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**Hurricane Isabel (2003)
Wind Study of the Doubletree Hotel
Norfolk Airport, Norfolk VA**

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1. Hurricane Isabel Overview

Hurricane Isabel was a 2003 mid-season tropical system that affected the North Carolina and Virginia regions on September 18, 2003. The storm began its life as a tropical depression near the Cape Verde Islands on September 6. The system quickly intensified and reached hurricane strength on September 7 as it moved steadily westward across equatorial North Atlantic.

Isabel strengthened to a Category 5 hurricane on September 11 with maximum sustained winds estimated at 145 knots at 1800 UTC that day. After this peak, the maximum winds

remained in the 130-140 knot range until September 15. The storm then gradually weakened over the next two days as environmental conditions became unfavorable. Isabel was downgraded to a category 3 storm on September 16. On September 18 Isabel came ashore near Fort Drum, North Carolina around 1700 UTC (1200 EDT) as a category 2 storm.

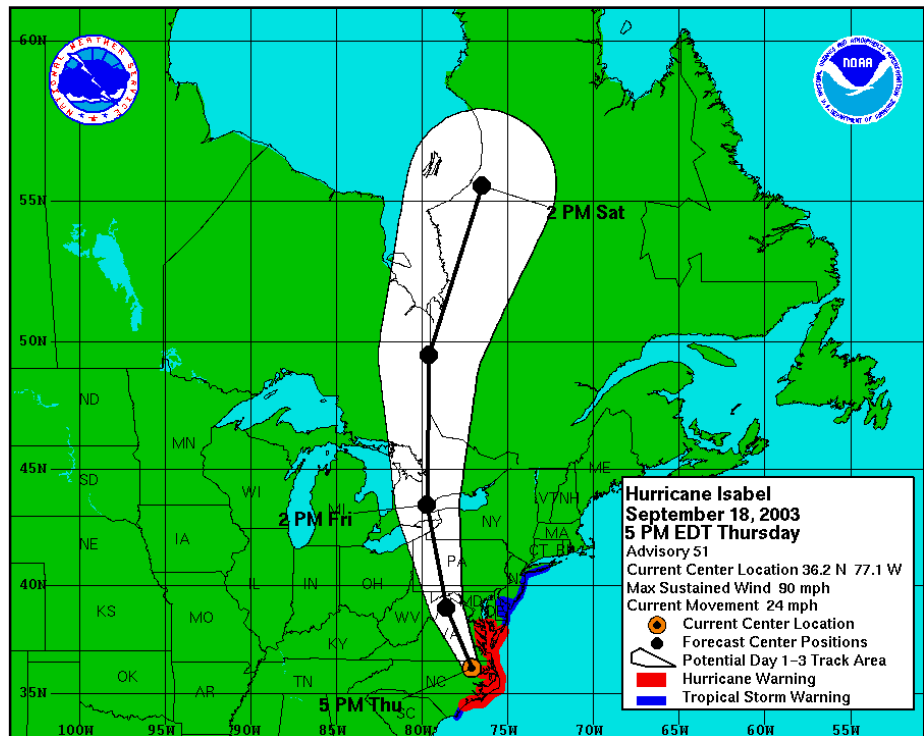


Figure 1: Hurricane Isabel forecast tract 5 PM September 18

After landfall, Isabel continued to steadily weaken and move northwestward over North Carolina, and Virginia and then northward into the Great Lake region. Isabel is considered to be one of the most significant tropical cyclones to affect portions of northeastern North Carolina and east-central Virginia since Hurricane Hazel in 1954 and the Chesapeake-Potomac Hurricane of 1933. Isabel is directly responsible for 16 deaths: 10 in Virginia, and 1 each in North Carolina, Maryland, New Jersey, New York, Rhode Island, and Florida. The deaths in Florida and Rhode Island were drownings in high surf generated by Isabel. Isabel was indirectly responsible for 34 deaths: 22 in Virginia, 6 in Maryland, 2 in North Carolina and Pennsylvania, and 1 each in New Jersey and the District of Columbia.

Isabel caused widespread wind and storm surge damage in coastal eastern North Carolina and southeastern Virginia. Storm surge damage also occurred along Chesapeake Bay and the associated river estuaries, while wind damage occurred over portions of the remaining area from southern Virginia northward to New York. The estimate for insured property damage is \$1.685 billion - \$925 million in Virginia, \$410 million in Maryland, \$170 million in North Carolina, \$80 million in Pennsylvania, \$45 million in New York, \$25 million in New Jersey, \$20 million in Delaware, and \$10 million in West Virginia. The total damage for Isabel is estimated to be about twice that of the insured damage, or \$3.37 billion (National Hurricane Center, 2004).

2. Hurricane Isabel Wind Study

This study will focus on the wind field of the hurricane that affected the Hampton Roads area, in particular the site of the Doubletree Hotel Norfolk Airport, Norfolk, Virginia. In addition to analyzing the surface winds, those winds that occur at a standard reporting height of 33 feet, an analysis of the vertical wind profile at the site will also be performed since the Doubletree Hotel is a high-rise building, with fourteen floors,

Hurricane Isabel's track brought it to the south of the Hampton Roads region at 2 PM on September 18, as it moved over the Pamlico Sound of North Carolina. The system continued northwestward through North Carolina and reached its closest point of approach to the Doubletree Hotel Norfolk Airport around 5 PM, at a distance of approximately 66.8 miles (figure 2). The system moved into Virginia around 7 PM, and then began moving northward toward the Richmond area where it arrived late in the evening of the 18th.

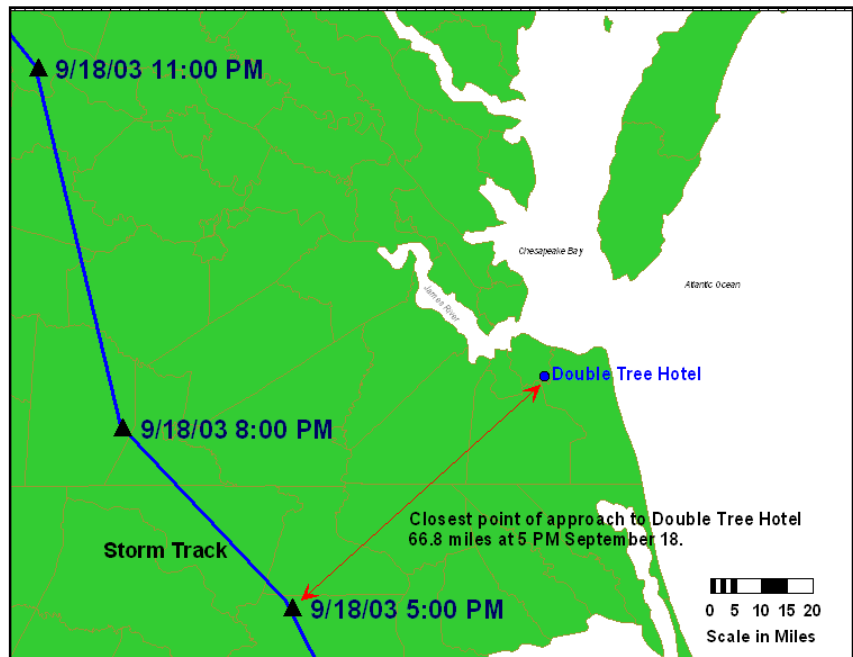


Figure 2: Hurricane Isabel track position on September 18

To examine the wind field produced by Isabel that affected the Doubletree Hotel, all recorded weather observations from National Weather Service and U.S. Military sites within 50 miles of the Doubletree site (dashed circle in figure 3) were reviewed and quality control checked. This process revealed that although there were almost a dozen sites that could have potentially been used for the study, only five sites consistently reported observations during the period. Several factors influenced weather reporting during this period, including a wide scale loss of power throughout the region, and the loss of sensors that were carried away by the storm. The five sites used for this study are listed in table 1, and are indicated on figure 3 with a light blue dot. Observers primarily take all of the observations at these stations, with the exception of the Newport News station, which solely uses an automated system. In addition, limited data from two public sites were also analyzed in this study. While these sites were not official weather observing stations, the data agreed well with local official sites, and the proximity of these two sites to the location of interest, enabled the data to provide further insight into conditions at the Doubletree on September 18, 2003. These two sites are indicated with gray dots on figure 3.

Table 1: Weather Observation Sites Used for Study

Site (station callsign)	Latitude	Longitude	Distance to Doubletree Hotel Norfolk Airport (miles)
Norfolk International Airport (KORF)	36.9 N	76.19 W	3.59
Fred Heutte Center, Norfolk – Ghent (FHU)	36.86 N	76.29 W	4.37
Norfolk Naval Air Station (KNGU)	36.93 N	76.3 W	7.34
Portsmouth Weather Record Service, Portsmouth VA (PWRS)	36.80N	76.33 W	7.45
Oceana Naval Air Station (KNTU)	36.82 N	76.03 W	10.28
Langley Air Force Base (KLFI)	37.08 N	76.35 W	17.55
Newport News / Williamsburg Airport (KPHF)	37.13 N	76.49 W	24.64

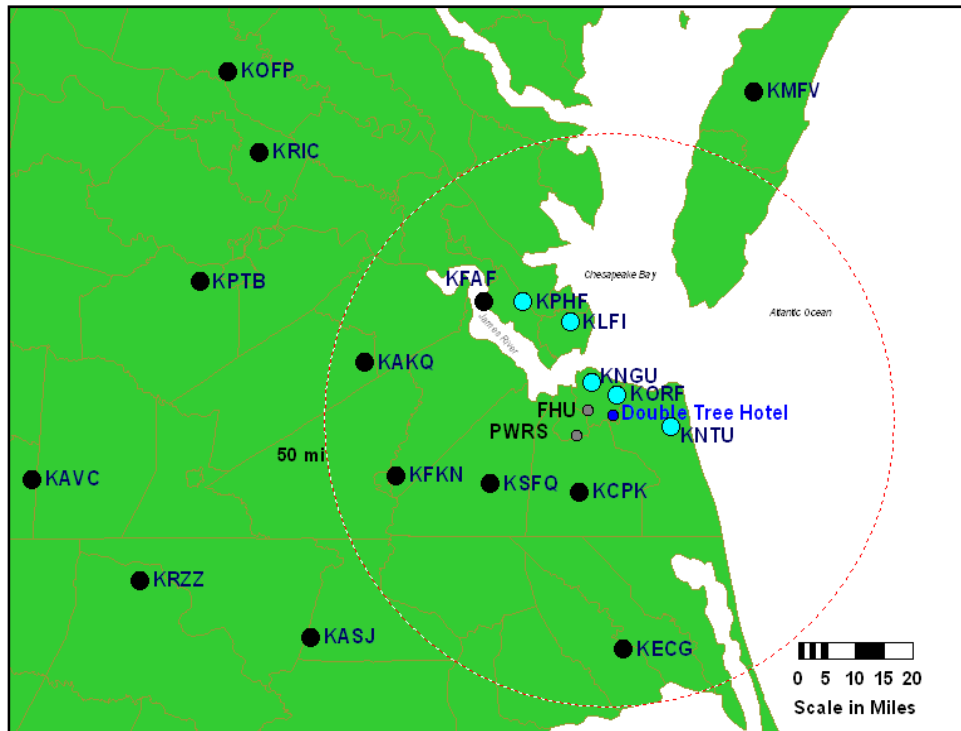


Figure 3: Weather Observing Sites

An independent review of each station’s weather observations was accomplished to determine the conditions that were most likely seen at the Doubletree Hotel. The raw weather observations from each site were individually reviewed, and quality control checked. Particular attention was made to any remarks included in the weather observation by the observer. Weather element data was then parsed electronically from each observation. This data was used to produce a time series of pertinent weather elements; sustained wind speed, sustained wind direction, wind gusts, and peak winds, for each site. Finally, graphs were produced that overlaid the weather element time series for all observation sites for expert examination to gain an understanding of the wind field at the hotel. In addition, individual spot weather observations of other locations in the region were reviewed to further amplify this analysis. Several of these observations provided insight into overall wind field that affected the hotel.

2.1 Regional Sustained Surface Wind Speeds

Sustained wind speed is determined by averaging the wind speed over a two-minute period. A summary of the sustained wind speed at the five official observation sites for the period is depicted in figure 4.

