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Witness: Peterka

PREPARED REBUTTAL TESTIMONY OF

JON A. PETERKA

ON BEHALF OF

SAN DIEGO GAS & ELECTRIC COMPANY

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA

DECEMBER 16, 2016

#310812

TABLE OF CONTENTS

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<u>ON BEHALF OF SAN DIEGO GAS & ELECTRIC COMPANY</u>

I. INTRODUCTION

Q. Please state your name and title.

A. My name is Jon A. Peterka. I am the Principal of Jon Peterka Engineering LLC.

Q. Have you previously submitted testimony in this proceeding?

A. Yes, I submitted Prepared Direct Testimony on September 25, 2015. In that testimony, I described my experience and qualifications and included a complete list of my professional history, memberships, publications, and experience in legal cases as Appendix 1.

Q. What is the purpose of your rebuttal testimony?

A. The purpose of my rebuttal testimony is to respond to various assertions, theories, and analyses set forth in the testimony of (1) Dr. Alexander Gershunov on behalf of the Utility Consumers' Action Network ("UCAN") ("Gershunov Testimony"); (2) Dr. Janice Coen on behalf of UCAN ("Coen Testimony"); and (3) Mr. Nils Stannik on behalf of the Office of Ratepayer Advocates ("Stannik Testimony"). In general, I demonstrate that my methodologies are sound, and their criticisms are unfounded. In addition, I show that Dr. Gershunov's estimates of wind speeds at the Witch, Guejito and Rice Fire ignition sites are too low.

Q. How is your testimony organized?

A. In <u>Section II</u>, I explain why the criticisms made of my methodology are unsound. For instance, while Dr. Coen criticizes the 1 kilometer resolution I use in my atmospheric modeling as being too low or coarse, her testimony implies that a higher resolution would have produced even greater wind speeds than what I presented. In any event, her criticism is more appropriately directed at Dr. Gershunov, who uses 10 kilometer resolution, which partly explains why his estimates of wind speeds are too low.

In Section III, I begin by explaining that Remote Automated Weather Station ("RAWS") wind speed data is unreliable because wind measurement devices (anemometers) at those locations are obstructed, which produces measurements that are too low. Dr. Gershunov attempts to argue that such obstructions may impact sustained wind speed measurements but that they do not impact wind gust speeds. He provides no support for that theory, and I believe it is wrong based on my own experience siting and working with anemometers. I also discuss Dr. Gershunov's methodology for estimating wind speeds, using a dataset that does not properly account for Santa Ana winds at inland locations (such as where the fire ignitions occurred) and which therefore produces estimates that are too low. I also show that he fails to validate his methodology in any reasonable way.

In Section IV, I explain why the coastal wind speed data Dr. Coen presents has no reasonable relationship to inland, Santa Ana winds.

II. RESPONSE TO CRITICISM OF MY METHODOLOGY FOR ASSESSMENT OF WIND CONDITIONS

Q. Please briefly summarize your methodology for determining the wind conditions at each fire ignition site.

A. I conducted an analysis, using a two-step process that included atmosphere (mesoscale) modeling, coupled with wind tunnel testing, which determined the impact of the local terrain on wind speeds. Essentially, I was able to take known atmospheric weather data and, through this modeling, bring it to the ground and determine the wind conditions at the fire ignition sites at the time of ignition. My analysis showed that the wind speeds and peak wind gusts at the time and location of each fire ignition were significant.[1] The wind speeds I presented for each of the three fire ignitions are shown below:

Fire	**Mean Wind** Speed, mph	**Peak 3-Second Gust** Speed, mph	**Wind Direction** degrees clockwise from North	**Height** above ground for cited speed, feet
Witch	56	78-87	83	66 ft (line height)
Guejito	34	59-68	72	24 ft (line height)
Rice	37	70-75	68	82 ft (tree branch level)

Q. Can you explain what information you used in the first step of your analysis?

A. Yes. I used the Weather Research and Forecasting ("WRF") model, which is a computer program that simulates the physical processes of the atmosphere. It is initiated using gridded atmospheric data appropriate for the time period to be simulated. I used WRF to derive wind information that I used in my wind tunnel testing.

