2009

North Carolina Division of Air Quality

Ambient Monitoring Section
5/28/2009

N.C. EXCEPTIONAL EVENT (MARCH 31, 2008)

The smoke from the Edna Buck Road wildfire in New Hanover County, North Carolina impacted measurements of a particulate matter monitor, operated by the North Carolina Division of Air Quality. The cover picture shows the fire head that reached within a few feet of the air pollution monitor.

Contents

ACRONYMS

AOD	Aerosol Optical Depth
DFR	Division of Forest Resources
FRM	Federal Reference Method
GASP	GOES Aerosol Smoke Product
GIS	Geographic Information Systems
GOES	Geostationary Operational Environmental Satellite
HMS	Hazard Mapping Service
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory Model
NOAA	National Oceanic and Atmospheric Administration
NC	North Carolina
NC DAQ	North Carolina Division of Air Quality
OC	Organic Carbon
OM	Organic Mass
OMI	Organic Mass Index
ORD	Office of Research and Development
PM2.5	Particulate Matter with an Aerodynamic Diameter of 2.5 microns or less
RTP	Research Triangle Park
TEOM	Tapered Elemental Oscillating Microbalance

EXECUTIVE SUMMARY

Overview

The NC DAQ believes that the smoke from the Edna Buck Road wildfire in New Hanover County, North Carolina may have been responsible for elevating PM2.5 FRM monitoring data above the PM2.5 daily standard (35 µg/m^3) and the data in Table 1 should be excluded from regulatory decisions. This NC DAQ report details the evidence of the Edna Buck Road wildfire, transport of the smoke, impacts on PM2.5 FRM concentrations with "atypical", and "but for" analysis. A quick overview of the main points in the report are as follows:

- The source of the fire was only 2-3 miles from the Castle Hayne PM2.5 FRM monitor, and penetrated to within a few feet of the NC DAQ monitors.
- Due to the dry local conditions, the fire penetrated into the "root mat" which creates the worst type of emissions from a fire. The residual smoke or smoldering from the burning roots continued past April 1, 2008 or 7-10 days after the start of the fire on 3-26-08.
- The "but for" analysis shows that the OMI could have reduced gravimetric PM2.5 mass by 50-70% on the 3-31-08 sample impacted by the Edna Buck Road Fire. (Organic carbon is associated with wood smoke from forest fires).
- The speciated particle monitors measured low sulfate levels (less than 1.5 µg SO4/m^3) at Raleigh, Hickory, and Lexington, NC on 3/31/08 which indicates that regional sulfates were low and could not have caused nor contributed to the high particulate reading at Castle Hayne on 3/31/08.
- The causal relationship is established by wind roses, wind direction/wind speed plots, ground pictures of the fire and the monitor, and forward/backward trajectories of air with the NOAA HYSPLIT model.
- Statistical modeling predicts that much lower PM2.5 FRM concentrations would have been expected.

Fire Start Date: March 26, 2008
Fire End Date: June 15, 2008
Fire Cause: Electrical Fence
Fire Location: Edna Buck Road and surrounding areas near Castle Hayne, NC

Data Requested for Exclusion

The data requested for exclusion are listed in Table 1:

Table 1 NC PM 2.5 FRM sample affected by the **Edna Buck Road** Fire Incident

Site Name	Sampling Frequency	County	Site Id.	Site Latitude	Site Longitude	Date of Exceedance	FRM-PM2.5 (µg m^{-3})
Castle Hayne	1-in-6 day	New Hanover	37-129-0002	34.36	-77.84	31-Mar-08	41.7

Evidence of Flagging

The wildfire began on 3/26/08 due to an electric fence that ignited a pasture whose grass fire reached the woodlands. The general fire perimeter came within a few yards of the Castle Hayne PM2.5-FRM monitor (Figure 1), but the fire head actually penetrated to within a few feet of the Castle Hayne PM2.5-FRM monitor (Figure 2). The wildfire quickly spread to 1,000+ acres. Once the Edna Buck Road wildfire went into the root mat, it caused persistent smoke issues due to the smoldering of the organic soil which lasted 7-10 days after the initial fire on 3/26/08. The primary fuel source was peat moss; therefore, the Edna Buck Road Fire could take months to burn out without substantial rain. The monitor was surrounded by smoldering combustion on all three sides. The smoldering emissions are the worst type of emissions as the smoke hugs the ground and drifts with the wind direction (Figure 2). Smoke was witnessed on Holly Shelter Road.

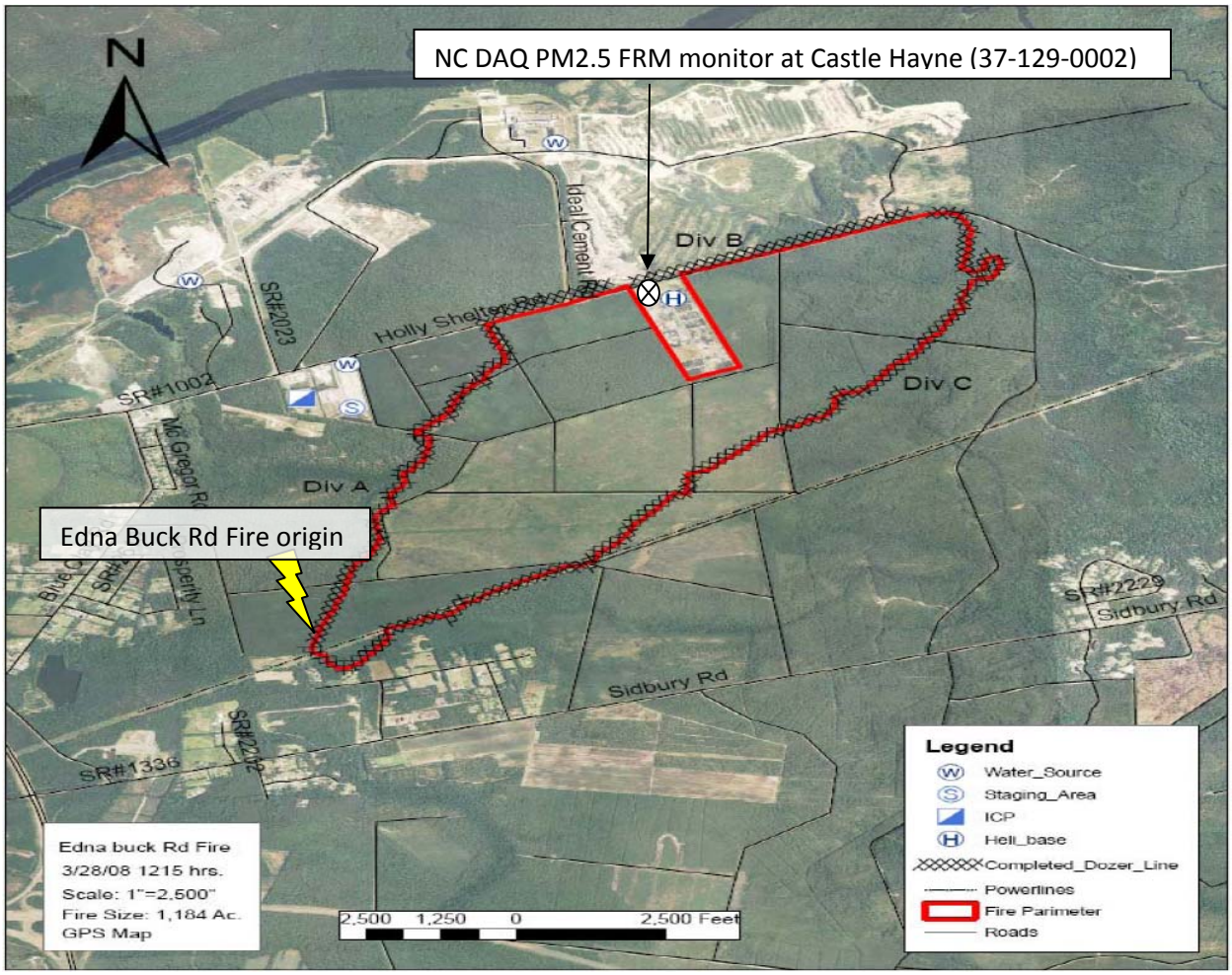


Figure 1: A general view of the Edna Buck Rd. Fire perimeter (shown with red line). Note the location of the NC DAQ PM2.5 FRM monitoring site is (⊗) inside the box. The GIS map is courtesy of Mr. Gary Curcio of the NC Division of Forest Resources and represents a general view of the fire perimeter.

