



November 18, 2013

### Colorado Front Range Gust Map – ASCE 7-10 Compatible

Prepared by  
Jon A. Peterka  
Cermak Peterka Petersen, Inc.  
Fort Collins, CO

#### INTRODUCTION AND METHODOLOGY

A Colorado Front Range Gust Map was prepared in 2006 by Peterka (2006) for use with ASCE 7-02 and ASCE 7-05. That map contained 50-year recurrence contours and was endorsed by the Structural Engineers Association of Colorado (SEAC). Many Front Range communities have used that map to guide code wind speed definition.

An International Building Code version which refers to ASCE 7-10 is now being adopted in Colorado. ASCE 7-10 uses wind maps with recurrence intervals of 700, 1700, and 300 years (for Risk Categories II, III-IV, and I respectively) within the standard, and maps of 10, 25, 50, and 100 years recurrence in Commentary Appendix C (Serviceability Considerations). To assist the process, this report has produced appropriate maps. It is intended that SEAC review and endorse this set of maps as a recommendation to local communities for structural design in the Front Range area. Maps are prepared in three formats: 1) printed maps in this report, 2) shape files usable in a geo-referenced application, and 3) a kmz file usable with Google Earth.

For this report, no new measured wind speed data was acquired or analyzed. The speed contours of the new maps were derived from the 2006 50-year map contours using the rate of change of speed with recurrence interval as determined by Peterka and Shahid (1998). Peterka (2006) showed the rate of change of wind speed with return period in the Front Range area was consistent with the 1998 paper. The rate of change of wind speed with return period is given by Equation 3 of Peterka and Shahid:

$$Frc = 0.36 + 0.10 \ln(12 T)$$

where T is the return period in years and Frc is the ratio of the return period speed at T years to the return period at 50 years (note that Frc = 1.00 at T=50) in the continental US. Table 1 represents the updated contour values rounded to the nearest 5 mph consistent with ASCE 7-10.

Table 1. 3-Second Wind Speeds in ASCE 7-10 Format

2006 Map Gust Spd mph	ASCE 7-10 Format 3-Second Gust Speed in mph for T, yrs						
	700	1700	300	10	25	50	100
90	115	120	105	75	85	90	95
100	125	135	120	85	95	100	105
110	140	150	130	90	100	110	120
120	150	160	140	100	110	120	130
130	165	175	155	110	120	130	140
140	175	190	165	115	130	140	150
180	225	245	210	150	165	180	190



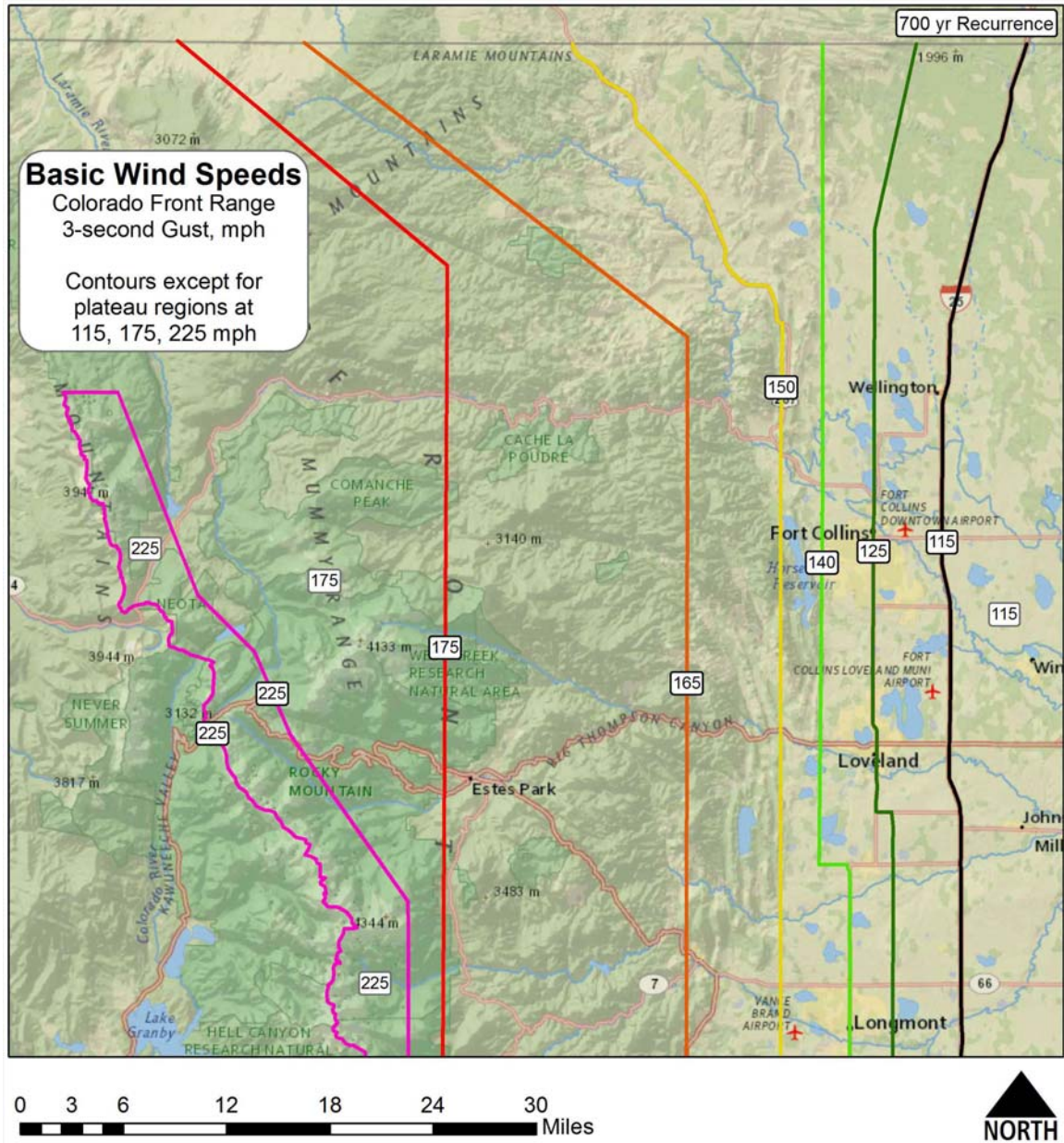
Figure 1 contains the 700-year, 1700-year, and 300-year recurrence maps suitable for use with Risk Category II, III-IV, and I structures respectively in ASCE 7-10. Speeds are at 10m height in effective open terrain. The map covers the area from the Wyoming border to south of Denver and from about I-25 west to the Continental Divide or Larimer County line. Maps needed for serviceability considerations in Commentary Appendix C of ASCE 7-10 are in Appendix 1.

The reason these maps were originally developed was a lack of knowledge of design level wind speeds for the Front Range area and significantly different speeds adopted by various communities prior to 2006. The logic used to develop the 2006 50-year map is not repeated here (see Peterka, 2006, available on the SEAC web site). Only the information required to use the maps has been repeated. In preparing the current maps, a few minor inconsistencies between the old map and word description of the contours were discovered. In making the new maps, the word description was used to guide the contour locations. All adjustments in contour locations were much smaller than our ability to know where the contours should be placed. The original 2006 map was based on 3-second gust wind data identified and organized into a suitable database by the Colorado State Climatologist's office under the direction of Nolan Doesken. Funding for the database was organized by the Colorado Chapter of the International Code Council, who assisted by contacting and involving 35 Front Range jurisdictions situated in the special wind region as defined by ASCE 7. Jon Peterka of Cermak Peterka Petersen, Inc. (CPP, Inc.) analyzed the data using a Type I Extreme Value Distribution along with spot reports from storm data publications to develop the map. A technical review by Bill Esterday of CPP assisted in finalizing the map. The current maps were produced by Jon Peterka with assistance from the CPP drafting department with a technical review by Bill Esterday.

High wind speeds in the Front Range area on the plains adjacent to the Rocky Mountains and in the mountains east of the Continental Divide are well known to residents as winter and spring events that are sometimes damaging. The winds are known to occur from roughly the Continental Divide/Larimer County Line (the line of highest terrain running approximately north to south that marks the high terrain western edge of the Front Range area) to approximately I-25 (that runs north-south about 8-15 miles east of the intersection of the mountains with the plains). The Continental Divide is very close to the plains in the Front Range area, resulting in high downslope wind speeds where the mountains and plains intersect.

