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Report on Thunderstorm Rainfall and Winds at 456 Main Street, Anytown, Florida on June 4, 2019

Prepared for:
XYZ Firm, LLC
123 Elm Street
Anytown, NE 5555

Prepared by:
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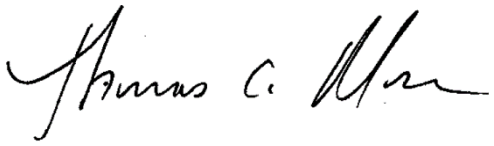
December 8, 2019

This report is subject to revisions based on new information and data if any becomes available

This is a report of strong thunderstorm that occurred at 456 Main Street, Anytown, Florida on June 4, 2019, bringing torrential rainfall and gusty winds to the location. The analysis, findings and opinions in this report are based on all relevant weather and other data records available at the time the report was written. This report has been prepared for use with this specific case only, and is subject to revision based on new information and data if any becomes available.

This report was prepared by Thomas C. ("TC") Moore, Certified Consulting Meteorologist (CCM). Mr. Moore has been a practicing meteorologist for over 30 years, and specializes in providing forensic meteorological services for a wide variety of clients as President, Atlantic States Weather. Clients of this firm have included the U.S. Department of Justice, the North Carolina Attorney General's Office, and over 100 law offices and other clients representing both plaintiffs and defendants in legal cases in 26 states, the District of Columbia, Puerto Rico, the United Kingdom, and Greece.

Submitted by,



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Raleigh, North Carolina
December 8, 2019

I. Summary

During late afternoon hours of June 4, 2019, a slow-moving thunderstorm produced intense rainfall and gusty winds at 456 Main Street, Sometown, FL (hereafter referred to as “the property”).

This thunderstorm remained over the property for a period of up to 40 minutes, producing rainfall rates as high 3.75” per hour. Approximately 2” of rain fell at the property, in less than an hour’s time. The intensity of rainfall experienced at the property on June 4, 20197 occurs relatively infrequently.

Winds associated with this storm gusted to approximately 50 mph at the property.

II. Report Preparation Process

Three sources of data were analyzed to determine the rainfall at the property on June 4, 2019.

National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Hydrometeorological Design Studies Center Precipitation Frequency Data Server

The Precipitation Frequency Data Server (PFDS) is a point-and-click interface developed to deliver NOAA Atlas 14 precipitation frequency estimates and associated information. Upon clicking a state on the map above or selecting a state name from the drop-down menu, an interactive map of that state will be displayed, and a location can be identified for which precipitation frequency estimates are needed. For this report, PFDS data for Sometown, FL was reviewed.

NOAA Archive Information Request System (AIRS) Service Records Retention System (SRRS) Text Products/Bulletin Selection.

The NOAA AIRS SRRS archives text products and bulletins issued by NWS offices around the country. For this report, “Special Weather Statements” issued by the Tampa Bay/Ruskin FL NWS office for June 4, 2019, were reviewed.

Doppler Radar Imagery

The NEXRAD or Nexrad (Next-Generation Radar) is a network of 159 high-resolution Doppler weather radars operated by the NWS, the Federal Aviation Administration (FAA), and the U.S. Air Force within the Department of Defense (DOD). Its technical name is WSR-88D (Weather Surveillance Radar, 1988, Doppler). These

NWS Doppler radars generate numerous products to help analyze the weather for a specific time and location. For this report, seven types of products from the Tampa, FL Doppler rate site were reviewed.

The most familiar product is called "*Base Reflectivity*" and is what you see on television or on the Internet. The radar sends out a pulse of energy and when it hits precipitation, part of the energy is reflected back to the radar. Colors on the radar imagery represent the strength of returned energy to the radar expressed in values of decibels (dBZ); as dBZ values increase so does the intensity of the rainfall. For areas of light precipitation, less of the energy is returned, and is indicated on base reflectivity products as the "cool" colored pixels (blue, green). As the precipitation gets heavier, more of the energy is returned to the radar and is shown as increasingly "warm" colored pixels (yellow, orange, red) in the image. The color scale is located in the lower right of each image.

