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MANAGING ENVIRONMENTAL AND CONSERVATION IMPACTS FROM PRESCRIBED FIRE PROGRAMS

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MANAGING ENVIRONMENTAL AND CONSERVATION IMPACTS FROM PRESCRIBED FIRE PROGRAMS

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) provides assistance in the preparation of an Integrated Wildland Fire Management Plan (IWFMP).

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format) through the World Wide Web at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through this link:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to installation personnel who are responsible for managing prescribed fire programs on all U.S. Army facilities with prescribed fire management programs.

3. References.

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 27 December 2007.

b. Department of Defense Instruction 4715.3, Subject: Environmental Conservation Program, 3 May 1996.

c. The Army Strategy for the Environment, "Sustain the Mission – Secure the Future," 1 October 2004.

d. Clean Air Act Extension, Public Law (PL) 91-604, 31 December 1970, as amended in 1990 (PL 101-549).

e. 40 Code of Federal Regulations (CFR) Parts 50 and 58, "National Ambient Air Quality Standards for Ozone"; Federal Register (FR) Vol. 73, No. 60; March 27, 2008.

f. 40 CFR Part 50, " National Ambient Air Quality Standards for Particulate Matter"; FR Vol. 70, No. 200; October 17, 2006.

g. 40 CFR Parts 50 and 51, "Treatment of Data Influenced by Exceptional Events"; FR Vol. 72, No. 55; March 22, 2007.

h. Endangered Species Act of 1973, PL 93-205, as amended.

i. "Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy," National Wildfire Coordinating Group, 20 June 2003.

4. Discussion.

a. The Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy (2003) defines a wildland fire (described as both wildfire and prescribed fire) as any nonstructure fire that occurs in the wildland. A wildfire is defined as any unplanned ignition as well as planned ignitions that are declared wildfires. The wildfire term applies to all unplanned ignitions, including events formerly termed wildland fire use. A prescribed fire is defined as any planned ignition and is sometimes also referred to as a controlled burn. AR 200-1 includes similar definitions and defines a wildland fire as any nonstructural fire that occurs on unimproved grounds. The regulation defines prescribed burning as the skillful application of fire to natural fuels under conditions of weather, fuel moisture, soil moisture, etc., to allow confinement of the fire to a predetermined area while producing the intensity of heat and rate of spread required to accomplish certain planned benefits. These benefits may include all or any objectives of silviculture, wildlife management, grazing, hazard reduction, etc. Its objective is to employ fire scientifically to realize maximum net benefits at minimum damage (if any) and acceptable cost.

b. Past practices of wildland fire suppression in the western United States have resulted in the over-accumulation of timber and undergrowth in forest, rangeland, and wildland-urban interface habitats. This over-accumulation of biomass has caused a degradation of wildlife habitat, forest health, and biodiversity; has reduced water quality and quantity; has led to spiraling costs for fire suppression and elevated risks to the public and firefighters; and has increased the occurrence of catastrophic wildfires and the levels of emissions they produce. For several decades, prescribed fire has been the preferred method for fuel management, possibly due, at least in part, to social and political resistance to nonburning treatment methods; however, it also results in some adverse impacts. Specifically, in the context of this document, prescribed fire produces emissions that contribute to air quality problems in the western United States.

c. Wildfires occur naturally and play varying roles in nearly all terrestrial ecosystems. Because different types of ecosystems produce and accumulate fuel more quickly than others, wildfire frequency and intensity are determined by the type and the stage of development of the ecosystem in which the fire occurs. Depending on the fire regime, many species evolve adaptation to fire, making fire important for competition with other species and sometimes necessary for reproduction. Fire, in a natural or prescribed form, is important to the maintenance and health of most ecosystems. Some fire-dependent ecosystems found on Army installations include: Midwest Tallgrass Prairie, Southwestern California Chaparral, Ponderosa Pine in the Southwest and Intermountain West, Lodgepole Pine communities of the Rocky Mountains, Southern Pine communities, Jack Pine communities of the Great Lakes Region, and Alaska's Boreal Forest and Tundra. Longleaf pine ecosystems have adapted to natural fire regimes (wildfires in ~3- to 7-year cycles) and now require periodic burning to maintain health.

d. Prescribed fire is a significant source of air pollutants, especially particulate matter (PM). Air quality managers must therefore consider restricting prescribed fires occasionally in an effort to comply with the Clean Air Act (CAA). On 21 September 2006, the U.S. Environmental Protection Agency (EPA) issued its most protective suite of national air quality standards for particle pollution ever. They strengthened the 24-hour $PM_{2.5}$ (fine PM less than or equal to 2.5 µm aerodynamic diameter) standard from the 1997 level of 65 $\mu g/m^3$ to 35 $\mu g/m^3$, and retained the current annual fine particle standard at 15 $\mu g/m^3$ (49 CFR 50, 2006). On 12 March 2008, the EPA limited the allowable amount of pollution-forming ozone in the air from 84 to 75 parts per billion (40 CFR 50 and 58, 2008). This trend of lowering national ambient air quality standards will continue for PM and ozone as health studies show health impacts at pollutant levels below current and proposed standards. The EPA has proposed lowering the 8-hour ozone standard to 60 to 70 ppm and has begun the process to lower the 24-hour $PM_{2.5}$ standard to 30–35 µg/m^3 and lower the annual $PM_{2.5}$ standard to 11–13 µg/m^3. Many parts of the country restrict prescribed-fire use during the summer months as part of regional strategies to limit ozone formation. On 14 March 2007, the EPA finalized a rule to establish criteria and procedures for use in determining if air quality monitoring data have been influenced by exceptional events (40 CFR 50 and 51, 2007). This rule can provide state regulatory agencies some relief when prescribed burn events cause the 24-hour $PM_{2.5}$ standard to be exceeded. Prescribed fire can also cause dangerously poor visibility conditions on roadways and result in complaints from civilian populations.

e. Continued use of prescribed fire as a critical component of ecosystem management strategies on numerous Army installations depends upon mitigating constraints imposed by conflicting regulatory requirements. Fire-dependent ecosystems are found across the southeastern and central United States, as well as portions of the West, representing approximately 630,000 hectares of Army training land and occurring on 50% of all Tier 1 and 2 Sustainable Range Program installations. Installations charged with sustainable management of fire-dependent ecosystems strive to implement prescribed burns at intervals that not only provide accessible, maneuverable, and defensible habitat conditions necessary for mission training, but also support biodiversity and threatened and endangered species (TES) recovery. Of the 188 federally listed TES and 240 identified species at risk that are potentially eligible for listing, a large percentage occur on Army installations and are directly or indirectly dependent upon reoccurring fire. Army use of prescribed fire as part of an ecosystem-based land management strategy is also mandated in Department of Defense Instruction 4715.3. More recently, the Army’s need to shift from compliance-driven to proactive management of its lands was described in The Army Strategy for the Environment (2004). Under this strategy, sustainable land management, which includes ecosystem-based fire management, is a critical component of mission-directed training and testing.

