Chapter 11

EMISSION INVENTORIES

Emission Inventories

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An inventory or estimate of total statewide (or some other geographically distinct unit) annual emissions of criteria pollutants is a necessary part of understanding the burden on the air resource in an area and taking appropriate control actions. Emission inventories are a basic requirement of state air resource management programs and are a required element of State Implementation Plans. Emission inventories help explain the contribution of source categories to pollution events, provide background information for air resource management, provide the means to verify progress toward emission reduction goals, and provide a scientific basis for state air programs. An accurate emissions inventory provides a measured, rather than perceived, estimate of pollutant production as the basis for regulation, management action, and program compliance. Emission inventories should include all important source categories including mobile, area, and stationary and are not complete unless difficult-to-quantify sources like agricultural burning, backyard burning, rangeland burning, and wildland and prescribed burning are each addressed.

Wildland and prescribed fires are extremely diverse and dynamic air pollution sources and their emissions can be difficult to quantify. Design and development of an emission inventory system is primarily the responsibility of state air regulatory agencies. But cooperation and collaboration between air regulatory agencies and fire managers is required to design an effective and appropriate emission inventory system. Wildland fire managers should have the knowledge and data necessary to calculate emissions from their burn programs and be prepared to work with the state in developing emission inventory systems for wildland fire.

At the most basic level, estimation of wildfire emissions requires knowledge of area burned, fuel consumed, and a fuel-appropriate emission factor. The estimate of emissions is made through simple multiplication of area burned (acres or hectares) times fuel consumed (tons per acre or kilograms per hectare) times an emission factor assigned with knowledge of the fuel type (lbs/ton or g/kg) (figure 11.1). Resulting emissions are in tons or kilograms.

Greater accuracy, precision, and complexity can be achieved through increasingly detailed knowledge of these basic parameters. For example, area burned is estimated pre-burn in many existing reporting systems; if area burned is reassessed post-burn the accuracy of the emission inventory will increase. Accuracy and precision will also be improved if fuel consumed can be estimated with knowledge of pre-burn loading and consumption of fuels in each of many possible categories based on fuel type, size, and arrangement; and with knowledge of fuel moisture conditions, weather parameters, and application of emission reduction techniques. A more precise emission factor can be assigned with knowledge of burning conditions that can shift fuel consumption from the less efficient smoldering combustion phase into the more efficient flaming phase (figure 11.2).

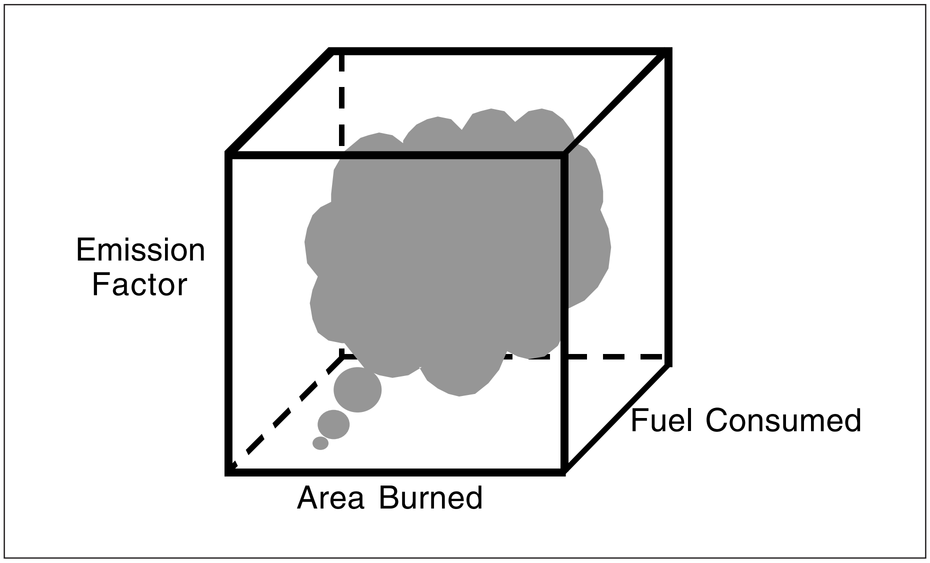

Figure 11.1. Basic information components needed to estimate the quantity of emissions from an individual wildland burn and compile an emissions inventory.

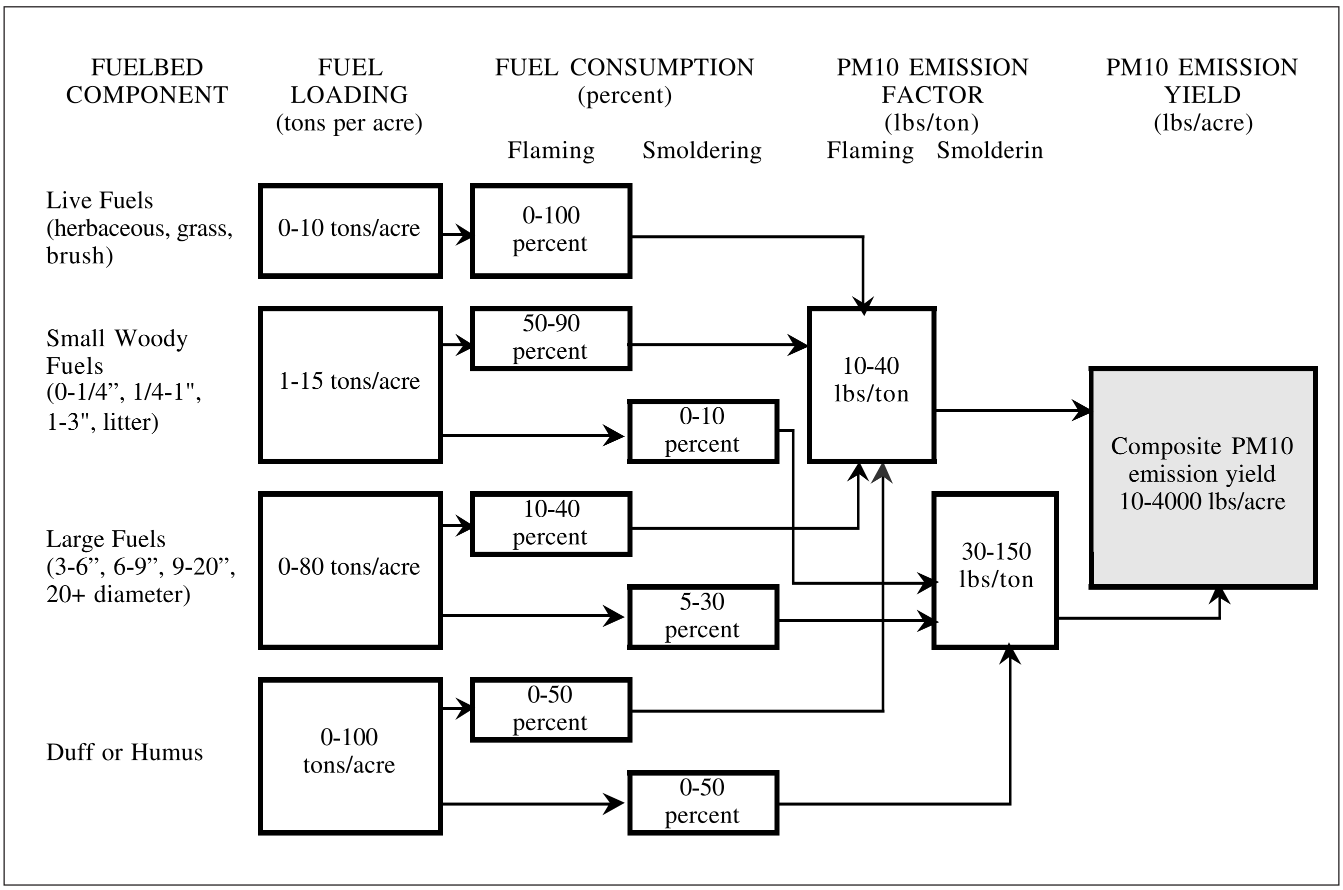

Figure 11.2. Detailed information about fuel loading and consumption by size class plus information to predict consumption by phase of combustion can increase the accuracy and precision of estimates of emissions from prescribed wildland fire for an emissions inventory (Modified from Sandberg [1988]). The ranges given in the figure cover the majority of fuel loading and consumption situations in wildland fuels but do not define the extremes. Numerous exceptions could likely be found in practice.

