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National Strategic Plan: Modeling and Data Systems for Wildland Fire and Air Quality

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Abstract

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This strategic plan is a technical discussion of the implementation and development of models and data systems used to manage the air quality impacts of wildland and prescribed fires. Strategies and priorities in the plan were generated by the Express Team (chartered by the National Wildfire Coordinating Group) and a diverse group of 86 subject matter experts who attended a national planning workshop.

Air pollution from fires used to manage ecosystems is an issue in many parts of the country. Land managers are rapidly expanding the use of fire for managing ecosystems, while air resource managers are accelerating efforts to reduce the impacts of fires on air quality. This plan provides a conceptual design as a first step toward balancing these goals, identifies information needs to support management and policy development, and identifies strategies for developing and implementing models and data systems. The conceptual design was based around a three-dimensional array of air resource components and fire management components at various project scales. This array was reduced to nine program elements, each with a description of their scope, current situation, desired state, and strategies to reach that state.

The Express Team recommends nine summary strategies as a synthesis of internal discussions, review comments, and proceedings of the national workshop. The strategies recommended relate to:

- Fuel and fire characterization
- Emission modeling systems
- Transport, dispersion, and secondary pollutant formation
- Air quality impact assessment
- Emissions tradeoffs and determination of natural visibility
- Impact and risk assessment of emissions from fires
- Monitoring guidelines and protocols
- National fire and air quality information database
- Public information and protection

Keywords: Fire, air, wildland fire, fire effects, fire management, fire modeling, air quality, air pollution, air resource management, data systems.

Summary

This strategic plan is a technical discussion intended to foster efficient development and implementation of models and data systems used to manage the air quality impacts of wildland and prescribed fires. The Express Team that developed this was sanctioned by the National Wildfire Coordinating Group (NWCG) Fire Use Working Team. Strategies and priorities recommended in the plan were generated by the Express Team and a diverse group of 86 experts who attended a national planning workshop sponsored by NWCG agencies and the U.S. Environmental Protection Agency in November 1997.

Fire has become an increasingly integral part of ecosystem management, but air pollutants emitted from those fires are an issue in many parts of the country. Policy development is underway to guide the expected increase and continuation in the use of prescribed fire and to improve air quality with respect to fine particulates, visibility, ozone, and regional haze. This plan provides the conceptual design and strategic direction as a first step in meeting the growing need for information to manage emissions from fire.

Managing the conjunction of wildland fire and air quality is a complex program of activities using an assortment of modeling and data systems. A framework placing specific issues within the context of the entire management job is needed to assess current capabilities and future needs. This strategic plan is framed around a three-dimensional array of air resource and fire management components at various project scales. The air resource component takes into consideration the effects of air pollution on receptors, ambient air quality, and the strength of the emission source. The fire management component accounts for planning, operations, and monitoring activities. The scale component ranges from the event through the landscape, state or tribal, and regional scales.

This plan reduces the three-dimensional array into reasonably sized program elements. The focus of the workshop was on refining a description of the current situation, desired future state, and strategies to research the desired state for each program element. The bulk of this document is devoted to a detailed presentation by the nine program element workgroups at the workshop. Workshop sessions also were used to begin merging strategies across related program elements.

The Express Team offers the following nine summary strategies as a synthesis of our internal discussions, review comments, and proceedings of the national workshop. The strategies are listed beginning with three strategies to describe the air pollutant source followed by strategies to assess air quality impacts and to communicate information. No priority is inferred by the order of presentation.

Fuels and fires characterization: The ability to characterize the wide variation in fuels and to model all types of fires for their potential to emit air pollutants is lacking for many fuel types across the continental United States and Alaska. Models and default values for fuel characteristics and fuel consumption should be expanded and new models developed to represent all major fuel and fire types. Standard sets of descriptors for fuel characteristics need to be developed to support an emission modeling system as well as models of other fire behavior and fire effects.

Emission modeling systems: Current models to predict emissions from fires are inadequate in coverage and incomplete in scope. Emission production models need improvement to include all fire and fuel types and to model multiple sources. Outputs will include the complete array of chemical and physical species and initial plume buoyancy. Emission models should be linked to models of fire behavior, air quality, and dispersion in a geographically resolved system and provide for aggregation or scaling to all spatial scales.

Transport, dispersion, and secondary pollutant formation: Air quality and land management planners lack spatially explicit planning and real-time systems for assessing air quality impacts. Systems integrated among agencies need to be developed to model plume behavior, dispersion, chemical transformations, and deposition for a wide range of fire, topographic, and transport conditions. The systems should be Geographic Information System based, include simple dispersion algorithms, and be linked to emission production models, meteorological models, and databases.

Air quality impact assessment: Air quality and land management planners need better wildland and prescribed fire information to compile emission inventories and regional haze analyses and to determine compliance with air quality standards. An integrated analysis and assessment system needs to be developed that enables prediction of landscape- to regional-scale air quality impacts, National Ambient Air Quality Standards compliance, visibility impairment, and nuisance events. These systems should use information from fuels, fires, emissions, and transport models to support state and tribal implementation plan development, fire management program evaluation, conformity determination, and public information efforts.

Emission tradeoffs and determination of natural visibility: No policy-driven or scientific definition of "natural" background visibility conditions exists for assessments of regional haze or analyses of tradeoffs between emissions from wildland fires and prescribed fires. First, a determination of which activities contribute to natural visibility impairment is needed from the policy community. Natural emission sources and background visibility conditions for all parts of the country could then be scientifically estimated and defined. This activity needs to include development of a modeling system that evaluates tradeoffs among prescribed fires, wildfires, and other fire or fuel treatments.

Impact and risk assessment of emissions from fires: Assessments of the current or potential risks to human health and welfare from fire emissions have been limited to exposure assessments involving firefighters. A comprehensive assessment of smoke exposures of forest workers and the public at current levels of fire activity needs to be done to provide a baseline for future risk assessments. Community and firefighter exposures to emissions must be periodically reassessed to evaluate the increased exposure and risk from future increases in prescribed and wildland fires.

Monitoring guidelines and protocols: Comprehensive guidelines do not currently exist for monitoring source strength, air quality, visibility, and nuisance impacts from fires. A forum including land managers, air resource managers, and interested public stakeholders could develop a common set of technical guidelines and quality assurance protocols for establishing, operating, maintaining, synthesizing, and reporting monitoring data. These monitoring guidelines would support consistent and quantitative evaluations of air quality impacts from wildland and prescribed fires in response to policy guidelines for monitoring being developed in other forums.

National fire and air quality information database: No readily accessible source is available for information on past, current, or predicted fire activity levels, emission production, or air quality impacts from fires. A nationally standardized database system will be developed and maintained for archival and retrieval of fire- and air quality-related information and be widely available to fire and air resource managers. The database will be used to support a learning system to analyze past experiences and replicate successes.

Public information and protection: No centralized system currently exists to provide the public with information on air quality impacts from fires, and no general criteria are available for response to adverse smoke impacts by land management or regulatory agencies. Information management systems are needed to inform the public about potential air quality impacts from current and planned fire programs, real-time monitored impacts of fires on air quality, and emergency notification of hazards. The capability of evaluating real-time air quality impacts against preestablished criteria is needed. Use of techniques such as web pages and media contacts in addition to direct communication with stakeholders is recommended to inform local, regional, and national audiences.

The strategic plan can be implemented by a team composed of a board of directors, a technical team, and designated technical reviewers.

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Introduction

Major policy initiatives and implementation of new management strategies are currently underway in both air resource and fire management. Land managers are rapidly expanding the use of fire to manage ecosystems, while air resource managers are accelerating efforts to reduce the local and regional impacts of fires on air quality. Balancing these goals requires an intensive flow of information among stakeholders to predict impacts, support decisionmaking, communicate factually, and monitor results. The National Wildfire Coordinating Group (NWCG) Fire Use Working Team sanctioned a self-directed interdisciplinary team—the Express Team—to construct a working framework for the coordinated development of modeling and data systems that achieve these goals.

This strategic plan is solely a technical discussion of current information needs and strategies. It is an initial attempt to coordinate and focus what has been a widely distributed ad hoc network of research, development, and applications to model and assess the air quality impacts of fires. It provides a conceptual framework to aid discussion, describes the current and desired future state of modeling and data systems, and offers strategies to reach the desired state. The plan is derived from a first draft by the Express Team, comments of peer reviewers, and a facilitated national workshop on modeling and data systems held in November 1997. The workshop brought together 86 people representing various stakeholder groups to review the plan and develop strategies.

Background

Land managers are implementing a several-fold increase in the use of fire to sustain ecosystems (U.S. Department of Agriculture 1997) and plan to maintain fully mature prescribed burning programs, such as in parts of the Southeastern United States. A new congressional appropriation is available for operational fuels management and the scientific support for a fuel management program on Federal lands. Although these changes most directly involve Federal land managers, they also affect other public, private, and tribal land managers.

Wildfires are increasing in many parts of the country, with increasing impacts on air quality. Part of the reason for this increase has been the effective suppression of fires in the 20th century that has resulted in a buildup of fuels and more severe fires. Wildfire activity can be expected to remain at historically high levels for several more decades until balance is restored. One way to manage the fuel buildup is to increase prescribed burning, which paradoxically also can adversely impact air quality.

The U.S. Environmental Protection Agency (EPA) has mandated new, more stringent regulations for fine particulate matter and ozone and has proposed regulations for regional haze that may further constrain the use of fire in some regions of the country. An important question is whether increases in fire use would cause violations of air quality standards. Other unanswered questions are, What constitutes the background of emissions from natural fires? and What is the tradeoff between prescribed fires and wildfires? The EPA formed the Wildland Fire Issues Group (WFIG), under the Federal Advisory Committee Act (FACA), to develop policy and science direction for this issue. To support the WFIG, EPA contracted the Western States Air Resources Council to form a stakeholder workgroup to review EPA policies addressing the air quality impacts from wildland fires.

The Federal Wildland Fire Management Policy and Program Review (U. S. Department of the Interior [USDI] and U.S. Department of Agriculture [USDA] 1995), its implementation action plan (USDI and USDA 1996), and the National Strategic Plan for Air Resource Management (USDA 1994) encourage an integrated, professional, and science-based approach to air quality and fire management. They recognize the essential role of fire in sustaining ecosystems and the need to control wildfires with more attention to cost and ecological impact, but with the overriding need to protect air quality and human health.

The USDI and the USDA Forest Service also endorse national implementation of the Grand Canyon Visibility Transport Commission recommendations, which identify the need for improved modeling and data systems for fire emissions.

This strategic plan is intended to serve as a technical reference to the teams involved in smoke management policy development and to those who will manage the development and implementation of models and data systems required to implement those policies.

Scope of Discussion

Prescribed fires are ignited intentionally to achieve ecosystem management or fire protection objectives, whereas wildland fires result from unplanned ignitions. Management response to wildland fires differs greatly according to economic efficiency, the values at risk (including air quality), and the expected ecological consequences. Wildlands include all the nonagricultural and nonresidential rural lands of the United States, including the wildland-urban interface, regardless of ownership, sovereignty, or management objective. Wildfires are at one end of the spectrum of wildland fires in that they are unwanted and unplanned, and thus they are suppressed. Other wildland fires may benefit ecosystem values and are managed with an appropriate, preplanned response. Unless otherwise specifically stated, the term “fires” in this plan includes all prescribed and wildland fires in the wildlands or wildland-urban interface. Because fires are a significant emitter of air pollutants, many other fire management activities such as fire prevention or fuel treatment may have an indirect effect on air quality.

Air resource management includes any activity to anticipate, regulate, or monitor air pollution, air pollutant emissions, ambient air quality, or the effects of air pollution resulting from fires or fire management. Air pollutant emissions, or simply “emissions,” are the production and release of air contaminants emitted from fires that have a potential to cause air pollution. This inclusive definition includes particulates, ozone, hydrocarbons, carbon monoxide and all other trace gases that may be hazardous or that are chemical precursors to secondary air pollution. Hazardous air pollutants are a special class of air pollutants identified in the Clean Air Act of 1963 as constituting a hazard to human health. Air pollution is the presence in the atmosphere of one or more contaminants of a nature, concentration, and duration to be hazardous to human health or welfare. Welfare includes potential to harm animal or ecosystem health, economic activity, or the comfortable enjoyment of life and property.

The scope of this plan includes all health and welfare effects of air pollution from fires, but does not include the effects of air resource management on ecosystem health or any other value. Air quality is a measure of the presence of air pollution or the effects of air pollution. Ambient air quality is defined by the Clean Air Act of 1963 as the air quality anywhere people have access. Ambient air quality standards are standards of air quality designed to protect human health or welfare.

Air pollution is the result of both human-caused and natural sources. In the past, emissions from prescribed fire were considered human-caused, and wildland fires were considered natural sources of emissions. Currently, there is policy debate over what should be considered natural; that is, to be reasonably unaffected by human influence. This debate results from the paradox that not all wildland fires are vigorously suppressed and that some prescribed burning is done to maintain healthy natural ecosystems where fire has previously been excluded. Increased wildfire activity in the last decade more than doubled the background concentration of pollutants in some regions. This confusion makes it difficult to technically define a background level of visibility impairment that is due to natural sources. The policy discussion to determine what is considered natural is still in progress.

Information includes all the observations, predictions, simulations, assessments, and standards regarding the effects of fire management on air quality, including the consideration of tradeoffs between air quality impacts of prescribed fires versus wildfires. Modeling and data systems include all the activities to generate and use information: specifically, research, development, analysis, knowledge synthesis, training, communication, and marketing and implementation of management techniques, programs, or policies. Data systems include the compilation, use, and communication of information. Emission inventories are one important example of a data system. Models include any mathematical representation or expert knowledge of any aspect of fires and air quality, and they are not limited to simulation of atmospheric dispersion processes. Models may be complex computer programs, expert systems, or simple displays such as graphs, charts, or tables.

Purpose of the Strategic Plan

The purpose of this strategic plan is to provide a framework to identify, prioritize, and manage the development and application of modeling and data systems that support fire and air resource management. Previously, modeling and data systems have been developed and applied ad hoc, which has resulted in a lack of efficiency and compatibility across geographic scales, management applications, and air quality objectives. This plan provides the conceptual design and strategic direction as a first step in meeting the growing need for information to manage air quality and emissions from fire.