f. Conflicts over Army use of prescribed fire will become increasingly pervasive, however, due to encroachment and the reductions of EPA air quality standards for fine particulate matter ($PM_{2.5}$) and ozone. CAA-imposed restrictions on or alteration of Army prescribed burn programs pose a number of negative consequences for military training. Direct impacts to the training mission include restrictions on the time, frequency, and location of training-land use; loss of desirable training-land characteristics; and increased risk of wildfires, which can damage significant investments in range infrastructure and threaten the health and safety of troops. Indirect impacts include increased risk of wildfires spreading off-installation; reduced ability to meet Endangered Species Act compliance and recovery goals; increased costs due to loss of effective management strategies established over decades of effort; and loss of prescribed fire as a highly effective tool for management of biodiversity, forest health, tick-borne diseases, and invasive species.

g. Appendix A discusses overall prescribed fire planning requirements and guidance.

h. Appendix B provides background, guidance, and tools for air quality and smoke management from prescribed fires.

i. Appendix C outlines forest management alternatives to prescribed fire.

j. Appendix D describes major terrestrial ecosystems found in the United States.

k. Appendix E lists references used in Appendices A–D.

l. Appendix F lists abbreviations used in this PWTB.

5. Points of Contact.

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APPENDIX A

PRESCRIBED FIRE PLANNING

Army Wildland Fire Policy Guidance (2002) requires that all "installations with unimproved grounds that present a wildfire hazard and/or installations that utilize prescribed burns as a land management tool will develop and implement an Integrated Wildland Fire Management Plan (IWFMP) that is integrated with the … installation's existing fire and emergency service program plan(s), and the Integrated Cultural Resources Management Plan (ICRMP)." The purpose of the IWFMP is to:

- reduce wildfire potential,
- effectively protect and enhance valuable natural resources,
- integrate applicable state and local permit and reporting requirements, and
- implement ecosystem management goals and objectives on Army installations.

The policy requires that the IWFMP be reviewed and updated annually and revised at least once every 5 years. The guidance outlines 15 components of IWFMPs and describes program authority for fire management. The guidance also includes certification, training, and fitness standards for wildland fire management personnel.

IWFMPs must include a section on prescribed fires that includes site-specific burn plans. At a minimum, burn plans will include the following:

- burn objectives,
- acceptable weather and fuel moisture parameters,
- required personnel and equipment resources,
- burn area map,
- smoke management plan,
- safety considerations,
- pre-burn authorization/notification checklist,
- coordination to consider wildlife, endangered species, cultural resources, and noxious weed effects,
- alternative plan of action if wind direction changes during prescribed burn, and
- plan for analysis of burn success and identification of lessons learned.

IWFMPs must also include a section on Smoke Management and Air Quality that describes the mission and environmental, human health, and safety factors. The section also includes applicable state and local permit reporting requirements specific to the installation and region that affect smoke management and identify necessary mitigation practices.

The National Wildfire Coordinating Group has developed the "Interagency Prescribed Fire — Planning and Implementation Procedures Guide" (2008). This document provides guidance for prescribed fire planning and implementation for the Department of the Interior's Bureau of Indian Affairs, Bureau of Land Management (BLM), the National Park Service (NPS), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Department of Agriculture Forest Service (USDA FS). This information can also be useful for Army installation use. The guidance describes 21 elements of a prescribed-fire plan and provides a template for these plans. This document can be found at the following link:

http://www.nwcg.gov/branches/ppm/fpc/archives/fire_policy/rx/rxfireguide.pdf

Several good examples of Army installation prescribed-fire planning documents can be found on the Internet.

A link to the prescribed fire information site for Fort Benning, Georgia, is shown below:

https://www.benning.army.mil/emd/land/prescribed_burning/index.htm

A link to Integrated Wildland Fire Management Plan for Fort Huachuca, Arizona, is shown below:

http://www.epa.gov/region9/nepa/huachuca/AppendixN.pdf

APPENDIX B

AIR QUALITY AND SMOKE MANAGEMENT

Health Effects of Smoke

Smoke is a complex mixture of carbon dioxide (CO_2), water vapor, carbon monoxide (CO), particulate matter (PM), hydrocarbons and other organic chemicals, nitrogen oxides, and trace minerals. The individual compounds present in smoke number in the thousands. Smoke composition depends on multiple factors, including the fuel type and moisture content, the fire temperature, wind conditions and other weather-related influences, whether the smoke is fresh or "aged." Different types of wood and vegetation are composed of varying amounts of cellulose, lignin, tannins and other polyphenols, oils, fats, resins, waxes, and starches, which produce different compounds when burned.

PM is the principal pollutant of concern from wildfire smoke for the relatively short-term exposures (hours to weeks) typically experienced by the public. A generic term for particles suspended in the air, PM is typically a mixture of both solid particles and liquid droplets. The characteristics, sources, and potential health effects of PM depend on its source, the season, and atmospheric conditions. Additionally, the size of particles affects their potential to cause health issues. Particles larger than 10 micrometers do not usually reach the lungs, but can irritate the eyes, nose, and throat.

Particles from smoke tend to be very small, with a size range near the wavelength of visible light (0.4–0.7 micrometers), and are therefore nearly completely within the fine particle ($PM_{2.5}$) fraction. The size range of smoke particles is very efficient at scattering light and reducing visibility. Moreover, such small particles can be inhaled into the deepest recesses of the lung and may represent a greater health concern than larger particles.

Another pollutant of concern during smoke events is CO, which is a colorless, odorless gas produced by incomplete combustion of wood or other organic materials. CO levels are highest during the smoldering stages of a fire, especially in very close proximity to it.

Other air pollutants, such as the potent respiratory irritants acrolein and formaldehyde as well as the carcinogen benzene, are present in smoke but at much lower concentrations than PM and CO.