Q. Dr. Coen criticizes your use of 1 kilometer grid spacing in that analysis.[2] How do you respond to that criticism?

A. Dr. Coen's criticism is that the resolution of the WRF modeling I used (1 kilometer) and the WRF modeling that Dr. Fovell used (666 meters) was too low or coarse. She says, for instance, that such resolution simulations "do not resolve the gravity wave breaking that creates the strongest sustained winds and gusty conditions."[3] I believe that the clear implication of Dr. Coen's testimony on this issue is that if we had used higher resolution models, the wind gust speeds produced by the modeling would have been *even higher*. Thus, Dr. Coen's testimony

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[1] Prepared Direct Testimony of Jon A. Peterka on Behalf of San Diego Gas & Electric Company (September 25, 2015) ("Peterka Direct"), pp. 13-19.

[2] Coen Testimony, pp. 7, 18-19.

[3] Coen Testimony, p. 18.

conflicts with Dr. Gershunov's position, which is that the wind speeds generated in my work, and Dr. Fovell's work, are too high. But Dr. Coen's criticism regarding resolution applies even more strongly to Dr. Gershunov's analysis, in which he used 10 kilometer grid spacing, which is ten times lower in resolution than what I used. As discussed further below, that is one of the reasons his modeling produces wind speeds that are too low.

Q. Earlier, you mentioned that the second step in your analysis was wind tunnel testing. Why did you perform wind tunnel testing?

A. As I indicated in my direct testimony, the terrain at each fire ignition site is complex and has an impact on the wind speeds at those locations.[4] I had models of the terrain at each site built, and then used wind data from the WRF model at a height that was just above the height where terrain would have an impact (250 meters). I then used an equation (power law) to bring the wind speed from 250 meters down to the surface at the level of powerline height at each ignition site. This power law takes account of the surface roughness (Zo).[5] Wind direction was accounted for, as were wind gusts, using a gust factor. Ultimately, the use of the wind tunnel, taking into account terrain and topography, generates more accurate information just above ground level than WRF (or any other atmospheric model) standing alone because those models tend to smooth the terrain.

Q. Dr. Coen criticizes the power law profile you used to calculate wind speeds at the height of the powerlines.[6] How do you respond to that criticism?

A. Dr. Coen criticizes my methods, but she then opines that there are no better methods than mine available. My response to these comments is that because wind flow near the ground

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4 Peterka Direct, pp. 6-11.

5 *Id.*

6 Coen Testimony, pp. 12-13.

surface is often well-represented by a power law or log law (even in many complex terrain environments), these are the natural formulas for use in fitting an equation to the measured profile to adapt the mesoscale profile to the shape dictated by the more detailed terrain shape possible near the ground surface in the wind tunnel model. In all cases, the fit was visually observed to ensure there was a reasonable fit to the wind tunnel profile. In order to have a benefit to the accuracy of my solution, it was not necessary to find a trial equation that was a solution to the underlying differential equations of motion of the wind flow as suggested by Dr. Coen.

Q. Dr. Gershunov criticizes your surface roughness calculations.[7] How do you respond to that criticism?

A. I believe Dr. Gershunov has insufficient experience with boundary layer wind tunnel testing and in how surface roughness (Zo) effects are actually determined in nature in order to make this criticism. Based on my experience, a wind flow near the ground surface that has been established over a long, flat upwind fetch, the published values of Zo that he quotes in his testimony are well-known and accepted, and they match very well with those given in Appendix 2. However, when the wind flows over topography that is not flat, the flow undergoes a local acceleration (for example, a wind flow up and over the top of a hill) or a local deceleration (for example, a wind flow down the back side of the hill). The local acceleration (deceleration) in the wind causes a local decrease (increase) in effective Zo value, making those Zo values quoted by Dr. Gershunov inaccurate on non-flat topography like that at the Witch Fire ignition site.

There is a local acceleration in the boundary layer winds over the Witch Fire ignition site for winds from the northeast coming up out of the drainage northeast to east of the Witch Fire

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[7] Gershunov Testimony (Part I), pp. 16-17.

site that causes an effective decrease in Zo value through a change in velocity profile shape similar to the case shown in Appendix 1. Appendix 3 shows that there is a drainage area south of Santa Ysabel in the NE-E sector from the Witch Fire ignition site that causes the wind flow blowing from the directions shown to accelerate as it moves toward the Witch Fire ignition site. The Zo values at all fire sites were determined from the shape of the vertical profile of wind speed measured over the physical model of the terrain in the wind tunnel, and are correctly stated in my testimony based on the shape of the measured local vertical profile. The local change in effective roughness caused by acceleration overpowers the roughness length for the site that would be judged appropriate for the ground surface from Appendix 2.