High winds in the Front Range region are apparently due to two meteorological conditions:

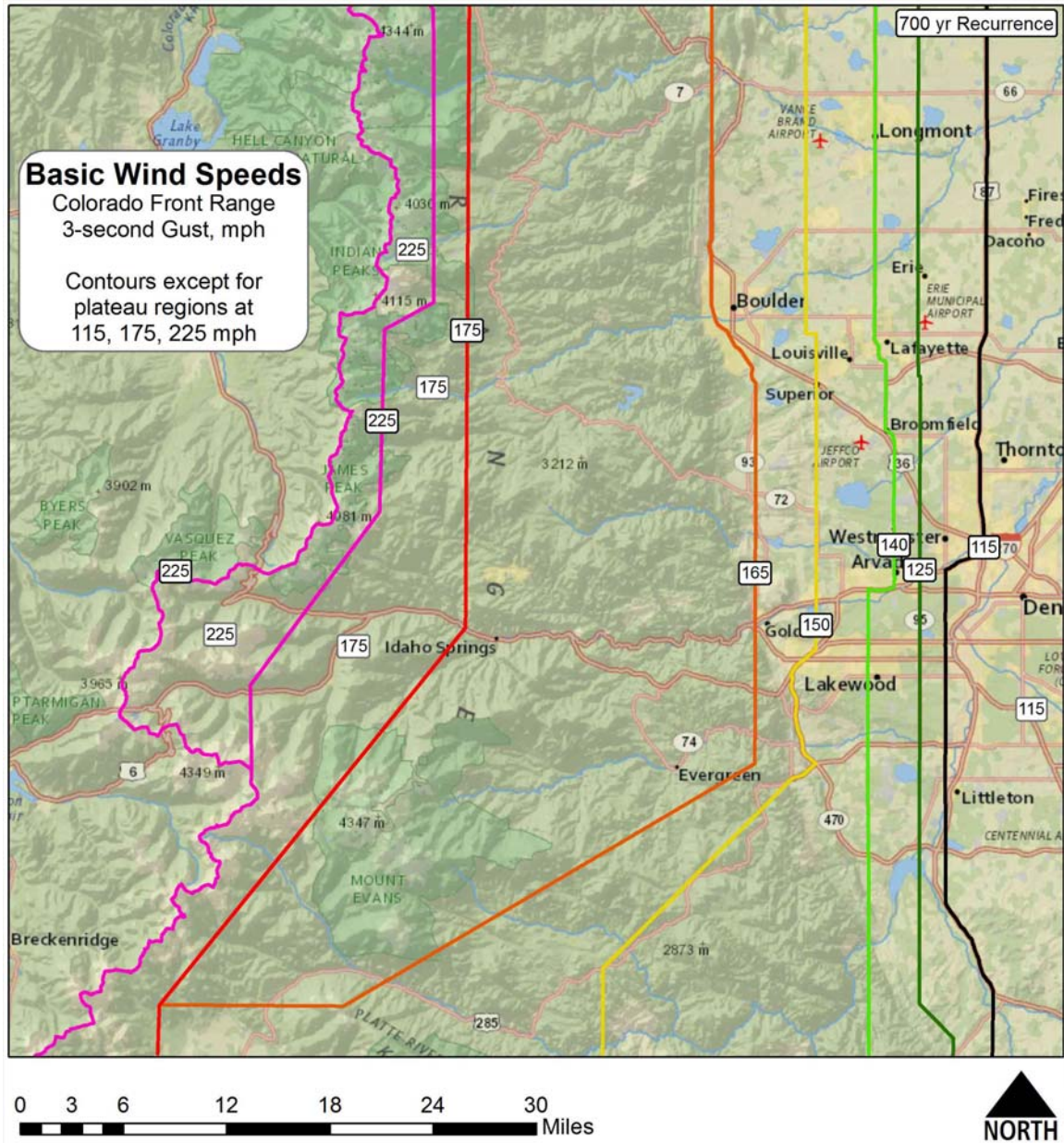
- (1) Downslope (known locally as "Chinook") winds are driven by a pressure gradient and act much like a hydraulic jump causing highest winds near the intersection of mountains and plains and in the mountains just west of the plains. Boulder, Colorado, is well known as being highly susceptible to downslope winds. A peak gust wind speed of 147 mph has been measured at the National Center for Atmospheric Research (NCAR) on Table Mesa at the southwest edge of the city of Boulder.
- (2) Jet stream winds dip close to mountain-top level causing high wind speeds at higher terrain elevations, peaking near the Continental Divide. A peak gust of 168 mph was measured on Niwot Ridge just east of the Continental Divide west of Boulder.



North Portion

Risk Category II, 700 year recurrence, 0.00143 probability per year

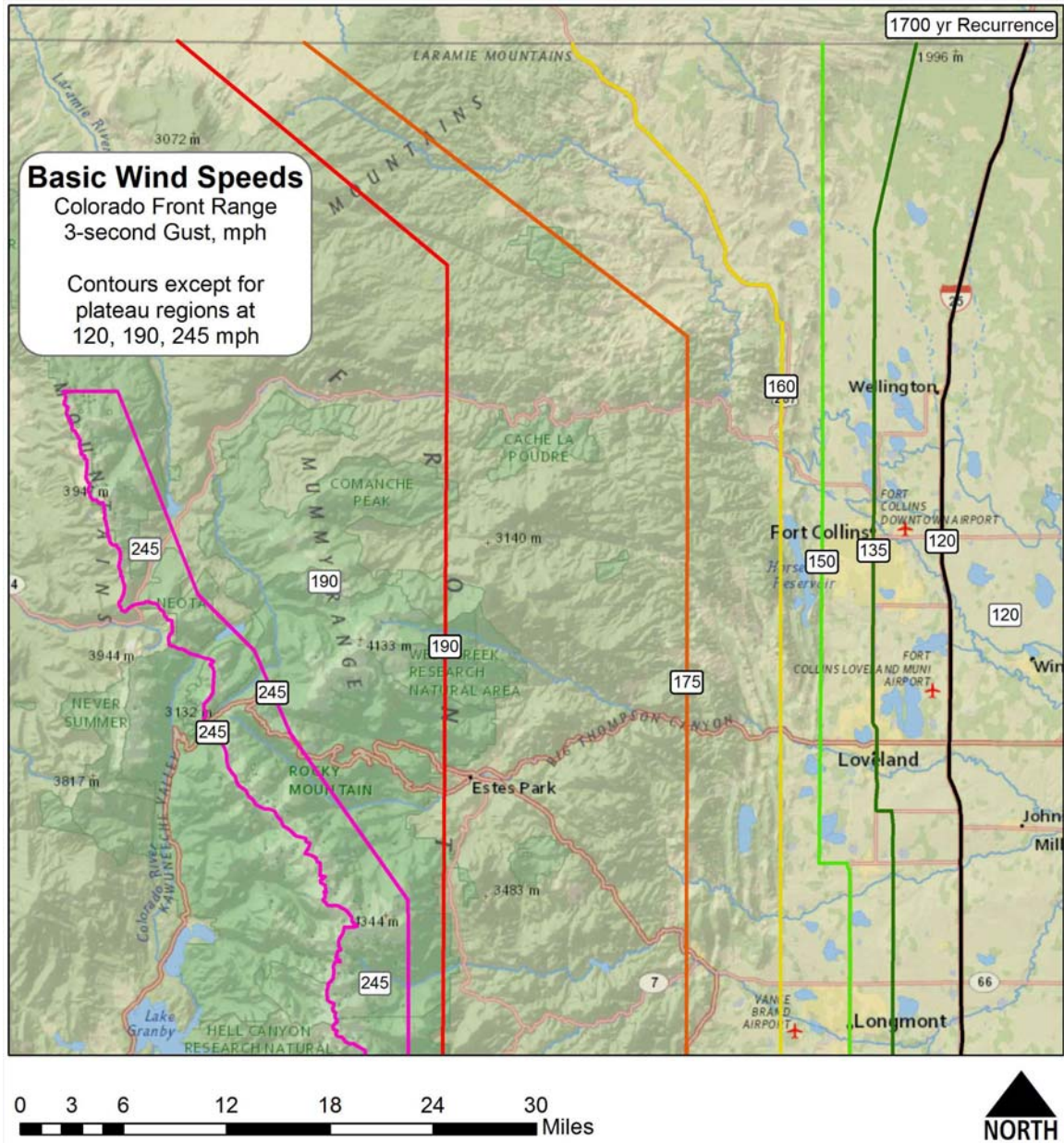
Figure 1a Colorado Front Range Gust Map.