"*Composite Reflectivity"* is the maximum base reflectivity value that occurs in a given vertical column in the radar coverage. NWS Doppler radars scan in several pre-defined "volume coverage patterns" (VCPs), where the radar makes a 360-degree horizontal sweep with the radar antenna tilted at a given angle above the horizontal, then changes the elevation angle, and completes another 360-degree sweep, and so on. Composite reflectivity gives a plan view (i.e., projected on a horizontal plane) of the most intense portions of thunderstorms, and can be compared with base reflectivity products to help determine the 3-D structure of a thunderstorm. Similar to base reflectivity products, red and purple pixels in composite reflectivity products indicate very heavy precipitation (greater than 50 dBZ energy return).

"*Instantaneous Precipitation Rate":* The Digital Instantaneous Precipitation Rate product (DPR) provides a grid of instantaneous precipitation rate values calculated from the radar's Quantitative Precipitation Estimation (QPE) algorithm, and is formatted as a digital data array. This product is used to pick out areas where the heaviest rain is occurring at the current time, and assists forecasters in monitoring for flash-flood potential.

"One-Hour Accumulation": The One-Hour Accumulation product (OHA) provides the hourly precipitation accumulation on a 2 km (1.1 nm) x 1° grid within 230 km (124 nm) of the radar. The product is updated once per volume scan by the QPE algorithm to provide the precipitation accumulation for the past 60 minutes. This product is used to assess changes in precipitation intensity in time and space, and for flood and flash flood watches, warnings, and statements.

"Digital Storm Total Precipitation": The Digital Storm Total Accumulation (DSA) product is a display of continuously updated radar-estimated storm total precipitation accumulations within 230 km (124 nm) of the radar. The DSA is calculated from the radar's Quantitative Precipitation Estimation (QPE) algorithm, and has data available in 256 data levels. The storm total precipitation is defined as the accumulation since the beginning of the storm event.

"*Velocity Azimuth Display (VAD) Wind Profile (VWP)":* The VWP product is based on the VAD product, which is a graphical presentation of the VAD algorithm processing logic for the particular altitude. This VAD presentation is a data plot of mean radial velocity values versus azimuth angle for one specific reporting altitude along with the best-fit sine wave curve that is used to compute the horizontal wind speed and direction. The VWP in turn, is a graphic display of wind barbs plotted on a height scale in 1,000-foot increments. The current plot (far right) and up to 10 previous plots may be displayed simultaneously on a time versus height scale. Wind speed and direction for up to 30 altitudes are displayed as wind barbs on a height scale. All altitudes are referenced to mean sea level. Wind speed and direction are reported to the highest altitude with sufficient signal available for processing by the VAD algorithm. If the VAD derived wind estimate at a given height is invalid (i.e., failed threshold for RMS, symmetry, or number of points), winds for that height is reported as "ND". The VWP product can be used in conjunction with other radar products to determine likelihood of strong winds at the surface. For this report, the VWP Products from the Tampa, FL NWS Radar for June 4, 2019 were reviewed.

"Echo Tops": The Echo Tops product provides the estimated height of the 18.5 dBZ (default) energy return (roughly correlated with precipitation), as estimated by the Echo Tops algorithm, and rounded to the nearest 5,000 ft MSL for display. While subject to errors resulting from radar beam and atmospheric characteristics, the Echo Top product can provide a rough estimate of the height of the storm, and particularly, the height at which precipitation is occurring. Echo Top heights can differ significantly from visual cloud top height.

III. Analysis of Rainfall and Wind Gusts Associated with a Thunderstorm at 456 Main Street, Anytown, Florida on June 4, 2019

a. Rainfall Analysis

A very narrow broken line of slow-moving thunderstorms, oriented north-south, developed over central Florida during the late afternoon of June 4, 2019. Due to the broken nature of the line of storms, and their north-south orientation, the rainfall from these storms was not adequately measured by any airport observing equipment near the property. Therefore, in order to assess the rainfall amounts at the property, Doppler radar products from the Tampa, FL NWS radar site were interrogated.

At approximately 5:30 pm EDT, June 4, 2019, one these thunderstorms moved over the property. The core of this storm, and thus the heaviest rainfall, then remained nearly stationary over the property for a period of up to 40 minutes. Figures 1 and 2 show composite reflectivity radar images for this period. The red pixels, indicating energy returns of 50 dBZ or greater, are associated with rainfall rates of approximately 2"/hour.