Someone who uses a wind tunnel in their professional practice as I do can also see this effect in the flow into the wind tunnel test section where a contraction in wind tunnel cross-sectional area causes the wind to speed up, the turbulence magnitude in the contracting section to decrease, and the effective Zo of the flow to also decrease (Rae and Pope, 1984, pp 357-368).

Q. Dr. Coen criticizes your use of a gust factor.[8] How do you respond to that criticism?

A. The peak gust is a key feature in my analysis since it is this speed that causes failures in structures. My experience in measurements in a boundary layer wind tunnel is that in the absence of flow separation at the surface (which did not occur at any of the fire sites), the boundary layer model that drives the analysis I used is generally a reasonable model for gusts. Dr. Coen again had no suggestion for a better method.

Q. Dr. Coen criticizes your use of a wind tunnel with neutral atmospheric stability to simulate a portion of the wind flow.[9] How do you respond to that criticism?

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[8] Coen Testimony, pp. 13-14.

[9] Coen Testimony, pp. 15-16.

A. Dr. Coen appears to be concerned that the wind tunnel has neutral atmospheric stability (*i.e.*, it does not include the thermal structure of the atmosphere observed in a Santa Ana event), and thus cannot correctly replicate all of the Santa Ana wind flow. I agree that the wind tunnel cannot replicate the entire Santa Ana event, but that is why I used a mesoscale model for the simulation that included appropriate thermal effects. This took these thermal effects into account. However, in high speed winds near the ground, the effect of these thermal events is minimal in any event. In those conditions, there is sufficient turbulent mixing associated with surface roughness and topography that any thermal structure near the ground is severely damped by turbulent mixing and becomes essentially neutrally stable and compatible with the wind tunnel neutral stability. Above this well-mixed surface layer, the non-neutral atmospheric characteristics are simulated by the mesoscale model.

Despite Dr. Coen's criticisms, the wind tunnel is a method for increasing the accuracy of the model in the first 200-250 meters above ground where the mesoscale model has smoothed terrain (1 kilometer resolution in my mesoscale model, 667 meters in Dr. Fovell's simulation) relative to the wind-tunnel terrain, which was modeled down to approximately 10 meter resolution. The wind tunnel is then able to resolve wind flow disturbances close to the ground surface due to small terrain features missed by the mesoscale model. My Prepared Direct Testimony showed the changes in wind profile in the 0-250 m range due to wind-tunnel-derived corrections provided modest changes to the mesoscale result.

Q. Are there other criticisms of your analysis to which you would like to respond?

A. Yes. Dr. Gershunov says, "that obstructions around anemometers are different at different stations as they are likely to be different at the three ignition sites (it is implicitly assumed in

Peterka's testimony that ignition sites are unobstructed, which is unlikely)."[10] At the end of the same paragraph, he says, "he did not consider the possible obstructions at ignition sites."[11] From these comments it is evident that Dr. Gershunov believes I have not examined the exposure of the powerline at each of the three fire ignition sites. However, in my direct testimony I list both the effective power law index (n) and the effective surface roughness (Zo) at each fire site:

For example, at the Witch Fire ignition site, the height of the transmission line evaluation point I used was 66 feet above the ground. From Appendix 4, which contains images from my file showing the Witch Fire site, it is evident that there are scattered trees upwind in the NE to E directions with heights well below the height of the lines. From Appendix 2, the site Zo would have a value of 0.1 to 0.5 m. Dr. Gershunov estimated Zo for the Witch site as a "brush or forest-covered surface (≥ 0.5)," indicating he had not closely examined the site since the ground is only partially covered with trees. My wind tunnel profile measurements provided a local effective Zo = 0.02 which is an indication of accelerated wind flow, showing that I did in fact properly evaluate this fire ignition site; the other two fire ignition sites were evaluated in a similar fashion.

III. RESPONSE TO DR. GERSHUNOV'S METHODOLOGY FOR ASSESSMENT OF WIND CONDITIONS

A. The Unreliability of RAWS Data

Q. What is the significance of RAWS data in this case?

A. Following the 2007 Wildfires, the California Department of Forestry and Fire Protection and the Commission's Consumer Protection and Safety Division ("CPSD") used wind speed measurements from RAWS at various locations in San Diego County as a proxy for the wind

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[10] Gershunov Testimony (Part I), p. 14.