South Portion

Risk Category II, 700 year recurrence, 0.00143 probability per year

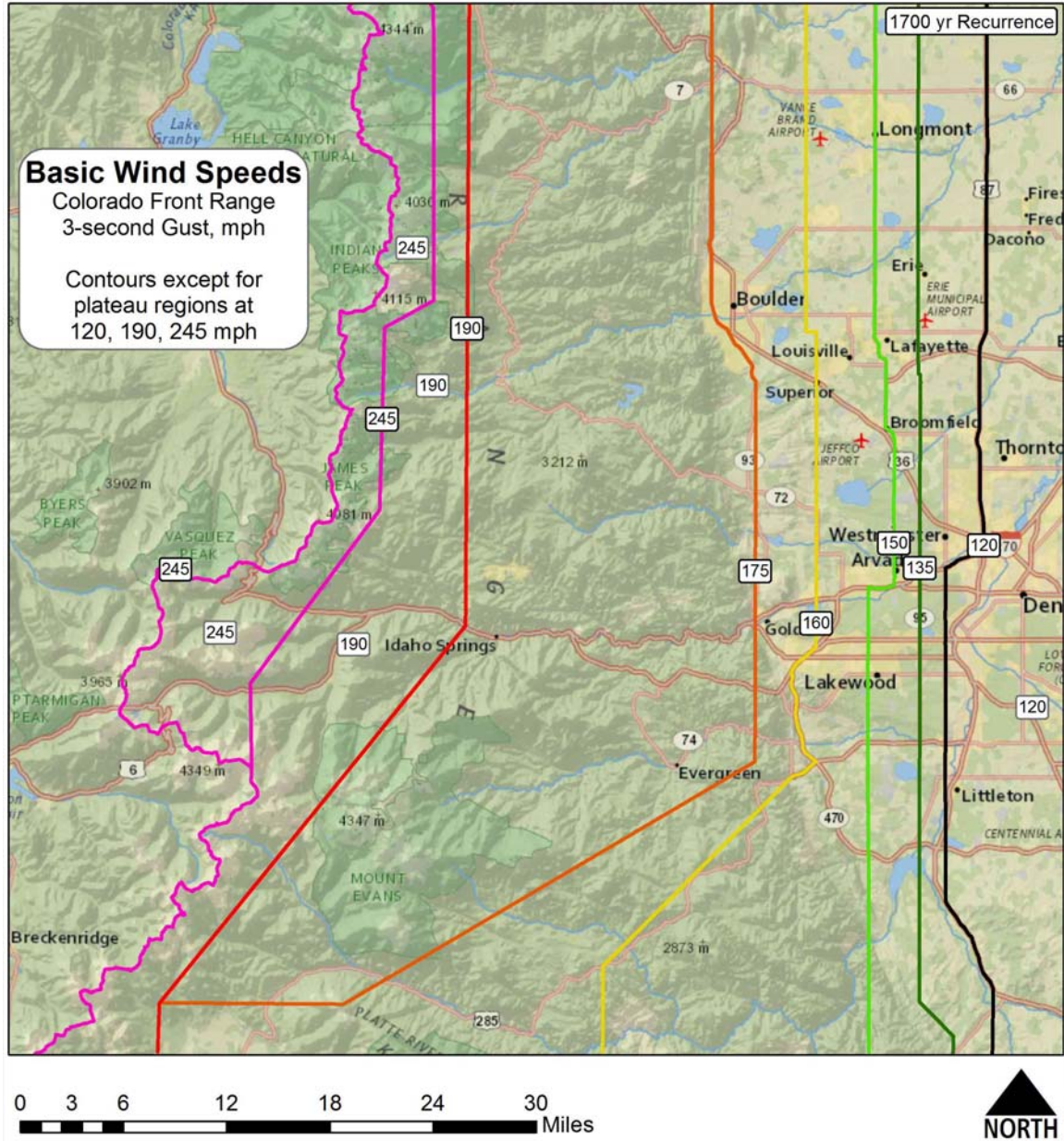
Figure 1b Colorado Front Range Gust Map.



North Portion

Risk Category III-IV, 1700 year recurrence, 0.00059 probability per year

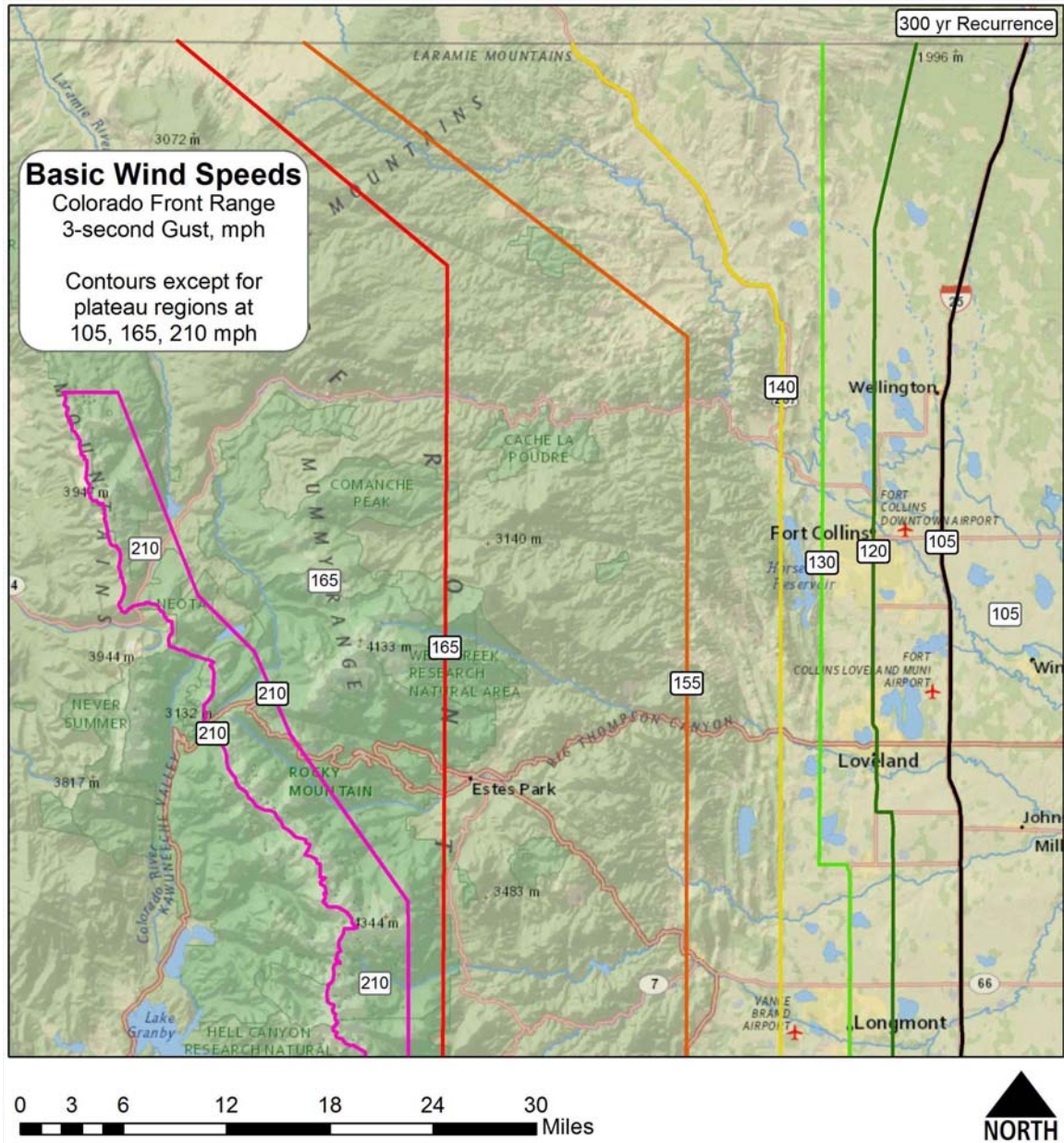
Figure 1c Colorado Front Range Gust Map.



