging, and/or adding lower chord extensions.

Insulated roof assemblies with very high wind resistance can be found in RoofNav. Some assemblies, including those using insulated steel deck have wind uplift ratings up to approximately 465 psf (22 kPa). This will allow for a cost-effective design for higher wind speeds associated with tornado design, including the application of pressure coefficients to reflect areas of the roof with higher wind pressures and a reasonable safety factor.

D.4 References

Applied Technology Council (ATC), Wind Design for Tornadoes (webinar), William L. Coulbourne, P.E.

ASTM International. *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Windborne Debris in Hurricanes.* ASTM E 1996-14a.

ASTM International. *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials.* ASTM E 1886-13a.

Federal Emergency Management Agency (FEMA). *Design and Construction Guidance for Community Safe Rooms*. FEMA P-361.

Federal Emergency Management Agency (FEMA). *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business.* FEMA P-320.

Nong, S. and Doddipatla, L.; Review of US Tornado Risk, FM Global, January, 2015.

Phalen, Thomas E., Jr. “The Mechanics of Gravel Instability, Scour and Movement Under Wind Conditions on Single-ply Loose Laid Roof Membranes.” RoofBlok Limited. Waltham, MA., 1984.

US Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). *1998-1999 Tornadoes and a Long-Term U.S. Tornado Climatology*. Technical Report 99-02. NOAA/NESDIS. August 2000.