Figure 2: Picture was taken on 3/28/08, but smoke from the ground fire smoldering lasted well past 4/1/08. The position of the Castle Hayne FRM-PM2.5 monitor relative to the smoke and fire's edge is indicated. Photo is courtesy of Mr. Gary Curcio of the NC Division of Forest Resources.

The HMS showed the satellite detection of the Edna Buck Road Fire (Figure 3):

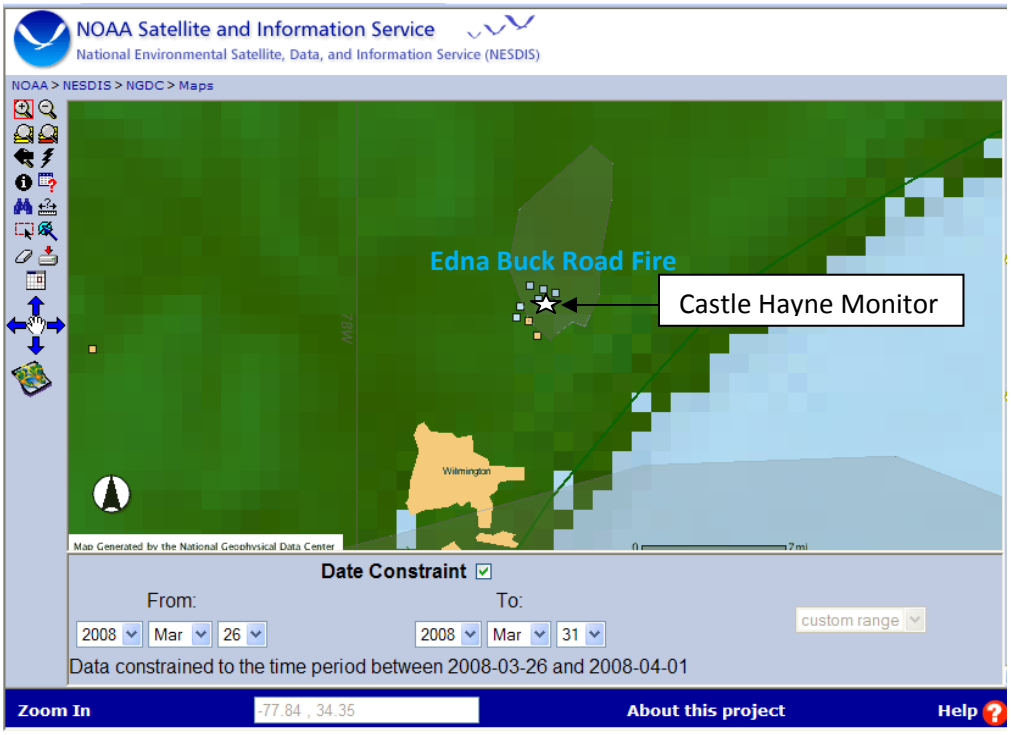


Figure 3: The fire and monitoring site are on top of each other. The NOAA HMS detected the fire at the approximate coordinates of -77.84, 34.35. The shaded area is smoke, the star (☆) represents the location of the Castle Hayne monitor (-77.84, 34.36), and the colored dots are HMS fire pixels.

CHRONOLOGY OF EVENTS

The filter loading percentage of the TEOM-PM2.5 monitor at Castle Hayne on 3-26-08 increased rapidly starting at 15:00 (Figure 4). The gap in the TEOM1HR data of Figure 4 between 11:00 and 15:00 represents monitor maintenance and a filter change of the TEOM-PM2.5 monitor. The rise in the TEOM-PM2.5 around 14:00 signals the arrival of the smoke from the Edna Buck Road wildfire. The TEOM-PM2.5 was reading at maximum range (200 µg/m^3) by 5 PM on 3-26-08.

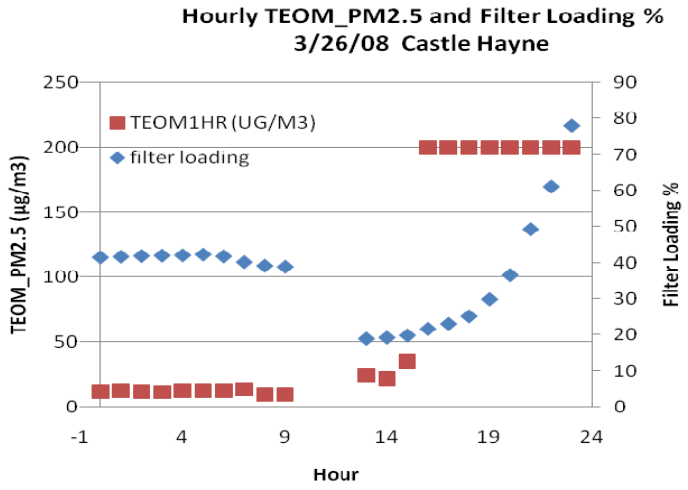


Figure 4: TEOM-PM2.5 hourly averages and filter loading percentage (3/26/08)

The FRM-PM2.5 exceedance of the daily PM2.5 standard occurred on 3-31-08 (Figure 5). The Castle Hayne monitor was approximately 2 miles from the origin of the fire and a few yards from the TEOM-PM2.5 monitor.

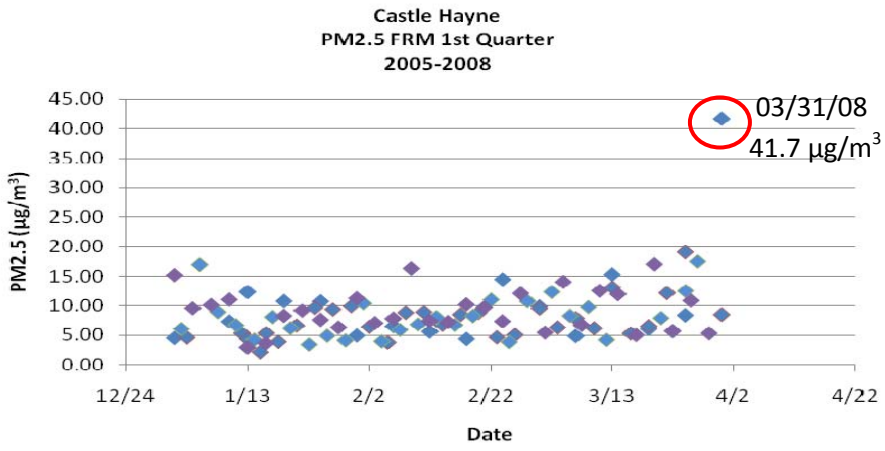


Figure 5: PM2.5 FRM daily averages (Jan-Mar, 2005-2008). The 95th percentile at Castle Hayne (Jan-Mar, 2005-2008) is 15.29 µg/m^3.

TRANSPORT

Beginning around 8AM on 03/31/08, the wind direction at the Castle Hayne PM2.5 FRM monitoring site changed from an easterly direction and began coming out of the South/Southwest/Southeast (Figure 6). The monitor was then in the direct path of the smoke.