South Portion

Risk Category III-IV, 1700 year recurrence, 0.00059 probability per year

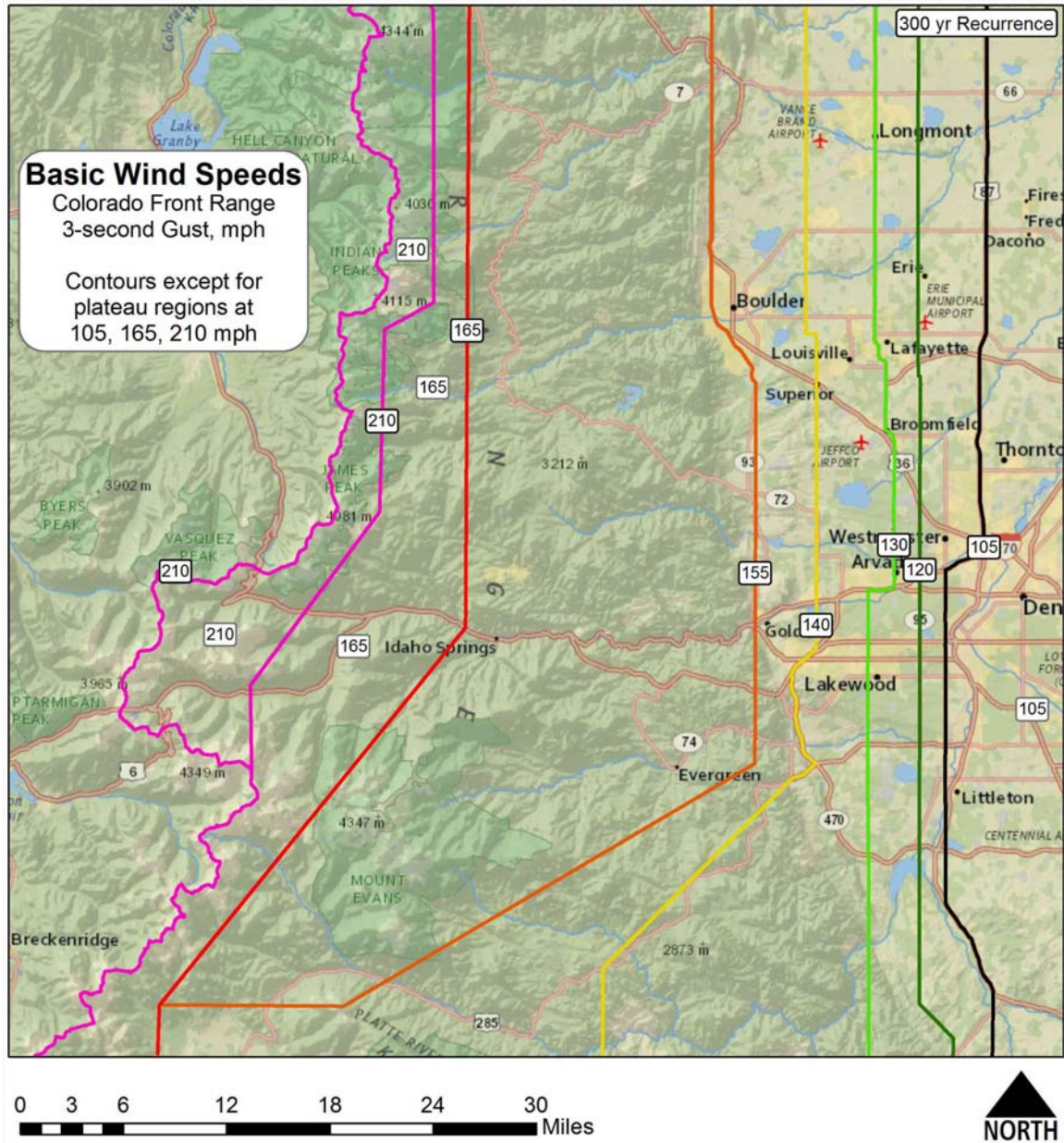
Figure 1d Colorado Front Range Gust Map.



North Portion

Risk Category I, 300 year recurrence, 0.00333 probability per year

Figure 1e Colorado Front Range Gust Map.



South Portion

Risk Category I, 300 year recurrence, 0.00333 probability per year

Figure 1f Colorado Front Range Gust Map.





## CONTOUR WORD DESCRIPTION

To assist in defining the locations of contours, a word description of each speed contour is as follows, using the 700-year map of Figure 1:

### 115 mph Contour

Federal Blvd. in Denver, south to U.S. 85 NW of Sedalia, follows 85 SSE to west of Sedalia, then due south. Federal Blvd. in Denver north to I-76, I-76 ENE to I-25, I-25 north to Wyoming line.

### 125 mph Contour

Sheridan Blvd. at the west edge of Denver due south to a point west of Sedalia, roughly SE to a point near the plains/mountains interface, then south.

Sheridan Blvd. at the west edge of Denver due north along the Boulder County/Adams County line, continuing along the Boulder County/Weld County line to Colorado 60 south of Loveland, west on 60 to U.S. 287, north on 287, leaving 287 in north Fort Collins when 287 turns west, continuing due north to about Buckeye Road, then roughly NNE to the Wyoming line.

### 140 mph Contour

Kipling in Lakewood south to map border.

Kipling in Lakewood north to I-70, ENE on I-70 to Wadsworth, Wadsworth north into Broomfield to U.S. 287, NW on 287 following 287 north out of Broomfield, north on 287 through Longmont to CO 56 west of Berthoud, west on CO 56 to 105° 08' (near 21 RD), north on this longitude (approximately 21 RD in Loveland and Overland Trail in Fort Collins) to the Wyoming line.

### 150 mph Contour

SW on I-70 from the intersection of the longitude line 105° 10' (just east of the I-70 & Colfax interchange) to C-470, south on C470 to U.S. 285, SW approximately along 285 to the Jefferson County Line, south on the Jefferson County line.

North from I-70 on approximately longitude 105° 10' (just east of the I-70 & Colfax interchange) to Baseline Road east of Boulder, west to 75<sup>th</sup> street, north on this longitude line (approximately longitude 105° 10.8') to a point on US 287 SE of The Forks (NW of Fort Collins) where 287 turns west from this longitude, then approximately NW on 287 to the Wyoming line.

### 165 mph Contour

South from near the intersection of CO 93 and CO 170 SE of Boulder along a longitude (105° 14') approximating the location of Colorado 93 to a point directly west of the intersection of C-470 and U.S. 285, SW to the summit of Mount Blaine (NE of Jefferson in South Park), west to the west edge of South park, then south. From near the intersection of CO 93 and CO 170 SE of Boulder, follow 93 NW through Boulder to Broadway, north on Broadway (approximately 105° 17') to a point north of the Poudre River at latitude 40° 45', then approximately NW to the Wyoming line.

### 175 mph Contour

From the intersection of I-70 with longitude 105° 33', southwest to connect to the 165 mph contour, then south on top of the 165 mph contour.

From the intersection of I-70 with longitude 105° 33', north on that longitude to a point approximately 1 km north of Dowdy Lake in Red Feather Lakes, then approximately NW to the Wyoming line.

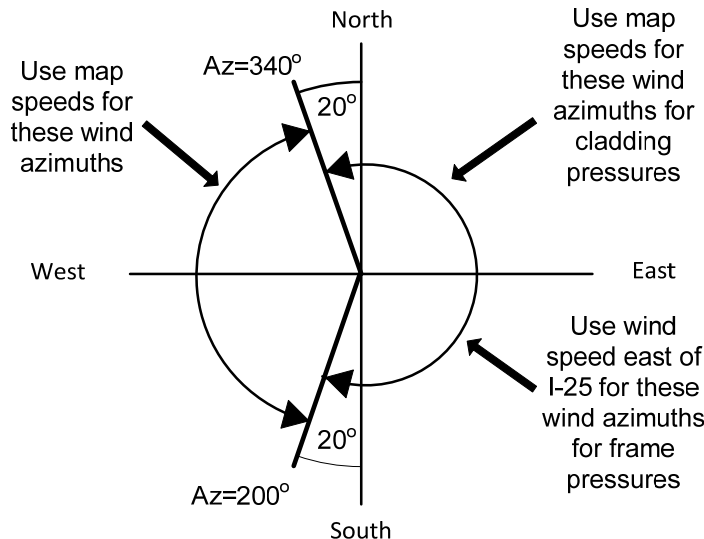
225 mph Contour

The west contour follows the Continental Divide and Larimer County Line.  
The east contour follows roughly parallel but east of the Continental Divide.

**APPLICATION**

Based on the data presented in the 2006 report, there are several observations that can be made about the data.

While wind direction has not been presented explicitly, both recorded wind directions and knowledge of the meteorological events giving rise to this special wind region shows that the higher winds in this region are due to winds from SSW through NNW, roughly 45 degrees to the N/S orientation of the high ridgeline that induces the high speeds. Thus, winds from roughly wind azimuths of 340 through 0 to 200 degrees may use the wind speed east of I-25 for design of main wind-force resisting systems (MWFRS) under the provisions of IBC or ASCE 7. Cladding pressure design under IBC or ASCE 7 must use the map wind speed since the provisions in ASCE 7 do not specify the wind direction giving the highest cladding pressures. Figure 2 illustrates these concepts.



WIND AZIMUTH means wind approaching FROM that direction

Figure 2. Design speed variation with wind direction

Many of the wind records used in this analysis are short. The Type I Extreme Value Distribution used for this analysis works best for long records of 50-100 or more years of observation (the standard deviation of prediction error decreases as the inverse of the square root of record length). For shorter records, the likelihood of prediction error increases and is statistically biased to higher wind speeds. This means that predictions using short records are somewhat more likely to predict speeds too high than too low. As more data is acquired in the future at the various stations, it is more likely that contour locations will move slightly to the west than it is that the contours will move slightly to the east. This situation is consistent with good engineering practice of designing for slightly higher loads in the presence of uncertainty. In general, wind speeds from the mid 1960's through the mid 1980's were higher than wind speeds in the late 1980's and 1990's in many of the records. This may be due to multi-decadal variability in the atmosphere. Which of these periods better represents the future (if either is the norm) is not known.