Sources of Prescribed Burning Activity Level Information

States with incomplete or no centralized burn reporting requirements will need to go to the burners themselves to quantify activity level. Federal agencies generally keep fairly accurate records of burning accomplished in a given time period and can also provide estimates of wildfire acres. Federal agencies that may need to be contacted in a given state or area include the Bureau of Land Management, Bureau of Indian Affairs or individual Tribes, National Park Service, Forest Service, and Fish and Wildlife Service. In some areas other federal agencies may need to be contacted. Such as the Department of Energy, Department of Defense, Natural Resources Conservation Service, Agricultural Research Service, U.S. Geological Survey, or the Department of Reclamation along with managers of National Preserves and National Monuments.

Specific state agencies with a forestry, wildlife, conservation, or natural resource management mandate are another source of activity level information. They may use prescribed burning themselves and may compile burning statistics for state lands and sometimes also for private lands. Private land owners, especially those managing timber-lands should be contacted as should The Nature Conservancy and the Audubon Society.

In some areas, especially where prescribed wildland burning is infrequent, the only source for activity level information may be a gross estimate for all prescribed fires for an entire state or area. This can sometimes be obtained from a single federal or state agency, or sometimes from an academic institution.

Type of Burn

Prescribed burning can be divided into categories depending on the arrangement of the fuels. Fuel arrangement can help predict total fuel consumption and the proportion consumed in the flaming vs. smoldering phases. Broadcast burning refers to fuels burned in place. This term can be used to describe natural woody fuels scattered under a stand of trees, woody debris scattered at random after a timber sale, brush burned in place, or grass. Fuels can also be concentrated into piles before burning. In addition to pile and broadcast burning, other general prescribed-fire-type categories that may be used include range, windrow, right-of-way, spot, black line, jack-pot, and concentration. Knowledge of the type of burn is valuable for estimating emissions as it can affect the accuracy and correct interpretation of estimates of area burned, fuel consumed, and assignment of an appropriate emission factor.

Area Burned

Area burned is generally the easiest parameter to obtain from fire managers. One caution is that area burned is often estimated prior to prescribed burning and not updated with the results of the burn, which may be smaller or larger (in the case of an escaped fire) than originally estimated. Also, area burned may reflect the area treated or the area within the wildland fire perimeter, rather than the area actually blackened by fire. The wildland fire perimeter may be considerably larger than the area actually blackened by fire. For example, a study of the Yellowstone fires of 1988 found that about 65% of the wildfire perimeter area within the park was actually blackened (Despain and others 1989), the remaining 35% was in unburned islands. In the case of prescribed fire, land managers may consider a larger area to have been treated or to have benefited by the fire than was actually blackened by flames. Compiling an accurate emission inventory requires actual acres (or hectares) blackened for an accurate estimate of emissions. Caution should be used with estimates of area burned, as this parameter is more prone to systematic overestimation than any other component of emissions estimation.

Fuel Consumed

Fuel consumed is generally estimated via a two-step process; first fuel loading is estimated, then a percent consumption is applied to calculate fuel consumed. At the most basic level, a single value for both total fuel loading and consumption can be used (for example 20 tons of fuel of which 50 percent consumed). In reality, a fuelbed is a complex mix of various sizes of woody fuels (tree boles, branches, and twigs), needle and/or leaf litter, decayed and partly decayed organic matter and rotten material (generally called duff or rot), and live fuels like brush, forbs, and grass. Each of these fuelbed components contributes to the total loading and is consumed to a greater or lesser extent. For example 100 percent of woody fuels less than 1 inch in diameter may burn whereas just 30 percent of those greater than 3 inches in diameter burn. In addition, some emission reduction techniques are specific by fuelbed component. Use of a single estimate of total fuel loading and consumption will fail to capture this. To gain accuracy in the emissions inventory and the ability to track the use and effectiveness of emission reduction techniques, further detail concerning fuel loadings by fuelbed component would ideally be tracked.

One simple method for obtaining a gross estimate of fuel loading is through the use of standardized fuel models. The most widely used example is the array of National Fire Danger Rating System (NFDRS) fuel models (Deeming and others 1977). These 20 models are standardized descriptions of different fuel types that can be used with some applicability to virtually all wildlands in the US. The NFDRS fuel models were designed as predictors of fire danger rather than to characterize the wide range of potential wildland fuel loadings as would be ideal for compilation of an emissions inventory. Another commonly used set of fuel models is based on predicting fire behavior. Thirteen fire behavior fuel models are described in Anderson (1982). Since both the NFDRS and fire behavior fuel models were designed for purposes other than accurate fuel loading estimation, these models should be used with caution. In addition, the use of standardized fuel models to estimate fuel loading means that efforts to reduce fuel loading for emission reduction purposes prior to prescribed burning cannot be tracked or reflected in the emissions inventory.

Other more detailed standardized fuel models called fuel characteristic classes (FCC's) are under development (Sandberg and others 2001) that are expected to greatly improve fuel loading estimates when they reach widespread use. It is estimated that there will be a core set of 48 to 64 FCC's in common usage with as many as 10,000 available in total describing the vast range of fuel types and conditions that can exist in wildlands across the country.

The most accurate method of estimating fuel loading is to have fire managers measure it in the field. Field estimation also enables reflection of the effect of emission reduction techniques on fuel loading. The most accurate method of estimating fuel consumption is through modeling (field measurement being unreasonably difficult in virtually all cases). In the west, two fuel consumption models are commonly used for this: the First Order Fire Effects Model (FOFEM) (Reinhardt and others 1997) and Consume (Ottmar and others 1993). These two models can provide very good estimates of fuel consumption if some basic knowledge of factors influencing fuel loading and moisture are known.

Estimating fuel loading and consumption for wildfire is much more difficult than for prescribed fire. For one thing, large wildfires often burn through many different fuel types where fuel loading can range from just a couple of tons per acre to over 100 tons per acre. Also, the science of predicting fuel consumption and emissions from a fire burning in tree crowns is extremely weak. The fuel type available from wildfire report forms is generally for the point of ignition rather than a reflection of fuel on the majority of acres burned.

Emission Factors

Wildland and prescribed-fire emission factors are contained in the EPA document AP-42 (EPA 1995) and in table 5.1 in the Smoke Source Characteristics chapter. Accuracy may be gained in an emissions inventory through knowledge of the portion of fuel consumed in the two primary consumption phases: flaming and smoldering. Flaming consumption emits far less emissions per unit of fuel consumed than smoldering consumption. Estimation of the flaming vs. smoldering ratio can be obtained through fuel consumption modeling and with knowledge of some influencing factors such as rate of ignition, fuel moisture conditions, and days since rain.

Federal Agency Reporting

The Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Park Service, and Bureau of Indian Affairs all have mandatory reporting requirements for wildland and prescribed fires although at present, they are all somewhat different. These reports contain some of the basic information needed to compile an emissions inventory. Within the next couple of years, all federal agencies will be moving toward a consolidated fire reporting database through implementation of the Federal Fire Policy.

Record keeping by state and private landowners is much more variable and may or may not be available to states wishing to compile an emissions inventory.

Forest Service

Forest Service forms FS-5100-29 (wildland fire) and FS-5100–29T (prescribed fire) require some of the basic inputs needed to compile an emissions inventory. The wildland fire report form requires reporting of acres burned within the fire perimeter regardless of landowner plus National Fire Danger Rating System (NFDRS) fuel model. It is significant to note that the instructions for estimating acres (USDA Forest Service 1999) specify reporting of all acres within the fire perimeter, unfortunately this value is not likely to equal acres blackened by fire. The number of acres blackened will always be less than the number of acres within the fire perimeter so use of this value without some adjustment will result in a serious systematic overestimation of acres actually burned and therefore of smoke produced. The NFDRS fuel model reported is the one in which the fire was burning at the time and place where another required element, the fire intensity level, was observed so it may or may not be representative of the majority of acres burned. Individual fire reports are collected throughout the year and can be analyzed through an electronic system called FIRESTAT (USDA Forest Service 1999).

