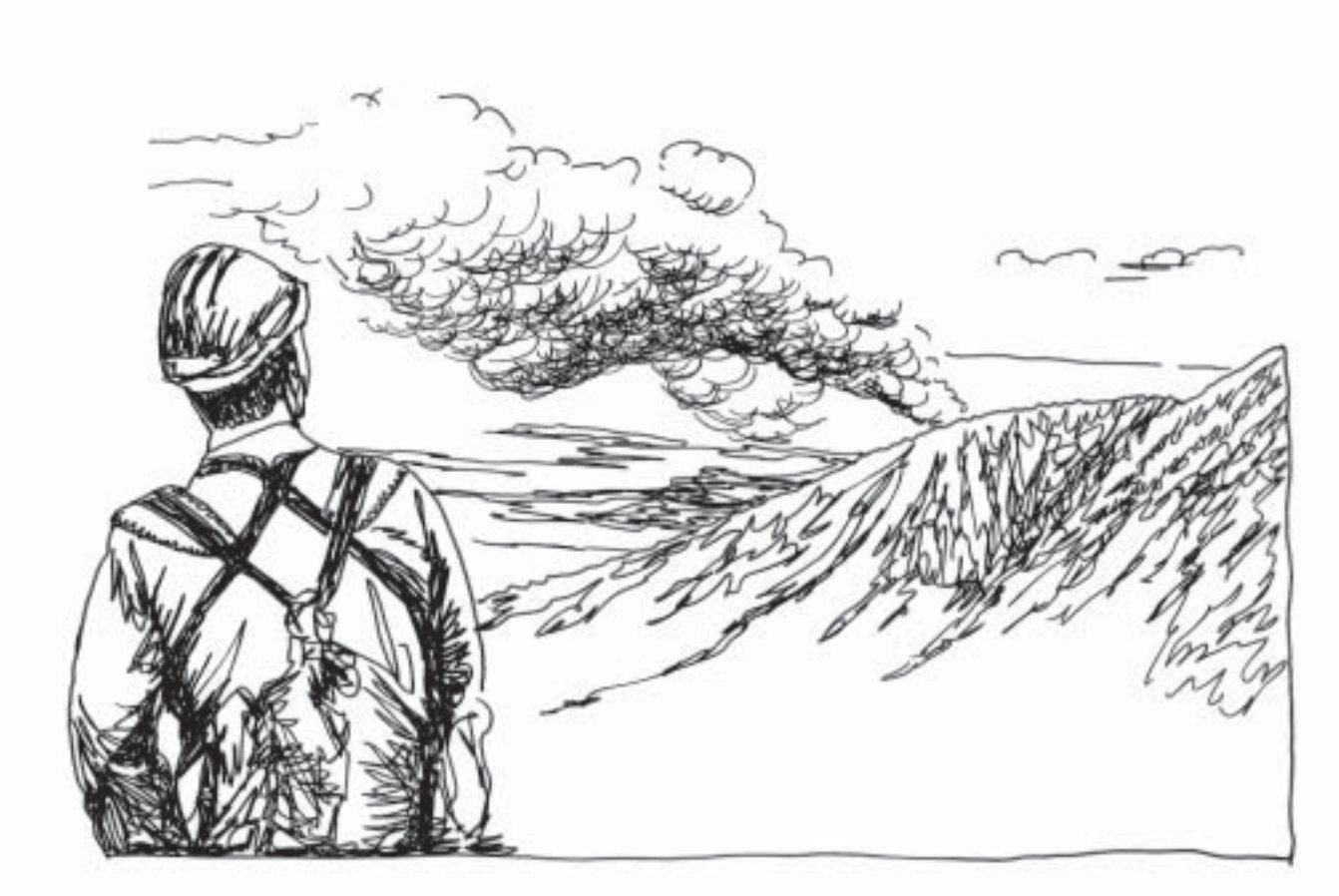
Smoke Management Techniques RX-410



NFES 2476

Student Workbook

SEPTEMBER, 2003

CERTIFICATION STATEMENT

on behalf of the

NATIONAL WILDFIRE COORDINATING GROUP

The following training material attains the standards prescribed for courses developed under the interagency curriculum established and coordinated by the National Wildfire Coordinating Group. The instruction is certified for interagency use and is known as:

Smoke Management Techniques, RX-410
Certified at Level I

This product is part of an established NWCG curriculum. It meets the COURSE DEVELOPMENT AND FORMAT STANDARDS – Fifth Edition, 2001 and has received a technical review and a professional edit.

Member NWCG and Training Working Team Liaison

Date 9/11/03

Chairperson, Training Working Team

Date 9/10/03

Description of the Performance Based System

The NWCG Wildland and Prescribed Fire Qualifications System is a "performance-based" qualifications system. In this system, the primary criterion for qualification is individual performance as observed by an evaluator using approved standards. This system differs from previous wildland fire qualifications systems which have been "training based." Training based systems use the completion of training courses or a passing score on an examination as a primary criteria for qualification.

A performance-based system has two advantages over a training based system:

- Qualification is based upon real performance, as measured on the job, versus perceived performance, as measured by an examination or classroom activities.

- Personnel who have learned skills from sources outside wildland fire suppression, such as agency specific training programs or training and work in prescribed fire, structural fire, law enforcement, search and rescue, etc., may not be required to complete specific courses in order to qualify in a wildfire position.

1. The components of the wildland fire qualifications system are as follows:

   a. Position Task Books (PTB) contain all critical tasks which are required to perform the job. PTBs have been designed in a format which will allow documentation of a trainee's ability to perform each task. Successful completion of all tasks required of the position, as determined by an evaluator, will be the basis for recommending certification.

      IMPORTANT NOTE: Training requirements include completion of all required training courses prior to obtaining a PTB. Use of the suggested training courses or job aids is recommended to prepare the employee to perform in the position.

   b. Training courses and job aids provide the specific skills and knowledge required to perform tasks as prescribed in the PTB.

   c. Agency Certification is issued in the form of an incident qualification card certifying that the individual is qualified to perform in a specified position.

2. Responsibilities

   The local office is responsible for selecting trainees, proper use of task books, and certification of trainees, see appendix A of the NWCG Wildland and Prescribed Fire Qualification System Guide, PMS 310-1, for further information.

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Sponsored for NWCG publication by the NWCG Training Working Team

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Comments regarding the content of this publication should be directed to:
National Interagency Fire Center, National Fire Training Support Group, 3833 S. Development Ave., Boise, Idaho 83705. Email: nwcg_standards@nifc.blm.gov.

Additional copies of this publication may be ordered from National Interagency Fire Center, ATTN: Great Basin Cache Supply Office, 3833 South Development Avenue, Boise, Idaho 83705. Order NFES 2476.

