TEXAS A&M FOREST SERVICE

Texas A&M Forest Service Smoke Management Plan

April 2018

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Introduction

Summary

Prescribed fire is recognized as an important forest and rangeland management tool in Texas and across the Southeastern United States. Prescribed burning has a positive and direct impact toward improving ecosystem health. Some specific benefits of prescribed fire include reducing invasive or competing vegetation, site preparation for planting, and forest or watershed health. Not only does prescribed fire serve as a resource management tool, but it also increases public safety by reducing fuels. The application of prescribed fire reduces hazardous fuel loading against future wildfires and directly protects lives and property. Although prescribed fire provides many benefits to public safety and ecosystem health, it does produce a hazardous byproduct: *Smoke.*

Smoke generated from prescribed fires can decrease air quality and aggravate health problems. Smoke can reduce visibility and result in dangerous roadway conditions. The general sight and smell of smoke can also be a nuisance to people with limited knowledge about this important land management tool.

Texas is home to over 27 million people as of July 2016. From 2010-2016, Texas's population has increased by 10% *(U.S. Census Bureau, 2017).* A direct result of the increasing population is the increase of the wildland urban interface (WUI). The WUI is where homes and communities are adjacent or intermingle with undeveloped land and fuels. WUI areas have a high potential of being impacted by smoke as prescribed burning occurs.

Most southern states have implemented some form of smoke management guidance for prescribed burning. Many of the state's smoke management procedures are voluntary guidelines, although several states issue permits for burning. **Texas A&M Forest Service does not have regulatory authority for prescribed burning and does not issue burn permits.**

The Texas A&M Forest Service will use this smoke management plan (SMP) as a support document during the implementation of prescribed fire on public lands. The SMP will serve as guidance to conduct agency burns.

Mission Statement

The SMP sets in place best management practices to limit impacts on air quality and smoke sensitive areas before, during, and after burning. The guide is also designed to provide educational material and references for proper smoke management across the state. The SMP will be reviewed periodically to refine and improve smoke management guidance.

Disclaimer

The Texas A&M Forest Service Smoke Management Plan is a voluntary approach with the Texas A&M Forest Service serving as a technical leader in the prescribed burning community. The SMP is not expected to be a perfect tool for solving all smoke-related problems, but can educate burn managers on how to reduce smoke impacts from prescribed fire.

The SMP is a decision support document providing fire managers an opportunity to better manage their own operations. The SMP does not relieve the private landowner or company conducting the burn from liability for fines or damages that might occur, or transfer any liability to the state. The Texas A&M Forest Service recommends that a trained, experienced, and certified (National Wildfire Coordination Group or Texas Department of Agriculture) burn boss prepare the burn plan and conduct all prescribed burns.

Smoke Management Procedures

Smoke Basics

Prescribed fire smoke is a mixture of small particles, water vapor, carbon dioxide, ash, organic material, and other invisible gases. Composition of smoke will vary between different fuel types being consumed. Particulate Matter (PM) levels are measured in micrometers with 2.5 micrometers (*Image 1*) being used as the base threshold to determine respiratory and visibility impacts *(Environmental Protection Agency, 2017).*

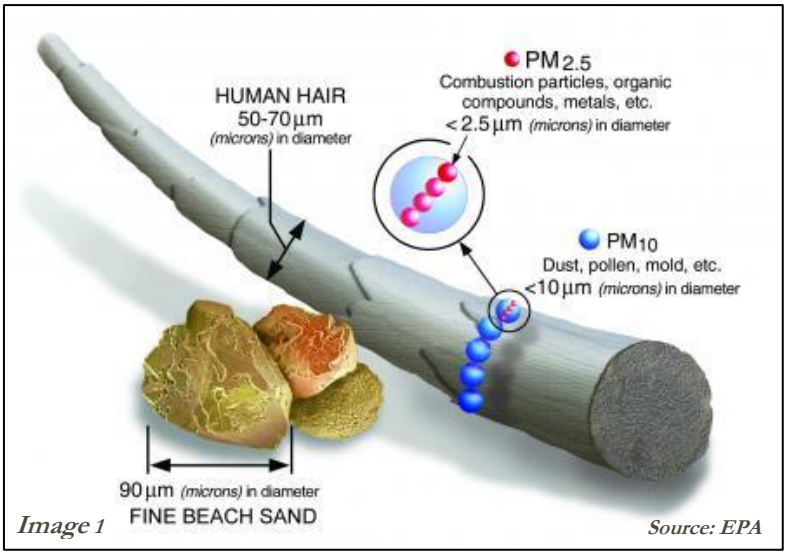


Image 1 *Source: EPA*

Smoke Management Procedures

A consistent process to best manage smoke will help prescribed fire managers complete the burn objectives and reduce smoke impacts *(Table* 1). The following five steps for smoke management are recommended to determine if the burn can be conducted when fuel and weather conditions are appropriate for burn objectives.