[11] *Id*.

speeds at the time and location of each of the Witch, Guejito and Rice Fires.[12] In the Commission's investigation into the Witch, Rice and Guejito Fires (I.08-11-006 and I.08-11-007) CPSD used those proxy wind speed measurements to support its claim that the wind speeds were "well-known Santa Ana winds."[13]

I was hired by SDG&E while the Commission's investigation was ongoing to investigate the wind speeds at the fire ignition sites. I examined the RAWS data and found that it was not representative of the actual wind conditions at any of the fire ignition location sites. In my Prepared Direct Testimony in this case, I further explained my conclusions about the problems with the RAWS data.[14] The primary reason why the RAWS data was unrepresentative of actual wind conditions at the fire ignition sites was because the local terrain and obstructions (e.g., trees, walls, buildings) in proximity to the anemometers caused that data to show significantly lower wind speeds and gusts than what would have occurred at the fire ignition sites.[15] I conducted my own analysis, using the two-step analysis I discussed above, which showed just how understated the RAWS data was.

Dr. Gershunov disputes my conclusions about the unreliability of RAWS data. He attempts to rehabilitate the RAWS data in Part I of his testimony because he needs to use it as a "validation" of the wind modeling he performs – that generates the relatively low wind speeds he presents for the time and location of the ignitions of each of the three fires – in Part II of his testimony.[16] As I discuss below, Dr. Gershunov fails to justify that validation.

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12 *See, e.g.*, Supplemental Direct Testimony of the Consumer Protection and Safety Division Regarding the Formal Witch and Rice Fire Investigations (I.08-11-006), March 20, 2009, p. 1-10.

13 *Id*.

14 Peterka Direct, pp. 13-19.

15 *Id*.

16 Gershunov Testimony (Part II), pp. 5-16.

Q. How does Dr. Gershunov attempt to rehabilitate the RAWS data?

A. Dr. Gershunov says that the anemometer obstructions I discussed have an impact on sustained wind speed measurements, but that those obstructions do not impact wind gust speed measurements.[17] From a common sense perspective, that claim is not sound. If obstructions slow a sustained wind, they will also slow a gust. Furthermore, Dr. Gershunov offers no proof that his claim is accurate.

Q. How do you respond to his statement that his own research shows that observed wind gusts are much less sensitive to obstructions around the anemometer than are sustained winds?[18]

A. Dr. Gershunov points to a research paper by Guzman-Morales, et al.,[19] which is in turn based on a research paper by Brasseur.[20] Those research papers do not, however, support the claim that Dr. Gershunov is making. Dr. Gershunov is claiming that wind gust speeds measured below the height of the tree canopy are representative of wind speed gusts in a wider environment and can be used without modification to represent wind speeds at the fire ignition sites. But the Brasseur paper does not discuss wind gusts within trees and foliage and instead discusses wind gusts that occur above the foliage canopy. My own experience also tells me that Dr. Gershunov is wrong.

Q. Please describe that experience.

A. I have extensive experience with installing and using anemometers in the field, and with siting anemometers to avoid errors in wind data readings. I am the co-author of Appendix 3 of

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17 Gershunov Testimony (Part I), p. 6-9.

18 Gershunov Testimony (Part I), pp. 8-9.

19 Janin Guzman-Morales, et al., "Santa Ana Winds of Southern California: their climatology, extremes, and behavior spanning six and a half decades," Geophysical Research Letters, Research Letter 10.1002/2016GL067887 (March 2016).

20 O. Brasseur, "Development and Application of a Physical Approach to Estimating Wind Gusts," Monthly Weather Review, Vol. 129, January 2001, pp. 5-25.

the Federal Aviation Administration Order 6560.21A (Peterka and Poreh, 1989; Peterka, 1991), which provides guidance for how to site anemometers for the Low Level Windshear Alert System that have been placed off-airport in suburban and/or hilly terrain to detect wind shear for alerting pilots in real time to wind shear events. In addition, I have sited dozens of anemometers to develop weather-related amperage limits for transmission lines. I have also conducted significant research into wind flows around and downwind of obstacles (examples include Peterka et al, 1985; Hunt, Abell, Peterka, Woo, 1975). Based on that experience, I know that wind gust speed measurements are sensitive to local obstructions.

