Draft #3

NCDFR~FIRE STAFF

RESEARCH & DEVELOPMENT

A Near Fatal Miss, What Caused This Fire Behavior Event ?

by

Gary M. Curcio

and

James B. Merrell

and

Anthony Ray

Gary M. Curcio is a fire staff specialist for the North Carolina Division of Forest Resources, Kinston, NC. James B. Merrell is the fire weather focal point meteorologist for the National Weather Service, Raleigh, NC. Captain Anthony Ray is a meteorologist for the United States Air Force, Operational Support Branch, Norman, Oklahoma.

Telephone: 919-522-4666
Fax: 919-522-1289
DG : SF.NC:S29L03A
EMAIL : NCS0096@INTERPATH.COM

Gary M. Curcio
NCDFR Stallings Field
Rt. & Box 88
Kinston, NC 28501 - 8946

WAS THIS A RARE EVENT?

For years researchers have been studying fire weather, extreme fire behavior and dangerous wildfires. What happened to the Division's Strike Team was an extreme fire behavior event, although it was not a rare one. This type of fire behavior has frequently occurred and has been associated with the pocosin fuels in the North Carolina's coastal plain. This fuel complex is composed of highly volatile brush species 4 to 12 ft tall and usually with a widely dispersed Pond Pine (Pinus serotina) overstory. The brush species are dominated by evergreens such as galberry, fetterbush, and redbay mixed with deciduous swamp cyrilla and honeycup.(Wendell 1962, Blackmarr 1975)

The extreme fire behavior during the Fish Day Fire (Photos 3,4,5,and 6), has been observed on other wildland fires. What caused the unexpected change ? What initiated the sudden shift in the wind direction and made a routine fire assignment life threatening? Was information available to wildland firefighters that would have alerted them to the high probability that extreme fire behavior would be experienced ?

Prior to this NEAR MISS the following information was available:

- **National Weather Service Zone Forecasts**
- **Conditions for Blow Up Fires.**
- **Critical Fire Danger Values from the National Fire Danger Rating System.**

THE NATIONAL WEATHER SERVICE ZONE FORECASTS.

The Zone Forecasts are prepared for a specific time period to reflect the worst probable fire weather for suppression activities within a geographic area. These forecasts are to depict the hottest, driest, and windiest conditions that can be experienced as compared to the General Public Forecast which depict the most prevailing or actual weather patterns. There were numerous warning signals of extreme fire behavior within the Zone Forecast. (Figure 2)

A NEAR FATAL MISS

A wildland fire behavior event occurred during the Fish Day Fire, May 26, 1994. Because of an unforecastable wind shift, a North Carolina Division of Forest Resources (NCDFR) Tractor and Plow Strike Team experienced a life threatening situation. The strike team consisted of a leader, 4 dozer operators and 4 crewman. Each operator operated an Incident Command System type 1dozer which was a low ground pressure unit and equipped with a heavy duty fire plow. The Strike Team's assignment was to construct containment lines on the northwest flank of the fire (Figure 1). As a standard safety practice the strike team was firing a black line. This is where a fire is set between the plowed containment line and the main body of the fire to remove unburned fuel and establish a wider, more controllable break. This also creates a safety zone, an escape area for firefighters should circumstances require a safe place to go (Photo 1).