Table 1: Smoke Management Procedures

Action	Purpose	Recommended Completion
Identify Smoke Sensitive Areas	To plan for potential impacts	When writing the burn plan
Develop Smoke Contingency Actions	Have pre-determined actions known if smoke becomes hazard	When writing the burn plan
Determine Category Day	Provide guidance on smoke dispersion based on Transport Winds and Mixing Height	Day Before and Day of Burn
Configure Smoke Model	Have documented predicted movement of smoke if burn is complex or large	Day of the Burn
Check Air Quality Index	Determine if smoke will reduce air quality to high levels of health concerns	Day of the Burn
Smoke Observations	Monitoring Smoke Impacts	During the Burn and After

Smoke Sensitive Areas

Identifying Smoke Sensitive Areas

Identifying smoke sensitive areas (SSA) is the first and most important step in developing a SMP. A smoke sensitive area contains people, livestock, or crops that are sensitive receptors susceptible to negative impacts from prescribed fire smoke (Texas Commission on Environmental Quality, 2015). Other SSAs are those with high volumes of traffic either on major roadways or airspace. The identification of SSAs should be completed when writing the prescribed burn plan well in advance of the burn. The distance of identifying SSAs from the burn unit will depend on the size of the burn and fuel type.

If smoke models and weather conditions indicate that a SSA will be impacted, mitigation will be needed to reduce smoke impacts at these areas or the burn will be postponed until a time the SSA is no longer at risk of being impacted by smoke. Steps that can be taken include reducing the size of the burn or using a different burn technique (i.e. back burn)

Below are examples of Smoke Sensitive Areas

- Nursing Homes/Hospitals
- Schools
- Designated "Class 1" areas of Texas Big Bend National Park Guadalupe Mountain National Park *(EPA, 2017)*
- Airports
- Interstate Corridors
- Chemical Emission Factories
- Livestock/Crops (nursery plants, cultivated mushrooms, plants used for pharmaceutical drugs)

SSA Identification Tools

With identification of SSA adjacent to the burn unit and a burn plan with weather/fuel parameters, the burn boss should model potential smoke impacts. This can be done using the internet based V-Smoke or hand drawn 30° diagram

V-Smoke is a web-based (http://weather.gfc.state.ga.us/GoogleVsmoke/vsmoke-Good2.html) smoke modeling tool developed by the state of Georgia. A burn boss may navigate to Texas and input fuel/weather parameters to view potential impacts on air quality on SSAs

V-smoke can provide the expected air quality *(Table 2)* adjacent and downwind from the burn site *(Image 2).* A KML file can be exported and opened into Google Earth if desired *(Image 3).*

Image 2

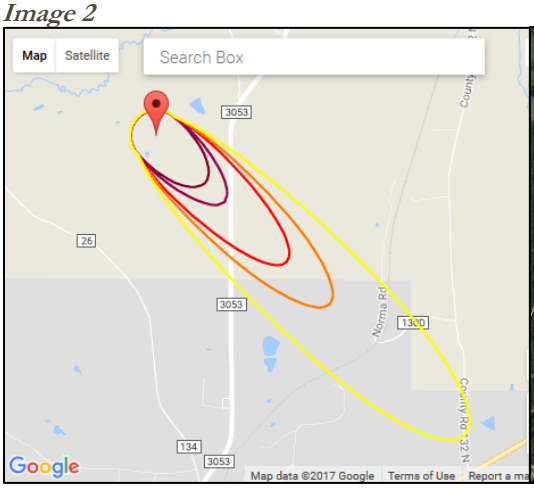


Image 3

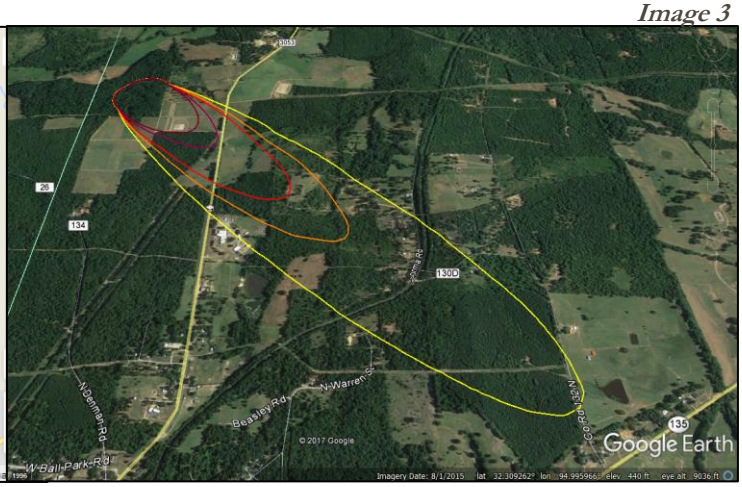


Table 2

Levels of Health Concern	AQI Value	Hourly PM 2.5 Conc.	Meaning
Good	0 to 50	0 to 38	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 to 100	39 to 88	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	89 to 138	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	139 to 351	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	352 to 526	Health alert: everyone may experience more serious health effects
Hazardous	301 to 500	> 526	Health warnings of emergency conditions. The entire population is more likely to be affected.