This strategic plan presents strategies and priorities derived mainly from the judgment of a diverse set of experts who attended the strategic planning workshop in 1997. Although the workshop was diverse, several important stakeholder groups, including tribes and private landowners, were underrepresented. The priorities would no doubt be different if there had better representation of tribal and other interests. There was no solicitation for public review because this is solely a technical document. Public and tribal involvement in the implementation of strategies and the use of information for policy development are advised.

These strategies make no attempt to balance air quality, economic, and ecological values: they focus entirely on the relation of fire to air quality. The strategies are purely technical, are value-neutral, and reflect a collective understanding of current and pending policy issues. The priorities are recommendations at one point in time and will no doubt change as new issues develop. Others outside this process will make the final choices of what to fund and implement, based on competing values or priorities and the availability of resources.

This plan is intended to benefit those who manage, regulate, or breathe the effects of wildland fire on air quality. Several intended audiences are targeted, but not all may use the plan in the same way: some will use the plan directly, others will use the models and data systems recommended in the strategies, and still others will use the information derived from the model and data systems. The intended audiences are as follows:

Implementation team: The Express Team assumes that a board of directors will be formed to implement the development of modeling and data systems. Whatever form that management team takes, we intend for this plan to guide their priority setting and resource allocations over the next several years.

Land managers: The intent of this plan is to inform land managers of current capabilities and development needs for modeling and data systems so that they can better balance their responsibility for managing fires and protecting air quality. Land managers will be primary users of models and data systems developed and implemented according to this plan.

Air resource managers: This plan is intended to serve state regulatory agencies and other air resource managers using information systems available for modeling and monitoring the impacts of wildland fire on air quality. Air resource managers are the other primary users of models and data systems.

Tribes: This plan is intended to serve as a technical information resource to tribes, in their dual responsibility for land management and air resource management. There is no way to generalize about tribes, which differ greatly in their size, sophistication, and management objectives. But we expect many tribes to be primary users of information systems and others to be users of information developed by models and data systems.

Interested public groups: Although not targeted specifically, this plan can advise public groups on the current and future capability to predict and measure the impacts of wildland fire on air quality, especially during the public-involvement processes associated with policy or program implementation. More importantly, the public should find value in the information collected and synthesized by models and data systems.

Scientists and developers: This plan should help align future development of modeling and data systems more closely with the priority needs of managers and advise researchers on the lines of work most relevant to current issues.

Review of the Problem

The issues, responsibilities, and tools revolving around wildland fire and air quality are varied and complex. It is easier to be specific in a discussion of the pertinent factors if at least three characteristics of the topic are understood: the application to fire management, to air resource management, and to geographic scale. We can envision the range of models and data systems in a three-dimensional diagram where information is visualized in reference to these three characteristics as orthogonal axes (fig. 1). We have used this framework to discuss and set priorities for information needs.

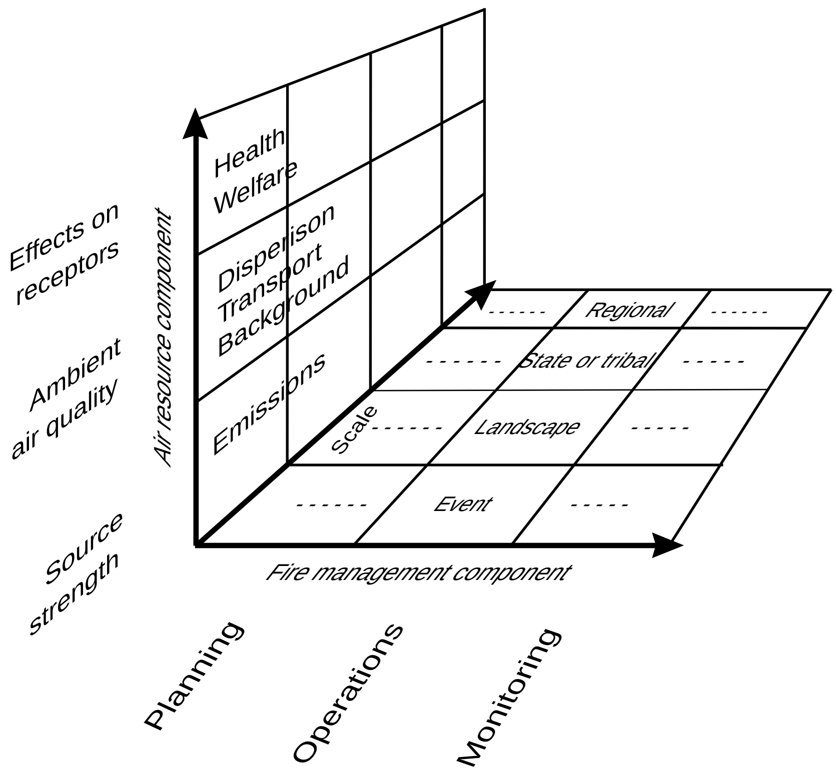


Figure 1—Three primary components of the issues, responsibilities, and tools related to wildland fire and air quality: air resource management, fire management, and scale.

Air Resource Component

The air resource component constitutes the set of objectives to be addressed through fire management and air resource management. The air resource component is affected by the source of air pollutant emissions, the transport and dispersion of pollutants in the atmosphere, and the effect on human values from exposure to air pollutants. These categories of the air resource component are ordered in time from the source to the effect along the vertical axis in figure 1. That axis is expanded horizontally in figure 2 to display regulatory approaches and their relation to the physical processes of biomass consumption and emissions, transport and dispersion, and health and welfare effects.

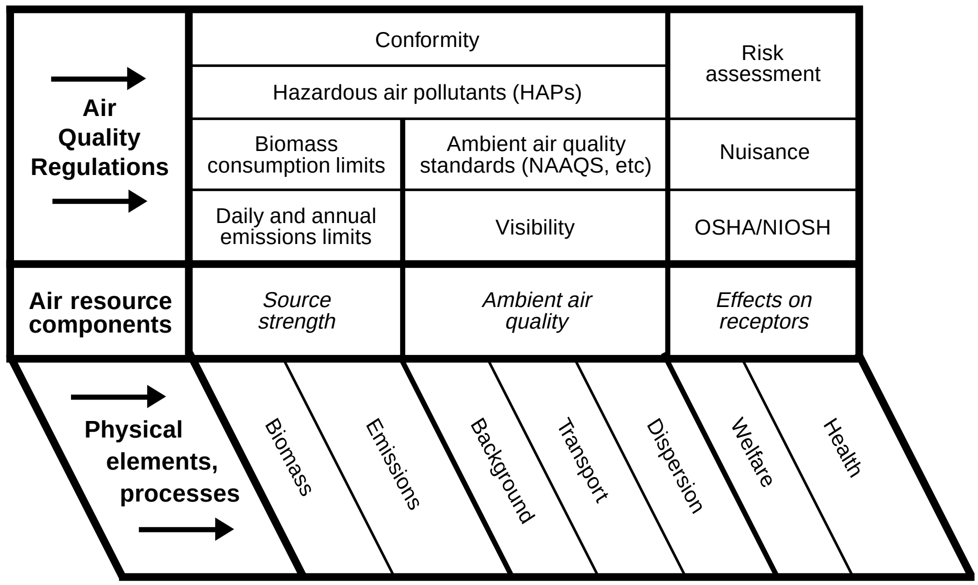


Figure 2—The relations of air regulations and physical processes to the three categories within the air resource component. OSHA/NIOSH = Occupational Safety and Health Administration/National Institute for Occupational Safety and Health.

Source strength—Modeling and data systems are needed to predict, measure, and monitor the area burned, biomass consumed, combustion efficiency, the chemical and physical composition of emissions, emission factors, heat release rates, and emission source strength for a wide variety of fires.

Source strength is the rate of air pollutant emissions in mass per unit of time, or in mass per unit of time per unit of area. Source strength is the product of the rate of biomass consumption (that is, fuel consumption) and an emission factor for the pollutant(s) of interest and is representative of the physical and chemical fuel characteristics. Total emissions from a fire or class of fires is the source strength integrated over the time of burning. Total emissions from a single class of fires (that is, a set of fires similar enough to be characterized by a single emission factor) can be estimated by multiplying that emission factor by the level of activity, which is the total biomass consumed by the class of fires. An emission inventory is the aggregate of total emissions from all fires or classes of fire in a given period for a specific geographic area.

Managing the source strength (or level of activity) of fires is the most direct way to control air pollution from wildland and prescribed fires. Knowledge of source strength is sometimes used to control the rate of emissions from fires, and it also is needed as an input to dispersion modeling. Standards or regulations are commonly set to limit the total emissions, emission of hazardous air pollutants, or the level of activity, so that estimates of biomass consumption can be essential for environmental assessment, permitting of prescribed fires, or measuring compliance. Emission inventories are a critical part of impact analyses and strategy development in the air resource management planning process, so the level of activity must be estimated whenever there is a regulatory interest in the source category.

Ambient air quality—Models and data systems are needed to predict, measure, and monitor the contribution of fires to the concentration, duration, and kinds of pollutants in the ambient atmosphere.

Ambient air quality can be measured at a point or as distribution of air quality over any space and time of interest. Ambient air quality is affected by the pollutants emitted to the atmosphere from fires, the background air quality that has already been degraded by other sources, the transport of the polluted parcels of the atmosphere, dispersion due to atmospheric movement and turbulence, secondary reactions, and removal processes. Detailed, gridded, three-dimensional meteorological data are required to model transport and dispersion. Plume rise is an important component of transport, because it determines where in the vertical structure of the atmosphere dispersion will begin. Dispersion has proven extremely difficult to model accurately, especially in complex terrain, so expert judgment is required to predict effect on ambient air quality.

Atmospheric conditions and emissions source strength can change rapidly, and almost always change diurnally. Plume rise, trajectory, and dispersion from fire that may last from one to several days must be modeled as a series of almost separate events, each lasting at most a few hours. Ambient air quality may change over time as a result of removal of pollutants from the atmosphere or by conversion in the atmosphere, such as by photochemical processes or other secondary chemical reactions.

Because it is difficult to directly measure and regulate the effects of air pollution on health and welfare, established relations between ambient air quality and the risk of adverse consequences have been used to set National Ambient Air Quality Standards (NAAQS). The NAAQS are the predominant set of standards for measuring compliance and conformity.

Regulations also are being drafted for managing regional haze, although it is not yet known what form they will take. Visibility improvement from current conditions to some as yet unspecified desired future state is expected to be mandated. Standards also are set for the concentration of hazardous air pollutants in some situations. Information systems are needed to model and monitor plume rise, local and regional transport and dispersion, secondary transformation and interactions of pollutants, and visibility impairment. Systems also are needed to assess compliance with regulations and standards.

Effects on receptors—Modeling and data systems are needed to predict, measure, and monitor the ultimate effects of air pollution from fires on human or ecosystem health, on the economy, and on the comfortable enjoyment of life and property. Risk assessment methods are needed to compare these effects with those from other sources.

Because the effects of air pollution are so difficult to measure in the broad population, there has been little effort to regulate or manage those effects directly. Many smoke management decisions are made on the basis of nuisance complaints as an indicator, rather than on quantitative measurements of impacts to health and welfare. Close to the source, efforts are being made to keep the exposure of firefighters to hazardous air pollutants within the standards set by the Occupational Safety and Health Administration. Hazard assessment describes the nature, concentration, and duration of pollutants. Exposure assessment quantifies the population exposed and the degree of exposure. Risk assessment describes the probable result for a population from all exposures. Integrated health risk assessments and economic assessments are still very rare.

Fire Management Component

The fire management component constitutes the set of activities, events, and decisions that create changes in air quality. Modeling and data systems are needed before, during, and after a fire management activity has an effect on air quality. Information is needed during the planning, operations, and monitoring stages of fire management.

Planning—Models and data systems are needed to anticipate and screen fire management operations and decisions concerning potential air quality consequences. Examples of fire management planning needs include documentation under the National Environmental Policy Act of 1969 (NEPA), tradeoff analyses that compare management options, modeling of emission sources and plumes to screen decisions, and contributions to land management plans.

Operations—Models and data systems are needed to support real-time decision-making during fire operations and to use current conditions as a basis for managing air quality impacts. This may include support for daily wildland fire situation analyses, decisions on whether to use prescribed fire, decisions on whether to burn, choice of ignition or suppression methods, and fire prevention activities.

Monitoring—Information is needed before, during, and after fire operations to document how fires affect air quality. Examples of monitoring include fuel loading estimates, emission inventories, personal exposure sampling, and recording of the level of fire activity. Validation of predictions of air quality impacts made during planning and operations often require the use of monitoring data.

Scale Component

Fire and air quality decisions must be made for a range of spatial scales, each associated with a characteristic time scale (that is, duration). It is important to relate the temporal and spatial scales of information systems to the scale of the air quality parameter of interest.

Event scale—The event scale is defined as the space and time affected by a single fire management operation or decision, such as a single prescribed burn or a wildland fire. The period of interest may range from the instant of peak impact to the number of hours or days that the operation lasts. Because meteorological conditions change rapidly, especially from day to night, it usually is necessary to consider impacts of an event on air quality in several segments of less than one day.

Landscape scale—The landscape scale is the integration of units within a geographic area and temporal period of interest and may refer to an administrative land management area (for example, National Forest, national park, or Bureau of Land Management [BLM] district) or to an area of sources or impacts (for example, area of impact, airshed, watershed, class I wilderness, or air quality maintenance district). The temporal period of interest is related primarily to a regulatory standard, ranging generally from a single workshift to 24 hours to a year.

State or tribal scale—The geography of the state or tribe scale is the geography of one state or tribal land boundary, and the period of integration may range from a single day to the number of years covered by a state or tribal implementation plan. Neither the state nor the tribe is a logical spatial scale from either an ecological or air resource perspective, but these are important administrative units because so many air resource and land management agencies use one or the other as a principal division.

Regional scale—The regional scale is an area of influence larger than a single state. It is an emerging zone of interest as agencies attempt to balance multistate contributions to regional haze and class I area intrusions, or prioritize fire operations across multiple states. The period of interest may range from a single day to many years.