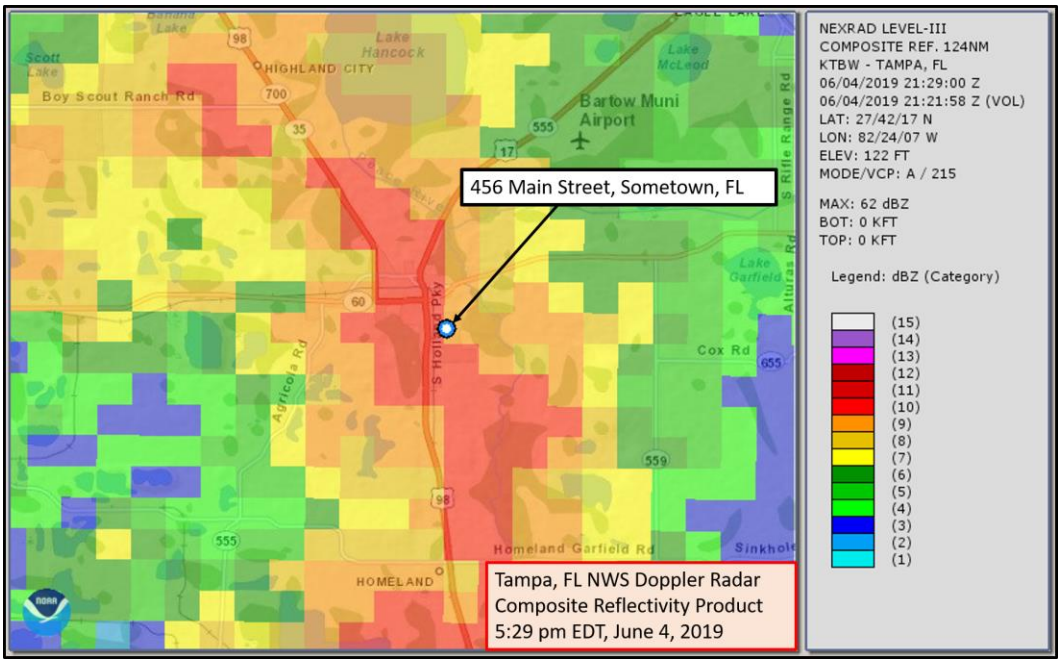

Fig. 1: *Tampa, Fl Doppler radar composite reflectivity image at 5:29 pm EDT (June 4, 2019), at the time the heaviest rain began falling at the property*