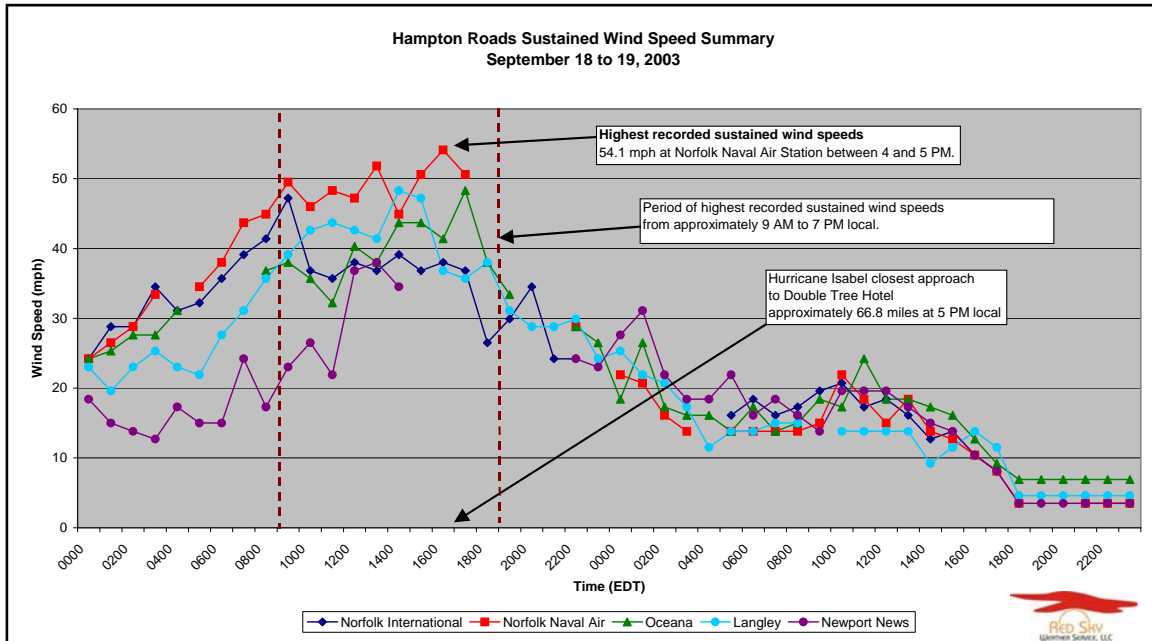


Figure 4: Sustained surface wind speed summary

Sustained surface wind speeds over all sites averaged between approximately 20 and 25 miles per hour at midnight on September 18; at this time the hurricane was still offshore of North Carolina. Sustained surface wind speeds steadily increased throughout the day as the system moved northward towards the region. By about 9 AM sustained surface wind speeds near 40 mph were recorded at most observing sites; with the exception of the farthest northern site at Newport News Airport where winds were about 20 mph. Norfolk Naval Air Station recorded sustained surface winds approaching 50 mph out the northeast (060 degrees) just before 10 AM. At this same time, the closest reporting station to the Doubletree, the Norfolk International Airport, reported its highest sustained surface wind of 47.2 mph out of the northeast (060 degrees). Winds remained high through the remainder of the afternoon, reaching their highest recorded wind speeds in the area at approximately 5 PM, when the system reached its closest point of approach to the Doubletree Hotel. The highest surface wind speed reported occurred between 4 and 5 PM, with an easterly 54.1 mph wind at the Norfolk Naval Air Station, 7.34 miles to the north-northwest of the site of interest. Other observing sites in this study were recording easterly wind between the mid 30s to the upper 40s mph at this time, with the airport recording 38 to 40 mph out of the east to east-southeast. At 5 PM the National Hurricane Center was reporting that the hurricane's maximum sustained surface winds were 80 knots, or 92 mph. The highest surface wind speed recorded in Virginia occurred at Gloucester Point. At 5 PM an observation was taken at this site with a sustained surface wind of 69 mph, and gusts to 92 mph (National Hurricane Center, 2004).

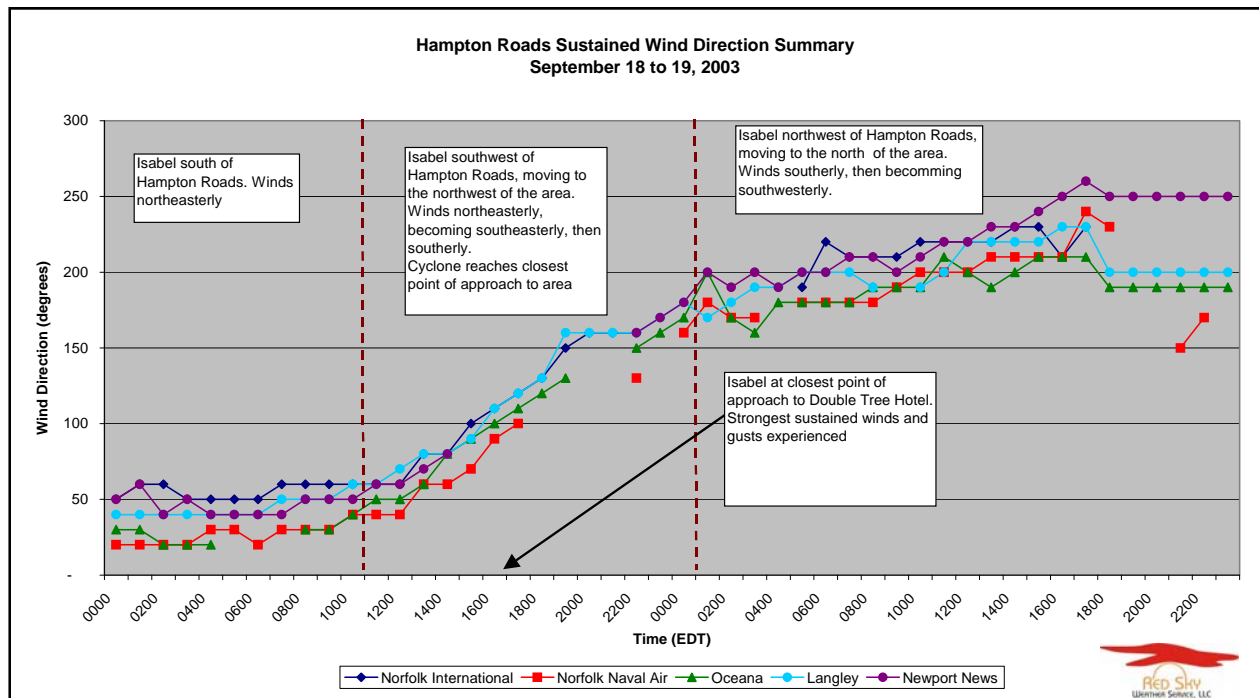
Although several of the sites lost power for a number of hours after 5 PM and no observations were reported at these sites, as is evident by missing data points in figure 3, the overall trend for all

reporting stations after 5 PM was for a steady reduction in the sustained surface wind speed. Sustained surface wind speeds decreased below 40 mph by 7 PM, and below 30 mph by 11 PM for most sites.

2.2 Sustained Wind Direction

Winds were predominately from the north-northeast to the northeast between midnight and noon on September 18. When the highest winds were recorded at the Norfolk airport between 9 and 10 AM, the winds were predominately out of the northeast over the region. At noon, when the hurricane came ashore over the coastal North Carolina, the winds began to rotate steadily clockwise towards the east, as can be seen in figure 5. By the time the storm reached its closest point of approach at 5 PM, winds over the Hampton Roads area had shifted to predominately easterly to east-southeast. As the system continued to move northward winds continued their steadily clockwise rotation, becoming southwestwardly by 2 AM on September 19. Winds continued to rotate clockwise, but at a slower pace after this point. Winds finally reached a steady direction by early on the 19th, becoming predominately southwestward at this point.

Figure 5: Sustained wind direction summary



2.3 Surface Wind Gusts

Wind gusts are measured by examining the most recent 10 minutes of wind observational data prior to the observation time. Gusts are indicated by rapid fluctuations in wind speed with a variance of 10 knots (12 mph) or more between peaks and lulls. The speed of the gusts is the maximum instantaneous wind speed during this 10-minute period.

Surface wind gusts early on September 18, near midnight, averaged between 20 and 35 mph. As Isabel moved northward the area began to experience the feeder bands and heavy rain showers associated with the storm, gusts steadily increased. As can be noted in figure 6, by 9 AM surface wind gusts were over 50 mph at all sites, except for the Newport News airport. Gusts in excess of 50 mph were experienced at all sites between 3 and 5 PM, with surface gusts up to 73.6 mph recorded at the Norfolk Naval Air Station. The highest surface wind gusts recorded at the Norfolk airport, 69 mph, occurred at the end of this period, just before 5 PM. As the storm moved to the northwest of the region during the evening of the 18th, surface wind gusts steadily decreased. By 8 PM surface wind gusts had decreased below 60 mph, and by 10 PM all sites had reported that surface gusts had reduced to below 50 mph.

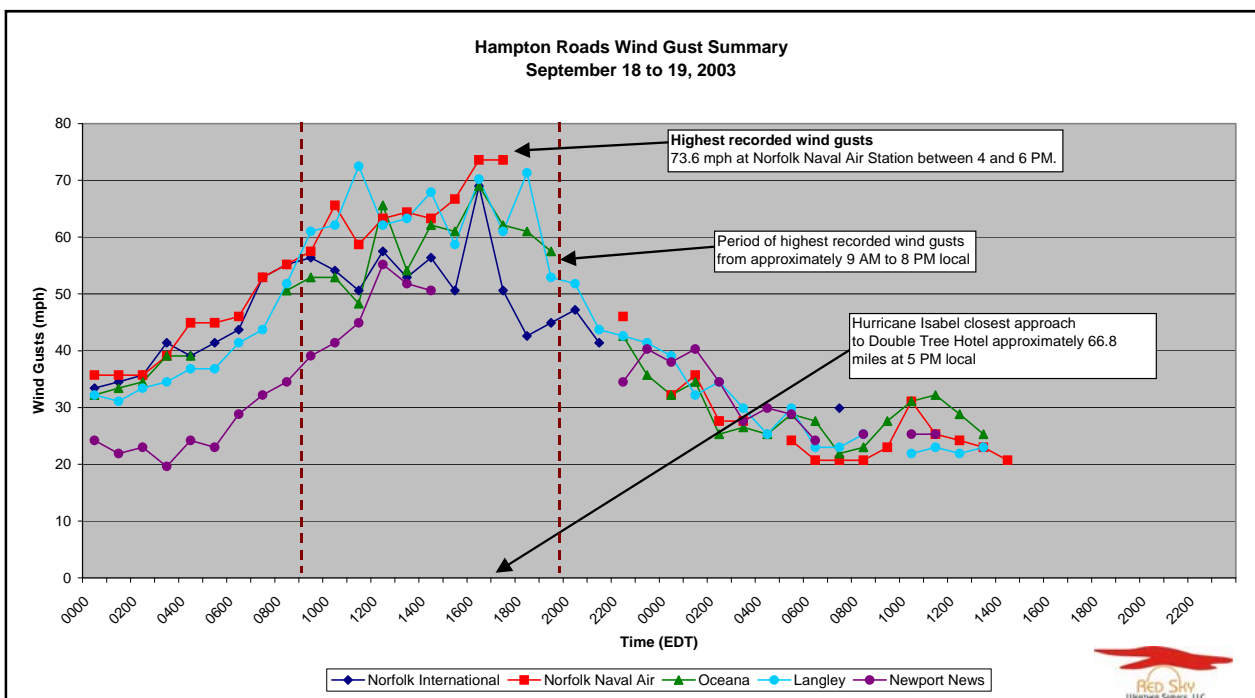


Figure 6: Surface wind gust summary

2.4 Peak Surface Wind Speed

Peak wind speed is the maximum instantaneous wind speed recorded since the last weather observation. Most sites in this study recorded peak wind speeds during this period.

Peak surface wind speeds were averaging between 30 and 40 mph early on the 19th. By 8 AM however, as more heavy precipitation moved into the region with the hurricane feeder bands, peak

surface wind speeds in excess of 50 mph out of the northeast were recorded at Norfolk International Airport and the Norfolk Naval Air Station. Between 2 and 7 PM, the area experienced the highest peak surface wind speeds, figure 7. Peak surface wind speeds averaged over 60 mph during this period; with a peak surface wind speed of 74.8 mph out of the east-northeast recorded at the Norfolk Naval Air Station at 5:28 PM. Peak surface wind speeds of 73.6 mph out of the east-northeast were recorded at the Norfolk airport at 4:49 PM and 5:01 PM. Although, it is noted that several sites lost power for a period of time after the storm passed, a review of the available observations indicates that the trend for the peak surface wind speed was for a rapid decrease after Isabel reached its closest point of approach around 5 PM. Peak surface wind speeds decreased to below 50 mph by 8 PM on the 18th, and below 40 mph by 2 AM on the 19th.

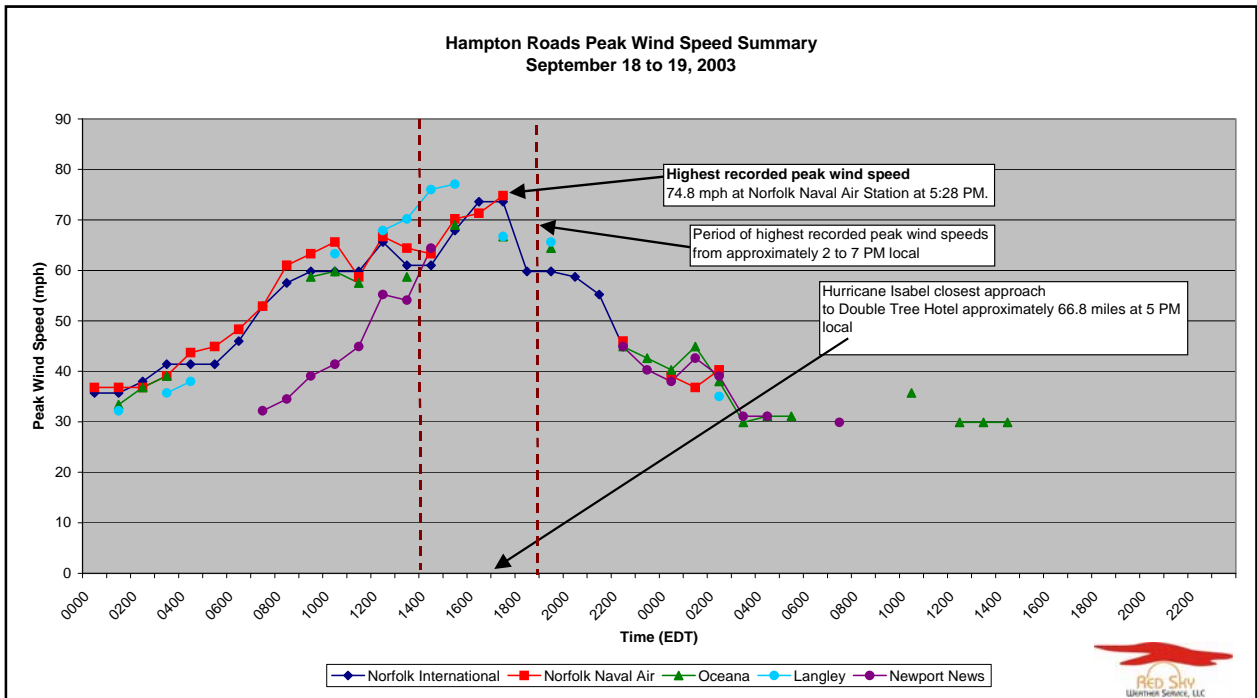


Figure 7: Peak surface wind speed summary

3. Wind Analysis at the Doubletree Hotel, Norfolk Airport

The purpose of this wind study is to determine the most probable wind conditions, both at the surface and over the vertical surface of the building, that affected the hotel on September 18, 2003 due to the passage of Hurricane Isabel. The Doubletree Hotel is a 14 story building (47.5 m total reported height), located at the Gallery of Military Circle. The hotel is located at the southwestern side of the Gallery at Military Circle, a large enclosed shopping mall. The hotel is surrounded by a mixture of commercial / retail buildings and residential homes, see figure 8 for an aerial view of the area.