PREFACE

Smoke Management Techniques, RX-410 is identified training in the National Wildfire Coordination Group's (NWCG), Wildland and Prescribed Fire Curriculum. This course has been developed by an interagency development group with guidance from the National Interagency Fire Center, Fire Training Group under authority of the NWCG, with coordination and assistance of personnel from the following agencies:

Bureau of Land Management
Mike Whalen, Brad Washa

U.S. Fish and Wildlife Service
Dennis Haddow

U.S. Forest Service
Ann Acheson, Roger Ottmar, Chuck Vickory

The Nature Conservancy
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National Weather Service
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National Interagency Fire Center, Fire Training Group
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Unit 0 - Introduction

OBJECTIVES:

1. Discuss administrative requirements of the course.
2. Introduce instructors, course coordinator and students.
3. Present course objectives.
4. Explain course process and identify student expectations.
5. Discuss completed pre-course work assignments.
6. Explain course evaluation system.

I. WELCOME

II. ADMINISTRATIVE INFORMATION

Discuss:

A. Transportation

B. Housing

C. Meal schedule/lunches

D. Course hours - night work

III. INTRODUCE INSTRUCTORS AND STUDENTS.

IV. COURSE GOAL AND OBJECTIVES

V. REVIEW COURSE AGENDA

- Time frames
- Teaching process
- Interactive exercises

VI. DISCUSS PRE-COURSE STUDY MATERIAL

Pre-course work will be used to generate topics in the panel discussion and provide examples for the units on State Smoke Management Programs and Incorporating Smoke Management into the Burn Plan.

VII. STUDENT PERFORMANCE

A. Unit objectives define what is expected upon completion of that unit.

1. Unit objectives will be presented at the beginning of each unit.

2. These objectives and lesson objectives will be measured by exercises and a final examination.

B. To satisfy the above objectives, the student must participate in the entire course and complete all exercises and assignments.

VIII. GRADING SYSTEM COMPONENTS

A. The student's grade is based entirely on the final exam. Students must score 70% or higher to successfully pass this course. (Reference: Field Managers Course Guide) The Final exam is closed book. The pre-course work and case studies are not graded due to their subjective nature.

B. Pre-course work – The pre-course work is an important component of the course and allows instructors to customize topics making them relevant to the student's needs. Pre-course work is not graded.

C. Case Studies – The case studies provide students with an opportunity to evaluate "real world" prescribed fire projects using the tools learned in class. The case studies are not graded.

IX. EXPECTATIONS

A. In groups of 3-5, have students list on a flipchart their expectations and expectations from their pre-course study assignment.

B. Groups report their expectations to the class, then post for tracking during the course.

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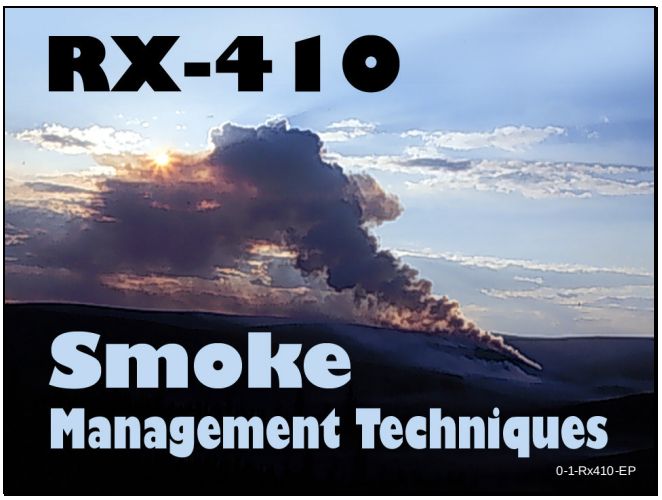

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Unit 0 Introduction

- Administrative requirements
- Introductions
- Expectations
- Course process
- Pre-course work assignments
- Course evaluation

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Overview

Given existing and potential air quality regulations, political and social sensitivities, you will learn to:

- **Predict, manage and monitor prescribed fire smoke.**
- **Describe the legal, professional, and ethical reasons for managing smoke.**
- **Describe the roles of federal, state and local agencies and organizations involved with and affected by smoke from prescribed fire.**

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Unit 1 - The Smoke Management Challenge
Why are we here?

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Discuss, in general, the legal, social, safety reasons and challenges for managing smoke.

2. Discuss, in general, our need to use fire as an ecological tool and reduce hazardous fuels.

3. Discuss, in general, our need to be available to predict, monitor, and minimize the amount and impact of smoke produced from prescribed fire.

4. Discuss how having trained staff to manage smoke will determine our ability to retain prescribed fire as a land management tool.

BACKGROUND: Throughout the country we are working on two programs that have significant public support and benefit: protecting air quality and reducing hazardous fuels. Protecting and improving air quality has been a national goal for a number of years. Recently there has been a national focus on reducing hazardous fuel levels that have contributed to the devastating wildfires over the past few years. Unfortunately, prescribed fire produces air pollutants that can be harmful to sensitive individuals and can obscure the ability to view some of our scenic national treasures.

In general, there are two separate groups working on these two potentially conflicting programs.

As land managers our challenge in using wildland fire is to balance public needs to protect human health and welfare while sustaining ecological integrity.

I. THE AIR QUALITY CHALLENGES

A. New and increasingly stringent National Ambient Air Quality (NAAQs) for fine particulates (PM-2.5). Currently 24-hours is the shortest averaging period but there is a trend to have even shorter air standards in the future (Idaho now has a 1 hour standard in their Emergency Episode Avoidance Plan).

70% or more of emissions from wildland fire are less than 2.5 microns in diameter. These smaller particulates can be taken deep into the lung and have been shown to cause adverse health impacts for certain individuals. High, short-term levels of PM-2.5 may be hazardous to everyone.

B. Regional Haze Regulations that require States to look at all sources including prescribed fire.

Particulates from wildland fire have a diameter that is very effective for scattering light (causing visibility impairment).

C. EPA has identified biomass burning as a source of toxics.

Five of the 33 air toxics that EPA is focusing attention on are emitted from biomass burning (Formaldehyde, Acrolein, Acetaldehyde, 1, 4 Butadiene and Polycyclic Organic Matter).

D. Smoke on the highway has been a continuing cause of death and injury in some parts of the country.

E. State's and EPA's increased air regulatory focus on large industrial sources may result in industry trying to shift some of that focus on prescribed fire.

F. Tools to help manage smoke are becoming more complex.

II. THE FUELS MANAGEMENT CHALLENGES

A. Most ecosystems in the Unites States have evolved under the consistent influence of fire as a process that influences numerous ecosystem functions.

B. Fire exclusion has caused significant changes in plant succession, species composition, nutrient cycles, biotic productivity, plant and animal diversity, and hazardous fuel accumulation.

C. Despite increases in fire management budgets, improvement in firefighting tools, and fire prevention projects the annual average area burned from wildfire is increasing in much of the country.

D. There is significant direction from Congress and agencies to increase fuel reduction targets and reduce hazardous fuels.

III. THE SMOKE MANAGEMENT CHALLENGES

WE NEED:

- To understand the air quality and fuels management challenges.
- To demonstrate the trade offs between wildfire and prescribed fire.
- To provide leadership for increased smoke mitigation practices.
- Tools to predict and monitor smoke emissions.
- Tools to minimize the amount and/or impact of prescribed fire emissions.
- **Trained people** to understand the issues and apply appropriate smoke management tools.

That is why we are here.

