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

Revision 3b (2025, English only, most recent revisions in red, original ECCC version here)

EF SCALE (CANADIAN IMPLEMENTATION)

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

NOTES

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 1-26 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).

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to SBO (Small Barns or Farm Outbuildings) and C-FSGB (Farm Silos and Grain Bins) are based on peer-reviewed but unpublished material related to work on a new wind speed estimation standard via ASCE – see: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

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^{-1}
Note: DIs starting with 'C' were developed for the original Canadian implementation

1. SMALL BARNS OR FARM OUTBUILDINGS (SBO)

Typical Construction:

- Less than 250 m^2
- 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

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^2 (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. subdivision) 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	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

DOD	Damage Description	EXP	LB	UB
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

DOD	Damage Description	EXP	LB	UB
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 story walls collapsed	255	220	295
6	Almost total destruction of top two stories	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 story exterior walls	220	195	250
8	Collapse of most top story walls	230	205	260
9	Collapse of top two floors of three or more stories	275	230	300
10	Total 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 or 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	Total destruction of a 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	Total destruction of entire building	270	230	310

9. SMALL PROFESSIONAL BUILDINGS: SINGLE STOREY, LESS THAN 500 m^2 (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	Total 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 a 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 a large section of the 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 a large section of the 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 a large section of the 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 a large section of the 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	Total destruction of a large section of or entire 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 a 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 a 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 a large portion 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	Total 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	Total destruction of a large section of building or entire 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:

- DOD descriptions and wind speeds reflect a better understanding of DI failure modes
- 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^2
- 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

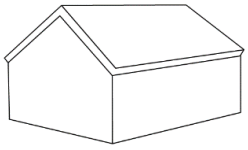
- Light wood, metal and/or plastic construction intended for outdoor use

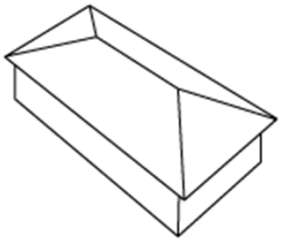
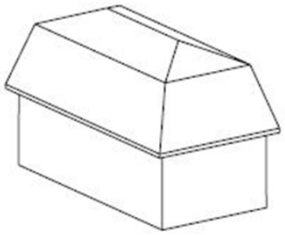
Notes:

- 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. 

Girt	A secondary horizontal structural member attached to sidewall or endwall columns to which a wall covering may be attached.
Hip roof	A roof that slopes back from all four sides to a single point, or line, at the top. 
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	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. 
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 fastenings. 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 TREE 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.

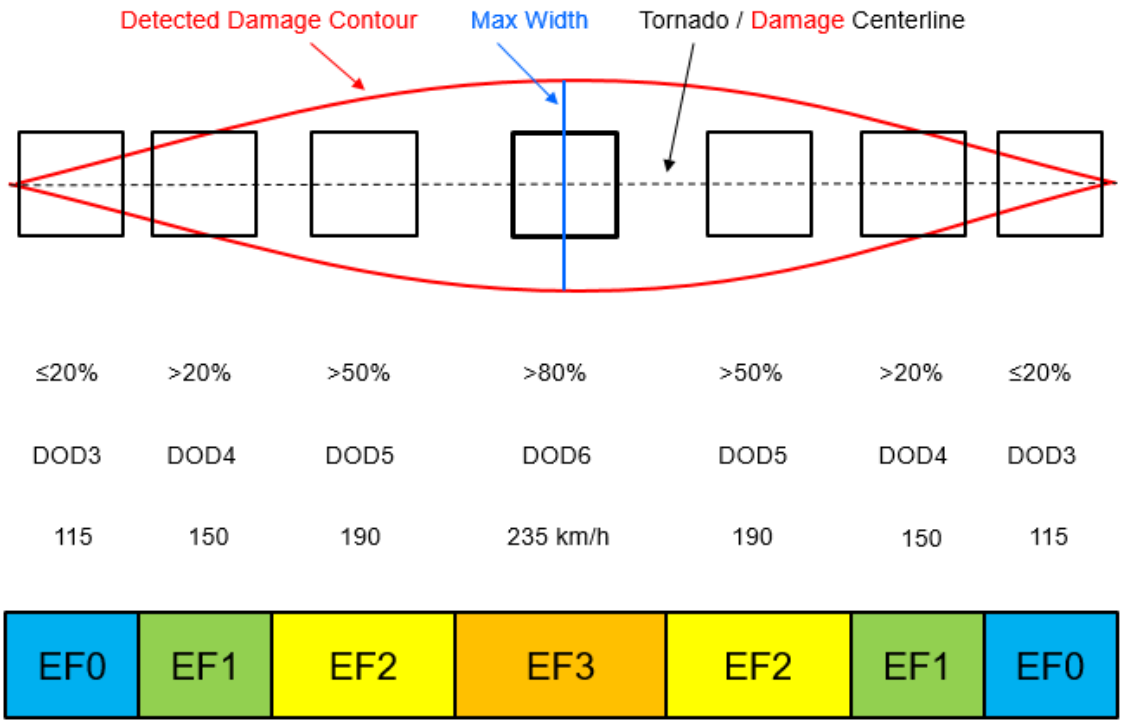


Figure 1. Scalable Box Method example for a slow-moving EF3 tornado with a straight path. Note that EXP wind speeds are assumed.