Workshop Process

The workshop was designed as a collaborative, problem solving process to review, revise, and complete the National Strategic Plan for Fire and Air Quality Modeling and Data Systems. The workshop process by which this strategic plan was developed is illustrated in figure 3. The strategic plan was originally drafted by the Express Team, and the workshop was used to develop the strategies section and improve the introductory, scope, current situation, and desired state portions of the document. A mix of land managers, scientists, and air resource managers representing Federal, state, tribal, and private entities from across the United States was selected to participate in the workshop (appendix A).

The workshop participation was designed around total group (plenary), component group, and program element group discussion. During several plenary sessions, all participants were given the draft strategic plan introductory material for review and group acceptance. Participants were then assigned to one of nine program element groups (fig. 4) to review, revise, and reach consensus on respective scope, current situation, and desired state sections as originally drafted by the Express Team. Each group generated a list of ranked implementation strategies and presented the top five strategies for discussion and ranking within the component group (appendix B). The top five implementation strategies were presented to the plenary session. Finally, all participants were involved in discussions to review, revise, and replace the draft implementation proposal and to nominate, assign, or volunteer individuals for roles in the implementation framework. Program element and component group documentation and strategies were presented to the Express Team for integration into this final document.

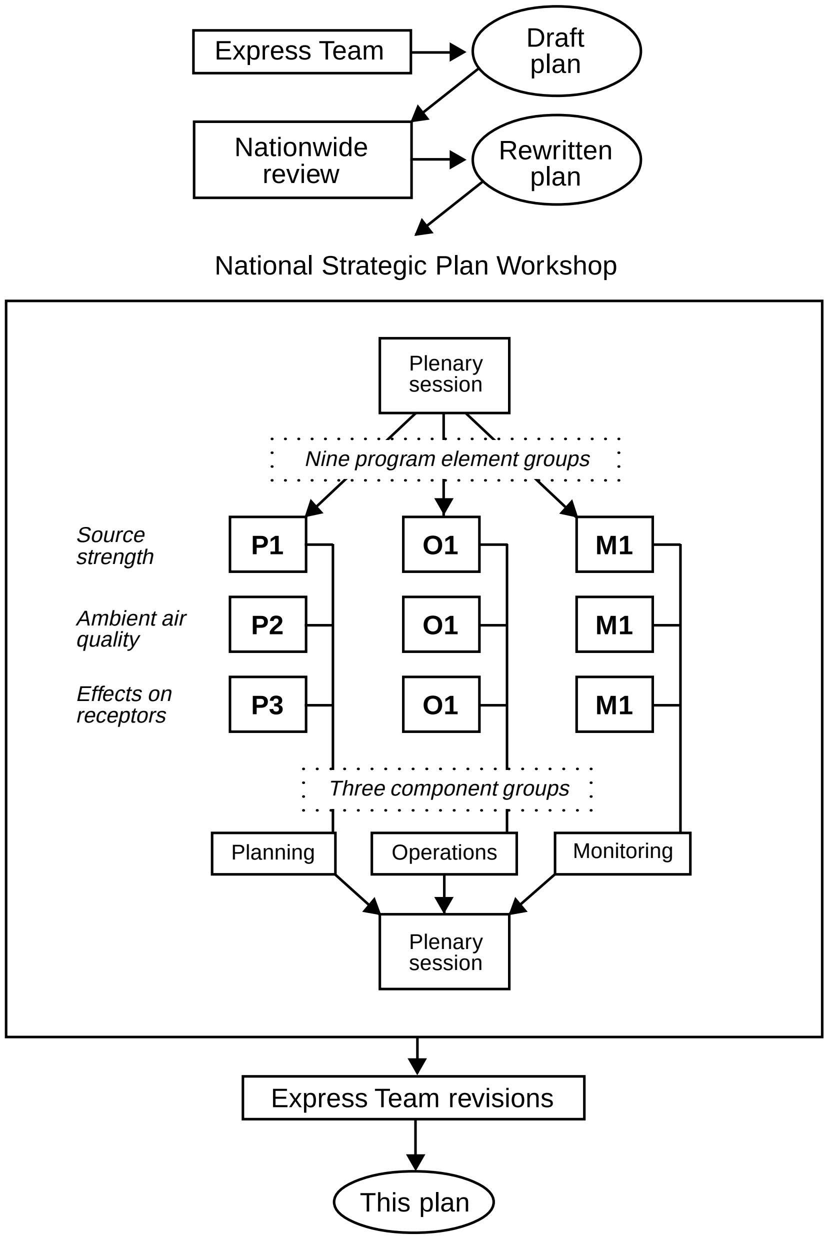


Figure 3—The process by which this strategic plan was developed, including work done by the Express Team both before and after the workshop.

Planning—Source Strength (P.1)

Don Arkell—WESTAR
Daniel Becker—US Marine Corps
John Blake—Savannah River Institute
Justin Dombrowski—Boulder Fire Dept.
Ron Myers—EPA
Janice Peterson#—USDA Forest Service
Kathy Solheim +—USDA Forest Service
Peter Teensma—BLM
Darold Ward—USDA Forest Service
Mark Woods*—USDA Forest Service

Planning—Ambient Air Quality (P.2)

Gary Achtemeier—USDA Forest Service
Jason Ching —EPA
Robert Clark—BLM
Sue Ferguson*—USDA Forest Service
Mark Fitch—Arizona DEQ
Brock LeBaron —Utah DEQ
Jim Nellessen—New Mexico DAQ
A1 Riebau—USDA Forest Service
Paula Seamon#—The Nature Conservancy
John Vimont—National Park Service
Clint Wright+—USDA Forest Service

Planning—Effects on Receptors (P.3)

Bruce Bayle+—USDA Forest Service
Gary Blais—EPA
Carl Dounan—USFWS
Dennis Haddow—DSDA Forest Service
Bill Leenhouts—USFWS
Joyce Pritchard+—USDA Forest Service
David Sandberg#—USDA Froest Service

Operations—Source Strength (O.1)

Lindsay Boring *—Jones Ecological Research Center
Diane Ewell—Idaho DEQ
Colin Hardy#—USDA Forest Service
Don Jones—US ARMY
Donna Lamb—USDA Forest Service
Lynn Marsalis—USDA Forest Service
Steven Miller—St. Johns R. Water Mgmt.
Dianne Sheppard+—USFWS
Paul Stokols—National Weather Service

Operations—Ambient Air Quality (O.2)

Coleen Campbell+—Colorado APCD
Jim Brenner—Florida Div. of Forestry
Carl Gorski—National Weather Service
Robert Habeck—Montana DEQ
John Heckman+—USDA Forest Service
Pete Lahm#—USDA Forest Service
Erich Linse—California Air Res. Board
Bud Rolofson—USFWS
Richard Stender—Washington DNR
Mike Ziolko—Oregon Dept. of Forestry

Operations—Effects on Receptors (O.3)

David Brownlie—USFWS
Frank Cole—Jones Ecol. Res. Cen.
Jim Douglas+—Dept. of the Interior
Rich Fisher—USDA Forest Service
Sara Hatfield+—USDA Forest Service
Carl Johnson—North Carolina Div. of Forestry
Joe Maguire—Dade County Parks
Ken McLaughlin—USFWS
Bernie Post—Colorado State For. Serv.
Dale Wade#—USDA Forest Service

Monitoring—Source Strength (M.1)

Wayne Cook*—USDA Forest Service
Chris Hawver—The Nature Conservancy
Roger Ottman#—USDA Forest Service
Helen Smith+—USDA Forest Service
John Szymoniak—USDA Forest Service
Jerome Thomas—USDA Forest Service

Monitoring—Ambient Air Qualtiy (M.2)

Teresa Alcock+—Univ. of Washington
Gerry Guay—Alaska DEC
Roy Hall—USDA Forest Service
Bill Jackson—USDA Forest Service
Wilson Laugher—Navajo EPA
Ellen Porter*—USFWS
Mark Schaaf—CH_2M Hill
Randy Sedlacek—Arizona DEQ
Ken Snell#—USDA Forest Service
Rob Wilson—EPA

Monitoring—Effects on Receptors (M.3)

Larry Adams—USFWS
Ann Acheson#—USDA Forest Service
Robert Bachman—USDA Forest Service
Laura Boothe—North Carolina DAQ
Tom Bragg—University of Nebraska
Andrea Holland+—USDA Forest Service
Tim Reinhardt—Radian International
Holly Sharpless*—BLM

Figure 4—List of program elements, participant assignments and their affiliations.
* = program element leader ; + = program element recorder; # = Express Team member.

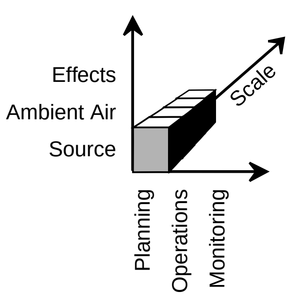
Table 1—The 3 air resource components are organized within each of the 3 fire management components

Program element	Fire management component	Air resource component	------------------	---------Scale---------	---------------------	----------------
P.1	Planning	Source strength	Event	Landscape	State or tribal	Regional
P.2	Planning	Ambient air quality	Event	Landscape	State or tribal	Regional
P.3	Planning	Effects on receptors	Event	Landscape	State or tribal	Regional
O.1	Operations	Source strength	Event	Landscape	State or tribal	Regional
O.2	Operations	Ambient air quality	Event	Landscape	State or tribal	Regional
O.3	Operations	Effects on receptors	Event	Landscape	State or tribal	Regional
M.1	Monitoring	Source strength	Event	Landscape	State or tribal	Regional
M.2	Monitoring	Ambient air quality	Event	Landscape	State or tribal	Regional
M.3	Monitoring	Effects on receptors	Event	Landscape	State or tribal	Regional

Program Elements

Thirty-six possible unique combinations, or key elements, can be formed within the major components of the three-dimensional diagram shown in figure 1. Two of the three primary axes relate either to responsibilities (fire management component) or issues (air resource component). It is thereby possible to frame the development and discussion of a national strategic plan within the context of all possible two-way combinations of the fire management components (planning, operations, and monitoring) and the air resource components (source strength, ambient air quality, and effects on receptors). The resulting nine key elements—hereafter called program elements—have been developed with fire management components at the highest organizational level; that is, the three air resource components are discussed within each of the three fire management components according to the organization shown in table 1.

Planning Program Element (P.1)—Source Strength (Fuels and Emissions)



Scope—This element includes techniques for estimating fuel loading and area burned, fuel consumption modeling, and emission characterization and prediction for the planning phase of wildland fire activities. This element will define methods of estimating source strength that:

1. Provide for state emission management requirements and requests
2. Provide inputs for the operation of transport, dispersion, and chemical mass balance models to forecast potential impacts to visibility and compliance with NAAQS
3. Assist large assessment programs to provide historical, current, and future impacts of wildland fire emissions
4. Support efforts to investigate potential wildfire emission reductions by use of prescribed fire and other fuel treatments
5. Provide tools for emission management planning
6. Provide new knowledge for estimating source strength for various treatments alternative treatments, and other emission reduction techniques

7. Support air quality planning efforts, including development of state and tribal implementation plans

This element includes work to completely characterize the chemical constituents of smoke. Models and tools included in this element would be used for source strength analysis at the event, landscape, state, or regional scale. The information produced may be aggregated or disaggregated to a different scale, as appropriate. The scope also includes the maintenance, technical support, and training needs associated with use of these models and procedures at all scales.

Current situation—Over the years, the USDA Forest Service and science community have developed procedures to estimate fuel loading and fuel consumption at the event scale, and to characterize emissions from prescribed burns and wildfires. Many techniques are available for estimating fuel loading and consumption (Brown 1974, Conard and Regelbrugge 1994, Huff and others 1995, Maxwell and Ward 1980, Southern Forest Fire Laboratory Personnel 1976). FOFEM (Reinhardt and others 1997) and CONSUME (Ottmar and others 1993) are two examples of models that allow fire managers to estimate the consumption of fuels. Both models, although very good for areas of the West, have limitations when used nationally. These software products enable users to estimate fuel consumption at the event scale and aggregate upward to the landscape, state or tribal, and regional scales.

Emission research in the Western United States has focused on prescribed burning of debris from logging or silvicultural activities (activity fuels); whereas, in the Southeast, systems have been developed for estimating source strength for event-scale prescribed fires (Southern Forest Fire Laboratory Personnel 1976). In addition, this emission research is limited to fine particulates, particulate matter, carbon monoxide, carbon dioxide, methane, and nonmethane hydrocarbons for low-intensity prescribed fires.

Emission factors developed from this research have been incorporated into:

1. Emission factor tables (Ward and Hardy 1991)

2. The source strength model EPM (Sandberg and Peterson 1984) used to provide emission and heat release data for most prescribed fire dispersion models

3. The fuel consumption models FOFEM (Reinhardt and others 1997) and CONSUME (Ottmar and others 1993)

4. SMSINFO (Peterson and Ottmar 1991), a model used to analyze prescribed burning records for state regulatory burn approval and fee collection

5. Smoke management guidelines for the Southeast (Southern Forest Fire Laboratory Personnel 1976)

All applicable emission factors developed from this research may not have been incorporated into AP-42 (U.S. Environmental Protection Agency 1972), which is used by most regulatory agencies to estimate emissions.

A few emission inventories for large-scale air regulatory planning efforts have been compiled (Chi and others 1979, Peterson and Ward 1992, Ward and others 1976, Yamate and others 1975).[1] The information required to compile these inventories is not readily available or consistent in accuracy.

Most recently, fuel loading, fuel consumption, and emission characterization research has shifted to wildfires and prescribed burning in both activity fuels and natural fuels of pine, grass, and mixed conifer types of the United States (Ward and Ottmar 1994). Fuel and emission research data collected from grasslands and tropical forests of Brazil and Africa may have application to fuel types in the United States.

Many emission reduction techniques have been described and quantified, especially for fuel types in the West (U.S. Environmental Protection Agency 1992).

Simulators, such as the forest vegetation simulator (FVS) (Beukema and others 1997, Hardy and Reinhardt 1998), provide analysis tools to assist with tracking and predicting changes in vegetation and fuels over time.

The wildfire-prescribed fire tradeoff model (Ottmar and others 1996, Schaaf 1996) analyzes potential wildfire emission reductions from fuel management activities, including prescribed fire and other fuel treatments.[2] However, the applicability of the current version of the model is limited to a small area of one state.