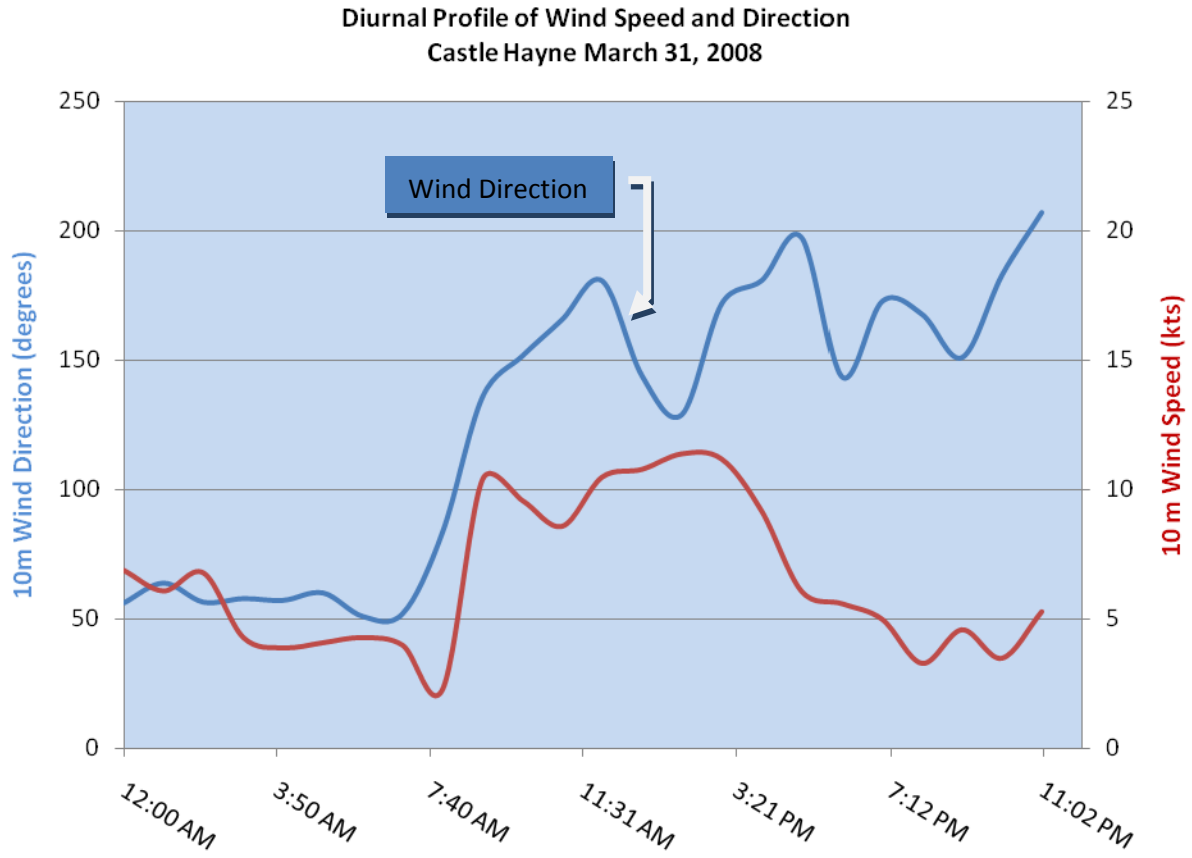


Figure 6: The wind direction shifted from blowing from the Northeast to blowing from the South/Southeast/Southwest. The windspeed is also shown (1 knot ≈ 1mph).

A wind rose for a meteorological station near Castle Hayne indicates that 70% of the winds were southerly (Figure 7) on 3/31/08.

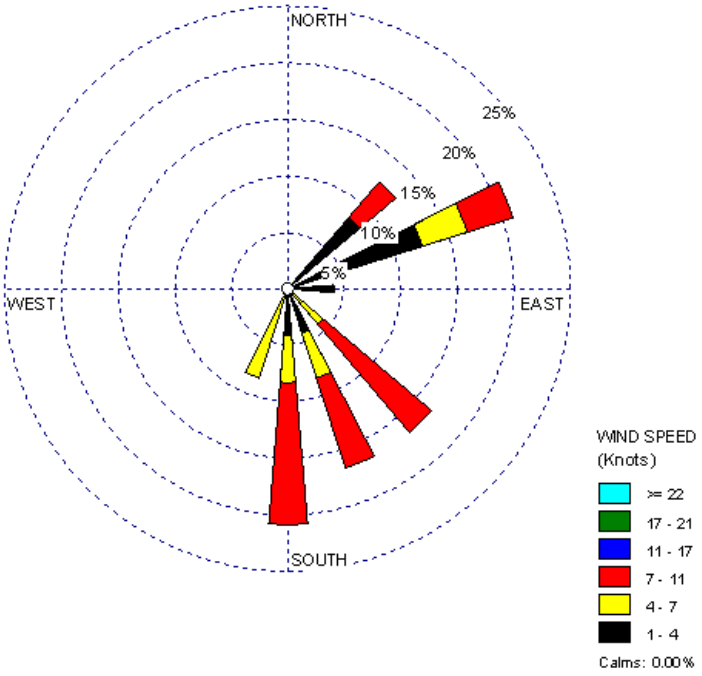


Figure 7: Wind rose for Castle Hayne on 3/31/08. The PM2.5 FRM monitor was surrounded by the fire on all three sides: South, East, and West.

As has been shown, the smoke hugged the ground and drifted with the direction of the wind. Both forward and backward trajectories also indicate an impact on the monitor throughout the day of March 31, 2008 (Figure 8 and Figure 9).

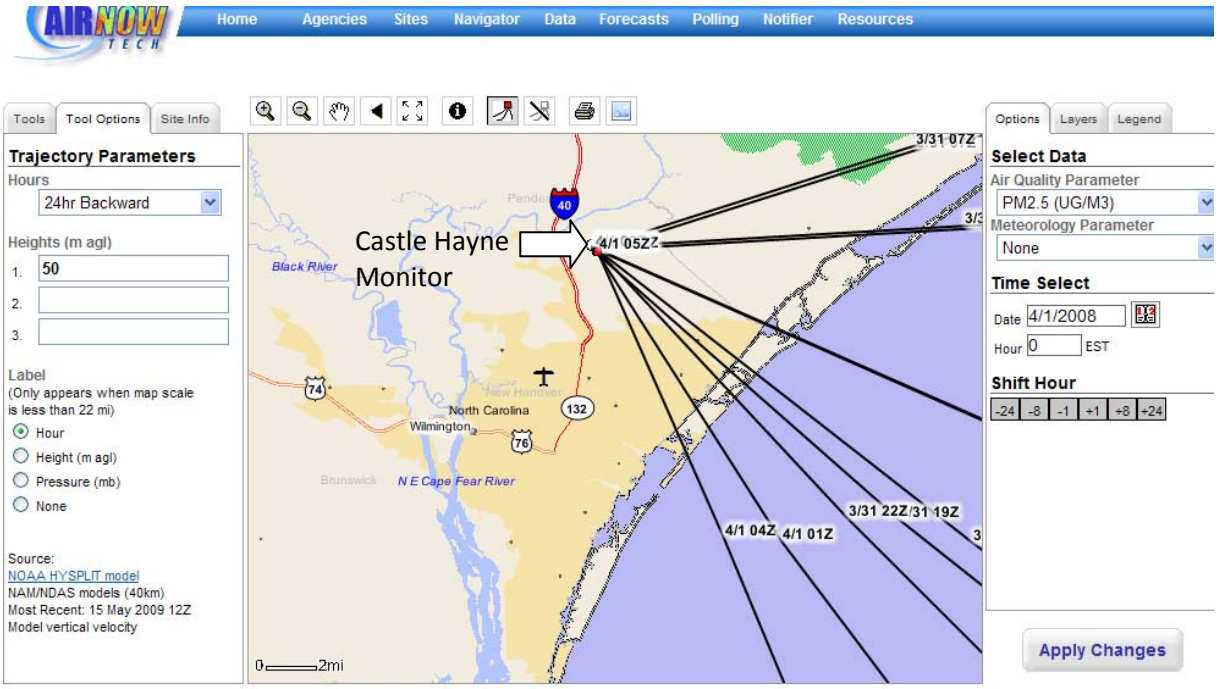


Figure 8: The 24-hour back trajectories to the Castle Hayne PM2.5 FRM monitor were examined using the Navigator tab at the AIRNOW TECH website. The source for the AIRNOW TECH back trajectories is the NOAA HYSPLIT model. The starting height input was 50 meters and the run times were 3AM, 6AM, 9AM, 12PM, 3PM, 6PM, 9PM of 3/31/08 and 12 AM for 4/1/08.

