

## ENHANCED FUJITA SCALE, DAMAGE INDICATORS AND DEGREES OF DAMAGE (CANADIAN IMPLEMENTATION)

*Revision 3d (2026)*

### EF SCALE (CANADIAN IMPLEMENTATION)

| EF-Scale Rating | EF-Scale Wind Speed (Rounded to 5 km h <sup>-1</sup> ) |
|-----------------|--------------------------------------------------------|
| 0               | 90 – 130                                               |
| 1               | 135 – 175                                              |
| 2               | 180 – 220                                              |
| 3               | 225 – 265                                              |
| 4               | 270 – 310                                              |
| 5               | 315 or higher                                          |

### NOTES

Damage indicator information for DIs 1-23 and 25-26 adapted from McDonald, J. and K. C. Mehta, 2006: A Recommendation for an Enhanced Fujita Scale (EF-Scale), Revision 2. Wind Science and Engineering Research Center, Texas Tech University, Lubbock, TX, 111 pp ([PDF](#)). Note that their DI numbering is retained for these DIs.

Portions of this document were originally published by Environment and Climate Change Canada in 2013 – see their webpage [here](#) and the related Sills et al. (2014) publication [here](#).

Damage indicator information for DI C-3 (C-HC) adapted from 'Churches' Damage Indicator developed by Keraunos for France – provided by Dr. Emmanuel Wesolek ([PDF](#)).

Revisions to SBO (Small Barns or Farm Outbuildings) and C-FSGB (Farm Silos and Grain Bins) are based on peer-reviewed but unpublished material related to work on a new wind speed estimation standard via ASCE – see:

Marshall, T., T. Brown-Giammanco, S.N. Krautwurst and N.L. de Toledo, 2022: On the current revision of the Enhanced Fujita (EF) scale. *Extended abstracts, 30th AMS Conference on Severe Local Storms*, Oct 19-28, Santa Fe, NM ([Link](#)).

Most glossary information adapted from NOAA's Warning Decision Training Division (see <http://training.weather.gov/wdtd>). Thanks to Dr. Sarah Stevenson for assistance with adding additional terms to the glossary.

## DAMAGE INDICATORS AND APPENDICES (CANADIAN IMPLEMENTATION)

*Note: all wind speeds are 3-s gusts at 10 m AGL rounded to the nearest 5 km h<sup>-1</sup>*

*Note: DIs starting with 'C' were developed for the original Canadian implementation*

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## 1. SMALL BARNs OR FARM OUTBUILDINGS (SBO)

Typical Construction:

- Wood or metal post and beam construction
- Wood or metal roof trusses
- Wood or metal panel wall covering
- Metal panel or wood shingle roof covering
- Gable roof and large doors
- One or two storeys

Notes:

- If it cannot be confirmed that a large windward door was closed at time of event, decrease toward lower-bound wind speed for DOD4 to DOD8

| DOD | Damage Description                                                                                                                         | EXP | LB  | UB  |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                                                                | 100 | 85  | 125 |
| 2   | Minor loss of roof / wall covering (up to 20%)                                                                                             | 120 | 100 | 145 |
| 3   | Collapse of large, closed doors; minor damage to roof structure (up to 20%)                                                                | 130 | 110 | 155 |
| 4   | Moderate loss of roof / wall covering (more than 20%); moderate damage to roof structure (>20% to 50%); collapse of some walls (up to 20%) | 145 | 125 | 175 |
| 5   | Major damage to roof structure (>50% to 80%); collapse of several walls (>20% to 50%)                                                      | 150 | 125 | 185 |
| 6   | Complete loss of roof; collapse of most walls (>50 to 80%)                                                                                 | 155 | 130 | 190 |
| 7   | Overturning or sliding of entire structure; all walls collapsed                                                                            | 165 | 140 | 195 |
| 8   | Complete destruction of building with most debris swept from foundation                                                                    | 180 | 150 | 210 |

## 2. ONE- OR TWO-FAMILY RESIDENCES: 100 - 500 m<sup>2</sup> (FR12)

### Typical Construction:

- Asphalt shingles, tile, slate or metal roof covering
- Flat, gable, hip, mansard or mono-sloped roof or combinations thereof
- Plywood/OSB or wood plank roof deck
- Prefabricated wood trusses or wood joist and rafter construction
- Brick veneer, wood panels, stucco, EIFS, vinyl or metal siding
- Wood or metal stud walls, concrete blocks or insulating-concrete panels
- Attached single or double garage

### Notes:

- Includes modular homes; if unanchored, use lower-bound wind speed for DOD5
- With hip roof, increase toward upper-bound wind speed for DOD4 and DOD6
- Decrease toward lower-bound wind speed for DOD9 (265 km/h or less) if subfloor remains completely intact
- For non-slab foundations (i.e., with basements or crawlspaces), DOD10 requires that roof, walls and floor joists are swept from the foundation area
- Houses in dense neighbourhoods (e.g. subdivisions) with many tall trees may have little in the way of direct wind damage, with most damage resulting from fallen trees

| DOD | Damage Description                                                                                                                                                 | EXP | LB  | UB  |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                                                                                        | 105 | 85  | 130 |
| 2   | Loss of roof covering material (up to 20%), gutters and/or awning; loss of vinyl or metal siding                                                                   | 125 | 100 | 155 |
| 3   | Broken glass in doors and windows                                                                                                                                  | 155 | 125 | 185 |
| 4   | Uplift of roof deck and loss of significant roof covering material (more than 20%); collapse of chimney; garage doors collapse inward; failure of porch or carport | 155 | 130 | 185 |
| 5   | Entire house shifts off foundation                                                                                                                                 | 195 | 165 | 225 |
| 6   | Large sections of roof structure removed (more than 50%); most walls remain standing                                                                               | 195 | 165 | 230 |
| 7   | Exterior walls collapsed                                                                                                                                           | 210 | 180 | 245 |
| 8   | Most walls collapsed, except small interior rooms                                                                                                                  | 245 | 205 | 285 |
| 9   | All walls collapsed                                                                                                                                                | 275 | 230 | 320 |
| 10  | Complete destruction of engineered and/or well-constructed residence; slab swept clean                                                                             | 320 | 265 | 355 |

### 3. MANUFACTURED HOMES: SINGLE WIDE (MHSW)

Typical Construction:

- Steel undercarriage supported on concrete block piers
- Metal straps and ground anchors (frame and/or over-the-top strap anchors)
- Asphalt shingles or one-piece metal roof covering
- Wood roof joists; metal, vinyl or wood siding
- Wood stud walls and partitions

| <b>DOD</b> | <b>Damage Description</b>                                                  | <b>EXP</b> | <b>LB</b> | <b>UB</b> |
|------------|----------------------------------------------------------------------------|------------|-----------|-----------|
| 1          | Threshold of visible damage                                                | 100        | 80        | 120       |
| 2          | Loss of shingles or partial uplift of one-piece metal roof covering        | 120        | 100       | 150       |
| 3          | Unit slides off block piers but remains upright                            | 140        | 115       | 165       |
| 4          | Complete uplift of roof; most walls remain standing                        | 145        | 115       | 180       |
| 5          | Unit rolls on its side or upside down; remains essentially intact          | 160        | 135       | 185       |
| 6          | Destruction of roof and walls leaving floor and undercarriage in place     | 170        | 140       | 200       |
| 7          | Unit rolls or vaults; roof and walls separate from floor and undercarriage | 175        | 155       | 205       |
| 8          | Undercarriage separates from unit; rolls, tumbles and is badly bent        | 190        | 165       | 220       |
| 9          | Complete destruction of unit; debris blown away                            | 205        | 175       | 240       |

### 4. MANUFACTURED HOMES: DOUBLE WIDE (MHDW)

Typical Construction:

