



STATE OF LOUISIANA

SMOKE MANAGEMENT PROGRAM



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Introduction

Natural fires have occurred throughout history and have shaped the landscape across much of the United States. Fire, once a common natural occurrence happens much less frequently today and is commonly initiated by man for a valued purpose. Prescribed fire in Louisiana is a useful management tool for croplands, rangelands, and forest maintenance. In Louisiana, natural resource managers burn approximately 650,000 acres a year. Prescribed fires assists with agriculture production, maintaining natural forests integrity, improves wildlife habitat, protects certain endangered species, and reduces property loss from wildfires. Several governmental agencies, such as; forestry, agricultural, environmental, wildlife and natural resources along with citizen driven organizations such as The Prescribed Fire Council have worked together to devise reasonable, science based guidelines that define the role and use of prescribed burning in a way that allows for desirable outcomes as well as a healthy ecosystem.

States prepare Smoke Management Programs or SMPs to foster better communication between agencies, landowners/public and air quality regulators. Better communication and proper planning will allow for prescribed fire to be used in a professional, safe and efficient manner while minimizing impacts to the public and the environment.

Acres Burned Annually in LA¹

Total Acres Burned by Management Type:

Forest land (KNF, Ft. Polk, FWS, LDWF, LDAF, Private industrial, private non-industrial):	~ 300,000 acres
Marsh land:	~ 150,000
Agricultural (mainly sugar cane):	~ 200,000
TOTAL:	650,000 acres

OR

Total Acres Burned by Ownership:

Federal (USFS, Army, FWS):	~ 200,000 acres
State (LDWF, LDAF, SOF, and State Lands):	~ 130,000
Private lands:	~ 320,000
TOTAL:	650,000 acres

Smoke from burning vegetation produces air pollutants that are regulated by the U.S. Environmental Protection Agency (US EPA) and the state of Louisiana because of their potential

¹ Estimate by Latimore Smith of The Nature conservancy from various sources, November 2007

for adverse health affects on the public and the environment. In order to preserve good air quality, it is important that (1) prescribed fire burners receive training in order to become knowledgeable regarding the emissions they produce and aware of the possible impacts burning has on air quality (2) prescribed fire practitioners take steps to reduce both the quantity and impact of these emissions on the environment and the public and (3) prescribed fire practitioners work in cooperation with state and federal regulatory agencies. Because prescribed burning is a necessary practice and has beneficial environmental and ecological results, it is important for state and federal air quality agencies to recognize these benefits. The goal of a smoke management program is to protect the health and welfare of the public while allowing the use of prescribed fire in the maintenance and preservation of healthy ecosystems.

Benefits of Prescribed Fire

Fire in the hands of a skilled practitioner can be a very effective natural resource management tool. Fire used in this manner is known as “prescribed fire.” Prescribed fire refers to the controlled application of fire, under specified weather conditions, utilized to meet management objectives.

Prescribed fire can be beneficial for:

1. Reduction of excessive vegetative fuels
 2. Forest management
 3. Wildlife enhancement
 4. Threatened and Endangered plants
-
1. By safely reducing excessive amounts of natural fuels, i.e., brush, shrubs, and trees, the chances of a damaging wildfire are significantly reduced. If there are limited available fuels, then large damaging wildfires occurrence will be reduced. In fact, prescribed fire is one of the most effective tools utilized in reducing the damage from wildfires.
 2. In forest management, prescribed fire can be used to remove unwanted vegetation and logging debris before seedlings are planted. It is also an economical tool used to decrease unwanted brush in pine stands. Prescribed fire effectively controls a host of disease-causing insects and organisms which can damage/destroy coniferous forests.
 3. Many wildlife species depend on and/or benefit from prescribed fire, as identified by Louisiana’s Wildlife Action Plan, including many threatened or endangered species. The list includes but is not limited to: red-cockaded woodpeckers, gopher tortoise, Bachman’s sparrow, and Henslow’s sparrow. Other common game species benefiting from prescribed fire include: numerous grassland birds, northern bobwhites, Eastern Wild Turkey, American woodcock, and white-tailed deer. Prescribed fire encourages the growth of native dietary vegetation and assists in the maintenance of proper habitat required for these

species. It promotes growth of valuable wildlife food plants such as native grasses, legumes, herbaceous plants, vines, and hardwood sprouts. Fire can remove thick undergrowth, making travel and feeding routes easier for species such as turkey and deer.

4. Certain plant species are also dependent on periodic fire to create an ecosystem suitable for their growth and reproduction. These include pitcher plants and several species of wild orchids, which are listed as Threatened and Endangered species.

Air Quality Considerations

The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards (NAAQS) for wide-spread pollutants from numerous and diverse sources considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards, Primary and Secondary.

Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.

EPA has set NAAQS for six principal pollutants, which are called "criteria" pollutants. These pollutants are: carbon monoxide, lead, nitrogen oxides, sulfur oxide, ozone and particulate matter (PM). The burning of wildland vegetation produces emissions of many different chemical compounds including the criteria pollutants particulate matter, nitrogen oxides, and carbon monoxide, in addition to other air pollutants such as carbon dioxide and organic compounds.

Tests indicate that, on average, 90 percent of smoke particles from wildland and prescribed fires are PM₁₀, and 70 percent are PM_{2.5} (or PM fine).² EPA has focused more recently on "PM fine" due to its ability to penetrate deeply into the lungs where the most adverse health effects may occur. Biomass burning or prescribed burning may also contribute to local and regional air pollutant loading, and interfere with an area's ability to meet state and federal air quality standards.

The Clean Air Act requires periodic review of the science upon which these standards are based. Every five years the standards are reviewed and revised based on the most current science and health studies. Recently, EPA reviewed and revised both the PM_{2.5} standard and the 8-hour ozone standard. In both cases, the standards were lowered, making them more stringent. These revisions have resulted in greater areas of the country being out of attainment with those standards. When an area doesn't meet the federal standard, then the state must prepare and submit a State Implementation Plan or "SIP" to the EPA which outlines the steps the state will

² Interim Air Quality Policy on Wildland and Prescribed Fires, US EPA, April 23, 1998.

take to reduce emissions and bring the area into attainment. These standards are of interest to the prescribed fire community because biomass burning is considered a source of air pollution which can contribute to ambient air concentrations of these criteria pollutants.