The effects of smoke range from eye and respiratory tract irritation to more serious disorders, including reduced lung function, bronchitis, exacerbation of asthma, and premature death. Studies have found that fine particles are linked (alone or with other pollutants) with increased mortality and aggravation of pre-existing respiratory and cardiovascular disease. In addition, particles are respiratory irritants, and exposures to high concentrations of PM can cause persistent cough, phlegm, wheezing, and difficulty breathing. Particles can also affect healthy people, causing respiratory symptoms, transient reductions in lung function, and pulmonary inflammation. PM can also affect the body's immune system and the physiological mechanisms that remove inhaled foreign materials from the lungs, such as pollen and bacteria. As noted earlier, PM exposure is the principal public health threat from short-term exposures to wildfire smoke.

Fuel Consumption and Air Pollution Estimation

A rough emission estimation method for prescribed fire can be found in Chapter 13.1 of the EPA's AP-42, "Compilation of Air Pollutant Emission Factors" (1995) that can be found at the following link:

http://www.epa.gov/ttnchie1/ap42/ch13/final/c13s01.pdf

This chapter contains Table 13.1-3 that presents, by fire and fuel configuration, emission factors for prescribed burns from various pollutants. Table 13.1-4 gives emission factors for prescribed burning by geographical area within the United States. Estimates of the percent of total fuel consumed by region were compiled by polling experts from the USDA FS. The emission factors are averages and can vary by as much as 50% with fuel and fire conditions. To use these factors, multiply the mass of fuel consumed per hectare by the emission factor for the appropriate fuel type. The mass of fuel consumed by a fire is defined as the available fuel. Local forestry officials often compile information on fuel consumption for prescribed fires and have techniques for estimating fuel consumption under local conditions. The "Southern Forestry Smoke Management Guidebook" (1976) and the "Prescribed Fire Smoke Management Guide" (1985) should be consulted when using these emission factors.

Another approach for estimating fuel consumption and emissions is the USDA FS ***Consume*** model. ***Consume*** is a decision-making tool designed to assist resource managers in planning for prescribed fire, managed wildland fire, and wildfire. ***Consume*** predicts fuel consumption, pollutant emissions, and heat release based on a number of factors including fuel loadings, fuel moisture, and other environmental factors.

Consume is based on 71 sites that were inventoried and burned in black and white spruce/hardwood forests (Alaska), chaparral (California), ponderosa pine/mixed-conifer forests (Oregon), and pine/hardwood forests (South Carolina, Tennessee, and Florida). Thirty-five sites were inventoried and burned in sagebrush on BLM, NPS, and USFWS lands in eastern Oregon, Nevada, Wyoming, Utah, and California. Additionally, over 150 sites were burned in clearcut and partial-cut logging debris fuelbeds in Washington and Oregon. Data from all burns have been compiled and analyzed. Consumption models were built for fuel categories within the following fuelbed types: Douglas fir/western hemlock, lodgepole pine, grand fir/Douglas fir, black and white spruce/hardwoods, longleaf and loblolly pine, ponderosa pine, grasslands, and sagebrush. Information about ***Consume*** can be found at the following website:

http://www.fs.fed.us/pnw/fera/research/smoke/consume/index.shtml

Consume is also designed to import data directly from the Fuel Characteristic Classification System (FCCS). The Fire and Environmental Research Applications team of the Pacific Northwest Research Station Pacific Wildland Fire Sciences Laboratory, USDA FS, has developed a National FCCS to accommodate this need.

The FCCS offers consistently organized fuels data along with numerical inputs to fire behavior, fire effects, and dynamic vegetation models.

- Users can access a fuelbed from the national fuelbed database within the FCCS that was compiled from published and unpublished literature, fuels photo series, fuels data sets, and expert opinion. They can also modify existing descriptions with enhanced information to create a set of fuelbeds to represent a particular scale of interest.

- When the user has completed editing the fuelbed data, FCCS reports the assigned and calculated fuel characteristics for each existing fuelbed component including the trees, shrubs, grasses, woody fuels, litter, and duff.

- The system also calculates a surface fire behavior, crown fire, and available fuel potential index between 0-9 for each FCCS national or customized fuelbed. These FCCS fire potentials facilitate communication among users and provide an index representation of the intrinsic capacity of each fuelbed for surface fire behavior, crown fire, and available consumption of fuels.

Information about FCCS can be found at the following website:

http://www.fs.fed.us/pnw/fera/fccs/index.shtml

Acquiring and Using Meteorological Data

Determining current and forecasted meteorological conditions is an important step in planning a prescribed burn event. Weather elements such as wind speed, temperature, and relative humidity directly impact the rate and intensity of a fire. These weather parameters also are normally part of a decision-making process to determine if a prescribed fire is allowable. Meteorology is also used as an input to models that can predict the downwind impact of a prescribed burn event.

Three sources of weather information are available: (1) National Weather Service (from the National Oceanic and Atmospheric Administration [NOAA]), (2) Fire Danger Rating System (National Weather Service, not available in all states), and (3) local observations. Use at least one of these before starting prescribed fires and during burning.

Field observations of weather should be made at or near the prescribed burn area before and during burning. Such observations serve both as a check on the weather forecast and to keep the burning crew updated on any changes or effects of local influences.

Compact portable weather kits containing a psychrometer to measure humidity and a wind speed measuring instrument are available. With this kit, and by observing cloud conditions and other weather indicators, a competent observer can obtain a fairly complete picture of current weather.

Successful prescribed burning and smoke management is based largely on adequate weather knowledge. Before a fire is set, the weather forecast should be known for at least the next 24 hr and, when possible, for the next 48 hr. A weather forecast for the next 4–5 days might be necessary on a large fire with high risk or potentially bad smoke management problems.

The National Weather Service is usually the best source of local weather forecasts and information, particularly for forecasts of several days in advance. Most states have at least one toll-free telephone number available to agencies. Ask for a spot weather forecast. Permanently staffed airport terminals are another good source of daily NOAA forecasts. Some National Weather Service offices will also furnish daily fire danger forecasts.

Secondary sources of weather forecasts and outlooks are local television or radio station meteorologists, who should be able to provide reliable 48-hr advance forecasts. Many local radio stations or weather radios provide an early morning daily agricultural forecast from 0600-0900 hours that gives relative humidity, wind, temperature, etc.

Current weather information may be checked via two-way radio communication with an automatic or instant indoor-outdoor weather station at a local headquarters or with readings from instruments from a portable weather kit.