- Steel undercarriage supported on concrete block piers
- Multi-unit connection at roof, floor and end walls
- Frame straps and ground anchors spaced 3-4 m apart
- Flat, gable or hip roof shape; asphalt shingles or metal roof panels; plywood/OSB roof decking; wood rafter or shallow joist construction; metal, vinyl or wood siding

| <b>DOD</b> | <b>Damage Description</b>                                                          | <b>EXP</b> | <b>LB</b> | <b>UB</b> |
|------------|------------------------------------------------------------------------------------|------------|-----------|-----------|
| 1          | Threshold of visible damage                                                        | 100        | 80        | 120       |
| 2          | Loss of shingles or other roof covering (up to 20%)                                | 120        | 100       | 140       |
| 3          | Damaged porches or carports                                                        | 125        | 110       | 155       |
| 4          | Broken windows                                                                     | 135        | 110       | 155       |
| 5          | Uplift of roof deck and loss of significant roof covering material (more than 20%) | 140        | 120       | 175       |
| 6          | Complete uplift of roof; most walls remain standing                                | 150        | 125       | 175       |
| 7          | Unit slides off CMU block piers                                                    | 150        | 125       | 175       |
| 8          | Removal of entire roof structure leaving most walls standing                       | 155        | 130       | 190       |
| 9          | Complete destruction of roof and walls leaving undercarriage in place              | 180        | 150       | 210       |
| 10         | Unit rolls, displaces or vaults                                                    | 185        | 130       | 210       |
| 11         | Undercarriage separates from floor, rolls and tumbles, badly bent                  | 205        | 175       | 235       |
| 12         | Complete destruction of unit; debris blows away                                    | 215        | 190       | 250       |

## 5. APARTMENTS, CONDOMINIUMS AND TOWNHOUSES: 3 STOREYS OR LESS (ACT)

Typical Construction:

- Flat, gable, hip or mansard roof
- Asphalt shingles, tile, metal or BUR roof covering
- Plywood/OSB roof decking
- Light-framed wood or metal roof trusses
- Wood, metal or vinyl panels, stucco brick veneer or EIFS wall covering; combinations of wall coverings
- Wood or metal stud walls; wood floor diaphragms
- Sliding patio doors; balconies

Notes:

- With hip roof, increase toward upper-bound wind speed for DOD3 and DOD4

| DOD | Damage Description                                                        | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                               | 120 | 100 | 155 |
| 2   | Loss of roof covering (up to 20%)                                         | 160 | 130 | 195 |
| 3   | Uplift of roof decking; significant loss of roof covering (more than 20%) | 200 | 170 | 235 |
| 4   | Uplift or collapse of roof structure leaving most walls standing          | 220 | 195 | 255 |
| 5   | Most top storey walls collapsed                                           | 255 | 220 | 295 |
| 6   | Almost complete destruction of top two storeys                            | 290 | 250 | 330 |

## 6. MOTELS (M)

Typical Construction:

- Less than or equal to four storeys
- Facility made up of one or more multi-storey, rectangular buildings
- Flat, gable, hip or mansard roof
- Asphalt shingles, tile, slate or BUR roof covering
- Plywood/OSB roof decking, wood or metal prefabricated roof trusses
- Wood floor diaphragms, wood or metal stud walls
- Stucco, EIFS, wood, metal or brick veneer wall cladding
- Canopy over driveway at entrance; exterior walkways or balconies

Notes:

- With hip roof, increase toward upper-bound wind speed for DOD4 and DOD6

| DOD | Damage Description                                                                                    | EXP | LB  | UB  |
|-----|-------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                           | 105 | 85  | 135 |
| 2   | Loss of roof covering (up to 20%)                                                                     | 130 | 110 | 160 |
| 3   | Broken windows or patio doors                                                                         | 145 | 120 | 170 |
| 4   | Uplift of roof decking; significant loss of roof covering (more than 20%); loss of EIFS wall cladding | 155 | 130 | 185 |
| 5   | Uplift or collapse of canopy over driveway                                                            | 160 | 130 | 190 |
| 6   | Uplift or collapse of roof structure leaving most walls standing                                      | 200 | 165 | 230 |
| 7   | Collapse of top storey exterior walls                                                                 | 220 | 195 | 250 |
| 8   | Collapse of most top storey walls                                                                     | 230 | 205 | 260 |
| 9   | Collapse of top two floors of three or more stories                                                   | 275 | 230 | 300 |
| 10  | Complete destruction of entire building                                                               | 305 | 260 | 350 |

## 7. MASONRY APARTMENTS OR MOTELS (MAM)

### Typical Construction:

- Less than or equal to four storeys
- Facility made up of one or more multi-storey, rectangular buildings
- Flat, gable, hip or mansard roof
- Asphalt shingles, tile, slate or BUR roof
- Light steel roof framing with metal deck and lightweight insulation
- Pre-cast or hollow-core concrete roof and floor system
- CMU non-bearing walls
- CMU load-bearing walls
- Stucco, EIFS, or brick veneer wall cladding
- Exterior walkways or balconies

| DOD | Damage Description                                  | EXP | LB  | UB  |
|-----|-----------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                         | 105 | 85  | 130 |
| 2   | Loss of roof covering (up to 20%)                   | 130 | 110 | 165 |
| 3   | Uplift of lightweight metal roof decking            | 155 | 130 | 185 |
| 4   | Uplift of concrete roof decking                     | 195 | 165 | 230 |
| 5   | Collapse of top storey walls                        | 215 | 185 | 240 |
| 6   | Collapse of top two floors of three or more storeys | 250 | 210 | 290 |
| 7   | Complete destruction of large section of building   | 290 | 255 | 330 |

## 8. SMALL RETAIL BUILDINGS (SRB)

### Typical Construction:

- Flat, hip, gable, mansard or mono-slope roof
- Asphalt shingles, metal panels, slate, tile, single-ply or BUR roof covering
- Plywood/OSB roof decking
- Wood or metal roof structure consisting of trusses or rafters and joists
- Wood or metal stud walls
- Typically have large areas of window glass and double entry doors
- Canopies, covered walkways or porches
- Wood, brick veneer, metal or vinyl siding, concrete blocks, EIFS or stucco wall cladding
- Best example is fast-food restaurant

### Notes:

- With hip roof, increase toward upper-bound wind speed for DOD4 and DOD6

| DOD | Damage Description                                                        | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                               | 105 | 85  | 130 |
| 2   | Loss of roof covering (up to 20%)                                         | 125 | 105 | 160 |
| 3   | Broken glass in windows and doors                                         | 140 | 115 | 165 |
| 4   | Uplift of roof decking; significant loss of roof covering (more than 20%) | 160 | 130 | 190 |
| 5   | Canopies or covered walkways destroyed                                    | 160 | 135 | 185 |
| 6   | Uplift or collapse of entire roof structure                               | 190 | 165 | 225 |
| 7   | Collapse of exterior walls; closely spaced interior walls remain standing | 220 | 195 | 255 |
| 8   | Complete destruction of entire building                                   | 270 | 230 | 310 |

## 9. SMALL PROFESSIONAL BUILDINGS: SINGLE STOREY, LESS THAN 500 m<sup>2</sup> (SPB)

### Typical Construction:

- Flat, gable, hip, mansard or mono-slope roofs with or without parapet walls
- Asphalt shingles, tile, slate, metal panels, single-ply or BUR roof covering
- Light-frame steel construction, steel joists and formed metal decking
- Load-bearing masonry construction with steel or wood roof structure
- Timber post and beam construction
- Wood or metal stud walls, non-bearing masonry walls
- Metal or vinyl panels, stucco or EIFS cladding
- Skylights and/or clear stories

### Notes:

- With hip roof, increase toward upper-bound wind speed for DOD5 and DOD7

| DOD | Damage Description                                                                                        | EXP | LB  | UB  |
|-----|-----------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                               | 105 | 85  | 130 |
| 2   | Loss of roof covering (up to 20%)                                                                         | 125 | 105 | 160 |
| 3   | Broken windows, including clear story windows or skylights                                                | 145 | 120 | 170 |
| 4   | Exterior doors fail                                                                                       | 160 | 130 | 190 |
| 5   | Uplift of roof decking; significant loss of roof covering (more than 20%); loss of rooftop HVAC equipment | 160 | 135 | 190 |
| 6   | Collapsed façade or parapet walls                                                                         | 165 | 135 | 200 |
| 7   | Uplift or collapse of entire roof structure                                                               | 200 | 170 | 235 |
| 8   | Collapse of exterior walls; closely spaced interior walls remain standing                                 | 230 | 200 | 265 |
| 9   | Complete destruction of entire building                                                                   | 255 | 240 | 320 |