A hand drawn 30° smoke diagram can also determine the general smoke path and potential impacts. Based on wind direction written in the burn plan, the burn boss can draw a line of predicted smoke trajectory for a small burn (Figure 1.). Additional lines drawn 30° on both sides of smoke trajectory provide guidance for minor shift in general wind direction.

For large burns (Figure 2), the burn boss should draw a line from the center of the burn unit and then lines in the same direction at both ends of the unit and add the 30° vector line. Using this method, the burn boss can identify any SSA that may be impacted. If SSAs are within this vector, decisions should be made or actions completed to minimize smoke production.

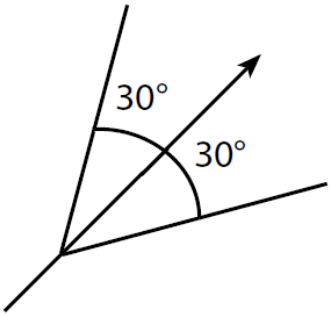


Figure 1. Small burn

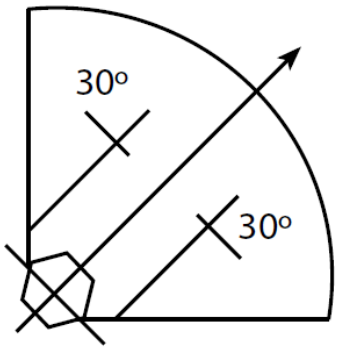


Figure 2. Large burn

Source: United States Forest Service

Develop Proactive Smoke Impact Actions

Questions to Ask

The burn boss should determine if any proactive actions can be completed prior to burning to limit prescribed fire smoke impacts. The following questions need to be addressed.

- What can be done prior to burning to reduce smoke production?
- Do adjacent landowners and SSAs need to be notified before burning? If so, how?
- What actions need to take place if smoke begins to affect an SSA?
- What actions need to take place if smoke starts to settle on a roadway?

Smoke Reduction

Depending on the prescribed fire objectives, actions can be taken before and during a prescribed fire to reduce the amount of smoke produced. Below are actions to consider before and during the burn to reduce smoke production:

- Thin or reduce fuel loading in the burn unit prior to burning.
- Burn unit in smaller sections over a period of time.
- Adjust firing technique to reduce amount of fuels consumed and smoke produced.
- Do not burn if smoke production will cause negative impacts toward SSAs.

Public Notification

The following actions should be set in place within a reasonable timeframe prior to the burn and also on the day of the burn for public notification purposes.

- Provide written or verbal statement of prescribed burn operation and smoke production to TFS *(Texas Administrative Code 111.217 and 111.219)*
- Post "Prescribed Fire in Progress" signs in proximity of State/ Interstate roads (Signs will be posted the morning of the burn by a burn boss designee.)
- Facebook and Twitter Notifications for burn area (This will be a standardized post to cut down on the time factor and the discrepancies between different areas. Coordination with communication department needed for TFS social media accounts)

Visibility on Roadways

Alerting motorists of smoke impacts from a prescribed burn may be done with the placement of prescribed burn signs along road(s) adjacent to the burn unit. Monitoring conditions and reduced visibility on roads should be done throughout the entire burn operations. Based on visibility, the actions below are recommended *(Table 3).*

Table 3: Roadway Visibility and Prescribed Fire Smoke	
Visibility on Roadway (feet)	**Recommend Action**
300 +	Continue to monitor
< 300	Slow traffic to 25 mph (use pilot cars)
< 200	Slow traffic to 15 mph (use pilot cars)
<100	Start one-way traffic
< 50	Close the road to traffic *(Adjust burn technique to clear road way, or shut down burn and begin mop-up)*

Determine Category Day

Fire Weather Forecasts

Texas is served by 13 NWS offices *(See Appendix for link to NWS Offices*), each with a fire weather forecast page. At minimum, prescribed fire managers should utilize NWS fire weather text forecasts the day of the planned prescribed fire *(Image 4)*. **SPOT weather forecasts are available and may be requested by government officials/burn bosses only**.

Each NWS office fire weather forecast web pages are unique in the content provided. Below are some helpful conversions.