Although research during the past 30 years has brought us a long way in developing techniques to estimate fuel loading and models for predicting smoke and source strength, there are major limitations to the existing approaches:

1. Fuel loading estimation techniques often are difficult to implement with less costly alternatives designed for activity fuels.[3]

2. The scope of fuel consumption and emission characterization modeling is limited and not appropriate for prescribed burning in natural fuels and many shrub fuel types (Ward and Ottmar 1994).

3. Current models make broad assumptions regarding how a prescribed fire is conducted and have reduced usefulness for wildfires.

4. Only limited knowledge is available on transported smoke, including secondary plume chemistry and the fate of emissions in the atmosphere.

5. Emission factors for hazardous air pollutants are inadequate.

The application and use of more recent research results to better manage fire emissions and reduce impacts and consequences are limited. This results from a lack of coordination, direction, maintenance, technical support, and training associated with use of these models, at all spatial scales.

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[1] Lahm, Peter; Peterson, Janice. Manuscript in preparation.
[2] Snell, J.A. Kendell. Manuscript in preparation
[3] Activity fuels: woody debris (for example, tree and brush slash) that remains on site after logging.

Desired state—Methods to estimate fuels, area burned, and fire and emission characteristics for a range of fire types and wildland conditions are available in software used by land managers in the planning and operational phases of event-, landscape-, state- or tribal-, and regional-scale wildland fire activities.

Appropriate models are available to estimate emission and emission characteristics required for local- and regional-scale inventories and modeling used for air quality management. Fire event information is available for emission estimation and inventory and is compatible among states. Emissions in future years can be projected from available information and methodologies. The AP-42 (U.S. Environmental Protection Agency 1972) contains current emission factors and the appropriate supporting background information.

In the desired future state, models will be dynamic and depend on historic, present, and projected vegetation and meteorological conditions. Model output reliability will be known. Tracers for biomass emissions will be described. "Background" or "natural" emission production will be estimated to compare emissions between wild and prescribed fire. Historic fire return intervals and emissions will be known.

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Develop and document prescribed burning and wildfire emission factors to incorporate into AP-42 (U.S. Environmental Protection Agency 1972) and user-friendly software and documents for event-scale through regional-scale estimation.

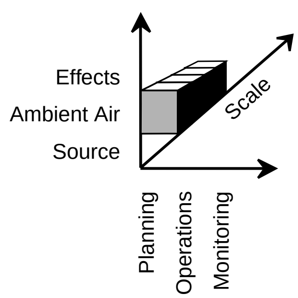
2. Complete a set of geographically resolved national emission source strength models (that is, production by chemical speciation and particle characteristics) that are coupled to fire behavior models for inputs to emission inventories, transport models, ozone production, and receptor impacts.

3. Develop a nationally applicable wildland fuel classification system, inventory, and database to monitor fuel characteristics, fuel treatments, and changes in fuel characteristics over time. This system should include spatial attributes and must be designed to allow reporting upward and downward for land and air quality management purposes.

4. Undertake and compile studies of all major ecosystems nationwide with the express purpose of determining historic fire regimes (return intervals, season of burn, severity, frequency, area of extent) and presented in GIS (Geographic Information System) and tabular formats.

5. Develop methods to collect data for fire and emission models for local agencies (city, county, district) to use that are compatible with those from the state to national levels.

Planning Program Element (P.2)—Ambient Air Quality (Effects on NAAQS and Visibility)



Scope—This element addresses the tools, information, and procedures needed during the planning phases of fire management projects to assess the potential impacts to air resources (that is, visibility, including regional haze, the national or state ambient air quality standards, public health and welfare concerns, and other resource impacts). The information needed includes, but is not limited to, assessment of atmospheric conditions; "natural" background conditions; current state of ambient air quality; applicable local, regional, and national standards; reporting and permitting requirements; land use and fire management goals; and all the elements included in Planning Program Element 1 (P.1). The tools needed include, but are not limited to, fire behavior models, emission models, air quality and dispersion models, multimedia models, meteorological models, databases, field monitoring, and atmospheric assessments. The project scale and the complexity of wildland fire at a geographic location will determine the amount and kind of information needed.

Information sources and tools included in this element would be used at the event, landscape, state or tribal, and regional scales. The scope also includes the maintenance, support, and training needs associated with the use of these information sources, tools, and procedures.

Current situation—Many of the information sources, tools, and processes outlined in the scope currently exist; however, users may not always be aware of them, have access to them, or have the expertise and resources to use them. There are two primary reasons for this lack of use. First there is a paucity of knowledge of the background or baseline state of the atmosphere at fire sites, coupled with an almost complete lack of workable techniques to measure atmospheric contamination resulting from fires during burns. Second, there is a lack of consistency in the practice of modeling fire emissions for planning, permitting, operations, and assessments. Although several models are available, models suitable for all fire situations and geographic areas either are not developed, are ill-applied, or have not undergone evaluations to make them acceptable to regulators. Also, many of the existing tools may be inadequate for emerging issues (for example, visibility across jurisdictions, regional haze, fine particulates) or inappropriate for different levels of planning.

At present, there is an urgency in addressing the impact of fire emissions on emerging visibility and ambient air standards as they relate to planning at strategic, programmatic, and operational scales. This requires integration of all emission sources, which may be beyond the scope of wildland fire alone. The weaknesses in the planning processes include the spatial and temporal variability in biomass burning emissions, meteorology, chemical characterization, the use of alternative treatment methods to burning, considerations of topographic variability, and issues of local concern. There is a lack of integrated land management planning and air quality planning. Unfortunately, there is little consistency in the type of information air regulators require from land managers for their smoke management programs. Some require nothing, some impose emission caps, and some require that a screening model be completed before a burn. Because of these disparities, many different tools are needed, along with support for field users on how and when to apply appropriate tools. As a result of the lack of training and technical support, users become unclear about planning for ambient air impacts, which decreases their confidence and interest in using the tools.

Desired state—Planners, at whichever planning horizon they address or whether they work for private interests, Federal, state, tribal, or local agencies, have tools and information approved for use by regulators. Rather than being constrained to using one tool for all needs, users have an array of scientifically refined and tested tools and high-quality information sources, supplemented by training and equipment, which provide accurate and integrated assessments of air quality impacts from single and cumulative sources. As future needs for tools and information are identified, coordinated projects will be developed that result in furthering the state of the science and improving practical emission management. This situation has as its cornerstone, cooperation among planners, researchers, and regulators in an atmosphere of continuing partnership and clear communications.

Top six program element strategies—Following are the top six strategies from this program element group.

1. Determine the "natural" visibility conditions for regional haze evaluations for all areas of the country. As part of this activity, develop a modeling system as part of this activity that can evaluate tradeoffs among prescribed fires, wildfires, and other treatments.

2. Develop integrated analysis and assessment system (to deal with regional haze, NAAQS, nuisance smoke, deposition, and so forth). Include dynamic databases and emission, meteorology, and air quality modeling covering all scales. The emission model would include fire behavior, fuel information, chemical speciation, and particle characterization. The air quality model would include chemical, transport, dispersion, and deposition issues.

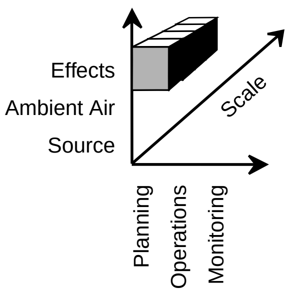
3. Develop five regional (Northeast, Southeast, Midwest, Northwest, and Southwest) model testing data sets (meteorology, fuels, emissions, plume tracks, concentrations, visibility, and so forth) to evaluate objectively the technical excellence, performance, and implementation (use by field personnel) of proposed smoke dispersion models.

4. Develop a strategic planning tool that uses GIS for regional to national assessment of potential visibility, regional haze, and air quality and addresses the conflict between stable burning and unstable burning conditions. The GIS module would include monthly climate, current and potential fuel loading, known emission sources, and simple dispersion algorithms.

5. Develop remote sensing methods for measuring smoke movement and concentration. Includes airborne remote sensing and image analysis for tracking single-fire smoke plumes night and day and van-mounted lidar and radar for measuring particle concentration throughout the whole plume.

6. Produce a report that brings together fire planning process requirements across agencies to facilitate the link between the planning and permitting processes.

Planning Program Element (P.3)—Effects on Receptors (Local Impacts, Exposure, and Consequences)



Scope—This element includes the assessment of possible consequences to human health and welfare of emissions resulting from fire management decisions. The consequence may be to the health, safety, property, economy, or quality of life, or constitute a nuisance to one person or a group, and to other human values such as visibility and ecosystem health. Planning involves the risk assessment of a proposed activity or policy to predict the impact on these human values. Risk assessment requires identification of the receptor population exposed to emissions, the nature of that exposure, the dose-response to exposure of that nature, and the cumulative impact (of fire emissions) on human health and welfare. Assessments could be made at any of the spatial scales from the event to regional. The scope also includes the maintenance, support, and training needs associated with the use of these model and data systems at all scales.

Current situation—A fair amount of current information exists at the event level. A primary source of this information, including firefighter health and safety concerns, is the prescribed fire plan prepared by fire practitioners. Comprehensive prescribed fire burn plans predict acute health impacts on firefighters as well as the acute effects on other sensitive receptors. The same event-level planning also holds true for wildland fires. The prediction of effects regarding firefighter health is done relatively well, whereas the level of planning for other receptors is at a coarser level—receptors are identified, and coarse assumptions are made regarding those receptors. Refined levels of event modeling are lacking.

On the programmatic level, land managers currently do not adequately address cumulative, long-term effects of emissions on receptors in land management and fire management plans. Although both are subject to the NEPA process, the tools are not available to accurately assess the long-term effects of fire emissions. Recent examples of models that address long-terms effects include the wildfire-prescribed fire tradeoff model (Ottmar and others 1996, Schaaf 1996), the fire emissions project model developed for the Grand Canyon Visibility Transport Commission, and the fire analysis performed for the interior Columbia River basin environmental impact statement (see footnotes 1 and 4).

Additional information is lacking on the long-term cumulative effects of repeated exposure to smoke on firefighter health, including dose-response relations as they pertain to wildland and prescribed fire. There is a need to fully address the combined effects of multiple projects that compete for the same resources and airshed.

Desired state—Ultimately, managers would be able to assess the economic, ecological, health, safety, and other human impacts of a planned activity, decision, or course of action related to wildland fire management at all three planning levels (operational, programmatic, and strategic). Assessments would not only estimate the emission source strength, dispersion, and ambient-air quality impacts of a course of action but

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[4] Ottmar, Roger D.; Alvarado, Ernesto; Hessburg, Paul F. [and others]. Historical and current forest and range landscapes in the interior Columbia River basin and portions of the Klamath and Great Basins. Part II: Linking vegetation patterns to potential smoke production and fire behavior. Manuscript in preparation.

also calculate impacts on human values affected by changes in air quality. The public would be informed of the assessments and the tradeoffs among human impacts of alternative fire management actions. This information, in addition to impacts on ambient air quality, would serve as the basis for public comment and regulatory control of planned activities.

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Establish a wildland fire information clearinghouse to maintain fire and air quality, and spatial and nonspatial data and information in a Federal Geographic Data Committee (FGDC) format and metadata standards searchable on the Internet.

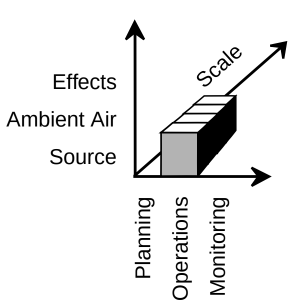
2. Hold a series of workshops with stakeholders to agree on interagency model coordination for consistent model development, use, guidance and evaluation. Possibly establish permanent clearinghouse, use EPA clearinghouse, or link to regional technology centers (proposed by FACA-WFIG[5]).

3. Establish a national fire database (wildland and prescribed fire) that contains the minimum data needed by air quality managers.

4. Synthesize existing research and information on risk assessment to public and firefighters from fire emissions. Develop and improve risk assessment models for air pollution effects from fires.

5. Develop a communication plan in cooperation with state forestry and air quality agencies for the general public regarding positives and negatives of wildfire effects. The plan should allow for displaying modeling results graphically and visually.

Operations Program Element (O.1)—Source Strength (Fuels and Emissions)



Scope—This element includes estimating fuel consumption and emissions during the operational phase of wildland and prescribed fire activities. This element will:

1. Support efforts to develop uniform minimum recording standards for prescribed fire accomplishments such as activity level and emissions

2. Provide real time inputs and continually validate for transport and dispersion models to estimate impacts on visibility and compliance with NAAQS

3. Integrate behavior models with emission production and dispersion models

4. Support efforts to compare fuel consumption and emissions between prescribed fire and wildland fire

5. Support research efforts to improve fuel models that operationally describe regional fuels and measure actual emissions outputs

6. Provide tools for improved smoke management planning and operations

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[5] FACA-WFIG is the Federal Advisory Committee Act Wildfire Interest Group, a diverse set of stakeholders developing policy and technical support documentation for future regulation of fine particulates, regional haze, and ozone.

Fuel loading estimates are not considered in this element because the manager should have estimated this variable during the planning phase, before the wildland fire operation. Models included in this element would be used at the event scale and aggregated to the landscape, state or tribal, and regional scales. The scope also includes the maintenance, technical support, and training needs associated with the use of these models and procedures—at all spatial scales.

Current situation—Over the years, procedures have been developed to estimate fuel consumption and to characterize emissions from prescribed burns and wildfires at the event scale. Recent fuel consumption research has led to two prominent fuel consumption models: FOFEM (Reinhardt and others 1997) and CONSUME 1.0 (Ottmar and others 1993). These software products enable managers to estimate fuel consumption at the event scale. These event-scale (project level) results can then be aggregated upward to the landscape, state or tribal, and regional scales. Current (several hours to several days before ignition) information representing operational conditions (fuel moisture, forecast and observed weather, predicted fire behavior) allows the prediction of fuel consumption and emissions from the currently available models and techniques.

Smoke management emissions and dispersion regulations and guidelines differ significantly across state boundaries. State regulations in the Pacific Northwest, for example, are significantly more stringent than in other parts of the country; also, direct operational costs are higher. Agency or company burning plan requirements also differ with location, and a state may have unique minimum requirements. The population of practitioners also differs by region and state. In the Southeast, for example, the use and application of prescribed fire by industry and the private sector is greater than that by state and Federal agencies. Many of the Southeastern states also have passed legislation identifying prescribed burning as a landowner right. Another regional or agency difference is the availability of good current weather information.