## 10. STRIP MALLS (SM)

### Typical Construction:

- Large, rectangular single-storey building with large surrounding parking lots
- Flat roof with parapet wall
- BUR or single-ply roof membrane with rigid insulation
- Wood or metal deck, wood-fibre cement panels
- Light-frame steel roof support with steel joists or joist girders
- Brick or concrete block wall construction
- Large window glass and glass entry doors
- Covered walkway attached to building

| DOD | Damage Description                                                        | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                               | 105 | 85  | 130 |
| 2   | Uplift of roof covering at eaves and roof corners                         | 130 | 105 | 160 |
| 3   | Broken windows or glass doors                                             | 140 | 115 | 170 |
| 4   | Uplift of roof decking                                                    | 165 | 135 | 195 |
| 5   | Collapsed façade or parapet walls                                         | 165 | 135 | 200 |
| 6   | Covered walkways uplifted or collapsed                                    | 165 | 140 | 200 |
| 7   | Uplift or collapse of entire roof structure                               | 195 | 165 | 230 |
| 8   | Collapse of exterior walls; closely spaced interior walls remain standing | 225 | 190 | 265 |
| 9   | Complete destruction of all or large section of building                  | 275 | 235 | 320 |

## 11. LARGE SHOPPING MALLS (LSM)

Typical Construction:

- Typically one or two storeys
- Flat roof; some areas with relatively large spans
- Skylights and clear stories
- Single-ply or BUR with or without roof gravel
- Metal stud walls with brick veneer, stucco or EIFS cladding
- Light steel structural framing with open web joists, light metal framing or 3-D space framing
- Glass at entries

| DOD | Damage Description                                                                                      | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                             | 115 | 95  | 140 |
| 2   | Loss of roof covering (up to 20%)                                                                       | 135 | 110 | 170 |
| 3   | Broken skylights, clearstory windows and atrium walls broken                                            | 150 | 120 | 185 |
| 4   | Uplift of some roof decking; significant loss of roofing material (more than 20%); loss of rooftop HVAC | 175 | 150 | 205 |
| 5   | Wall cladding stripped starting at corners and progressing to other areas                               | 180 | 150 | 210 |
| 6   | Roof structure uplifted or collapsed                                                                    | 205 | 175 | 240 |
| 7   | Exterior walls in top storey collapsed                                                                  | 230 | 200 | 265 |
| 8   | Interior walls of top storey collapse                                                                   | 255 | 225 | 300 |
| 9   | Complete destruction of all or large section of building                                                | 330 | 285 | 400 |

## 12. LARGE ISOLATED RETAIL BUILDINGS (LIRB)

Typical Construction:

- Flat roof with BUR and gravel or single-ply membrane roof; generally has a 1-m parapet
- Open web joists and steel girders or joist girders supported by tall pipe columns
- Metal deck with rigid insulation or lightweight concrete fill slab
- Large windows on front side of building
- CMU walls, tilt-up concrete panels, metal stud walls covered with EIFS or combinations of these

| DOD | Damage Description                                                                                      | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                             | 110 | 90  | 135 |
| 2   | Loss of roof covering (up to 20%)                                                                       | 130 | 110 | 165 |
| 3   | Uplift of some roof decking; significant loss of roofing material (more than 20%); loss of rooftop HVAC | 165 | 140 | 200 |
| 4   | Long roof spans collapsed downward                                                                      | 195 | 165 | 230 |
| 5   | Uplift and removal of roof structure                                                                    | 215 | 185 | 255 |
| 6   | Inward or outward collapse of exterior walls                                                            | 220 | 190 | 255 |
| 7   | Complete destruction of all or large section of building                                                | 280 | 235 | 325 |

### 13. AUTOMOBILE SHOWROOMS (ASR)

Typical Construction:

- Typically one storey with flat roof
- Roof system is BUR or single-ply membrane
- Metal roof deck or plywood panels
- Steel structural framing with open web steel joists
- Metal stud walls with EIFS, stucco or tilt-up panels
- Exterior walls on 2 or 3 sides have large glass windows

| DOD | Damage Description                                                                                      | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                             | 105 | 75  | 130 |
| 2   | Loss of roof covering (up to 20%)                                                                       | 130 | 110 | 165 |
| 3   | Broken glass in windows or doors                                                                        | 140 | 115 | 170 |
| 4   | Uplift of some roof decking; significant loss of roofing material (more than 20%); loss of rooftop HVAC | 165 | 135 | 195 |
| 5   | Cladding stripped off walls                                                                             | 180 | 150 | 210 |
| 6   | Uplift or collapse of roof structure                                                                    | 190 | 160 | 225 |
| 7   | Exterior walls collapsed                                                                                | 205 | 170 | 240 |
| 8   | Complete destruction of all or large section of building                                                | 255 | 220 | 290 |

### 14. AUTOMOBILE SERVICE BUILDINGS (ASB)

Typical Construction:

- Typically one storey with flat roof and relatively tall walls with parapet
- Roof coverings are typically BUR with gravel or single-ply membrane
- Roof structure is light steel framing or open web steel joists and metal roof deck
- Exterior walls are concrete masonry or pre-cast tilt-up panels
- Numerous large metal overhead doors

| DOD | Damage Description                                                                                      | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                             | 100 | 75  | 125 |
| 2   | Loss of roof covering (up to 20%)                                                                       | 125 | 105 | 160 |
| 3   | Failure of large overhead doors                                                                         | 145 | 125 | 175 |
| 4   | Uplift of some roof decking; significant loss of roofing material (more than 20%); loss of rooftop HVAC | 160 | 130 | 190 |
| 5   | Collapse of non-bearing masonry or tilt-up walls                                                        | 185 | 150 | 215 |
| 6   | Uplift or collapse of roof structure                                                                    | 195 | 165 | 230 |
| 7   | Collapse of load-bearing walls                                                                          | 205 | 170 | 240 |
| 8   | Complete destruction of all or large section of building                                                | 255 | 220 | 290 |

## 15. ELEMENTARY SCHOOLS (ES)

### Typical Construction:

- Typically one storey with flat roofs; CMU bearing walls with brick veneer, stucco or EIFS cladding; walls can have a large percentage of window glass
- Building may contain a small gym or cafeteria with moderately long spans between supports
- Building has long interior hallways with bearing or non-bearing walls
- BUR, single-ply membrane or metal standing seam roof panels; metal or plywood roof decking supporting rigid insulation boards or a lightweight poured gypsum deck
- Roof structure consists of open web steel joists bearing on exterior walls and steel interior girders; exterior non-bearing walls constructed with CMUs, glass curtain walls or metal studs with brick veneer, stucco or EIFS cladding

| DOD | Damage Description                                                                                      | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                             | 105 | 75  | 130 |
| 2   | Loss of roof covering (up to 20%)                                                                       | 125 | 105 | 160 |
| 3   | Broken windows                                                                                          | 140 | 115 | 170 |
| 4   | Exterior door failures                                                                                  | 160 | 135 | 190 |
| 5   | Uplift of some roof decking; significant loss of roofing material (more than 20%); loss of rooftop HVAC | 165 | 130 | 195 |
| 6   | Damage to or loss of wall cladding                                                                      | 175 | 150 | 205 |
| 7   | Uplift or collapse of roof structure                                                                    | 200 | 175 | 240 |
| 8   | Collapse of non-bearing walls                                                                           | 225 | 190 | 260 |
| 9   | Collapse of load-bearing walls                                                                          | 245 | 210 | 290 |
| 10  | Complete destruction of all or large section of building                                                | 285 | 245 | 325 |