Latest Fire Weather Forecast (FWFSHV)

```
000
FNUS54 KSHV 140958
FWFSHV

Fire Weather Planning Forecast for Southwest Arkansas...
Northwest Louisiana...East Texas...and Extreme Southeast Oklahoma
National Weather Service Shreveport LA
458 AM CDT Thu Sep 14 2017

.DISCUSSION...
An increasingly warm and dry forecast lies ahead over the next few
days as upper level ridge of high pressure settles across our area
fire districts. Afternoon temperatures will return to the low 90s
for nearly all of the region by Friday and continue through this
weekend. Persistent southerly winds will also allow Gulf moisture
to return as well, but minimum relative humidity values are still
expected to remain near to below 50 percent for the next several
days. Rain chances will be quite slim with mainly isolated diurnal
showers and storms possible as we move into the weekend with this
more typical summertime pattern prevailing well into next week.
```

```
Carthage, Nacogdoches, and Center
458 AM CDT Thu Sep 14 2017

                        Today        Tonight      Fri

CLOUD COVER             MClear       Clear        MClear
PRECIP TYPE             None         None         None
CHANCE PRECIP (%)       0            0            0
TEMP (24H TREND)        91 (+6)      67 (+5)      90
RH % (24H TREND)        40 (+3)      98 (+6)      46
20FTWND-AM(MPH)         S  4                      S  6
20FTWND-PM(MPH)         S  5         SE  4        SE  8
PRECIP AMOUNT           0.00         0.00         0.00
PRECIP DURATION         0            0            0
MIXING HGT(M-MSL)       1828                      1841
MIXING HGT(FT-MSL)      5997                      6039
TRANSPORT WND (M/S)     S  4                      SE  6
TRANSPORT WND (MPH)     S  9                      SE 13
VENT RATE (M^2/S)       7312                      11046
CATEGORY DAY            3                         4
MIX HGT 500 TEMP(F)     76                        78
STABILITY CLASS         B            F            B
```

Image 4

1 meter (m) = 3.28 feet (ft.)
1 knot (kt) = 1.15 miles per hour (mph)

Category Day

A Category Day forecast can provide a burn manager guidance toward the dispersion and movement of smoke. Category Day forecasts can be found in the NWS Fire Weather Forecast web page or be determined using the Ventilation Index System *(Kansas Flint Hills Smoke Management, 2017*).

Ventilation Index System = Mixing Height (Meters) x Transport Winds (Meters/Second)

With either the forecast Category Day or calculated Ventilation Index System, the burn manager can use the Category Day recommended guidelines *(Table 4)* for decision making.

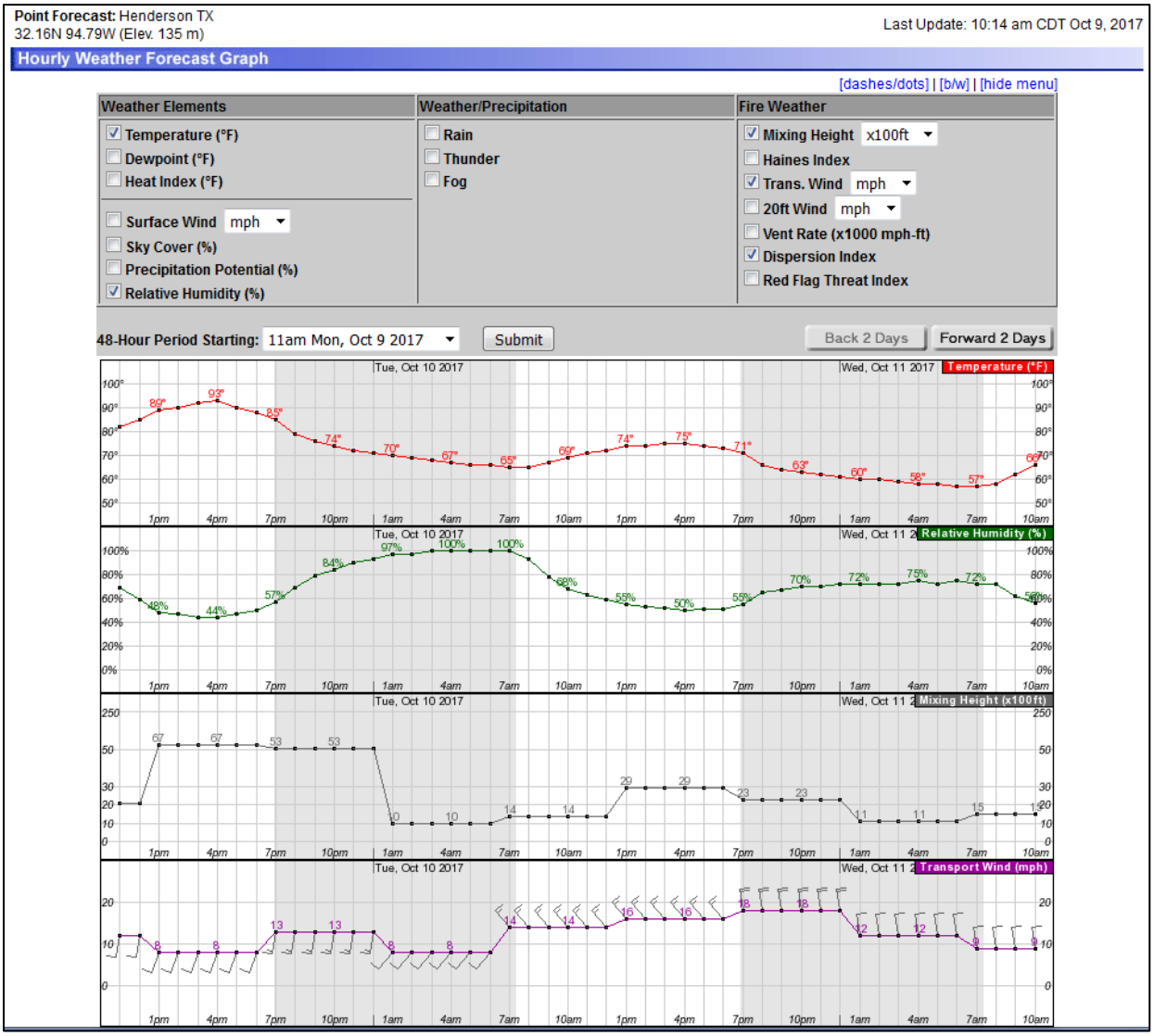
Table 4: Category Day Recommended Guidelines