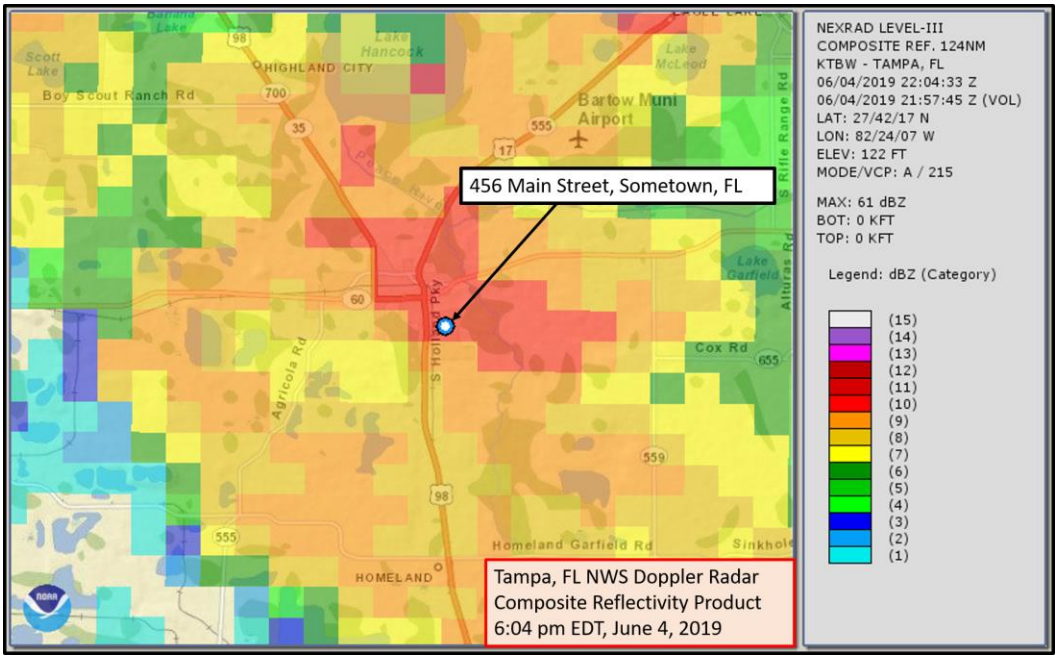

Fig. 2: *Tampa, Fl Doppler radar composite reflectivity image at 6:04 pm EDT (June 4, 2019), at time the heaviest rain was ending at the property*

Precipitation rates during the storm, derived from Doppler radar data, were as high as 3 to 4" per hour over the property. Figure 3 shows an instantaneous precipitation rate product from the Tampa NWS Doppler radar at 5:56 pm EDT on June 4, 2019, and indicates a precipitation rate of approximately 3.75"/hour at that time. This was the highest precipitation rate indicated by radar during the storm.

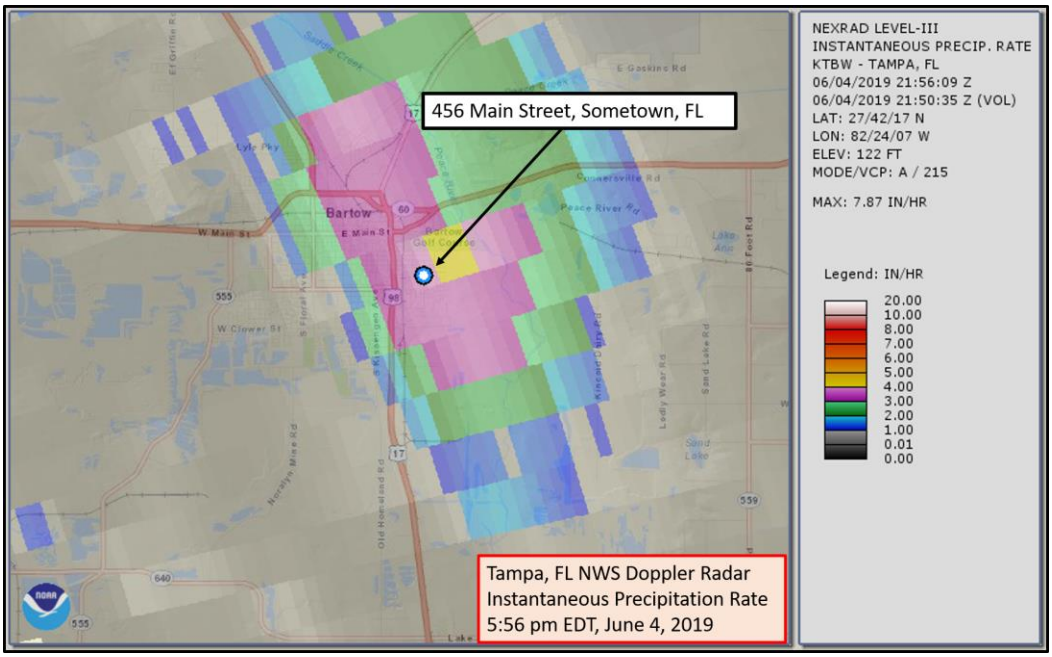

Fig. 3: *Tampa, Fl Doppler radar instantaneous precipitation rate image at 5:56 pm EDT (June 4, 2019)*

This is a radar-derived (calculated) product, and as such may differ from the actual rainfall rate that occurred at the property. However, it is generally representative of the thunderstorm conditions, and is indicative of the torrential nature of the rainfall associated with this storm.

Assuming a maximum precipitation rate precipitation of 3.75”/hour, and assuming precipitation fell at this rate over the property for approximately 40 min, then the calculated maximum precipitation total for the property is approximately 2.5”. However, the average rainfall rate during storm was lower than the highest instantaneous rate, and therefore the total rainfall from this storm was less than 2.5”.

Figure 4 shows a “Digital Storm Total Precipitation” product calculated by the Tampa NWS radar for this storm; this product indicates that a little over 2” of rain fell at the property during this storm.