In addition to the NAAQS, the EPA also indirectly regulates prescribed burning through the Clean Air Visibility Rules. These rules were promulgated to address visibility in the country's Federal Class I areas such as International Parks, National Memorial Parks, National Parks and Wilderness Areas. States are required to prepare and submit State Implementation Plans (SIPs) to address clean air and visibility in these federally protected areas. In the west, wildfires have been shown to be significant contributors to impairment of visibility in national parks and wildlife areas. Many states have implemented smoke management programs as an integral part of clean air strategies for improving haze and most are included in the state implementation plans.

Louisiana's only Class I Area within its geographic borders is the Breton National Wildlife Refuge. (See Figure 1.) Air dispersion modeling has shown that Louisiana may also contribute to visibility impairment at Caney Creek Wilderness Area in Arkansas. Louisiana has already submitted a State Implementation Plan to address these regional haze and visibility issues. The plan includes emission controls on certain older operating equipment at major stationary sources. In addition to the emission control strategy, this Smoke Management Program is included as a part of that SIP.

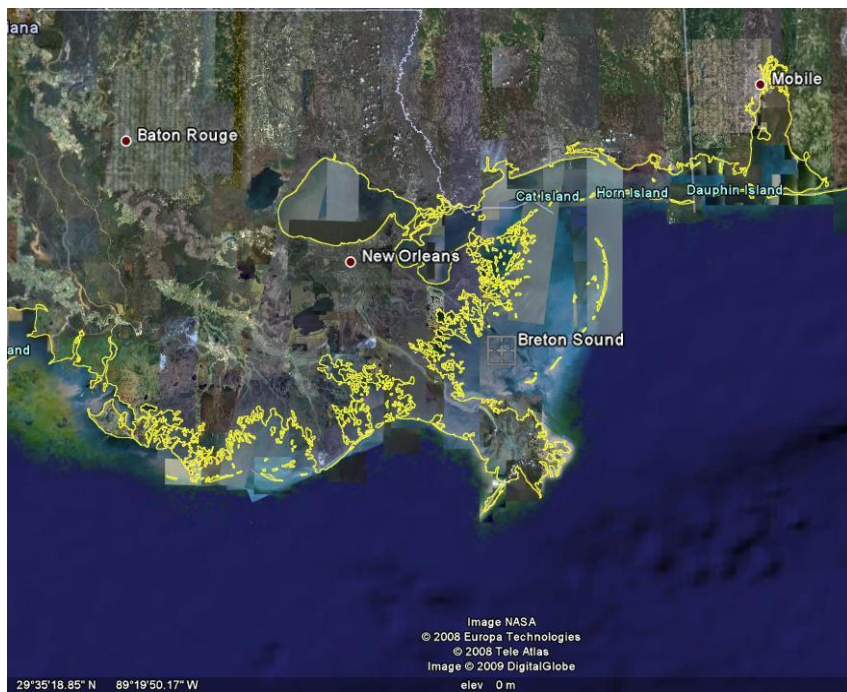


Figure 1. Class I Breton Wilderness Area Image from Google Earth.

On March 22, 2007, EPA published its proposed Exceptional Events Rule. This rule allows certain air monitoring data which has been influenced by an exceptional event to be flagged and excluded from monitoring data used to determine attainment with a federal NAAQS.

Exceptional event is defined as an event that (1) affects air quality; (2) is not reasonably controllable or preventable; (3) is an event caused by human activity that is unlikely to recur at a particular location or a natural event; and (4) is determined by EPA through the process established in these regulations to be an exceptional event.³ Examples of exceptional events are chemical spills and/or accidents, structural fires, transported pollution, terrorist attacks, natural events including volcanic and seismic activity, high wind, wildfires and wildland fires, etc. Prescribed fires may also be determined to be exceptional events providing certain criteria are met. However, in order for a state to request and receive permission to exclude impacted data, the state must certify that it has adopted and has implemented a Smoke Management Program as described in the 1998 Interim Air Quality Policy on Wildland and Prescribed Fires, issued on May 15, 1998.

Louisiana Smoke Management Program

This Smoke Management Program (SMP) establishes a basic framework of procedures and requirements for managing smoke from fires for resource benefits. The Department of Agriculture and Forestry administers the SMP, partnering with the Louisiana Department of Environmental Quality, Louisiana Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, United States Fish and Wildlife Service, United States Forest Service, The Nature Conservancy and prescribed burners statewide. The purpose of the SMP is to balance the use of prescribed fire thus assuring that fire remains a viable tool to achieve land management objectives while protecting Louisiana's air quality.

A burn falls under this SMP if the PM₁₀ emissions are expected to be greater than or equal to one ton per day or if the pile volume per day is greater than or equal to 5,000 cubic-foot. The one ton of PM₁₀ threshold is meant to be roughly equivalent to current permitting thresholds for stationary sources. Impacts to air quality are expected to be minimal at an emission rate of less than one ton of PM₁₀ per day.

The basic framework of a SMP consists of six elements that must be addressed: authorization, minimizing air pollutant emissions, smoke management components, air quality monitoring, public education and awareness, surveillance and enforcement, and program evaluation. These required elements can be found in EPA's [*Interim Air Quality Policy on Wildland and Prescribed Fires*](#). Louisiana's SMP addresses each of these elements as described below.

³ Fed. Reg. Vol. 72, No. 55/Thursday, March 22, 2007, p. 13563.