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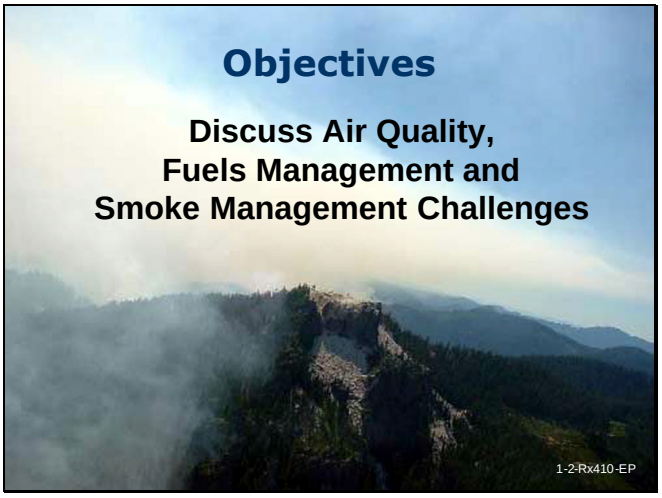

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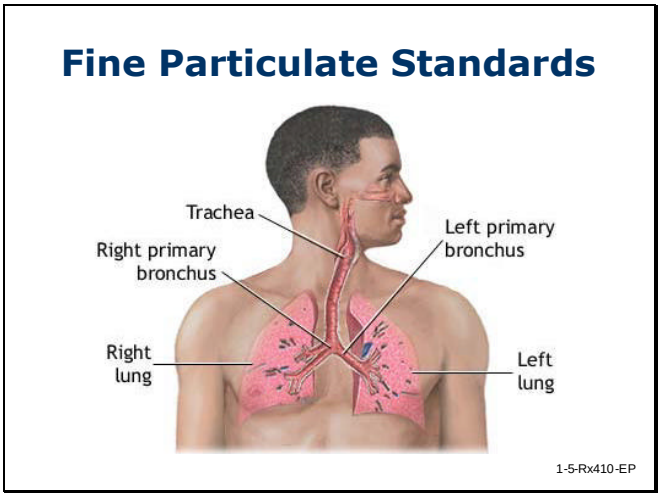

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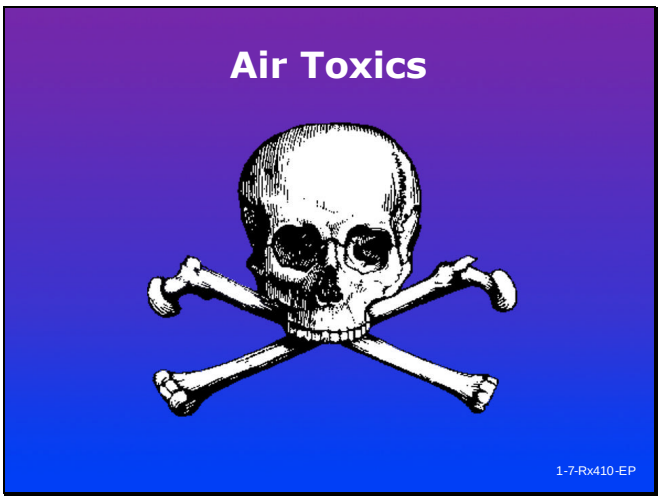

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Unit 2 - Leadership in Smoke Management

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Discuss the relationship between leadership principles and smoke management.

2. Use the Incident Response Pocket Guide to define leadership and specific leadership tasks.

Investigations of tragedy fires have found that lack of leadership is frequently a contributing cause to the tragedy.

- Some firefighters were confused about who was making the decisions on strategy and tactics.
  –From the South Canyon Fire Investigation

- Leadership, management, and command and control were all ineffective due to a variety of factors, such as the lack of communication and miscommunication, fatigue, lack of situational awareness, indecisiveness, and confusion about who was in control.
  –From the Thirtymile Fire Investigation Report

There are many issues in smoke management that require leadership skills. For example, many of you have faced a least one of the following situations:

PEER PRESSURE - You are the burn boss and have 30 people chomping at the bit to ignite, but the wind direction is just out of prescription. What do you do?

ETHICAL DILEMMA - To achieve burn objectives you know that you will produce smoke that has a negative impact on a smoke sensitive area. How do you resolve these conflicting objectives?

CRISIS MANAGEMENT - You just smoked out the highway and an accident occurs. How do you handle the situation?

CONFLICT RESOLUTION - You are the agency administrator and are receiving multiple complaints about smoke management issues. What actions do you take?

MAKING THE HARD CALL - You are an air quality regulator faced with shutting down all burning because emissions exceed minimum standards.

Most position task books have some leadership related tasks, for example:

Leadership Tasks from the Prescribed Fire Burn Boss Task Book (RXB2 and RXB1)

- Demonstrate communication skills as they relate to supervision.
- Articulate performance requirements to subordinates.
- Develop subordinates through training and coaching.
- Brief subordinates on operational procedures, objectives and hazards.
- Lead and direct the actions of subordinates.
- Evaluate the performance of subordinates and take appropriate action.
- Recognize personal fatigue symptoms and take corrective actions such as rotating duties, adjusting rest periods.

Leadership definition:

Leadership means providing purpose, direction and motivation to people working to accomplish difficult tasks, under dangerous, stressful circumstances.

In confusing and uncertain situations, a good operational leader will:

TAKE CHARGE of assigned resources.

MOTIVATE firefighters with a “can do safely” attitude.

DEMONSTRATE INITIATIVE by taking action in the absence of orders.

COMMUNICATE by giving specific instructions and asking for feedback

SUPERVISE at the scene of action.

Leadership in smoke management is:

- **Educating yourself on smoke management issues and being proficient at your job.**

- **Setting the example. Recognize important smoke management issues and teach with your actions.**

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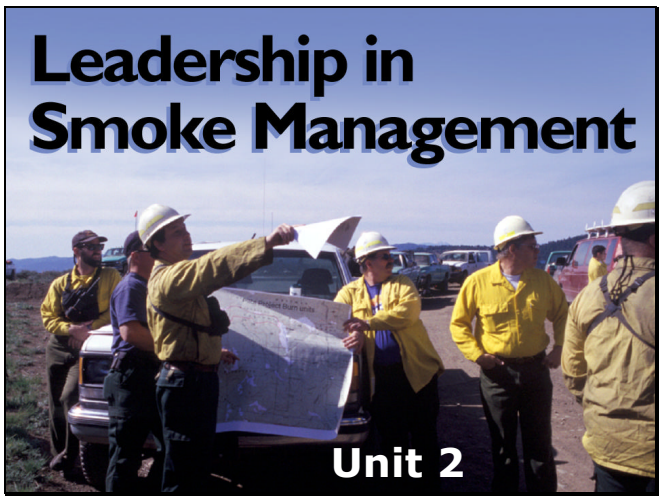

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Unit 2 Objectives

- **Discuss the relationship between leadership principles and smoke management.**
- **Use the Incident Response Pocket Guide to define leadership and specific leadership tasks.**

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Leadership Counts

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Past Experience

Some firefighters were confused about who was making the decisions on strategy and tactics.