## RECOMMENDATIONS FOR THE FUTURE

The lack of long records at the various sites used in this study significantly impacted the ability to accurately place contours on the map of Figure 1. The lack of data in many regions was an even larger impediment to placing contours accurately. In particular, the lack of wind speed data in the suburbs west of Denver and in the mountains made the map preparation more difficult.

It is recommended that communities install one or more anemometers to measure wind speeds and directions in their areas. Anemometer placement should be at least 1.5 to 2 times the heights of typical structures or trees in the area. For suburban areas, this means anemometers at 20 meters (60 ft) or higher. In the mountains, the tree height often dictates anemometer heights of nearly 30 m (100 ft). The author has extensive experience in siting of anemometers to measure wind speeds (as a co-author of the anemometer siting provisions of FAA, 1989) without significant interference of nearby shielding elements such as buildings or trees. This information can be used to advise on specific locations.

## GUIDE FOR REPRODUCTION

This document has been copyrighted to protect the content for public use. Unrestricted use of this document, including copying of the document, extraction and use of the wind speed maps, and copying and use of any text within this document, is hereby granted for use in building codes or standards, for use by engineers, architects and others for the purpose of documenting their use of the wind speeds of these maps, and for any other use beneficial to the public, providing that no charge is made for distribution of the content beyond reasonable cost of making the information available. Use of the contents should acknowledge the report title and author, and cite the date of the document.

## REFERENCES

- ASCE 7-02 (2003), "Minimum Design Loads for Buildings and Other Structures," *Standard ANSI/ASCE 7-02*, American Society of Civil Engineers and American National Standards Institute, New York.
- ASCE 7-05 (2006), "Minimum Design Loads for Buildings and Other Structures," *Standard ANSI/ASCE 7-05*, American Society of Civil Engineers and American National Standards Institute, New York.
- ASCE 7-10 (2010), "Minimum Design Loads for Buildings and Other Structures," *Standard ANSI/ASCE 7-10*, American Society of Civil Engineers and American National Standards Institute, New York.
- FAA (1989), Siting Guidelines for Low Level Windshear Alert System (LLWAS) Remote Facilities, Appendix 3: Guidelines for Siting Individual LLWAS Anemometers, FAA Order 6560.21A. Appendix 3 prepared by Jon Peterka and Michael Poreh.
- Peterka J.A. and Shahid, S. (1998), "Design gust Wind Speeds for the U.S.," *Journal of Structural Engineering*, Vol. 124, 207-214.
- Peterka J.A. (2006), Colorado Front Range Gust Map, CPP, Inc. report for use by Colorado structural Engineers Association and Colorado Front Range communities.



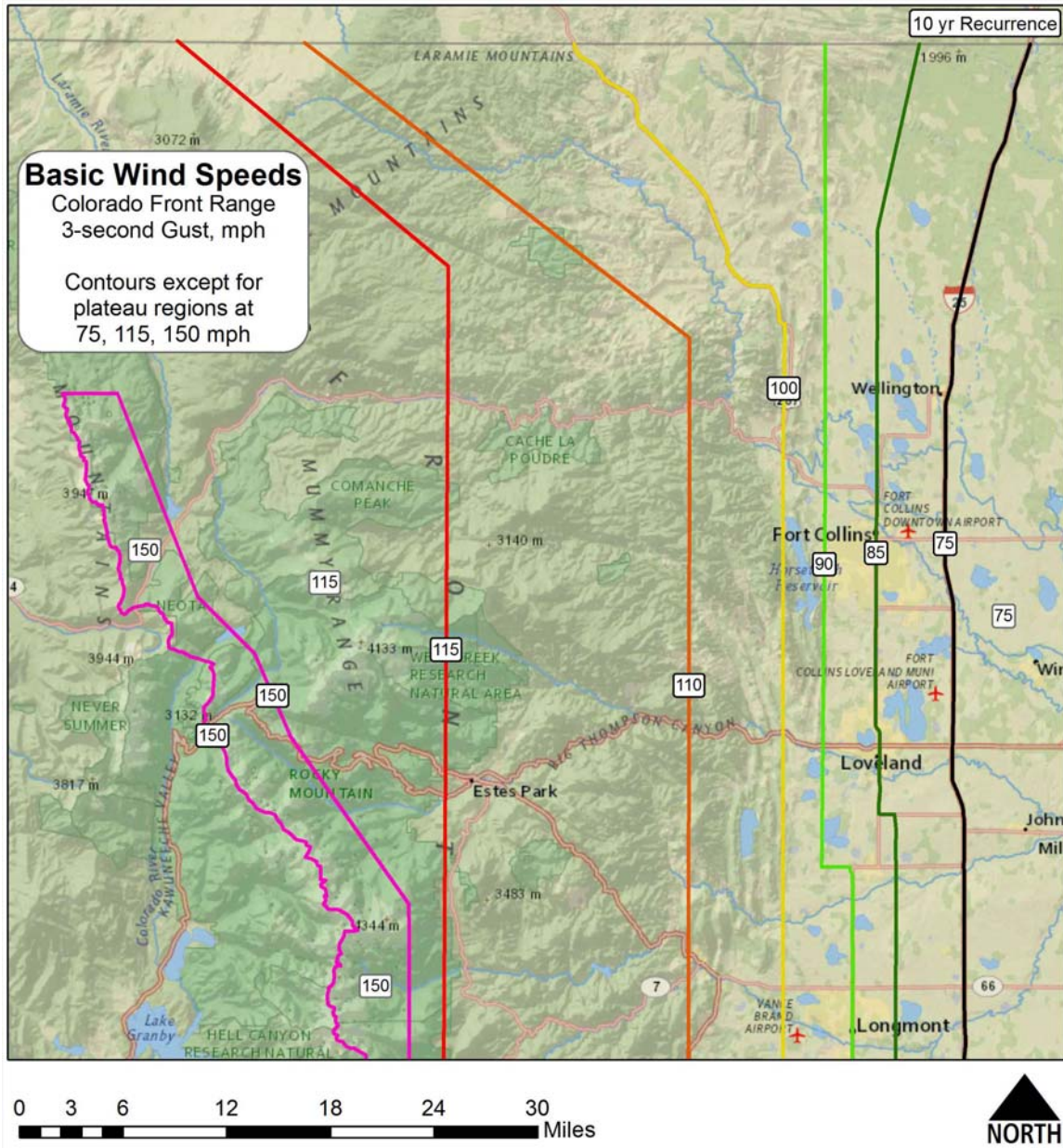
CERMAK  
PETERKA  
PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