Data collected by the Forest Service about prescribed burning that is useful for compiling an emissions inventory includes the prevailing NFDRS fuel model; the total acres plus the percent of acres burned; the preburn loading of dead fuels 0-3 inches in diameter; 3+ inches in diameter, and live; and the percent of these fuels that consumed. The prescribed fire report allows more accurate estimation of emissions since the percent of acres burned is reported and fuel loading and consumption is estimated in three categories. The Forest Service reporting system does not include estimates of duff consumption which can contribute as much as 50 percent of the emissions from a prescribed burn in certain areas under dry conditions, though is generally much less than that.

Fish and Wildlife Service

The Fish and Wildlife Service also has mandatory fire reporting requirements and uses a system called the Fire Reporting System (FRS) for data collection. The FRS requires reporting of project area size plus the actual burned area or acres blackened for both wildland and prescribed fire. It also allows multiple entries for NFDRS fuel model and links a specific area burned to each. Fuel loading is assigned based on NDFRS defaults in seven categories: dead woody fuels of diameter 0-1/4”, 1/4-1", 1-3", 3+; herbaceous; live woody; and duff. Users then specify percent consumption for each fuelbed category. Custom fuel models may also be defined. Data collected as part of the FRS provides very good information for estimating emissions from both wildland and prescribed fire on Fish and Wildlife Service burns though this is a very small part of total burning in most areas of the country with notable exceptions in the Southeastern states and Alaska.

Bureau of Land Management

The BLM reporting requirements include estimation of area burned for wildland and prescribed fire, less any unaltered areas as an estimate of acres blackened. The fire behavior fuel model that best represents the fuels in the burn area is required as is the NFDRS fuel model in the vicinity of the fire origin. The model representing fuels in the burn area is more appropriate for emissions estimation. In addition, for prescribed fire up to two fire-behavior fuel models can be selected and the percent of the burned area assigned. Fuel loading (tons per acre) and consumption (percent) can be reported in each of six fuel size classes: 0-1", 1.1-3", 3.1-9", greater than 9", shrub and herb, and litter and duff. If actual field data for fuel loading and consumption is not available, the most appropriate standard fuel loading and consumption range can be selected. Fuel loads can be assigned as light, average, or heavy for the fire behavior fuel model type and fuel consumption can be assigned as light, average, or heavy making some customization of the standard fuel models possible. The BLM reporting system also accommodates the unique requirements of estimating loading and consumption of prescribed burning of debris piles.

National Park Service

The NPS has mandatory fire reporting requirements but the information collected is of little use for emissions estimation, especially for wildland fire. For wildland fires, acres burned is required but the instructions don't specify whether perimeter acres or acres blackened is to be reported. The only required description of vegetation assigns one of three categories: commercial forest land, non-commercial forest land, or non-forest watershed which provides little or no information for estimating fuel loading and consumption. There is an optional field for input of NFDRS fuel model but how often this is used is unknown. Prescribed fire and wildland fire for resource benefit requires input of both NFDRS fuel model and a fire behavior fuel model.

Bureau of Indian Affairs

Fire reporting requirements for the BIA are similar to those for the NPS (see discussion above). One minor difference exists in the reporting of prescribed and wildland fire for resource benefits, where a fire behavior model may be input (but is not required). Further, a fire danger rating (NFDR) fuel model cannot be input.

Choosing the Appropriate Accuracy and Precision in an Emissions Inventory

The appropriate accuracy and precision for a state emissions inventory should be designed through analysis of the importance of the source in the affected area (sub-state, state, or multi-state area). Variables influencing the importance of prescribed burning as a source can be assessed through addressing issues such as:

- whether there are current impacts from prescribed fire or wildfire smoke,
- the aggressiveness of state goals for emission reduction and air quality improvement,
- the trend in burning in the local area and the rate of increase or decrease,
- a professional or financial motivation by burners to track and/or reduce emissions,
- the need to associate wildland fire emissions with specific air pollution episodes.

Tables 11.1 and 11.2 summarize information needed for a prescribed burning emissions inventory and for a wildland fire emissions inventory. Each table lists the categories of information needed to inventory emissions, proposes a minimum requirement for a basic inventory, and lists options for increasing the accuracy and precision of the inventory which may be desirable if wildland fire in the area of interest is of concern or controversial.[1]

Data requirements for producing an emissions inventory for either prescribed burning or wildland burning are very similar. They both require information about the time period of the burn, the location, the area actually burned, a description of the fuelbed, how much fuel burned, and site specific information for assigning an emission factor. A prescribed burning

[1] Sandberg, David, V.; Peterson, Janice. 1997. Emission inventories for SIP development. An unpublished technical support document to the EPA Interim Air Quality Policy on Wildland and Prescribed Fires. August 15, 1997. (Available from the authors or online at http://www.epa.gov/ttncaaa1/faca/pbdirs/eisfor6.pdf).

Table 11.1. Summary of information needed to compile a prescribed fire emissions inventory and options for increasing accuracy.

Information Needed	Units	Minimum Requirement	Overview of Options for Increasing Precision	Comments
1. Time period	time	year	season, month, day	
2. Location	n/a	administrative area	county, latitude and longitude, legal description	Latitude and longitude, and legal descriptions may be the burn start-point or mid point. All burners should be consistent.
3. Area actually burned	acres	acres	stratify by fuelbed description, area burned by time intervals (hourly or longer)	Should be retrospective to get an accurate estimate. Time interval estimates would be necessary for accurate dispersion modeling.
4. Fuelbed description	type or tons per acre	grass/brush/ forest floor/ forest crowns or slash	vegetative type, fuel model, fuel model by loading category (high/medium/low), inventoried fuel loadings	Critical for accurately estimating fuel loading and assigning an emission factor but may also be used for estimating fuel consumed. Use of BACM techniques may be detected with refined information.
5. Fuel consumed	percent or tons/acre	expert estimate	site specific information for driving predictive models	Critical variables for gaining precision will vary with fuel type and area, fuel moisture is nearly universal. Use of BACM techniques may be detected with refined information.
6. Emission factor	lbs/ton	burn average based on fuelbed description	site specific information to allow consumption to be apportioned into flaming vs. smoldering phases	Assigned based on AP-42.
7. Type of burn or fuelbed	category	none	broadcast, pile, right-of way, spot burning	Can increase accuracy of consumption estimates and emission factor assignment.
8. Purpose of Burn	category	none	ecosystem management, waste disposal, habitat enhancement, etc.	Can be useful if SIP strategies or permitting differs by purpose of burn.

Table 11.2. Summary of information needed to compile a wildland fire emissions inventory and options for increasing accuracy

Information Needed	Units	Minimum Requirement	Overview of Options for Increasing Precision	Comments
1. Time period	time	year	season; month; wildfire start, major spread, control, and declared-out dates; activity by day	Finest time resolution for which the inventory results will be used.
2. Location	n/a	administrative area	county; latitude and longitude	
3. Area actually burned	acres	acres	acres black stratified by other categories of information such as date, fuelbed, area burned in severe, moderate and low intensity, etc.	Currently, reported wildfire area burned is generally perimeter area which results in a systematic overestimation of area burned by as much as one third.
4. Fuelbed description	type or tons per acre	grass/brush/ forest floor/ forest crowns or slash	vegetative type, fuel model, fuel model by loading category (high/medium/low), percent of area burned by fuelbed description	Critical for estimating fuel loading and assigning an emission factor but may also be used for estimating fuel consumed. Unfortunately "cover type at point of ignition" is generally what is indicated on fire reports. Minimally, acres burned are to be stratified by grass, brush, forest floor, timber crowns, or slash. This is the most critically lacking variable in most current fire reports, and some approach to augmenting the information should be considered.
5. Fuel consumed	percent or tons/acre	expert estimate	more research is needed to develop algorithms to predict wildfire fuel consumption	Very difficult to estimate accurately and likely varies widely throughout a wildfire area.
6. Emission factor	lbs/ton	average value from table	see fuelbed description	Assigned based on AP-42.
7. Control strategy	category	none	full suppression, modified, limited	May be used in some SIP strategies in order to identify sources that are allowed to burn to achieve resource benefits or economic efficiency.

emissions inventory includes extra information about the type of burn or fuelbed arrangement plus the purpose of the burn. These are optional data items that may be useful in some cases. A wildland burning emissions inventory includes information about the control strategy used to fight the fire.