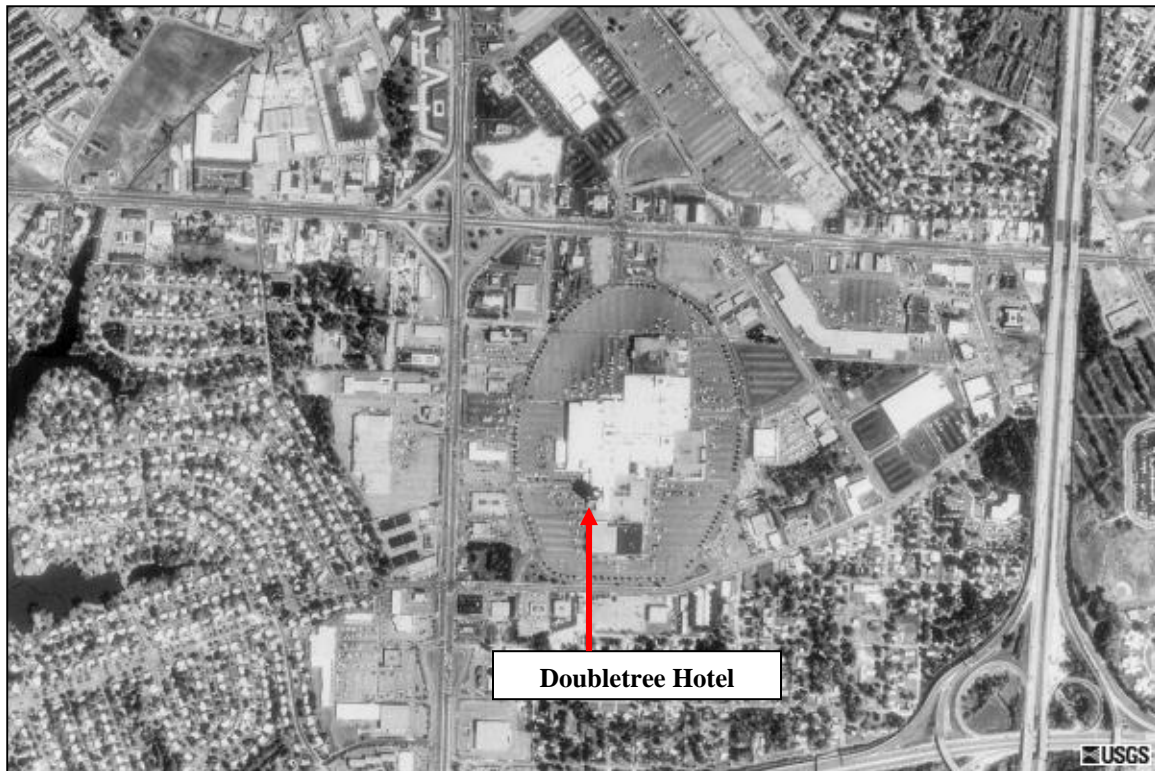


Figure 8: Aerial view of the Gallery at Military Circle, USGS 1990

Since a weather-observing site was not located at the Doubletree Hotel, it is not possible to know precisely what wind conditions actually affected the site. However, other weather observations in the local area may be used to deduce the conditions at the site. Four out of five of the weather observing sites used in this study were manned by trained and experienced weather observers. The closest site to the hotel, the Norfolk International Airport, is only 3.5 miles from the hotel. Observations were available from this site throughout the entire period that the storm was affecting the area.

3.1 Surface Wind Directionality

Directionality of the winds during the period at the hotel was most likely quite similar to the directionality experienced at the reporting sites. Although the sites were geographically displaced over a 25-mile area, all sites were in very good agreement with each other along the timeline. Winds began north-northeasterly around midnight on the 18th, and then steadily rotated clockwise as the storm approached. Winds were easterly by late afternoon, and then became southerly around

midnight, moving into the 19th of September. Winds finally settled into a southwesterly direction by mid-morning on the 19th.

3.2 Maximum Sustained Surface Wind Speeds

Sustained surface wind speeds were fairly well bounded over the region, with surface wind reports ranging between about 35 mph to 55 mph at the height of the storm, a 20 mph spread. Surface winds at the Doubletree Hotel site, due to its more inland location were most likely slightly lower than those reported at the Norfolk International Airport, 3.5 miles north of the hotel. An examination of the maximum sustained surface winds in the region, blue numbers depicted in figure 9, indicate that sustained surface winds reached 47 mph at the Norfolk International Airport, 48 mph at the Oceana Naval Air Station, and 54 mph at the Norfolk Naval Air Station to the northwest of the site. Due to the proximity of these sites to large bodies of water, the Chesapeake Bay and Atlantic Ocean, and the trajectory of the highest winds out of the northeast to east, these wind speeds were most probably higher than those experienced at the Doubletree due to a longer trajectory over land before the winds reached the hotel site. This is indicated well by the 30 mph maximum sustained surface wind recorded at the Portsmouth site, which is approximately eleven miles to the south, and shoreward of the Chesapeake Bay. Maximum sustained surface winds therefore at the Doubletree Hotel most probably fell between 30 mph reading at Portsmouth and the 47 mph reading at the Norfolk International Airport, and that this wind speed should fall within the higher region of this wind speed band due to the proximity of the hotel to the Norfolk International Airport and its more northward location placing it closer to the Chesapeake Bay, then the Portsmouth site.

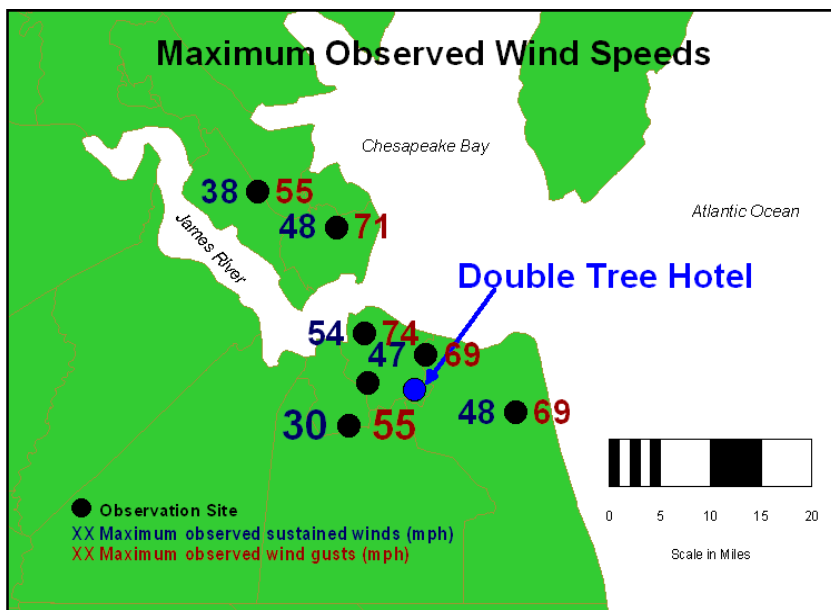


Figure 9: Maximum observed wind speeds

This is indicated well by the 30 mph maximum sustained surface wind recorded at the Portsmouth site, which is approximately eleven miles to the south, and shoreward of the Chesapeake Bay. Maximum sustained surface winds therefore at the Doubletree Hotel most probably fell between 30 mph reading at Portsmouth and the 47 mph reading at the Norfolk International Airport, and that this wind speed should fall within the higher region of this wind speed band due to the proximity of the hotel to the Norfolk International Airport and its more northward location placing it closer to the Chesapeake Bay, then the Portsmouth site.

3.3 Maximum Surface Wind Gusts

To substantiate this hypothesis, maximum wind gusts, and maximum peak winds were also examined. Maximum wind gusts, red numbers depicted in figure 9, further indicate that due to the directionality of the strongest winds and the spatial relationship of the observing sites to the hotel, that maximum recorded surface gusts were higher at observation sites to the north through east of the hotel, closer towards the bay. Maximum recorded surface gusts were 69 mph to the east of the hotel at Oceana and to the north at the Norfolk International Airport, and 74 mph to the northwest of the hotel at the Norfolk Naval Air Station, however maximum surface gusts were only 55 mph to the southwest in Portsmouth. The maximum surface gusts experienced at the Doubletree should therefore fall between these readings, 55 mph and 74 mph.

3.4 Maximum Peak Surface Wind

The final wind to be examined was the maximum peak surface wind recorded at the observation sites. Figure 10 depicts these winds.

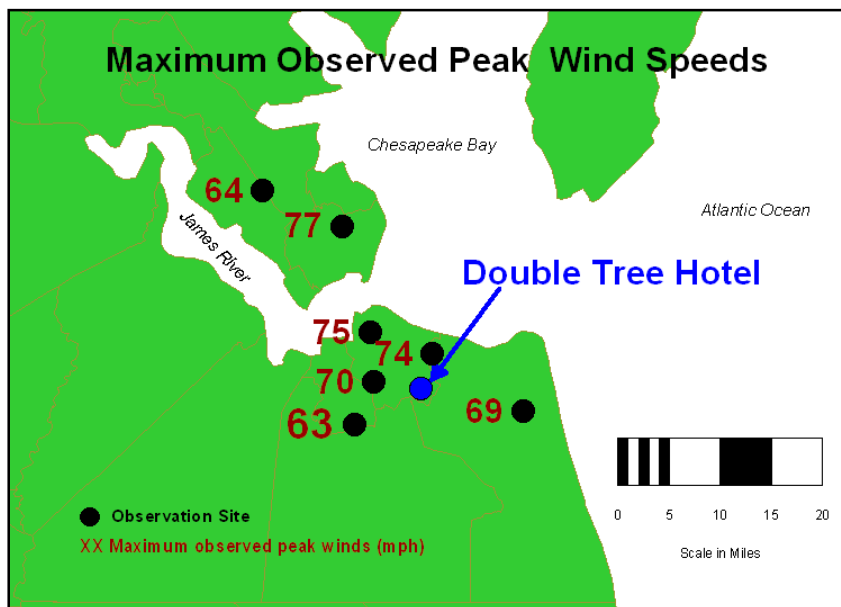


Figure 10: Maximum observed peak surface wind speed

Figure 10 indicates that maximum observed peak surface wind speeds over the area ranged from the mid-70's mph near the Chesapeake Bay, to the lower 60's mph farther south over Portsmouth. Maximum peak wind speeds of 70 mph were recorded to the west of the hotel at Ghent, in downtown Norfolk, and 69 mph to the east of the hotel, at Oceana Naval Air Station.

3.5 Determination of Wind Speeds at the Doubletree Hotel

An analysis of the spatial relationship of the maximum peak surface winds indicated that the site at Ghent was more representative of conditions at the Doubletree Hotel. Several factors were utilized to make this determination, including:

- The Ghent and Doubletree sites were roughly the same distance away from Isabel's storm track
- The site at Ghent is roughly the same distance from the Chesapeake Bay along a northerly to northeasterly line as the hotel, the predominate wind direction for maximum winds experienced during the storm
- Both the Ghent site and the hotel are located in a similar low to medium building density area

It was therefore estimated that the observed 70 mph peak surface wind speed should be similar to the peak surface winds that most probably occurred at the Doubletree Hotel site.

To verify this estimate, a peak wind speed was calculated by using the standard Shepard's Method of the inverse distance weighted model for all seven sites depicted in figure 10. The form of this model is:

$$\text{Site Peak Wind Speed} = \sum_{i=1}^n W_i \times O_i$$

Where W_i is the weighting function at the observation site and O_i is the peak surface wind speed observed at the observation site. The weighting function is of the form:

$$\text{Weighting Function} = \frac{d_i^{-2}}{\sum_{j=1}^n d_j^{-2}}$$

Where d is the distance from the observation site to the Doubletree Hotel.

The weighting function rapidly reduces the influence of each observation as the distance between the observation site and the site of interest, the Doubletree Hotel, increases. Figure 11 depicts this weighting function, versus the distance between the observation site and the site of interest.