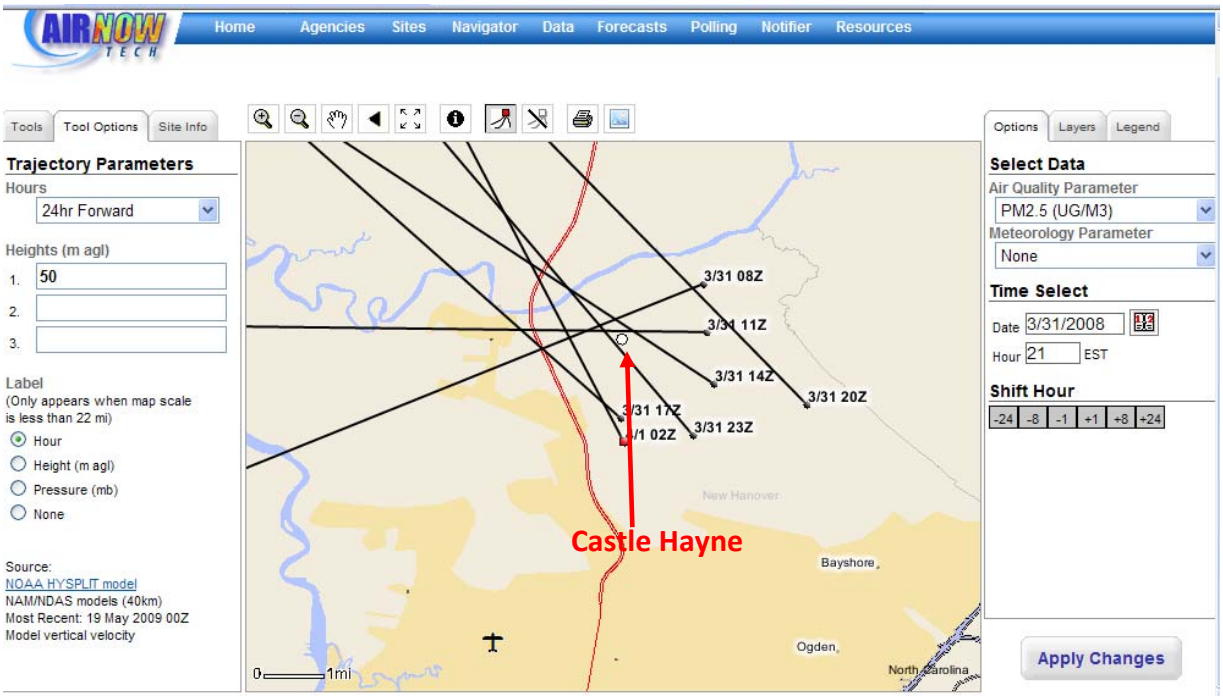


Figure 9: The 24-hour forward trajectories to the Castle Hayne PM2.5 FRM monitor were started at 50 meters and run at 3AM, 6AM, 9AM, 12PM, 3PM, 6PM, and 9PM for 3/31/08.

ATYPICAL ANALYSIS

The atypical analysis shows, quite thoroughly, the extent of the influence on the monitoring data caused by the **Edna Buck Road** Fire. Shown in Table 2 is the actual value measured (2008 Exceptional Candidate) as it compares to the benchmark 84th and 95th percentiles. The exceedance is more than twice the next highest recorded value in the first quarter for the previous four years (Table 3). The values were flagged in AQS with an "rt" flag for Forest Fire. EPA concurrence for the forest fire flag is sought.

Table 2: Comparison of the PM2.5 FRM 3/31/08 exceedance of the daily standard with historical percentiles at Castle Hayne, Jan-Mar, 2005-2008 at Castle Hayne

Site Name	Site Id	Benchmark Percentiles Jan-Mar 2005-2008		**2008 Exceptional Candidate**	Ratio to percentiles		Flag
		84%	95%		84%	95%	
Castle Hayne	37-129-0002	12	15.29	41.67	3.4	2.73	rt

Table 3: Ten highest historical concentrations, Jan-Mar, 2005-2008 at Castle Hayne

41.67	19.00	17.50	17.00	17.00	16.30	15.29	15.20	14.46	14.00

"BUT FOR" ANALYSIS

Organic Carbon "But for"

The exceedance of the PM2.5 daily standard may not have occurred but for the **Edna Buck Road** Fire impact. The organic mass is a large fraction of the total PM2.5 mass during a woodsmoke impact. Andrews, et. al (2000)[1] has noted that the *differences* between gravimetric mass and reconstructed mass were *greatest* when aerosol was influenced by *forest fire emissions* and aged anthropogenic pollutants. NC DAQ utilized the OMI that was calculated with a similar fire regime (Evans Road Fire) that impacted our Millbrook FRM-PM2.5 monitor on June 12, 2008. The Evans Road Fire was similar to the **Edna Buck Road** Fire in that the fire penetrated the top layer of the soil horizon which is a fine mesh of roots (the "root mat" as shown in the appendix); therefore, ground fuels were present in both fires.

The OMI that was borrowed from the Evans Road Fire indicates that the organic mass that is associated with woodsmoke from a fire that uses ground fuels may contribute nearly 50-70% to the total PM2.5 gravimetric mass (air volume basis was a cubic meter of air). In Table 4, we indicate the type of PM2.5 concentrations that could result at Castle Hayne without the OMI contribution to the total particulate mass. The sulfate levels at the Hickory, Lexington, and Millbrook speciated monitoring stations on 3/31/08 were below 1.5 µg/m^3; therefore, sulfates did not make a significant contribution to the particulate mass on 3/31/08. The maximum statewide PM2.5 FRM value recorded on 3/31/08 was at Castle Hayne (Table 4), and the next highest PM2.5 FRM value on 3/31/08 was 7.1 µg/m^3, which was measured by a NC DAQ PM2.5 FRM monitor near Waynesville, NC.

Table 4: North Carolina PM 2.5 (µg m^{-3}) 3/31/08 data adjusted for the OMI of the Evans Road Fire

Site Name	County	Site ID	Date	Actual	Adjusted[1] OMI = 46	Adjusted[2] OMI = 66
Castle Hayne	New Hanover	37-129-0002	3/31/08	41.7	20.85	12.51

[1]PM2.5 FRM$_{adjusted}$ ≈ actual value × 0.5, [2]PM2.5 FRM$_{adjusted}$ ≈ actual value × 0.3

OMI calculation

The organic mass increment (OMI) to the fine particle concentration (PM2.5) was calculated using the following equation[2]: $\mathrm{OMI} = \left(\mathrm{OC}_{\mathrm{observed}} - \mathrm{OC}_{\mathrm{average}}\right) \times 2$. In a personal communication, Dr. Chris Geron, US EPA ORD, RTP, NC indicated that many recent studies indicate that the OM:OC ratio could be much higher than the factor of 2 assumed in calculating the OMI.

[1] Andrews, E., Saxena, P., Musarra, S., Hildemann, L. M.,Koutrakis, P.,McMurry, P. H., Olmez, I., and White, W. H. (2000). Concentration and Composition of Atmospheric Aerosols from the 1995 SEAVS Experiment and a Review of the Closure between Chemical and Gravimetric Measurements, *J. Air Waste Manag. Assoc.* 50:648–664.

[2] Daniel Garver, EPA 2009 Region 4 Presentation (http://www.epa.gov/region4/sesd/training/air/)

The NC DAQ obtained two estimates of OMI to use in the **Edna Buck Road** Fire as shown in Table 5.