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Chapter 12

ADMINISTRATION AND ASSESSMENT

Smoke Management Program Administration and Evaluation

Peter Lahm

Smoke management program administration can range from activities conducted at the local burn program level to a multi-state coordinated effort to manage smoke. The EPA Interim Air Quality Policy on Wildland and Prescribed Fires (Interim Policy) (EPA 1998) recommends that smoke management programs be administered by a central authority with clear decision-making capability. As smoke management programs range from voluntary efforts to mandatory regulatory driven programs, the administration will vary accordingly[1]. On the more local level, the programs may be administered by a group of land managers or private landholders seeking to coordinate burning efforts to avoid excessive smoke impacts. Mandatory regulatory driven smoke management programs tend to be administered by tribal/state/district air quality regulatory agencies or state forestry entities. The administration of smoke management programs allows for a number of different approaches to meet EPA objectives and to maintain cooperative and interactive efforts to manage the dual objectives of good air quality and land stewardship.

The Interim Policy also recommends periodic evaluation of smoke management programs to ensure that air quality objectives are being met. From the land management point of view, these same reviews are critical to assessing whether land management objectives are being met under the smoke management program. EPA also recommended periodic evaluation of smoke management rule or regulation effectiveness as part of its Interim Policy. For programs that are under scrutiny by a concerned public or are growing rapidly, continuous evaluation should also be considered. All smoke management efforts—from formal interagency smoke management plans to less structured efforts to address smoke from individual fire operations—can benefit from continuous and periodic evaluation. If a smoke management program changes size, jurisdiction, or regulatory responsibilities, the level of effort applied to managing smoke should also change. To keep a program ahead of growing air quality concerns, a continuous effort to evaluate smoke management effectiveness is useful. This evaluation is also critical for local unit programs that are under formal state or tribal smoke management plans. The evaluation process has applicability to all types of fire, including wildland fire under suppression, wildland fire use and prescribed fire.

[1] Examples of specific state smoke management programs are provided in chapter 4, section 4.2.

Smoke Management Program Administration

Administration of a smoke management program is frequently a function of the size of the burn program using a metric such as acres burned or emissions generated, coupled with the complexity of the local air quality issues. Fire programs located in areas that are not rife with Class I areas, PM_{10} non-attainment areas, or smoke-sensitive transportation corridors are commonly under voluntary smoke management programs and may be locally administered. These types of programs may be focused on concerns of local area impacts such as nuisance or transportation safety and can be well addressed through local level coordination among burners. State forestry agencies and their respective districts are frequently central points for dissemination of information; many examples of this type of program can be found in the southeastern states.

As air quality complexity rises with potential smoke impacts on non-attainment areas or Class I areas, legal requirements also rise, and frequently trigger a more centralized regulatory-based smoke management program. Attendant with the increased program requirements is the commensurate increased cost of the program. Direct costs of smoke management program administration are frequently recovered through the charging of fees to burners. Fees are frequently based on emissions production or tonnage of material to be consumed and are used to offset an authority's program administration costs. The increased indirect cost of frequent reporting requirements and other permitting tasks such as modeling of impacts and smoke management plan preparation are frequently overlooked. The most common centralized program approach is administered by the state or tribal air quality authority and can be found in such states as Colorado. States such as Florida and Oregon have opted to use their forestry agencies to help directly manage their smoke management programs. Oversight by the respective air quality regulatory authority is usually a part of such a program. There is an option for interagency approaches to smoke management program administration. This approach blends the lines between air quality regulatory agencies and land managers. Personnel from a land management agency may be out-stationed to the respective air quality regulatory authority to assist in the smoke management program administration. The states of Utah and Arizona use this approach respectively and have avoided program management fees in this fashion. This approach can also foster good inter-agency communication and development of joint air quality and land management objectives for smoke management programs.

The future of smoke management program administration will be a reflection of the implementation of the Regional Haze Rule (40 CFR Part 51), which creates a paradigm in which air quality impacts are viewed in a regional sense rather than by locality or state. Tribal smoke management programs are being rapidly developed and will help support this regional approach. The establishment of multi-state smoke management jurisdictions is rapidly becoming a reality with a joint effort by Idaho and Montana being a recent example. The $PM_{2.5}$ and ozone standards will also support this type of approach as the impacts of smoke are viewed as a long-range transport issue. The inclusion of all sources of fire emissions, such as agricultural burning and wildland burning, into a singular smoke management program is also a future direction in these programs, and can already be found in the Title 17 Rule in California.

Evaluation of Smoke Management Programs

Size of Program — In lieu of any other parameter that can describe the activity level of a burn program, the number of acres can be used to trigger level of effort for smoke management and subsequent evaluation of smoke effects. As mentioned elsewhere, the representation of fire activity in terms of emissions is more effective for air quality purposes. In lieu of emissions, fire size and fuel type can be used for triggering different smoke management requirements. Small burns located in remote areas with low emissions may not dictate any evaluation greater than tracking the activity level and date of burn. However, more complex situations such as a burn of several days' duration with heavy emissions located in the wildland/urban interface should be tracked more extensively for smoke management effectiveness. This same complex situation may track the effectiveness of emission reduction practices. It may be beneficial if the criteria are established in consultation with the local or state air regulatory agency. For federal agencies, these criteria can also be linked to the management plan's monitoring program. A post burn analysis of the smoke management plan and the burn's smoke effects can be extremely valuable to all concerned parties.

Intensity and Duration of Smoke Effects — The intensity and duration of smoke impacts are critical parameters that can represent a variety of smoke management effectiveness measures. Duration of smoke impacts upon the public, a non-attainment area, a transportation corridor or Class I area can be tracked and assessed through direct air quality monitoring.[2] The public can be tolerant of one day of heavy levels of smoke, however consecutive day impacts may lead to a rash of complaints. The criteria for evaluating a program may be to assess the number of consecutive days/hours of impact to a specific area. The intensity level of smoke impact also plays a role, as short bursts of high levels of smoke punctuated by clear air is frequently tolerable by receptors. An application of this type of criteria exists in Oregon where number and intensity of smoke intrusions is tracked annually. This type of criteria is applicable to individual incidents as well.

Methods of tracking the intensity and duration of smoke impact include:

- Number and type of public complaints (citizen, doctor, hospital, etc.);
- Intrusion of smoke into designated smoke sensitive areas through specific air quality measurement;
- Violations or percent increase of criteria pollutants attributable to smoke;
- Visibility impacts (local and regional).

As the National Ambient Air Quality Standards (NAAQS) include both short term and annual standards, the full impact of smoke on the NAAQS may not be readily determined until well after the burn season is completed, which further supports the importance of incorporating evaluation into a smoke management program. Impacts on visibility were previously viewed on an annual basis, however that has changed to tracking impacts on Class I areas to determine effects on the 20% clearest and 20% dirtiest days. These methods for tracking and evaluation should be established prior to the event or as part of the overall smoke management program as they can take significant planning or coordination. Pre-planning for the air quality element of the Wildland Fire Situation Analysis used by federal agencies for wildland fires

(USDI and USDA Forest Service 1998) can also be beneficial as the public, air quality regulatory community, and land management entity has the opportunity to increase acceptance of smoke effects.

The evaluation criteria should be as quantitative as possible in light of the complexity of the burn or program and the air quality concerns of the area. Proximity to non-attainment or Class I areas should automatically trigger some programmatic evaluation. Visibility should be considered in terms of plume blight, regional haze and impacts on safety (transportation). Conversely, a small incident with a small quantity or short duration of emissions in an area with few air quality concerns should not warrant extensive programmatic or individual incident evaluation effort. Again, advance coordination with concerned parties can help determine this varying level of effort.

If an incident or program results in a smoke intrusion above a pre-defined level such as number of complaints or presence of smoke in an avoidance area, the cause should be evaluated as soon as possible. The breakdown of the smoke management plan for an incident is equivalent to the breakdown of the fire behavior prescription for the burn. Smoke management contingency programs are another element of a smoke management program included in the Interim Policy (EPA 1998). Factors such as weather/smoke dispersion forecasting or fuel condition changes can lead to such a smoke intrusion and need to be evaluated quickly following a failure of the system in order to be addressed in a proactive fashion. Determination of what caused the adverse air quality impact allows for growth of the program through implementation of changes to avoid future recurrence. If a program or incident was conducted such that no smoke criteria were exceeded, evaluation of the factors which led to success are also valuable in building confidence among cooperating parties. The development of an annual report which outlines the air quality effects of a burning program or the smoke management program demonstrates the commitment to addressing both land management and air quality objectives and can show significant and useful trends to concerned parties. The knowledge that smoke impacts are being addressed effectively in terms of specific criteria is valuable when working with the concerned public and media.