Ventilation Index System (meters)	Category Day	Guidelines
< 2,000	**1**	No Burning, Mixing Height and Transport Winds too low to disperse smoke
2,000-3,999	**2**	No burning until after 10 AM and not before surface inversion has lifted. Recommended fire operations near completion by 4 PM for sufficient ventilation
4,000-7,999	**3**	Daytime burning only,but not before surface inversion has lifted
8,000-16,000	**4**	Burning Anytime
>16,000	**5**	Unstable and Windy, Excellent smoke dispersal, **burn with caution**

Supplemental Weather Products

A supplemental tool for prescribed burn managers and smoke management planning is the NWS Activity Planner tool. The Activity Planner provides a 48-hour graphical display of several meteorological conditions *(Image 5)* from a selected latitude and longitude. Forecast data can be used for planning purposes before, during, and after the prescribed fire.

Image 5

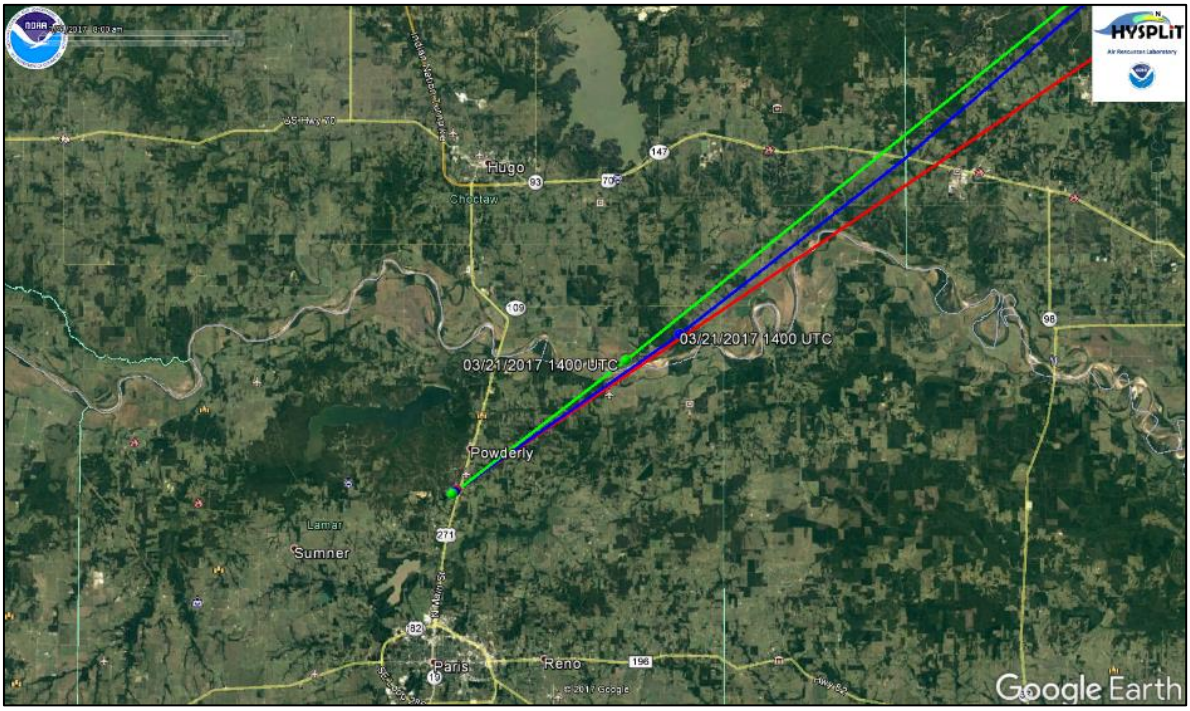


Configure a Smoke Model

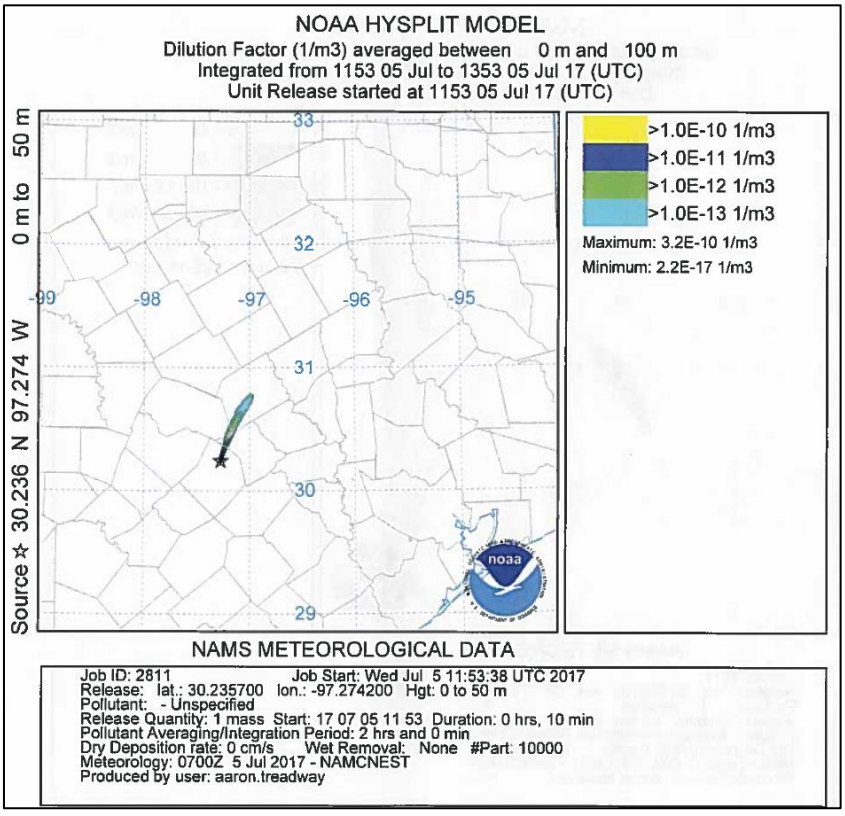
The NOAA Air Resources Laboratory has developed the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) trajectory and dispersion models for point source emissions of potentially harmful materials emitted and transported into the atmosphere using gridded weather data. The HYSPLIT is limited in scope as the user is unable to incorporate fuels and burn duration into the model. This is an advanced modeling tool that may have application for smoke management on complex prescribed burns or larger burn units (> 2,000 acres) in Texas. A HYSPLIT smoke model is only a recommendation if the burn boss feels a model is needed.

Below are the Basic HYSPLIT model outputs from a NWS SPOT Weather Request in either a stand along map or KML file able to be loaded into Google Earth.