Q. Does Dr. Gershunov attempt to evaluate the accuracy of RAWS anemometers in measuring wind gust speeds?

A. Yes, but his evaluation is faulty. Dr. Gershunov claims that "measured wind speeds (especially gusts) are generally consistent between different [RAWS] stations."[21] But any such consistency does not demonstrate that any particular RAWS station is accurately measuring wind speeds.

Q. Mr. Stannik claims that your criticisms of RAWS data conflicts with Mr. Vanderburg's use of RAWS data in a statistical relationship he analyzes between the Julian RAWS and the SDG&E West Santa Ysabel weather station.[22] How do you respond to that claim?

A. Mr. Stannik is mischaracterizing both my testimony and Mr. Vanderburg's in order to create confusion. He says that I have testified that "all data produced by these sites is unreliable and therefore cannot be used in any analysis."[23] That is not my testimony. I never said RAWS data "cannot be used in any analysis." My testimony is that the wind speed measurements at the

[21] Gershunov Testimony (Part I), p. 14.

[22] Stannik Testimony, pp. 37-38.

[23] Stannik Testimony, p. 38.

RAWS sites cannot be used as a direct proxy for the wind speeds at any of the fire ignition sites. Mr. Vanderburg did not, however, use the Julian RAWS wind speed measurements in such a manner. Rather, he used it as a point of comparison. The Julian RAWS was recording wind speed measurements at the time of the Witch Fire. Mr. Vanderburg realized that the West Santa Ysabel weather station, which was installed after the Witch Fire a few spans away from the fire ignition site (and on the same transmission line) would have provided the best wind speed measurements for the Witch Fire ignition site if it had existed at that time. Thus, he calculated the statistical relationship between Santa Ana wind speeds at the Julian RAWS and the West Santa Ysabel weather station, and based on that relationship, was able to estimate what the wind speeds at West Santa Ysabel would have been in the October 2007 Santa Ana wind event. I think that is a very reasonable analysis (I have done similar analyses in the past), and it does not conflict with any of my conclusions about the reliability of RAWS data. While the Julian RAWS data is biased low, in my opinion, it is consistently biased low, which is why it serves as a reliable comparison data point for Vanderburg's analysis.

B. Dr. Gershunov's Methodology for Estimating Wind Speeds

Q. Please briefly describe your understanding of Dr. Gershunov's methodology for estimating wind speeds at the time and location of the Witch, Guejito and Rice Fire ignitions.

A. Dr. Gershunov relies the CaRD10 dataset, which is based on the Regional Spectral Model developed by Kanamitsu and Kanamaru. CaRD10 is a dataset of climatological variables for California ranging from 1948-2012 which was developed by Kanamitsu and Kanamaru for climate change research. The database was developed from climatological data taken from a global climate change dataset with 100–200 kilometers (approximately 60 to 120 miles) spacing and placed on a 10 kilometer (approximately 6 mile) grid over all of California.[24]

Q. Are there any problems with Dr. Gershunov's use of the CaRD10 dataset?

A. Yes. Dr. Gershunov testified that: "I employ data from an existing integration of a numerical mesoscale model that simulated weather, including wind, at 10x10 km spatial resolution over California recorded at hourly temporal resolution."[25] That statement contains two problems that significantly limit the accuracy of the conclusions in his analysis.

First the development of the CaRD10 dataset was not validated by any physical wind measurement locations in high elevations and higher speed Santa Ana areas, which are the locations in which the Witch, Guejito and Rice Fires occurred. Rather, it used wind measurement locations that were off-shore (buoys) or near-coastal stations that have only lower Santa Ana wind speeds that had marginal correlation between the measured field sites and the completed CaRD10 database (Kanamitsu and Kanamaru, 2007, Figure 1, Table 2c, Table 4). Thus, use of the CaRD10 database by Dr. Gershunov to examine higher speed historical Santa Ana winds at higher elevations in Southern California – *i.e.*, the fire ignition sites in this case – lacks a reasonable basis. This flaw is a reason why his wind speed estimates are far too low.

Q. What is the other problem with Dr. Gershunov's statement?

A. The CaRD10 dataset uses a 10 kilometer grid size. Dr. Fovell (2012) performed experiments with grid size and found that, "Model horizontal grid spacings wider than 2 km were determined in-sufficient to properly capture the terrain shape." My use of 1 kilometer grid spacing is much closer to the 667 meter to 2 kilometer grid spacing used by Fovell (2012) and

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[24] Gershunov Testimony (Part II), pp. 5-16.