Sources for Evaluation — Evaluation can be the assessment of air quality monitoring data collected by the land manager or utilization of existing air quality networks as operated by a regulatory agency (state/district/county/EPA/tribe). The meteorological conditions under which burns occur is another criteria that can be evaluated to help assess the smoke management program. For complex smoke areas, the use of digital camera points could allow distribution of the real-time images over the Internet to concerned parties, including the public. The concerned public can also be directly queried as to the level of smoke levels and duration of effects.

Annual Evaluation — One of the most effective means of evaluating the smoke management program is to hold periodic meetings amongst the concerned parties such as the burners, regulators and potentially-concerned public. The frequency of such reviews should depend on the air quality complexity and smoke impacts. Many statewide smoke management programs meet annually to review the years' activities, successes and problems. These meetings could include review of activity/emissions of burners, record-keeping efforts, effects tracked through the previously mentioned methods, and discussion of program logistics and costs. This same review meeting is also an opportune time to plan for future changes, discuss emerging issues, and conduct training if needed. The Interim Policy (EPA 1998) also urges such an evaluation process occur annually. These annual sessions may be an effective way of addressing an Interim Policy goal of assessing the adequacy of the rules and regulations pertaining to smoke management for a respective state, tribe or other managing entity. Reflecting the state of the smoke management program, whether statewide or at the land manager level, through the issuance of an annual program report on smoke management can be another technique for assessing the program and informing the public of the investment into smoke management.

Continuous Evaluation — If a specific incident were to have significant adverse effects, it might trigger immediate review to prevent a repeat occurrence. This immediate incident assessment can be an effective way of addressing pressing public concerns that may have arisen due to the impacts. During a wildland fire use incident, daily conference calls amongst the land manager and the regulatory agencies which discuss acres/fuels/emissions or qualitative smoke behavior can be very effective at addressing smoke concerns. This real-time evaluation can prevent conflict over smoke impacts and can ensure accurate information be provided to the public as well as incorporated into the message transmitted to the media by the respective agencies.

Incident debriefings should consider air quality effects and how they were addressed. In wildland fire use, there is a continuous evaluation of air quality as part of the Wildland Fire Situation Analysis (USDI and USDA Forest Service 1998). Establishment of criteria for evaluation of air quality effects prior to the actual event or implementation of a program can allow for greater buy-in by potentially affected parties when the fire occurs. Criteria for evaluation should also include indicators of success.

Literature Citations

Environmental Protection Agency. 1998. Interim air quality policy on wildland and prescribed fires. Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711. 39p.

40 CFR Part 51. Vol. 64 No. 126. Regional Haze Regulations – Final Rule. July 1, 1999.

USDI and USDA Forest Service. 1998. Wildland and prescribed fire management policy—implementation procedures reference guide. National Interagency Fire Center, Boise, ID. 81 pp. and appendices.

APPENDIX

Appendix A

Glossary of Fire and Smoke Management Terminology

The terms listed below were either taken from existing glossaries or developed specifically for this Guide. Where terms were taken from an existing glossary or document, the source reference is indexed in brackets (e.g. [source number]), with full reference citations provided at the end of the glossary. Note: Although the referenced definitions in this glossary were taken from other sources, the editors have revised or changed many of them from their original version.

Absorption coefficient	A measure of the ability of particles or gases to absorb photons; a number that is proportional to the number of photons removed from the sight path by absorption per unit length. (See Extinction coefficient). [2]
Activity fuel	Debris resulting from such human activities as road construction, logging, pruning, thinning, or brush cutting. It includes logs, chunks, bark, branches, litter, stumps, and broken understory trees or brush.
Activity level	Fuels resulting from, or altered by, forestry practices such as timber harvest or thinning, as opposed to naturally created fuels. [1]
Adiabatic lapse rate	Rate of decrease of temperature with increasing height of a rising air parcel without an exchange of heat at the parcel boundaries. (See Dry adiabatic lapse rate, Saturated adiabatic lapse rate, and Atmospheric stability).
Advection	The transfer of atmospheric properties by the horizontal movement of air, usually in reference to the transfer of warmer or cooler air, but may also refer to moisture. [1]
Aerial ignition	Ignition of fuels by dropping incendiary devices or materials from aircraft. [1]
Aerosol	A suspension of microscopic solid or liquid particles in a gaseous medium, such as smoke and fog. [2]

Air mass	An extensive body of air having similar properties of temperature and moisture. [1]
Air pollution	The general term referring to the undesirable concentration of substances (gases, liquids, or solid particles) to the atmosphere that are foreign to the natural atmosphere or are present in quantities exceeding natural concentrations. [1]
Air quality	The composition of air with respect to quantities of pollution therein; used most frequently in connection with “standards” of maximum acceptable pollutant concentrations. [1]
Allowable emissions	The emissions rate that represents a limit on the emissions that can occur from an emissions unit. This limit may be based on a federal, state, or local regulatory emission limit determined from state or local regulations and/or 40 Code of Federal Regulations (CFR) Parts 60, 61, and 63. [3]
Ambient air	Any unconfined portion of the atmosphere: open air, surrounding air. [4]
Ambient standards	Specific target threshold concentrations and exposure durations of pollutants based on criteria gauged to protect human health and the welfare of the environment. Ambient standards are not emissions limitations on sources, but usually result in such limits being placed on source operation as part of a control strategy to achieve or maintain an ambient standard. [3]
Anthropogenic	Produced by human activities. [2]
Area sources	A source category of air pollution that generally extends over a large area. Prescribed burning, field burning, home heating, and open burning are examples of area sources. [1]
Atmospheric inversion	(1) Departure from the usual increase or decrease with altitude of the value of an atmospheric property (in fire management usage, nearly always refers to an increase in temperature with increasing height). (2) The layer through which this departure occurs (also called inversion layer). The lowest altitude at which the departure is found is called the base of the inversion. (See Atmospheric stability; Temperature inversion; Mixing height; Mixing layer; Stable atmosphere; Unstable atmosphere; Subsidence inversion) [1]

Atmospheric pressure	The force exerted by the weight of the atmosphere, per unit area. At sea level the atmospheric pressure fluctuates around 1013 millibars (mb). At 5,000 feet (~1,500 m) above sea level the atmospheric pressure fluctuates around 850 mb. (See Standard atmosphere).
Atmospheric stability	The degree to which vertical motion in the atmosphere is enhanced or suppressed. (See Atmospheric inversion; Temperature inversion; Mixing height; Mixing layer; Stable atmosphere; Unstable atmosphere). [1]
Attainment Area	An area considered having air quality as good as or better than the National Ambient Air Quality Standards (NAAQS) as defined in the Clean Air Act. Note that an area may be in attainment for one or more pollutants but be a nonattainment area for one or more other pollutants. (See Non-attainment area). [3]
Avoidance	A smoke emission control strategy that considers meteorological conditions when scheduling prescribed fires in order to avoid incursions into smoke sensitive areas. [1]
Background level	In air pollution control, the concentration of air pollutants in a definite area during a fixed period of time prior to the starting up, or the stoppage, of a source of emission under control. In toxic substances monitoring, the average presence in the environment, originally referring to naturally occurring phenomena. [1]
Best Available Control Measures (BACM)	An emission limitation action based on the maximum degree of emission reduction (considering energy, environmental, and economic impacts) achievable through application of production processes and available methods, systems, and techniques. [4]
Burn severity	A qualitative assessment of the heat pulse directed toward the ground during a fire. Burn severity relates to soil heating, large fuel and duff consumption, consumption of the litter and organic layer beneath trees and isolated shrubs, and mortality of buried plant parts. [1]
Carbon dioxide (CO_2)	A colorless, odorless, nonpoisonous gas, which results from fuel combustion and is normally a part of the ambient air. [1]
Carbon monoxide (CO)	A colorless, odorless, poisonous gas produced by incomplete fuel combustion. Carbon monoxide is a criteria pollutant and is measured in parts per million. (See Criteria pollutants).

