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[1] CPP 2001 designates the report by Peterka and Esterday (2001) referenced in Section 5 of this report.

ABSTRACT

The ASCE 7 peak-gust map divides the United States into two adjacent wind speed zones that do not reflect correctly the country's differentiated extreme wind climate. Following a request by the National Institute of Standards and Technology, CPP Inc. through Texas Tech University provided information used for the development of the map and for its *a posteriori* justification. Using this information it is shown that the methodology used in the map's development averages out real climatological differences and causes severe bias errors in four ways. First, the estimation of the speeds was based on superstations of which 80 percent included stations also contained in one or two other superstations. Second, stations with significantly different physical geography and meteorology were in many cases included in the same superstation. Third, legitimate wind speed data were omitted from data records when analyses resulted in speeds different from those postulated in the map. Fourth, off-the-shelf smoothing software was used that does not account for physical geography and meteorological differences. We present case studies showing that the map entails severe bias errors, thus misstating the extreme speeds over vast areas of the country, and causing unnecessary waste due to overestimated wind loads or potential losses due to underestimated wind loads.

Key Words: Building technology; extreme wind speeds; meteorology; physical geography; statistics; wind forces.

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1. INTRODUCTION

One of the major products of the NSF-sponsored cooperative program in wind engineering between Colorado State University (CSU) and Texas Tech University (TTU) was the generation by CSU of a peak-gust wind speed map for the continental U.S. and Alaska (*Cooperative Program in Wind Engineering*, 1994 or for short *CPWE*, 1994). This map was adopted for use in the 1995 and subsequent versions of the ASCE 7 Standard *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-95), and is referred to in this report as the ASCE 7 peak-gust map.

The ASCE 7 peak-gust map differs from the ASCE 7-93 Standard wind map in three major ways: (a) it uses 3 s peak gust speeds, rather than fastest-mile speeds; (b) it is based on analyses of data for sets of stations grouped into *superstations*, rather than for individual stations, and (c) except for special wind regions and hurricane-prone regions, it divides the conterminous United States into just two adjacent wind zones. As shown in more detail in Section 2, this division results for large areas of the country in wind loads that are either significantly higher or significantly lower than the loads inherent in the ASCE 7-93 wind map.

Is the ASCE 7 peak-gust map warranted from a climatological point of view or is it the result of an inadequate meteorological and statistical approach to its development? This question was raised in a discussion by Simiu and Filliben (1999) of the Peterka and Shahid (1998) paper in which – three years after its adoption in the ASCE 7-95 Standard – the ASCE 7 peak-gust map was for the first time presented in a refereed journal. It was noted in that discussion that neither the data nor the superstation definitions used for the development of the ASCE 7 peak-gust map were available to the engineering community, and that this rendered impossible an independent, objective, and reliable scrutiny of the basis for the map.

For this reason the NIST/TTU Cooperative Agreement/Windstorm Mitigation Initiative, with Dr. Peterka's helpful cooperation, undertook the task of making public the information needed to verify the adequacy of the map. A report by CPP, Inc. (2001), henceforth referred to as CPP (2001), is available from the Wind Engineering Research Center at Texas Tech University, Lubbock, Texas 79409. The report includes a compact disk (CD) with the description of the superstations used for the original estimates (i.e., the names of the individual stations of which the superstations are composed), the recorded largest annual peak gusts at each station, the station anemometer height histories, the largest annual speeds at 10 m above ground at each station, and the description of two additional sets of alternative superstation definitions. This information can be accessed as indicated at the end of this section.

In Section 2 we discuss the basic features of ASCE 7 peak-gust map and the changes it entails with respect to the ASCE 7-93 wind map. In Section 3 we list and discuss the composition of the superstations used for the original estimates, and note that 80 % of those superstations include stations that appear in at least two superstations. In Section 3 we consider typical case studies from the alternative superstations listed in the CPP (2001) CD, and analyzed in the article by Peterka and Esterday (2001) attached to CPP (2001). We end the report with a set of conclusions.

Note: **Instructions for accessing files excerpted from ccp (2001):**

The files can be downloaded from the following FTP site: "ftp.nist.gov" using the username *anonymous* and, as a password, *the user's e-mail address*. The files are located in the subdirectory: "pub/bfrl/emil/NISTTTU". In this subdirectory, five files can be downloaded. They include:

- *ReadMeCPP.txt*
- *Original Superstation List.txt*: contains the list of original superstations used in the development of the ASCE 7-95 peak-gust map.
- *Set1 Superstation List.txt* and *Set2 Superstation List.txt*: contain lists of alternative superstations in CCP (2001).
- *wind speed data.txt*: contains wind speed data for the stations included in the superstations.

2. DIFFERENCES BETWEEN ASCE PEAK-GUST MAP AND ASCE 7-93 WIND MAP

The ASCE 7 peak-gust map differs from the ASCE 7-93 wind map in three major ways:

First, it provides values of 50 yr peak 3 s gust speeds, instead of 50 yr fastest-mile wind speeds, as was the case for the ASCE 7-93 wind map. Based on research conducted at Texas Tech University for five National Weather Service stations (Lubbock, TX; Amarillo, TX; Kansas City, MO; Minneapolis, MN; and Syracuse, NY), a ratio between 3 s peak-gust speeds and the corresponding fastest-mile wind speed of about 1.2 was judged to be reasonable (*CPWE*, 1994, p. 7). If this ratio is used, 3 s speeds of 38 m/s (85 mph) and 40 m/s (90 mph) correspond approximately to 31 m/s (70 mph) and 33 m/s (75 mph) fastest-mile speeds, respectively.

Second, it is based on analyses of data for sets of stations ("superstations"), rather than on analyses of data for individual stations. In principle, the aggregation of individual stations into superstations has the advantage of yielding estimates based on larger data sets and therefore having smaller sampling errors. This advantage is real, however, only if the aggregation into superstations is sound from a statistical and meteorological viewpoint.