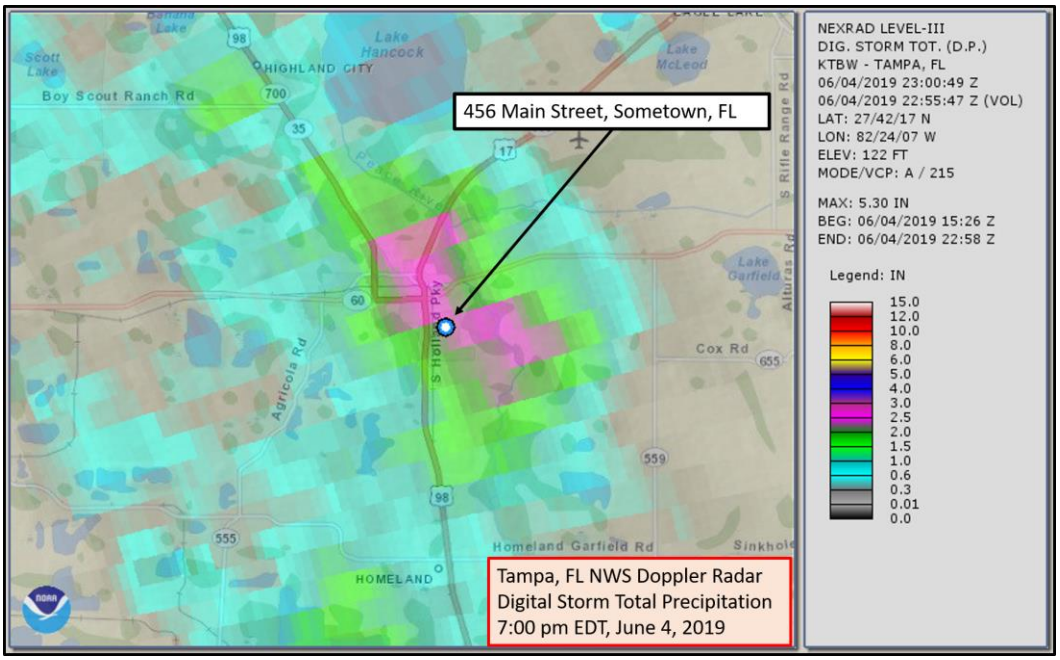

Fig. 4: *Tampa, Fl Doppler digital storm total precipitation image valid at 7:00 pm EDT (June 4, 2019)*

There are several additional “one-hour total” and “storm total precipitation” products available from the Tampa, FL Doppler radar, each using slightly different algorithms and calculations. These products (not shown) show a range of 1.5” to 2.5” of total rainfall associated with this storm at the property.

Taking all the Tampa NWS Doppler radar data products into account, it is estimated that approximately 2” of rain fell on the property in less than an hour.

To assess how frequently rainfall rates of 2”/hour occur at Sometown, PFDS data

was reviewed. Table 1 is a chart showing PFDS precipitation rate frequency estimates for Sometown FL, and provides estimates of the average recurrence interval (in years) for a specific rainfall rate. Per the chart, a rainfall rates of 2" in less than an hour would be expected only once every 1-2 years, indicating that the intensity of rainfall experienced at the property on June 4, 2019, is relatively infrequent.