## 16. JUNIOR OR SENIOR HIGH SCHOOLS (JHSH)

### Typical Construction:

- Generally large one- or two-storey buildings with flat roofs; may contain gymnasium, cafeteria and auditorium with large structural spans; may have a basement
- Classroom wings have interior hallways with bearing or non-bearing interior walls
- BUR or single-ply membrane roof covering with or without gravel; structural system may consist of an all-steel structure or all-reinforced concrete structure or a combination of both
- Roof structure may be light steel construction with open web joists supported on steel beams; corrugated metal roof deck with rigid insulation or poured gypsum deck
- Exterior walls constructed of concrete or clay blocks with brick veneer, stucco or EIFS; metal and glass curtain walls; walls may have more than 30% windows

| DOD | Damage Description                                                                                       | EXP | LB  | UB  |
|-----|----------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                              | 110 | 90  | 135 |
| 2   | Loss of roof covering (up to 20%)                                                                        | 125 | 105 | 160 |
| 3   | Broken windows                                                                                           | 140 | 115 | 170 |
| 4   | Exterior door failures                                                                                   | 165 | 135 | 195 |
| 5   | Uplift of metal roof decking; significant loss of roofing material (more than 20%); loss of rooftop HVAC | 165 | 135 | 190 |
| 6   | Damage to or loss of wall cladding                                                                       | 175 | 150 | 205 |
| 7   | Collapse of tall masonry walls at gym, cafeteria or auditorium                                           | 185 | 150 | 220 |
| 8   | Uplift or collapse of light steel roof structure                                                         | 200 | 175 | 240 |
| 9   | Collapse of exterior walls in top floor                                                                  | 225 | 195 | 245 |
| 10  | Most interior walls of top floor collapsed                                                               | 255 | 215 | 300 |
| 11  | Complete destruction of all or large section of building                                                 | 310 | 260 | 360 |

## 17. LOW-RISE BUILDINGS: 1 - 4 STOREYS (LRB)

### Typical Construction:

- Generally consist of rectangular modules but can be odd shaped in plan-view sense
- Most will have flat roofs but can have gable, hip or mansard shapes
- Roofing materials include BUR, single-ply membrane, metal panels or standing seam
- Roof deck is wood or metal deck, poured gypsum deck or concrete slab
- Steel or reinforced concrete structural frame
- Glass and metal curtain walls, metal studs with EIFS, non-bearing masonry walls with stucco or brick veneer
- Examples are office buildings, medical facilities and bank buildings

### Notes:

- With hip roof, increase toward upper-bound wind speed for DOD3 and DOD5

| DOD | Damage Description                                                                                           | EXP | LB  | UB  |
|-----|--------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                                  | 110 | 90  | 135 |
| 2   | Loss of roof covering (up to 20%)                                                                            | 130 | 110 | 165 |
| 3   | Uplift of metal roof decking at eaves and roof corners; significant loss of roofing material (more than 20%) | 165 | 135 | 195 |
| 4   | Broken glass in windows, entryways or atriums                                                                | 165 | 135 | 195 |
| 5   | Uplift of lightweight roof structure                                                                         | 215 | 185 | 255 |
| 6   | Significant damage to exterior walls and some interior walls                                                 | 230 | 195 | 270 |
| 7   | Complete destruction of all or large section of building                                                     | 305 | 260 | 355 |

## 18. MID-RISE BUILDINGS: 5 - 20 STOREYS (MRB)

### Typical Construction:

- Generally consist of rectangular shapes but can have curved or triangular footprints
- Roofs are generally flat; may have an elevator/mechanical penthouse and/or parapet walls
- Structural frame is steel or reinforced concrete
- Roofing materials are BUR or single-ply membrane with or without gravel
- Penthouse is steel framing with metal panels, or metal studs with stucco or EIFS
- Exterior cladding is glass or metal curtain walls; pre-cast concrete window wall panels or a combination of the two
- Roof structure consists of metal deck, poured gypsum deck or concrete slab
- Examples are office buildings, medical facilities and residential buildings

| DOD | Damage Description                                                                         | EXP | LB  | UB  |
|-----|--------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                | 115 | 95  | 140 |
| 2   | Loss of roof covering (up to 20%)                                                          | 135 | 110 | 165 |
| 3   | Damage to penthouse roof and walls; loss of rooftop HVAC equipment                         | 150 | 120 | 180 |
| 4   | Damage to parapet walls or coping                                                          | 160 | 135 | 190 |
| 5   | Broken glass in curtain walls; glass in entryways; significant damage to building interior | 165 | 135 | 195 |
| 6   | Uplift of lightweight roof decking; significant loss of roofing material (more than 20%)   | 190 | 160 | 225 |
| 7   | Broken curtain wall panel anchors                                                          | 210 | 175 | 240 |
| 8   | Uplift or collapse of roof structure                                                       | 220 | 190 | 255 |
| 9   | Significant damage to curtain walls and some interior walls                                | 235 | 195 | 270 |
| 10  | Permanent structural deformation                                                           | 340 | 290 | 430 |

## 19. HIGH-RISE BUILDINGS: GREATER THAN 20 STOREYS (HRB)

### Typical Construction:

- Generally consist of rectangular shapes but can have curved or triangular footprints
- Roofs are generally flat but may have a more complex roof shape as part of aesthetic statement; roofing material single-ply membrane fully adhered, polyurethane foam roof, metal or copper-clad roof covering
- Structural frame is steel or reinforced concrete; penthouse is steel framing with metal panels
- Exterior cladding is glass or metal curtain walls or pre-cast concrete window panels
- First floor often has very large glass areas that are susceptible to debris impact
- Atriums with overhead glazing or tall window walls
- Examples are hotels, office buildings and condominiums

| DOD | Damage Description                                                              | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                     | 115 | 95  | 140 |
| 2   | Loss of roof covering (up to 20%)                                               | 140 | 110 | 170 |
| 3   | Damage to penthouse roof and walls; loss of rooftop HVAC equipment              | 150 | 120 | 180 |
| 4   | Broken glass in exterior walls at 1st and 2nd floors; broken glass in entryways | 165 | 135 | 195 |
| 5   | Damage to parapet walls or coping                                               | 165 | 140 | 195 |
| 6   | Broken curtain wall panel anchors                                               | 210 | 175 | 255 |
| 7   | Significant loss of roofing material (more than 20%)                            | 230 | 185 | 265 |
| 8   | Significant damage to curtain walls and interior walls                          | 235 | 200 | 275 |
| 9   | Uplift or collapse of roof structure                                            | 255 | 200 | 295 |
| 10  | Permanent structural deformation                                                | 365 | 305 | 465 |

## 20. INSTITUTIONAL BUILDINGS (IB)

### Typical Construction:

- Examples are hospitals, courthouses, university buildings, government buildings and jails
- Range in height 1 to 10 storeys; balconies, porches and porticos with heavy façade
- Roofing materials include fully adhered and mechanically fastened single-ply membranes, polyurethane foam, and copper-clad domes
- Structure is normally reinforced concrete, relatively small windows
- Walls are masonry with cut stone or pre-cast panels – may be very ornate

| DOD | Damage Description                                                                                   | EXP | LB  | UB  |
|-----|------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                          | 115 | 95  | 140 |
| 2   | Loss of roof covering (up to 20%)                                                                    | 140 | 115 | 175 |
| 3   | Damage to penthouse roof and walls; loss of rooftop HVAC equipment                                   | 150 | 120 | 180 |
| 4   | Broken glass in windows or doors                                                                     | 155 | 125 | 185 |
| 5   | Uplift of lightweight roof deck and insulation; significant loss of roofing material (more than 20%) | 185 | 155 | 220 |
| 6   | Façade components torn from structure                                                                | 190 | 155 | 225 |
| 7   | Damage curtain walls or other wall cladding                                                          | 210 | 175 | 245 |
| 8   | Uplift of pre-cast concrete roof slabs                                                               | 230 | 190 | 260 |
| 9   | Uplift of metal deck with concrete fill slab                                                         | 235 | 190 | 275 |
| 10  | Collapse of some top story exterior walls                                                            | 240 | 205 | 275 |
| 11  | Complete destruction of all or large section of building                                             | 340 | 285 | 430 |