Air Pollutant Emission Impact Modeling

Smoke and air pollution impact management revolves around predicting downwind concentrations of air pollutants and smoke particles. A variety of wildland fire specific models are available that serve this purpose. These models range from very simple screening-type tools to large modeling frameworks that link fuel loading, fire consumption, fire emissions, and smoke dispersion tools together. Descriptions of many of these models are provided below. Army environmental personnel should always check with local or state air quality regulatory bodies to determine if there is a requirement to use a specific model.

Simple Smoke Screening Tool – The Southern High Resolution Modeling Consortium (SHRMC) provides the Simple Smoke Screening Tool. This tool is best used for daytime conditions for burns smaller than 250-300 acres that will be completed within a few hours. The "Southern Forestry Smoke Management Guidebook" (1976) uses a simple graphical smoke screening system that relies upon a simple protractor to use with paper maps in marking out a smoke impact zone. SHRMC has created a digital version of this tool. This simple screening tool is designed to help identify smoke-sensitive targets, not to predict smoke concentrations. A link to this tool is provided below:

http://shrmc.ggy.uga.edu/maps/screen.html

Florida Forestry Smoke Screening Tool – The Florida Division of Forestry provides the Internet Smoke Screening Tool, which uses a simple model and forecasted weather data to view the potential impacts from a smoke plume. Anyone can use the tool, but it is primarily designed to allow individuals who are planning on conducting acreage or pile burning to view a predicted smoke plume for the planned burn. A link to this tool is provided below:

http://flame.fl-dof.com/wildfire/tools_sst.html#SST

VSmoke-Web - The SHRMC provides VSmoke-Web, which is a web-based version of the VSmoke model. It is designed to assist with planning prescribed burns in the Southern United States. VSmoke is a simple Gaussian smoke dispersion model that calculates isopleths of surface smoke concentration. Output from the model represents peak hourly concentrations of $PM_{2.5}$ or visibility (under development). This tool is best used for daytime conditions. A link to this tool is provided below:

http://shrmc.ggy.uga.edu/maps/vsmoke.html

PB-Piedmont - The SHRMC provides PB-Piedmont, which is a local smoke modeling tool designed for the prediction of smoke movement at night. This tool is especially helpful for determining whether a burn may cause problems with smoke on the highway and accounts for the potential for localized fog as well. A link to this tool is provided below:

http://shrmc.ggy.uga.edu/smoke/pb-piedmont/index.html

BlueSky Framework – Bluesky is a framework linking existing models and datasets. BlueSky links with meteorological models, fire activity reporting systems, mapped fuel loadings, fuel consumption models, fire emission models, and air quality trajectory, dispersion, and atmospheric chemistry models to produce predictions of surface $PM_{2.5}$ concentrations (and in some cases predictions of ozone and other trace gas concentrations). The predictions typically extend out 2–3 days in time. It is a centralized web-based application. A link to the BlueSky website is provided below:

http://blueskyframework.org/

WFDSS Air Quality Portal – The Wildland Fire Decision Support System (WFDSS) Air Quality portal contains the following eight wildland fire air quality tools:

- Point Forecasts

- Smoke Guidance Regional Maps
- Remote Automatic Weather Station (RAWS) Wind Roses
- Climatological Ventilation Index
- Current Air Quality Conditions
- Interactive Trajectories
- Probabilistic Smoke Impacts
- Customized Fuels, Consumption, and Smoke Modeling

A link to this portal is provided below:

http://firesmoke.us/wfdss/

National Smoke Management Website – This website has the following tools and information.

- Tools
  - Smoke/Weather Forecasts
  - Smoke Modeling
  - Smoke Monitoring
  - Remotely Sensed Data
  - After Action Review
  - National Environmental Policy Act (NEPA) Environmental Analyses on Smoke Impacts
- Regulations and Policies
- Emissions
- Training

A link to this website is provided: **http://www.nifc.gov/smoke**

Greenhouse Gas Management

Prescribed fires are a source of the greenhouse gases CO_2, methane, and nitrous oxide. Due to the role of photosynthesis in the carbon cycle, CO_2 emissions from prescribed fire would not be included in an Army installation's greenhouse gas footprint. This is true because the carbon from these emissions would be effectively stored in the biomass that grows to replace the biomass removed during the prescribed burn.

Over time, the ecosystem could either be a source or a sink of carbon depending on the complex cycles of growth, decay, and removal by fire. Because of the complex movement of carbon in ecosystems, the federal guidance for developing federal facility greenhouse gas emission inventories that are mandated by Executive Order 13514 do not include any carbon sequestration or emissions from ecosystems. This policy may change as better emission and sequestration estimation methods are developed.

State-level Air Quality Requirements and Programs

Many states have their own requirements and guidance for managing air pollutant emissions from prescribed burning. Army installation personnel should always check with their state or local air quality regulatory agency for specified procedures. In many cases, a specific dispersion modeling tool must be used so that the air quality management process is consistent. Below are links showing examples of these state programs.

- North Carolina: http://www.dfr.state.nc.us/fire_control/fc_smoke_management_guidelines.htm
- New Jersey: http://www.state.nj.us/dep/parksandforests/fire/prescribed_burning.htm
- Georgia: http://www.gaepd.org/air/airpermit/downloads/planningsupport/regdev/smoke_plan/SMP%20Draft%20one%20DS.pdf
- Arizona http://www.adeq.state.az.us/environ/air/smoke/index.html
- California http://www.arb.ca.gov/smp/smp.htm
- Florida http://www.fl-dof.com/wildfire/
- Idaho http://www.idl.idaho.gov/bureau/firemgt.htm
- Washington http://www.dnr.wa.gov/Publications/rp_burn_smptoc.pdf

APPENDIX C

ALTERNATIVES TO PRESCRIBED FIRE

Treatment Options

Four categories of treatment options are available: manual/hand, mechanical, chemical, and grazing. These four categories are not mutually exclusive, and treatments frequently combine methods. Each category involves specific techniques appropriate to various conditions and situations.

Manual/Hand

Handwork involves picking up and moving limbs and brush, as well as cutting downed and standing materials using hand tools or chainsaws. The gathered or cut material is then either piled (often for subsequent burning) or scattered (to remain on site and decay naturally). Below the supervisorial level, work crews can generally be comprised of unskilled personnel. Manual methods usually entail a fairly large crew or a prolonged schedule.

Constraints on manual methods are: fuel size; site accessibility (e.g., slope, density of understory, rocks, safety, proximity to vehicle access); limited opportunity to utilize materials; slow production rate (defined as the acreage that is treated per unit of time — for example, acres per person per day); and needs (support, safety, sanitation) of personnel.