Third, with the exception of hurricane-prone areas and areas of special winds, the ASCE peak-gust map is divided into two adjacent wind speed zones. In the first zone, comprising the entire conterminous United States except for California, Oregon, and Washington, the specified 50 yr 3 s peak gust speed is 40 m/s (90 mph). The second zone comprises these three states, for which the specified speed is 38 m/s (85 mph). The changes in design wind speeds entailed by the use of the ASCE 7 peak-gust map instead of the ASCE 7-93 map have the following consequences:

- For areas for which (a) the ASCE 7-93 Standard specified a *31 m/s (70 mph) 50 yr fastest-mile speed* (corresponding in accordance with the proposed *CPWE* (1994) ratio to an approximately 37 m/s (84 mph) 3 s peak-gust speed) and (b) the ASCE 7 peak-gust map specifies a *40 m/s (90 mph) 50 yr 3 s peak gust*, the ASCE 7 peak-gust map entails an *increase* in wind loads by a factor of about $(90/84)^2$ = *1.15*. In structural engineering terms this is significant, and would be equivalent to increasing the wind load factor from 1.6 to 1.84, or from 1.5 to 1.72.

- For areas for which (a) the ASCE 7-93 Standard specified a *36 m/s (80 mph) 50 yr fastest-mile speed* and (b) the ASCE 7 peak-gust map specifies a *38 m/s (85 mph) 3 s peak gust*, the ASCE 7 peak-gust map entails a *decrease* of the wind loads by a factor of $(85/96)^2$ = *0.78*. This factor is even smaller for the considerable areas where the actual peak-gust wind speed is larger than 36 x 1.2 = 43 m/s (96 mph).

3. SUPERSTATIONS USED FOR DEVELOPMENT OF ASCE 7 PEAK-GUST MAP

One feature of the superstations used for the development of the ASCE 7 peak-gust map is that the overwhelming majority contain stations included in at least two superstations. The inclusion of the same stations in more than one superstation tends to weaken differences between superstations by biasing results of the statistical analyses, and is therefore inappropriate for statistical analysis purposes. A critique of this feature was therefore produced by NIST within the framework of the NIST/TTU Cooperative Agreement/Windstorm Mitigation Initiative. Following this critique CPP (2001) performed analyses of alternatively aggregated superstations, in which no station appears in more than one superstation. We comment on the composition of and statistical analyses for alternative superstations in Section 4.

We now list the superstations used to develop the ASCE peak-gust wind map. The superstation identifying numbers are taken from the CPP (2001) CD. *The list shows in bold type the stations that appear in more than one superstation.* Two or more stations with the same name listed in one superstation represent nearby but distinct stations (with one station administered, e.g., by the National Weather Service, and the other by, e.g., the Air Force). Longitudes and latitudes for each station are available in the CD.

Superstation 99100 (OR): Burns **Eugene** Medford **Salem** Klamath Falls;

Superstation 99101 (OR, WA): Pendleton **Eugene Olympia** Portland **Salem Yakima Astoria**;

Superstation 99102 (DE, PA): **Dover Philadelphia Philadelphia Wilmington**;

Superstation 99103 (NJ, PA): **Belmar McGuire Middletown Allentown Lakehurst Willow Grove Pittsburgh**;

Superstation 99104 (NY, NJ, MA, PA, CT, OH): **Binghamton Belmar Chicopee Falls McGuire Hempstead Middletown Suffolk County Stewart New York Buffalo Newark Albany Allentown Hartford Wilkes-Barre** Williamsport **Lakehurst New York Willow Grove Youngstown** Erie **Bridgeport New York New York Pittsburgh**;

Superstation 99105 (RI): **Providence Quonset Point**;

Superstation 99106 (GA, SC): **Augusta Myrtle Beach Sumter Columbia**;

Superstation 99107 (GA, SC): **Augusta Savannah** Greer **Myrtle Beach Savannah Sumter** Charleston **Columbia** Beaufort;

Superstation 99108 (SD): **Huron Rapid City Rapid City**;

Superstation 99109 (SD): Aberdeen **Huron Sioux Falls Rapid City Rapid City;**

Superstation 99110 (AR, TN): **Blytheville** Chattanooga Knoxville **Memphis Memphis**;

Superstation 99111 (TN, OH): **Sewart** Bristol **Nashville Cincinnati**;

Superstation 99112 (TX) **Corpus Christi Corpus Christi Kingsville**;

Superstation 99113 (TX): Victoria Victoria Beeville;

Superstation 99114 (TX): Houston San Antonio San Marcos Randolf Port Arthur San Antonio San Antonio Houston Del Rio Del Rio;

Superstation 99115 (TX): Austin Austin;

Superstation 99116 (TX): Robert Gray Fort Hood Waco Waco;

Superstation 99117 (TX): **San Angelo San Angelo**;

Superstation 99118 (TX): **San Angelo** Midland **San Angelo**;

Superstation 99119 (TX): Biggs El Paso;

Superstation 99120 (TX): **Dallas/Ft Worth Fort Worth**;

Superstation 99121 (TX): **Dallas/Ft Worth** Mineral Wells **Abilene Fort Worth Abilene**;

Superstation 99122 (TX): **Abilene Abilene**;

Superstation 99123 (TX): **Abilene Abilene** Webb;

Superstation 99124 (TX): **Perrin Wichita Falls Reese** Lubbock;

Superstation 99125 (OK, TX): **Clinton Altus Oklahoma City Perrin Wichita Falls Oklahoma City Reese Lubbock** Amarillo;

Superstation 99126 (TX): Brownsville **Corpus Christi Corpus Christi Kingsville**;

Superstation 99127 (UT): Milford Ogden **Dugway Salt Lake City**;

Superstation 99128 (UT): **Dugway Salt Lake City**;

Superstation 99129 (VA, NC): **Norfolk Norfolk Oceana Weeksville**;

Superstation 99130 (VA): Langley **Lynchburg Richmond Roanoke Chincoteague** Fort Eustis;

Superstation 99131 (MD, VA): **Washington DC Washington DC Anacostia Dahlgren Quantico Davison Washington DC**;

Superstation 99132 (NY, MA, VT, NH): **Plattsburgh Maynard Fort Devens Bedford Chicopee Falls Albany Boston** Burlington **Concord Milton Worcester**;

Superstation 99133 (WA): **Olympia Yakima**;

Superstation 99134 (WA): **Fairchild Spokane**;

Superstation 99135 (WA): **Moses Lake Fairchild Spokane**;

Superstation 99136 (WA): **Gray Everett Tacoma Seattle Seattle Seattle**;