– **From the South Canyon Fire Investigation**

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Past Experience

Leadership, management, and command and control were all ineffective due to a variety of factors, such as the lack of communication and miscommunication, fatigue, lack of situational awareness, indecisiveness, and confusion about who was in control.

– **From the Thirtymile Fire Investigation Report**

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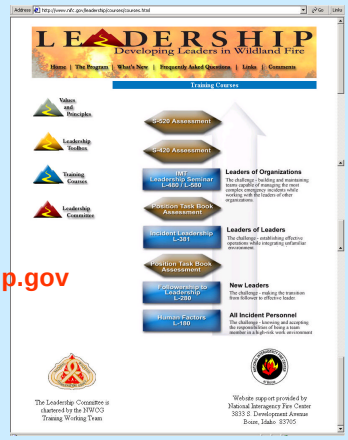
Leadership Curriculum



www.fireleadership.gov

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What does leadership have to do with smoke management?

Consider the following situations:

- Peer pressure
- Ethical dilemma
- Crisis management
- Conflict resolution

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Peer Pressure

You are the burn boss and have 30 people chomping at the bit to ignite, but the wind direction is just out of prescription. What do you do?

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Ethical Dilemma

To achieve burn objectives you know you will produce smoke that has a negative impact on a sensitive area.

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Crisis Management

You just smoked out the highway and an accident occurs. How do you handle the situation?

2-10-Rx410-EP

Slide 11

Conflict Resolution

You are the agency administrator and are receiving multiple complaints about smoke management issues.

What actions do you take?

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Leadership Tasks

from the prescribed fire burn boss task book:

- **Demonstrate communication skills as they relate to supervision.**
- **Articulate performance requirements to subordinates.**
- **Develop subordinates through training and coaching.**

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Leadership Tasks

- Brief subordinates on operational procedures, objectives and hazards.
- Lead and direct the actions of subordinates.
- Evaluate the performance of subordinates and take appropriate action.
- Recognize personal fatigue symptoms and take corrective actions such as rotating duties, adjusting rest periods.

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What is Leadership?

Leadership means providing purpose, direction and motivation to people working to accomplish difficult tasks, under dangerous, stressful circumstances.

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In confusing situations, a good leader will:

- TAKE CHARGE of assigned resources.
- MOTIVATE firefighters with a “can do safely” attitude.
- DEMONSTRATE INITIATIVE by taking action in the absence of orders.
- COMMUNICATE by giving specific instructions and asking for feedback
- SUPERVISE at the scene of action.

2-15-Rx410-EP

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Leadership is…

- Educating yourself on smoke management issues and being proficient at your job.
- Setting the example. Recognize important smoke management issues and teach with your actions.

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Unit 2 Objectives

- Learn the relationship between leadership principles and smoke management.
- Use the Incident Response Pocket Guide to define leadership and specific leadership tasks.

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Unit 3 - Ecological and Historical Role of Fire

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Identify major differences between the pre-European settlement and post-European settlement fire regime periods in the United States as they relate to fire emissions.

2. Describe the need to reintroduce and maintain fire in fire dependent ecosystems and the resulting smoke management implications.

3. Describe the magnitude of prescribed fire occurrence and emission levels in the United States.

4. Describe current policies that govern fuels treatment and fire management.

I. OBJECTIVES

Definition of fire regime –

- Frequency / Return interval
- Scale
- Intensity – general term relating to the heat energy released in a fire (combustion rate, fireline intensity)
- Severity – degree to which a site has been altered or disrupted by fire; a product of fire intensity and residence time (light, moderate, severe)

II. Major differences between pre- and post-European settlement fire regime periods in the United States. How did we get here? Typically, we tend to use the time period of the mid 1880's to early 1900's as the break between "natural" fire regimes and current fire regimes.

A. Reflect on: Past fire regimes in particular region. Knowledge of fire history, fire regimes and fire effects allows land stewards to develop informed management strategies.

1. Fuels characteristics

2. Fire occurrence

3. Return intervals

4. Fire intensity and severity

5. Pre-settlement (Native American fire practices)

6. Post-settlement

7. Air quality records, information or histories

8. Historical studies show that in the past, much more fire was present on the landscape than now.

9. Scale (landscape vs. small sites)

10. Seasonality

B. Post-settlement practices and policies have dramatically altered fire regimes.

1. 10 AM policy – USFS policy to contain and control a fire by 10 a.m. following the initial report.

2. Full suppression and the resulting reduction in acres burned.

3. Resistance to "controlled burning" as a management tool in certain regions of the country became prevalent.

   - Western timber producing states in the 1912 to early 1920 time period.

4. Smoke was not a major national issue until the 1970s.

   - Increase in the number of people living in the wildland urban interface.

5. An increase in world wide land clearing has caused an increase in vegetative burning, leading to increased emissions which may contribute to global climate change.

   - Population increase
   - El Nino/drought
   - Increased CO2 levels, which may result in increased regulations.

C. Recurring fires are often an essential component of the natural environment.

1. Many ecosystems in North America are fire dependent, and periodic burning is essential for healthy ecosystem function.

   a. Harold Weaver, in 1943, reported that the "complete prevention of fires in the ponderosa pine region has certain undesirable ecological and silvicultural effects and that conditions are already deplorable and becoming increasingly serious over large areas."

   b. C. F. Cooper, 1961-"…fire has played a major role in shaping the world's grasslands and forests. Attempts to eliminate fire have introduced problems fully as serious as those created by accidental conflagrations."

   c. In the book "Ecology of a Cracker Childhood", the author makes reference to the clearcutting and replacement of southern longleaf pine by plantations of slash and loblolly pine and the resulting change in understory and species composition. Now, J. Walker (1993) cites at least 66 rare plant species in the southeast that are maintained by frequent fire.

2. Fire acts at landscape, community, population and individual scales.

3. Humans have altered fire regimes, especially fire frequency and severity.

   a. Bar graph showing average annual burned acreage in the Western US

b. Condition Class Maps

Shows vegetation types at risk due to fuel buildup (fire exclusion), drought and insect damage.

(1) Increase in size and severity of wildfires

(2) Loss of species diversity

(3) Site degradation

(4) Change in vegetative structure and composition

(5) A marked increase in invasive species

(6) Increased risk to communities and firefighters

(7) Increased risk to the public from wildfire emissions

c. Leenhouts estimated acres burned in pre-industrial times (200-400 years ago) and compared it to current data. To see the full study, link to:

http://www.consecol.org/vol2/iss1/art1/index.html#Abstract

(1) Results suggest 10 times more area burned in pre-industrial area

(2) Adjusted for land use changes, suggests about 50% less land is burned currently

d. Similar studies have tried to estimate emissions

The amount and character of emissions have changed due to changes in fire type and frequency. Most wildfires in pre-European times were high frequency and low intensity, but high-intensity wildfires are now common. One study estimates 53 million pounds of respirable particulate matter was produced over a 58-day period from Oregon's Silver Fire in 1987.

III. MAGNITUDE OF PRESCRIBED FIRE OCCURRENCE AND EMISSION LEVELS IN THE US.

A. Mandate for fuels treatment nationally with an emphasis on prescribed fire; National Fire Plan; "health of the land" issues; fuel loading reduction; restoring lost species diversity.