[25] Gershunov Testimony (Part II), p. 4.

Cao and Fovell (2013) in their analyses. By using a 10 kilometer dataset, however, Dr. Gershunov does not provide an adequate simulation of Santa Ana wind events.

Q. Why does the 10 kilometer dataset fail to provide an adequate simulation of Santa Ana wind events?

A. Because terrain affects winds by creating downslope winds. Santa Ana winds are downslope winds, as Dr. Coen acknowledges.[26] A 10 kilometer resolution significantly smoothes out the terrain, including mountains and foothills, which mitigates the effect of downslope winds, generating artificially low wind speeds.

Q. Do you have concerns with Dr. Gershunov's attempted validation of the CaRD10 dataset?

A. Yes. In order for the CaRD10 database to represent a long-duration record of RAWS data during Santa Ana events, the CaRD10 dataset must be validated by comparison to a dataset known to be correct. Dr. Gershunov testified that: "[t]he modeled winds were already validated against observations by Guzman Morales et al. (2016)."[27] But the Guzman paper only provides correlation analysis for the RAWS measured data compared to the CaRD10 data, and does not establish either as a reasonably correct dataset. I have discussed above how neither source can be shown to be correct due to shortcomings in each. That these two sources may have some level of correlation does not overcome the fundamental issue that neither can be shown to be valid by itself. At a minimum, Dr. Gershunov must demonstrate that one of the datasets reasonably represents Santa Ana wind speeds, and he has not done this.

Q. Did you validate the analysis you presented in your direct testimony?

[26] Coen Testimony, p. 7.

[27] Gershunov Direct Testimony, Part 2, p. 5.

A. Yes. I discussed my corroboration analysis using the Ramona Airport Automated Observation System. I also noted that Dr. Fovell's analysis, which included its own validation, corroborated my analysis.[28]

Q. Mr. Stannik claims that your analysis has not been independently validated.[29] How do you respond to that claim?

A. As noted, I did perform a validation exercise. Furthermore, both components of my methodology – WRF and wind tunnel testing – have been validated.

IV. RESPONSE TO DR. COEN'S WIND SPEED DATA

Q. Have you reviewed the wind gust measurement data Dr. Coen presents in Section 5 of her testimony?[30]

A. Yes.

Q. Do you have any concerns about that data?

A. Yes, I do. I have researched wind gust speeds for a large majority of the gust records at U.S. over-land stations recorded at National Climactic Data Center ("NCDC") for the period 1948-1990 to produce wind speed maps for structural design of buildings and other structures (Peterka and Shahid (1998)). The design level wind maps resulting from this research have been used by the U.S. National Wind Load Standard ASCE 7 (ASCE -10) in the 1995 through 2010 versions. Investigations into specific high speed entries in the NCDC data archive indicated that almost all recorded gust wind speeds above about 110 mph were erroneous for various reasons. On this basis, there is a high probability that the three largest speeds (ranging from 116 to 164 mph) in Dr. Coen's Table 1 are incorrect. It appears that essentially all of the gust wind speeds

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[28] Peterka Direct, pp. 11-13.

[29] Stannik Testimony, pp. 38-41.

[30] Coen Testimony, pp. 21-24

in this table are, at most, in areas of weak portions of Santa Ana events and are not representative of higher-speed Santa Ana events.

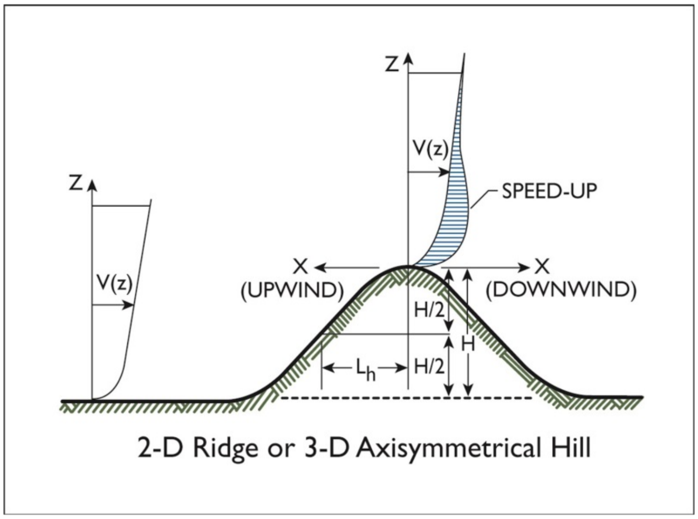
V. CONCLUSION

Q. Does this conclude your prepared rebuttal testimony?

A. Yes, it does.

Appendix 1

APPENDIX 1



Appendix 1. Wind gust acceleration over a hill from ASCE 7-10. The shaded area on top of the hill represents the gust acceleration in comparison to the approaching wind profile. Note that decreases in gust wind speed exist downwind of the hill.