Superstation 99137 (WA, OR): **Moses Lake Fairchild** Spokane **Gray Everett Tacoma Olympia Seattle Yakima Seattle** Whidbey Island **Seattle Astoria** Quillayute;

Superstation 99138 (WI, MI): **Green Bay Houghton Lake**;

Superstation 99139 (WI, MI, IL): Madison **Milwaukee Muskegon Glenview Green Bay Grand Rapids**;

Superstation 99140 (WV, VA, OH): Huntington **Beckley** Elkins **Lynchburg Roanoke** Charleston **Columbus**;

Superstation 99141 (WV, VA): **Beckley Lynchburg Richmond Roanoke**;

Superstation 99142 (WY): Cheyenne **Lander Casper**;

Superstation 99143 (WY): **Lander** Sheridan **Casper**;

Superstation 99144 (NY, MA): **Binghamton Plattsburgh Maynard Fort Devens Bedford Chicopee Falls Boston Milton Worcester**;

Superstation 99910 (FL, MS, AL): **Pensacola Pensacola Keesler Mobile Mobile Barin Pensacola Pensacola Whiting**;

Superstation 99911 (AL): **Maxwell Craig Montgomery**;

Superstation 99912 (AL, GA): **Cairns Field Albany Maxwell Fort Benning Craig Marietta Atlanta Birmingham Montgomery Atlanta Columbus**;

Superstation 99913 (AL): **Huntsville Maxwell Craig Birmingham Montgomery**;

Superstation 99914 (AR, TN): Little Rock **Blytheville Memphis** Little Rock **Memphis**;

Superstation 99915 (AZ): Fort Huachuca **Yuma Yuma Davis Monthan Tucson Yuma**;

Superstation 99916 (AZ): Flagstaff **Yuma Yuma** Williams **Davis Monthan** Luke **Tucson** Pheonix Winslow **Yuma** Litchfield Park;

Superstation 99917 (CA): San Diego Chula Vista El Centro Miramar San Diego Imperial Beach;

Superstation 99918 (CA): Camp Pendleton March Long Beach Los Angeles El Toro Los Alamitos Tustin San Nicholas San Clemente;

Superstation 99919 (CA): **Edwards Norton George** Oxnard Sandberg Point Mugu Vandenberg;

Superstation 99920 (CA): Bakersfield **China Lake**;

Superstation 99921 (CA): Lemoore Monterey Fresno Fritzsche Jolon;

Superstation 99922 (CA): Castle Oakland San Francisco Stockton Alameda Moffet Field;

Superstation 99923 (CA): Travis Mather McClellan Hamilton;

Superstation 99924 (CA): Blue Canyon Eureka Red Bluff Beale;

Superstation 99925 (CO): **Alamosa Colorado Springs Pueblo USAF Academy**;

Superstation 99926 (CO): Denver **Alamosa** Denver Grand Junction **Colorado Springs Pueblo USAF Academy**;

Superstation 99927 (CT, RI): **Hartford Providence Quonset Point Bridgeport**;

Superstation 99928 (DE, PA): **Dover Philadelphia Philadelphia Wilmington**;

Superstation 99929 (DE, NJ, PA, VA): **Dover Atlantic City Philadelphia Atlantic City Chincoteague Philadelphia Wilmington Atlantic City**;

Superstation 99930 (FL): **Key West Key West**;

Superstation 99931 (FL): **Homestead Miami Miami**;

Superstation 99932 (FL): **Homestead Key West Miami** West Palm Beach **Key West Miami**;

Superstation 99933 (FL): Avon Park Macdill Tampa;

Superstation 99934 (FL): Orlando Sanford Cocoa Beach Cape Canaveral;

Superstation 99935 (FL): Apalachicola Daytona Beach;

Superstation 99936 (FL): **Mayport Jacksonville Jacksonville Jacksonville**;

Superstation 99937 (FL, AL): **Pensacola** Duke Valparaiso **Pensacola Tyndall** Valparaiso **Tallahassee Barin Pensacola Pensacola Whiting**;

Superstation 99938 (GA, AL, FL): Macon **Savannah Cairns Field Mayport Albany Savannah Fort Benning Tyndall** Valdosta Warner Robins **Jacksonville Tallahassee Jacksonville** Brunswick **Columbus**;

Superstation 99939 (GA, SC): **Augusta Sumter** Athens **Marietta Atlanta Columbia Atlanta**;

Superstation 99942 (MN, IA, NE, SD): **Rochester Des Moines Omaha** Sioux City **Sioux Falls Omaha Waterloo North Omaha**;

Superstation 99943 (ID): Mountain Home Boise Pocatello;

Superstation 99944 (IL, MO): Belleville **St Louis Rantoul Peoria** Springfield;

Superstation 99945 (IL, WI, IN): **Rantoul** Chicago **Milwaukee Peoria South Bend Glenview** Moline **Peru** Chicago O'Hare;

Superstation 99946 (IN): Fort Wayne **South Bend**;

Superstation 99947 (IL, IN): **Rantoul** Evansville Indianapolis **Peru**;

Superstation 99948 (KS): McConnel Wichita Dodge City Hutchinson;

Superstation 99949 (MO, KS): **Richards Gebaur** Forbes Salina **Whiteman Olathe**;

Superstation 99950 (KS): Fort Riley **Concordia** Topeka;

Superstation 99951 (KS): **Concordia** Goodland;

Superstation 99952 (KY, TN): Fort Campbell **Sewart Nashville Cincinnati**;

Superstation 99953 (KY): Paducah Jackson Fort Knox;

Superstation 99954 (KY): Lexington Louisville;

Superstation 99955 (LA): **Fort Polk Lake Charles** Barksdale Shreveport;

Superstation 99956 (LA): **Fort Polk Lake Charles** Boothville New Orleans New Orleans England Baton Rouge New Orleans;

Superstation 99957 (MA, NY, CT): **Maynard Fort Devens Bedford Chicopee Falls** Falmouth **Suffolk County Boston Hartford Milton** South Weymouth **Worcester**;

Superstation 99958 (MD, VA): Andrews **Washington DC** Patuxent **Washington DC Anacostia** Annapolis **Dahlgren Quantico Davison Washington DC**;