Table 5: PM2.5 adjustment factors using the OMI

Organic Carbon (µg m^{-3}) at Duke Forest		OMI (µg OC m^{-3})	PM2.5 Adjustment Factor
Observed (6/12/08)	Summer Avg (2005-2008)		
26.6 (Daily Avg.)	3.70	46	0.5
36.5 (12pm-12am)		66	0.3

The $OC_{observed}$ was obtained using organic carbon data collected during the Evans Road Fire on June 12, 2008 at an EPA research site located at Duke Forest, Durham, NC (Table 6). The summer average of Organic Carbon at Durham, NC was obtained from the paper by Geron[3].

Table 6: Duke Forest Organic Carbon (Dr. Chris Geron, US EPA ORD, RTP, NC)

Date	Time	Organic Carbon (µg m^{-3})
6/12/08	12:00 AM	13.53
6/12/08	3:00 AM	17.83
6/12/08	6:00 AM	10.48
6/12/08	9:00 AM	14.64
6/12/08	12:00 PM	44.17
6/12/08	3:00 PM	48.66
6/12/08	6:00 PM	27.53
6/12/08	9:00 PM	28.2
6/13/08	12:00 AM	33.96
	Daily Average OC	**26.5**
	Average (12PM – 12 AM)	**36.5**

Adjustment Factor Calculation

The determination of the adjustment factors proceeds as follows: on June 12, 2008, the Millbrook PM2.5 FRM, the closest NC DAQ site to the Duke Forest, measured a 99.04 µg/m^3 due to the Evans Road Fire impact. Adjusting the total PM2.5 gravimetric mass at Millbrook on June 12, 2008 with the OMI gives:

$PM2.5\ FRM_{adjusted}$ = 99.04 – 46 = 52.04 µg/m^3 (≈ 0.5 × actual value)
$PM2.5\ FRM_{adjusted}$ = 99.04 – 66 = 33.04 µg/m^3 (≈ 0.3 × actual value)

Similar OMI adjustment factors as at Millbrook were assumed for the Castle Hayne impact due to the **Edna Buck Road** Fire.

Statistical "But For"

A second approach to the "but for" analysis used by the NC DAQ was to develop a statistical model using historical data of explanatory variables which usually include wind speed, wind direction, precipitation,

[3] The organic carbon data set is courtesy of Dr. Chris Geron of US EPA ORD (RTP, NC): Geron, Chris. Carbonaceous Aerosol over a *Pinus Taeda* Forest in Central North Carolina, USA. *Atmospheric Environment*, **43** (2009), 959-969

precipitation lag, ambient temperature, relative humidity, etc. to predict the PM2.5 concentration at Castle Hayne on March 31, 2008. The model output shown in Table 7 indicates that the expected PM2.5 concentration at Castle Hayne on 3/31/08 would be 7.2 µg/m^3. Excluding the exceedance candidate, the average PM2.5 FRM concentration on 3/31/08 as measured by 27 statewide PM2.5 FRM monitors was 4.3±1.2 µg/m^3, with the maximum value being 7.1 µg/m^3 at Waynesville, NC.

Table 7: Statistical model predictions of PM2.5 FRM values without Edna Buck Road Fire influences

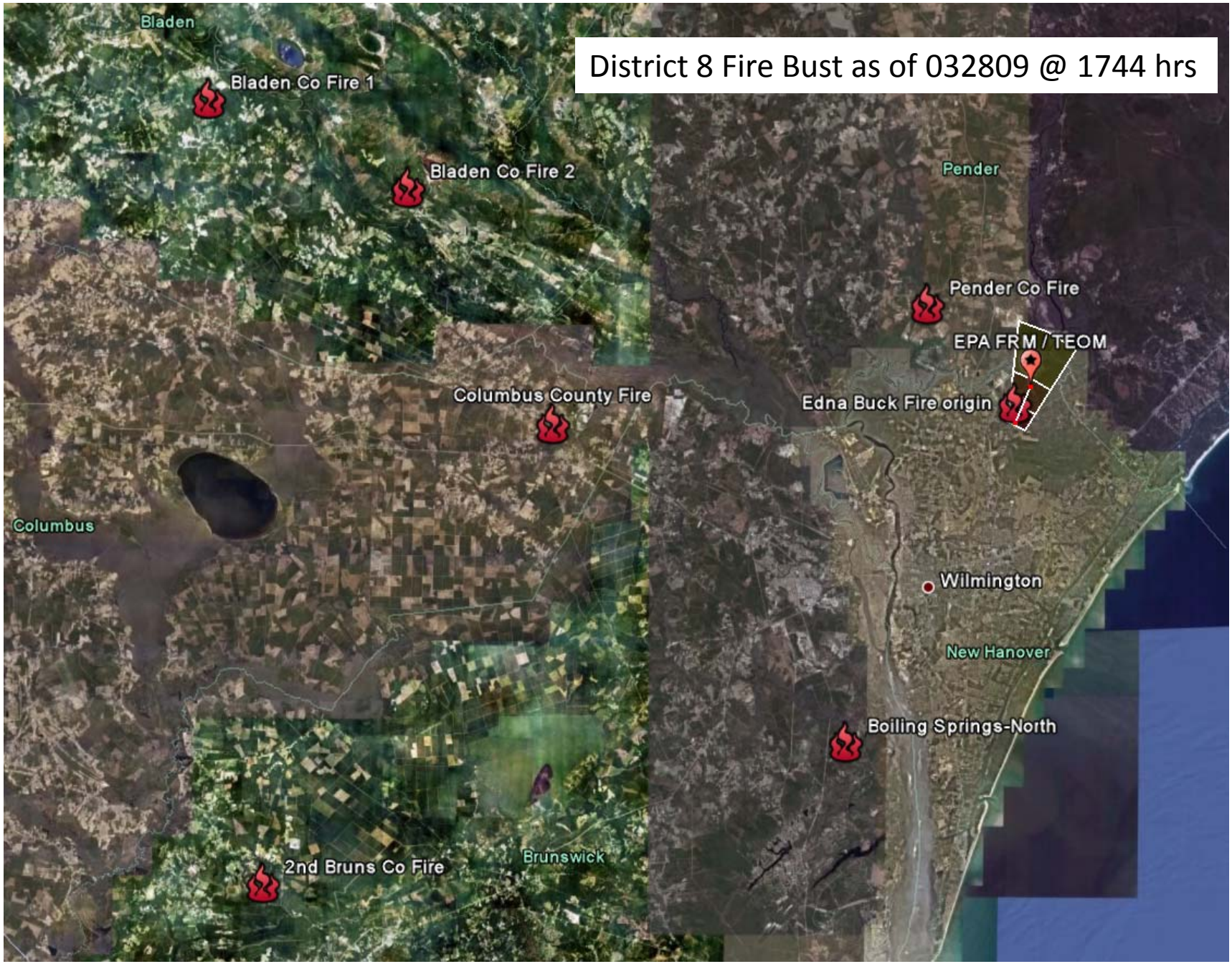
RowNames	actual	expectation	UPLimit.99	Df	R.2
CH.model2	41.67	7.2	15.37	98	0.1169

The data used in the model is comprised of the past four years of the same calendar quarter (Jan-Mar, 2005-2008 at Castle Hayne) in which the exceedance occurred. The upper limit of the expected concentration, 15.37 µg/m^3, has only a 1% chance of being exceeded; therefore, the 3/31/08 value would not have occurred. The R.2 is an indication of the predictive power of the model (an R.2 value of 1 indicates good predictive power), and smaller R.2 values greatly widen the 99% confidence band making it more difficult to exceed the upper limit (UPLimit.99).