Authorization

The Louisiana Department of Agriculture and Forestry coordinates prescribed fire activities for the State of Louisiana. LDAF Dispatch Centers will receive notifications via phone or fax on the day of the burn. Burn managers will be required to notify the appropriate LDAF Dispatch Center on the morning of the prescribed fire by calling (see attachment; LDAF State Forestry Office map)

Each burn manager should prepare a written burn plan prior to the prescribed fire. The Burn Plan will contain the following information to provide to the LDAF Dispatch Centers:

1. Person in charge of the prescribed fire and contact information;
2. Location of the prescribed fire (section, township, range or GPS reading and parish);
3. Total acres to be burned;
4. Purpose of the prescribed fire (hazard fuel reduction, wildlife habitat, etc.);
5. Planned ignition time and duration of prescribed fire.

A sample of an acceptable “prescribed burn plan” can be viewed and downloaded at www.ldaf.state.la.us/portal/Offices/Forestry/ForestProtection. Individuals without internet access can contact a Dispatch Center to receive a “hard copy” of the burn plan.

On the morning of the actual prescribed fire, the prescribed fire manager will notify the appropriate LDAF Dispatch Center and reference the burn plan for “acceptance consideration”. If “no objections” are warranted, the Dispatch Center will provide a “PB Authorization Number” which shall then be recorded on the written prescribed burn plan by the manager. This authorization number shall also be recorded, for record, on the LDAF Daily Prescribed Fire log sheet. At that time, the fire manager may proceed with the prescribed fire as conditions allow.

The PB Authorization Number shall only be valid for that calendar day of issuance. Any ignitions of fuels, occurring on a different calendar date or on a site other than listed in the prescribed burn plan, shall require a separate PB Authorization Number.

Communication

Communication with local fire authorities should be practiced. Burn Managers should notify their local Fire Districts of their intent and locations so they will be aware that a controlled burn will occur in their response area.

Dispatch Centers will review daily prescribed fire requests and promptly make a “no objection/no burn” decision. This decision will be based on the existing air quality and

the ability of the airshed to disperse emissions for that particular day. For fires lasting longer than one day, forecasted meteorological conditions will be considered before a determination is made.

All partnering agencies and associates will promote the “Certified Prescribed Burn Manager Program” defined under Louisiana RS 3:17.

Fire managers shall follow the authorized burn plan or maintain records to adequately justify why it was necessary to deviate from the authorized plan.

Minimizing Air Pollutant Emissions

The prescribed burn plan should document steps to be taken before, during and after the burn to reduce smoke impacts. Where applicable, burn managers shall use one or more of the following approaches:

- Reduce the size of the burn to achieve allowed emission levels.
- Reduce the fuel loading in the area to be burned by mechanical means or by using frequent, low-intensity burns to gradually reduce fuels.
- Reduce the amount of fuel consumed by the fire by burning when fuel moistures for larger fuels and duff moistures are high.
- Rapid and complete mop-up after the burn or mop-up of certain fuels.
- Reference “Smoke Management Guide for Prescribed Fire and Wildland Fire” by National Wildfire Coordinating Group Fire Use Working Team, publication NFES 1279.

Wildland owners/managers are encouraged to consider alternative methods, as discussed in the Interim air Quality Policy (see section V.A.1. Collaboration Among Land and Air Quality Managers, Land and Vegetation Management, Alternative Treatments).

Wildland owners/managers may have an array of tools, including fire, which can be used to accomplish land use plans, depending on the resource benefits to be achieved.

Alternatives to consider may involve one or a combination of treatments, including utilization and mechanical treatments, chemical treatments, and fire treatments. When fire is the chosen management tool, a combination of treatment methods may be the best approach to achieving the desired resource benefits with minimum air quality impacts.

While these optional treatment types should be considered, the exclusion of fire is not without economical consequences. Among these are increased costs, degradation of fire

dependent ecosystems (coniferous forests and gulf coastal plains) and an increased threat of damages to communities and critical infrastructure resulting from wildfires.

To assist burners in the determination of emissions, the table below translates one ton of PM₁₀ into acreages of different vegetation types and pile volumes. The relationship between PM₁₀ emissions and pile volume was developed using Hardy's information⁴. The threshold of 5,000 cubic feet of pile volume is roughly equivalent to one ton of PM₁₀ emitted.

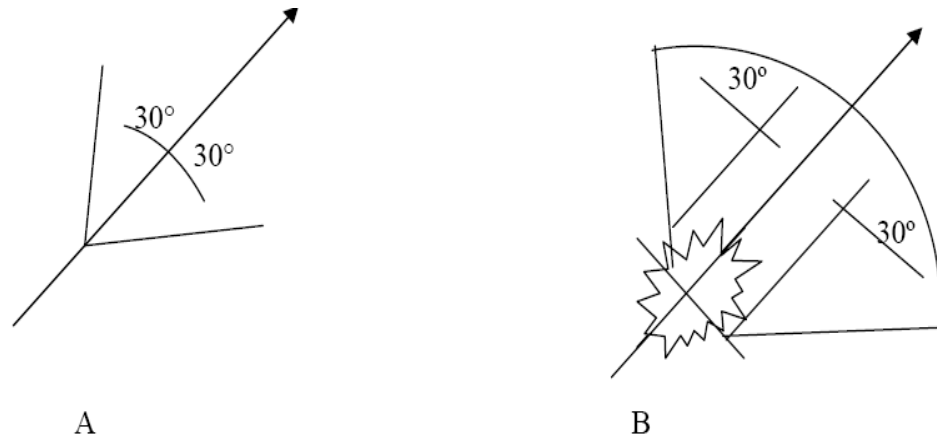
Vegetation Type	One Ton PM₁₀
Field Crops (sugarcane, wheat, etc.)	65 Acres
Shrub land	34 Acres
Forest land	23 Acres
Grass land	100 Acres
Piled vegetative material (logging slash)	5000 Cubic Feet

Smoke Management Components

Every effort should be made to keep smoke away from sensitive areas. Examples of sensitive areas include: airports, highways, communities, Class I areas recreation areas, schools, hospitals, nursing homes, and industry (especially facilities that emit sulfur dioxide – smelters, coal fired power plants, and factories with large boilers). Follow these five steps to identify smoke- sensitive targets:

1. Delineate on a map the prescribed fire's location and all potential smoke sensitive targets.
2. Determine the wind direction that will have the least impact on smoke sensitive targets.
3. Draw a line representing the centerline of the path of the smoke plume using the wind direction chosen in the previous step.
4. Determine the distance from the edge of the prescribed fire to the nearest smoke-sensitive target.
5. To allow for horizontal dispersion of the smoke, as well as shifts in wind direction, draw two other lines from the burn at an angle of 30 degrees from the centerline(s). If a prescribed fire's area is less than Hardy's One Ton PM₁₀ equivalent then represent the area as a spot, draw as in Figure A. If larger, draw as shown in Figure B.