Superstation 99959 (MD): Aberdeen Baltimore Fort Meade;

Superstation 99960 (NH, ME): **Portsmouth Brunswick Portland**;

Superstation 99961 (ME): Dow Loring;

Superstation 99962 (MI): **Mount Clemens Detroit Flint Lansing Grosse Ile Detroit Grand Rapids**;

Superstation 99963 (MI): **Mount Clemens Oscoda Detroit Flint Lansing Muskegon Grosse Ile Houghton Lake Detroit Grand Rapids**;

Superstation 99964 (MI): **Oscoda** Sault Ste. Marie **Houghton Lake** Kincheloe Gwinn Alpena;

Superstation 99965 (MN, IA): **Minneapolis Rochester Minneapolis Waterloo**;
Superstation 99966 (MN): Duluth International Falls **Minneapolis Minneapolis**;

Superstation 99967 (MO): **Fort Leonard Wood Columbia**;

Superstation 99968 (MO): **Whiteman Springfield**;

Superstation 99969 (MO, KS): **Richards Gebaur Fort Leonard Wood Columbia** Kansas City Fort Leavenworth **Whiteman St. Louis Springfield Olathe**;

Superstation 99970 (MS): **Meridian Meridian**;

Superstation 99971 (MS): **Columbus**;

Superstation 99972 (AL, MS): **Huntsville Meridian Keesler Maxwell Columbus Mobile Craig Meridian Birmingham Mobile Montgomery Barin** Tupelo;

Superstation 99973 (MT): Billings **Malmstrom Great Falls Helena Missoula**;

Superstation 99974 (WA, MT): **Moses Lake Malmstrom Fairchild Great Falls Helena** Kalispell **Missoula Spokane**;

Superstation 99975 (NC): **Wilmington Cherry Point New River**;

Superstation 99976 (NC): **Goldsboro Raleigh Cape Hatteras Fort Bragg**;

Superstation 99977 (NC): Asheville **Charlotte**;

Superstation 99978 (NC, VA): **Goldsboro** Fayetteville **Raleigh** Greensboro **Norfolk Wilmington Norfolk Cherry Point Oceana Weeksville Charlotte New River Cape Hatteras Fort Bragg**;

Superstation 99979 (ND): Fargo Grand Forks;

Superstation 99980 (ND): Bismarck Minot Williston;

Superstation 99981 (NE): Lincoln Grand Island Lincoln;

Superstation 99982 (IA, NE): **Des Moines** Norfolk **Omaha Omaha** North Platte **North Omaha**;

Superstation 99983 (NH, ME): **Portsmouth Brunswick Concord Portland**;

Superstation 99984 (NJ): **Atlantic City Atlantic City Atlantic City**;

Superstation 99985 (NJ, NY): **Belmar McGuire Hempstead Suffolk County New York Newark Lakehurst New York New York New York**;

Superstation 99986 (NM): Holloman Las Cruces;

Superstation 99987 (NM, TX): Clovis **Reese** Albuquerque;

Superstation 99988 (NV, CA): Desert Rock Las Vegas **Edwards Norton George** Las Vegas **China Lake**;

Superstation 99989 (NV): Stead Ely Reno Winnemucca Fallon;

Superstation 99990 (NY, NJ): **Hempstead Suffolk County New York Newark New York New York New York**;

Superstation 99991 (NY, PA, CT): **Stewart Wilkes-Barre Bridgeport**;

Superstation 99992 (NY, MA): **Binghamton Chicopee Falls Buffalo Albany**;

Superstation 99993 (NY) Niagara Falls Rochester Syracuse;

Superstation 99994 (OH): Springfield Wright Patterson Wright Patterson Wilmington Dayton **Columbus**;

Superstation 99995 (OH, PA): Columbus Columbus Mansfield Akron **Pittsburgh**;

Superstation 99996 (OH): Cleveland **Youngstown** Toledo;

Superstation 99997 (OK): **Altus** Fort Sill;

Superstation 99998 (OK): **Clinton Oklahoma City Oklahoma City**;

Superstation 99999 (OK): Enid Tulsa.

As noted earlier, about 80 % of the total number of superstations contain stations included in at least two superstations. Of the remaining 20 %, more than half consist of at most three stations. Given the composition of the superstations it is not surprising that the estimates reflected in the maps tend to consist of the same wind speeds over areas in which the extreme wind climates are in fact non-uniform.

4. ALTERNATIVE SUPERSTATIONS (CPP 2001)

Following questions raised by NIST on the composition of the superstations listed in the preceding section, two sets of alternative superstations with no common stations were developed by CPP (2001) to justify the validity of the wind speeds used in the ASCE 7 map. The sets are listed as Set 1 and Set 2 (see files accessible as explained at the end of Section 1). In this section we comment on the composition of typical alternative superstations and on the results obtained from the analysis of the respective data.

For consistency with the estimates by Peterka and Shahid (1998) and CPP (2001), our own estimates were obtained by the method of moments applied to the Extreme Value Type I distribution (see Simiu and Scanlan, 1996, Chapter 3):

$$V_{50} = \overline{X} + 2.6s,$$

$$SD(V_{50}) = 3.376\frac{s}{\sqrt{n}},$$

where V_{50} is the estimated 50 yr speed, $SD(V_{50})$ is the estimated standard deviation of the sampling error in the estimation of the 50 yr speed, $\overline{X}$ and s are the sample mean and standard deviation of the largest yearly speeds, respectively, and n is the sample size. The data used for the estimates were the peak-gust speeds at 10 m elevation contained in the CPP (2001) CD and in the files accessible as indicated at the end of Section 1.

In the superstations listed in this section the first, second, and third number within parentheses indicates the estimated 50 yr 3 s peak gust speed, the sample size, and the corresponding estimated standard deviation of the sampling error in the estimation of that speed. The numbers in **bold type** following the semicolon indicate the estimated speed for the superstation based on the consolidated set of superstation data. In some cases these estimated speeds differ mostly by small amounts from their counterparts as estimated in CPP (2001). Physical station descriptions contained in this section are based on National Climatic Center/Local Climatological Data Narrative Summaries. The locations of the stations are shown in the maps of Appendix 1. Owing to space limitations, and because they are typical of the approach used in CPP (2001), fourteen typical superstations from Set 1 are commented upon. To enable the reader to examine other superstations we provide in Appendix I maps for the entire conterminous United States, which contain all superstations. The requisite data and superstation listings (for the original set, Set 1 and Set 2), as well as sample statistics and wind speed estimates, as excerpted from the CPP (2001) CD, can be accessed as indicated at the end of Section 1. In the case studies that follow we list the speeds in both m/s and mph.