Carcinogen Any substance that can cause or contribute to the production of cancer. [1]

Clean Air Act A federal law enacted to ensure that air quality standards are attained and maintained. Initially passed by Congress in 1963, it has been amended several times. [1]

Combustion efficiency The amount of products of incomplete combustion released relative to amounts produced from theoretically perfect combustion, expressed as a dimensionless percentage. Because perfect combustion produces only CO_2 and water, its combustion efficiency is 1.0. In combustion of wildland fuels, combustion efficiency can roughly range from as high as 0.95 (for flaming combustion) to as low as 0.65 (for smoldering combustion).

Condensation nuclei The small nuclei or particles with which gaseous constituents in the atmosphere (e.g., water vapor) collide and adhere. [2]

Consumption The amount of a specified fuel type or strata that is removed through the fire process, often expressed as a percentage of the preburn weight. [1]

Convection column The rising column of gases, smoke, fly ash, particulates, and other debris produced by a fire. The column has a strong vertical component indicating that buoyant forces override the ambient surface wind. [1]

Convergence The term for horizontal air currents merging together or approaching a single point, such as at the center of a low-pressure area producing a net inflow of air. The excess air is removed by rising air currents. Expansion of the rising air above a convergence zone results in cooling, which in turn often gives condensation (clouds) and sometimes precipitation. [1]

Criteria Pollutants Pollutants deemed most harmful to public health and welfare and that can be monitored effectively. They include carbon monoxide (CO), lead (Pb), nitrogen oxides (NO_x), sulfur dioxide (SO_2), Ozone (O_3), particulate matter (PM) of aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) and particulate matter of aerodynamic diameter less than or equal to 2.5 micrometers ($PM_{2.5}$). [3]

Deciview A unit of visibility proportional to the logarithm of the atmospheric extinction. (See Extinction coefficient; Visibility; Visual range). [2]

De minimis level	A level of emission or impact that is too small to be considered of concern. From the Latin phrase "de minimis non curat lex," meaning the law is not concerned with trifles.
Dew point	Temperature to which a specified parcel of air must cool, at constant pressure and water-vapor content, in order for saturation to occur. The dew point is always lower than the wet-bulb temperature, which is always lower than the dry-bulb temperature, except when the air is saturated and all three values are equal. Fog may form when temperature drops to equal the dew point. (See Dry-bulb temperature; Wet-bulb temperature). [1]
Dormant season burning	Prescribed burning conducted during the time of year when vegetation is not actively growing. In some parts of the country, dormant season burns are typically less intense than growing season burns.
Drift smoke	Smoke that has drifted from its point of origin and is no longer dominated by convective motion. May give false impression of a fire in the general area where the smoke has drifted. [1]
Dry adiabatic lapse rate (DALR)	Adiabatic cooling in a dry atmosphere. Usually about -5.5 degrees Fahrenheit per 1,000 feet (~-10 degrees centigrade per kilometer). (See Adiabatic lapse rate; Saturated adiabatic lapse rate).
Dry-bulb temperature	Originally, the temperature measured with a mercury thermometer whose bulb is dry. Commonly it is a measure of the atmospheric temperature without the influence of moisture. (See Wet-bulb temperature; Dew point).
Duff	The partially decomposed organic material above mineral soil that lies beneath the freshly fallen twigs, needles, and leaves and is often referred to as the F (fermentation) and H (humus) layers. Duff often consumes during the less efficient smoldering stage and has the potential to produce more than 50 percent of the smoke from a fire.
Ecosystem health	A condition where the parts and functions of an ecosystem are sustained over time and where the system's capacity for self- repair is maintained, allowing goals for uses, values, and services of the ecosystem to be met.

Ecosystem maintenance burn	A prescribed fire or wildland fire managed for resource benefits that is utilized to mimic the natural role of fire in an ecosystem that is currently in an ecologically functional and fire resilient condition. [5]
Ecosystem Processes	The actions or events that link organisms and their environment, such as predation, mutualism, successional development, nutrient cycling, carbon sequestration, primary productivity, and decay. Natural disturbance processes often occur with some periodicity
Ecosystem Restoration	The re-establishment of natural vegetation and ecological processes that may be accomplished through the reduction of unwanted and/or unnatural levels of biomass. Prescribed fires, wildland fires managed for resource benefits and mechanical treatments may be utilized to restore an ecosystem to an ecologically functional and fire resilient condition. [5]
Extinction coefficient	A measure of the ability of particles or gases to absorb and scatter photons from a beam of light; a number that is proportional to the number of photons removed from the sight path per unit length. (See Absorption coefficient; Deciview; Visibility; Visual range). [2]
Effective windspeed	The mid-flame windspeed adjusted for the effect of slope on fire spread. [1]
Emission factor (EFp)	The mass of particulate matter produced per unit mass of fuel consumed (pounds per ton, grams per kilogram). [1]
Emission inventory	A listing, by source, of the amount of air pollutants discharged into the atmosphere of a community. [3]
Emission rate	The amount of an emission produced per unit of time (lb./min or g/sec). [1]
Emission reduction	A strategy for controlling smoke from prescribed fires that minimizes the amount of smoke output per unit area treated. [1]
Emission Standards	A general type of standard that limit the mass of a pollutant that may be emitted by a source. The most straightforward emissions standard is a simple limitation on mass of pollutant per unit time (e.g., pounds of pollutant per hour). [3]

Extinction	The attenuation of light due to scattering and absorption as it passes through a medium. [2]
Federal Class I area	In 1977, Congress identified 156 national parks, wilderness areas, international parks and other areas that were to receive the most stringent protection from increases in air pollution. It also set a visibility goal for these areas to protect them from future human-caused haze, and to eliminate existing human-caused haze, and required reasonable progress toward that goal. [5]
Fine fuel moisture	The moisture content of fast-drying fuels that respond to changes in moisture within 1 hour or less; such as, grass, leaves, ferns, tree moss, pine needles, and small twigs (0-1/4" or 0.0-0.6 cm). (See Fuel moisture content; One-hour timelag fuels). [1]
Fire-adapted ecosystem	An ecosystem with the ability to survive and regenerate in a fire-prone environment.
Fire-dependent ecosystem	An ecosystem that cannot survive without periodic fire.
Fire exclusion	The policy and practice of eliminating fire from an area to the greatest extent possible, through suppression of wildland fires and a lack of fire use.
Fire regime	Periodicity and pattern of naturally occurring fires in a particular area or vegetative type, described in terms of frequency, biological severity, and area extent. [1]
Fire regime groups	Classes of fire regimes grouped by categories of frequency (expressed as mean fire return interval) and severity. Refers specifically to five groups used in Federal policy and planning: 0-35 years, low severity; 0-35 years, stand replacement; 35-100 years, mixed severity; 35-100 years, stand replacement; 200+ years, stand replacement. (See Fire return interval; Fire regime).
Fire return interval	Mean fire return interval. A mean, area-weighted time (in years) between successive fires for a respective area (i.e., the interval between two

	successive fire occurrences); the size of the area must be specified.
Fire severity	(See Burn severity.)
Fire use	The combination of wildland fire use and prescribed fire application to meet resource objectives. [6]
Fireline intensity	The rate of heat release per unit time per unit length of fire front. Numerically, it is the product of the heat yield, the quantity of fuel consumed in the fire front, and the rate of spread. [1]
Flaming combustion phase	Luminous oxidation of gases evolved from the rapid decomposition of fuel. This phase follows the pre-ignition phase and precedes the smoldering combustion phase, which has a much slower combustion rate. Water vapor, soot, and tar comprise the visible smoke. Relatively efficient combustion produces minimal soot and tar, resulting in white smoke; high moisture content also produces white smoke. (See Soot; Smoldering combustion phase). [1]
Forest floor material	Surface organic material, including duff, litter, moss, peat, down-dead woody pieces.
Forest residue	Accumulation in the forest of living or dead (mostly woody) material that is added to and rearranged by human activities such as harvest, cultural operations, and land clearing. (See Activity fuel). [1]
Fuel loading	The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area. This may be available fuel (consumable fuel) or total fuel and is usually dry weight. [1]
Fuel moisture content	The quantity of moisture in fuel expressed as a percentage of the weight; derived by weighing fuel sample both before and after thorough drying at (nominally) 212 degrees F (100 degrees C). (See Fine fuel moisture). [1]
Fuel reduction	Manipulation, including combustion, or removal of fuels to reduce the likelihood of ignition and/or to lessen potential damage and resistance to control. [1]
Fuel size class	A category used to describe the diameter of down dead woody fuels. Fuels within the same size class are assumed to have similar wetting and drying properties, and to preheat and ignite at similar rates during the combustion process. [1]