Southwest winds were forecasted at the fire site by the National Weather Service for the entire day. Fire growth would spread to the northeast. This direction was parallel to the planned constructed fire break or containment lines. At approximately 2:30 pm DST, the wind shifted to the south and windspeeds increased to 20 to 30 mph. This caused the fire's spread to change direction and run directly at the containment lines being constructed on the fire's northwest flank. The strike team was now encountering a fire that was running at them with flame lengths from 25 to 100 feet long. The shifting wind carried burning embers across the containment lines and began to easily ignite numerous new spot fires (Photo 2). The adjacent fuel had already been preheated and dried by the radiant heat from the black line firing. The fire was now burning on both sides of the constructed fire lines. The firefighters were in danger of being fatally burned. The quickness of this event surprised the strike team even though they were actually forewarned by an immediately eerie calm preceding the wind shift. The Strike Team members were visibly cut off from each other being separated by walls of fire. Unable to reach their safety zone each member accepted the fact that they would probably be fatally burned. Some began to run in an attempt to escape the advancing flaming fronts. Realizing this was futile some operators with their dozers began to knock down the head tall dense brush. Hopefully, if time would permit, they would be able to clear an area to deploy their fire shelters and then hope for the best. As quick as events were unfolding, no one really believed that they would have the necessary time. It would be to late. However, suddenly for a brief moment, there was a break in the rapidly approaching flames as an alley of relatively clear clean air formed amongst the thick, dense, unbreathable smoke and unbearable heat. Remembering their training they all headed for the established safety zone. Each strike team member recognized and seized the opportunity to make it back into the previously created safety zone. A place were one would be able to survive being burned over. The strike team was understandably shaken by the turn of events; they had narrowly escaped being fatally burned.

- **Synopsis - Approaching Cold Front**

  The position of an initiating or ongoing fire is very critical in relation to existing frontal passages and the formation low pressure troughs (Brotak 1977)
  These combinations of weather and fire have produced large dangerous forest fires.

- **Weather Today - Zone 17**

  PM Thunderstorm Activity and Cumulonimbus development can severely impact on going wildfire's behavior.

- **Minimum Relative Humidity - Zone 17**

  The morning forest predicted the RELATIVE HUMIDITY at 40%. However this was updated at 1200 PM to fall as low as 30 percent (Figure 3). Field conditions were not following the National Weather Service computer projection models. The relative humidity was still in a dangerous range for a major fire run as previously reported by Rollo T. Davis(1969).

- **Adjacent Weather Zone -16 & Sea Breeze.**

  Weather zone,16, was adjacent to zone 17 - the location of the Fish Day Fire, would eventually e influenced by the sea breeze and its' shifting winds.
  Sea breezes and their influences have been well documented by Williams (1974).

- **Wind Profile Analysis - Questionable**

  The morning and evening radiosondes recorded for May 26,1994 indicated an adverse wind profiles - type B and Brotak's wind profile. In North Carolina these wind profiles have long been associated with extreme fire behavior and dangerous large wildfires. An update was to be issued but was not.

- **Burning Forecast Today**

  The weather parameters, mixing height, transport wind , and burning category, indicated a very unstable atmosphere. Any fire, controlled or uncontrolled, would be difficult to contain. If the Haine's Index had been in use, it would have assigned a rating of 5. This rating would be interpreted as an excellent rating for small fires to become large fires exhibiting extreme fire behavior.(Haines 1988)

CONDITIONS FOR BLOW UP FIRES IN NORTH CAROLINA.

Blow up fires are associated with plume dominated wildfires as reported by G. Byram (1958). Such fires exhibit erratic directions of spread and extremely fast rates of spread. Spotting is a serious hazard. It is frequent and numerous and the spotting distances are short as well as long range. The conditions suitable for Blow- up fires and large fire growth in the North Carolina's coastal plain have been determined to be:

- **Relative humidity < or = 30 percent**
- **Fine fuel moisture < or = 6.5 percent**
- **Build Up Index > or =25**
- **Prediction of instability, the presence of an adverse stable wind profile.**

In reviewing the 830 am morning weather forecast for May 26, 1994 (figure 2) and the weather zone in which the fire was located, Zone 17, the worse predicted relative humidity for the day was 40 percent. This was later amended at 1200 PM (figure 3) and re-forecasted to reach as low as 30 percent. This updated forecast was a direct result of onsite weather readings being recorded and transferred to the National Weather Service from another major wildfire in the adjacent weather zone 16.