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 9, Version 2

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	6.30 (5.15-7.58)	7.10 (5.80-8.57)	8.35 (6.79-10.1)	9.34 (7.54-11.4)	10.6 (8.22-13.3)	11.5 (8.74-14.8)	12.3 (9.06-16.5)	13.1 (9.24-18.3)	14.1 (9.53-20.4)	14.7 (9.74-22.0)
10-min	4.61 (3.76-5.56)	5.20 (4.24-6.28)	6.12 (4.97-7.41)	6.83 (5.52-8.33)	7.76 (6.02-9.76)	8.42 (6.40-10.8)	9.04 (6.63-12.1)	9.62 (6.76-13.4)	10.3 (6.98-14.9)	10.8 (7.14-16.1)
15-min	3.75 (3.06-4.52)	4.23 (3.45-5.10)	4.98 (4.04-6.02)	5.56 (4.49-6.77)	6.31 (4.90-7.94)	6.85 (5.20-8.82)	7.35 (5.39-9.81)	7.82 (5.50-10.9)	8.39 (5.67-12.1)	8.78 (5.80-13.1)
30-min	2.88 (2.35-3.47)	3.25 (2.65-3.92)	3.83 (3.11-4.64)	4.28 (3.46-5.22)	4.87 (3.78-6.13)	5.29 (4.01-6.81)	5.68 (4.16-7.57)	6.04 (4.25-8.39)	6.48 (4.38-9.37)	6.79 (4.48-10.1)
60-min	1.87 (1.53-2.25)	2.11 (1.72-2.55)	2.49 (2.03-3.02)	2.80 (2.26-3.41)	3.21 (2.50-4.05)	3.51 (2.67-4.54)	3.81 (2.80-5.10)	4.10 (2.88-5.71)	4.46 (3.02-6.47)	4.73 (3.12-7.05)
2-hr	1.15 (0.950-1.37)	1.30 (1.07-1.55)	1.53 (1.26-1.84)	1.73 (1.41-2.09)	1.99 (1.57-2.50)	2.19 (1.68-2.81)	2.39 (1.77-3.18)	2.58 (1.84-3.58)	2.84 (1.94-4.10)	3.03 (2.02-4.49)
3-hr	0.832 (0.691-0.988)	0.937 (0.777-1.11)	1.11 (0.919-1.33)	1.26 (1.03-1.51)	1.47 (1.17-1.84)	1.63 (1.26-2.10)	1.80 (1.34-2.40)	1.97 (1.41-2.73)	2.20 (1.51-3.18)	2.38 (1.59-3.52)
6-hr	0.476 (0.400-0.560)	0.535 (0.449-0.630)	0.640 (0.535-0.756)	0.735 (0.611-0.874)	0.877 (0.709-1.11)	0.996 (0.783-1.28)	1.12 (0.851-1.50)	1.26 (0.912-1.75)	1.46 (1.01-2.10)	1.61 (1.08-2.36)
12-hr	0.270 (0.230-0.315)	0.304 (0.258-0.354)	0.367 (0.311-0.430)	0.428 (0.360-0.505)	0.525 (0.431-0.663)	0.609 (0.485-0.783)	0.702 (0.538-0.935)	0.804 (0.589-1.11)	0.953 (0.668-1.37)	1.08 (0.728-1.57)
24-hr	0.155 (0.133-0.179)	0.175 (0.150-0.202)	0.213 (0.183-0.248)	0.252 (0.214-0.294)	0.314 (0.262-0.397)	0.370 (0.298-0.474)	0.432 (0.335-0.573)	0.501 (0.370-0.692)	0.603 (0.426-0.865)	0.688 (0.468-0.995)
2-day	0.089 (0.078-0.102)	0.101 (0.087-0.115)	0.124 (0.107-0.142)	0.146 (0.126-0.169)	0.183 (0.154-0.229)	0.216 (0.176-0.274)	0.252 (0.197-0.333)	0.293 (0.219-0.402)	0.354 (0.252-0.504)	0.404 (0.277-0.581)
3-day	0.066 (0.058-0.075)	0.074 (0.065-0.084)	0.090 (0.079-0.103)	0.106 (0.092-0.122)	0.132 (0.112-0.164)	0.155 (0.127-0.195)	0.180 (0.141-0.235)	0.208 (0.155-0.283)	0.249 (0.178-0.353)	0.283 (0.195-0.405)
4-day	0.054 (0.047-0.061)	0.060 (0.053-0.068)	0.073 (0.064-0.083)	0.085 (0.074-0.098)	0.105 (0.089-0.129)	0.122 (0.100-0.153)	0.141 (0.111-0.183)	0.162 (0.121-0.220)	0.193 (0.138-0.272)	0.218 (0.150-0.311)
7-day	0.037 (0.033-0.042)	0.042 (0.037-0.047)	0.050 (0.044-0.056)	0.057 (0.050-0.065)	0.069 (0.058-0.083)	0.078 (0.065-0.097)	0.089 (0.071-0.115)	0.101 (0.076-0.135)	0.118 (0.085-0.165)	0.131 (0.091-0.187)
10-day	0.030 (0.027-0.034)	0.034 (0.030-0.038)	0.040 (0.035-0.045)	0.045 (0.040-0.051)	0.053 (0.046-0.064)	0.060 (0.050-0.074)	0.068 (0.054-0.087)	0.076 (0.057-0.101)	0.087 (0.063-0.121)	0.096 (0.067-0.136)
20-day	0.021 (0.019-0.024)	0.024 (0.021-0.026)	0.027 (0.024-0.030)	0.030 (0.027-0.034)	0.035 (0.030-0.041)	0.038 (0.032-0.046)	0.042 (0.034-0.053)	0.046 (0.035-0.060)	0.051 (0.037-0.070)	0.055 (0.039-0.078)
30-day	0.018 (0.016-0.020)	0.020 (0.018-0.022)	0.023 (0.020-0.025)	0.025 (0.022-0.028)	0.028 (0.024-0.033)	0.031 (0.026-0.037)	0.033 (0.027-0.041)	0.036 (0.027-0.047)	0.039 (0.029-0.054)	0.042 (0.029-0.059)
45-day	0.015 (0.014-0.016)	0.016 (0.015-0.018)	0.019 (0.017-0.021)	0.021 (0.019-0.023)	0.023 (0.020-0.027)	0.025 (0.021-0.030)	0.027 (0.022-0.034)	0.029 (0.022-0.037)	0.031 (0.023-0.042)	0.033 (0.023-0.046)
60-day	0.013 (0.012-0.014)	0.015 (0.013-0.016)	0.017 (0.015-0.018)	0.019 (0.017-0.020)	0.021 (0.018-0.024)	0.022 (0.019-0.026)	0.024 (0.019-0.029)	0.025 (0.019-0.032)	0.027 (0.020-0.036)	0.028 (0.020-0.039)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Table 1: *Precipitation Frequency (Inchers/Hour) Estimates for Sometown, FL (90% Confidence Intervals)*