Fuel treatment	Manipulation or removal of fuels to reduce the likelihood of ignition and/or to lessen potential intensity, rate of spread, severity, damage, and resistance to control. Examples include lopping, chipping, crushing, piling and burning. [1]
Fuel type	An identifiable association of fuel elements of distinctive species, form, size, arrangement, or other characteristics that will cause a predictable rate of spread or resistance to control under specified weather conditions. [1]
Glowing combustion phase	Oxidation of solid fuel accompanied by incandescence. All volatiles have already been released and there is no visible smoke. This phase follows the smoldering combustion phase and continues until the temperature drops below the combustion threshold value, or until only non-combustible ash remains. (See Combustion; Flaming combustion phase; Smoldering combustion phase). [1]
Growing season burning	Prescribed burns conducted during the time of year when vegetation is actively growing, or when leaves have matured but not fallen.
Hazard reduction	Any treatment of living and dead fuels that reduces the threat of ignition and spread of fire. [1]
Haze	A sufficient concentration of atmospheric aerosols to be visible. The particles are so small that they cannot be seen individually, but are still effective in visual range restriction. (See Visual range; Extinction; Absorption coefficient; Regional haze). [2]
Heat release rate	(1) Total amount of heat produced per unit mass of fuel consumed per unit time. (2) Amount of heat released to the atmosphere from the convective-lift fire phase of a fire per unit time. [1]
Hydrocarbons	Compounds containing only hydrogen and carbon. [2]
IMPROVE	Interagency Monitoring of Protected Visual Environments. A cooperative visibility monitoring effort, using a common set of standards across the United States, between the EPA, Federal land management agencies, and state air agencies. [5]

Integrating nephelometer	An instrument that measures the amount of light scattered (scattering coefficient) and can be used to measure particulate matter concentrations from fires. [2]
Inversion	(See Atmospheric inversion) [2]
Isothermal layer	A layer of finite thickness in any medium in which the temperature remains constant.
Landscape	An area composed of interacting and inter-connected ecosystems that are repeated because of the geology, landform, soils, climate, biota, and human influences throughout the area. A landscape is composed of watersheds and smaller ecosystems.
Lead (Pb)	A criteria pollutant, elemental lead emitted by stationary and mobile sources can cause several types of developmental effects in children including anemia and neurobehavioral and metabolic disorders. Non-ferrous smelters and battery plants are the most significant contributors to atmospheric lead emissions. (See Criteria pollutants). [3]
Litter	The top layer of forest floor, composed of loose debris of dead sticks, branches, twigs, and recently fallen leaves or needles; little altered in structure by decomposition. (See Duff; Forest floor material). [1]
Mass fire	A fire resulting from many simultaneous ignitions that generates a high level of energy output. [1]
Mean fire interval	(See Fire return interval)
Micron	Micrometer (mm)—a unit of length equal to one millionth of a meter; the unit of measure for wavelength and also for the mean aerodynamic diameter of atmospheric aerosols. [2]
Mixing height	Measured from the surface upward, the height to which relatively vigorous mixing occurs in the atmosphere due to turbulence and diffusion. Also called mixing depth. [1]
Mixing layer	That portion of the atmosphere from the surface up to the mixing height. This is the layer of air within which pollutants are mixed by turbulence and diffusion. Also called mixed layer. (See Ventilation Index). [1]

Mopup	Extinguishing or removing burning material near control lines, felling snags, and trenching logs to prevent rolling after an area has burned, to reduce the chance of fire spreading beyond the control lines, or to reduce residual smoke. [1]
Mosaic	The central spatial characteristic of a landscape. The intermingling of plant communities and their successional stages, or of disturbance (especially fire), in such a manner as to give the impression of an interwoven, "patchy" design. [1]
National Ambient Air Quality Standards (NAAQS)	Maximum recommended concentrations of criteria pollutants to maintain reasonable standards of air quality. (See criteria pollutants). [3]
National Wildfire Coordinating Group (NWCG)	National interagency operational group authorized by the U.S. Secretaries of Agriculture and Interior and the National Association of State Foresters, designed to coordinate fire management programs of participating federal, state, local and private agencies to avoid wasteful duplication and provide a means of constructive cooperation.
Natural background condition	An estimate of the visibility conditions at each Federal Class I area that would exist in the absence of human-caused impairment. [5]
Nitrogen dioxide (NO_2)	The result of nitric oxide combining with oxygen in the atmosphere. A major component of photochemical smog. [1]
Nitrogen Oxide[s] (NO_x)	A class of compounds that are respiratory irritants and that react x with volatile organic compounds (VOCs) to form ozone (O_3). The primary combustion product of nitrogen is nitrogen dioxide (NO_2). However, several other nitrogen compounds are 2 usually emitted at the same time (nitric oxide [NO], nitrous oxide [NO], etc.), and these may or may not be distinguishable in available test data. [3]
Non-attainment area	An area identified by an air quality regulatory agency through ambient air monitoring (and designated by the Environmental Protection Agency), that presently exceeds federal ambient air standards. (See Attainment area). [1]
Nuisance smoke	The amount of smoke in the ambient air that interferes with a right or privilege common to members of the public, including the use or enjoyment of public or private resources.

One-hour timelag fuels	Fuels consisting of dead herbaceous plants and roundwood less than about one-fourth inch (6.4 mm) in diameter. Also included is the uppermost layer of needles or leaves on the forest floor. Fuel elements of this size usually respond to changes in moisture within one hour or less, hence the term 1-hr timelag. (See Fuel moisture content; Fine fuel moisture). [1]
One-hundred-hour timelag fuels	Dead fuels consisting of roundwood in the size range of 1 to 3 inches (2.5 to 7.6 cm) in diameter and very roughly the layer of litter extending from approximately three-fourths of an inch (1.9 cm) to 4 inches (10 cm) below the surface. Fuel elements of this size usually respond to changes in moisture within about one hundred hours or 3 to 5 days, hence the term 100-hr timelag. (See Fuel moisture content). [1]
One-thousand-hour timelag fuels	Dead fuels consisting of roundwood 38 inches in diameter and the layer of the forest floor more than about 4 inches below the surface. Fuel elements of this size usually respond to changes in moisture within about one thousand hours or 4 to 6 weeks, hence the term 1000-hr timelag. (See Fuel moisture content). [1]
Ozone (O_3)	A criteria pollutant, ozone is a colorless gas, ozone is the major component of smog. Ozone is not emitted directly into the air but is formed through complex chemical reactions between precursor emissions of volatile organic compounds (VOCs) and NO_X in the presence of sunlight. (See Criteria pollutants). [3]
Particulate matter	Any liquid or solid particle. “Total suspended particulates” as used in air quality are those particles suspended in or falling through the atmosphere. They generally range in size from 0.1 to 100 microns. [1]
Piling-and-burning	Piling slash resulting from logging or fuel management activities and subsequently burning the individual piles. [1]
PM_{10}	Particulate matter of mass median aerodynamic diameter (MMAD) less than or equal to 10 micrometers. A measure of small solid matter suspended in the atmosphere that can penetrate deeply into the lung where they can cause respiratory problems. Emissions of PM_{10} are significant from fugitive dust, power plants, commercial boilers, metallurgical industries, mineral industries, forest and residential fires, and motor vehicles. (See Criteria pollutants). [3]