4



Figures A and B. Examples of how to estimate smoke plume dispersion for prescribed fire planning.

Planning and public notification are recommended when igniting large areas in a short amount of time, such as is done with aerial ignition. The heat produced from a prescribed fire may allow the smoke to penetrate above the mixing height where dispersion of the smoke is minimal. Smoke from these prescribed fires may travel long distances before descending to the ground. Therefore, it is important to monitor the smoke column downwind to determine if an impact has developed.

One goal of safely conducting a prescribed fire in Louisiana is to perform the burn when atmospheric conditions will disperse the smoke so that people and Class I areas are not adversely effected. The smoke management plan uses two pieces of information to determine how many tons of fuels can be consumed within an air shed:

1. Downwind distance to the nearest smoke-sensitive target
2. Daily Fire Weather “Category Day.”

The National Weather Service (NWS) measures the transport wind speed and mixing height daily by 8:00 a.m. and an estimate is made for the afternoon. The predicted afternoon mixing height and transport wind speed is used by the NWS to calculate the “Category Day (see Table 2 for Category Day Burning guidelines).

The Category Day will assist LDAF in determining wither to issue PB Authorization Numbers or to suspend the “no objection” to burning until more favorable atmospheric conditions occur. Table 3 lists the category day for various combinations of mixing height and transport wind speed. The National Weather Service issues an afternoon forecast predicting conditions for the following day. Using the afternoon forecast, the predicted category day for the following day is for planning purposes only. The category

day utilized by the LDAF Dispatch Centers will remain in effect until a new forecast is received the following morning.

The forecasts are transmitted on the Internet by the National Weather Service (NWS) from offices in Shreveport, Lake Charles, New Orleans and Jackson, MS. This information is generally available by 9:00 a.m. each day. The National Weather Service will also broadcast the Category Day on the National Oceanic and Atmospheric Administration (NOAA) weather radio channel. The Internet addresses are:

Lake Charles area: <http://www.srh.noaa.gov/data/LCH/FWFLCH>

New Orleans/Baton Rouge area: <http://www.srh.noaa.gov/data/LIX/FWFLIX>

Shreveport area: <http://www.srh.noaa.gov/data/SHV/FWFSSHV>

Jackson, MS area: <http://www.srh.noaa.gov/data/JAN/FWFJAN>

Smoke Dissipation Category Days

“Mixing Height” or “Mixing Depth” (feet or meters) signifies the height above the surface throughout which a pollutant such as smoke can be dispersed. During times of surface temperature inversions (typically nighttime with clear skies), the mixing height may fall below the minimum level and smoke dispersion will be minimal.

“Transport Wind” signifies the average wind speed (mph or m/s) throughout the depth of the mixed layer.

“Ventilation Rate” (VR) equals the product of the two (feet or m*m/s) and represents the ability of the boundary layer to disperse smoke. When VR values are low, there is minimal mixing potential and surface air quality suffers. When VR values are consistently low (day and night), it is possible for immediate and downwind areas to be negatively impacted by smoke.

Ventilation Rate (m*m/s) = Mixing Height (m) x Transport Wind (m/s)

Based on these variables, a “Category Day” system has been developed relating ventilation rate to smoke dispersal. A set of burning guidelines based on VR and Category Day has been developed and is shown below:

CATEGORY DAY	VENTILATION RATE (Mixing Height (m) x Transport Wind (m/s))	BURNING GUIDELINES
I	< 2,000	No Burning.
II	2,000 - 4,000	No burning until 11:00 am and not before surface inversion has lifted. Fire should be substantially burned out by 4:00 pm.
III	4,000 - 8,000	Daytime burning only after inversion has lifted.
IV	8,000 - 16,000	Burning anytime. Night burns use backing fires with surface wind speeds greater than 4 mph.
V	> 16,000	"Unstable" and windy. Excellent smoke dispersal. Burn with caution.

Burn managers should follow the "Burning Guidelines" timeframes, based on the NWS Category Day of the burn, to be in compliance with state voluntary guidelines and to minimize negative impacts from smoke.

Air Quality Indexes (LA. Dept. of Environmental Quality)

Occasionally, during periods of relatively stagnant air, the Environmental Protection Agency and/or the Louisiana Department of Environmental Quality will forecast or issue an Ozone Action Day. This advisory requires a smoke management Category Day 1 be issued. When an Ozone Action Day is forecasted, burn managers are asked not to ignite any new fires and to complete any fires burning at the time the Ozone Action Day is declared. **LDAF Dispatch Centers will not issue PB Authorization Numbers on identified Ozone Action Days.**

LDAF Dispatch Centers will also monitor the Air Quality Index map, found on the AirNow website, on a daily basis for the determination of issuance of PB Authorization numbers. This site, administered by the US Environmental Protection Agency may be found at www.airnow.gov. The site maintains 6 ratings concerning Ozone and PM2.5

particle ratings ranging from “Good” to “Hazardous.” LDAF may only issue PB Authorization numbers if the current reading for area of concern is; (a) Good or (b) Moderate. All other AQI ratings will default to a “no issuance” of PB Authorization number.