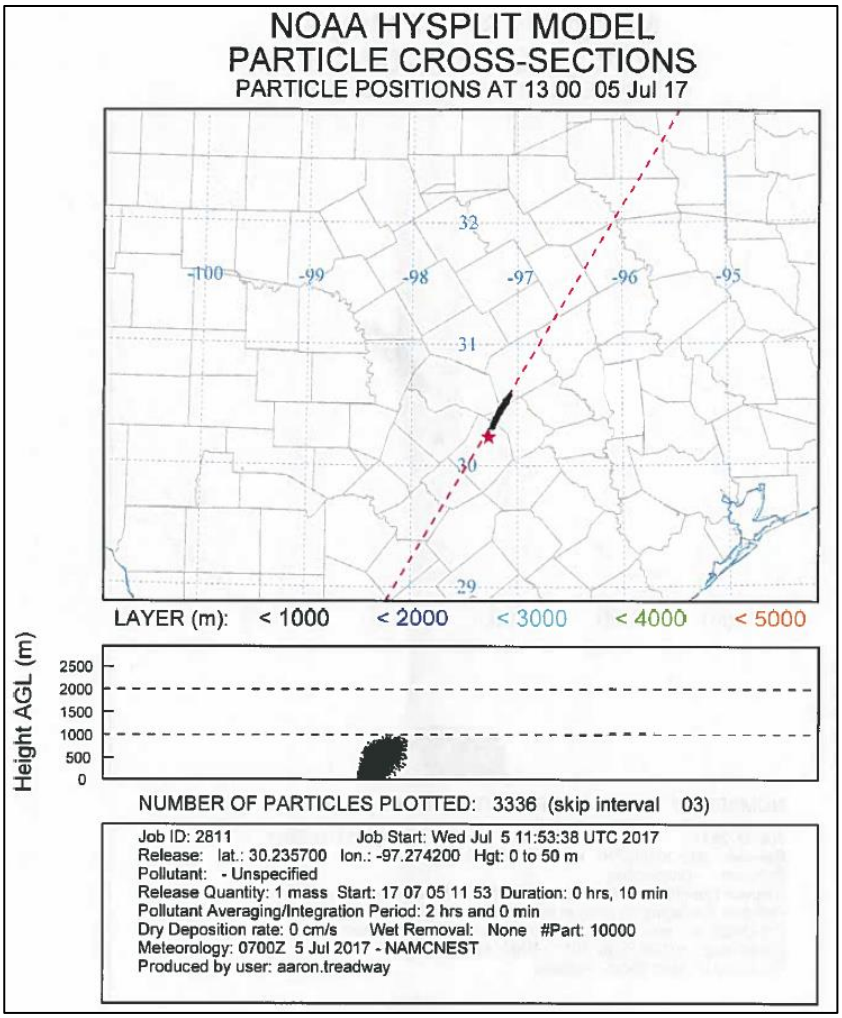
Trajectory Model - Colored arrows/lines represent single air parcel movement over a default 72-hour period at different heights Above Ground Level (AGL). The time frame is set and cannot be changed.



Dispersion Model – Single air parcel plume showing the concentration of emissions over a period of time. This output does not take into account continued emissions that occur during a prescribed fire. There is no guarantee that smoke will be located in area based of model output. Several dilution factor maps are generated showing differences in time, but of the default single parcel.



Particle Cross Section Model– This model provides a vertical profile of potential smoke concentrations based on a default single emission. This output may be used for long range impacts on larger (> 2,000 acres) burn units. Several particle cross-section maps are generated showing differences in time, but of the single emission.



With the SPOT Weather forecast data, burn bosses may default to V-Smoke or the 30° Diagram to determine smoke impacts on the day of the burn.

Check Forecasted Air Quality

The AirNow (www.airnow.gov) web based index that surveys the daily air quality index (AQI) for the United States. This webpage provides six color coded air quality index values. The EPA has assigned a specific color to each AQI category to make it easier for people to understand quickly whether air pollution is reaching unhealthy levels in their community.

Referencing this index (*Table 5*) is recommended to check forecasted air quality conditions before adding more particulates into the air from the prescribed fire. The burn boss should use caution if attempting to burn at moderate (51-100) AQI and hold off from burning when Unhealthy for Sensitive Groups (101-150) is forecasted.

Table 5: Air Quality Index

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	**0 to 50**	**Air quality is considered satisfactory, and air pollution poses little or no risk.**
Moderate	**51 to 100**	**Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.**
Unhealthy for Sensitive Groups	**101 to 150**	**Members of sensitive groups may experience health effects. The general public is not likely to be affected.**
Unhealthy	**151 to 200**	**Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.**
Very Unhealthy	**201 to 300**	**Health alert: everyone may experience more serious health effects.**
Hazardous	**301 to 500**	**Health warnings of emergency conditions. The entire population is more likely to be affected.**

Smoke Observations

Potential Use of a Field Evaluator

The burn boss is responsible for observing and documenting smoke production from the burn unit. Depending on the complexity of the burn, delegation of smoke observations may be given to a field evaluator to assist the burn boss during low or moderate complexity prescribed fires. During a high complexity burn, a field evaluator will be used to assist the burn boss with the overall observation of the fire.

This observer will be monitoring:

- Smoke Dispersion (Making sure roadways are clear, Monitoring SSAs)
- Fire Behavior
- Are burn and smoke objectives being met?
- Checking weather (Every Hour or 30-minutes, Use of belt weather kit, Kestrel, RAWS site)
- Recording Information on significant events

Special Considerations

Night time Smoke Dispersion and Super Fog

Once prescribed burn operations are completed, the burn boss is still responsible for the smoke generated during the smoldering phase of operations. Smoldering may continue throughout the overnight hours

At night, surface temperatures cool with the loss the solar radiation and low level atmospheric stability normally occurs. Winds typically decrease and less mixing occurs, therefore there is less smoke dispersion and transport decreases. Colder air at the surface is denser and will pool in lower areas such as valley or river drainages. Smoke can settle in these lower topographic features and impact SSAs and roadways.

Super fog is a condition where fog develops and mixes with remnant smoke and can greatly reduce visibility on roadways. There have been documented Super fog events that have caused multiple fatalities on roadways in the Southeastern United States.