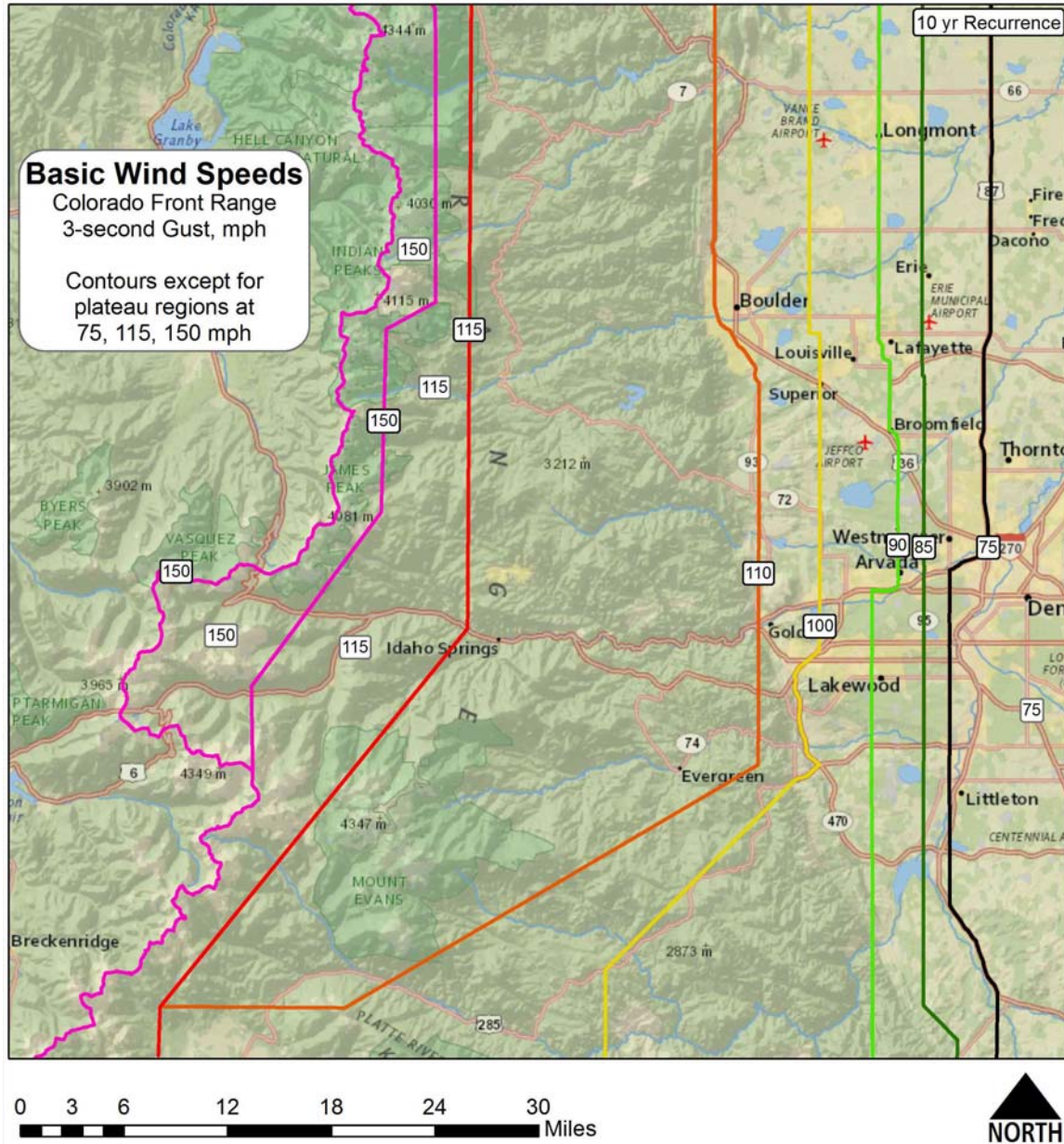
November 18, 2013

Page 12 of 20

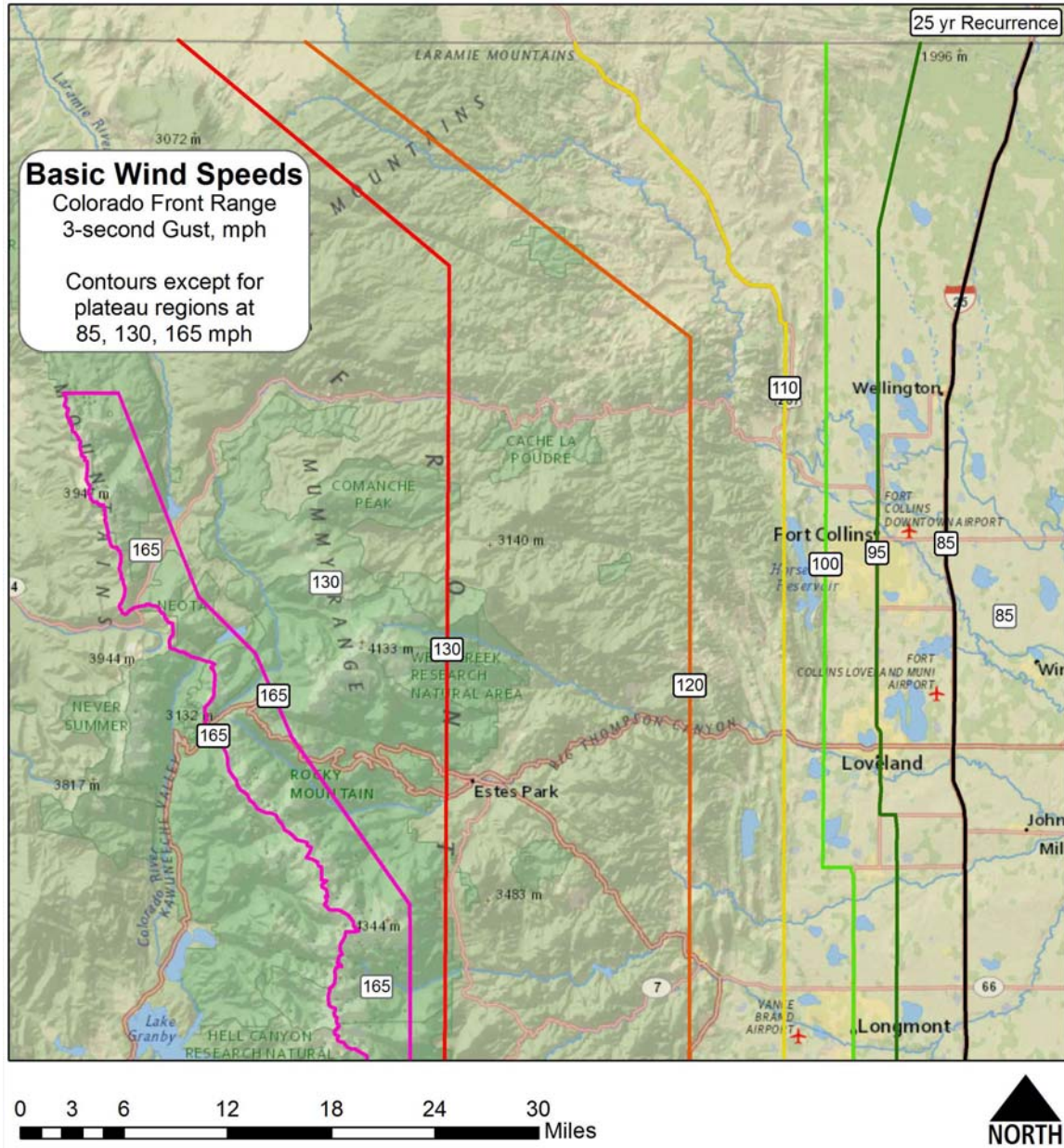
APPENDIX 1  
RECURRENCE INTERVAL MAPS  
TO BE USED  
ONLY  
FOR  
SERVICABILITY CONSIDERATIONS IN  
ASCE 7-10 COMMENTARY APPENDIX C



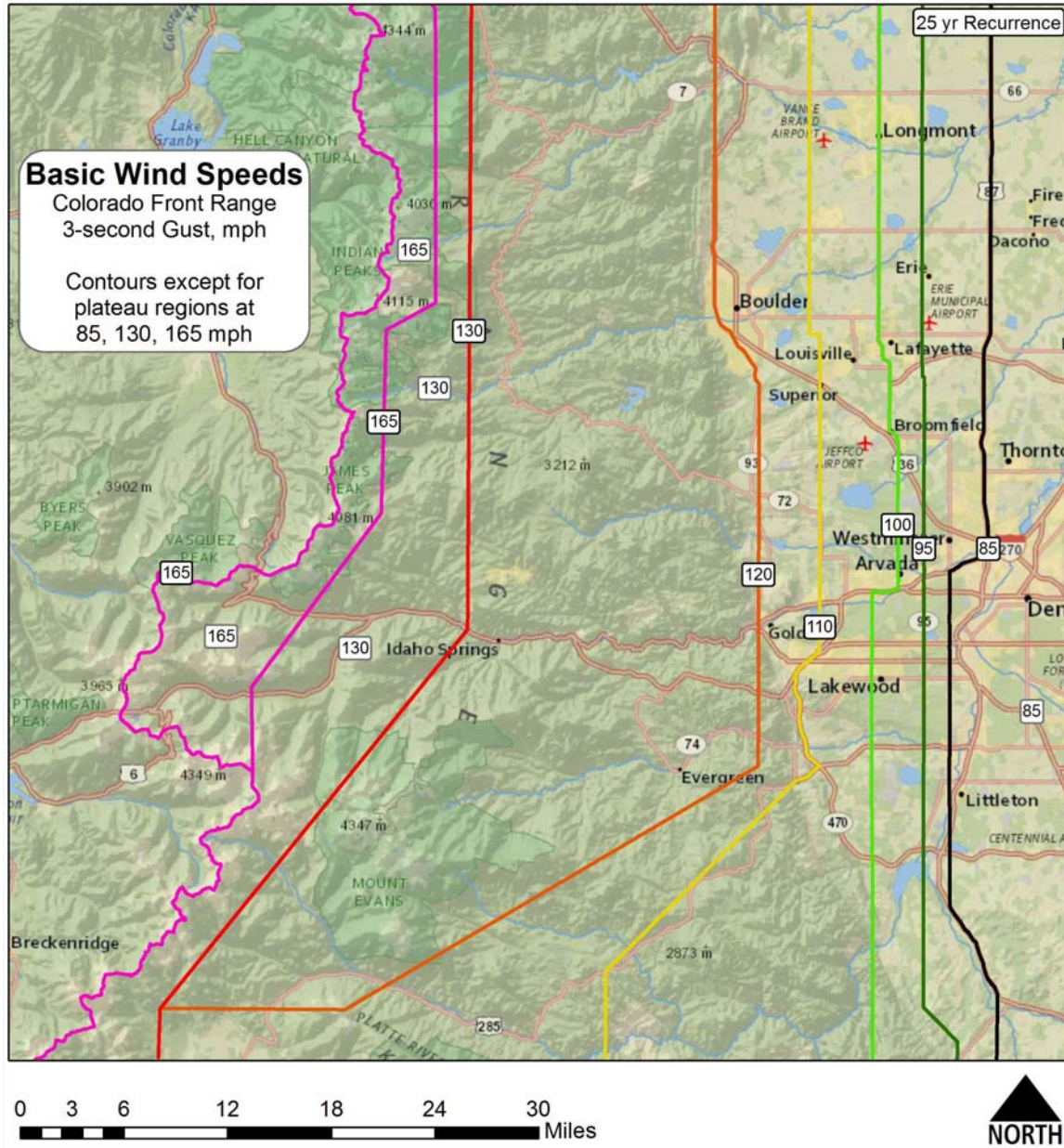
Colorado Front Range 3-Second Gust Map – 10-year recurrence interval north.