Set 1, Superstation 99100 (OR): Burns [36 m/s (81 mph), 5, 6 m/s (14 mph)], Eugene [32 m/s (71 mph),19, 3 m/s (6 mph)], Medford [31 m/s (69 mph), 21, 2 m/s (5 mph)], Salem [33 m/s (75 mph), 19, 3 m/s (6 mph)], Klamath Falls [33 mph (75 mph), 20, 2 m/s (5 mph)]; **33 m/s (74 mph)**.

Comment: For this superstation, the consolidation of the individual station data into a larger data set does not appear to add any useful information as far as most individual stations are concerned. The exception is Burns, for which the sample size is too small, however, for the statistical analysis to yield reliable results. As can be seen from the map of Oregon (Appendix 1), the wind climates of Eugene or Salem on the one hand and Burns, Medford, or Klamath Falls on the other are determined by different meteorological conditions. Eugene is located at the southern end of Willamette Valley between the Coast Range and the Cascade Mountains, and experiences relatively strong winds mostly from the southwest. Burns is located near the center of a high plateau area. Before reaching Burns, maritime air moving in from the Pacific Ocean is modified not only by the Coast Range but by the Cascade Mountains as well. Highest wind velocities in Medford are reached when a well-developed storm off the coast of California causes a chinook wind off the Siskiyou Mountains in the south. There is little commonality between Medford's wind meteorology and, say, Eugene's. Even though in the particular case of these two stations the respective estimated 50 yr speeds are almost the same, it is generally not the case that superstations can be composed without regard for their specific meteorological and physical geography features. This is clearly demonstrated by other examples given in this section.

Set 1, Superstation 99101 (OR, WA): Pendleton [37 m/s (83 mph), 19, 3 m/s (6mph)], Olympia [31 m/s (70 mph), 16, 3 m/s (6mph)], Portland [40 m/s (90 mph), 32, 3 m/s (7 mph)], Yakima [34 m/s (76 mph), 20, 2 m/s (5 mph)]; **37 m/s (84 mph)**.

Comment: Pendleton is located in the southeastern part of the Columbia basin, which is almost entirely surrounded by mountains, the most important break in the barriers surrounding the basin being the gorge in the Cascade Range on the west. Olympia is well protected by the Coast Range from the strong south and southwest winds accompanying many of the Pacific storms during the fall and winter. In contrast, the protection offered by the Coast Range to Portland is described by the National Climatic Center as limited. This may explain Portland's stronger extreme wind climate relative to Olympia's. Yakima is located in a small east-west valley in the northwestern part of Yakima Valley. Local topography is complex, resulting in marked variations in winds within short distances. Note, for example, that the inclusion of Portland in a superstation with stations having different physical geography results in a significant reduction of its estimated extreme speeds. Such a reduction is in our opinion unwarranted and imprudent.

Set 1, Superstation 99961 (ME): Loring [32 m/s (71 mph), 35, 1 m/s (3 mph)]; **32 m/s (71 mph)**.

Comment: This "superstation" consists of only one station. In this case this is, in our opinion, judicious. This station's conditions are different from those of other stations in ME owing both to its physical geography and its distance from the coast. However, given that the estimated peak-gust speed is 32 m/s (71 mph), there is no reason arbitrarily to assign to this superstation a 40 m/s (90 mph) 50 yr peak-gust speed, as is done in the ASCE 7 peak-gust map.

Set 1, Superstation 99132 (VT,NY): Burlington [33 m/s (75 mph), 16, 3 m/s (6 mph)], Plattsburgh [32 m/s (72 mph), 33, 1 m/s (3 mph)]; **32 m/s (73 mph).**

Comment: Judging from the NY and VT maps in Appendix 1, the consolidation of these stations into one superstation is in our opinion warranted. If the 50 yr 3 s gust for Burlington is estimated from the 33-yr fastest-mile speeds record (see Simiu, Changery, and Filliben, 1979, p. 280) by using a 1.2 ratio between fastest-mile and 3 s peak gusts speeds, the result obtained is 35 m/s (79 mph). There is in our opinion no reason to believe that the 32 m/s (73 mph) estimate obtained by consolidating the two stations is more realistic than the 35 m/s (79 mph) estimate. However, this is a moot point. What is definitely the case is that the 50 yr 3 s peak gust speed for Burlington and Plattsburgh should be less than 40 m/s (90 mph). In fact the value corresponding to the fastest-mile speed specified in the ASCE 7-93 map is about 37 m/s (84 mph). In contrast, ASCE 7 peak-gust map specifies a 40 m/s (90 mph) speed. It was seen earlier that the assignment of a blanket 38 m/s (85 mph) value for the whole state of Oregon is not appropriate for the Portland, OR area. The assignment of a 40 m/s (90 mph) for the Burlington and Plattsburgh areas is similarly inappropriate.

Set 1, Superstation 99927 (NJ; MA; NY; CT; RI): Belmar [30 m/s (67 mph), 7, 3 m/s (7 mph)], Newark [38 m/s (85 mph), 17, 3 m/s (6 mph)], McGuire [36 m/s (81 mph), 42, 3 m/s (6 mph)], Lakehurst [39 m/s (87 mph), 41, 3 m/s (6 mph)]; Maynard [30 m/s (67 mph), 13, 4 m/s (9 mph)], Fort Devens [28 m/s (63 mph), 18, 2 m/s (4 mph)], Chicopee Falls [42 m/s (95 mph), 21, 4 m/s (9 mph)], Falmouth [41 m/s (93 mph), 22, 3 m/s (6 mph)], Boston [40 m/s (89 mph), 42, 2 m/s (4 mph)], Milton [55 m/s (123 mph), 8, 8 m/s (18 mph)], South Weymouth [35 m/s (78 mph), 33, 2 m/s (5 mph)], Worcester [36 m/s (80 mph), 29, 2 m/s (4 mph)]; Hampstead [38 m/s (86 mph), 13, 4 m/s (9 mph)], Stewart [36 m/s (81 mph), 21, 3 m/s (6 mph)], Suffolk County [37 m/s (84 mph), 12, 4 m/s (8 mph)], New York [46 m/s (104 mph), 18, 4 m/s (9 mph)], Albany [34 m/s (76 mph), 19, 2 m/s (5 mph)], New York/Central Park [28 m/s (64 mph), 7, 4 m/s (9 mph)], New York [35 m/s (79 mph), 9, 4 m/s (8 mph)]; Bridgeport [33 m/s (75 mph), 16, 3 m/s (6 mph)], Hartford [41 m/s (93 mph), 10, 7 m/s (16 mph)], Providence [40 m/s (91 mph), 38, 3 m/s (6 mph)], Quonset Point [43 m/s (96 mph), 26, 3 m/s (7 mph)]; **40 m/s (90 mph).**