B. Trend toward rapid increase in acreage burned by prescribed fire and the resulting emission levels.

Under the same conditions, if it is a wildfire

- You have no control of production and transport of emissions.
- Smoke produced from wildfire is two to four times that of prescribed fire. (Reference Ottmar and others, 2000)
- You don't have the planning and operational strategies to minimize smoke production and impacts.

IV. CURRENT POLICIES THAT GOVERN FUELS TREATMENT AND FIRE MANAGEMENT.

A. Current conditions and recent events have focused the need to change fire management strategies.

Fire and smoke do not respond to political or artificial boundaries, therefore collaborative efforts are required for these new strategies to succeed.

1. New federal policies and guidance emphasize the need for:

   a. More detailed analysis of smoke effects from projects and as a result tighter constraints

   b. Intensified modeling and monitoring

   c. Improved fire prevention and suppression

   d. Hazardous fuels reduction

   e. Restoration of fire-adapted ecosystems

   f. Community assistance

2. EPA's Interim Air Quality Policy on Wildland and Prescribed Fire (1998) provides guidance on air quality issues relative to prescribed fire. Goals of the document are:

   a. To allow fire to function, as nearly as possible, in its natural role in maintaining healthy wildland ecosystems

   b. To protect public health and welfare by mitigating the impacts of air pollution emissions on air quality and visibility. The document identifies significant procedural and legal benefits for states, tribes, and users of wildland fire if they develop smoke management programs that are state certified.

3. State/tribal smoke management programs have been established or updated. The purposes of smoke management programs are:

   a. To minimize the amount of smoke entering populated areas, preventing public health and safety hazards, and problems at sensitive receptor sites.

   b. To avoid significant deterioration of air quality and National Ambient Air Quality Standards.

   c. Over time, reduce human-caused visibility impacts in Class I areas.

   d. Reduce / avoid nuisance smoke intrusions,

B. Past successes and future commitment.

1. Explain past advances in knowledge, development, and cooperation by federal, state, tribal, and local fire managers, land managers, and air quality regulators.

2. Our challenge is to further the leadership role the land management agencies have shown in innovative techniques, new information, technology, and to share this with our partners, outside agencies, and the public.

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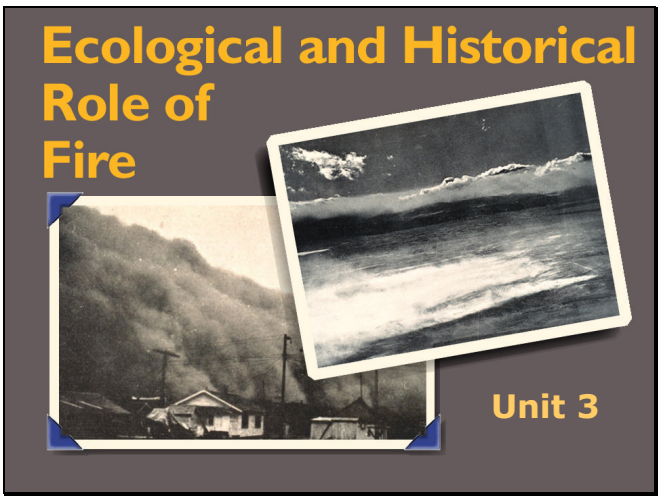

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Unit 3 Objectives

- Identify major differences between the pre- and post-European settlement fire regime periods in the U.S. as they relate to fire emissions.
- Discuss the need to reintroduce and maintain fire in fire-dependent ecosystems, and the resulting smoke management implications.
- Describe the magnitude of prescribed fire occurrence and emission levels in the U.S.
- Describe current policies that govern fuels treatment and fire management.

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Slide 3

Fire Regime

- Frequency/Return Interval
- Scale
- Seasonality
- Intensity
- Severity

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Slide 4

Major Differences Between Pre- and Post- European Settlement Fire Regime Periods

- Past fire regimes have been changed or manipulated.
- Knowledge of fire history, fire regimes and fire effects allows land managers to develop informed management strategies.

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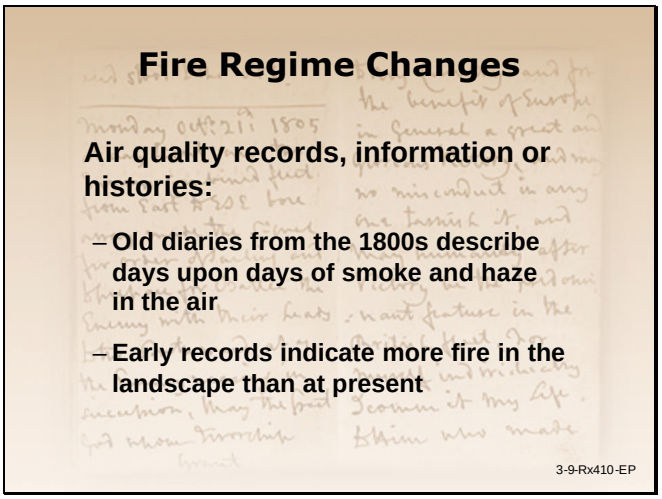

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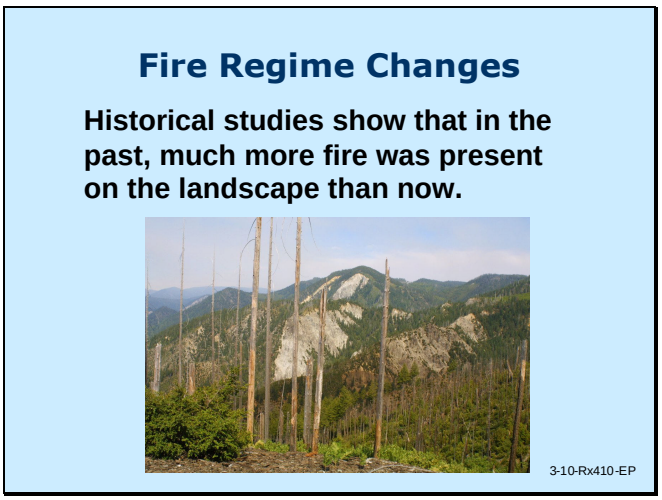

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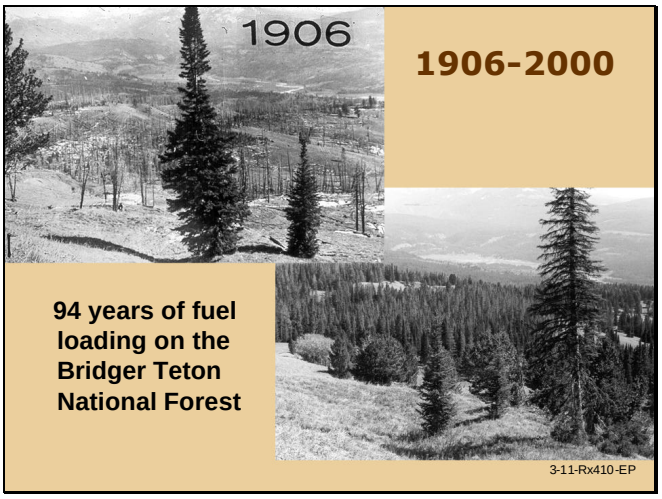