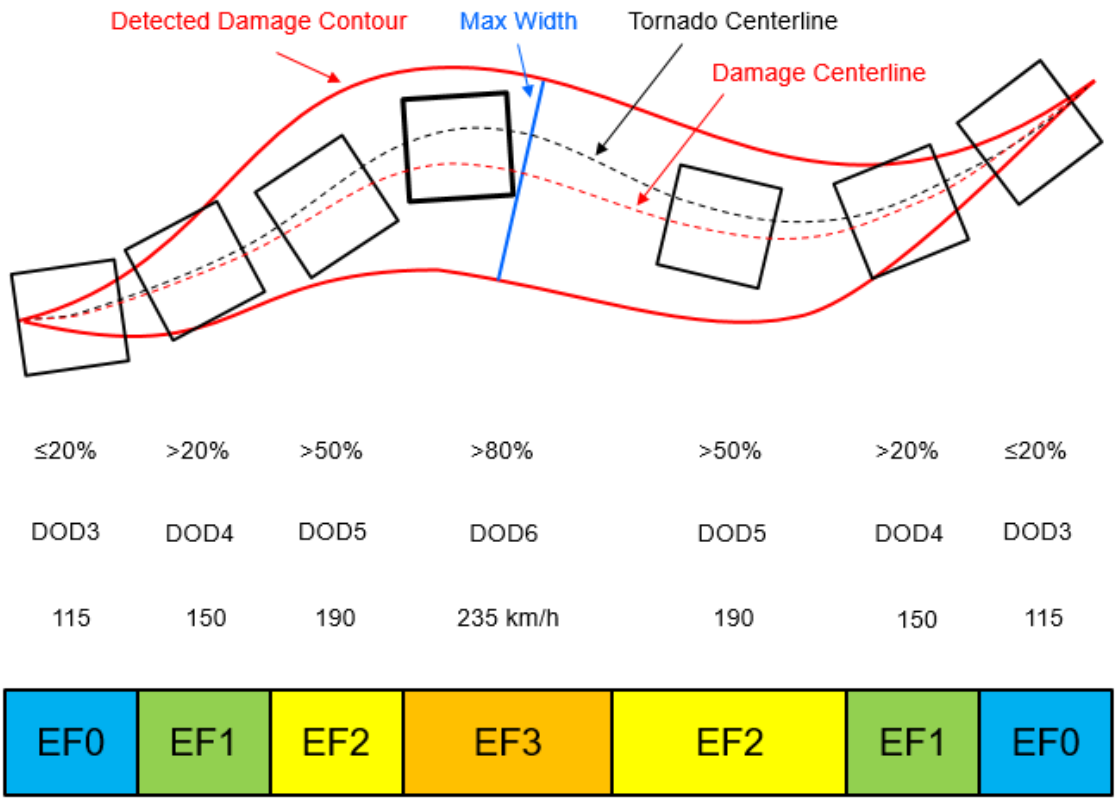


Figure 2. Scalable Box Method example for a slow-moving EF3 tornado with a curved path. Note that EXP wind speeds are assumed.

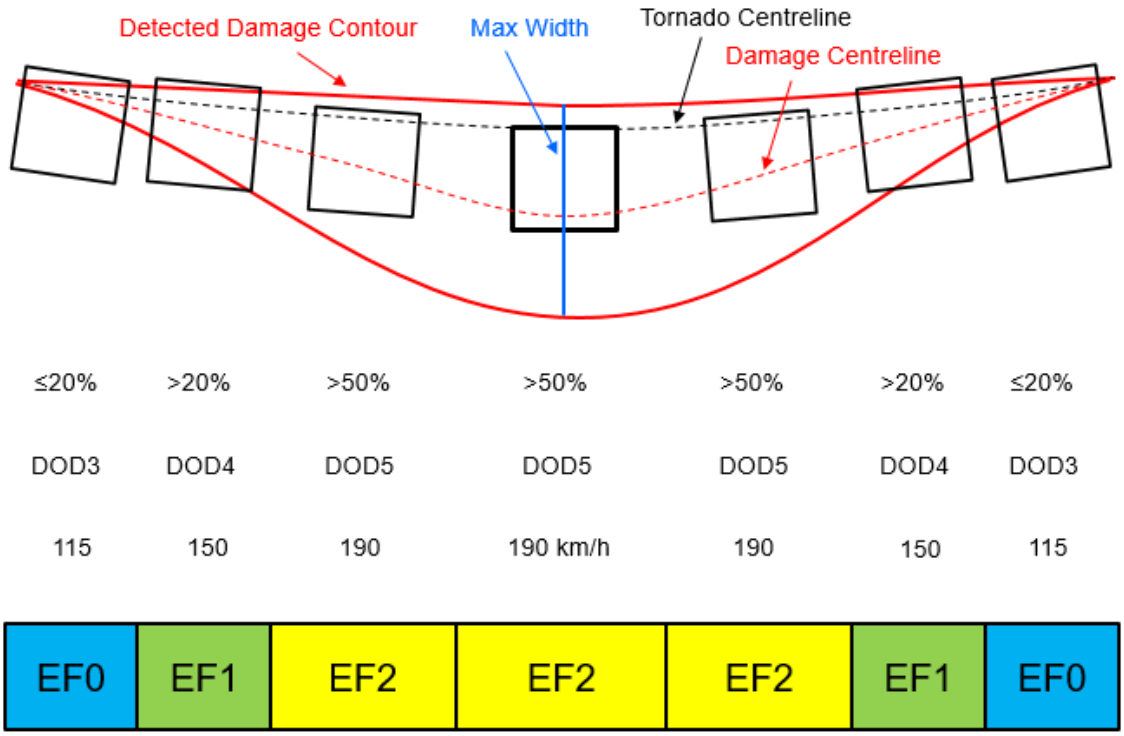


Figure 3. Scalable Box Method example for a fast-moving EF2 tornado. Note that EXP wind speeds are assumed.

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 the 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.