It is recommended that the burn boss or manager consult the local National Weather Service for fog potential. Mitigation measures and decisions should be made if fog development is forecasted. The Low Visibility Occurrence Risk Index (LVORI) can be a tool to indicate reduced nighttime visibility. The range of 1-10 is used to determine the likelihood of smoke or fog

contributing to motor vehicle accidents. A LVORI of 10 is the highest likelihood. The Atmospheric Dispersion Index can be requested by the local National Weather Service office.

Low Visibility Occurrence Risk Index

	Atmospheric Dispersion Index (ADI)											
RH	1	2	3-4	5-6	7-8	9-10	11-12	13-16	17-25	26-30	31-40	> 40
< 55	2	2	2	2	2	2	2	2	2	2	1	1
55-59	3	3	3	3	3	2	2	2	2	2	1	1
60-64	3	3	3	3	3	3	2	2	2	2	1	1
65-69	4	3	3	3	3	3	3	3	3	3	3	1
70-74	4	3	3	3	3	3	3	3	3	3	3	3
75-79	4	4	4	4	4	4	4	4	3	3	3	3
80-82	6	5	5	4	4	4	4	4	3	3	3	3
83-85	6	5	5	5	4	4	4	4	4	4	4	4
86-88	6	6	6	5	5	5	5	4	4	4	4	4
89-91	7	7	6	6	5	5	5	5	4	4	4	4
92-94	8	7	6	6	6	6	5	5	5	4	4	4
95-97	9	8	8	7	6	6	6	5	5	4	4	4
> 97	10	10	9	9	8	8	7	5	5	4	4	4

Table of LVORI values as a function of Atmospheric Dispersion Index and Relative Humidity. Green = Conditions with lowest proportion of accidents. White = proportion of accidents increased by a factor of 2-10 over green. Yellow = proportion of accidents increased by a factor of 10-40 over green. Orange = proportion of accidents increased by a factor of 40-150 over green.

Super Fog Watch Out Factors

The burn boss should monitor forecasted weather conditions for the evening and night time hours after the burn. Meteorological factors can be found in SPOT Weather Request or directly from the National Weather Service.

Factor	*Watch Out Thresholds*
Surface Temperature	***≤70°, Critical ≤55°***
Relative Humidity	***Critical >90%***
Surface Wind speed	***Critical ≤ 4 mph***
Cloud Cover	***Critical < 40%***
Stability Class	***E or F***
Atmospheric Dispersion Index	***Critical ≤ 6***
Low Visibility Occurrence Risk Index	***≥7, Critical ≥ 9***
Transportation Corridor	***≤ 3 miles from burn site***

Pasquill Stability Class (For Super Fog Reference)

Class	Description
A	Extremely unstable conditions
B	Moderately unstable conditions
C	Slightly unstable conditions
D	Neutral Conditions
E	Slightly Stable conditions
F	Moderately stable conditions
G	Extremely stable

Glossary

Category day – a scale from 1 to 5 based on transport wind speed and mixing height. For smoke dispersal, 1 is poor and 5 is excellent.

Class I area – an area set aside under the Clean Air Act to receive the most stringent protection from air quality.

Inversion – increase of temperature with height in the atmosphere. This condition often exists in the morning and prevents smoke from rising into the atmosphere.

Mixing height – the layer of the atmosphere that pollutants are dispersed into due to turbulent mixing. A forecast of mixing height indicates the height of the top of the layer with respect to mean sea level.

Prescribed fire – any fire ignited by management actions to meet specific objectives.

Prescribed fire Burn Manager/Burn Boss – person responsible for managing a prescribed fire, from planning to ignition and mop up.

Smoke management – conducting a prescribed fire under fuel moisture, meteorological conditions, and firing techniques that keep the impact of the smoke on the environment within acceptable limits.

Smoke plume – the column of smoke resulting from prescribed fire.

Smoke-sensitive area – areas that can be harmed by smoke. Examples: airports, major highways, communities, Class 1 areas, recreation areas, schools, hospitals, nursing homes, factories, etc.

Transport wind – the average wind speed and direction through the mixing height. Higher wind speeds allow for more rapid transport of pollutants downwind.

Ventilation Rate-The rate at which the lower atmosphere is able to diffuse and disperse smoke. It is the mathematical product of the mixing height and transport wind speed.

Appendix

National Weather Service Offices serving Texas
http://ticc.tamu.edu/PredictiveServices/FireWeather.htm

Texas Commission on Environmental Quality: Outdoor Burning in Texas
https://www.tceq.texas.gov/publications/rg/rg-049.html

Texas Commission on Environmental Quality: Area and Regional Offices
https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gi/gi-002.pdf

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Special thanks to Sean Luchs with the National Weather Service Houston Office for providing technical guidance toward the smoke modeling section.