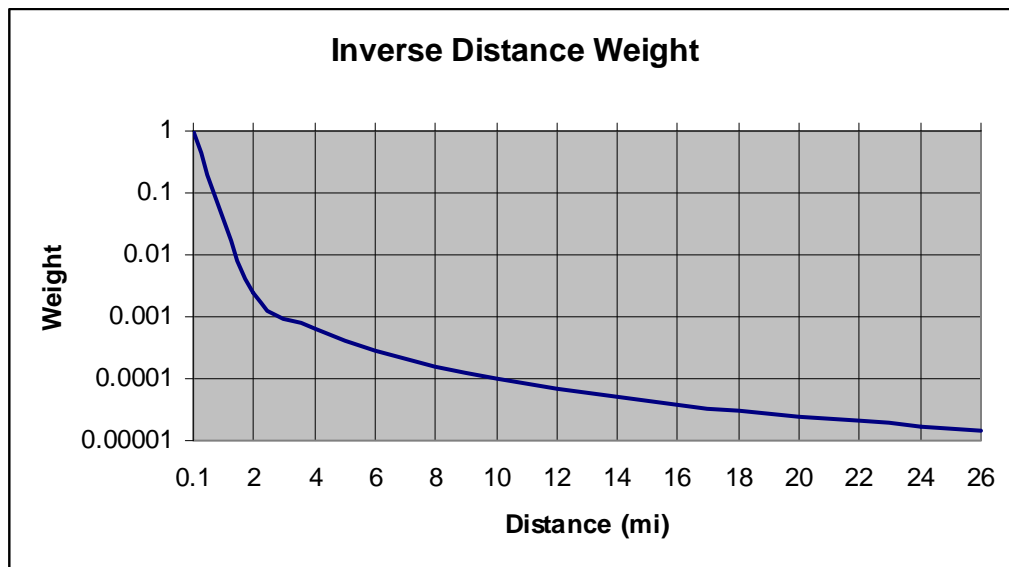


Figure 11: Inverse Distance Weighting Function

Calculations of peak surface wind speed utilizing this inverse distance weighting scheme yielded the following results:

Table 2: Inverse Distance Weighted Observed Peak Surface Winds

Site (station callsign)	Distance to Doubletree Hotel (miles)	Observed Peak Wind	Distance Weighting Factor	Weighted Wind Component
Norfolk International Airport (KORF)	3.59	74	0.42894	31.7415
Fred Heutte Center, Norfolk – Ghent (FHU)	4.37	70	0.28948	20.2637
Norfolk Naval Air Station (KNGU)	7.34	75	0.10261	7.6958
Portsmouth Weather Record Service, Portsmouth VA (PWRS)	7.45	63	0.09960	6.2750
Oceana Naval Air Station (KNTU)	10.28	69	0.05231	3.6095
Langley Air Force Base (KLFJ)	17.55	77	0.01795	1.3820
Newport News / Williamsburg Airport (KPHF)	24.64	64	0.00911	0.5828
Summation			1.0000	71.5503

Therefore, the calculated peak surface wind speed at the Doubletree Hotel site is 71.6 mph, which verifies the hypothesis that the peak wind speed at the site was approximately 70 mph. A value of 70 mph may therefore be confidently used as the most probable peak surface wind speed the occurred at the Doubletree Hotel site on September 18, 2003.

To determine the most probable maximum sustained surface winds and surface gusts at the Doubletree Hotel, all wind observations from the five official reporting sites in the area were evaluated to determine the wind gust factor. The wind gust factor is the ratio of the peak wind to the sustained wind. The calculated gust wind factor is listed in the below table for the five official observation sites in the area.

Table 3: Wind Gust Factor for Hurricane Isabel at Hampton Roads

	Norfolk International Airport	Norfolk Naval Air Station	Oceana Naval Air Station	Newport News Airport	Langley Air Force Base	Average
Wind Gust Factor	1.620387	1.34814	1.513934	1.71831	1.590784	1.558311

Using the average wind gust factor of 1.558311, along with the determined probable maximum peak surface wind of 70 mph, the most probable maximum sustained surface wind speed at the Doubletree Hotel was 45 mph. This 45 mph maximum surface sustained wind speed substantiates the hypothesis that maximum surface wind speed at the hotel site fell between 30 mph and 47 mph, and that this wind speed should fall in the upper region of this wind speed band due to the hotel's proximity to the Norfolk International Airport and the Chesapeake Bay.

To determine the maximum surface gust experienced at the hotel, an identical technique was used as that used to determine the maximum surface sustained wind speed, however in this case a ratio was determined between the observed sustain wind speed and the corresponding wind gust. The table below lists the calculated wind factors for all five official observation sites in the area.

Table 4: Wind Factor for Hurricane Isabel at Hampton Roads

	Norfolk International Airport	Norfolk Naval Air Station	Oceana Naval Air Station	Newport News Airport	Langley Air Force Base	Average
Wind Factor	1.395471	1.300874	1.420507	1.601975	1.483904	1.440546

Using the average wind factor of 1.440546, and a determined maximum sustained surface wind speed of 45 mph, the most probable maximum surface wind gust at the Doubletree Hotel was 65 mph.

3.6 Summary of Probable Surface Wind Conditions at the Doubletree Hotel

In conclusion, the passage of Hurricane Isabel to the south and west of the Doubletree Hotel site on September 18, 2003 most probably produced surface wind conditions where winds began northeasterly around midnight on the 18th, with sustained surface winds averaging between 20 to 25 mph and gusts 25 to 30 mph. By the mid-morning however, sustained surface winds had increased to over 40 mph, most probably reaching a maximum of 45 mph out of the northeast, with surface wind gusts averaging up to 50 mph. Winds remained moderately high through the rest of the morning and into the afternoon, with sustained surface wind speeds most probably averaging between 30 to 35 mph out of the northeast then becoming easterly by early to mid-afternoon. Surface wind gusts reached a maximum in the afternoon as the storm approached its closest point of approach to the region. Maximum surface wind gusts most probably reached 65 mph out of the east, and maximum peak surface winds most probably reaching 70 mph during this period at the site. Winds then steadily decreased into the evening, and rotated clockwise towards the south. By midnight surface winds had most probably decreased to less than 20 mph out of the south, with gusts less than 30 mph.

4. Vertical Wind Profile at the Doubletree Hotel

4.1 Logarithmic Vertical Wind Profile

The lowest layer of the earth’s atmosphere is known as the surface boundary layer. The surface boundary layer, a layer of air of order tens of meters, is a region where the generation of turbulence due to the influence of the underlying surface is highly pronounced. This mechanical turbulence is generated due to surface roughness caused by the underlying surface; its topography, the vegetation and built structures. As the air flows over this surface wind speed is reduced due to surface drag, and the conversion of

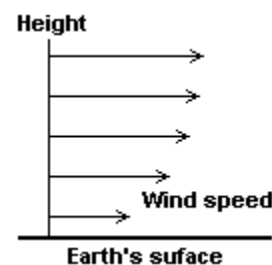


Figure 12: Vertical wind profile

straight line wind flow to chaotic wind flow takes place, manifest in gusty wind conditions. These affects cause a variation in the mean surface wind flow where the wind speed increases with height, figure 11. This change in wind speed with height is known as wind shear.

In a neutral stable atmosphere, which is the case when strong turbulent mixing is occurring (such as in a hurricane), the wind speed profile in the vertical may be calculated utilizing the standard logarithmic vertical wind profile.

$$W_2 = W_1 \times \frac{\ln\left(\frac{z_2}{z_o}\right)}{\ln\left(\frac{z_1}{z_o}\right)}$$

Where W_1 is the measured wind speed at height z_1 , and W_2 is the calculated wind speed at z_2 . z_o is the aerodynamic roughness length, which is a measure of the roughness of the underlying surface.

4.2 Aerodynamic Roughness Length

The key parameter in the logarithmic vertical wind profile equation is z_o , the aerodynamic roughness length. The aerodynamic roughness length is the height above the displacement plane at which the mean wind becomes zero when extrapolating using the standard logarithmic wind-speed profile downward through the surface layer towards the surface of the earth. Some standard accepted values of z_o are:

Table 5: Aerodynamic Roughness Length Values

Surface	z_o (m)
Smooth water	0.002
Open ground	0.03
Rough crops	0.1
Scattered obstacles; trees, hedges	0.25
Urban; towns, suburban, mixed construction	1.0

Note that z_o at a particular site depends on the underlying surface along which the wind blows towards the site. Since the surface will most likely not be uniform in all directions, z_o typically depends on the directionality of the wind.

To most accurately determine the vertical wind profile at a specific site using the logarithmic wind profile equation, a value of z_o must be known for the site. A site specific value of z_o however is typically determined by taking wind measurements using scientific caliber anemometer instrumentation at multiple heights at the site, over a prolonged period of time. Such measurements have only been made at a handful of sites throughout the world however, and were not available at the Doubletree Hotel. A review of research performed at a similar site was performed however to determine an appropriate value of z_o to use for the wind study at the Doubletree Hotel.

The reviewed research dealt with the determination of aerodynamic roughness of urban areas derived from wind observations (Grimmond, et al., 1998). During this research data was collected using both slow and fast response anemometry in suburban areas of Chicago, Los Angeles, Miami and Vancouver. In all cases the instruments were mounted on tall towers, data were sorted by stability condition, and zero-plane displacement (z_d) was taken into account. A review of the sites used in this research, indicated that the site in Chicago was most similar to the surface conditions at the Doubletree Hotel. Surface conditions at the Chicago site along directionality from the northeast through the south were low to medium density with mixed commercial and residential structures. An aerial view of these sites is shown in figure 13.

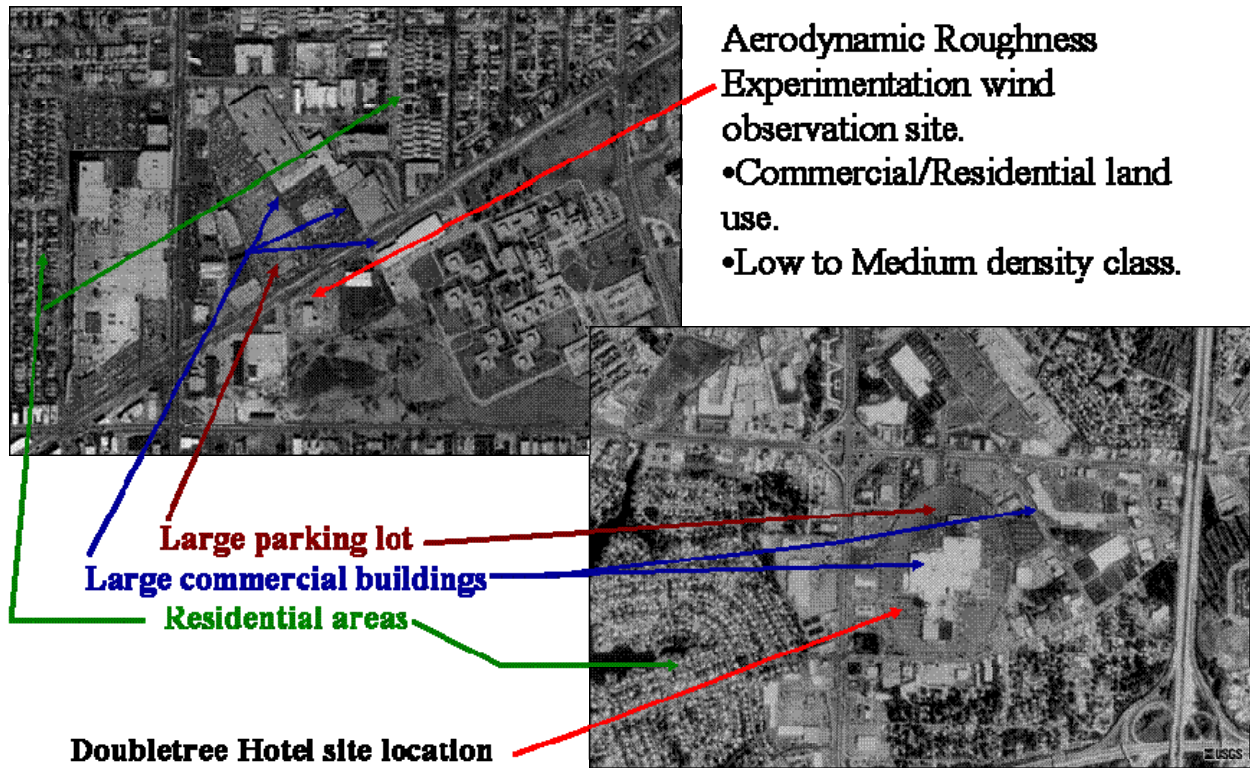


Figure 13: Site comparisons

Since the main directionality of the maximum winds that affected the Doubletree Hotel site were from the northeast to the east, the wind would have to blow over the mixed use area of the residential buildings, large commercial / retail buildings, the parking lot and the mall itself, figures 8 and 13, before it reached the location of the hotel. Note the similarities of the two sites to the northeast and east of the sites, with the large open parking and roadway areas, large, low commercial buildings, and large residential zones.

At the Chicago site, measurements of wind speed and temperature were conducted from July 1992 until June 1993 (Grimmond et al., 1994). The instruments were mounted on a 101 m tall triangular lattice tower. Anemometers (R. M. Young wind sentry) and temperature sensors (the aspirated model of Grant and Heisler (1994) and Gill radiation shielded Vaisala HMP35C) were located at three levels ($z_1 = 24.6$, $z_2 = 43.1$, and $z_3 = 69.5$ m) on booms 0.05 m in diameter, which extended 6 m from the tower. Data were 15 minute averages determined from 0.2 Hz samples. All instruments were compared before and after the study, and the data reported was corrected for inter-instrument differences. Almost 600 observations were taken at this site during the summer and over 200 observations in the fall of 1992 and 1993 by the research team.