## 21. METAL BUILDING SYSTEMS (MBS)

Typical Construction:

- Examples are warehouses, industrial facilities and small arenas
- Metal panel walls and standing seam roof
- Nearly always have a gable roof and relatively tall walls
- Large overhead doors
- Large-span single bay rigid frames
- 'Z'- or 'C'-shaped purlins and girts span between rigid frames
- Lateral loads resisted by cross-bracing

| DOD | Damage Description                                           | EXP | LB  | UB  |
|-----|--------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                  | 110 | 85  | 135 |
| 2   | Inward or outward collapse of overhead doors                 | 145 | 120 | 175 |
| 3   | Metal roof or wall panels pulled from the building           | 155 | 125 | 195 |
| 4   | Column anchorage failed                                      | 190 | 155 | 215 |
| 5   | Buckling of roof purlins                                     | 190 | 155 | 220 |
| 6   | Failure of cross-braces in the lateral load resisting system | 220 | 190 | 255 |
| 7   | Progressive collapse of rigid frames                         | 230 | 195 | 270 |
| 8   | Complete destruction of building                             | 250 | 210 | 285 |

## 22. SERVICE STATION CANOPIES (SSC)

Typical Construction:

- Modern service stations consist of a very large canopy covering the entire pump area and a small building that houses cashier and retail space
- Canopy structure constructed of steel beam framework supported on four or more tall columns
- Metal panels cover bottom side of the canopy
- Lightweight fascia materials, either metal or plastic, cover the perimeter of canopy

| DOD | Damage Description                                | EXP | LB  | UB  |
|-----|---------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                       | 100 | 70  | 125 |
| 2   | Fascia material blown from canopy                 | 125 | 105 | 155 |
| 3   | Metal roof panels stripped from canopy            | 150 | 120 | 180 |
| 4   | Columns bend or buckle under wind load            | 175 | 140 | 215 |
| 5   | Canopy collapsed due to column foundation failure | 185 | 145 | 230 |
| 6   | Complete destruction of canopy                    | 215 | 175 | 260 |

## 23. WAREHOUSE BUILDINGS (WHB)

Typical Construction:

- This category includes all building systems except 'Metal Building Systems'
- Examples include warehouse, storage and industrial buildings
- Buildings are generally rectangular in plan with flat, gable or hip roofs
- Built-up roofs with gravel, single-ply membrane ballasted, mechanically attached or fully adhered
- Light-frame steel construction with masonry bearing walls
- Large overhead doors
- Pre-cast concrete columns, beams and double tees with tilt-up wall panels
- Heavy timber construction with stud walls and wood panels

| DOD | Damage Description                                                                                        | EXP | LB  | UB  |
|-----|-----------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                               | 110 | 90  | 135 |
| 2   | Loss of roofing material (up to 20%)                                                                      | 135 | 110 | 170 |
| 3   | Inward or outward collapse of overhead doors                                                              | 140 | 120 | 170 |
| 4   | Uplift of roof deck; significant loss of roofing material (more than 20%); loss of rooftop HVAC equipment | 165 | 140 | 195 |
| 5   | Collapse of other non-bearing exterior walls                                                              | 185 | 150 | 205 |
| 6   | Collapse of pre-cast concrete tilt-up panels                                                              | 200 | 165 | 230 |
| 7   | Complete destruction of all or large section of building                                                  | 255 | 210 | 300 |

## 25. FREE-STANDING TOWERS (FST)

Typical Construction:

- Cell phone pole or tower
- Microwave tower

| DOD | Damage Description                 | EXP | LB  | UB  |
|-----|------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage        | 150 | 120 | 180 |
| 2   | Collapsed cell-phone pole or tower | 215 | 180 | 255 |
| 3   | Collapsed micro-wave tower         | 220 | 185 | 255 |

## 26. FREE-STANDING LIGHT POLES, LUMINARY POLES, FLAG POLES (FSP)

Typical Construction:

- Cantilevered metal pole

| DOD | Damage description          | EXP | LB  | UB  |
|-----|-----------------------------|-----|-----|-----|
| 1   | Threshold of visible damage | 130 | 110 | 160 |
| 2   | Bent pole                   | 165 | 135 | 195 |
| 3   | Collapsed pole              | 190 | 160 | 220 |

## C-1. ELECTRICAL TRANSMISSION LINES (C-ETL)

### Typical Construction:

- Single wood poles with wood crossarms, 7-35 m in height and 15-60 cm in diameter (at 2 m above ground)
- Single steel or concrete poles with metal crossarms
- Metal trussed towers

### Notes:

- Whether poles go down or not is related to size, composition (wood / concrete / steel) and load (wire tension, number of transformers)
- For small diameter (~15-20 cm) or very old wood poles, decrease toward lower-bound wind speed; for large diameter (~45-60 cm) wood poles, increase toward upper-bound wind speed
- Keep in mind – one weak or overloaded pole going down can cause other poles along the line to break due to wire tension
- Trees falling on lines can bring down poles – *do not use this DI if this is the case*
- Metal truss towers where lines change direction are often more strongly reinforced, increase toward upper-bound wind speed
- If damage path orientation is approx. perpendicular to orientation of transmission line (within +/- 30°), reduce selected wind speed by 20 km/h

| DOD | Damage Description                     | EXP | LB  | UB  |
|-----|----------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage            | 130 | 110 | 155 |
| 2   | Broken wood crossarm                   | 155 | 125 | 175 |
| 3   | Wood poles leaning                     | 175 | 135 | 200 |
| 4   | Broken wood poles                      | 195 | 145 | 220 |
| 5   | Broken or bent steel or concrete poles | 210 | 180 | 240 |
| 6   | Collapsed metal truss towers           | 220 | 185 | 255 |

## C-2. TREES (C-T)

### Typical Species:

- Hardwood: Oak, Maple, Birch, Ash, Beech, Cherry, Hickory, Walnut, Aspen, Elm, Poplar
- Softwood: Pine, Spruce, Fir, Hemlock, Cedar, Larch, Redwood, Cypress

### Notes:

- General differences in the responses of softwood and hardwood species are less important than other factors
- To estimate the percentage of trees snapped and/or uprooted, use the NTP Scalable Box Method as described in Appendix B.
- In dense neighbourhoods (e.g. subdivision) with many tall trees, the vast majority of the damage can be snapped and uprooted trees, with damage to houses mainly from the fallen trees.
- For satellite-based assessments of forest damage (having limited imagery resolution, lack of tree health/species information, lack of plantation/age information), the NTP defaults to the lower-bound wind speed – with the following exceptions:
  - DOD6, deep soil and close to 100% treefall (EXP-20 km/h)
  - DOD5, deep soil and close to 80% treefall (EXP-20 km/h)
  - No leaves on trees in spring or fall (EXP)
- For all other assessment types, the NTP defaults to the expected wind speed – with the following exceptions:
  - Very shallow soil (LB)
  - Poor tree health (disease/infestation, broken at base of trunk due to girdling, etc.), shallow root balls, even-aged monoculture plantation (LB)
  - Most trees snapped in area without deep soil (EXP-20 km/h)
  - Forests or woodlots composed of mature, deep-rooted red oak, red maple, beech, hemlock or white cedar (EXP+20 km/h)
  - No leaves on trees in spring or fall and very shallow soil (EXP)
  - No leaves on trees in spring or fall and soil between very shallow and deep (EXP+20 km/h)
  - No leaves on trees in spring or fall and deep soil (UB)

| DOD | Damage Description                                                                                                                                      | EXP | LB  | UB  |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Small limbs broken (up to 5 cm diameter)                                                                                                                | 70  | 55  | 85  |
| 2   | Large limbs broken (greater than 5 cm diameter)                                                                                                         | 90  | 65  | 110 |
| 3   | Up to 20% of mature trees snapped and/or uprooted                                                                                                       | 115 | 80  | 150 |
| 4   | More than 20% of mature trees snapped and/or uprooted                                                                                                   | 150 | 105 | 190 |
| 5   | More than 50% of mature trees snapped and/or uprooted                                                                                                   | 190 | 145 | 230 |
| 6   | More than 80% of mature trees snapped and/or uprooted; numerous trees may be denuded/debarked by missiles with only stubs of largest branches remaining | 235 | 190 | 275 |