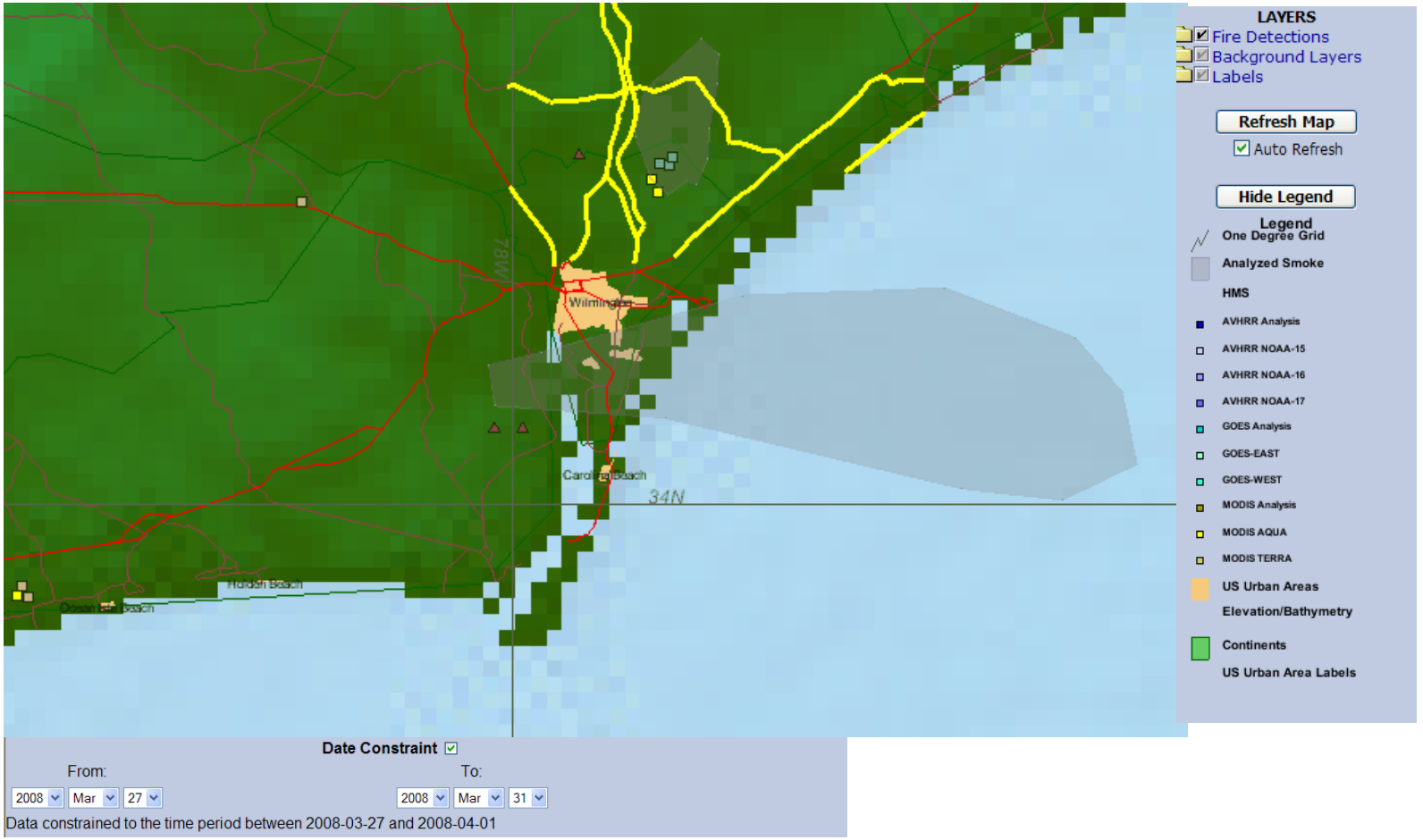
The higher PM2.5 concentration could not have been caused by industrial emissions because the NC DAQ has an extensive permitting, compliance, and enforcement program designed to minimize industrial emissions. Mandatory controls on industrial atmospheric particulate emissions are often 99.97% effective. Moreover, influences from historical industrial emissions are implicitly included in the linear model.