Smoke emissions research has focused on the prescribed burning of debris from logging or silvicultural activities (activity fuels) in the Western United States. The emission factors developed from this research have been incorporated into numerous documents and models, including (1) EPA's compilation of emission factors (AP-42; U.S. Environmental Protection Agency 1972), which is out of date and hard to use; (2) emission factor tables (Ward and Hardy 1991); (3) the source strength model, EPM (Sandberg and Peterson 1984), used to provide emissions and heat release data for most dispersion models, which is limited by fuel consumption and available emission factors (Breyfogle and Ferguson 1996, Lavdas 1996); (4) the fuel consumption models FOFEM (Reinhardt and others 1997) and CONSUME 2.0 (in development); (5) SMSINFO (Ottmar and others 1995, Peterson and Ottmar 1991), a model used to analyze prescribed burning records for burn approval and fee collection; and (6) CalPFIRS (California Prescribed Fire Information System; Little n.d.).

Although research during the past 30 years has carried us a long way in developing techniques to estimate fuel loading and models for predicting emissions and source strength, there are major limitations to these approaches. The fuel consumption and emission characterization modeling is limited in scope and not appropriate for prescribed burning in natural fuels and many shrub fuel types (Ward and Ottmar 1994). Current models are not linked to the commonly accepted fire behavior model (BEHAVE; Andrews and Chase 1990) thereby reducing their acceptance and use by practitioners. BEHAVE also requires modification (from a single point source ignition) for this link to occur. This adaptation is currently performed through good professional judgment. Additionally, some regions or fire managers, or both, are unaware of or do not have access to smoke management models. These managers perform smoke management planning by using Wade and Lunsford (1989).

Operationally, fire managers do not generally quantify emissions—not even after the fact. The tools currently available and discussed above are not especially developed or useful for wildfire events without modification.

The application and use of research products by land managers to better manage emissions and to reduce the potential impacts and consequences are meager at best. The lack of direction and political support, the limited maintenance and technical assistance, and the need for training all inhibit the use of these models at all spatial scales.

Desired state—The desired state is for land managers, scientists, and regulatory agencies (Federal, state or tribal, and local) to reach consensus and consistency among all parties on smoke management source-strength protocol for operational decisionmaking and administration under state or regionally unique conditions. All parties involved would work collaboratively to plan and implement a research and development program filling critical gaps in both models and protocols for estimating operational fuel consumption and emission production from fires across the United States, at all scales. The professional practitioners would have access to research and training programs as well as technical software support to apply the latest models for smoke management planning at the event, landscape, state or tribal, and regional scales.

Identified future states or needs include:

1. A standardized dynamic database or model to document prescribed fire events and analyze expected results based on past experience, both to learn from mistakes and to replicate successes.

2. All components and conditions of the fuel array to be characterized by one of several fuel characteristic classes containing information required by emission production models. The fuel characteristic classes are integrated with, or linked to, standard fire behavior fuel models and prediction systems. There is a need for a model or integrated models that link fuels, loading and consumption, fire behavior, smoke emissions, and dispersion and can be aggregated upward from the event level.

3. Fuel consumption and emission models to more accurately apply to all regional natural (nonactivity) fuels.

4. Management of agricultural burning and other open burning sources to be better coordinated. This may include improving tools, techniques, etc., to address major types of agricultural burning.

5. AP-42 (U.S. Environmental Protection Agency 1972) or similar information for emission factor compilation to be updated and made more user-friendly.

6. Sufficient training opportunities to be available to encourage wise smoke management practices.

7. Real-time burn and local weather information to be available to enable better emission production estimates for the operational phase.

8. Emission models to more accurately calculate fuel consumption and emission production from wildfires for each fuel type.

9. Wildland fire information to be collected that will enable development of emission inventories compatible across the United States and of appropriate specificity for the local level.

10. Knowledge of activities and outcomes at the event scale to be more easily aggregated to other scales.

11. The benefits of activities that reduce emissions at the event scale to be better documented, tracked, and aggregated to other scales. As an example, this may include the fuel reductions from frequently burned areas, different firing techniques, and prescriptions for understory burning that target 1- and 10-hour fuels leaving 100- and 1000-hour fuels unburned. There may be need for a model to examine "what ifs" on prescriptions and emission benefits.

12. Continual feedback from fire practitioners from all regions to the research community on weaknesses and strengths and the need for new or improved research products as a result of field application. This will include the commitment from the research community for timely incorporation of feedback.

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Develop a comprehensive fire and smoke management system linking behavior, fuel consumption, emission, and dispersion models. This system must be user-friendly and accurately represent the full array of fuel types and conditions. Outputs can be aggregated across all spatial scales.

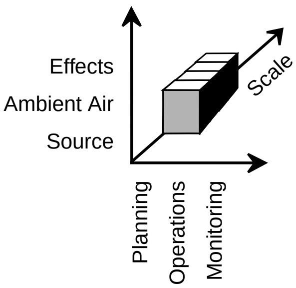
2. Develop a standard set of default or inferred preburn fuel characteristic classes (average loading and variance) for all cover types in the United States for emission inventories or smoke management decisions.

3. Develop a standardized dynamic database or model to document data, such as date, location, acres, fuel types, weather, cost, and emissions for all fire events and to analyze expected results based on past experience to learn from mistakes and replicate successes.

4. Make real-time local weather information available to all users to enable a better emission production estimate to be made for the operations phase.

5. Update (and reformat to make user-friendly) AP-42 (U.S. Environmental Protection Agency 1972), or similar information for emission factor compilation.

Operations Program Element (O.2)—Ambient Air Quality (Effects on NAAQS and Visibility)



Scope—This element addresses the information needed to compare and discuss the potential impacts of fire to the applicable air quality standards (Federal, state, local, and tribal) and visibility impairment on a real-time basis through meteorological forecasting, model use or outputs, or both, and expert judgment. It includes, for example:

1. Smoke management analytical tools

2. Tools to predict or estimate impacts of wildfire

3. Tools to collect real-time data (meteorological information, etc.) for immediate use in assessing potential impacts of emissions from fire

Approaches and tools included in this element would be used at the event, landscape, state or tribal, and regional levels of analysis. This element also encompasses the maintenance, support, and training needs associated with the use of these systems. These tools will allow for analyses addressing different levels of complexity; for example, duration of event(s), location of event(s), type of event(s), sensitive receptor(s), cumulative impacts of fire emissions and other sources, and fuel types.

Current situation—Smoke management programs exist at various levels of sophistication across the country. A common element among the more comprehensive programs is the daily decision process and forecasting needed for authorizing prescribed burns. Information used includes meteorology, air quality data, and impact screening methods. Public sensitivity to smoke from prescribed fire generally has more of an impact on decisionmaking than does regulatory standards, such as the NAAQS. Specifically the programs use:

1. Output from meteorological models and local surface to upper air meteorological data

2. Air quality data gathered from ambient monitoring sites and reports from practitioners or the public, or both

3. Simple dispersion models, equations, ventilation indices, expert judgment, and nomograms

4. Postevent analysis of air quality (emission production, ambient air monitoring, and visibility)

The screening process also relies heavily on professional judgment to assimilate complex terrain, variations of fuel characteristics, and airshed loading, and to compensate for the inadequacies of current dispersion models. This process can result in blanket or conditional authorizations, or denial of burn requests or permits.

Impacts from wildland fires on air quality are not adequately accounted for in current suppression strategies. Reporting of wildland fire data is inadequate to support inclusion into smoke management decisionmaking. In addition, this lack of reporting prevents emergency action plan implementation and dissemination of information on the potential risk to public health and safety from the emissions of fires.

Meteorological information and products for both onsite or offsite use are inconsistently available from Federal and non-Federal entities.

Programs are unable, in certain states and situations, to address the needed decisionmaking workload owing to constrained funding and resources, which has resulted in denied authorizations of burns. There also is a lack of a systemic approach to the balance of air quality and land management objectives.

Real-time transfer and resolution of information on air quality and meteorological data even in the more comprehensive programs are inadequate for current decisionmaking. This can affect the viability of the current prescribed fire program through poor decisions, which can result in adverse air quality impacts.

Current dispersion models have difficulty in handling complex terrain; temporal, spatial, and cumulative effects of multiple or large-scale burns; and residual emissions. These models do not fully address the impacts to air quality standards, visibility impairment, or regional haze. Additionally, the models are not user-friendly.

Desired state—The desired state would be for the onsite decisionmaker for fires to have the necessary tools and information to assess air quality impacts. This information would be used to enhance decisions on ignition or suppression actions.

The offsite decisionmaker for wildland and prescribed fires will have decisionmaking systems (for example, models, professional judgment, and impact criteria) that integrate current and future meteorology, air quality, and source information to enhance operational smoke management decisions. The system will accommodate all scales and complexities.

The system will facilitate consultation with stake holders and provide a mechanism for public notification and education on projected fire emission impacts.

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Update and develop wildland emission factors and fuel moisture nomograms.

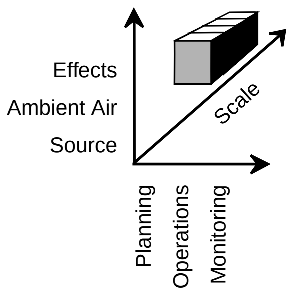
2. Develop an interagency task force to coordinate and develop or approve of, or both, an operation level smoke management modeling system to address air quality, emission production, and dispersion for varying types of fire and complexity.

3. Develop a uniform, linked, air quality, fire, and meteorological database that supplies sufficient data for operational decisionmakers to use models developed by an interagency task force.

4. Develop a mechanism for fire emission impact information to be disseminated to the public during planning and operational phases in response to wildland fire activities.

5. Develop a mechanism to incorporate wildland fire impacts on air quality into onsite suppression decisions and to inform or involve other decisionmakers and the public.

Operations Program Element (O.3)—Effects on Receptors (Local Impacts, Exposure, and Consequences)



Scope—This element addresses the direct and indirect effects (both positive and negative) and consequences of emissions on receptors during the operational phase of burning. It considers the information, tools, and techniques enabling land managers, air quality regulators, and fire practitioners to:

1. Identify the affected receptors at risk including—

    - specific human populations (for example, fireline personnel, nearby and distant residential areas, wildland visitors, motor vehicle operators, and airplane pilots)
    - class I areas
    - flora and fauna
    - nonbiological receptors such as industrial and commercial activities (e.g., clean rooms in manufacturing processes)

2. Evaluate the nature of the hazard to receptors including type, duration, dose, and concentration of exposure to emissions.

3. Manipulate sources and accommodate receptors to reduce hazards. Source manipulation includes adjusting ignition methods and timing, and limiting or extinguishing fires. Receptor accommodation includes advance public education and notification, adjusting work rules, providing protective equipment to people on the fireline, and temporarily evacuating people, closing roads, and ceasing industrial and commercial activities.

The scope also includes the maintenance, support, and training needs associated with the use of tools and techniques across all spatial scales.

Current situation—The effects and consequences of emissions are managed most easily for proximate receptors where plumes are easily identified. Effects and consequences over longer distances may be the result of multiple fires or other sources; they usually are the result of more dilute concentrations and therefore are more difficult to identify and quantify. A variety of existing tools, techniques, and information exists to manage effects and consequences on receptors, some of which are not easily accessible or usable by all practitioners and managers in all locations.

Many effects and consequences of emissions on burn personnel, nearby human populations, transportation corridors, and class I areas are recognized. The effects and consequences on more distant human populations, flora, fauna, and nonbiological receptors are often are not so readily identifiable or quantifiable.

Many tools, techniques, and types of information exist to help practitioners and managers evaluate the nature of the hazard. These include real-time weather information, emission and dispersion models (for example, EPM [Sandberg and Peterson 1984], FOFEM [Reinhardt and others 1997], TSARS [Hummel and Rafsnider 1995], SASEM [Sestak and Riebau 1988]), ambient air monitoring (for example, gas, particle and visibility samplers, personnel dosimeters), and human observation. The ability of practitioners and managers to effectively use these aids is limited by their access to them in the field, as well as the complexity, adequacy, applicability, and timeliness of the aids themselves.

A variety of tools, techniques, and information is available to practitioners and managers to modify the rate, quantity, timing, and duration of emissions. These include manipulating fuel, carefully choosing fuel condition, selecting appropriate meteorology, adjusting firing techniques and ignition patterns, employing rapid mop-up, and using suppression tactics.

Receptors that are easily identifiable, proximate to, or directly impacted by sources are generally accommodated. Measures include adjusting work rules, temporarily evacuating people, closing roads, and ceasing industrial and commercial activities. Also, burning often is scheduled to coincide with lower visitor use. Mitigating actions are taken less often where distant receptors are at risk; this is often due to the lack of timely feedback from the receptor to the practitioner.

Desired state—Managers and practitioners can identify all receptors at risk; evaluate the nature, effects and consequences of hazards; manipulate emission sources; and accommodate receptors at risk. Tools, techniques, and information are easy to use, applicable to all types of receptors both near and distant, and applicable for single and multiple fires and for cumulative effects. Achieving the desired state requires improved and new, easily usable tools, techniques, and information and the maintenance, support, and training necessary for their use.

Managers and practitioners have the tools, techniques, and information:

1. To identify all potential receptors

2. To determine the type, duration, dose, and concentration of exposure to evaluate the hazards to receptors

3. When and where they need it to modify the rate, quantity, timing, and duration of emissions

4. To determine how to accommodate potentially affected receptors based on the effectiveness, practicality, and cost of these accommodation actions

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Develop a real-time analytical tool (computerized data display system) linked to GIS and easily communicable that integrates current meteorology (fine-scale meteorological data fields) and air quality data to provide a complete picture of the near and far field impacts of emissions from an ongoing burn.

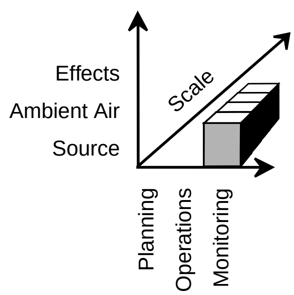
2. Develop a spatially interactive database of information and characteristics of all types of receptors that can be linked to emissions information to evaluate hazards.