### C-3. HERITAGE CHURCHES (C-HC)

Typical Construction:

- Built with bricks and/or stones
- Solidly built roof structure
- May also have one or more bell towers

| DOD | Damage Description                                                                                         | EXP | LB  | UB  |
|-----|------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                                | 90  | 70  | 110 |
| 2   | Loss of roof covering material (up to 20%)                                                                 | 115 | 90  | 140 |
| 3   | Loss of significant roof covering material (more than 20%); light damage on the bell-tower summit          | 145 | 115 | 175 |
| 4   | More than 50% of roof structure removed; collapse of the bell-tower summit (spire); walls remain standing  | 185 | 150 | 220 |
| 5   | More than 80% of roof structure removed; walls partly collapsed; bell-tower structure damaged              | 225 | 190 | 260 |
| 6   | Roof structure totally removed and blown away; many walls collapsed; bell-tower structure mostly destroyed | 270 | 230 | 310 |
| 7   | Complete destruction of building                                                                           | 315 | 275 | 355 |

### C-4. SOLID MASONRY HOUSES (C-SMH)

Typical Construction:

- Asphalt shingles, tile, slate or metal roof covering
- Flat, gable, hip, mansard or mono-sloped roof or combinations thereof
- Plywood/OSB or wood plank roof deck
- All exterior walls are solid masonry construction (e.g. double brick)
- Roof is wood joist and rafter construction

Notes:

- With hip roof, increase toward upper-bound wind speed for DOD4 and DOD5

| DOD | Damage Description                                                                                                                                                 | EXP | LB  | UB  |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Threshold of visible damage                                                                                                                                        | 105 | 85  | 130 |
| 2   | Loss of roof covering material (up to 20%), gutters and/or awning; loss of vinyl or metal siding                                                                   | 125 | 100 | 155 |
| 3   | Broken glass in doors and windows                                                                                                                                  | 155 | 125 | 185 |
| 4   | Uplift of roof deck and loss of significant roof covering material (more than 20%); collapse of chimney; garage doors collapse inward; failure of porch or carport | 155 | 130 | 185 |
| 5   | Large sections of roof structure removed (more than 50%); most walls remain standing                                                                               | 195 | 165 | 240 |
| 6   | Exterior walls collapsed                                                                                                                                           | 245 | 210 | 285 |
| 7   | Most walls collapsed, except small interior rooms                                                                                                                  | 285 | 245 | 325 |
| 8   | Complete destruction of building                                                                                                                                   | 315 | 275 | 355 |

## C-5. FARM SILOS OR GRAIN BINS (C-FSGB)

### Typical Construction:

#### Farm silos

- Used for livestock feed storage
- Cylindrical structures typically 4-10 m in diameter and 20-50 m in height
- Construction is wood staves, concrete staves, cast concrete, poured concrete or glass-lined steel (e.g. Harvestore)

#### Grain bins

- Used for grain crop storage
- Cylindrical structures typically 5-20 m in diameter and 5-30 m in height with upward-pointing conical roof
- Construction is galvanized steel panels and purlins

### Notes:

- DOD4 has been removed; there is no longer a pathway to EF3 with this DI
- With cast/poured concrete or brick silos and full grain bins/silos, an engineering analysis would need be required to obtain a wind speed estimate

| DOD | Damage Description                                                                                                                                                                                    | EXP | LB  | UB  |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Silo cap blown off; empty unanchored grain bin lofted / toppled and/or rolled; empty anchored grain bin or half-full grain bin buckled                                                                | 105 | 90  | 120 |
| 2   | Empty portion of concrete stave silo blown down; empty portion of glass-lined steel silo buckled; empty anchored grain bin lofted / toppled and/or rolled; roof blown off half-full or full grain bin | 150 | 120 | 180 |
| 3   | Full portion of concrete stave silo blown down; empty glass-lined steel silo blown over                                                                                                               | 195 | 145 | –   |

## C-6. SHEDS, FENCES OR OUTDOOR FURNITURE (C-SFOF)

### Typical Construction:

#### Shed

- Single storey and less than 12 m<sup>2</sup>
- Wood, metal and/or plastic construction
- Metal, wood, plastic or shingle roof
- May have wood, metal or vinyl siding
- May have one or more windows
- May be unanchored or weakly anchored

#### Wood fence

- Wood rails, panels and posts (sunk into post holes)

#### Outdoor furniture

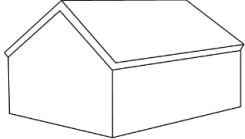
- Light wood, metal and/or plastic construction intended for outdoor use

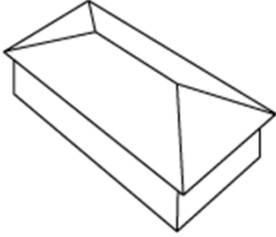
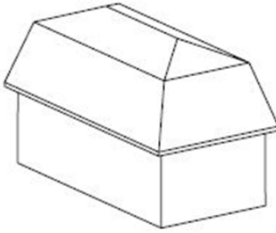
### Notes:

- Increase toward upper-bound wind speed for large and/or well-anchored sheds
- DOD3 has been removed; there is no longer a pathway to EF2 with this DI

| DOD | Damage Description                                                                   | EXP | LB  | UB  |
|-----|--------------------------------------------------------------------------------------|-----|-----|-----|
| 1   | Garden shed overturned; wood fence blown down; outdoor furniture blown over          | 90  | 70  | 110 |
| 2   | Garden shed rolled or carried through the air; outdoor furniture carried through air | 135 | 110 | 160 |

## APPENDIX A – GLOSSARY

|                   |                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3-D space framing | A truss-like, lightweight, rigid structure constructed from interlocking struts in a geometric pattern. It is often used to span large areas with few interior supports.                                                                                                                                                                                                                                 |
| BUR roof covering | 'Built Up Roof' covering is a continuous, semi-flexible membrane consisting of plies of saturated felts, coated felts, fabric or mats assembled with alternate layers of bitumen and surfaced with mineral aggregate, bituminous material or granule surface sheets.                                                                                                                                     |
| Clerestory        | A pronounced high wall with a band of windows along the top. It usually rises above an adjoining roof.                                                                                                                                                                                                                                                                                                   |
| CMU walls         | 'Concrete Masonry Unit' walls are forms of portland cement and aggregates made to various shapes, typically 20 cm high by 40 cm wide. CMUs can be either normal or heavy weight for load-bearing conditions. Light weight units are intended for non load-bearing conditions such as veneers.                                                                                                            |
| DOD               | Degree of Damage                                                                                                                                                                                                                                                                                                                                                                                         |
| EIFS              | 'Exterior Insulation and Finish Systems' are multi-layered exterior wall systems built for commercial and residential buildings. EIFS consists of insulation board secured to the exterior wall surface by adhesive or mechanical attachment. There is a water-resistant base coat applied on top of the insulation and reinforced with fibreglass mesh. There is a finish coat applied to the exterior. |
| EXP               | 'Expected' value for 3-second gust wind speed at 10 m in flat, uniform, open terrain.                                                                                                                                                                                                                                                                                                                    |
| Floor Diaphragm   | A wood frame floor system consisting of joists, sheathing overlaid on joists, rim joists. Studs below provide a load path to the rim joists. Building codes may only require floor diaphragms to be fastened along continuously supported panel edges, often called an unblocked diaphragm. A fully blocked diaphragm means that each panel segment edge not on a joist is supported by a block.         |
| Foundation        | The element of a structure that connects it to the ground and transfers loads from the structure to the ground. Foundation types can include basement walls, crawlspace walls, or flat slabs, and they are typically constructed of poured concrete, concrete blocks, field stones, or preserved wood.                                                                                                   |
| Gable roof        | A roof having two sloping sides that come together at a ridge, creating end walls with a triangular extension, called a gable, at the top.<br>                                                                                                                                                                       |