b. Wind Gust Analysis

A detailed analysis of the structure of the thunderstorms near and over the property on June 4, 2019 shows that a combination of intense rainfall, storm height, and upper level winds led to wind gusts of up to 50 mph at the property.

Figure 5 shows a Tampa, FL Doppler radar VWP product, valid for the time of the storm. The product indicates that winds of up to 58 to 75 mph were blowing from the northwest at an altitude of 35,000 to 40,000 feet, at the time the thunderstorm was over the property.

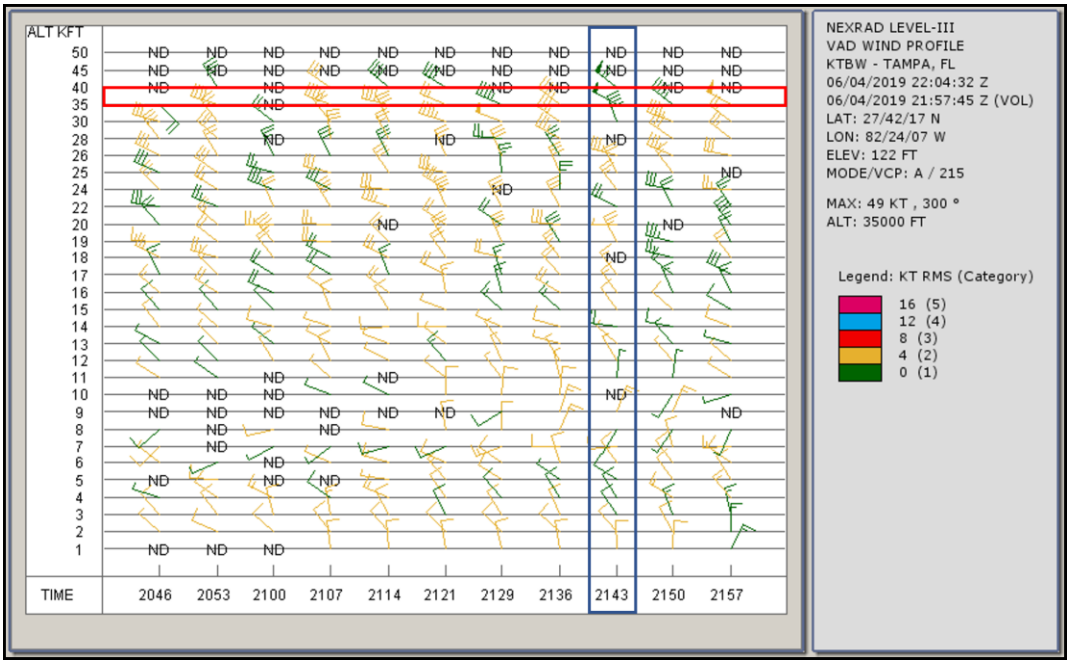

Fig. 5: *Tampa, Fl Doppler radar VWP image at 6:04 pm EDT (June 4, 2019) and showing winds at various altitudes for the previous hour. The barbed pennants at 35K and 40K feet altitude and valid at 5:43 pm EDT indicate winds of up to 50 to 65 knots (58 to 75 mph)*