3. Develop an annotated list of educational tools and techniques including notification, a model law for burner certification, and model bylaws for fire council establishment.

4. Develop an expert knowledge base that aids in rapidly selecting receptor accommodation and source manipulation techniques (including costs, effectiveness, and practicality) to mitigate impacts on receptors.

5. Develop criteria to determine when a receptor impact becomes unacceptable and determine the practicality of receptor mitigation strategies (for example, a matrix of impacts and mitigation techniques).

Monitoring Program Element (M.1)—Source Strength (Fuels and Emissions)



Scope—This element includes techniques for monitoring fuel loading before the operation phase (O.1) of fires and monitoring the area burned, fuel consumption, and emission production after the operation phase of fire activities. The monitoring data would be collected by using established standards and guides and will provide input for information systems to:

1. Verify fuel loading, area burned, fuel consumption, and emission production estimates used in the planning phase (P.1)

2. Provide data to prescribed fire managers, incident command teams, air regulatory agencies, smoke management forecasters, and other user groups

3. Support land management and air regulatory agencies in tracking area burned, fuel consumed, and emissions produced for air quality planning efforts, including development of state and tribal implementation plans

4. Support research, development, application, and refinement of fuel loading, fuel consumption, and emission production models

Monitoring protocols included in this element would be used at the event scale or aggregated to the landscape, state or tribal, and regional scales. The scope also includes the maintenance, technical support, and training needs associated with use of these monitoring procedures.

Current situation—There are several protocols available for monitoring fuel loading, area burned, fuel consumption, and emissions production from fires at the event scale. The protocol of choice depends on established standards and guidelines, desired accuracy, resource availability, and organizational priorities. The most accurate method of monitoring requires field measurements of fuel loading (Brown 1974), fuel consumption, and emissions produced (Ward and Hardy 1991). These procedures are uncommon because of the time and sophistication required to use them. A more common but less accurate method uses visual assessment of fuel loading. The loading estimates are then used as model inputs to predict fuel consumption (Ottmar and others 1993, Reinhardt and others 1997) and emissions production (Reinhardt and others 1997, Sandberg and Peterson 1984, Ward and Hardy 1991).

Although this procedure is generally less expensive, fuel loading, fuel consumption, and emission modeling are limited to activity fuels with a lack of approaches designed for natural fuels and shrublands. Both field measurements and established visual methods linked to models, can be aggregated upward from the event scale to the landscape, state or tribal, and regional scales.

Research scientists, land managers, and air regulators are collaborating on new, more efficient, and consistent approaches to monitoring fuel loading and fire emissions for most major fuel types across the Nation. These techniques use a combination of newly developed photo series, remote sensing attributes, and the latest fuel consumption and emission production models across all temporal scales. However, it may take several years before this technology is proven and gains acceptance as an alternative to onsite measurements. The methods currently in use are not consistent among users and do not capitalize on the technologies available for accessing and disseminating information.

Desired state—Better methods to monitor fuel loading, area burned, and emissions production for a range of fuel and fire conditions are available in software for use by land managers and regulators. Researchers, land managers, states, and air regulators would form partnerships to establish common standards and guides for monitoring. These standards and guides would provide an integrated approach to the collection, calculation, storage, maintenance, dissemination, and evaluation of fuel loading, area burned, fuel consumption, and emissions production for fires.

Land managers would routinely monitor emission production of fires according to the established standards and guidelines. The partners would have identified potential research needs and implemented the development and application of technology to monitor fuel loading, fuel consumption, and emissions production for major fuel types across all scales. Policies would be integrated to provide a uniform understanding of the management of fuels and source strength monitoring (for example, Federal Wildland Fire Policy, Grand Canyon Visibility Transport Commission, state implementation plans, and others).

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Facilitate a forum where land managers, states, and air regulators will form partnerships to establish common standards and guides for monitoring and modeling source strength of fires and publish a nationally accepted guidebook.

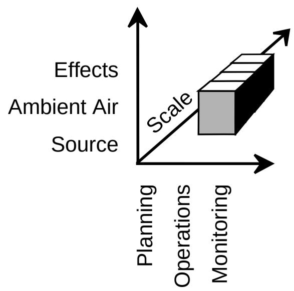
2. Use fuel photo series and expert field knowledge to develop and expand fuel characteristic classes to represent fuel types not currently available.

3. Validate and modify fuel loading, fuel consumption, and emission models for all major fuel types.

4. Establish an integrated and consistent approach for collecting input variables to estimate daily emissions from fires (for example, wildland fire recording form).

5. Develop a virtual web page that will provide an integrated and consistent approach to the collection, calculation, storage, maintenance, dissemination, and evaluation of fuel loading, area burned, fuel consumption, and emission production for fires. Data sets would be aggregated by latitude and longitude, fuel model, date, owner class, fire type, and emissions across all scales.

Monitoring Program Element (M.2)—Ambient Air Quality (Effects on NAAQS and Visibility)



Scope—This element is limited to operational assessment of ambient air quality and meteorology during management of wildland fires to:

1. Verify compliance with NAAQS and regional haze regulations

2. Provide data feedback to smoke management forecasters, practitioners, and incident command teams and data for planners of prescribed fires and NEPA documents

3. Document impacts to visibility (regional haze and plume impacts; for example, scenic vistas, class I areas, and roadways) and ambient air quality

4. Provide information to air regulatory agencies (state, local, tribal) for their efforts to monitor criteria pollutants generated from wildland fires

5. Support research, development, application, and verification of air quality models

6. Provide data for public health advisories

7. Serve as the basis for further research into harmful effects of nonparticulate emissions (for example, sulfur dioxide, oxides of nitrogen, aldehydes, and others)

Monitoring protocols included in this element would be used at the event, landscape, state or tribal, and regional scales. It includes maintenance and support of equipment, including communication links and building of a database, as well as training of personnel on its use during the operational phase of a wildland fire.

Current situation—Most ambient air quality monitoring in the United States has been performed by air regulatory agencies in or near urban areas for assessment of compliance with the NAAQS. Little or no ambient air quality monitoring has been performed to assess impacts from fire operations in wildlands (for example, Federal, tribal, and state) or urban areas. Even less monitoring has been performed that is designed to warn the public of exposure to harmful levels of pollutants from wildland fires. However, some Federal land managers do conduct limited-criteria pollutant monitoring as well as monitoring of impacts to visibility. Some air regulatory agencies also monitor impacts to visibility.

Air quality impacts differ as a function of burn type and environmental conditions, thus presenting a challenge to simple monitoring strategy development; current meteorological monitoring may provide inadequate data for modeling air quality impacts from wildland fire. Further, little has been done to develop air quality and meteorological monitoring protocols for assessing impacts from wildland fire, and protocols for monitoring pollutant concentrations for different types of burns, at various temporal and spatial scales, have not been determined. There are some efforts underway (for example, State of Colorado and Forest Service Rocky Mountain and Pacific Northwest Regions) to develop such protocols.

Apportionment of air quality impacts among vegetative burning sources (for example, agricultural, silvicultural, residential wood burning) is difficult at present. Air quality, fire parameters, and meteorological data are not typically stored in accessible databases.

Desired state—Monitoring of air quality impacts from wildland fires and meteorological conditions would provide data for daily smoke management forecasts, long-term planning and evaluations, validation and development of models, regional assessments, and protection of public health and welfare. Site monitoring would augment other air monitoring networks as needed, and mobile equipment would be available to move into areas not presently monitored but potentially impacted (for example, tribal lands, Federal, state, and local). A network of air quality and meteorological monitoring sites would be in place to address local (event) as well as regional air quality and visibility impacts from wildland fires. Trained staff would be available to maintain and repair air quality and meteorological monitoring equipment and to use and interpret the data collected.

In the desired state, monitoring protocols would be developed to assess air quality and visibility impacts from wildland fires. These monitoring protocols would address various types of burns and environmental conditions (for example, terrain, fuel conditions, and weather), as well as spatial and temporal scales. An information system on air quality, fire parameters, and meteorological data would be developed, maintained, and made accessible to users.

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Develop air quality, visibility, and meteorological monitoring protocols to support, assess, and evaluate wildland fire impacts. Protocols should include siting, operation and maintenance, quality assurance and quality control, system design, etc.; cover temporal and spatial scales; include public notification; and include differences between wildfires and prescribed fires.

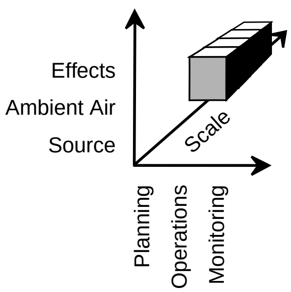
2. Conduct air quality, visibility, and meteorological monitoring to provide data to assess wildfire and prescribed fire impacts.

3. Develop and maintain a national information system for air quality, visibility, and fire data and receptor impacts.

4. Develop training programs or identify existing programs to address needed skills for air quality, visibility, and meteorological monitoring operations, data use, interpretation, and analyses.

5. Perform intensive field monitoring studies to assist in network design, protocol development, model development and evaluation, and pollutant (for example, ozone, oxides of nitrogen, volatile organic compounds, particulate matter) impact assessments.

Monitoring Program Element (M.3)—Effects on Receptors (Local Impacts, Exposure, and Consequences)



Scope—This monitoring element includes the actual measurement of exposures and consequences of exposures among receptors to air pollutants from wildland fire. Receptors are those components of the environment that affect:

1. Human health, property, economy, or quality of life

2. The ecosystem

Results of monitoring would be used at the event scale and aggregated to the landscape, state or tribal, and regional scales. This element also includes maintenance, support, research, and training needs.

Current situation—Current knowledge documents smoke exposure and associated acute and chronic adverse health effects among firefighters. Many data link adverse health effects in communities to wood smoke exposure; however, systematic monitoring of community and firefighter exposures and resulting epidemiology does not exist. Although the PM2.5 (fine particulates) criteria document (U.S. Environmental Protection Agency 1996) adds substantially to our knowledge, it is not based on the mix of pollutants in wildland fire smoke. Awareness of consequences to political and economic issues and to natural ecosystems exists; however, there is little organized effort to assess these effects.

Desired state—The desired state is to observe and understand the long- and short-term impacts of emissions from wildland fire on human health, socioeconomic and political issues, and natural ecosystems. This will be accomplished through coordinated monitoring and information distribution to appropriate agencies, organizations, and individuals for application. The information will provide feedback for planning, operations, and other uses.

Top five program element strategies—Following are the top five strategies selected by this program element group.

1. Develop information needs for short- and long-term impacts (for example, economic, medical, ecological, social, political, and public safety).

2. Develop a central or Federal body by drawing on existing organizational models (for example, Federal Emergency Management Agency, National Interagency Fire Center, Incident Command System) to plan and coordinate responses to smoke impacts.

3. Define and establish protocols and organization of response teams appropriate to scale of smoke event.

4. Establish dose response relations between smoke and receptors for short- and long-term exposures (public and tribal communities, subgroups, and ecosystems).

5. Implement a retrospective and prospective epidemiological analysis in communities with high smoke impact incidents.

Strategies

This section presents a short list of high-priority strategies for developing and implementing modeling and data systems linking wildland fire and air quality. The Express Team synthesized the many strategies developed at the National Strategic Planning Workshop in Nebraska. This synthesis is quite general, and more detail can be found in the sections on each of the nine program elements. Within each general strategy are numerous short-and long-term products that could be selected during the tactical stage of implementation.

An interesting generality can be drawn from the nine strategies summarized below. One can see a strong bias toward strategies that would be found near the origin of our systems diagram; that is, figure 1. The highest priority is given to models and data systems that can be used in the planning stage of fire management; that is, those predicting the source strength and ambient air quality impacts of single events. We can see two reasons for this bias: (1) currently, most information exchange between fire managers and air resource managers takes place within this region of the system diagram; and (2) it is impossible to understand or manage subjects farther from the origin (that is, effects, operations, monitoring, and landscape to regional effects) without the knowledge that lies near the origin of the diagram.

Currently, there is limited activity and little interest in a risk assessment of the effects of fire emissions on health and welfare. We recognize that such interest is sporadic and will surface again after extreme wildfire years; for example, after a year such as 1988 when this type of assessment was considered a priority. To be prudent, we recommend at least a baseline exposure assessment of firefighters and communities to hazardous air pollutants.

With that said, we conclude that the highest priority remains improving the ability to model the source strength and ambient air quality impacts from single fires. However, we also foresee a not-too-distant future when improved modeling and data systems are needed for (1) real-time information exchange during fire events; (2) compiling emission inventories and impacts on ambient air quality from multiple projects; and (3) aggregating information from the single location to the landscape, state or tribal, and regional scales.

This raises the question of the expertise and skills needed to design, manage and maintain such systems. These systems are complex, requiring attention by trained personnel. When committing to developing these systems, agencies will need to objectively assess whether they have adequate “systems” expertise both now and in the future to do the job. Are personnel in place to design or oversee the development of such a system? Which agency will take the lead in the design? What kind of data security is needed and how will it be controlled? In the future, will affected agencies and organizations need to hire people with different skills than they did in the past to design, manage, and maintain these modeling and data systems? These questions need to be thoroughly addressed when implementing the strategic plan.

Finally, a commitment by the agencies and organizations to improve and link modeling and database systems means a parallel commitment to training. Assuming a linked modeling and database system is designed with the end user in mind, agencies and organizations will need to rigorously and continuously train their personnel so that they can most effectively use the existing tools to make better decisions. Communication skills will have to be a priority in training. As more information is available on the

Internet, agencies and organizations will need skilled people to communicate the significance of that information to interested persons.

In this strategic planning process, we have tended to focus on the information needs of state and Federal air resource managers and state and Federal land managers, neglecting somewhat the needs and perspectives of private landowners, tribes, and the public. The public, especially, has a need to access synthesized information derived from modeling and data systems so that they can make informed input to program or policy implementation or respond to projected or real-time smoke impacts. We encourage developers and managers of modeling and data systems to carefully design information systems for use by all stakeholders.

Summary of Strategies

The strategies below are listed in a logical sequence beginning with three strategies to describe the air pollutant source followed by strategies to assess air quality impacts and communicate information. No priority should be inferred by the order of presentation.