Air Quality Monitoring

The prescribed fire burn plan should include some type of monitoring of the smoke from the prescribed fire. The extent of the monitoring should match the size and expected duration of the fire. For small, or short duration fires (such as those in grass or leaf litter), visual monitoring of the directions of the smoke plume and monitoring nuisance complaints by the public may be sufficient. Other monitoring techniques include posting personnel on vulnerable roadways to look for visibility impairment and to initiate safety measures for motorists; posting personnel at other smoke sensitive areas to look for smoke intrusions; using aircraft to track the progress of smoke plumes; and the continued tracking of meteorological conditions during the fire.

For prescribed fires in fuels with longer duration burning (such as timber litter or slash), and which are expected to last more than one day, the burn manager might consider locating real-time particulate matter (PM) monitors at smoke- sensitive areas to facilitate timely response to smoke problems.

Public Education and Awareness

In 1993 the Louisiana Legislature passed Act 589 authorizing the Louisiana Department of Agriculture & Forestry (LDAF) to implement and administer the Louisiana Certified Prescribed Burner program.

Prior to this law anyone conducting a prescribed burn was, based on state law, involved in a “inherently hazardous activity” and as such if any damage could be linked to the burn the burner was automatically at fault and liable for said damages. Act 589 identifies and defines a Certified Prescribed Burner and instructs LDAF to conduct the needed training for burners to meet the standards for identification as a Certified Prescribed Burner. The Act further stipulates that Certified Prescribed Burners are held to the same standards of proof of negligence in court as any other professional.

In order to meet the standards for identification as a Certified Prescribed Burner an individual must:

1. Provide documentation to having received either formal or “on the job” training in prescribed burning.
2. Conducted five burns as the supervising professional.
3. Burn with a written prescribed burning plan.
4. Adhere to all Louisiana Voluntary Smoke Management Guidelines and Voluntary Best Management Practice Guidelines.
5. Meet the Louisiana Notification of Burn directives.
6. Attend a one day Certified Prescribed Burner Course and successfully pass all exams with a score of 70% or higher.

A Certified Prescribed Burner course is taught by the LSU Cooperative Extension Service. Generally the courses are offered at the LSU School of Renewable Natural Resources at Baton Rouge and the LA. Tech School of Forestry at Ruston. LDAF administers the final written exam, necessary to obtain Prescribed Burner certification status.

Compliance

The prescribed burn manager ensures that the burn is conducted in accordance with the prescribed fire plan. LDEQ and LDAF will enforce national and Louisiana air quality regulations and laws. Smoke complaints will be investigated in accordance with department policies and procedures. Memorandums of understanding will be used when necessary to specify the responsibilities of each State/Federal agency in implementing the SMP.

The Department of Agriculture and Forestry (LDAF) will work closely with the Department of Environmental Quality (LDEQ) to monitor air quality conditions especially with regard to air quality monitoring arising from fires.. LDEQ continues to post to both AirNow (EPA) and LDEQ PM data and other smoke information on the LDEQ webpage, including: air quality alerts for sensitive groups and deployment of the Mobile Air Monitoring Laboratory when appropriate. LDEQ has a sizeable continuous PM monitoring network in place.

LDAF and LDEQ will also coordinate with the US Fish and Wildlife Services Air Quality group. This agency operates and contracts out management of the southeast Louisiana Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring site near Slidell.

Program Evaluation

The LDAF and LDEQ will annually:

1. Collect and review information on acres burned by prescribed fire and wildfire.
2. Review the reference, continuous, and IMPROVE monitoring station data maintained by LDEQ.
3. Use information from reports of nuisance complaints or significant smoke intrusions to measure the effectiveness of the SMP.
4. Provide recommendations to the Louisiana Prescribed Fire Council concerning the SMP.

The SMP will be re-evaluated for effectiveness beginning in 2015 and every 5 years following. LDAF will record any nuisance complaints concerning smoke intrusions. Information gathered will be reviewed by: LDAF, LDEQ and the LA. Prescribed Fire Council to determine if changes to operational procedures are warranted or if adjustments to the SMP are required.

Appendix A : Tools for Predicting Smoke Transport

SHRMC

One tool that is available for burn managers was developed by the Southern High Resolution Modeling Consortium. This consortium collaborates with other scientists, local, state, and federal air quality regulators, and other interested parties as part of a national **framework** of regional interagency modeling consortia.

This simple smoke screening tool can provide burn managers with information regarding expected areas of smoke impact from their operations:

<http://shrnc.ggy.uga.edu/maps/screen.html>

VSmoke

The VSmoke Model is a meteorologically oriented dispersion model used to predict the smoke and dry weather visibility impact of a single prescribed fire at several downwind locations. The model allows the user to control what percentage of smoke is dispersed at the ground level and how the remaining smoke plume will rise to its maximum height into the atmosphere at 31 fixed distances. VSMOKE can be used either on its own or as part of a system of prescribed fire management programming tools.

VSmoke consists of six different computational components: (1) modeling of pollutant constituents, heat emissions, and vertical and horizontal distribution of smoke; (2) a plume rise model; (3) a plume atmospheric dispersion model to estimate smoke concentrations at specified distances downwind from the fire; (4) a crossplume sightline characteristics model that estimates the visibility and contrast ratio for the plume at specific downwind distances; (5) a dispersion rate model; and (6) a statistical model that estimates a Low Visibility Occurrence Risk Index (LVORI).

VSmoke provides conservative estimates and can be used as a screening system to determine the potential for smoke-related hazards. Once those potential hazards are identified with this model, other models, such as INPUFF or PLUVUE, can be used to more completely determine the nature and impacts of the hazard (Lavdas, 1996).