Fine fuel moistures for dead fuels < 1/4 inch (cm.)in diameter and 1/4 inch (cm.)in litter depth were only 8.1 percent as determined by a remote automated weather station (RAWS). However, what was very disturbing was the extremely low fuel moistures in the larger fuel size classes. The trend was observed from RAWS units throughout the southern half of the coastal plain. The 10 hr. timelag fuels (1/4 to 1 in. (cm.) in diameter and 1/4 to 1 in. in litter depth) were drier than the fine fuels. The 100hr. timelag fuels (>1 to 3 in. (cm.) in diameter and 1 to 4 in. (cm.) in litter depth) were at moisture values usually associated with the smaller 10 hr. fuels.

The fire danger stations provide measured and calculated fuel moistures.

1300 Hr. Fuel Moistures May 26,1994

FD Station	1 hr.	10 hr.	100hr.	1000 hr.
Whiteville	7.5	9.4	12.7	22.1
Catherine Lake	**8.1**	**6.6**	**12.8**	21.7
Fairfield	5.8	12.7	12.8	19.0
Pocosin Lake	8.2	7.3	14.1	21.7

Catherine Lake was a fire danger station within the adjacent zone forecast area. It recorded the worst 10 hr. moisture content levels. Even at 8 percent, fine fuels were easily

ignitable, and to have the larger 10 hr. fuels at an even lower moisture content of 6.6 percent indicated very explosive and intense burning conditions.

The **Build Up Index** (BUI) is an old fire danger index from the early days when a National Fire Danger Rating System was first initiated. It has now evolved into the Energy Release Component. The BUI reflects the cumulative drying effects in the litter below the immediate surface layer to a depth of 2-3 inches (cm.) and the forest floor branchwood up to 2-3 inches (cm.) in diameter. There is no single critical point on the BUI but values above 30 indicate that the BUI is above normal.(Keetch 1954, nelsoon 1961, 1966). Catherine Lake's fuel moisture readings and calculations in conjunction with a BUI of 46 unequivocally revealed that the fuels were dry and plentiful enough to support high intensity wildfires.

Atmospheric instability was noticeable throughout the NWS forecast:

- **Cold front passage**
- **PM thunderstorm activity**
- **Windspeed @ the surface**
- **Questionable Wind profile Analysis**
- **Burning Forecast**

In North Carolina the key ingredient or triggering mechanism for large fire growth is atmospheric instability. The Cape Hatteras upper air radiosondes recorded by the NWS at dawn and at dusk for May 26, 1994 indicated adverse wind profiles. [**Note:** This term "adverse"originated from the now closed Southeastern Research Fire Lab In Macon, GA. In the late 1950's George Byram investigated wind profiles (windspeed and its' change with altitude) and their relationship to a wildfire's behavior (Byram 1954 and unpublished key). Profiles were considered adverse, questionable, or favorable. Adverse -vertical wind profiles were associated with the worst case wildfires exhibiting extreme fire behavior, towering smoke column development & in some cases the presence of low level jets). This work was later followed in the 1970's by Ed Brotak (1977) who identified a large fire growth profile which will be referred to as the "Brotak wind profile".] For firefighters in the southeast the two most troublesome wind profiles documented in the literature were present on May 26. These wind profiles provided the uncontained Fish Day Fire every opportunity to exhibit extreme and dangerous fire behavior. Figure 4 represents the morning and afternoon profiles for the Fish Day Fire and the Air Force Bomb Range Fire (Wade 1973). Respectively these fires consumed 24,600 and 29,300 acres. Each fire experienced major burning periods with these adverse wind profiles. An association has also been made that these profiles can contain drier air aloft (lower relative humidity) than what is at the surface. Thereby further exasperating burning conditions as the dry air aloft is brought down through the fire's convective activity and the air's vertical mixing.

Critical Fire Danger Values From NFDRS.