Reviewed research at the Chicago site indicated a median summer value for aerodynamic surface roughness of 0.5 m, and a mean value of 0.81 m, along directionality from northeast through the south. The value for the fall period had a mean value of 0.72 m for this same sector. In view of this study, it was decided to not exceed a value of 0.8 m for z_o for this study. To provide a comprehensive review of the probable conditions at the hotel, a range for z_o , between 0.3 m (scattered obstacles) to 0.8 m (near the high value of the Chicago study), was used to calculate the vertical wind speed profile at the Doubletree site.

4.3 Calculating the Vertical Wind Profile at the Doubletree Hotel

The standard logarithmic equation for the vertical wind profile was used to determine the winds at the Doubletree Hotel site.

$$W_2 = W_1 \times \frac{\ln\left(\frac{z_2}{z_o}\right)}{\ln\left(\frac{z_1}{z_o}\right)}$$

The following parameters were used with the equation:

Table 6: Vertical Wind Profile Model Parameters

Parameter	Value
Z ₁ , reference wind speed height	10 m (33 ft)
Z ₂ , calculation heights	10 to 50 m (33 to 164 ft), in 5 m steps
Z _o , roughness length	0.3 to 0.8 m (1 to 2.6 ft)
W ₁ , maximum sustained wind speed	45 mph
W ₁ , maximum gusts	65 mph
W ₁ , maximum peak wind speed	70 mph

Using an aerodynamic roughness length of 0.3 m (1 ft), the vertical wind profile calculated by the logarithmic wind profile is:

Table 7: Maximum Vertical wind profile, z_o = 0.3 m (1 ft)

Z ₂ (ft)	Sustained Wind (mph)	Wind Gusts (mph)	Peak Wind (mph)
33	45	65	70
49	50	73	78
66	54	78	84
82	57	82	88
98	59	85	92
115	61	88	95
131	63	91	98
148	64	93	100
164	66	95	102

These values are plotted in figures 14, 15 and 16.

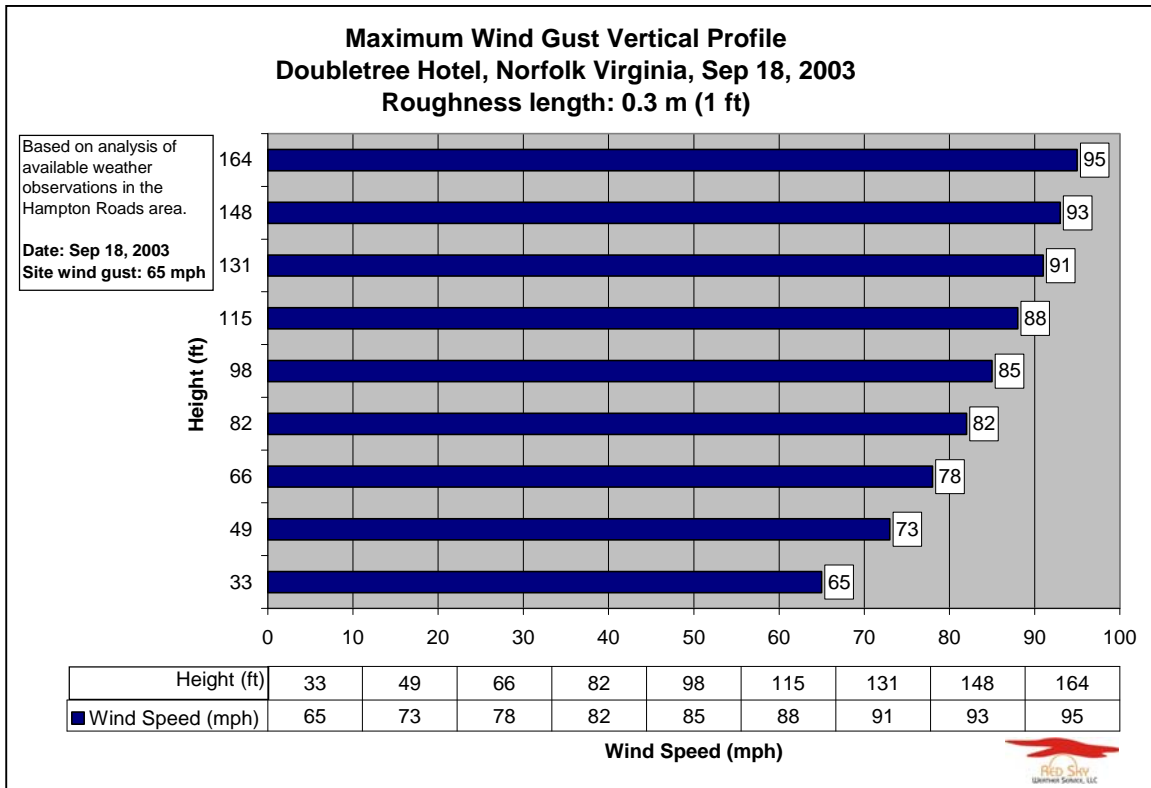


Figure 14: Maximum sustained wind speeds vertical profile, $z_0 = 0.3$ m (1 ft)

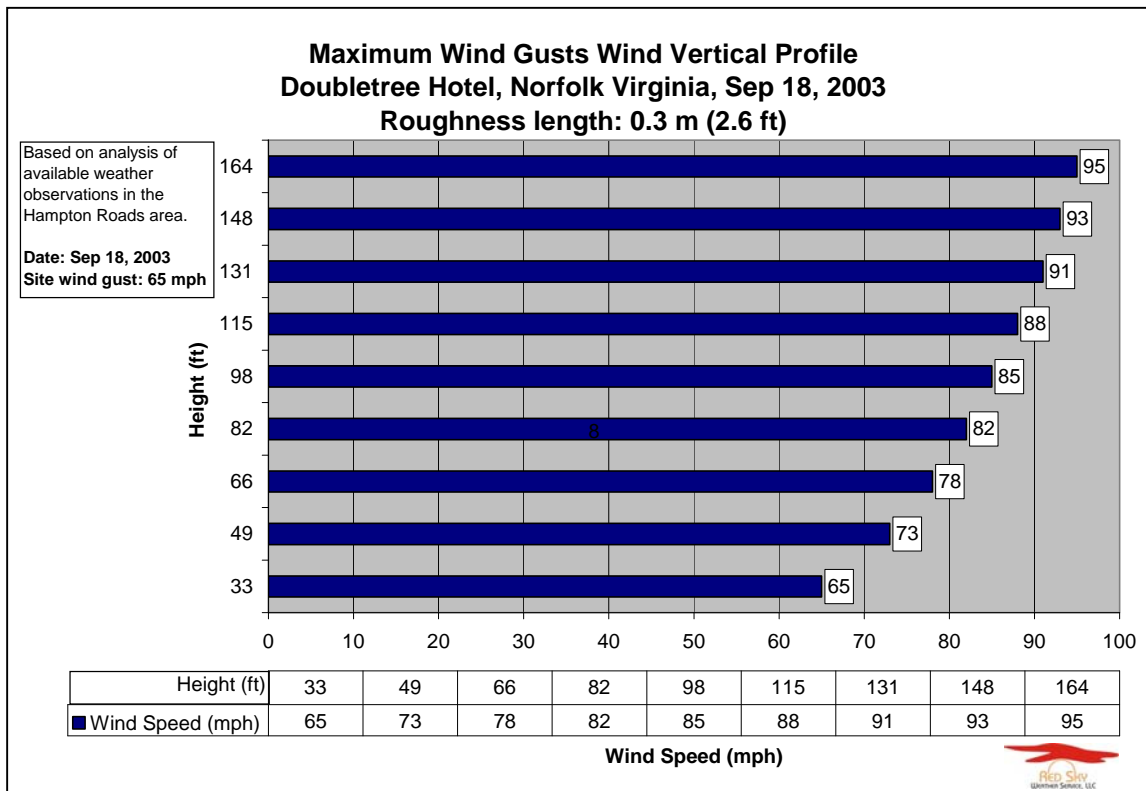


Figure 15: Maximum wind gusts vertical profile, $z_0 = 0.3$ m (1 ft)

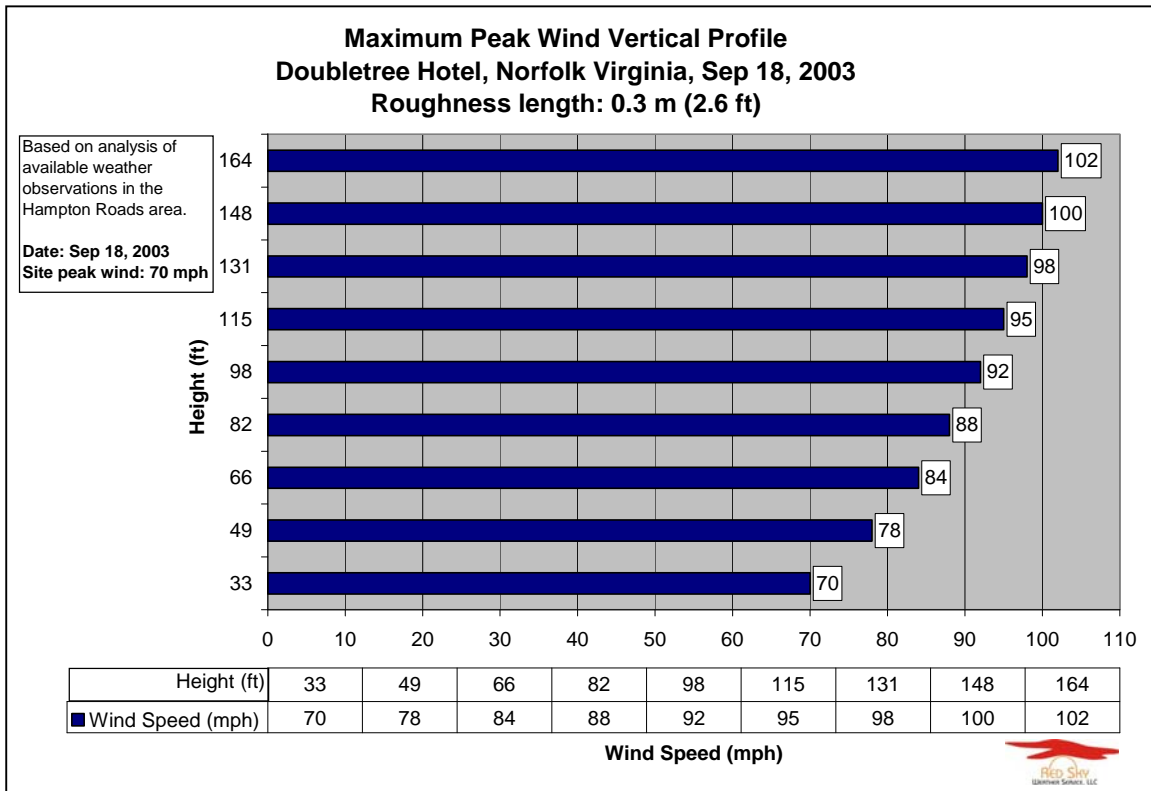


Figure 16: Maximum peak wind speeds vertical profile, $z_0 = 0.3$ m (1 ft)

Using an aerodynamic roughness length of 0.8 m (2.6 ft), the vertical wind profile calculated by the logarithmic wind profile is:

Table 8: Maximum Vertical wind profile, $z_0 = 0.8$ m (2.6 ft)

Z_2 (ft)	Sustained Wind (mph)	Wind Gusts (mph)	Peak Wind (mph)
33	45	65	70
49	52	75	81
66	57	83	89
82	61	89	95
98	65	93	100
115	67	97	105
131	70	101	108
148	72	104	112
164	74	106	115

These values are plotted in figures 17, 18 and 19.