Manual work is generally limited to materials of roughly 9 in. (~23 cm) or less in diameter. Larger materials can be handled, but efficiency, production rate, and safety decrease rapidly as size increases. If the fuels requiring treatment include many large logs, hand work is not a good option.

Although hand crews are not subject to the same non-negotiable constraints of access and mobility as mechanical equipment, such constraints must nevertheless be considered. Steeper slopes become decreasingly efficient and increasingly hazardous. Density of vegetation can impede access to the work site and movement within it. Daily travel times can be prohibitive if the work site is too far from available road access.

Handwork rarely generates material for utilization. It is difficult and inefficient to carry material to a location where it can be transported off site. Firewood is often collected and carried for short distances by hand, but most other types of utilization require machinery to enter the treatment area.

Hand treatments may address rearrangement as opposed to removal of fuels. While this can be effective in certain conditions, it is typically a short-term solution. Alternatively, it can be used as a primary treatment that is followed by burning to consume residual material; the site may subsequently be managed by prescribed maintenance burns.

Mechanical

Mechanical treatments employ equipment as the primary method of modifying or removing fuels. Mechanical treatments include mowing and masticating (grinding) as well as traditional harvest operations. Mechanical treatments commonly require vehicle access.

In general, mechanical equipment consists of a power source and carrier and some type of cutting head. Heads can be fixed mounted, limited-movement mounted, or attached to an articulating arm. A wide array of equipment is available for use on different kinds of terrain and to address different fuel types and structures. Many innovative methods and designs have evolved from technology that was developed for the logging and heavy construction industries.

Mechanical treatment types can be broadly divided into two categories: those that leave materials on site and those that remove materials off site. ***Onsite techniques*** include forming piles either mechanically or by hand. Machine piles are generally larger than manual piles and risk incorporation of more litter and soil, the presence of which can substantially increase smoke production when the piles burn. Another set of onsite techniques uses machinery to masticate, mow, or crush, material into smaller pieces that can then be redistributed on the ground surface or removed from the site. Because materials processed in this fashion can be much more densely packed than materials that are scattered by hand or piled, the available oxygen supply is reduced, which inhibits spread of fire and flame height. At the same time, increasing the density can increase smoldering, leading to heightened pollutant production if the material is eventually burned in place.

Offsite techniques to remove forest materials have developed as the timber industry has evolved. The four broad categories of material removal techniques are bole removal, whole-tree yarding, cut-to-length processing, and chipping/grinding.

Chemical

Chemical treatments entail the application of herbicides. Chemical treatments do not remove fuels but either kill existing vegetation or inhibit growth. In general, chemicals are appropriate to treat flashy understory growth such as the weedy vegetation under power transmission lines or along railroad rights-of-way. Also, some chemicals target specific types of vegetation (e.g., broadleaf species); these can be used to address incursions of invasive nonnative species or to manage vegetative structure following fuel treatments. Alternatively, chemical treatments can be used in conjunction with other treatment types, including prescribed burning, to extend the period between necessary management activities.

A chemical treatment technique called brown-and-burn was widely used in vegetation and fuel management programs in the past. While it is still used under certain circumstances, its application has decreased in recent years. In this technique, pesticides are used to kill target species of understory vegetation, converting live fuel to dead fuel. The chemical treatment can be applied in spring, when nontarget species remain green, thereby facilitating a prescribed burn to remove the vegetation that has been rendered flammable. One impact associated with brown-and-burn treatments is the potential aerial dispersal of toxic substances released through the burning of treated vegetation. However, because this technique is properly a pre-burning procedure, it cannot be considered a nonburning alternative.

The growth-inhibiting function of chemical treatment is useful for the maintenance of fuel breaks. Fuel breaks are typically established along ridge tops, where mechanical or manual treatments have been applied to reduce fuel loads and create an area where, in the event of a wildfire, the decreased fuel load will retard the spread of the fire and fire crews can work at blaze containment and control. Periodic chemical treatments could be used to maintain the desired fuel characteristics within the fuel break, making mechanical or prescribed burning treatments unnecessary for many years.

The drawbacks to chemical treatment methods include very stringent regulatory requirements, the possibility of adverse impacts on water quality, destruction of species that are not target species, toxicity levels, and negative public opinion.

Grazing

Grazing involves the use of livestock to manage the growth and composition of brush and grasses. While it is of limited utility in forested habitats, it can be an effective technique in the wildland-urban interface and in selected grassland and shrubland habitats.

Environmental Considerations

The primary goals of promoting nonburning alternatives for wildland regions are to reduce the environmental impacts of burning on visibility and air quality and to reduce or eliminate the risk of escapes. While the alternatives may achieve the desired results pertaining to air quality, attention must be given to other environmental impacts. For example, use of heavy equipment on sensitive soils can result in soil compaction, and the resultant erosion can lead to ecosystem damage as well as degradation of water quality. Consideration of these potential impacts should constitute part of any analysis of alternatives.

- *Adverse impacts on air quality*. Although a primary motivation for selecting nonburning instead of burning treatment options is the reduction of adverse impacts on air quality, even nonburning alternatives may create adverse effects. For instance, mechanical equipment produces emissions, and the movement of heavy equipment can generate fugitive dust.

- *Soil compaction*. Soil compaction is of particular concern when conducting mechanical treatments. Passage of heavy equipment can compact soils. Compaction can impede permeability, which in turn can reduce groundwater recharge and increase surface runoff. Moreover, the removal of air spaces in the soil can impair the soil's ability to support root development.

- *Water quality degradation*. Soil compaction can increase runoff, posing potential threats to water quality. Additionally, removal of vegetative growth can, by eliminating demand for surface and shallow subsurface water, also increase surface runoff. Increased surface runoff can increase erosion, degrade riparian habitats, and discharge damaging quantities of sediment into watercourses. Also, scarification caused by some techniques can contribute to increased sediment discharge and channelized erosion problems.

- *Removal of nutrients from site*. An important component of any ecosystem is the recycling of nutrients back into the soil. In fire-adapted habitats, periodic naturally occurring fire is a significant mechanism of nutrient recycling; the complex processes of decay and deterioration are also important. Prescribed burning can mimic the role of naturally occurring fire in nutrient recycling; however, nonburning alternatives that remove substantial quantities of biomass can impair this cycle.

- *Undesirable impacts on wildlife habitat*. Many materials that constitute potentially problematic fuels can also serve as important components of wildlife habitat. For example, snags (standing dead trees) provide breeding habitat for a variety of species; surface vegetation provides cover for birds, mammals, reptiles, amphibians, and invertebrates; and surface litter can provide an important substrate for small vertebrates and invertebrates.