Land Managers with wildland fire responsibilities daily face the problem of estimating tomorrow's fire business.(Lancaster 1978). Being able to plan an agency's level of readiness for the anticipated fire problem is projecting the day's potential fire danger. This is accomplished by the National Fire Danger Rating System. It is the firefighters responsibility to understand the system and to be able to put into perspective the system's outputs. What do the NFDRS components and indexes mean? How do the they impact the suppression effort? These outputs give the firefighter a daily evaluation of the upper limits of the behavior of initiating fires. For the Fish Day Fire the nearest and most reliable fire danger station was the Catherine Lake remote automated weather station. Located approximately 30 miles to the southeast of the fire , Catherine Lake yielded the following components and index. These values can better be put into perspective when compared with the previous maximum peak values ever recorded.

Catherine Lake RAWS	5/26/94 NFDRS outputs	Previously Recorded May's Max. Peak Values
• **Ignition Component**	**57**	**50**
• **Spread Component**	**102**	**84**
• **Energy Release Component**	**57**	**63**
• **Burning Index**	**162**	**156**

Comparing these outputs, **the fire danger for May 26 set three new maximum peak values for the pocosin fuel complex**. Critical fire danger breakpoints in the pocsin fuel complex have long been established for Ignition Component at > 20 , Burning Index at > 75, and Spread Component at >40. On May 26, 1994 the Fish Day Fire was not an initiating fire . It was still uncontained and running. These new maximum peak Fire Danger values indicated that the Fish Day Fire containment efforts would be extremely difficult and dangerous. The Fish Day Fire itself was in command of the situation. Until the fuel or weather conditions changed enough to effectively lower the fire's intensity, the fire was in control. These present NDFRS values projected the following concerns for firefighters:

- severe spotting.
- problems in holding any firing operations.
- fire growth would exceed any rate of line construction capability.
- indirect attack may be the only safe method for containment.

- mopup would be a major effort as deep burning in the organic fuels would be likely.
- fire behavior would be extreme - short & long range spotting, horizontal vortices as described by Haines(1987, 1982,1971) torching, and active crown fires where the pond pine overstory density was sufficient.
- Interagency resources would be required.

The Wind Shift

A wind shift of at least 30 degrees from the southwest to south was observed at all observation sites in southeastern North Carolina beginning around 12:00 pm DST or1600 UTC at Wilmington, progressing up the coast and inland during the afternoon (figure 5). Thus the wind shift was a mesoscale event rather than a microscale one, i.e. it was not induced by the fire itself.

The wind shift was evident at Cherry Point Naval Reserve Station ((NKT) figure 6) with a change from south-southwest at 12:00 pm(1600 UTC) to south at 1:00 pm (1700 UTC) and an increase in speed from 5 knots to 10 knots. The speed increased to 15 knots at 2:00 pm (1800 UTC) then decreased to 10 knots with a wind shift back to south-southwest.

The wind shift exhibited several sea breeze characteristics:

- wind shift direction more perpendicular to the coastline
- propagated far inland perpendicular to coastline
- cloud formation

It also exhibited several non-sea breeze characteristics:

- propagated far inland against strong synoptic flow
- fast movement > 10 mph ( )
- temperature continued to increase
- dew point decreased
- wind shift persisted only 1 to 2 hours

inland convection dissipated when intersected by wind shift line later in the afternoon

The wind shift line was eventually detected as a boundary in reflectivity and velocity imagery by the National Weather Service Raleigh WSR-88d Doppler radar (KRAX). Time lapses of this imagery clearly shows the boundary progressing inland toward the radar several hours after the initial wind shift at the coast. The boundary was seen to

intersect convection within 50 miles of the radar and the convection diminished rather than intensified.

Tony Ray , doing related research at the time of the fire on boundaries detected by Doppler radar, described the feature as an " Unknown Moving Boundary " (UMB) as he unable to definitely identify its source or cause.