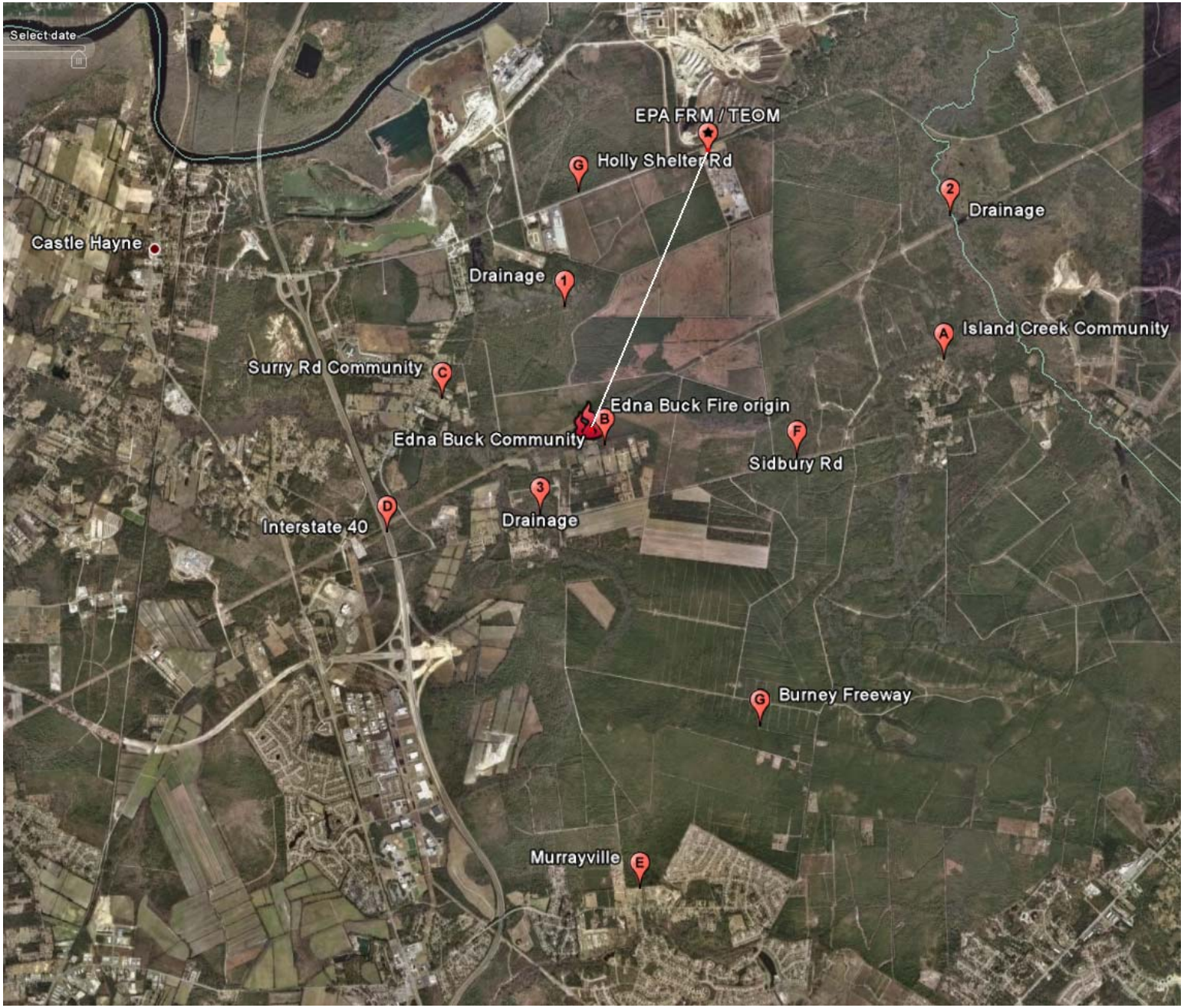
APPENDIX A

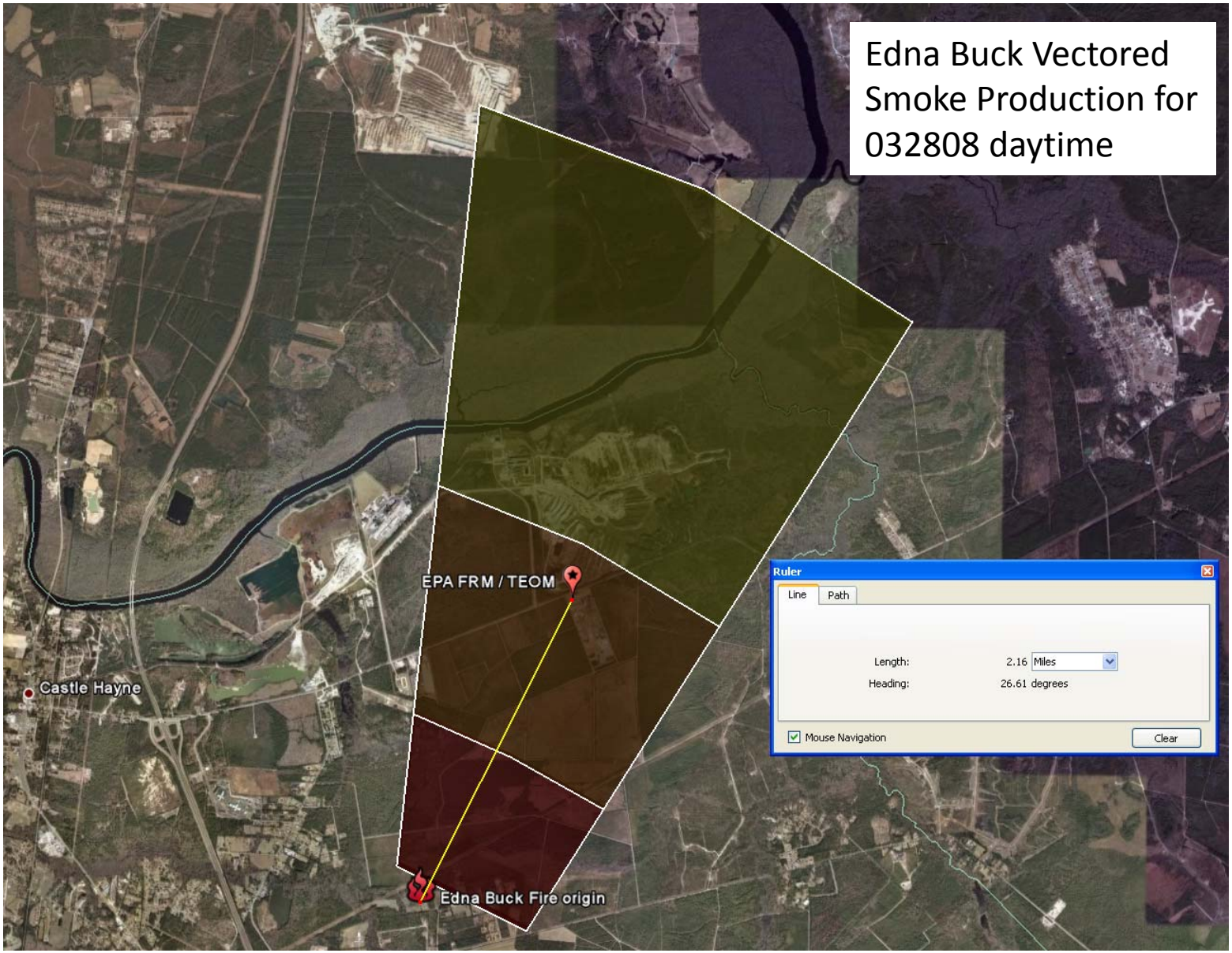
A package with additional information regarding the Edna Buck Road Fire (courtesy of Gary Curcio, NCDFR).

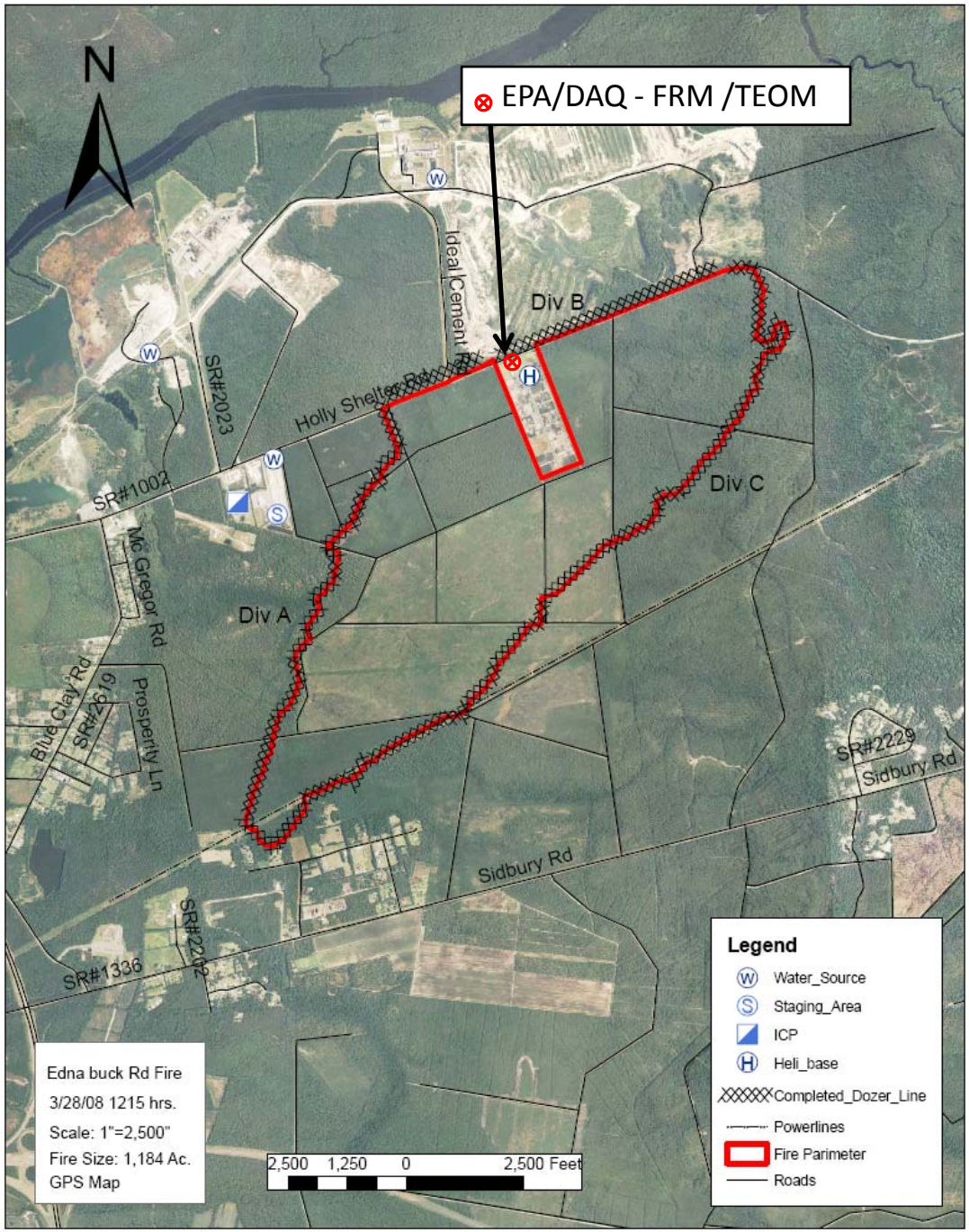

District 8 Fire Bust as of 032809 @ 1744 hrs
Bladen
Bladen Co Fire 1
Bladen Co Fire 2
Pender
Pender Co Fire
EPA FRM / TEOM
Edna Buck Fire origin
Columbus County Fire
Columbus
Wilmington
New Hanover
Boiling Springs-North
2nd Bruns Co Fire
Brunswick