Comment: In contrast to the Loring, ME "superstation" which, with due consideration of specific geographical features, consisted of only one station, this superstation consists of a large number of stations consolidated, in our opinion, in an indiscriminate fashion. For example, it may be expected that New York/Central Park, being in the center of a large city, has a local wind climate different from that of a typical airport. In view of the ASCE assumption that wind maps represent wind speeds in open terrain, the inclusion of this station in the superstation is, in our opinion, inappropriate. Albany is located some 240 km (150 miles) north of New York City and the Atlantic Ocean. Its wind conditions bear no resemblance to those of, say, Belmar, NJ, and its inclusion in the same superstation as the latter and other Atlantic Coast locations is questionable. For Milton, MA it is indicated in the National Climatic Center Local Climatological Data Summaries that hills increase the wind speed. This is confirmed by its relatively high average wind speed (as indicated in the Summaries, more than 7 m/s (15 mph), versus a less than 4 m/s (9 mph) average for Albany). CPP (2001) also implies that the extreme wind climate in Central Massachusetts is similar to the wind climates in Central New Jersey and on the Atlantic Coast from Belmar, NJ to Boston. In our opinion this is unconvincing. As the results of the analyses show, for numerous areas included in this superstation the 50 yr 3 s peak gust speed at 10 m in open terrain is considerably less than the 40 m/s (90 mph) value estimated, in our opinion, incorrectly, by consolidating those areas into one superstation.

Set 1, Superstation 99112 (TX): Victoria [35 m/s (79 mph), 32, 2 m/s (4 mph)], Victoria [32 m/s (72 mph), 10, 2 m/s (5 mph)], Corpus Christi [38 m/s (86 mph), 20, 3 m/s (7 mph)], Beeville [37 m/s (84 mph), 33, 3 m/s (6 mph)], Corpus Christi [45 m/s (100 mph), 43, 3 m/s (7 mph)], Kingville [41 m/s (91 mph), 38, 3 m/s (7 mph)]; **39 m/s (88 mph)**.

Comment: All the stations included in this superstation are on the Gulf coast. Some of the wind speeds listed for these stations were induced by hurricanes (e.g., Corpus Christi, 08/10/1980; 09/11/1961; 09/20/1967; 08/03/1970). The estimation of wind speeds by fitting the superstation data to an Extreme Value Type I distribution is therefore of dubious validity (see, e.g., Simiu and Scanlan, 1996, Chapter 3).

Set 1, Superstation 99113 (TX): Houston [38 m/s (86 mph), 38, 2 m/s (5 mph)], San Antonio [36 m/s (82 mph), 44, 2 m/s (5 mph)], San Marcos [28 m/s (63 mph), 5, 3 m/s (6 mph)], Randolf [35 m/s (79 mph), 43, 2 m/s (4 mph)], Port Arthur [34 m/s (76 mph), 19, 3 m/s (6 mph)], San Antonio [36 m/s (81 mph), 21, 3 m/s (7 mph)], San Antonio [36 m/s (80 mph), 11, 4 m/s (9 mph)], Houston [42 m/s (95 mph), 22, 5 m/s (10 mph)]; **37 m/s (83 mph)**.

Comment: The ASCE 7-93 map specifies for San Antonio a 50 yr fastest-mile wind speed of about 31 m/s (70 mph), equivalent to a 50 yr 3 s peak gust speed of about 37 m/s (84 mph). In contrast, the ASCE 7 peak-gust wind map specifies a speed of 40 m/s (90 mph). The analyses for the individual San Antonio records in this superstation do not warrant the specification of a 50 yr 3 s peak gust in excess of 38 m/s (85 mph). This superstation includes Gulf coast stations, which should not be consolidated with inland stations for extreme wind speed estimation purposes. Even this consolidation, effected for the superstation by CPP (2001), does not result in speeds higher than 37 m/s (83 mph). These comments again support our view that there is no justification to assigning a blanket 38 m/s (85 mph) speed to the states of California, Oregon, and Washington, and a blanket 40 m/s (90 mph) speed to the rest of the conterminous United States except for special wind and hurricane-prone regions.

Set 1, Superstation 99114 (TX): Austin [36 m/s (81 mph), 43, 2 m/s (5 mph)], Austin [35 m/s (78 mph), 20, 3 m/s (6 mph)]; **36 m/s (80 mph).**

Comment: For Austin the ASCE 7 Standard peak-gust map specifies a peak gust speed of 40 m/s (90 mph), in spite of the lower estimated wind speeds shown above. Again, there is in our opinion no justification for doing so.

Set 1, Superstation 99115 (TX): Robert Gray [37 m/s (83 mph), 26, 3 m/s (6 mph)], Fort Hood [31 m/s (69 mph), 10, 2 m/s (5 mph)], Waco [33 m/s (75 mph), 17, 3 m/s (6 mph)], Waco [38 m/s (85 mph), 19 , 4 m/s (8 mph)]; **36 m/s (80 mph).**

Comment: For the stations contained in this superstation the data analyses – both those for individual stations and for the superstation constructed by CPP (2001), -- a 40 m/s (90 mph) speed, as specified in the ASCE 7 peak-gust wind map, is clearly unjustified.