|                         |                                                                                                                                                                                                                                                                                                                           |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Girt                    | A secondary horizontal structural member attached to sidewall or endwall columns to which a wall covering may be attached.                                                                                                                                                                                                |
| Hip roof                | <p>A roof that slopes back from all four sides to a single point, or line, at the top.</p>                                                                                                                                               |
| HVAC                    | Heating, Ventilation and Air-Conditioning                                                                                                                                                                                                                                                                                 |
| ICF                     | 'Insulating Concrete Forms' are used with poured concrete to produce permanent walls. Forms are made of foam insulation and a steel frame. Concrete occupies the interior of the form. ICF panels are connected with plastic ties.                                                                                        |
| LB                      | 'Lower Bound' value for 3-second gust wind speed at 10 m in flat, uniform, open terrain.                                                                                                                                                                                                                                  |
| Mansard roof            | <p>A type of hip roof where each sloping section is divided in two to create maximum space under the roof; the first section near the walls rises steeply while the second section continues at a milder pitch toward the center.</p>  |
| Open web joist          | A structural system designed to bear loads with a minimum of mass. It consists of structural wood top and bottom chords or steel tube webs with interconnecting pins.                                                                                                                                                     |
| OSB                     | 'Oriented Strand Board', similar to plywood but uniform and cheaper, is a manufactured 2.4 m by 1.2 m wood panel made up of 2-5 cm long wood chips and glue.                                                                                                                                                              |
| Parapet wall            | A low wall or railing along the edge of a platform, terrace or roof.                                                                                                                                                                                                                                                      |
| Polyurethane foam roof  | Roof decking is sprayed with an elastic, closed-cell foam and then covered with an additional coating. The final cover is 5-10 cm thick.                                                                                                                                                                                  |
| Poured gypsum roof deck | A gypsum concrete roof deck consisting of gypsum concrete that is mixed with either wood fibres or mineral aggregate.                                                                                                                                                                                                     |

|                          |                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Purlins                  | Channel-shaped steel structures used to span roof trusses of metal buildings and serve to support the roof deck. Common Purlins come in 'Z' and 'C' shapes.                                                                                                                                                                                                        |
| Sill plate               | A horizontal member sitting on-flat at the bottom of a light-frame wood building that is anchored to the foundation, often with bolts and washers. With a slab foundation, the wall bottom plate acts as a sill plate. With other foundation types, the sill plate can be beneath the floor joists.                                                                |
| Single-ply membrane roof | Consists of a single waterproof membrane laid on a roof deck and attached by mechanical or adhesive fasteners. The membrane edge is tucked inside a metal perimeter flashing.                                                                                                                                                                                      |
| Standing seam roofing    | Composed of preformed or field formed pans, usually 45-60 cm wide. These pans run parallel to the roof and are joined to adjacent pans with double-locked standing seams. The seams have cleats 30 cm apart which locks the panels on the deck. Metal (e.g., copper) roofing may exhibit this type of construction.                                                |
| Subfloor                 | Typically a thin wood panel product such as plywood that is installed on top of the floor structure to provide a flat surface for flooring installation. For foundations with basements or crawl-spaces, the first-story subfloor is fastened to vertically oriented floor joists that are either embedded in the foundation concrete or fastened to a sill plate. |
| Tilt-up concrete panel   | A prefabricated concrete wall panel, often containing openings for windows and doors, that is hoisted into place by a crane or other mechanism. The roof diaphragm acts as a connector between the panels. However, the panels typically are not connected to each other to allow for expansion and contraction.                                                   |
| UB                       | 'Upper Bound' value for 3-second gust wind speed at 10 m in flat, uniform, open terrain.                                                                                                                                                                                                                                                                           |

## APPENDIX B – NTP SCALABLE BOX METHOD FOR USE WITH TREES DI

The Canadian EF scale includes a tree damage indicator that requires the percentage of trees down along a portion of a tornado path as input. A method was developed by NTP to estimate the percentage of trees snapped or uprooted over a sampling area in order to consistently employ the tree DI (see Sills et al. 2020 [here](#)). The Scalable Box Method is simple and fast, and the sampling area scales with tornado path width.

The following steps are required, as illustrated in Figs. B1 to B3.

Step 1 – Create a contour around the detected EF0+ damage along the tornado damage path and find the damage centreline (center of the damage along the path) and the tornado centerline (line of damage convergence along the path). Note for satellite imagery-based use, only the damage centreline is available and is assumed to be the same as the tornado centreline.

Step 2 – Using a line perpendicular to the damage centreline, find the maximum path width.

Step 3 – Create a sampling box that is 50% of the maximum path width on all sides.

Step 4 – Use the sampling box at various locations along the path to estimate the percentage of trees uprooted / snapped and determine the degree of damage (DOD), particularly in the area of worst damage (which may not be at the location of maximum width).

Step 5 – Estimate the wind speed based on the DOD for each box.

Step 6 – Determine EF-scale rating based on estimated wind speed for each box.

Step 7 – Use the maximum EF-scale rating along the track to assign EF-scale rating to tornado.

Note that the sampling box:

- must be aligned with the tornado centreline at the location being sampled, but can be moved across the tornado centreline to the location best representing the damage as long as the tornado centreline goes through the sampling box or is along its edge,
- must be no less than 100 m per side,
- must have at least 50% treed area within the box when sampling.

NTP has tested the Scalable Box Method against numerous cases with aerial data and found that it provides a consistent approach that matches results from other damage indicators. If samples are taken at representative locations along the damage path, a 1-D representation of the EF-scale rating along the tornado track can be generated.

Note that this method does not work as well with downburst damage. A 50% box size is generally too large to be representative. Revisions to the method for use with downbursts are being investigated.

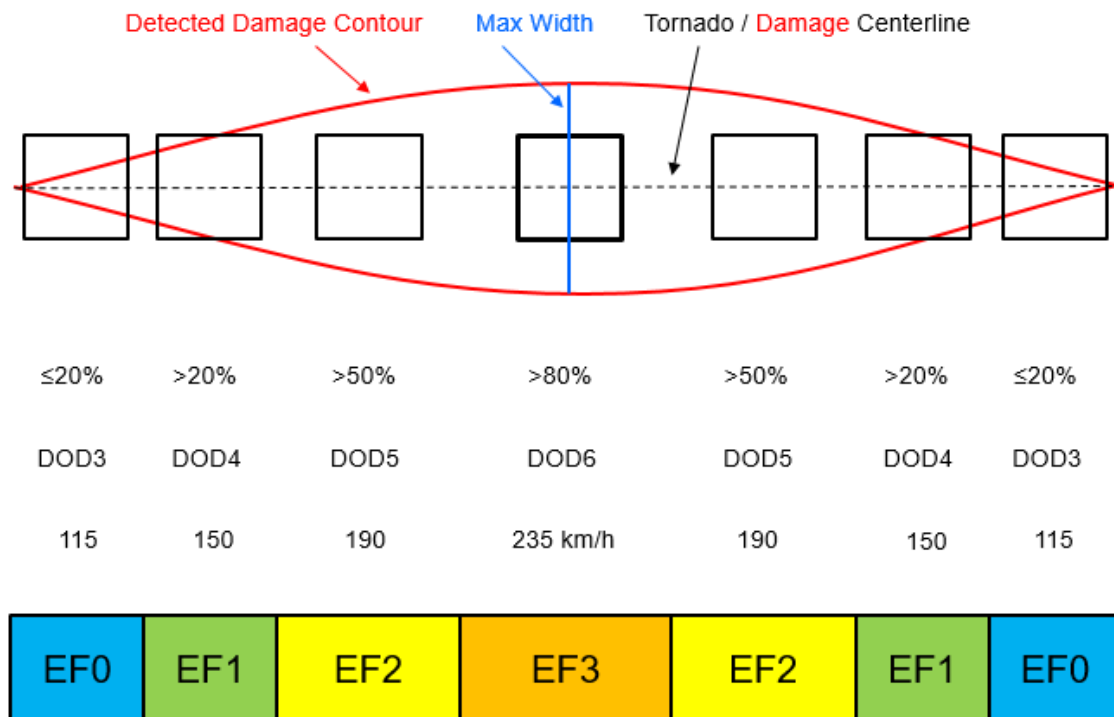


Figure 1. Scalable Box Method example for a slow-moving EF3 tornado with a straight path. Note that EXP wind speeds are assumed.