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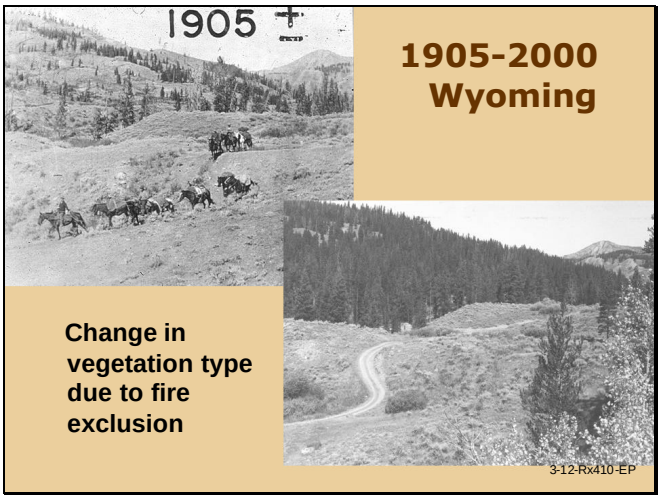

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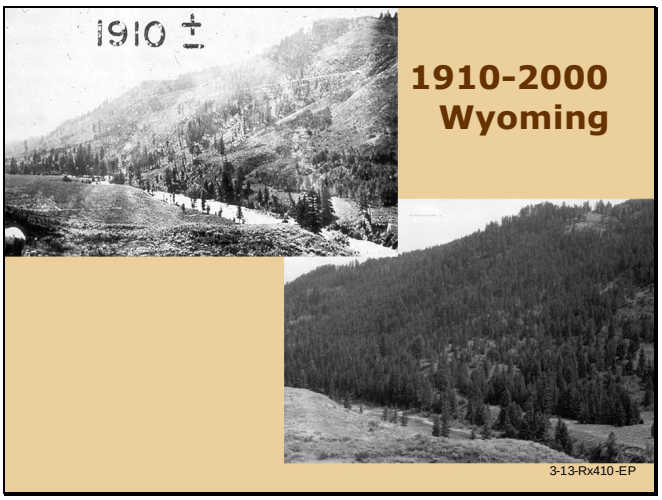

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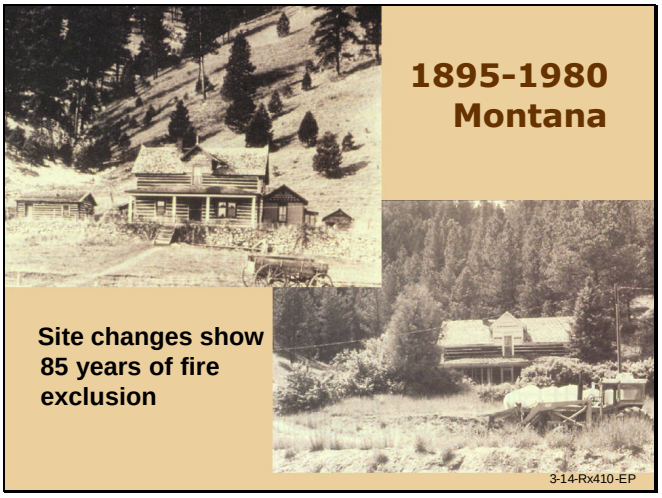

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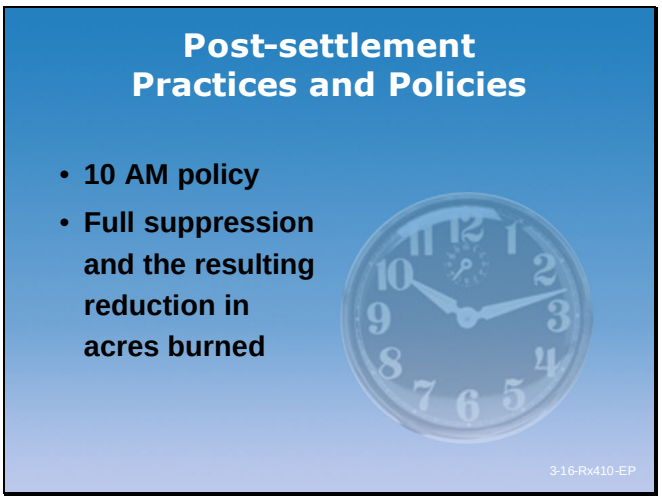

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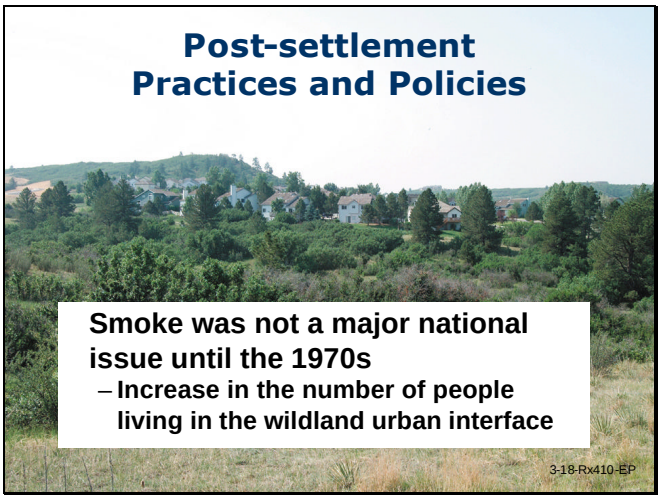

Slide 19

Post-settlement Practices and Policies

An increase in world wide land clearing has caused an increase in vegetative burning, leading to increased emissions which may contribute to global climate change

- **Population increase**
- **El Nino/drought**
- **Increased CO_2 levels, which may result in increased regulations**

3-19-Rx410-EP

Slide 20

Post-settlement Practices and Policies

Recurring fires are often an essential component of the natural environment

- **Many ecosystems in North America are fire dependent, and periodic burning is essential for healthy ecosystem function**

3-20-Rx410-EP

Slide 21

Post-settlement Practices and Policies

Harold Weaver, in 1943, reported that the *"complete prevention of fires in the ponderosa pine region has certain undesirable ecological and silvicultural effects and that conditions are already deplorable and becoming increasingly serious over large areas"*

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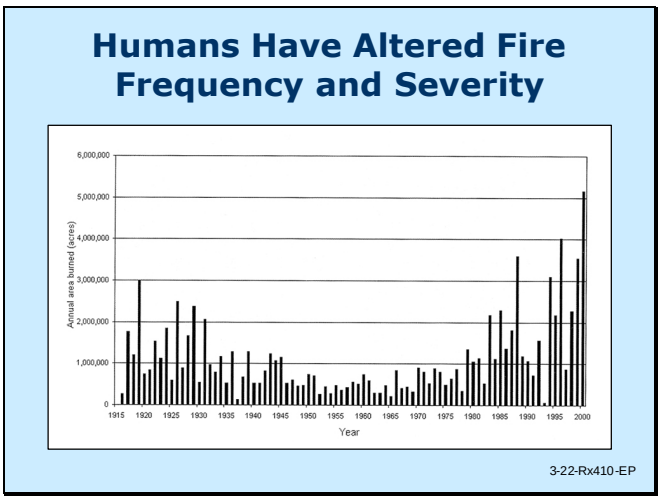
Slide 22