- *Threatened and endangered species*. While it must be accepted that any habitat modification will affect plant and wildlife habitat, particular care must be given to habitat that supports or that could support threatened and endangered species. In some cases, even seemingly insignificant modifications can have far-reaching effects on certain species. A careful review should be made of special-status species that could occur in the treatment area, and a thorough evaluation of the impacts of alternative treatments on such species should be conducted.

- *Augmented spread of undesirable species*. Many invasive plant species exploit areas of soil disturbance; such areas can be created by implementation of various treatment methods, especially mechanical methods. Additionally, equipment can transport seeds of invasive species on tires and treads.

- *Augmented disease/pest impacts*. The process of cutting trees and brush precipitates vegetative production of pheromones that attract pests such as wood boring beetles. An influx of such pests can cause damage to remaining vegetation, particularly if stands have been compromised by earlier conditions.

- *Adverse impacts on cultural resources*. The potential of inflicting adverse impacts on cultural resources, which include religious and sacred resources, is largely associated with mechanical treatment options. The environmental review process should address the likelihood of such resources being present in the treatment area and, if they are, to the establishment of suitable protection or mitigation plans.

- *Noise.* Noise can result from a variety of treatment methods (e.g., manual treatments employing chainsaws, mechanical treatments). Noise impacts can disturb human residents in proximity to treatment areas, but they can also cause adverse impacts on wildlife. However, most noise impacts are of fairly short duration.

Economic Considerations

Conventional wisdom suggests that, as a rule, nonburning alternatives are more expensive than burning. Table C-1 shows a generic comparison of the economic costs and benefits associated with prescribed fire and a representative selection of treatment methods. Economic considerations include cost per unit of production, production rate, labor requirements, skill requirements, risks of collateral damage, and the potential generation of revenue from materials produced through the treatment method selected. Because nonburning alternatives are typically more expensive and time consuming than burning, they can present greater challenges in securing funding.

Table C-1. Generic Comparison of Fuel Reduction Treatment Alternatives

Treatment	Cost range	Key benefit	Key problem	Products?
Prescribed fire	$35–300/acre	Low cost	Restricted use	No
Mastication on site	$100–1,000/acre	No smoke	Material left on site	No
Cut/pile/burn	$100–750/acre	Low Access	Burning limitations	No
Whole-tree yarding	$30–40 bdt*	Offsets costs	Soil impacts	Yes
Biomass removal	$34–48 bdt	Usable fiber	High cost, low value	Yes

* bone-dry ton

Adapted from: USDA FS Research and Development. 2003. *A Strategic Assessment of Forest Biomass and Fuel Reduction Treatments in Western States.*

APPENDIX D

TERRESTRIAL ECOSYSTEMS

Midwest Tallgrass Prairie

Historically, tallgrass prairies covered parts of Nebraska, Illinois, Iowa, and Kansas. To the west, the tallgrass prairie graded into shortgrass prairie. To the east, the tallgrass prairie included increasing numbers of trees, first as scattered oak savannahs and gallery forests, eventually becoming forests with prairie openings. These extended eastward into the Ohio Valley.

Tallgrass prairie is primarily made up of grasses and forbs with some shrubs and trees. Prairie plant communities are a result of fire and drought, although some community structure is in part from grazing by bison and elk. Drought not only acts a direct stress on the prairie ecosystem but also dries potential fuels, making conditions for wildfires more likely. In pre-Colombian times, natural fire sources were primarily from lightning strikes, although there is evidence that deliberate fires started by Native Americans were also common. Fires in the prairie usually occurred in 5- to 10-year cycles with moderate regularity. Fire in tallgrass prairies burns above-ground biomass, which kills woody plants and allows sunlight to reach the soil, changing the soil pH and nutrient availability. Grassland fires can cover large areas in a short time as fire fronts are driven by prairie winds. However, because grass is of low fuel quality, grassland fires usually are not intense.

Productivity usually increases following a fire in the prairie. Growth is stimulated by the removal of litter and preparation of the seedbed. In addition, perennials have greater seed production, germination, and establishment after a fire. The seeds of some forbs, such as prairie sunflower, are scarified by fire (allowing gasses and water to enter the seed) and leave dormancy. Growth of native species such as big bluestem, little bluestem, and Indian grass all increase significantly following a fire. Fire promotes grasses at the expense of woody species (in savannahs, these are usually thick-barked species such as bur oak). Because of predominantly westerly winds across American prairies, trees are sometimes found on the eastern bank of streams and rivers that stop fires spread by these winds.

When fire is removed from a prairie ecosystem, woody shrubs and trees eventually replace grasses and forbs. Mowing is not a good replacement for fire in prairies because it does not reduce litter. Grazing is not a good replacement because it exerts a selective pressure on some grass species while leaving others untouched.

Almost exclusively, burning is prescribed for the restoration and maintenance of prairie reserves. In most managed prairies, prescribed fire is introduced on a 2- to 3-year cycle. The time of the year during which these fires are ignited is of primary importance. Plant recovery following a prairie fire is fastest in the spring and fall when soil moisture is high and plants are not producing seeds. If the area is burned when soil moisture is low, or when plants are starting to produce seeds, recovery following the fire will take longer.

Southwestern California Chaparral

Chaparral is a general term that applies to various types of brushland found in Southern California, Arizona, New Mexico, and parts of the Rocky Mountains. True chaparral exists primarily in Southern California and describes areas that have a Mediterranean-like climate with hot, dry summers and mild, wet winters. The chaparral in this region is primarily fire-induced, and grows in soils that are shallow and unable to hold water. Generally, the terrain is steep and displays severe erosion. Variation in species cover throughout the area is attributed to the soil type and exposure, the altitude at which it grows, and the frequency of wildland fires.

Chamise (greasewood) is a common plant in this ecosystem; other important shrubs include manzanitas, Ceanothus, and scrub oaks. Natural fires occur in 15- to 25-year cycles with high regularity. Southern California chaparral dries during the dry summer months when winds blow from the inland deserts toward the Pacific Ocean, so plant growth in this vegetation occurs during the wet winter months. Fires usually occur during the late summer Santa Ana winds, which are strong (up to 60 mph) and dry. These winds tend to drive fire rapidly through the dry brush.