Appendix 2

APPENDIX 2

TABLE C2.1. Neutral Boundary-Layer Parameters

Class	Terrain Description	$(z_0)_r$(m) (1)	N (2)	$1/\alpha$ (3)	I_u(%) (4)	${}^xL_u$ (m) (5)	Exposure (6)	z_g(m) (6)
1	Open sea, fetch at least 5 km	~0.0002	0.10	0.09	9.2	190	D	213
2	Mud flats, snow; no vegetation, no obstacles	0.005	0.13		13.2	140	-	-
3	Open flat terrain; grass, few isolated obstacles	0.03	0.14	0.11	17.2	110	C	274
4	Low crops; occasional large obstacles, $x'/h > 20$	0.10	0.18		21.7	84	-	-
5	High crops; scattered obstacles, $15 < x'/h < 20$	0.25	0.22	0.14	27.1	64	B	366
6	Parkland, bushes; numerous obstacles, $x'/h \sim 10$	0.5	0.29		33.4	55	-	-
7	Regular large obstacle coverage (suburb, forest)	1.0 - 2.0	0.33	0.20	43.4	45	A	457
8	City center with high- and low-rise buildings	=2	0.40 -0.67		-	-	-	-

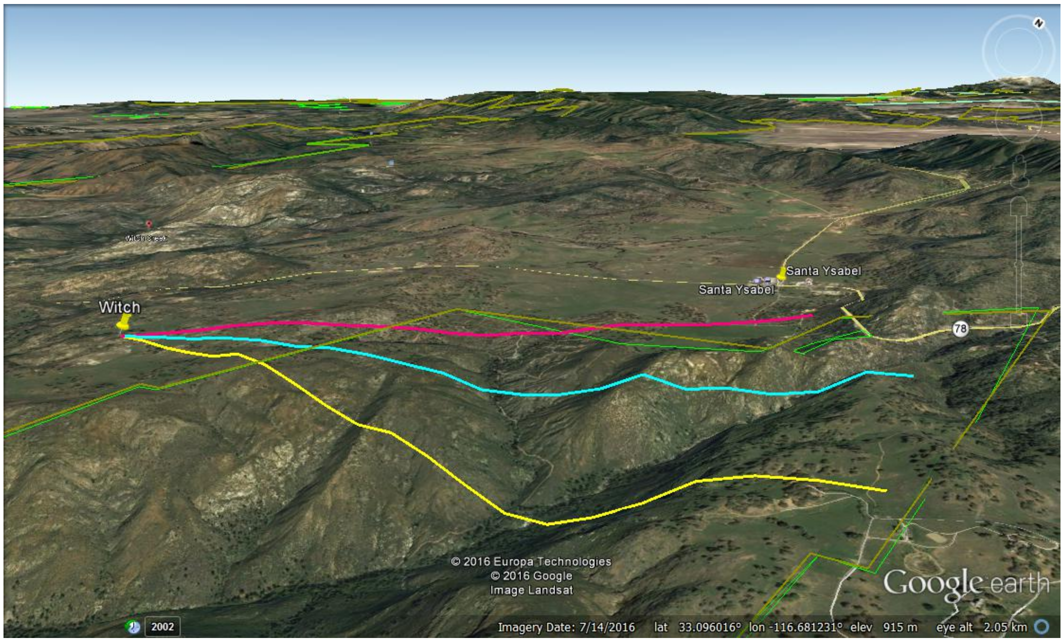
(1) Regional roughness lengths from Wieringa (1992).
(2) Mean velocity power-law exponents from Davenport (1960) and ASCE 7-93.
(3) 3-second gust power-law exponents from ASCE 7-95, ASCE 7-98, ASCE 7-02.
(4) Turbulence intensities for FUR terrain ($z = 10$ m) with the same "local" roughness length according to Eq. C2-6.
(5) Integral lengths of turbulence for $U_{10} = 20$ m/s, $z=10$ m, and $f_c = 1\times10^{-4}$ rad/s from ESDU 85020 (1993).
(6) Exposure categories and gradient heights from ASCE 7.
Note: x' is typical spacing between obstacles.