Fuels and fires characterization—The abilities to characterize the wide variation in fuels and to model all types of fires for their potential to emit air pollutants are lacking for many fuel types across the continental United States and Alaska. Models and default values for fuel characteristics and fuel consumption need to be expanded and new models developed to represent all major fuel and fire types. Standard sets of descriptors for fuel characteristics are needed to support an emission modeling system as well as other fire behavior and fire effect models.

Emission modeling systems—Current models to predict emissions from fires are inadequate in coverage and incomplete in scope. Emission production models need improvement to include all fire and fuel types and to model multiple sources. Outputs will include the complete array of chemical and physical species and initial plume buoyancy. Emission models need to be linked to models of fire behavior, air quality, and dispersion in a geographically resolved system and provide for aggregation or scaling to all spatial scales.

Transport, dispersion, and secondary pollutant formation—Air quality and land management planners lack spatially explicit planning and real-time systems for assessing air quality impacts. Systems integrated among agencies need to be developed to model plume behavior, dispersion, chemical transformations, and deposition for a wide range of fire, topographic, and transport conditions. The systems should be GIS based, include simple dispersion algorithms, and be linked to emission production models, meteorological models, and databases.

Air quality impact assessment—Air quality and land management planners need better wildland and prescribed fire information to compile emission inventories and regional haze analyses and to determine compliance with air quality standards. An integrated analysis and assessment system need to be developed that enables prediction of landscape- to regional-scale air quality impacts, National Ambient Air Quality Standards (NAAQS) compliance, visibility impairment, and nuisance events. These systems should use information from fuel, fire, emission, and transport models to support state or tribal implementation plan development, fire-management program evaluation, conformity determination, and public information efforts.

Emission tradeoffs and determination of natural visibility—No policy-driven or scientific definition of "natural" background visibility conditions exists for assessments of regional haze or analyses of tradeoffs between emissions from wildland fires and prescribed fires. First, a determination of which activities contribute to natural visibility impairment is needed from the policy community. Natural emission sources and background visibility conditions for all parts of the country could then be scientifically estimated and defined. This activity needs to include development of a modeling system that evaluates tradeoffs among prescribed fires, wildfires, and other fire or fuel treatments.

Impact and risk assessment of emissions from fires—Assessments of the current or potential risks to human health and welfare from fire emissions have been limited to exposure assessments involving firefighters. A comprehensive assessment of smoke exposures of forest workers and the public at current levels of fire activity is needed to provide a baseline for future risk assessments. Community and firefighter exposures to emissions need to be reassessed periodically to evaluate the increased exposure and risk from future increases in prescribed and wildland fires.

Monitoring guidelines and protocols—Comprehensive guidelines do not currently exist for monitoring source strength, air quality, visibility, and nuisance impacts from fires. A forum is needed that includes land managers, air resource managers, and interested public stakeholders to develop a common set of technical guidelines and quality assurance protocols for establishing, operating, maintaining, synthesizing, and reporting monitoring data. The monitoring guidelines will be developed to support consistent and quantitative evaluations of air quality impacts from wildland and prescribed fires in response to policy guidelines for monitoring that are being developed in other forums.

National fire and air quality information database—There is no readily accessible source of information on past, current, or predicted fire activity levels, emission production, or air quality impacts from fires. A nationally standardized database system will be developed and maintained for archival and retrieval of fire- and air quality-related information and be widely available to fire and air resource managers. The database will be used to support a learning system to analyze past experiences and replicate successes.

Public information and protection—No centralized system currently exists to provide public information on air quality impacts from fires, and there are no general criteria for land management or regulatory agencies to respond to adverse smoke impacts. Information management systems need to be provided to inform the public about potential air quality impacts from current and planned fire programs, real-time monitored impacts of fires on air quality, and emergency notification of hazards. The capability of evaluating real-time air quality impacts against preestablished criteria needs to be developed. Use of techniques such as web pages and media contacts, in addition to direct communication with stakeholders, is recommended to inform local, regional, and national audiences.

Implementation Process

Long Term (6 Months to Years)

The strategic plan will be implemented by a team composed of a board of directors, a technical team, and designated technical reviewers. These bodies must be diverse in their interests, and their perspective must consider Federal, tribal, state, private, and public perspectives. The board of directors would provide resources, policy direction, and the overall charter to implement the plan. The technical team (to be formally assigned) will guide implementation of the strategic plan by recommending to the board of directors the specific allocation of resources, drafting periodic work plans, revising and updating the plan, evaluating progress, and serving as a technical resource. Both the board and the technical team will need to appropriately market the strategic plan. The designated technical reviewers will be responsible for peer review of the work of the technical team before it is submitted to the board of directors. The entire team will be guided by the following:

1. Ensure policy-level ownership of the strategic plan.

2. Ensure diverse participation that considers all stakeholders (other entities, disciplines).

3. Integrate with other existing programs for funding and personnel.

4. Interface with other existing interagency special interest groups such as the National Wildfire Coordinating Group (NWCG), Western States Air Resource Council, and State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials.

5. Use the strategic plan to guide implementation.

6. Realize that the plan cannot be implemented by a single individual or entity.

Board of directors—This board will be composed of national leaders in positions to commit or influence resources (funding, people, time) requested by the technical team. In this way, they will market the plan at the national level and to the public. The board uses its national perspective to oversee and guide the technical team. The board will meet infrequently, but as needed, to guide the technical team.

Technical team—This team is a technical committee composed of 5 to 10 individuals with technical expertise, time, and energy to champion the implementation of the strategic plan. This team will recommend to the board of directors how the goals of the strategic plan can be met. This includes developing work plans that describe coordination, costs, benefits, funding, personnel, process, and time needed to reach goals. This team also needs to carefully consider how to market the plan most effectively to technical specialists. This team may need to meet frequently to initiate work and coordinate progress toward work plan goals.

Designated technical reviewers—The technical reviewers will be responsible for peer review of the work and recommendations of the implementation team. A maximum of 18 designated reviewers need to be identified for the nine program elements in the strategic plan. These individuals would work closely with the implementation team through correspondence and phone conversations. A face-to-face meeting probably would not be necessary.

Short Term (Within 6 Months)

Transition team—A team was identified at the Nebraska workshop to form a bridge between the work of the Express Team and the implementation team. The transition team will ensure that the guiding principles and framework listed above are followed in forming the implementation team. The transition team is:

Name	Affiliation
Mike Ziolko	Oregon Department of Forestry
David Sandberg	Pacific Northwest Research Station
Frank Cole	J.W. Jones Ecological Research Station
Steve Miller	St. Johns River Water Management
Coleen Campbell	Colorado Air Pollution Control Division
Dick Stender	Washington Department of Natural Resources
Gary Blais	U.S. Environmental Protection Agency
Tom Bragg	University of Nebraska
Wilson Laughter	Navajo Environmental Protection Agency
Bud Rolofson	U.S. Fish & Wildlife Service
Members of the Express Team[6]	

NWCG commitment—The NWCG committed the Express Team to developing the strategic plan and incorporating the workshop results for a final product. Members of the Express Team and transition team will present the final plan, including implementation recommendations, to NWCG who will then take appropriate action on behalf of their organization.

Express Team—The Express Team has been a self-selected, self-motivated group of individuals who committed the energy, time, and knowledge to advance the development and implementation of a strategic plan for modeling and data systems. The Express Team will complete the strategic plan and will serve as a technical resource for as long as necessary. The team will become unnecessary once a permanent implementation process is established.

Acknowledgments

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[6] See appendix A for list of team members.

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Appendix B

Complete Report on Workshop Strategies

Planning program element (P.1): source strength (fuels and emissions)—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Develop and document prescribed burning and wildfire emission factors to incorporate into AP-42 (U.S. Environmental Protection Agency 1972) and user-friendly software and documents for event- through regional-scale estimation.

    - Develop and document all available emission factors applicable to forest fires.
    - Incorporate available emission factors into AP-42 (U.S. Environmental Protetion Agency 1972) and user-friendly software for event- through national-scale estimation.
    - Update AP-42 (U.S. Environmental Protection Agency 1972) to be more user-friendly and to include all current emission factors and background information.

2. Complete a set of geographically resolved national emission source strength models (that is, production by chemical speciation and particle characteristics) that are coupled to fire behavior models for inputs to emission inventories, transport models, ozone production, and receptor impacts.

- Complete a set of national emissions source strength, chemical speciation, and particle morphology models (fuel consumption and emissions) that are coupled to fire behavior models (stylized fuel models).
- Develop methodologies for estimating plume characteristics for air quality models.
- Provide for smoke management systems on accepted and validated transport (carbon mass balance) model for evaluating local and regional impacts of smoke on receptors.
- Complete and merge the chemistry needed to understand the fate of smoke in the atmosphere into EPA-certified transport, ozone, and particulate matter models.
- Incorporate available speciation profiles (component breakdowns of total organic compounds and particulate matter) into SPECIATE (U.S. Environmental Protection Agency 1998).
- Catalog of methods to estimate fuels and fire characteristic emissions for applicable situations. Assess the various current and future methodologies for evaluating fuel characteristics for precision and accuracy in estimating burn behavior.

3. Develop a nationally applicable wildland fuel classification system, inventory, and database to monitor fuel conditions, fuel treatments, and changes in fuel characteristics over time. This system should include spatial attributes and must be designed to allow upward and downward reporting for land and air quality management purposes.

   - Provide a national database to track fuel characteristics, treatments, and other changes over time.

   - Develop a national GIS-based map of fuel loading, fuel conditions, and fuel characteristics (for example, fuel characteristic classes).

   - Develop a consistent national fuel classification and inventory system.

4. Undertake and compile studies of all major ecosystems nationwide to determine historic fire regimes (return intervals, season of burn, severity, frequency, area of extent), and present in GIS and tabular formats.

   - Compile a GIS-based fire regime map (historic and current).

5. Develop methods to collect data for fire and emission models for local agencies (city, county, district) that are compatible at state and national levels.

   - Develop methodologies for assembling county, state or tribal, regional, and national inventories and model inputs.

   - Develop a document for states to use when designing fire emission inventory systems so that the systems are locally appropriate in precision and detail and compatible with data collected by other states.

***Other strategies*—**These strategies were developed by the group but were not selected for the top five.

- Identify information gaps for assessing burn characteristics and emissions generation.

- Develop wildfire fuel consumption estimation techniques. Improve fuel consumption models for underburning of natural fuels in short-rotation ecosystems.

- Develop a national system for predicting changes in vegetation and fuel characteristics.

- Provide training programs for using available methods to determine fuel characteristics and estimate emissions.

- Develop agreed upon models, guidance for states or tribes for development of state or tribal implementation plans.

- Develop guidance or policy on how to calculate natural or background emissions for regulatory purposes and public information and education.

- Update “Aids to Determining Fuel Models” (Anderson 1982) or develop a new guide with more specific statements of fuel loads based on area (region), fuel types, time of year, past burn frequency, and actual availability of fuels for consumption given recent weather parameters.

- Compile a national inventory of spatially resolved emissions for current and planned future prescribed burning in the United States.

- Develop a nationally applicable fire emission tradeoff model (for example, wildfire-prescribed fire tradeoff model (Ottmar and others 1996, Schaaf 1996).

- Develop a system for evaluating fuel management treatments (efficiency and effectiveness of fuel treatments as well as emissions).

- Develop a system for prioritizing fuel management treatments for optimizing emissions.

- Create a system for (spatial and temporal) scheduling of fuel management treatments over long periods (that is, planning, not operational, smoke management).

Recommended procedural changes—The procedures in this section were identified by the group during strategy development; they are important and valuable concepts but did not fit our definition of a strategy.

- Develop tools and processes that meet target need yet are flexible to meet various planning levels and scales (temporal and spatial).

- Provide for timely technology transfer (training) to target users as new tools are developed.

- Provide users with unbiased, standardized methodologies to use for predicting and analyzing burn conditions.

- Provide users with standardized methodologies for measuring the area of burn.

- Develop a method of technology transfer from research and development to the end users (field personnel) to enable operational personnel to use developed models in fire planning and to facilitate the transfer of meaningful data back to research and development and regulatory agencies.

- Expand a single model or tool rather than develop new independent products: “less is more” concept.

- Make sure a platform required to operate is readily available to target users.

- Base new tools on a common user-friendly interface and platform.

- Develop a mechanism for feedback from users on the usability and performance of methodologies, models, and software provided.

Planning program element (P.2): ambient air quality (effects on NAAQS and visibility)—

Top six program element strategies—Following are the top six strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Determine the natural visibility conditions for regional haze evaluations for all areas of the country. Develop a modeling system as part of this activity that will evaluate tradeoffs among prescribed fires, wildfires, and other treatments.

    - Conduct long-term research on emission tradeoffs from treatment vs. wildfire.

2. Develop integrated analysis and assessment system (to deal with regional haze, NAAQS, nuisance smoke, deposition, and others). Includes dynamic databases and emission, meteorology, and air quality modeling covering all scales. Emission model includes fire behavior, fuel information, chemical speciation, and particle characterization. Air quality model includes chemical, transport, dispersion, and deposition issues.

3. Develop five regional (Northeast, Southeast, Midwest, Northwest, Southwest) model testing data sets (meteorology, fuels, emissions, plume tracks, concentrations, visibility, etc.) to evaluate objectively the technical excellence, performance, and implementation (use by field personnel) of proposed smoke dispersion models.

4. Develop a strategic planning tool that uses GIS for regional to national assessment of potential visibility, regional haze, and air quality that addresses the conflict between stable and unstable burning conditions. The GIS module includes monthly climate, current and potential fuel loading, known emission sources, and simple dispersion algorithms.

5. Develop remote sensing methods for measuring smoke movement and concentration. Includes airborne remote sensing and image analysis for tracking single-fire smoke plumes night and day, and van-mounted lidar or radar for measuring particle concentration throughout the whole plume.

6. Produce a report that brings together fire planning process requirements across agencies to facilitate the link between the planning and permitting processes.

Other strategies—These strategies were developed by the group but were not selected for the top six.

- Identify existing effective smoke management plans and make them available as examples.

- Develop air quality modeling forecast system.

- Develop emission factors for all vegetation types.

- Develop user-friendly protocols for implementation of planning tools.
- Research carbon sequestration issues (to support joint implementation).
- Develop a framework for planning within the current regulatory environment.
- Develop a strategy for monitoring as an element of planning.
- Further develop complex terrain models.

Recommended procedural changes—The procedures in this section were identified by the group during strategy development; they are important and valuable concepts but did not fit our definition of a strategy.