Plants in this ecosystem are adapted to the Mediterranean climate, local soils, and the fire regime. Fire adaptations include vigorous stump sprouting after fires by many shrubs, including the manzanitas, Ceanothus, and scrub oak. Chamise produces dormant seeds that require fire for scarification; these seeds create a large seed bank during nonfire years. In addition, most chaparral plants seed quickly, usually within 3 to 5 years after sprouting. Many of the shrubs, especially chamise, promote fire by producing highly flammable dead branches after about 20 years. Another chaparral plant, Ceanothus, has leaves that are coated with flammable resins. Fires occurring at intervals greater than 20 years are often high intensity because of the large amount of fuel existing in shrub tops. Many nutrients are locked in the foliage of chaparral plants. Through burning, these nutrients are recycled into the soil.

After fires in chaparral, forbs are usually profuse on the newly opened floor. After a year, the plant community is dominated by annual grasses. Five years after a fire, chaparral shrubs once again dominate the ecosystem; for this reason, more frequent fires favor grasses over shrubs. Fire has not been successfully removed from this ecosystem, so how the community would respond to lack of fire is not well-known, although nonfire-adapted trees and shrubs might replace the chamise, manzanita, and Ceanothus.

Wildland fire control in the southern California chaparral ecosystem is very difficult because of the Santa Ana winds, the length of the summer season, and the heat and dryness present throughout the season. This ecosystem contains water-repellent soils, loose surface debris, and steep terrain, all adding to the high risk of unwanted wildland fire. Obstacles to using prescribed burning include the nearness of housing (urban-wildland interface) and the issue of smoke management. Burning also increases the amount of soil erosion, which is especially problematic in developed areas. Some work has been accomplished to replace the chaparral plant community with grasses, but this practice further threatens the existence of species dependent on this ecosystem.

Ponderosa Pine in the Southwest and Intermountain West

Ponderosa pine ecosystems occur as transitions between grasslands and deserts at lower elevations and higher level alpine communities. These ecosystems are found from the southwestern mountains as far north as Washington and Oregon, and east to the Dakotas, sometimes as nearly pure stands of ponderosa pine, and sometimes mixed with other species, such as Douglas fir. This forest community generally exists in areas with annual rainfall of 25 in. (63.5 cm) or less.

The characteristic surface cover in a ponderosa pine forest is a mix of grass, forbs, and shrubs. The natural fire regime has a cycle of 5–25 years, with moderate regularity. These fires tend to be low intensity ground fires that remove woody shrubs and favor grasses, creating open, park-like ponderosa stands.

The life history of ponderosa pine is well-adapted to high-frequency, low-intensity fires. These fires burn litter and release soil nutrients, thus providing a good seedbed for ponderosa pine seeds. For the first 5 years of their life cycle, ponderosa pine seedlings vigorously compete with grasses for survival and are vulnerable to fire. Eventually, at about 5–6 years of age, the tree begins to develop thick bark and deep roots and to shed lower limbs. These factors increase its ability to withstand fire and decrease the possibility of a fire climbing to the crown; crown fires can kill ponderosa pines. Ponderosa needles on the ground facilitate the spread of low intensity ground fires, and reduce grasses that can intensify these fires.

In ponderosa pine stands, fire is generally prescribed on 5–10 year intervals to reduce fuel loads. Shorter burn intervals have insufficient fuel built up to maintain the fire, and longer periods may run the risk of causing tree-killing crown fires. Prescribed fires usually result in maintenance of stand composition.

Douglas fir is commonly found in association with ponderosa pine but is able to survive without fire. Additionally, Douglas firs possess characteristics that enable them to withstand fire when it does occur, making it more resistant to fire than most other conifers. Additionally, the Douglas firs’ abundantly produced seeds are lightweight and winged, allowing the wind to carry them to new locations where seedlings can establish. Douglas fir regenerates readily on sites that are prepared by fire. In fact, nearly all the natural stands of Douglas fir in the United States originated following fire. One of the main benefits of fire in these forest communities is the removal of fuel and consequent reduction in the chances for severe crown fires. Because Douglas fir exists in the presence of other types of trees, the life cycles of many species must be considered when timing a prescribed fire in this type of forest community.

Lodgepole Pine Communities of the Rocky Mountains

Lodgepole pines are found throughout the Rocky Mountains of the western United States, generally in unmixed stands at higher elevations. Major fires occur at intervals of 200–300 years in this ecosystem, and these fire events are often high intensity crown fires that kill trees. Each successional stage of a lodgepole pine community displays different reactions to fire.

At 40–50 years following a stand-replacing fire, herbaceous plants and lodgepole seedlings grow between the snags and the logs that were damaged by the fire. The forest tends to resist fire at this stage, since large logs are the only available fuel and they do not readily burn. From the age of 50 to 150 years, seedlings grow to a height of 50 ft, and the stands become so dense that little sunlight reaches the forest floor, therefore suppressing the growth of the understory. The sparseness of undergrowth also discourages the possibility of wildfire.

It is during the next successional stage of 150 to 300 years that the threat of wildland fire increases. Because of over-crowding, some of the lodgepole pines begin to die, which allows sunlight through, spurring vegetative growth. After 300 years, the original lodgepole pines die, making the forest highly susceptible to wildland fire. The lodgepole pine stands in the Yellowstone area during the 1988 fires, for example, were 250-350 years old.

When fire does not occur, lodgepole pines are sometimes gradually replaced by Engleman spruce and subalpine fir, although the successional pathway is site dependent. Fire regimes in lodgepole pine communities can be very irregular, thus community dynamics are difficult to predict.

Wildland fire management in lodgepole pine communities can be problematic. Fires in these communities tend towards high intensity crown fires. Allowing lightning-ignited fires to burn may result in vast acreages being burned and fires that are difficult to contain within management units. Prescribed fire is difficult to manage for the same reasons and can endanger nearby human communities. Fire suppression, however, creates a fuel buildup that is difficult to manage, and suppression is not consistent with maintaining ecological communities.

Southern Pine Communities

Southern pine forests, consisting mainly of loblolly, shortleaf, or longleaf pines, are found from Texas east to Florida and north to Maryland. Various species of oaks are often present, especially when fire has not occurred recently. Shrubs such as saw palmetto and bayberry can also be present; grasses are also common, such as little bluestem and wiregrass.

Lightning-ignited fires in southern pine communities are common. More frequent fires favor longleaf pines, which are more fire adapted; less frequent fires tend to favor shortleaf and loblolly pines. Frequent fires also create pine savannahs when understory shrubs are burned away, favoring the establishment of grasses beneath the pines. In cases where fire does not occur for 25 years or more, such as when fire is removed from the system or on wet sites where fire seldom occurs, hardwoods such as oaks and hickories gradually replace the pines.