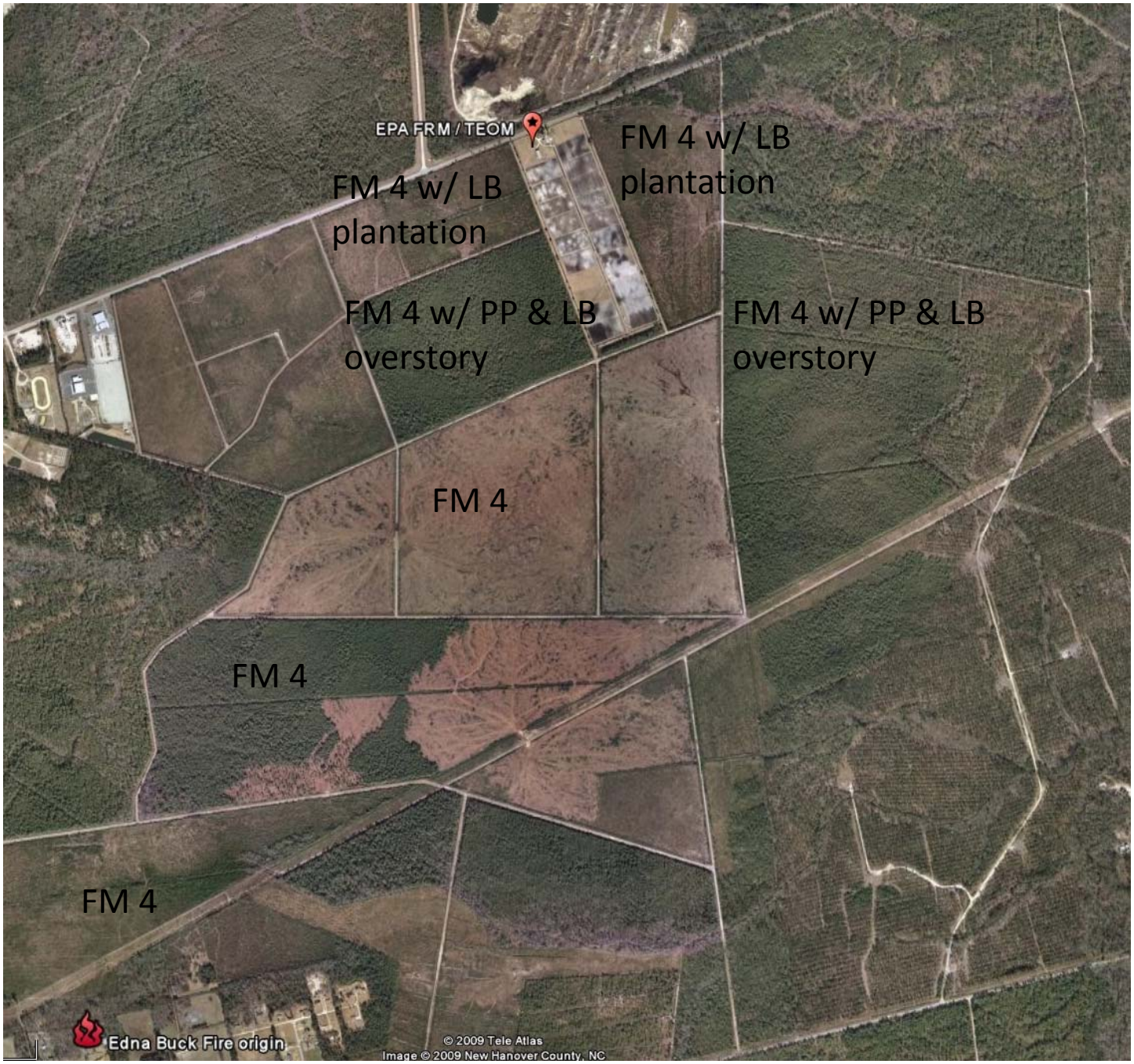
NOAA Satellite Services Division Fire Products




Select date
EPA FRM / TEOM
Holly Shelter Rd
Drainage
Castle Hayne
Drainage
Island Creek Community
Surry Rd Community
Edna Buck Fire origin
Edna Buck Community
Sidbury Rd
Interstate 40
Drainage
Burney Freeway
Murrayville


Edna Buck Vectored Smoke Production for 032808 daytime
EPA FRM / TEOM
Castle Hayne
Edna Buck Fire origin
Ruler
Line
Path
Length:
2.16
Miles
Heading:
26.61 degrees
Mouse Navigation
Clear


N
EPA/DAQ - FRM /TEOM
Ideal Cement Rd
Div B
Holly Shelter Rd
SR#2023
SR#1002
Div C
Mc Gregor Rd
Div A
Blue Clay Rd
SR#2619
Prosperity Ln
SR#2229
Sidbury Rd
Sidbury Rd
SR#2202
SR#1336
Edna buck Rd Fire
3/28/08 1215 hrs.
Scale: 1"=2,500"
Fire Size: 1,184 Ac.
GPS Map
2,500 1,250 0 2,500 Feet
Legend
Water_Source
Staging_Area
ICP
Heli_base
Completed_Dozer_Line
Powerlines
Fire Parimeter
Roads


EPA FRM / TEOM
FM 4 w/ LB plantation
FM 4 w/ LB plantation
FM 4 w/ PP & LB overstory
FM 4 w/ PP & LB overstory
FM 4
FM 4
FM 4
Edna Buck Fire origin
© 2009 Tele Atlas
Image © 2009 New Hanover County, NC

Root Mat moisture content reaches 150 % or less the probability of sustained ignition dramatically increases & residual smoke becomes a serious issue

Headfire of Edna Buck reaches DAQ monitors .

After the fire's surface run through surface and aerial fuels, the Edna Buck Fire goes in the ground as the root mat ignites causing persistent smoke issues that places at risk 24/7 the safety and health of firefighter's and public.

	Edna Buck Road **FIRE UPDATE** **For fire information phone:** 828-273-0982 for David Brown or 919-218-3179 for Bill Swartley	*NC Forest Service* *Incident Management Team* **March 31, 2008** **9:00 a.m.**
Current Status	Rains received since midnight Saturday have helped to cool the 1,184-acre Edna Buck Road Fire. Holly Shelter Road was opened to traffic Sunday morning. The fire remains contained within 50-foot wide firebreaks that are being patrolled and monitored by the NC Forest Service. It will take several inches of rain to completely extinguish the ground fire that is burning within the containment lines. With the wet weather there is currently no threat of the fire escaping, but smoke could become a problem in the Castle Hayne area. Breeze conditions will dissipate the smoke, but when the wind dies down visibility in the fire area could be limited. Motorist should use caution. Castle Hayne residents may smell smoke from the fire for several days. The Edna Buck Road Fire started on March 26, 2008, and quickly spread to over 1,000 acres in size. Forest Service personnel and equipment will remain on the fire scene for several more days. Fire engines, full tracks (all terrain engines) and tankers are being used to extinguish ground fire where it is accessible. Bulldozers are working to isolate ground fire areas and create access for the engines. A plan to rehabilitate roads and fire breaks has been developed, and will be implemented over the next several days.	
Estimated Acreage	1,184	
Containment	100% (Fire perimeter is secure, but significant areas of ground fire are still burning.)	
Cause and Date Started	Electric fence, 03/26/08	
Resources on the Fire	7 bulldozers, 3 full tracks, 4 engines, 2 water tenders, 1 farm tractor	
Cooperators	New Hanover County Emergency Management, Castle Hayne Fire Department, National Weather Service, Martin Marietta, NC DOT, New Hanover County Sheriffs Department, Progress Energy	
Plans for Tomorrow	Firefighters will monitor smoke from ground fire, and use bulldozers and engines to confine and extinguish ground fire. The rehabilitation plan will be implemented.	
Fire weather	Light rain and high relative humidity have aided firefighters. The rain will not completely extinguish the fire. If there is an inversion, smoke will not dissipate and could limit visibility in the fire area.	