Mean velocity profiles in the ASL are given by the well established logarithmic distribution

Appendix 2. Table of roughness length Zo and roughness power law exponent N as they vary with ground surface roughness. Other parameters associated with the atmospheric boundary layer are also shown. Table is from ASCE 49-12 (2012), page 22. Roughness lengths Zo in this table were taken from Wieringa (1992), while mean velocity power law exponents N were taken from Davenport (1960).

Appendix 3

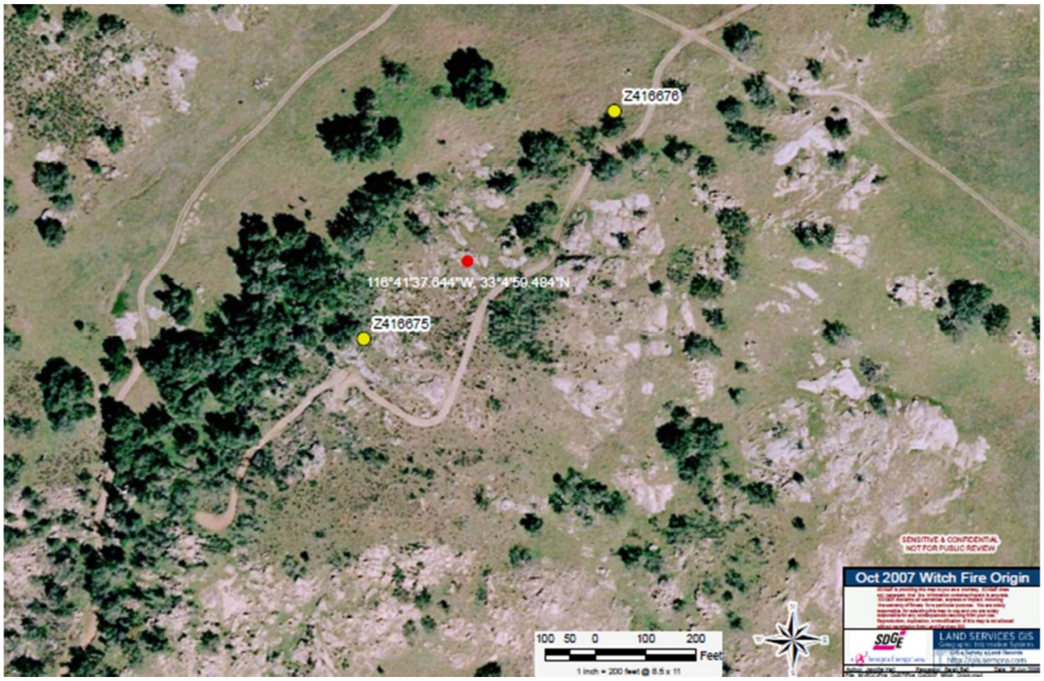
APPENDIX 3



Appendix 3. Lines are on ground topography emanating from the Witch fire site traveling toward the northeast (maroon), east-northeast (blue), and east (yellow). View point is about 2 km above ground surface looking generally northwest. Each line is 3.2 km long. The image shows that wind from these directions blowing toward the Witch site pass through the drainage area south of Santa Ysabel before rising up to the plateau where Witch is located.

Appendix 4

APPENDIX 4

a) 

b) 

Appendix 4. a) Witch fire site plan view produced by SDGE; red dot is fire ignition location; yellow dots are pole locations. b) photo taken by Peterka at Witch site looking northeast along the power line. Note the foliage height is significantly below line height, and the density of trees is scattered.

Appendix 5

Appendix 5 – References

[1] ASCE 7–10, American Society of Civil Engineers (2010), Minimum Design Loads for Buildings and Other Structures (ASCE 7–10). The same information is contained in other previous aversions of the standard: ASCE 7-95, ASCE 7-98, and ASCE 7-05.

[2] Cao, Y. and R.G. Fovell (2013), Predictability and Sensitivity of Downslope Windstorms in San Diego County, 15th Conference on Mesoscale Processes, Portland, OR.

[3] ASCE 49-12, American Society of Civil Engineers Standard 49-12 (2012), Wind Tunnel Testing for Buildings and Other Structures.

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