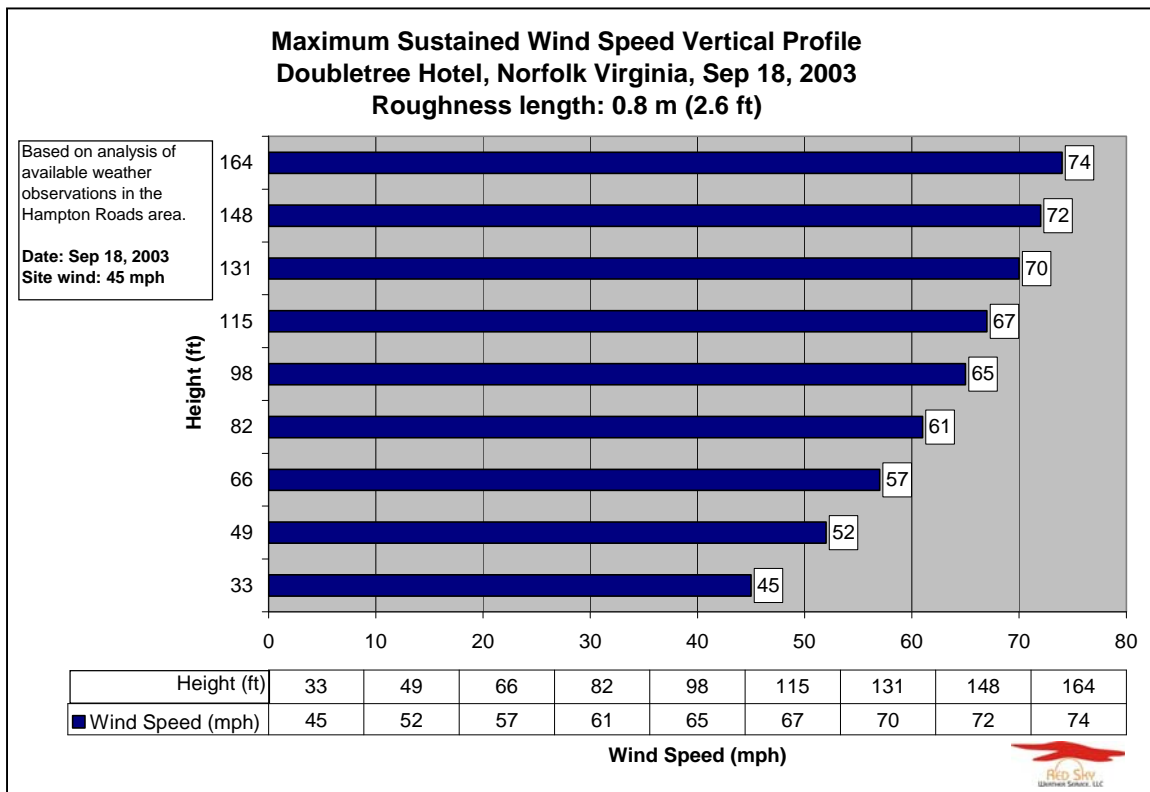


Figure 17: Maximum sustained wind speeds vertical profile, $z_0 = 0.8$ m (2.6 ft)

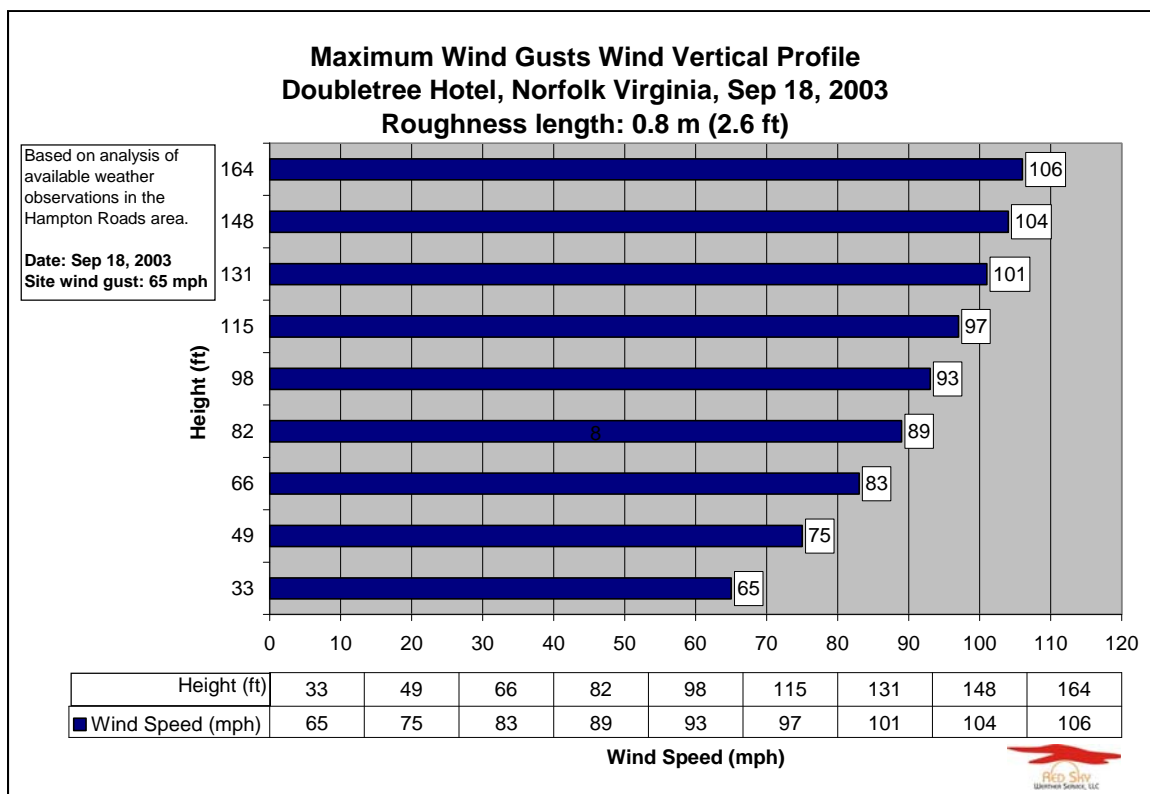


Figure 18: Maximum wind gusts vertical profile, $z_0 = 0.8$ m (2.6 ft)

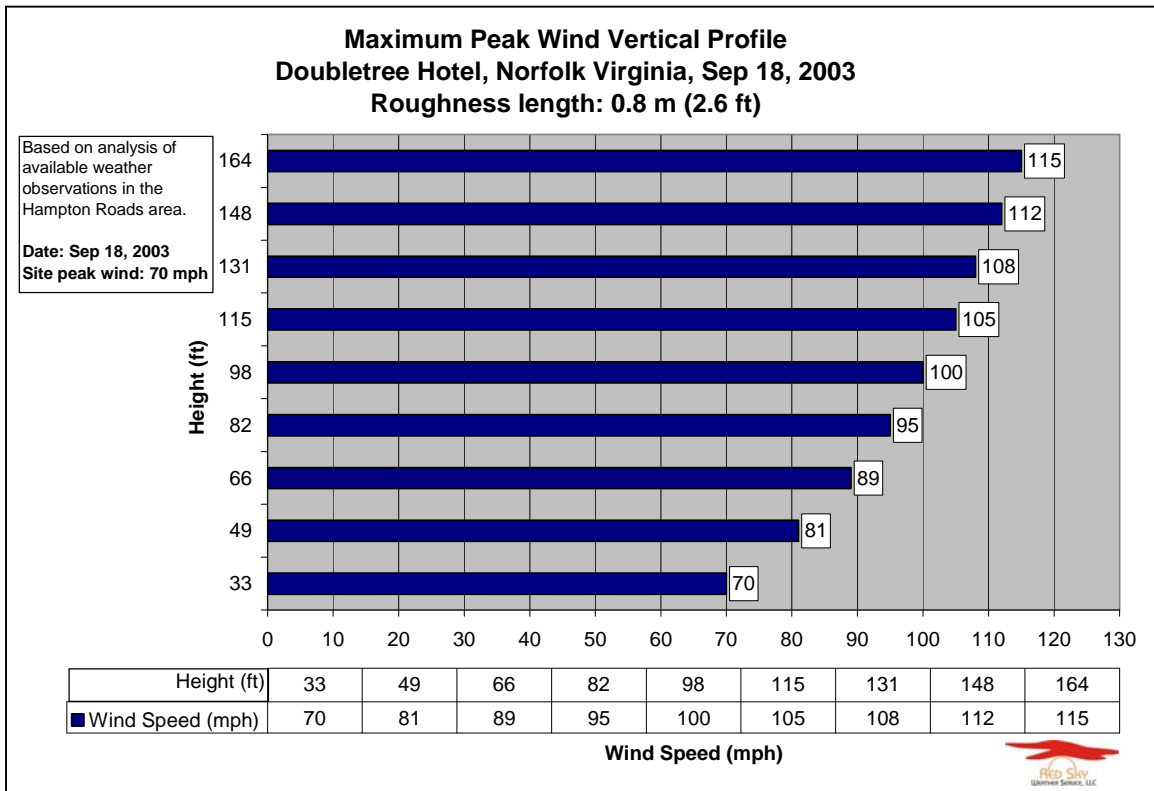


Figure 19: Maximum peak wind speeds vertical profile, $z_0 = 0.8$ m (2.6 ft)

4.4 Vertical Wind Profile Summary

In summary, based on a range of the aerodynamic roughness length between 0.3 to 0.8 m (1 to 2.6 ft) and using the most probable surface wind speeds of 45 mph, 65 mph and 70 mph for the maximum sustained, maximum gusts and peak wind, the overall ranges of the vertical wind profile from 33 to 164 feet at the site of the Doubletree Hotel is denoted in the following table.

Table 9: Maximum Vertical wind profile, $z_0 = 0.3$ (1 ft) to 0.8 m (2.6 ft)

Z_2 (ft)	Sustained Wind (mph)	Wind Gusts (mph)	Peak Wind (mph)
33	45	65	70
49	50 - 52	73 - 75	78 - 81
66	54 - 57	78 - 83	84 - 89
82	57 - 61	82 - 89	88 - 95
98	59 - 65	85 - 93	92 - 100
115	61 - 67	88 - 97	95 - 105
131	63 - 70	91 - 101	98 - 108
148	64 - 72	93 - 104	100 - 112
164	66 - 74	95 - 106	102 - 115

Finally, to determine the maximum probable wind speeds experienced at the roof height for the Doubletree Hotel, an examination of public records was performed. Records indicate that the Doubletree Hotel at the Norfolk Airport is approximately 150 ft in total height, with a roof height of approximately 120 to 125 ft. Therefore, as is detailed in the pervious table (table 9), and using a range of 116 to 131 feet for the roof height, calculations indicate that the probable maximum sustained winds at the roof height were most probably 60 to 70 mph, that the maximum wind gusts at the roof height were approximately 90 to 100 mph and the maximum peak gusts at the roof height were approximately 95 to 110 mph. As noted in section 3.5 of this report, these maximum winds most probably had a directionality of north-east to east, blowing over the residential buildings, commercial / retail buildings and the mall itself, all lying upwind of the hotel.

Table 10: Most Probable Wind Speeds at the Roof Height of the Doubletree Hotel Site

Maximum sustained winds	60 to 70 mph
Maximum wind gusts	90 to 100 mph
Maximum peak winds	95 to 110 mph

5.2 Norfolk Naval Air Station

Weather Observations - Norfolk Naval Air Station

Location: Norfolk, Virginia
 Latitude: 36.93N
 Longitude: 76.3W
 Elevation: 13.1 (ft)

Red Sky
 Weather Service, LLC
 redskyweather.com
 757-410-5708

Date: September 18, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind Direction (degrees)	Speed (mph)	Gusts (mph)	Peak Instantaneous Wind Direction (degrees)	Speed (mph)	Time
0055	71.6	1017.1		-SHRA BR	1.6	020	24.2	35.7	020	36.8	0040
0155	71.6	1016.7	T	-SHRA BR	1.6	020	26.5	35.7	020	36.8	0108
0255	71.6	1015.6	T	-SHRA BR	5	020	28.8	35.7	030	36.8	0218
0355	73.4	1014.6	T	-SHRA BR	6	020	33.4	39.1	030	39.1	0345
0455	73.4	1013.7		-SHRA BR	6	030	M	44.9	020	43.7	0439
0555	73.4	1012.9		-SHRA BR	6	030	34.5	44.9	020	44.9	0515
0655	73.4	1011.7		-SHRA BR	5	020	38	46	020	48.3	0636
0755	73.4	1010.6		RA BR	2	030	43.7	52.9	020	52.9	0731
0855	73.4	1003.8		BR	2	030	44.9	55.2	030	61	0835
0955	73.4	1006.5				030	49.5	57.5	030	63.3	0913
1055	73.4	1003.7		RA BR	2	040	46	65.6	040	65.6	1055
1155	73.4	1001.1		+RA BR	1.5	040	48.3	58.7	040	58.7	1155
1255	73.4	998.5	0.04	+RA BR	0.75	040	47.2	63.3	040	66.7	1233
1355	75.2	996.1		RA BR	1.75	060	51.8	64.4	050	64.4	1346
1455	75.2	993.5	0.18	RA BR	2.5	060	44.9	63.3	070	63.3	1426
1555	73.4	991.6		+RA BR	2	070	50.6	66.7	060	70.2	1535
1656	73.4	990.7	1.7	SHRA BR	1.25	090	54.1	73.6	070	71.3	1649
1756	71.6	990.1		+SHRA BR	1	100	50.6	73.6	070	74.8	1728
1856	M	M	M	M	M	M	M	M	M	M	M
1956	M	M	M	M	M	M	M	M	M	M	M
2056	M	M	M	M	M	M	M	M	M	M	M
2156	M	M	M	M	M	M	M	M	M	M	M
2256	69.8	997.8	T	-SHRA BR	5	130	28.8	46.0	120	46	2244
2356	M	M	M	M	M	M	M	M	M	M	M

Date: September 19, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind Direction (degrees)	Speed (mph)	Gusts (mph)	Peak Instantaneous Wind Direction (degrees)	Speed (mph)	Time
0056	69.8	1002.2			7	160	21.9	32.2	140	39.1	0005
0156	69.8	1004.4			7	180	20.7	35.7	190	36.8	0132
0256	71.6	1005.9			7	170	16.1	27.6	180	40.3	0211
0356	73.4	1007.0			7	170	13.8	27.6			
0456	M	M	M	M	M	M	M	M	M	M	M
0556	75.2	1009.4			7	180	13.8	24.2			
0656	73.4	1011.1			7	180	13.8	20.7			
0756	73.4	1012.4			7	180	13.8	20.7			
0856	75.2	1013.2			7	180	13.8	20.7			
0956	78.8	1013.9			7	190	15	23			
1056	82.4	1014.5			7	200	21.9	31.1			
1156	82.4	1014.8			7	200	18.4	25.3			
1256	84.2	1015.1			7	200	15	24.2			
1356	84.2	1015.2			7	210	18.4	23			
1456	86	No Report			7	210	13.8	20.7			
1556	86	1015.8			7	210	12.7				
1656	86	1016.0			7	210	10.4				
1756	84.2	1016.5			7	240	8.1				
1856	80.6	1017.0			7	230	3.5				
1956	78.8	1017.5			7						
2056	73.4	1018.3			7						
2156	73.4	1019.0			7	150	3.5				
2256	73.4	1019.3			6	170	3.5				
2356	71.6	1019.5			6	VRB	3.5				