Why The Wind Shift Occurred

Upon investigating why this wind shift occurred, the following weather clues were revealed:

- The synoptic situation indicated southwesterly flow at the surface and aloft for the fire area as high pressure was centered well off the south Atlantic coast and the low pressure center was moving through the eastern Great Lakes with an associated coldfront across the Ohio and the lower Mississippi valleys (figure 7). Frontal passage at the fire site was forecasted for late on May 26 or early on May 27, 1996.

- A possible sea breeze was indicated along the south coast of North Carolina even with the strong southwest synoptic flow. The fire weather forecast issued by the National Weather Service Raleigh was updated at 12:30 pm (1630 UTC) to indicate this but only for the south coast. The fire site was in the adjacent forecast zone (central coastal area).

- The 8:00 am (1200 UTC) upper air sounding (figure 8) from Cape Hatteras, North Carolina (HAT) indicated a low level inversion from the surface to approximately 950 Mb with dry air above the top of the inversion up to 700 Mb. Thus if the inversion was broken and the temperature was able to reach the convective temperature approximately 80 degrees Fahrenheit, some of the dry air would likely be mixed down to the surface.

- Satellite imagery (figure 9) showed mid-level clouds along the North Carolina coast during the morning that dissipated from the southwest to the northeast during the early afternoon. This allowed the low level inversion to burn off first near Wilmington as the clearing skies allowed the temperatures to warm up faster there than other coastal locations.

- The 8:00 am (1200 UTC) 850 Mb analysis (figure 10) indicated a low level jet axis from Athens, Georgia (AHN) to Cape Hatteras, North Carolina. Wind speeds were generally from 20 to 30 knots. Much stronger winds (35 to 45 knots) were indicated from 950 - 850 Mb, likely due to trapping beneath the inversion.

These clues lead to the following hypothesis of the formation of the UMB:
A sea breeze developed and its propagation inland was enhanced by the traverse circulation around the low level jet (figure 11) . However , instead of the cooler and more moist air being advected in from off the ocean, dry air mixed down from aloft. This resulted in the atypical sea breeze effects of temperatures continuing to warm and dew points decreasing. The boundary itself could initiate weak cloud development but the overall affect would be to suppress convection. Also, with the low level inversion broken , stronger winds from aloft would be expected to surface to coincide with the wind shift. After the passage of the sea breeze boundary, the strong synoptic flow became dominant again resulting in a wind shift back to south-southwest.

The unusual wind shift that resulted in the fire behavior incident that endangered lives during the Fish Day Fire would have been very difficult to forecast. Most of the data indicated strong synoptic flow from the southwest which would preclude a sea breeze except along the immediate south coast. The key appears to be the presence of the low level jet and its orientation parallel to the coastline. Although this was not forecasted, there were several indicators of possible adverse fire behavior during the day of the incident.

Summary

The forest fuel conditions and the weather conditions created an environment for severe fire behavior. As firefighters we need to stay fully aware of all the aspects of what is happening around us. We must constantly remember to look up, look down, and look around. Take the time to notice, and reflect. We need to ask such questions as:

- Is a convective column developing and if so, what is it doing?
- Are cumulus clouds developing?
- Are there rolling vorticesat the head or the flanks of the fire? If so,are they single, double or multiple?
- Are wind shifts predicted? Where is my safety zone?
- Is my safety zone immediately accessible?
- What do I need to consider to remain safe today?

This re-examination needs to be continually ongoing. Because as conditions change, our actions need to make the necessary, complimentary adjustments. The temporary wind direction shift during the Fish Day Fire was recorded by Fire Danger Stations throughout the coastal plain. The shift can be attributed to the combined effect of the sea breeze and the low level wind jet. Rolling horizontal vortices were a common occurrence (Photos 3,4,5,and 6) and this increased the danger to personnel who were working in close proximity to the vortex. Pilots flying over the fire observed the shifting smoke column and

saw vortices development at the fire's head and flanks. How many burning embers or firebrands were being deposited in new fuels by the vortices? The sudden eerie calm that was experienced by the strike team has been previously noted as a reliable indication of a precluding change (wind shift or a sudden down burst air). It acts as warning signal. **Information available to firefighters needs to be fully understood. Firefighters need to be aware of how the indices, components, and weather relate to each other. They need to be able to reflect on how they must act for each situation before it even develops. This can be accomplished by being aware of your surroundings, utilizing the power of observation and having the necessary training and field experience. Attention to a dynamic environment is essential in order to make the appropiate decisions before it is to late.**