BlueSky

The BlueSky Smoke Modeling Framework is a web-based system that provides real-time smoke concentration predictions. The framework is designed to determine cumulative impacts from forest, agricultural and range fires using emissions, and meteorology and dispersion models. BlueSky also uses fire information and predictions developed from a weather forecast model to

estimate forecasts of ground concentrations of smoke. BlueSky is an open source modeling platform - there are various models that can be used in each step in determining impacts. Currently, most BlueSky implementations use the Fuelbed Characteristic Classification System (FCCS) fuel loading map and Emissions Production Model, CALPUFF, and HYSPLIT (discussed below). (<http://www.airfire.org/projects/bluesky/bluesky-modeling-framework>)

HYSPLIT

The HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model is the newest version of a complete system. It can be used for tasks as simple as computing simple air parcel trajectories, or as complex as dispersion and deposition simulations. The model can be run interactively on the Web through the READY system on the National Oceanic and Atmospheric Administration (NOAA) website, or the executable code and meteorological data can be downloaded to a Windows PC. The model can simulate the transport of smoke utilizing the archived meteorological data on the READY web site. Through this site, the model is most appropriate for long range transport of smoke due to the 40 km horizontal grid spacing of the archived meteorology. For more information go to <http://www.arl.noaa.gov/ready/hysplit4.html>

The HYSPLIT model can be used retrospectively: (1) to help determine the forward path of smoke plumes from past known fires, and (2) to investigate whether a monitored PM concentration may have been affected by known fire(s) in another area. While retrospective analysis obviously has limited or no direct use in smoke management, there may be an indirect benefit in that understanding the transport of smoke during past fire events may improve predictions of where smoke will travel in future fires. Satellite photographs (and satellite measurements of aerosol optical depth) are another way to look at past smoke transport. However, satellite photographs do not automatically tell whether smoke was present at the surface at points below what appears to be the smoke trajectory, because satellite photographs indicate all the smoke in a vertical column of air. If a smoke plume rises quickly past the mixed layer height (or boundary layer) height, a satellite photograph may indicate the path of a smoke plume that is not affecting concentrations at the surface. However, if HYSPLIT modeling of trajectories within the mixed layer match the trajectory suggested by the satellite photograph, or if it is known that the smoke stayed low to the ground, it is more likely that the satellite photograph indicates the presence of smoke at ground level.

HYSPLIT can also be used prospectively to generate forward trajectories to predict the path of an ongoing fire or a contemplated future fire. The READY website can be used to do these predictive trajectories, but an additional user registration step will need to be completed.

ClearSky

ClearSky (<http://www.clearsky.wsu.edu/>) is a plume dispersion model housed at Washington State University that uses meteorological forecasts and emissions estimates to determine surface level smoke concentrations and dispersion. ClearSky uses a web-based application to allow burn managers input data specific to the area of concern to create realistic simulations. This data is combined with meteorological forecasts developed from the Mesoscale Modeling Group MM5

(discussed below) and CALPUFF dispersion calculations to generate dispersion scenarios. Hourly PM_{2.5} predictions at specific receptor locations (i.e., these locations have the necessary instrumentation to measure PM_{2.5}) are also provided to the burn manager. This tool allows local burn managers to generate multiple field-burning scenarios and view animations of the simulation results to help shape their burn decisions.

Local temperature soundings

Localized atmospheric conditions including current weather and upper air data are available through the National Weather Service (NWS) and associated federal agencies. Local surface data may be easily obtained via the NWS website at www.weather.gov. These surface data are typically collected at Automated Surface Observing Systems (ASOS) or Automated Weather Observation Systems (AWOS) sites, many of which are located at airports. Upper air data, including temperature, dew point, and winds are able to be measured through multiple different methods including Radiosondes, Rawinsondes, Radio Acoustic Sounding Systems (RASS), microwave radiometers, Light Detection and Ranging (LIDAR), and aircraft measurements. Radiosondes and Rawinsondes are more widely used worldwide, in concert, and have a predictable schedule with more easily accessible data. Radiosondes or Rawinsondes (which include wind data) are balloon-borne sensors released by NWS from 92 sites in North America and select Pacific Islands at 0000 and 1200 UTC (coordinated universal time) daily. They collect temperature and dew point, and often wind data as well, as they ascend through the atmosphere. The data are available at: <http://rap.ucar.edu/weather/upper/> in the form of Skew-T diagrams which can be used to determine mixing heights and, if a rawinsonde is used, winds at given pressure level.

Pibal Weather Balloons (Pibals)

Pibals allow observers on the ground to project where an object or smoke plume will likely travel in the horizontal as it ascends vertically through the atmosphere. Pibals are usually a natural or synthetic rubber balloon filled with either Hydrogen or Helium. They come in varying 'weights' which correspond to varying maximum ascent altitudes. They are limited in use today due to the growing availability of other vertical profiling instrumentation, but are still used occasionally in rural areas where more modern vertical profilers or model estimates are unavailable. The use of a Pibal is typically accompanied by the use of a theodolite, which allows the ground observer to mechanically keep track of the pibal height and bearing during its ascent.

Satellite images/maps, remote sensing

(e.g. MODIS, GOES) - An extensive array of satellite-based systems (see table) with the capability of covering broad spatial areas and measuring atmospheric column total species has been established by United States and European Satellite programs lead by the National Aeronautics and Space Administration (NASA) and NOAA in the United States and the European Space Agency (ESA). A suite of satellites including Aqua, Aura, CALIPSO, OCO, Glory, as well as NOAA-17, NOAA-18 and NPOESS, have either been launched since about the year 2000 or have other near-term proposed launch dates. Collectively, the remote sensing techniques can measure spatial distributions, as well as columns and/or profiles of aerosols

(AOD - Aerosol Optical Depth), other pollutants, and atmospheric parameters such as temperature and H₂O (water). Most of these satellites have a near-polar orbit allowing for two passes per day over a given location. When taken together, a group of five satellites (Aqua, Aura, CALIPSO, OCO, as well as CloudSat and PARASOL - coined the A-Train) fly in a formation that crosses the equator a few minutes apart at around 1:30 local time to give a comprehensive picture of atmospheric conditions. On the other hand, the NOAA Geostationary Operational Environmental Satellites (GOES) satellites provide continuous monitoring, over portions of the globe, by circling the Earth in a geosynchronous orbit that allows them to hover continuously over one position on the surface. The geosynchronous plane is about 22,300 miles above the earth, high enough to allow the satellites a full-disc view of the earth. Because they stay above a fixed spot on the surface, they provide continuous measurements for that area of the earth so as to monitor pollutant emissions and track their movements.