- Develop or use existing nationally organized training as a vehicle for communication.
- Develop a process for approval and acceptance of modeling tools. Foster collaboration among the U.S. and state environmental protection agencies and Federal, state, tribal, and local land managers.
- Educate the public on wildland fire and air quality issues.
- Develop and implement regional air quality planning centers and link locally.

Planning program element (P.3): effects on receptors (local impacts, exposure, and consequences—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Establish a wildland fire information clearinghouse to maintain fire and air quality, spatial and nonspatial data and information in a Federal Geographic Data Committee format and metadata standards searchable on the Internet.
2. Hold a series of workshops with stakeholders to agree on interagency model coordination for consistent model development, use, guidance, and evaluation. Possibly establish permanent clearinghouse, use EPA clearinghouse, or link to regional technology centers (proposed by FACA-WFIG[1]).
    - Decide which models to use and how: an assessment of existing models.
    - Display modeling results at a level appropriate for the general public.

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[1] FACA-WFIG is the Federal Advisory Committee Act-Wildfire Interest Group, a diverse set of stakeholders developing policy and technical support documentation for future regulation of fine particulates, regional haze, and ozone.

3. Establish a national fire database (wildland and prescribed fire) containing the minimum data needed by air quality managers.

4. Synthesize for the public and firefighters existing research and information on risk assessment from fire emissions. Develop and improve risk assessment models for air pollution effects from fires.

    - Conduct a literature search to determine the extent of research completed in this arena and effects on receptors.

    - Review results of completed studies to determine trends and establish baseline data.

5. Develop a communication plan, in cooperation with state forestry and air quality agencies, for the general public regarding positives and negatives of wildfire effects. The plan should allow for displaying modeling results graphically.

Other strategies—These strategies were developed by the group but were not selected for the top five.

- Assess public attitudes (at all levels) toward prescribed fire and emissions by using surveys, media reviews, literature searches, etc. (whatever vehicle is appropriate).

- Develop and implement a public (national, regional, all levels) survey regarding attitudes on prescribed fire and smoke.

- Develop questionnaire(s) or other vehicle(s) for validating perception of general population regarding air quality and use of prescribed fire.

- Maintain a technical infrastructure supported by staff modelers in land management agencies; link with software company to provide software support manuals.

- Have full-time smoke modelers on staff in land management agencies.

- Maintain a technical infrastructure to operate models.

- Set up a long-term epidemiological study of fire emission effects at firefighter and community level.

- Identify receptors in a given area to determine scale of the problem.

- Partner with health organizations to set up an epidemiological study for long-term effects of fire at the community level.

- Revise AP-42 (U.S. Environmental Protection Agency 1972).

- Present final results of this workshop to National Association of State Foresters and STAPPA-ALAPCO[2] national meetings.

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[2] STAPPA-ALAPCO is the organization of State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials.

- Quantify economic and environmental tradeoffs of wildfire versus prescribed fire. Priority is local level but it needs to be done at all levels.

- Quantify economic benefits of prescribed fire on ecosystems.

Recommended procedural changes—The procedures in this section were identified by the group during strategy development; they are important and valuable concepts but did not fit our definition of a strategy.

- Develop operational, programmatic, and strategic plans that identify economic, ecological, health, and human welfare impact threshold objectives and critical monitoring indices.

- Open up, improve dialog between state air quality and forestry agencies.

Operations program element (O.1): source strength (fuels and emissions)—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Develop a comprehensive fire and smoke management system that links behavior, fuel consumption, emissions, and dispersion models. This system must be user-friendly and must accurately represent the full array of fuel types and conditions. Outputs can be aggregated across all spatial scales.

2. Develop a standard set of default or inferred preburn fuel characteristic classes (average loading and variance) for all cover types in the United States for emission inventories or smoke management decisions.

3. Develop a standardized dynamic database or model to document data, such as date, location, acres, fuel types, weather, cost, and emissions for all fire events, and to analyze expected results based on past experience to learn from mistakes and replicate successes.

4. Make real-time burn and local weather information available to all users to enable a better emissions production estimate to be made for the operations phase.

5. Update (and reformat to make user-friendly) AP-42 (U.S. Environmental Protection Agency 1972), or similar information for emission factor compilation.

Other strategies—These strategies were developed by the group but were not selected for the top five.

- Increase quantity and quality and improve delivery of training opportunities among agencies and universities to encourage wise fire and smoke management practices for Federal, state, and tribal governments, and private sector.

- Document the benefits of activities that reduce emissions at the event scale and track and aggregate to other scales.

- Develop large-scale models that can take vent inputs and forecast state or regional effects.

Recommended procedural changes—The procedures in this section were identified by the group during strategy development; they are important and valuable concepts but did not fit our definition of a strategy.

- Increase coordination with agricultural burning such as improving applicability of tools, training, and reporting.

- Create and implement a process for continual feedback from fire practitioners (from all regions) to the research community regarding the need for new and timely research products as a result of field application.

- Improve coordination among involved land managers and local, tribal, and state regulatory agencies for operational decisionmaking and administration of smoke management programs and policies.

- Improve information and technology transfer between states, tribes, and agencies through a web site dedicated to fire issues.

Operations program elements (O.2): ambient air quality (effects on NAAQS and visibility)—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Update and develop wildland emission factors and fuel moisture nomograms.

    - Develop fuel moisture nomograms applicable to all parts of the country (currently they address only the West).

    - Update and develop emission factors for all fire types.

2. Develop an interagency task force to coordinate and develop or approve an operation-level smoke management modeling system to address air quality, emission production, and dispersion for varying types of fires and complexity.

    - Create a smoke management decisionmaking system (incorporating emissions models, dispersion models, visibility models, and professional judgment).

    - Use only dispersion models that have been peer reviewed and validated and have sufficient data for operations.

    - Have models available to accurately predict emissions production (prescreening and burn day applications).

    - Develop visibility and regional haze models for fires.

    - Get consistent national approval and usage of models.

- Develop and implement state-of-the-science smoke dispersion models from mesoscale meteorological model input for use in planning and operations at the field and smoke management decisionmaking levels.

3. Develop a uniform, linked, air quality, fire, and meteorological database that supplies sufficient data for operational decisionmakers to use with models developed by an interagency task force.

    - Develop a linked air quality, fire, and meteorological (current and forecast) database on GIS.

    - Develop real-time data systems that include monitoring thresholds and guidelines for health advisories.

    - Develop protocols to guide practitioners, regulators, and planners through the models and tools to assess burns of all scales and complexities.

    - Develop an expanded system model to document burn and not-to-burn decisions by smoke management coordinators.

    - Use, approve, and enhance observational data systems to support smoke management decisions in conjunction with the National Weather Service.

4. Develop a mechanism for fire emissions impact information to be disseminated to the public during planning and operational phases in response to wildland fire activities.

    - Develop simple onsite systems to estimate and disseminate information on air quality impacts from fire to offsite regulators and the public.

5. Develop a mechanism to incorporate wildland fire impacts on air quality into onsite suppression decisions, and to involve or inform other decisionmakers and the public.

    - Incorporate wildfire impacts on air quality into decisionmaking both onsite and offsite.

    - Develop real-time data systems that include monitoring thresholds and guidelines for health advisories when needed.

Recommended procedural changes—The procedures in this section were identified by the group during strategy development; they are important and valuable concepts but did not fit our definition of a strategy.

- Develop policy tools, training, and expertise to incorporate air quality considerations into wildland fire suppression activities.

- Conduct baseline epidemiological studies on the public health of rural communities affected by fire emissions.

- Develop public affairs program (early on) to notify the public of the benefits and risks of landscape burning.

- Increase efforts of implementors of the new Federal burning goal to assist state smoke management programs in using state-of-the-art tools and techniques for regulation.

- Consider not only Federal impacts but also impacts on non-Federal groups, including state, tribal, and local governments and private land owners, in all workshop recommendations.

- Include in smoke management plans steps to mitigate emissions that have become a hazard to health or a public nuisance.

- Ensure that offsite decisionmakers have adequate meteorological expertise to support needed decisionmaking in smoke management programs.

Operations program elements (O.3): effects on receptors (local impacts, exposure, and consequences)—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Develop a real-time analytical tool (computerized data display system) linked to GIS and easily communicable that integrates current meteorology (fine-scale meteorological data fields) and air quality data to provide a complete picture of the near and far field impacts of emissions from an ongoing burn.

    - A prerequisite to accomplishing this strategy is development of a real-time, reporting, ambient air monitor that is readily available for easy deployment near chosen receptors around burns.

2. Develop a spatially interactive database of information and characteristics of all types of receptors that can be linked to emissions information to evaluate hazards. A prerequisite to accomplishing this strategy is expansion and improvement of the emissions database (generation, characterization, and fate) for fuel types and conditions and fire behavior.

3. Develop an annotated list of educational tools and techniques including notification, a model law for burner certification, and model bylaws for fire council establishment.

4. Develop an expert knowledge base that aids in rapidly selecting receptor accommodation and source manipulation techniques (including costs, effectiveness, and practicality) to mitigate impacts on receptors.

5. Develop criteria to determine when a receptor impact becomes unacceptable and determine the practicality of receptor mitigation strategies (for example, a matrix of impacts and mitigation techniques).

Other strategies—These strategies were developed by the group but were not selected for the top five.

- Create an easy-to-use dispersion model that uses current data to predict air pollutant impacts 3, 6, and 12 hours into the future.
- Provide support to all burners from regional fire weather and smoke forecast offices.
- Develop standardized emissions inventory system linked to GIS and reported in daily situation report.

Monitoring program elements (M.1): source strength (fuels and emissions)—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Facilitate a forum where land managers, states, and air regulators will form partnerships to establish common standards and guides for monitoring and modeling source strength of fires; publish those standards in a nationally accepted guidebook.
    - Synthesize existing knowledge of fuel loading, fuel consumption, and emission models for all ecosystems.
    - Publish a national fuels inventory sampling guidebook that covers all sampling methods.
2. Use fuel photo series and expert field knowledge to develop and expand fuel characteristic classes to represent fuel types not currently available.
3. Validate and modify fuel loading, fuel consumption, and emission models for all major fuel types.
    - Update and validate fuel consumption models with field measurements.
4. Establish an integrated and consistent approach for collecting input variables to estimate daily emissions from fires (for example, wildland fire recording form).
5. Develop a national web page to provide an integrated and consistent approach to the collection, calculation, storage, maintenance, dissemination, and evaluation of fuel loading, area burned, fuel consumption, and emission production for fires. Data sets would be aggregated by latitude and longitude, fuel model, date, owner class, fire type, and emissions across all scales.

Other strategies—These strategies were developed by the group but were not selected for the top five.

- Extend natural and activity fuel photo series to include additional major fuel types for fuel loading monitoring.
- Link weather models to dispersion models.
- Establish demonstration science-management-public partnerships to work on monitoring source strength pilot projects.
- Create and support an information system (for example, Internet discussion group) focusing on monitoring source strength related issues.

Recommended procedural changes—The procedures in this section were identified by the group during strategy development; they are important and valuable concepts but did not fit our definition of a strategy.

- Provide guidance that requires land managers and air regulators to use standards and guidelines.
- Assess information and develop a definition of “natural” emissions to contribute to policy analysis.

Monitoring program elements (M.2): Ambient air quality (effects on NAAQS and visibility)—

Top five program element strategies—Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Develop air quality, visibility, and meteorological monitoring protocols to support, assess, and evaluate wildland fire impacts. Protocols should include siting, operation and maintenance, quality assurance and quality control, system design, etc.; temporal and spatial scales; public notification; and the differences between wildfires and prescribed fires.
2. Conduct air quality, visibility, and meteorological monitoring to provide data to assess wildfire and prescribed fire impacts.
3. Develop and maintain a national information system for air quality, visibility, and fire data and receptor impacts.
4. Develop training programs, or identify existing programs to address needed skills for air quality, visibility, and meteorological monitoring operations, data use, interpretation, and analyses.
5. Perform intensive field monitoring studies to assist in network design, protocol development, model development and evaluation, and pollutant (for example, ozone, oxides of nitrogen, volatile organic compounds, particulate matter) impact assessments.

***Other strategies*—**These strategies were developed by the group but were not selected for the top five.

- Develop a standard portable monitoring system for ambient air quality, visibility, and meteorology.

- Provide support and assistance to parties affected by wildland fires (for example, tribes, private individuals, local and remote communities) for air quality, meteorological, and visibility monitoring.

Monitoring program elements (M.3): effects on receptors (local impacts, exposure, and consequences)—

***Top five program element strategies*—**Following are the top five strategies from this program element group. If a numbered strategy was the product of multiple brainstormed strategies, the brainstormed strategies are listed after the numbered strategy to provide extra detail and clarity.

1. Develop information needs for short- and long-term impacts (for example, economic, medical, ecological, social, political, and public safety).

2. Develop a central or Federal body to draw on existing organizational models (for example, FEMA, National Interagency Fire Center, Incident Command System) to plan and coordinate responses to smoke impacts on receptors.

3. Define and establish protocols and organization of response teams appropriate to the scale of the smoke event.

4. Establish dose response relations between smoke and receptors for short- and long-term exposures.

5. Implement a retrospective and prospective epidemiological analysis in communities with incidents of high impact from smoke.

***Other strategies*—**These strategies were developed by the group but were not selected for the top five.

- Do a screening risk assessment (and refine if warranted) of adverse impacts among key populations.

- Develop a centralized information management system for smoke levels and receptor impacts.

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Sandberg, David V.; Hardy, Colin C.; Ottmar, Roger D.; Snell, J.A. Kendall; Acheson, Ann; Peterson, Janice L.; Seamon, Paula; Lahm, Peter; Wade, Dale. 1999. National strategic plan: modeling and data systems for wildland fire and air quality. Gen. Tech. Rep. PNW-GTR-450. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 60 p.

This strategic plan is a technical discussion of the implementation and development of models and data systems used to manage the air quality impacts of wildland and prescribed fires. Strategies and priorities in the plan were generated by the Express Team (chartered by the National Wildfire Coordinating Group) and a diverse group of 86 subject matter experts who attended a national planning workshop.

Keywords: Fire, air, wildland fire, fire effects, fire management, fire modeling, air quality, air pollution, air resource management, data systems.

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