Statistics for September 18 and 19

Temperature Maximum	86	Total Precipitation	1.92	Visibility Maximum	7	Wind Speed Maximum	54.1	73.6	Peak Wind Maximum	74.8
Minimum	69.8			Minimum	0.75					

Key:

M: Missing data - no observation taken
 Weather Elements: BR = Mist
 FG = Fog
 Precipitation Type: R = Rain
 DZ = Drizzle
 FRZ R/DZ = Freezing Rain or Drizzle
 Rainfall: T = < 0.05 in
 Snowfall: T = < 0.5 in

5.3 Oceana Naval Air Station

Weather Observations - Oceana Naval Air Station Location: Virginia Beach, Virginia Latitude: 36.82N Longitude: 76.03W Elevation: 19.7 (ft)	Red Sky Weather Service, LLC redskyweather.com 757-410-5708
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Date: September 18, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind			Peak Instantaneous Wind		
						Direction (degrees)	Speed (mph)	Gusts (mph)	Direction (degrees)	Speed (mph)	Time
0056	71.6	1016.4		-SHRA BR	5	030	24.2	32.2			
0156	71.6	1015.9		-SHRA BR	5	030	25.3	33.4	030	33.4	0122
0256	71.6	1014.5		BR	5	020	27.6	34.5	030	36.8	0205
0356	71.6	1013.5		BR	5	020	27.6	39.1	030	39.1	0354
0456	71.6	1012.1		-SHRA BR	4	020	31.1	39.1			
0556	M	M	M	M	M	M	M	M	M	M	M
0656	M	M	M	M	M	M	M	M	M	M	M
0756	M	M	M	M	M	M	M	M	M	M	M
0856	71.6	1006.9		-SHRA BR	0.75	030	36.8	50.6			
0956	71.6	1004.7		+SHRA BR	1	030	38	52.9	020	58.7	0940
1056	73.4	1003.1		+SHRA BR	1.5	040	35.7	52.9	030	59.8	1004
1156	73.4	1000.1		SHRA BR	1.25	050	32.2	48.3	050	57.5	1141
1256	73.4	997.2		SHRA BR	1.5	050	40.3	65.6			
1356	75.2	994.7		-SHRA BR		060	38	54.1	060	58.7	1311
1456	75.2	992.7		-SHRA BR		080	43.7	62.1			
1556	73.4	991.5		-SHRA BR	0.75	090	43.7	61	080	69	1511
1656	71.6	991.1		-SHRA BR	1	100	41.4	69			
1756	71.6	991.2		SHRA BR	1.25	110	48.3	62.1	090	66.7	1725
1856	71.6	992.6		-SHRA BR	1.75	120	38	61			
1956	71.6	993.8		-SHRA BR	0.75	130	33.4	57.5	130	64.4	1919
2056	M	M	M	M	M	M	M	M	M	M	M
2156	M	M	M	M	M	M	M	M	M	M	M
2256	69.8	999.6		-SHRA BR	5	150	28.8	42.6	140	44.9	2200
2356	69.8	1001.7			7	160	26.5	35.7	160	42.6	2317

Date: September 19, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind			Peak Instantaneous Wind		
						Direction (degrees)	Speed (mph)	Gusts (mph)	Direction (degrees)	Speed (mph)	Time
0056	69.8	1003.8		BR	6	170	18.4	32.2	160	40.3	0028
0156	71.6	1006.1			6	200	26.5	34.5	190	44.9	0144
0256	73.4	1006.9			7	170	17.3	25.3	180	38	0201
0356	73.4	1007.9			7	160	16.1	26.5	200	29.9	0325
0456	75.2	1008.8			7	180	16.1	25.3	180	31.1	0408
0556	75.2	1010.1			7	180	13.8	28.8	170	31.1	0501
0656	75.2	1011.5			7	180	17.3	27.6			
0756	75.2	1013.1			7	180	13.8	21.9			
0856	77	1013.7			7	190	15	23			
0956	80.6	1014.3			7	190	18.4	27.6			
1056	82.4	1014.9			7	190	17.3	31.1	200	35.7	1001
1156	82.4	1015.3			7	210	24.2	32.2			
1256	82.4	1015.4			7	200	18.4	28.8	210	29.9	1159
1356	84.2	1015.3			7	190	18.4	25.3	190	29.9	1201
1456	84.2	1015.5			7	200	17.3	32.2	190	29.9	1417
1556	84.2	1015.8			7	210	16.1				
1656	84.2	1016.0			7	210	12.7				
1756	82.4	1016.5			7	210	9.2				
1856	80.6	1017.1			7	190	6.9				
1956	80.6	1017.1			7	190	6.9				
2056	80.6	1017.1			7	190	6.9				
2156	80.6	1017.1			7	190	6.9				
2256	80.6	1017.1			7	190	6.9				
2356	80.6	1017.1			7	190	6.9				

Statistics for September 18 and 19

Temperature		Total		Visibility		Wind Speed		Peak Wind	
Maximum	84.2	Precipitation	0	Maximum	7	Maximum	48.3	Maximum	69
Minimum	69.8			Minimum	0.75				

Key: M: Missing data - no observation taken
 Weather Elements: BR = Mist Precipitation Type: R = Rain
 FG = Fog DZ = Drizzle Rainfall: T = < 0.05 in
 FRZ R/DZ = Freezing Rain or Drizzle Snowfall: T = < 0.5 in

5.4 Langley Air Force Base

Weather Observations - Langley Air Force Base Location: Hampton, Virginia Latitude: 37.08N Longitude: 76.35W Elevation: 9.8 (ft)			Red Sky Weather Service, LLC redskyweather.com 757-410-5708
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Date: September 18, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind			Peak Instantaneous Wind		
						Direction (degrees)	Speed (mph)	Gusts (mph)	Direction (degrees)	Speed (mph)	Time
0055	69.8	1017.8		BR	5	040	23.0	32.2			
0155	69.8	1017		-RA BR	4	040	19.6	31.1	040	32.2	0105
0255	71.6	1016.1		-RA BR	4	040	23.0	33.4			
0356	71.6	1014.8		BR	3	040	25.3	34.5	040	35.7	0328
0455	71.6	1014.1		BR	4	040	23.0	36.8	030	38	0431
0556	71.6	1013.8		-SHRA BR	3	040	21.9	36.8			
0655	73.4	1012.6		-SHRA BR	4	040	27.6	41.4			
0755	73.4	1011.2		-SHRA BR	3	050	31.1	43.7			
0855	69.8	1009.4		SHRA BR	2.5	050	35.7	51.8			
0957	69.8	1007.7		-SHRA BR	2.25	050	39.1	61.0			
1057	73.4	1006		RA BR	1.25	060	42.6	62.1	050	63.3	1037
1155	73.4	1003.3		+RA BR	0.5	060	43.7	72.5			
1255	73.4	1000.1		+RA BR	0.75	070	42.6	62.1	060	67.9	1231
1355	73.4	997.9		RA BR	0.75	080	41.4	63.3	080	70.2	1301
1455	73.4	994.8		+RA BR	0.5	080	48.3	67.9	070	76	1408
1555	75.2	993.4		-RA BR	1.5	090	47.2	58.7	100	77.1	1509
1655	73.4	992.4		RA BR	1	110	36.8	70.2			
1755	73.4	991.4		RA BR	1	120	35.7	61.0	110	66.7	1736
1855	71.6	991.1		RA BR	1	130	38.0	71.3			
1955	73.4	992.1		BR	3	160	31.1	52.9	130	65.6	1910
2059	75.2	994.1		BR	5	160	28.8	51.8			
2155	69.8	995.7		-SHRA BR	6	160	28.8	43.7			
2255	69.8	997.2		-SHRA BR	6	160	29.9	42.6			
2359	69.8	999.4		-SHRA	7	170	24.2	41.4			

Date: September 19, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind			Peak Instantaneous Wind		
						Direction (degrees)	Speed (mph)	Gusts (mph)	Direction (degrees)	Speed (mph)	Time
0055	69.8	1001.2		-SHRA	7	180	25.3	39.1			
0159	69.8	1003.8			7	170	21.9	32.2			
0259	69.8	1005.5			7	180	20.7	34.5	190	35	0212
0355	73.4	1006.3			7	190	17.3	29.9			
0455	73.4	1007.3			7	190	11.5	25.3			
0555	75.2	1008.4			7	200	13.8	29.9			
0655	73.4	1010.6			7	200	13.8	23			
0756	75.2	1011.9			7	200	15	23			
0855	75.2	1012.8			7	190	15	25.3			
0955	M	M	M	M	M	M	M	M	M	M	M
1055	80.6	1013.9			7	190	13.8	21.9			
1158	82.4	1014.1			7	200	13.8	23			
1258	82.4	1014.6			7	220	13.8	21.9			
1357	84.2	1014.8			7	220	13.8	23			
1455	84.2	1015			7	220	9.2				
1555	84.2	1015.3			7	220	11.5				
1658	86	1015.6			7	230	13.8				
1759	84.2	1016.3			7	230	11.5				
1855	80.6	1016.7			7	200	4.6				
1955	80.6	1016.7			7	200	4.6				
2055	80.6	1016.7			7	200	4.6				
2155	80.6	1016.7			7	200	4.6				
2255	80.6	1016.7			7	200	4.6				
2355	80.6	1016.7			7	200	4.6				

Statistics for September 18 and 19

Temperature		Total		Visibility		Wind Speed		Peak Wind	
Maximum	86	Precipitation	0	Maximum	7	Maximum	48.3	Maximum	77.1
Minimum	69.8			Minimum	0.5				

Key:

M: Missing data - no observation taken
 Weather Elements: BR = Mist
 FG = Fog
 Precipitation Type: R = Rain
 DZ = Drizzle
 FRZ R/DZ = Freezing Rain or Drizzle
 Rainfall: T = < 0.05 in
 Snowfall: T = < 0.5 in

5.5 Newport News / Williamsburg Airport

Weather Observations - Newport News / Williamsburg International Airport Location: Newport News/Williamsburg, Virginia Latitude: 37.13N Longitude: 76.49W Elevation: 42.7 (ft)	Red Sky Weather Service, LLC redskyweather.com 757-410-5708
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Date: September 18, 2003

Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind			Peak Instantaneous Wind		
						Direction (degrees)	Speed (mph)	Gusts (mph)	Direction (degrees)	Speed (mph)	Time
0054	69.8	1017.5			10	050	18.4	24.2			
0154	69.8	1017.2	T	-RA	10	060	15.0	21.9			
0254	69.8	1016.3	0.01	-RA	9	040	13.8	23.0			
0354	69.8	1015.2	0.01		8	050	12.7	19.6			
0454	69.8	1014.3			7	040	17.3	24.2			
0554	71.6	1014.1			8	040	15.0	23.0			
0654	71.6	1012.8	T		9	040	15.0	28.8			
0754	71.6	1011.7	0.02	RA BR	3	040	24.2	32.2	050	32.2	0753
0854	71.6	1009.5	0.24	+RA BR	1.5	050	17.3	34.5	030	34.5	0848
0954	71.6	1008.2	0.17	+RA BR	2	050	23.0	39.1	040	39.1	0948
1054	71.6	1006.2	0.25	+RA BR	1.25	050	26.5	41.4	060	41.4	1048
1154	73.4	1003.8	0.31	+RA BR	1	060	21.9	44.9	070	44.9	1151
1254	73.4	1000.8	0.47	+RA FG	0.5	060	36.8	55.2	060	55.2	1253
1354	73.4	997.8	0.3	-RA BR	1.75	070	38.0	51.8	060	54.1	1302
1454	73.4	994.5	0.26	+RA BR	1	080	34.5	50.6	080	64.4	1356
1554	M	M	M	M	M	M	M	M	M	M	M
1654	M	M	M	M	M	M	M	M	M	M	M
1754	M	M	M	M	M	M	M	M	M	M	M
1854	M	M	M	M	M	M	M	M	M	M	M
1954	M	M	M	M	M	M	M	M	M	M	M
2054	M	M	M	M	M	M	M	M	M	M	M
2154	M	M	M	M	M	M	M	M	M	M	M
2254	68	996.4	T	-RA BR	5	160	24.2	34.5	150	44.9	2200
2354	68	998.4	T		8	170	23.0	40.3	070	40.3	2348