Temporal characterization.

The polar orbiting tracks provide wide spatial coverage of reasonable horizontal (10-50 km) resolution, but deliver only twice daily snapshots of a pollutant species. Consequently, temporal patterns of pollutants as well as a time-integrated measure of pollutant concentrations cannot be delineated explicitly through these satellite measurements alone. However, geostationary satellite platforms, such as the GOES for fire products (imagery and AOD), provide near continuous coverage. There also are proposed campaigns within NASA and across partnership Federal agencies to deploy geostationary platforms with measurement capabilities for aerosols and trace gases to enhance space-based characterization of tropospheric air quality.

Spatial Characterization

Polar orbiting satellites typically provide horizontal spatial resolution between 10 and 100km, depending on the angle of a particular swath segment. Spatial resolution less than 10km is possible with geostationary platforms. With few exceptions, satellite data typically represents a total atmospheric column estimate. However, for aerosols and certain important trace gases (e.g., NO₂, SO₂, HCHO (formaldehyde)), the majority of mass resides in the boundary layer of the lower troposphere, enabling associations linking column data to surface concentrations or emissions fields. For example, reasonable correlations, especially in the Eastern United States, have been developed between concentrations from ground level PM_{2.5} stations and aerosol optical depths (AOD) from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua and Terra satellites. Correlations between AOD and surface aerosols generally are better in the Eastern United States, relative to the West, due to excessive surface light scattering from relatively barren land surfaces. The Infusing Satellite Data into Environmental Applications (IDEA, <http://idea.ssec.wisc.edu/>) Internet site provides daily displays and interpretations of MODIS and surface air quality data. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite provides some ability to resolve aerosol vertical gradients.

Use of Satellite data in air quality management assessments.

Satellite data, particularly fire and smoke plume observations and GOES meteorological data, support various air quality analysis efforts. Satellite products complement existing observational platforms and support the air quality assessment process through:

- direct observational evidence of regional and long range intercontinental transport
- direct evidence of the occurrence of biomass burning
- emission inventory improvements through inverse modeling
- evaluation of Air Quality Models
- tracking emissions trends (accountability)
- complementing surface networks through filling of spatial gaps

As air quality assessments, including those related to the transport and dispersion of pollutant emissions from wildland and prescribed fires, evolve toward embracing more pollutant categories, an attendant need to characterize a variety of spatial (and temporal) scales places demands on developing more compositionally rich characterizations of air pollutants. Satellite technologies combined with Federal agency partnerships, such as NASA and NOAA, are assisting the air quality community by providing data that covers broad spatial regimes in areas lacking ground based monitors and/or detailed data for calculating fire-related emissions.

NASA's Aura satellite (http://www.nasa.gov/mission_pages/aura/spacecraft/index.html) mission, launched in 2004, deploys sensors theoretically capable of measuring aerosols, all criteria gases and many other pollutants - a multiple pollutant space-based complement to the NCore multiple pollutant ground based network and intensive field campaigns. NASA's Orbiting Carbon Observatory (OCO), planned to be launched in 2013, will be dedicated to tracking carbon dioxide levels which currently are captured on the Aqua based Atmospheric Infrared Sounder (AIRS) instrument. The Aqua, Terra, and Aura satellites and OCO are all part of NASA's Earth Observation System (EOS). When used in combination with air quality models, satellite data can be used as an observation driven top-down check and modification through inverse modeling of emission inventories. Satellite data for CO, NO₂, and HCHO, as an indicator for biogenic isoprene, have been used for improving emission inventories. As longer term records are developed, satellite imagery offers another means of checking progress of major emission strategy plans.

CALIPSO builds on the ongoing success of MODIS instrument aboard NASA's Terra (EOS AM) and Aqua (EOS PM) satellites which has provided total aerosol column optical depths (AOD) for use in:

- Supporting development of wildfire and prescribed burning emission inventories (the 2005 NEI will include emissions from fires utilizing MODIS),
- Evaluating ability of air quality models such as CMAQ to characterize total column aerosol loadings, and

- Complimenting ground based PM2.5 monitors by filling in spatial gaps and adding intelligence to conceptualize our understanding of aerosol episodes (see <http://idea.ssec.wisc.edu/>).

More specifically with regard to wildland and prescribed fires, GOES WF_ABBA (Wildfire Automated Biomass Burning Algorithm), and other satellite measurements and products can be especially useful. Emission estimates obtained through modeling of biomass burning using satellite-derived vegetative fuel loadings, fuel moisture, and fire sizes can be supported across the United States. For example, fuel loading can be developed from MODIS data including land cover type, vegetation continuous field and monthly leaf-area index. The weekly fuel moisture category can be retrieved from (Advanced Very High Resolution Radiometer (AVHRR) data for the determination of fuel combustion efficiency and emission factor. The burned area can be simulated from GOES by identifying burned areas in individual "fire pixels". This is critical input to calculation of the diurnal, seasonal, and interannual biomass burning emissions. The burned areas can also be used to exhibit diurnal variability with a temporal scale of half hours; burned areas from detections of GOES active fires can be at near real time and data.