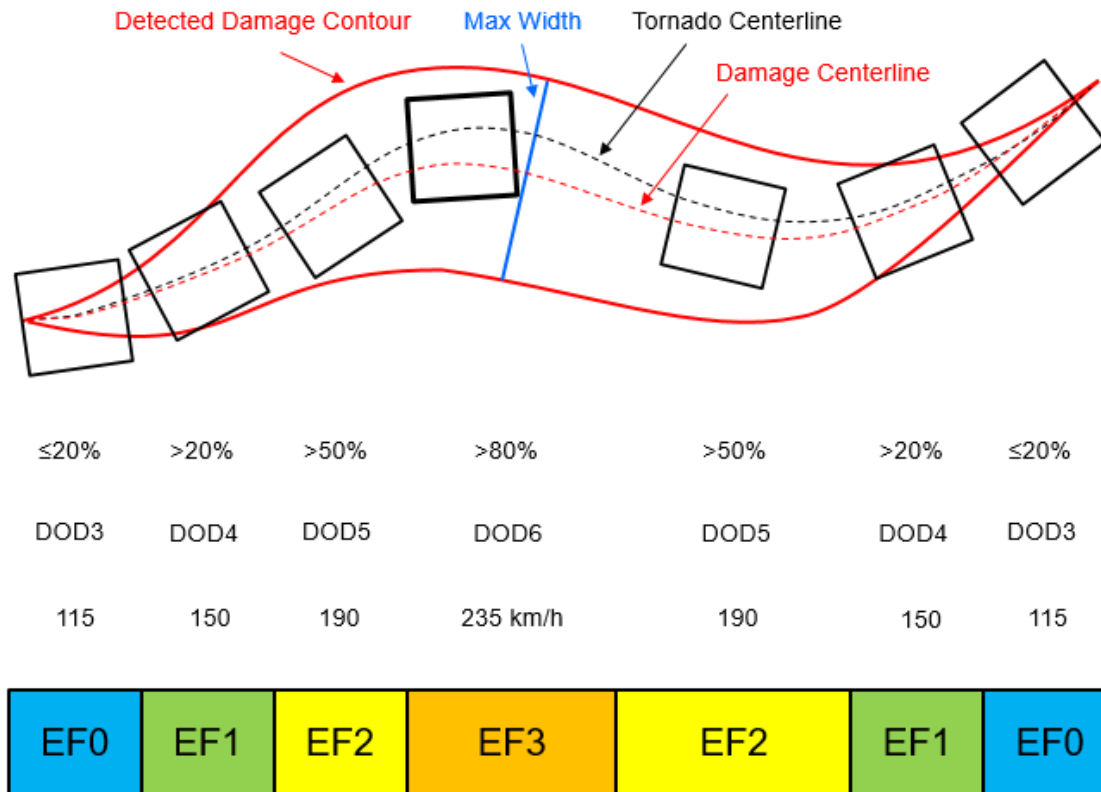


Figure 2. Scalable Box Method example for a slow-moving EF3 tornado with a curved path. Note that EXP wind speeds are assumed.

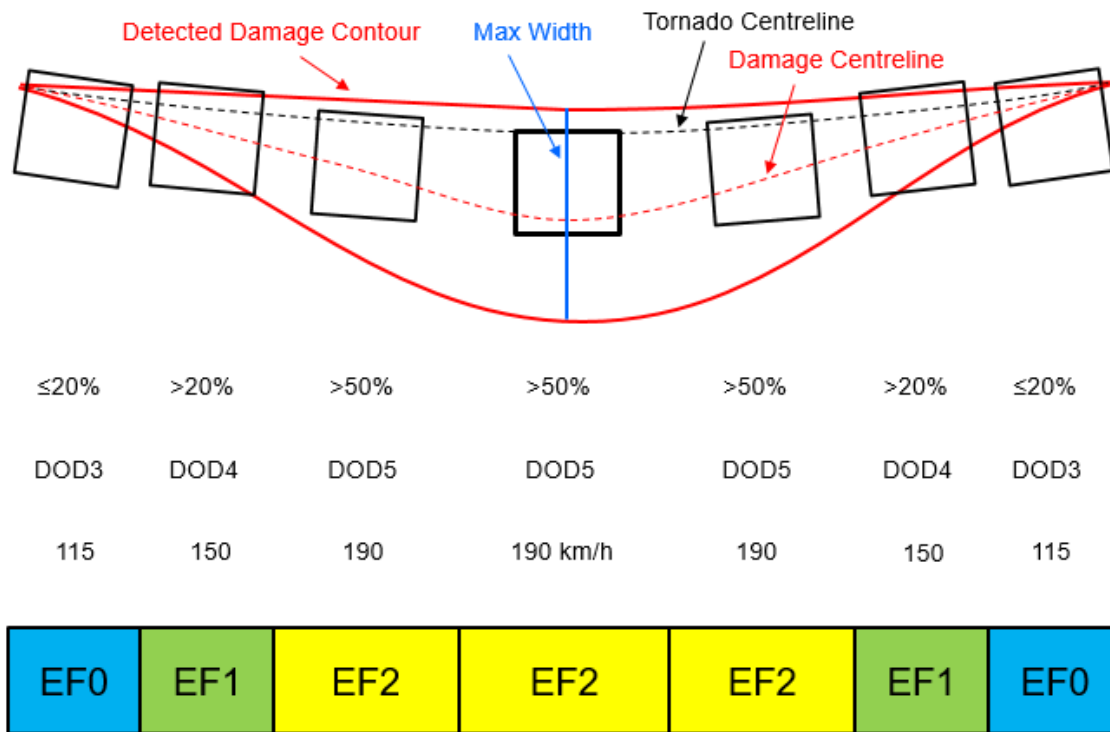


Figure 3. Scalable Box Method example for a fast-moving EF2 tornado. Note that EXP wind speeds are assumed.

## APPENDIX C – IN-SITU WIND SPEED MEASUREMENTS

In-situ wind speed measurements may be used to determine EF-scale ratings if they meet the following criteria:

- must be recorded by a fixed anemometer of professional quality (no handhelds, no vehicle-based observations, no consumer-grade instruments)
- the anemometer must be located at or below 100 m AGL
- the wind speed must not exceed the stated capabilities of the instrument
- measurements must include the following data and meta data:
  - wind speed units
  - height of anemometer above ground level with units
  - sampling and/or averaging frequencies with units
  - exact location, preferably in decimal lat/lon
  - time of measurement with the time standard used (to nearest minute if possible)
  - anemometer type, make/model, and speed measurement capabilities
  - anemometer service / calibration record
  - estimate of exposure conditions for all wind directions
  - details of gust measurement, if available
  - co-located wind direction with units, if available
  - wind measurement time history with units for time, if available.

Given that EF scale wind speed estimation uses a 3-s gust, any wind data must be converted to this standard before use in determining an EF-scale rating. EF scale wind speeds are also supposed to be at a height of 10 m AGL. However, there is no standard height conversion process for tornado wind speeds at this time.

Exposure in the vicinity of the anemometer needs to be good (i.e., few if any obstructions within 100 m). No corrections for exposure are permitted at this time.

If the anemometer has not been recently calibrated within the past year, then the instrument must be calibrated before the data are used.

An example of determining tornado wind speed from anemometer data can be found in:

Lombardo, F.T., 2017: Engineering analysis of a full-scale high-resolution tornado wind speed record. *J. Struct. Eng.*, **144**, [https://doi.org/10.1061/\(ASCE\)ST.1943-541X.0001942](https://doi.org/10.1061/(ASCE)ST.1943-541X.0001942).