Like many fire-adapted trees, longleaf pine requires mineral soil for seed germination; ground fires prepare the seedbed by removing litter and releasing soil nutrients. The longleaf seedling grows slowly in the early years, devoting much energy to developing a thick root that is protected from fire and to forming a dense protective layer of needles around the buds. Loblolly and shortleaf pines are less fire tolerant than longleaf pine, but the thick barks of these species also make them more fire tolerant than most other competitive tree species.

Jack Pine Communities of the Great Lakes Region

A mixture of pines and other tree species is found in the forests of the Great Lakes states. Red, white, and jack pine grow among paper birch and aspen. Grasses, forbs, and shrubs such as big bluestem, little bluestem, raspberry, blueberry, and huckleberry grow under the trees of these communities. The communities of the Great Lakes states have suffered many disturbances since European settlement, making it difficult to determine the “natural” state of these ecosystems.

Jack pines are small trees, rarely exceeding 80 ft (~24m) in height. They occur in poor soils, usually in open “pine barrens,” and often form savannahs when grasses are present on the thin soils. Fires occur in jack pine stands approximately every 125–180 years.

Jack pine is well-adapted to fire. Serotinous cones, which have a waxy outer coating to protect the seeds, remain on the tree rather than dropping to the forest floor. Seeds can remain viable on the tree for 20 years or longer. When a fire occurs, the thick cone protects the jack pine seed from the intense heat. Jack pine seeds have been known to still be viable after exposure to heat at 1000°F (538°C). That heat, however, opens the scales of the cone and releases the seed onto the ground where the fire has removed much of the existing vegetation and litter. Jack pine seeds require contact with mineral soil to germinate, so fire serves to prepare the seedbed, reduce competition from other plants, and release the jack pine seed. In addition, the short stature of jack pines makes crown fires likely; these very crown fires are necessary to release the seeds from dormancy.

When fire is withheld from jack pine stands, they are replaced by other boreal tree species, such as balsam fir, white spruce, and the hardwoods that occur in this ecosystem. Prescribed fire is used in jack pine stands in central Michigan in order to maintain habitat for the rare Kirtland's warbler, which requires young jack pine stands for nesting.

Alaska's Boreal Forest and Tundra

Alaska is a vast landscape covered with boreal forest and tundra, all prone to wildland fire. The boreal forest is found in southern Alaska extending as far north as Fairbanks. Tundra is found in the higher elevation of this zone. Tundra extends from the Brooks Range north to the Arctic Ocean.

While the boreal forest has large vegetation (e.g., spruce and birch trees) and nutrient-ladened soil, the tundra is a low landscape comprising scrubby and herbaceous vegetation, often only a few inches high. Much of the tundra soil and its nutrients are locked in permafrost. Often the soil is shallow; in some places it is no deeper than the shallow root structure of the tundra vegetation.

On the south-facing slopes of the boreal forest are spruce, birch, and aspen. North-facing slopes contain mostly black spruce and birch. Both of these slopes exhibit a unique succession, the stages of which are greatly impacted by wildland fire.

Following a fire, cottongrass, fireweed, and other herbaceous plants invade. Shrubs and berries move in after a few years only to be replaced by more mature trees such as willow, aspen, and birch. Eventually the spruce becomes established and dominates, usually until the next fire. The heavy mass accumulation of litter makes these forests very susceptible to fire.

Fires in the boreal forest and tundra typically burn in a patchwork, leaving a mosaic across the landscape. Time of year, moisture present, wind speed and direction at the time of the fire, and biomass accumulation since the last fire, etc., all add to the rendering of the mosaic.

Because of Alaska's cool year-round temperatures, vegetation decays at a very slow rate, thereby releasing nutrients at a very slow rate. Following a fire in the boreal forest or tundra, large amounts of nutrients are released. Plants exploit this opportunity, especially the early successional plants. In turn, wildlife exploits the lush growth. Consequently, Alaska's plant and animal communities are highly dependent on fire regimes.

APPENDIX E

REFERENCES

Clean Air Act Extension, Public Law (PL) 91-604, 31 December 1970, as amended in 1990 (PL 101-549).

Department of the Army. 2002. Assistant Chief of Staff for Installation Management (DAIM-ZA) memorandum, subj: Army Wildland Fire Policy Guidance, 4 September 2002, Washington, DC.

Endangered Species Act of 1973, PL 93-205, as amended.

Executive Order 13514. 2009. Federal Leadership in Environmental, Energy and Economic Performance.

National Wildfire Coordinating Group (NWCG). 2003. "Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy."

______. 2008. "Interagency Prescribed Fire: Planning and Implementation Procedures Guide."

Prescribed Fire Smoke Management Guide, 420-1, BIFC-BLM Warehouse, Boise, ID, February 1985.

U.S. National Archives and Records Administration. 2010. Code of federal regulations. Title 40, Subchapter C, Part 50 (40 CFR 50). "National Primary and Secondary Ambient Air Quality Standards."

U.S. Department of Agriculture Forest Service (USDA FS). 1976. "Southern Forestry Smoke Management Guidebook," Gen. Tech. Rep. SE-10. Asheville, NC: USDA FS.

______. 2003. "A Strategic Assessment of Forest Biomass and Fuel Reduction Treatments in Western States," Gen. Tech. Rep. RMRS-GTR-149. Fort Collins, CO: USDA FS, Rocky Mountain Research Station.

U.S. Environmental Protection Agency (EPA). 1995. Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Vol. 1, "Stationary Point and Area Sources," Chapter 13.1, "Wildfires and Prescribed Burning."

APPENDIX F

ABBREVIATIONS

Term	**Spellout**
AR	Army Regulation
BLM	Bureau of Land Management
CAA	Clean Air Act
CERL	Construction Engineering Research Laboratory
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO_2	Carbon dioxide
CONUS	Continental United States
EPA	Environmental Protection Agency; also U.S. EPA
ERDC	Engineer Research and Development Center
FCCS	Fuel Characteristic Classification System
FR	Federal Register
HQUSACE	Headquarters, U.S. Army Corps of Engineers
ICRMP	Integrated Cultural Resources Management Plan
IWFMP	Integrated Wildland Fire Management Plan
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
PM	Particulate matter
POC	Point of contact
PWTB	Public Works Technical Bulletin
SHRMC	Southern High Resolution Modeling Consortium
TES	Threatened and endangered species
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDA FS	United States Department of Agriculture Forest Service
USFWS	United States Fish and Wildlife Service