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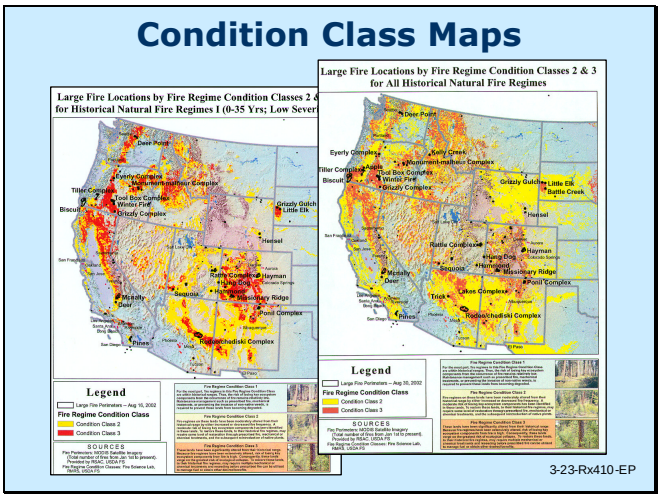

Slide 24

Slide 25

Results of Fire Exclusion in North American Ecosystems

- Loss of species diversity
- Site degradation
- Change in vegetative structure and composition

cheatgrass

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Slide 26

Results of Fire Exclusion in North American Ecosystems

A marked increase in invasive species

yellow star thistle

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Slide 27

Results of Fire Exclusion in North American Ecosystems

- Increased risk to communities and firefighters
- Increased risk to the public from wildfire emissions

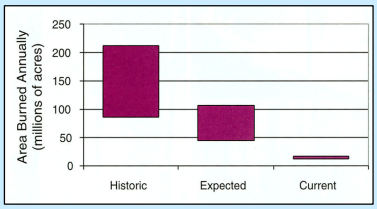
3-27-Rx410-EP

Slide 28

Comparative Acres Burned

Leenhouts estimated acres burned in pre-industrial times (200-400 years ago) and compared it to current data

- **Results suggest 10 times more area burned in pre-industrial area**
- **Adjusted for land use changes, suggests about 50% less land is burned now.**



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Slide 29

Present Magnitude of Prescribed Fire Occurrence

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Slide 30

Example

Under the same conditions, if it is a wildfire:

- **You have no control of production and transport of emissions**
- **Smoke produced from wildfire is two to four times that of prescribed fire. (reference Ottmar and others, 2000)**
- **You don't have the planning and operational strategies to minimize smoke production and impacts.**

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Slide 31

Summary

Years of fire exclusion and different land use patterns have generated new national policy to address the historical role of fire, and current resource management practices.

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Slide 32

Unit 3 Objectives

- **Identify major differences between the pre- and post-European settlement fire regime periods in the U.S. as they relate to fire emissions.**
- **Discuss the need to reintroduce and maintain fire in fire-dependent ecosystems, and the resulting smoke management implications.**
- **Describe the magnitude of prescribed fire occurrence and emission levels in the U.S.**
- **Describe current policies that govern fuels treatment and fire management.**

3-32-Rx410-EP

Smoke Management Techniques, Rx-410

Unit 4 - Characteristics of Smoke from Wildland Fire

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Describe the key compounds of smoke as a pollutant.

2. Identify emission factors for various chemical compounds, particle size distribution and possible air toxins.

3. Relate major concerns about smoke to its physical and chemical characteristics.

Air is a resource and that resource is limited. An airshed can only hold so much smoke until impacts on the health and welfare of the public and visibility degradation begin to occur.

Here are a few concerns about smoke:

- Health of the public (young and the old, individuals with chronic respiratory problems) and firefighters (lung function decrease, loss of mental acuity from overexposure to carbon monoxide)

- Safety (visibility impairment leading to automobile accidents)

- Liability (visibility impairment leading to automobile accidents)

- Laws and Regulations (National Ambient Air Quality Standards, State Implementation Plans)

- Nuisance (blackened laundry, plume blight)

- Social/Political (individuals moving to areas they assume will be less polluted)

- Threatened and Endangered Species (no burning during T&E breeding period)

Section 109 of The Clean Air Act requires EPA to create Primary Air Pollutant Standards to protect human health and Secondary Standards to protect human welfare and the environment.

Primary air quality standards are designed to protect the most sensitive members of the public including the very old, the very young, and members with heart and lung problems.

The primary and secondary air quality standards are called the National Ambient Air Quality Standards (NAAQS) for certain pollutants, called criteria pollutants. They are ozone, nitrogen oxides, lead, carbon monoxide, sulfur oxides, and particulate matter.

Of these, carbon monoxide and particulate matter are produced by wildland biomass burning in significant concentrations. Particulate matter is the criterion of most concern from wildland fire.

A perfectly efficient combustion environment would create only water and carbon dioxide. However, nature is very rarely perfect. During the four combustion phases, many compounds and gases are generated including hot air, gases, soot and tars, particulate matter, carbon monoxide, and carbon dioxide.

The larger particles of soot, water, tars, and ash are the small "bits" of particles you can often see formed from chemical reactions in the plume (soot) or remnants of the flaming stage (ash). The vapors and gases such as carbon monoxide are not visible.

The primary smoke products from prescribed and wild fire include carbon dioxide, water vapor, carbon monoxide, particulate matter, hydrocarbons, other organics, nitrogen oxides, and trace minerals. The majority of the emissions from wildland fire are carbon dioxide, carbon monoxide, and particulate matter.

The strength of a given smoke emission is described by a term called an "emission factor." Emission factors are expressed in terms of the mass of emission released per mass of fuel consumed. In that way, if the oven-dry mass of fuel consumed is either known or predicted, the mass of an emission can be calculated. In the case of smoke emission, the units are expressed either as grams of emission per kilogram of fuel consumed (g/kg), or pounds per ton of fuel consumed (lb/ton). If the emission factor is in grams per kilogram, multiplying by 2 will roughly convert it to pounds per ton.

Emission production is very easy to calculate. Basically, you multiply the fuel consumed (tons per acre) by an emission factor (pounds per acre) for the pollutant of concern to obtain emission produced (pounds per acre). Once you have obtained the emissions produced per acre, one multiplies this by the number of acres burned (black acres) and obtain total emissions (pounds or tons).

Carbon Dioxide (CO2): Carbon dioxide is produced during a fire when the carbon of the fuel (50% of the fuel is carbon) combines with two molecules of oxygen of the air (O2). In other words, there is more mass of CO2 produced than the mass of fuel that was consumed to produce it. This reaction occurs very strongly during

the flaming phase and it is interesting to note that the emission factor is higher during the more efficient flaming stage and lower during the less efficient smoldering phase. The emission factor is generally higher during less efficient smoldering stage as compared to the flaming stage in most other compounds generated during a wildland fire.