Colorado Front Range 3-Second Gust Map – 10-year recurrence interval south.

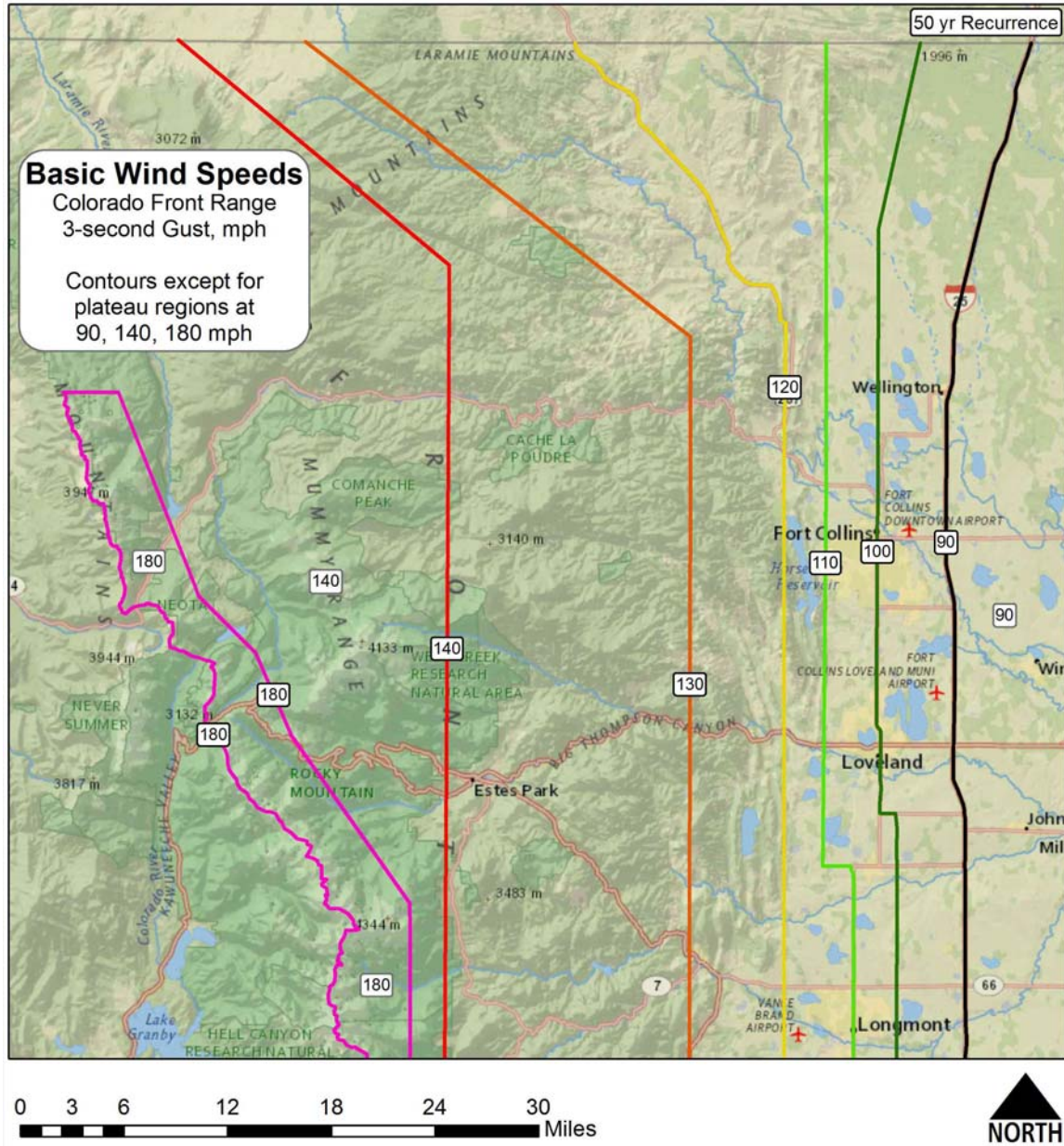


Colorado Front Range 3-Second Gust Map – 25-year recurrence interval north.

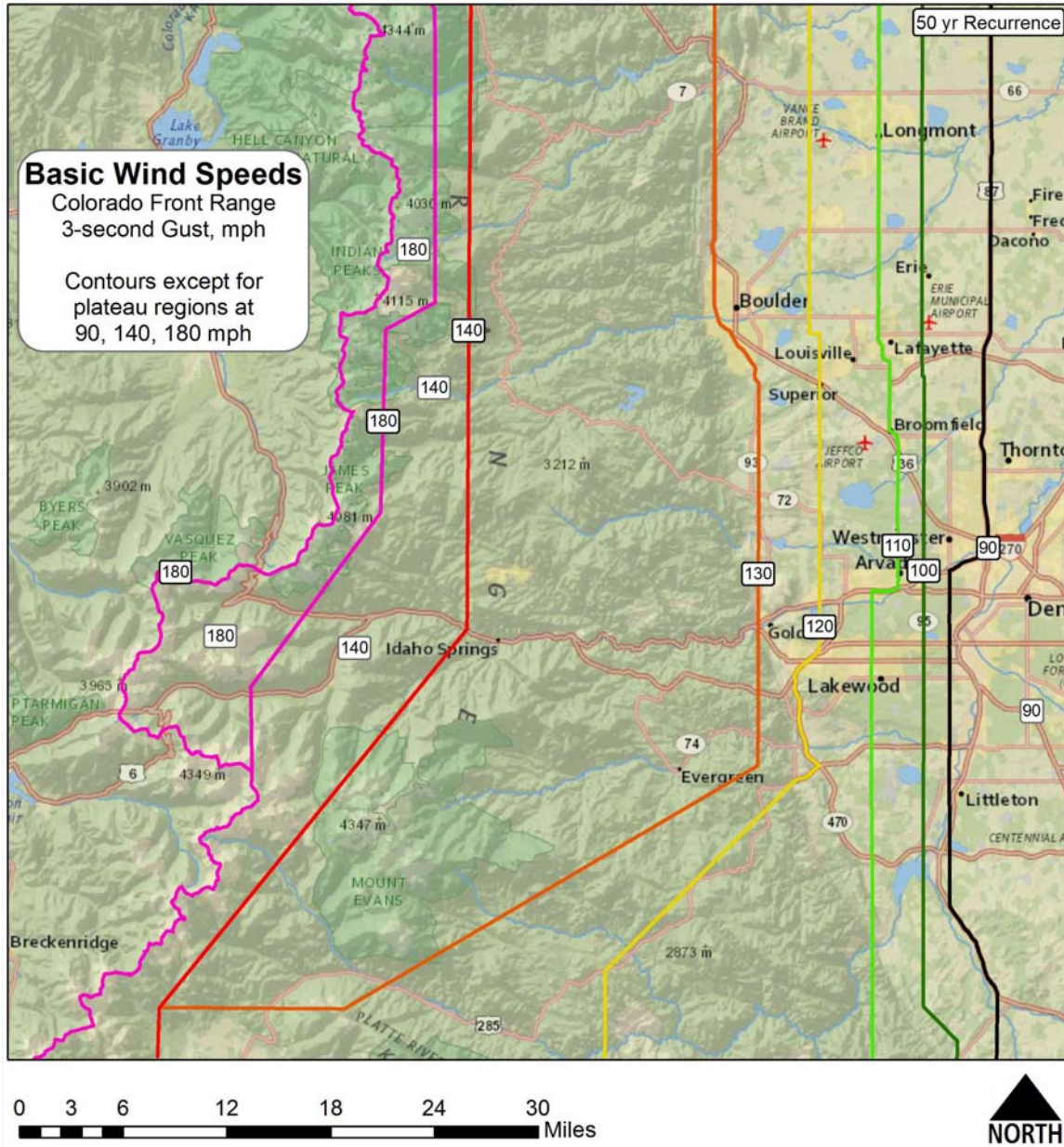


Colorado Front Range 3-Second Gust Map – 25-year recurrence interval south.