Satellite-based Air Quality Observing Systems¹

Instrument	Satellite Platform ³	Lead Federal Agency	Initiated	Measurement Parameters	Orbit & Horizontal Resolution	Location of Information and/or Data
OLS (Operational Linescan System)	DMSP satellites	DOD	1962?	Identify fires and smoke plumes	Polar Imagery only	http://www.af.mil/factsheets/factsheet.asp?fsID=94
BUV (Backscatter Ultraviolet Spectrometer)	Nimbus 4	NASA	1970-1980	O3, CO2, SO2	Sun synchronous	http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1970-025A
SBUV (Solar Backscatter Ultraviolet Spectrometer)	Nimbus 7	NASA	1978-1993	O3, SO2	Polar	http://jwocky.gsfc.nasa.gov/n7toms/nimbus7tech.html
TOMS (Total Ozone Mapping Spectrometer)	Nimbus 7 Meteor 3 Earth-Probe	NASA	1978-1993 1991-1994 1996	O3, SO2, Aerosols	Polar ~100km	http://toms.gsfc.nasa.gov/fltmodel/spacecr.html
LIMS (Limb Infrared Monitor of the Stratosphere)	Nimbus 7	NASA	1978-1979	O3, HNO3, NO2,	Polar	http://lims.gats-inc.com/about_lims.html
ATMOS (Atmospheric Trace Molecule Spectroscopy)	Spacelab 3 ATLAS -- 1,2,3	NASA	1985, 1992, 1993, 1994	O3, CFC13, CF2Cl2, ClONO2, HCl, HF, CO, CH4, HCN, HNO3, NO, NO2, N2O, N2O5, Aerosols		http://remus.jpl.nasa.gov/atmos/sl3.html
CLAES (Cryogenic Limb Array Etalon Spectrometer)	UARS	NASA	1991-1993	O3, CFC13, CF2Cl2, ClONO2, CH4, HNO3, NO, NO2, N2O, N2O5, Aerosols		http://umpgal.gsfc.nasa.gov/
HALOE (Halogen Occultation)	UARS	NASA	1991-2005	O3, HCl, HF, CH4, NO, NO2, Aerosols		http://umpgal.gsfc.nasa.gov/

Experiment)						
ISAMS (Improved Stratospheric and Mesospheric Sounder)	UARS	NASA	1991-1992	O3, CO, CH4, NO2, N2O, N2O5, Aerosols		http://umpgal.gsfc.nasa.gov/
MLS (Microwave Limb Sounder)	UARS	NASA	1991-1999	O3, ClO, CH3CN, HNO3, SO2		http://umpgal.gsfc.nasa.gov/
GOES Imager (Geostationary Operational Environmental Satellites)	GOES-10 GOES-12	NOAA	1994	Fire products for WF_ABBA (imagery) and GASP (aerosol optical depth)	Geostationary	http://www.nesdis.noaa.gov/
GOES Sounder (Geostationary Operational Environmental Satellites)	GOES-10 GOES-12	NOAA	1994	Total column O3	Geostationary	http://cimss.ssec.wisc.edu/goes/goesmain.html#sndrinfo
AVHRR (Advanced Very High Resolution Radiometer)	NOAA-15 NOAA-16 NOAA-17 ²	NOAA	1998	Aerosol optical depth, particle size information and vegetation/drought index products related to air quality through fires	Polar 4km	http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html
SBUV/2 (Solar Backscattered Ultraviolet Radiometer Model 2)	NOAA-16 NOAA-17 ²	NOAA	2000	Total and profile O3 from surface to top of atmosphere in ~5 km thick Umkehr layers	Polar	http://www2.ncdc.noaa.gov/docs/podug/html/c4/sec4-4.htm

1. Non-U.S. satellite systems are not included in table at this time.
2. As of 3/15/06 the operational satellite platforms may need to include NOAA-18.
3. CALIPSO -- Cloud-Aerosol Lidar & Infrared Pathfinder Satellite Observations
DMSP: Defense Meteorological Satellite Program
EOS: Earth Observing System
GOES: Geostationary Operational Environmental Satellites
NOAA: National Oceanic and Atmospheric Administration
NPOESS: National Polar-orbiting Operational Environmental Satellite System

OCO: Orbiting Carbon Observatory
UARS: Upper Atmosphere Research Satellite

MM5

The Department of Atmospheric Sciences at the University of Washington Mesoscale Model produces high resolution meteorological forecast for the Pacific Northwest twice a day (<http://www.atmos.washington.edu/mm5rt/>). The MM5 uses an outer grid of 36 km horizontal resolution and a nested grid of 12 km resolution that covers Washington, Oregon, and Idaho. These forecasts provide additional information to smoke management coordinators when deciding whether meteorological conditions are adequate for conducting a burn.

Monitoring equipment and data management systems - For response oriented fire and smoke monitoring, air quality concerns are most closely linked to (PM concentrations. In order to quantify the amount of PM in a fire impacted area, several PM monitoring methods are available. These methods are ideal because of the portability of the instrument and their near-real time measurement capabilities.

The more widely used instrument for smoke monitoring is the Met One EBAM. It can give a concentration of PM in as quickly as 15 minute intervals. The EBAM detects PM by determining the attenuation of beta radiation of the collected ambient PM on a glass fiber filter tape to determine ambient PM concentrations. EBAMs use the same beta attenuation method as one of the current Federal Equivalent Method instruments for both PM10 and PM2.5. Therefore, it is fairly correlated to an FEM measurement over longer averaging periods (such as an hour averaging period). The EBAM is equipped to collect meteorological data (temperature, relative humidity, wind speed and direction) and also can run on battery power. The unit is capable of disseminating data (including associated met data if available) via AIRSIS satellite modems. The existing infrastructure established with AIRSIS just for the EBAM allows for easy web access to EBAM data.

The other instrument that can be deployed in a smoke monitoring situation is a nephelometer. Nephelometers use light scattering properties of passing ambient PM to determine a backscatter coefficient that may be translated into a PM concentration. Nephelometers have an advantage over the EBAM by essentially providing real-time data. In addition, these instruments are also quite portable and consume very little power. However, nephelometers are generally not as tightly correlated to Federal Reference Method or Federal Equivalent Methods as the EBAM might be in a dynamic environment such as response-oriented smoke monitoring. Nephelometers are also essentially only effective for looking at PM2.5, and are much more easily biased by environmental conditions, especially by humidity. They are useful for at least providing "ballpark" representation of PM2.5 concentrations, but are not necessarily recommended to be used to assign publicly recognized air quality indicators such as those used by the Air Quality Index.