$PM_{2.5}$	Particulate matter of mass median aerodynamic diameter (MMAD) less than or equal to 2.5 micrometers A measure of fine particles of particulate matter that come from fuel combustion, agricultural burning, woodstoves, etc. Often called respirable particles, as they are more efficient at penetrating lungs and causing damage. (See Criteria pollutants). [3]
Point sources	Large, stationary, identifiable sources of emissions that release pollutants into the atmosphere. Sources are often defined by state or local air regulatory agencies as point sources when they annually emit more than a specified amount of a given pollutant, and how state and local agencies define point sources can vary. [3]
Precursor emissions	Emissions from point or regional sources that transform into pollutants with varied chemical properties. [2]
Prescribed fire	Any fire ignited by management actions to meet specific objectives. A written, approved prescribed fire plan must exist, and NEPA requirements must be met, prior to ignition. This term replaces management ignited prescribed fire. [6]
Prescribed natural fire	Obsolete term. (See Wildland fire use) [6]
Prescription	A written statement defining the objectives to be attained as well as the conditions of temperature, humidity, wind direction and speed, fuel moisture, and soil moisture, under which a fire will be allowed to burn. A prescription is generally expressed as acceptable ranges of the prescription elements, and the limit of the geographic area to be covered. [1]
Prevention of Significant Deterioration (PSD)	A program identified by the Clean Air Act to prevent air quality and visibility degradation and to remedy existing visibility problems. Areas of the country are grouped into 3 classes that are allowed certain degrees of pollution depending on their uses. National Parks and Wilderness Areas meeting certain criteria are “Class I” or “clean area” in that they have the smallest allowable increment of degradation. [1]
Reasonably Available Control Measures (RACM)	Control measures developed by EPA that apply to residential wood combustion, fugitive dust, and prescribed and silvicultural burning in and around “moderate” PM10 nonattainment areas. RACM is designed to bring an area back into attainment and uses a smoke management program that relies on weather forecasts for burn/no-burn days.

	(See Best Available Control Measures [BACM]). [1]
Regional Haze	Visibility impairment caused by the cumulative air pollutant emissions from numerous sources over a wide geographic area. (See Haze).
Relative humidity (RH)	The ratio of the amount of moisture in the air, to the maximum amount of moisture that air would contain if it were saturated. [1]
Residual combustion phase	(See Smoldering combustion phase)
Residual smoke	Smoke produced by smoldering material. The flux of smoke originating well after the active flaming combustion period with little or no vertical buoyancy, and, therefore, most susceptible to subsidence inversions and down-valley flows. (See Nuisance smoke). [1]
"Right-to-burn" Law	A state law that provides liability protection for prescribed burners, providing they meet specified training and planning criteria. The degree of liability protection varies by state.
Saturated adiabatic lapse rate (SALR)	Adiabatic cooling in an atmosphere that is saturated with moisture. Usually about -3.0 degrees Fahrenheit per 1,000 feet (~-5.5 degrees centigrade per kilometer). (See Adiabatic lapse rate; Dry adiabatic lapse rate).
Scattering (light)	An interaction of a light wave with an object that causes the light to be redirected in its path. In elastic scattering, no energy is lost to the object. [2]
Secondary aerosols	Aerosol formed by the interaction of two or more gas molecules and/or primary aerosols. [2]
Slash	(see Activity fuel) [1]
Smoke concentration	The amount of combustion products (in micrograms per cubic meter) found in a specified volume of air. [1]
Smoke intrusion	Smoke from prescribed fire entering a designated area at unacceptable levels. [1]

Smoke management	The policies and practices implemented by air and natural resource managers directed at minimizing the amount of smoke entering populated areas or impacting sensitive sites, avoiding significant deterioration of air quality and violations of National Ambient Air Quality Standards, and mitigating human-caused visibility impacts in Class I areas.
Smoke management program (SMP)	A standard framework of requirements and procedures for managing smoke from prescribed fires, typically developed by States or Tribes with cooperation from stakeholders.
Smoldering combustion phase	Combined processes of dehydration, pyrolysis, solid oxidation, and scattered flaming combustion and glowing combustion, which occur after the flaming combustion phase of a fire; often characterized by large amounts of smoke consisting mainly of tars. Emissions are at twice that of the flaming combustion phase. (See Combustion; Flaming combustion phase, Glowing combustion phase). [1]
Soot	Carbon dust formed by incomplete combustion. [4]
Stable atmosphere	A condition of the atmosphere in which vertical motion in the atmosphere is suppressed. Stability suppresses vertical motion and limits smoke dispersion. In a stable atmosphere the temperature of a rising parcel of air becomes cooler than its surroundings, causing it to sink back to the surface. Also called stable air. (See Atmospheric stability; Unstable atmosphere).
Standard atmosphere	A horizontal and time-averaged vertical structure of the atmosphere where standard atmospheric pressure at sea level is 1,013 mb, at 5,000 feet (~1,500 m) it is 850 mb, at 10,000 feet (~3,000 m) it is 700 mb, and the standard atmospheric pressure at 20,000 feet (~6,000 m) is 500 mb. Actual pressure is nearly always within about 30% of standard pressure. (See Atmospheric pressure).
State Implementation Plan (SIP)	Plans devised by states to carry out their responsibilities under the Clean Air Act. SIPs must be approved by the U.S. Environmental Protection Agency and include public review. Same as Tribal Implementation Plan (TIP). [5]
Subsidence inversion	An inversion caused by settling or sinking air from higher elevations. (See Atmospheric inversion; Temperature inversion).

Sulfur dioxide (SO_2)	A gas (SO_2) consisting of one sulfur and two oxygen atoms. Of interest because sulfur dioxide converts to an aerosol that is a very efficient at scattering light. Also, it can convert into acid droplets consisting primarily of sulfuric acid. (See Criteria pollutants). [2]
Sulfur oxides (SO)	A class of colorless, pungent gases that are respiratory irritants and precursors to acid rain. Sulfur oxides are emitted from various combustion or incineration sources, particularly from coal combustion. [3]
Temperature inversion	In meteorology, a departure from the normal decrease of temperature with increasing altitude such that the temperature is higher at a given height in the inversion layer than would be expected from the temperature below the layer. This warmer layer leads to increased stability and limited vertical mixing of air. [2]
Ten-hour timelag fuels	Dead fuels consisting of roundwood 1/4 to l-inch (0.6 to 2.5 cm) in diameter and, very roughly, the layer of litter extending from immediately below the surface to 3/4 inch (1.9 cm) below the surface. Fuel elements of this size usually respond to changes in moisture within about ten hours or less than a day, hence the term 10-hr timelag. (See Fuel moisture content). [1]
Total fuel	All plant material both living and dead that can burn in a worst-case situation. [1]
Tribal Implementation Plan (TIP)	Plans devised by tribal governments to carry out their responsibilities under the Clean Air Act. TIPs must be approved by the U.S. Environmental Protection Agency and include public review. Same as State Implementation Plan (SIP). [5]
Understory burn	A fire that consumes surface fuels but not overstory trees (in the case of forests or woodlands) and shrubs (in the case of shrublands).
Unstable atmosphere	A condition of the atmosphere in which vertical motion in the atmosphere is favored. Smoke dispersion is enhanced in an unstable atmosphere. Thunderstorms and active fire conditions are common in unstable atmospheric conditions. In an unstable atmosphere the temperature of a rising parcel of air remains warmer than its surroundings, allowing it to continue to rise. Also called unstable air. (See Atmospheric stability; Stable atmosphere).

Ventilation index	An index that describes the potential for smoke or other pollutants to ventilate away from its source. Also called clearing index. It is the product of mixing height and the mean wind within the mixed layer (trajectory wind).
Visual range	Maximum distance at which a given object can just be seen by an observer with normal vision. [1]
Volatile Organic Compounds (VOC)	Any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate that participates in atmospheric photochemical reactions. [3]
Wet-bulb temperature	Originally, the temperature measured with a mercury thermometer whose bulb is wrapped in a moist cloth. Commonly it is a measure of the atmospheric temperature after it has cooled by evaporating moisture. (See Dry-bulb temperature; Dew point).
Wildland Fire	Any non-structure fire, other than prescribed fire, that occurs in the wildland. This term encompasses fires previously called both wildfires and prescribed natural fires. [6]
Wildfire	An unwanted wildland fire. This term was only included [in the new Federal policy] to give continuing credence to the historic fire prevention products. This is NOT a separate type of fire under the new terminology. [6]
Wildland Fire Managed for Resource Objectives	(See Wildland Fire Use) [6]
Wildland Fire Use	The management of naturally ignited wildland fires to accomplish specific pre-stated resource management objectives in predefined geographic areas outlined in Fire Management Plans. Wildland fire use is not to be confused with "fire use," which is a broader term encompassing more than just wildland fires. [6]
Wildland Urban Interface (WUI)	The line, area, or zone, where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuel.

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