Date: September 19, 2003

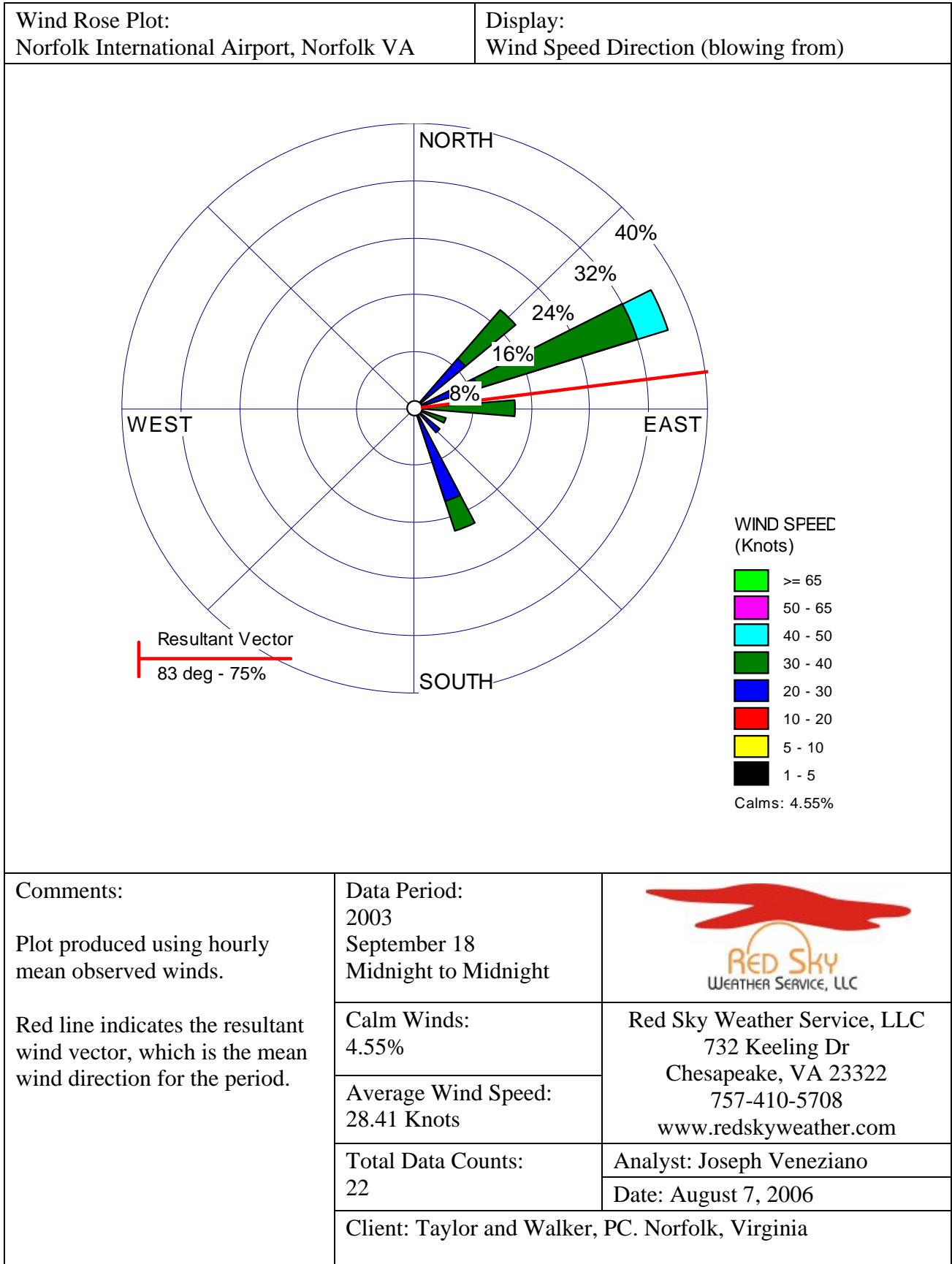
Time (Local)	Temp (F)	Pressure (mb)	Precipitation (in)	Significant Weather	Visibility (mi)	Wind			Peak Instantaneous Wind		
						Direction (degrees)	Speed (mph)	Gusts (mph)	Direction (degrees)	Speed (mph)	Time
0054	68	1000.5	T	-RA	9	180	27.6	38	180	38	0049
0154	68	1002.7	T		10	200	31.1	40.3	180	42.6	0122
0254	69.8	1004.8			10	190	21.9	34.5	200	39.1	0226
0354	71.6	1006.1			10	200	18.4	27.6	210	31.1	0341
0454	73.4	1006.9			10	190	18.4	29.9	210	31.1	0420
0554	73.4	1008.1			10	200	21.9	28.8			
0654	71.6	1010.0			10	200	16.1	24.2			
0754	71.6	1011.3			10	210	18.4		200	29.9	0709
0854	73.4	1012.2			10	210	16.1	25.3			
0954	75.2	1013.1			10	200	13.8				
1054	78.8	1013.5			10	210	19.6	25.3			
1154	80.6	1014.0			10	220	19.6	25.3			
1254	82.4	1014.2			10	220	19.6				
1354	82.4	1014.4			10	230	17.3				
1454	84.2	1014.9			10	230	15				
1554	84.2	1015.1			10	240	13.8				
1654	82.4	1015.5			10	250	10.4				
1754	82.4	1016.1			10	260	8.1				
1854	78.8	1016.5			10	250	3.5				
1954	78.8	1016.5			10	250	3.5				
2054	78.8	1016.5			10	250	3.5				
2154	78.8	1016.5			10	250	3.5				
2254	78.8	1016.5			10	250	3.5				
2354	78.8	1016.5			10	250	3.5				

Statistics for September 18 and 19

Temperature		Total		Visibility		Wind Speed		Peak Wind	
Maximum	84.2	Precipitation	2.04	Maximum	10	Maximum	38	Maximum	64.4
Minimum	68			Minimum	0.5				

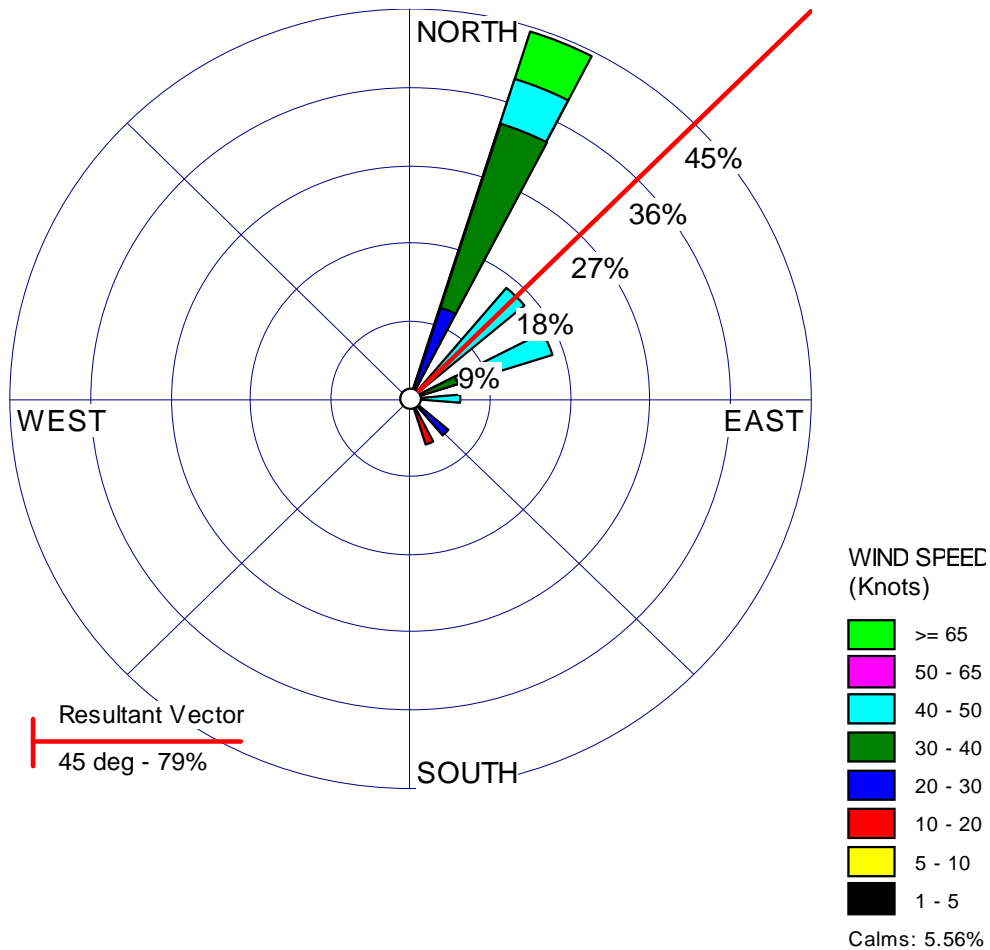
Key: M: Missing data - no observation taken
 Weather Elements: BR = Mist Precipitation Type: R = Rain
 FG = Fog DZ = Drizzle Rainfall: T = < 0.05 in
 FRZ R/DZ = Freezing Rain or Drizzle Snowfall: T = < 0.5 in

6. Weather Observation Site Wind Roses



Wind Rose Plot:
Norfolk Naval Air Station, Norfolk, VA

Display:
Wind Speed Direction (blowing from)



Comments:

Plot produced using hourly mean observed winds.

Red line indicates the resultant wind vector, which is the mean wind direction for the period.

Data Period:
2003
September 18
Midnight to Midnight

Calm Winds:
5.56%

Average Wind Speed:
36.61 Knots

Total Data Counts:
18

Client: Taylor and Walker, PC. Norfolk, Virginia



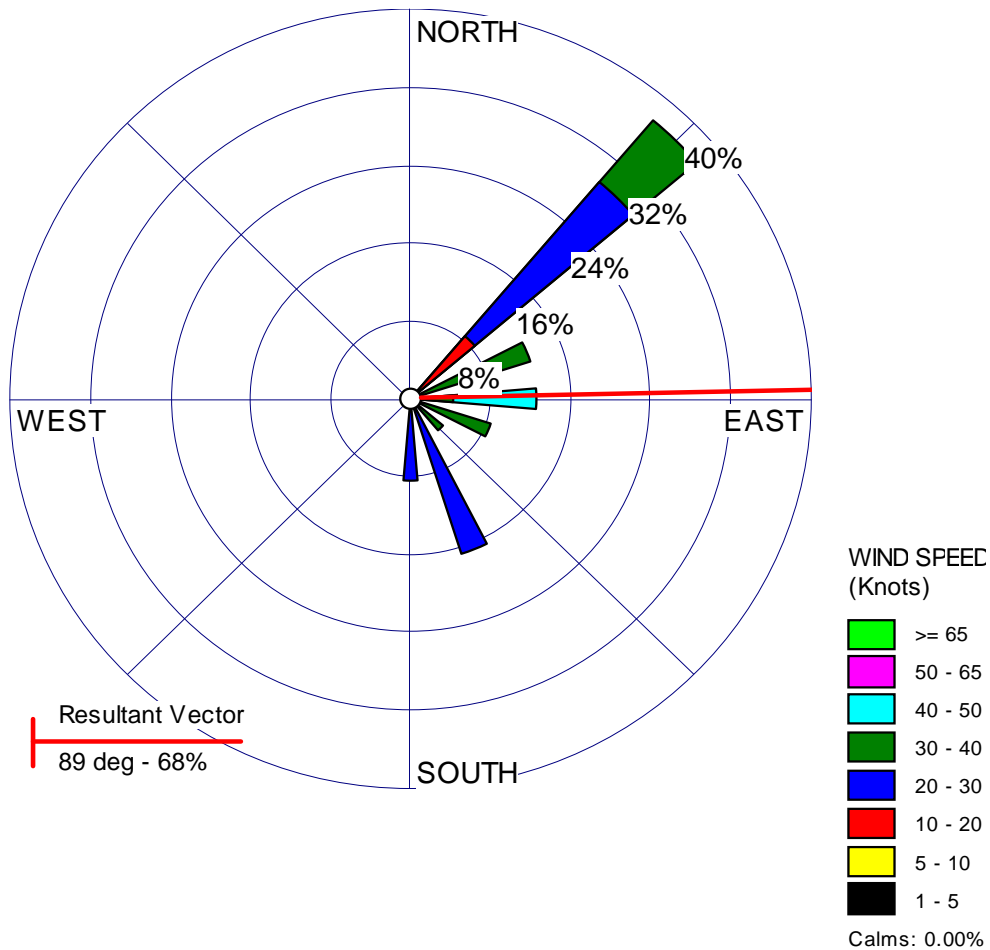
Red Sky Weather Service, LLC
732 Keeling Dr
Chesapeake, VA 23322
757-410-5708
www.redskyweather.com

Analyst: Joseph Veneziano

Date: August 7, 2006

Wind Rose Plot:
Langley Air Force Base, Hampton VA

Display:
Wind Speed Direction (blowing from)



Comments:
Plot produced using hourly mean observed winds.

Red line indicates the resultant wind vector, which is the mean wind direction for the period.

Data Period:
2003
September 18
Midnight to Midnight

Calm Winds:
0.00%

Average Wind Speed:
28.63 Knots

Total Data Counts:
24

Client: Taylor and Walker, PC. Norfolk, Virginia



Red Sky Weather Service, LLC
732 Keeling Dr
Chesapeake, VA 23322
757-410-5708
www.redskyweather.com

Analyst: Joseph Veneziano
Date: August 7, 2006

7. References

1. National Hurricane Center, 2004. Jack Bevin and Hugh Cobb. Tropical Cyclone Report - Hurricane Isabel 6 – 19 September, 2003
2. C. S. B. Grimmond, T. S. King, M. Roth and T. R. Oke. Aerodynamic Roughness of Urban Areas Derived From Wind Observations. *Boundary-Layer Meteorology* 89: 1–24, 1998.
3. Grimmond, C. S. B., Souch, C., Grant, R. H., and Heisler, G.:1994, 'Local Scale Energy and Water Exchanges in a Chicago Neighborhood', in E. G. McPherson, D. J. Nowak and R. A. Rowntree (eds.), *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project*, USDA Forest Service Northeastern Forest Experiment Station, General Technical Report NE- 186, pp. 41–61.