Set 1, Superstation 99117 (TX): Webb [48 m/s (107 mph), 23, 5 m/s (10 mph)], San Angelo [28 m/s (64 mph), 11, 2 m/s (5 mph)], Midland [43 m/s (96 mph), 19, 3 m/s (7 mph)], San Angelo [44 m/s (98 mph), 19, 4 m/s (8 mph)]; **45 m/s (101 mph).**

Comment: For this superstation the ASCE 7 peak-gust map specifies a speed of 40 m/s (90 mph). For the San Angelo station containing 11 yearly wind speed data, the anemometer elevation is (a) unknown for the first five years (1948-1952), (b) 43 m (140 ft) for the years 1953, 1955, 1956, (c) 31 m (101 ft) for 1954, and (c) 20 m (66 ft) for 1957-1958. Since the data are relatively old, were recorded at anemometer elevations that are unknown for almost half of the data and varied somewhat erratically for the other half, and constitute a relatively small sample, their use might weaken the overall quality of the estimates. The area covered by this superstation should be assigned a peak gust speed of about 45 m/s (100 mph) or more. The 40 m/s (90 mph) specified in the ASCE 7 peak-gust map leads in this case to an underestimation of wind loads for this region by a factor of about 0.81 or less.

Set 1, Superstation 99128 (UT): Ogden [45 m/s (100 mph), 44, 3 m/s (6 mph)]; **45 m/s (100 mph).**

The results of the statistical analysis of the data at this "superstation" again show that the 40 m/s (90 mph) specified for Ogden in the ASCE 7 peak-gust map is too low.

Set 1, Superstation 99138 (WI): Green Bay [39 m/s (88 mph), 16, 4 m/s (9 mph)]**; 39 m/s (88 mph).**

Comment: On the basis of the analysis of the Green Bay data from CPP (2001), it would appear that the 40 m/s (90 mph) speed specified in the ASCE 7 peak-gust speed map is appropriate. However, the sample size for this "superstation" is relatively small, and the corresponding standard deviation of the sampling errors is relatively large. The sample size for the fastest-mile wind speed record at Green Bay is larger (29 years, rather than 16 years), and the estimated 50 yr fastest-mile wind speed is 39 m/s (88 mph) (Simiu, Changery, Filliben, 1979). If the 1.2 ratio between the peak-gust and the fastest-mile speed is assumed (*CPWE*, 1994), this fastest-mile speed corresponds approximately to a 47 m/s (106 mph) peak-gust speed. Note that, during the 29 year period 1949-1977, the highest recorded fastest-mile wind speed reduced to a 10 m above ground elevation at Green Bay was 46 m/s (103 mph). In our opinion, the fact that CPP (2001) did not take into account the extreme wind climatological information listed by Simiu, Changery and Filliben (1979) weakens the quality of the estimates, as is shown clearly by this example. For the particular case of this "superstation" the available data suggest that the peak-gust speed specified for Green Bay should exceed 40 m/s (90 mph).

Set 1, Superstation 99139 (WI): Madison [44 m/s (98 mph), 19, 5 m/s (10 mph)]; **44 m/s (98 mph).**

Comment: The analysis of the CPP (2001) (2001) data shows that the 40 m/s (90 mph) speed specified in the ASCE 7 peak-gust map for the Madison "superstation" is too low. This is confirmed by statistical analysis of the 31-year fastest-mile wind speed data set listed in Simiu, Changery and Filliben (1979), according to which the estimated 50 yr fastest-mile wind speed in Madison is 38 m/s (85 mph). This corresponds to a 50 yr 3 s peak gust of about 1.2 x 38=45 m/s (102 mph).

Set 1, Superstation 99140 (WV): Beckley [32 m/s (71 mph), 15, 2 m/s (5 mph)]; **32 m/s (71 mph).**

Comment: The analysis of the CPP (2001) data shows that the 40 m/s (90 mph) speed specified in the ASCE 7 peak-gust map for Beckley is too high.

In our opinion, the typical examples shown in this section show that the blanket 38 m/s (85 mph) and 40 m/s (90 mph) 50 yr 3 s peak gust speeds specified in the ASCE 7 wind map do not reflect the reality of the extreme wind climate in the United States. This conclusion is valid regardless of whether Set 1 or Set 2 is considered.

CPP (2001) state that "the overall pattern of contours remains very similar" if superstation definition is changed. They conclude on this basis that "the speeds obtained from the superstation analysis are sufficiently close to and centered about 40 m/s (90 mph) for states east of California, Oregon and Washington that closer specification by a contour map for design wind speeds does not appear to be necessary or desirable." Our results show that this is not the case unless:

(a) Relatively large wind speeds are arbitrarily eliminated from data sets. For example, Peterka and Esterday (2001) state: "by removing one data point from station 23034 (93 mph, 41 m/s) .... the 95 mph (42 m/s) region disappears". Thus, CPP (2001) eliminated from their analyses the largest speed from the 19-year record at San Angelo, TX (i.e., the 44 m/s [98 mph] speed at 10 m elevation or 41 m/s [93 mph] at 6 m elevation recorded in 1974). By means of this elimination procedure, estimated wind speeds were changed to conform to the postulated wind speed pattern of the ASCE 7 peak-gust map.

(b) The estimated speeds, already smoothed out among various stations by virtue of the arbitrary aggregation of stations into superstations and the selective elimination of data, are again smoothed out by computer smoothing routines which are not designed to take physical geography or meteorological features into account.

5. CONCLUSIONS

Our conclusions are as follows:

1. The ASCE 7 peak-gust map division of the conterminous United States into two adjacent wind speed zones -- with the exception of hurricane-prone areas and zones of special winds -- does not reflect correctly the differentiated extreme wind climate of the United States. The methodology used to develop the map tends to average out real wind climatological differences among stations, for the following reasons:

- The estimation of the speeds specified in the ASCE 7 peak-gust map was originally based on the use of superstations so composed that, in 80 % of the cases, component stations belong to more than one superstation.
- Superstations were in many instances composed of stations with different physical geography and meteorological features.
- For a number of stations legitimate wind speed data (i.e., data of which there is no reason to believe that they entailed recording or measurement errors) were omitted from the record. The omission of such data biased extreme speed estimates and eliminated correct estimates that did not conform to the speeds arbitrarily assigned to those stations in the ASCE peak-gust map.
- In the development of the map its authors used off-the-shelf smoothing software that lacks the capability to account for physical geography and meteorological differences. Such differences are readily apparent to human operators and played a significant role in the development of the ASCE 7-93 wind map.