A review of Echo Top products (not shown) indicates that heavy precipitation (possibly including small hail) was occurring at altitudes of up to 45,000 feet. Thus, this heavy precipitation was falling through the upper level winds of 58 to 75 mph at an intense enough rate to transfer up to 50% of those wind speeds (i.e., up to 50 mph) to the surface.

This assessment is validated by a Tampa Bay/Ruskin, FL NWS "Special Weather Statement" during the late afternoon on June 4, 2019, warning of the presence of thunderstorms capable of producing wind gusts of up to 50 mph for many locations in center Florida, to include Sometown. Figure 6 shows the Special Weather Statement, with both the warning for wind gusts, and Sometown as a specific impacted location, highlighted.

NWS SRRS PRODUCTS FOR: 2019060300 to 2019060600 WWUS82 KTBW 041955
SPSTBW Special

TBW WWUS82 KTBW 042046 SPSTBW Special Weather Statement National Weather Service Tampa Bay Area Ruskin FL 446 PM EDT Tue Jun 4 2019
FLZ052-056-057-061-251-255-042130- Inland Manatee FL-DeSoto FL-Highlands FL-Polk FL-Hardee FL- Inland Hillsborough FL

- 446 PM EDT Tue Jun 4 2019 ...

SIGNIFICANT WEATHER ADVISORY FOR SOUTHWESTERN HIGHLANDS... HARDEE...NORTHEASTERN MANATEE...SOUTHWESTERN POLK...EASTERN HILLSBOROUGH AND DESOTO COUNTIES UNTIL 530 PM EDT...

At 444 PM EDT, Doppler radar was tracking thunderstorms along a line extending from Lakeland to near Wauchula to 10 miles east of Southeast Arcadia. Movement was south at 5 mph. Thunderstorms are expected to intensify through 530 PM and will be capable of producing strong gusty winds and hail. Half inch hail and wind gusts up to 50 mph will be possible with these storms.

Locations impacted include... SOMETOWN, FL

Fig. 6: *Tampa Bay/Ruskin, FL NWS Special Weather Statement valid 4:46 pm EDT until 5:30 pm DT.*

Note that this Special Weather Statement also warns for half inch hail, indicative of the strong vertical motions within these thunderstorms. In addition, this statement highlights the 'torrential rainfall' associated with these thunderstorms, as discussed previously in this report.

IV. Findings and Opinions

- Torrential rainfall associated with a slow-moving thunderstorm occurred at the property on June 4, 2019
    - Instantaneous rainfall rates as high as 3.75”/hour occurred at the property
    - Approximately 2” of rain fell at the property in less than an hour
    - Rainfall rate occurrences of this intensity are relatively infrequent at the property
- Wind gusts of up to 50 mph impacted the property

V. References

National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Hydrometeorological Design Studies Center Precipitation Frequency Data Server: Data for Sometown, FL. Available online at https://hdsc.nws.noaa.gov/hdsc/pfds/

National Weather Service Online Weather School (Jetstream): Reflectivity Radar Products. Available online at: https://www.weather.gov/jetstream/refl

NOAA Archive Information Request System (AIRS) Service Records Retention System (SRRS) Text Products/Bulletin Selection. Special weather Statements from the Tampa Bay/Ruskin, FL NWS office for June 4, 2019. Available online at https://www.ncdc.noaa.gov/has/HAS.StationYearSelect?datasetname=9957ANX&subqueryby=STATION&applname=SRRSBTNSEL&outdest=APPS&dtypesort=dtypeord&stationsort=id

NOAA/National Centers for Environmental Information, NCEI: NWS Tampa, FL Doppler radar images June 4, 2019. Available online at: https://www.ncdc.noaa.gov/nexradinv/