Literature Cited

Blackmarr, W.H. and Flanner, W.B.1975. Moisture variation in selected pocosin shrubs of eastern North Carolina. Research Paper SE-124. U.S. Department of Agriculture- Forest Service Southeastern Forest Experiment Station Asheville NC. 10p.

Brotak, E. A. and Reifsynder, W.E. 1973. Predicting major fire occurrence. U.S. Department of Agriculture - Forest Service. Fire Control Notes. Spring 1977 Vol.38 No.2.

Byram, G.M. 1954. Atmosphere conditions related to blowup fires. Station Paper No.35. U.S. Department of Agriculture - Forest Service. Southeastern Forest Experiment Station Asheville, NC.

_____. 1957. Unpublished key - vertical wind profiles and associated fire behavior in flat country. Southeastern Forest Experiment Station . 26p.

Davis, R. T.1969. Atmospheric stability forecast and fire control. U. S. Department of Agriculture - Forest Service. Fire Control Notes. Summer. Vol. 30. No. 3. 3p.

Haines, D. A. 1988. A lower atmospheric severity index for wildland fires. National Weather Digest. 13(2):23-27.

_____, and Updike, G.H. 1971. Fire whirlwind formations over flat terrain. Research Paper NC-71. U.S. Department of Agriculture - Forest Service.North Central Forest Experiment Station. St. Paul, MN. 12p.

_____, and Mahlon C.S.1987. Three type of horizontal vortices observed in wildland mass crown fires. Journal of Climate and Applied Meteorology. 26(12):1624-1637.

_____, 1987. Horizontal vortices and the New Miner Fire. Fire Management Notes. Vol.48 No.4 p.26-28.

_____,1982. Roll vortices and crown fires. Journal of Applied Meteorology. p. 751-763.

Keetch, J.J.1954. Instructions for using forest fire danger meter type 8. Station Paper No.33. U.S. Department of Agriculture - Forest Service Southeastern Forest Experiment Station Asheville, NC 7p.

Lancaster, J. W. 1978. Fire management application of the national fire danger rating system . National Wildfire Coordinating Group. May 1978 S&PF-CFP.

Literature Cited

Nelson. R.M.1961. Some applications of danger ratings in forest fire control and management. Station Paper No.129. U.S. Department of Agriculture- Forest Service. Southeastern Forest Experiment Station .Asheville, NC 26p.

_____.1966. Derivation of spread phase tables national fire danger rating system. U.S. Department of Agriculture - Forest Service.Southeastern Forest Experiment Station. Asheville NC.54p.

Wade,D.D. and Ward,D.E.1973. An analysis of the Air Force Bomb Range Fire.Research Paper SE105.U.S. Department of Agriculture - Forest Sevice.Southeastern Forest Experiment Station.Asheville NC. 38p.

Wendell, G.W., Storey, TG, and Byram, G.M>19562. Forest fuels on organic and associated soils in the coastal plain of North Carolina.Station Paper No.144. U.S. Department of Agriculture - Forest Service.Southeastern Forest Experiment Station. Asheville NC.46p.

Williams,D.T.date unknown.Spring season sea breeze fronts in coastal Georgia. Forest Meteorology (Project Theo) Work Unit. Southern Forest Fire Laboratory. Southeastern Forest Experiment Station, Macon, GA.21p.

_____. 1974. Predicting the Atlantic sea breeze in the southeastern states. Weatherwise.Vol.27.No.3. June.p.106-109.