Therefore, the approach used for the development of the ASCE 7 peak-gust map creates multiple biases in the estimation of the speeds for large numbers of stations. These biases by far outweigh any theoretical advantages that might be obtained from a reduction of the sampling errors.

2. In our opinion, failure to make use of publicly accessible sets of National Climatic Data Center fastest-mile wind speed data lowers the quality of extreme wind speed estimates. Such data should therefore be included in future extreme speed estimation efforts. It should be recalled in this connection that that fastest-mile wind speed data are stabler (i.e., they have smaller inherent variability) than peak gust data. They cover in many instances periods not covered by peak gust data. Finally, the possibility may exist of combining historic fastest-mile data sets not only with peak gust data, but also with adjusted largest two-minute data currently being recorded at Automated Surface Observation System (ASOS) stations (*ASOS User's Manual*, 2001, p. 14).

3. The ASCE 7 peak-gust map entails, on a national scale, significant waste of material due to overestimated wind loads and losses due to underestimated wind loads. Therefore,

the wind map to be included in future versions of the ASCE 7 Standard needs to be improved substantially with respect to the current map. The improved map should be based on estimates that benefit from the experience accumulated in the development of the current and earlier wind maps. Its developers should utilize and make public the requisite data and other relevant information, and promote the early public scrutiny of the data and methodologies proposed for the development of the map.

4. The potential for the development of a significantly improved, more realistic wind map exists and should be utilized. Where appropriate, such development may include the use of the superstation concept, provided that careful consideration is given to relevant meteorological and physical geography factors and that good statistical practices are used.

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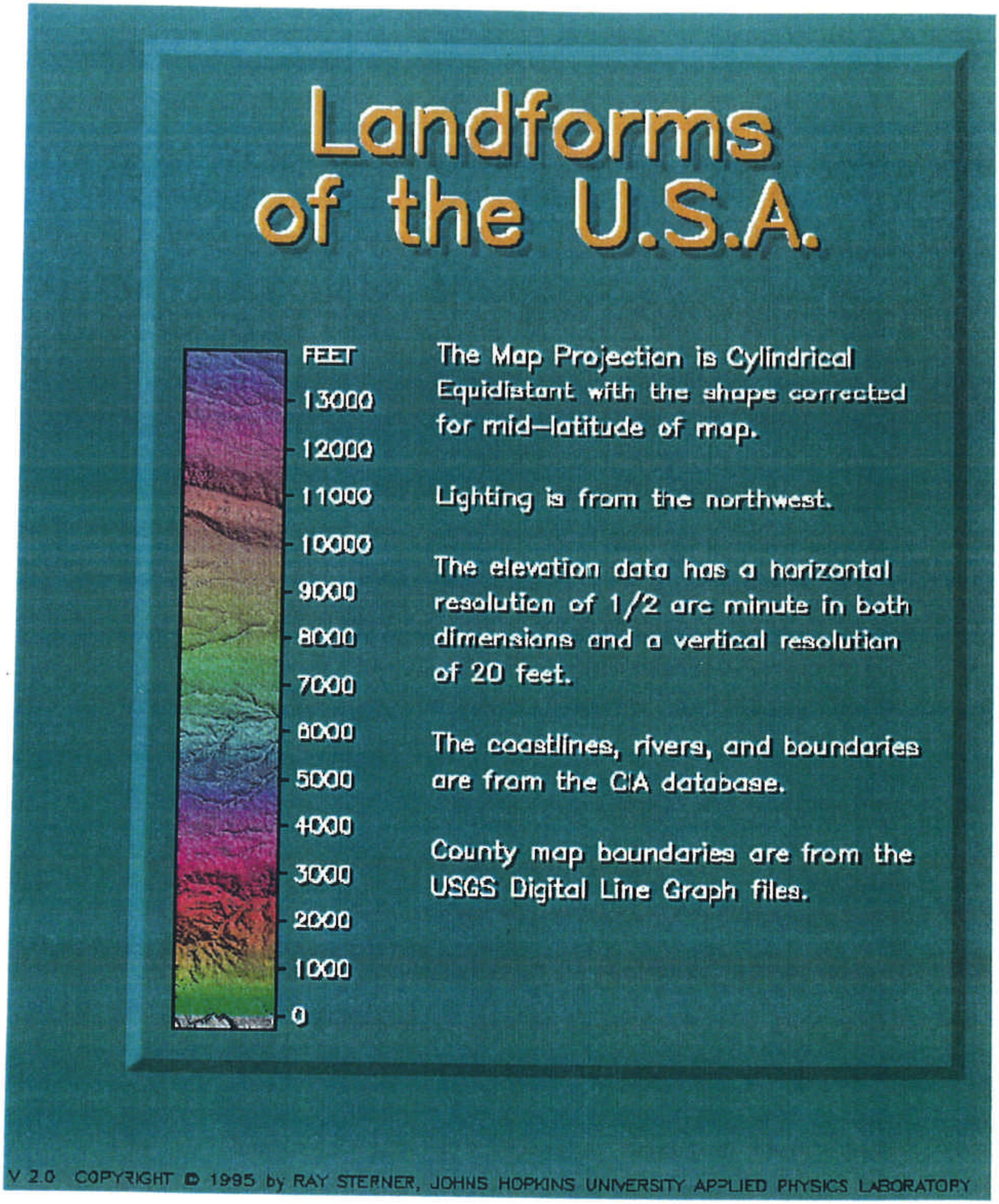
APPENDIX 1

LANDFORMS OF THE U.S.A.,
AND STATE MAPS WITH STATION NUMBERS/LOCATIONS AND CPP (2001)
SET 1 SUPERSTATIONS


Landforms of the U.S.A.
FEET
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
The Map Projection is Cylindrical Equidistant with the shape corrected for mid-latitude of map.
Lighting is from the northwest.
The elevation data has a horizontal resolution of 1/2 arc minute in both dimensions and a vertical resolution of 20 feet.
The coastlines, rivers, and boundaries are from the CIA database.
County map boundaries are from the USGS Digital Line Graph files.
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