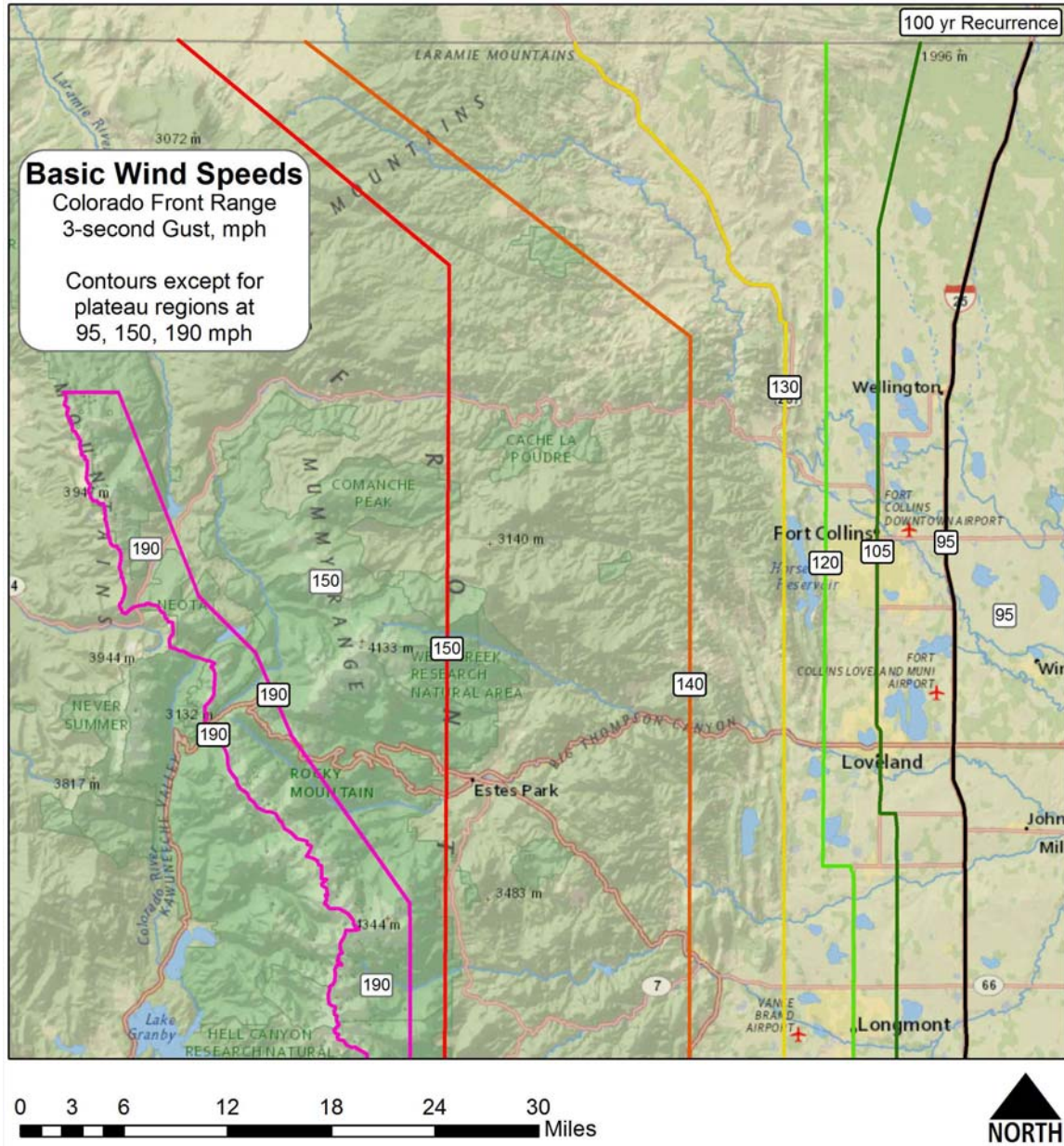




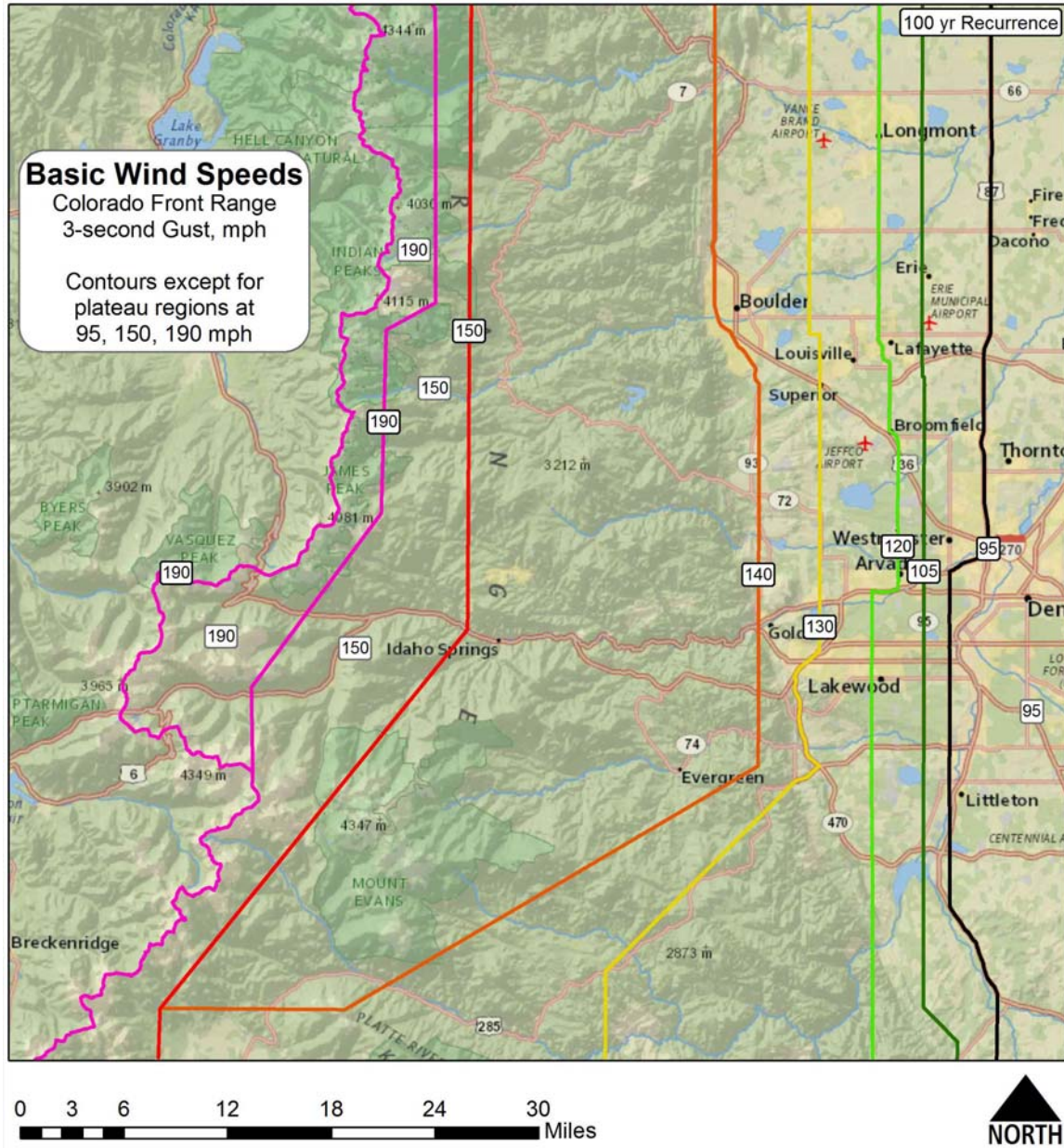
Colorado Front Range 3-Second Gust Map – 50-year recurrence interval north.



Colorado Front Range 3-Second Gust Map – 50-year recurrence interval south.



Colorado Front Range 3-Second Gust Map – 100-year recurrence interval north.



Colorado Front Range 3-Second Gust Map – 100-year recurrence interval south.