The carbon dioxide emission factor for prescribed burning is 2,000-3,500 lbs/ton. That is, for every ton of organic matter burned, between 2,000 and 3,500 pounds of carbon dioxide is produced. Please note that the range of emission factors for a particular compound is generally large because it represents emission factors for both the flaming and smoldering phase. Carbon dioxide is not regulated by EPA or the States. However, increases in carbon dioxide concentrations in the atmosphere may play a role in global climate change. Global climate change is rapidly becoming one of the most "important" environmental issues. However, all decomposition of organic material, either by fire or microbial action, produces carbon dioxide.

Carbon Monoxide (CO): The carbon monoxide emission factor for prescribed burning is 20-500 lbs/ton. Carbon monoxide is a colorless, odorless gas that can cause health effects and even death at high concentrations. It is classified as a criteria pollutant by EPA. That is, EPA considers ambient carbon monoxide concentrations enough of a threat to health and welfare that it has developed ambient air quality standards to protect the public. As a result of rapid dilution, carbon monoxide emissions from prescribed burning are not a concern to the general public. However, carbon monoxide emissions may be a concern to firefighters and persons on prescribed burning crews.

Particulate matter (PM, PM 10, PM 2.5): Particulate matter is any solid or liquid particles less than 100 microns in diameter that are suspended in the atmosphere. A micron is equal to 1/25,000 of an inch or one millionth of a meter.

The emission factor for particulate matter is 10 100 lbs/ton. Particulate matter is presently the major pollutant of concern from prescribed burning and is a criteria pollutant. It has a direct effect on human health and welfare, adverse impacts on firefighters, and can cause major visibility impairment. Finally, particulate matter can carry small compounds called polycyclic aromatic hydrocarbons (PAHs) deep into the lungs. These compounds are known to be carcinogenic.

Particulate matter is described and regulated on the basis of the size fraction, or size class, of the particles. The size of a particle is determined by the aerodynamic mass and diameter, and is expressed in terms of micrometers, or microns, from the combustion of woody biomass.

Definitions of particulate matter:

- PM = all particulate matter
- PM_{10} = All particulate matter less than or equal to 10 microns in diameter.
- $PM_{2.5}$ = All particulate matter less than or equal to 2.5 microns in diameter.

Smoke particles from wildland fires are relatively small.

- 10% by mass are greater than 10 microns in diameter (fly ash)
- 20% by mass are between 2.5 and 10 microns in diameter (dust)
- 70 % by mass are smaller than 2.5 microns in diameter (pollen)

This slide illustrates, with a pie chart, the size class distribution of particle matter in smoke from wildland fires.

This slide shows the size comparison of PM, PM 10 and PM 2.5. 100,000 smoke particles equal a piece of beach sand.

The human body has defense mechanisms to reduce the impact of particulate matter entering the respiratory system. The nose hairs and mucous capture most of the large particles greater than 10 microns. The second line of defense is the trachea where mucous and cilia capture many of the particles greater than 5 microns. However, many of the smaller particles less than 5 microns will make it to the lower parts of the lung and be deposited. As seen in the previous slides, 70 percent of the particles generated by wildland fire are less than 2.5 microns in diameter and thus can enter the human airways and be deposited deep in the lungs thus causing respiratory problems.

Particulate matter can cause health problems including increased premature deaths, respiratory ailments, lung function decrements, increased work loss, change in lung function, structure, and natural body defenses. A recent research study of 90 major cities in the Untied States indicated that a 0.5 % increase in daily death rate can be expected for each 10 micrograms per cubic meter increase in PM 10 exposure.

Because of the impact of particulate matter on health and visibility, particulates are a criteria pollutant. EPA has developed particulate standards and visibility regulations.

The PM 2.5 standards are:

- 15 µg/m3, annual arithmetic mean
- 65 µg/m3, 24-hour average

The PM 10 standards are:

- 50 µg/m3, annual arithmetic mean
- 150 µg/m3, 24-hour average

In extreme cases, smoke from wildland burning can severely reduce visibility and be a high health risk, especially for those individuals with respiratory aliments.
This slide is a photograph of young men playing soccer in Maraba, Brazil. The smoke is from agricultural and land clearing burning in the Amazon.

Some examples of extreme cases of wildland fire smoke include:

- 1910 - Coeur d'Alene lights on by 3 PM
- 1987 - Happy Camp, CA. > 4000 µg/m3
- 1992 - Maraba, BZ. > 3500 µg/m3
- 2000 - Idaho and Montana wildfires > 1500 µg/m3

A majority of the smoke particles generated by wildland fire are about the same diameter as the wavelength of light and scatter about 85 percent of the light that strikes them. The particles are also generally made up of organic and elemental carbon and absorb light. The scattering and absorption of light by the particles generated by wildland fire cause regional haze and visibility impacts. In addition, the particles are so small that once lofted into the atmosphere, they can stay suspended for many days. For example, it takes 35 days for a particle between 0.1 and 1 micron in diameter to fall 1000 feet.

The hydrocarbons emission factor for prescribed fire is 4 40 lbs/ton. While hydrocarbons are not a criteria pollutant, they may impact health and visibility.

The water vapor emission factor for prescribed burning is 500 1,500 lbs/ton. The only possible concern about water vapor is visibility reduction in the vicinity of the fire.

The nitrogen oxides emission factor for prescribed fire is 1 9 lbs/ton. Nitrogen oxides are a criteria pollutant and can impact health and visibility. However, the low emission factor for nitrogen oxides for wildland fire virtually eliminates it as an ambient air quality concern.

Secondary emissions pollutants are formed in the atmosphere by photochemical transformation of primary emissions. They include oxidants such as ozone which is a criteria pollutant. The specific emission factors for secondary emissions from prescribed burning are unknown but are believed to be relatively small. At this time, secondary emissions from prescribed burning are not a major concern. Ozone will be discussed in more detail next.

The photo chemical reaction that takes place during ozone formation is very complex. Simply stated, in the presence of sunlight, oxygen (O2) reacts with nitrogen oxides (NOx) and Volatile Organic Compounds (VOCs) to produce ozone (O3). The simple equation is:

$$\mathbf{VOCs + O_2 + sunlight \;>>\; O_3 + NO}$$

VOCs are organic chemicals that easily vaporize at room temperature and are called organic because they contain carbon in their molecular structure. VOCs have no color, smell or taste and are often produced from the burning of coal, oil, gasoline, and vegetative material.

Hazardous Air Pollutants (air toxics)

> An air toxic is defined in the 1990 Clean Air Act as "...pollutants which present, or may present, through inhalation or other routes of exposure, a threat of adverse human health effects (including, but not limited to, substances which are known to be, or may reasonably be anticipated to be carcinogenic, mutagenic, teratogenic, neurotoxic, which cause reproductive dysfunction, or which are acutely or chronically toxic)...".
>
> Fire emits numerous toxic substances. Some components of smoke, such as many polycyclic aromatic hydrocarbons (PAH) are carcinogenic. Other components, such as the aldehydes (i.e., acrolein and formaldehyde), are acute irritants. These are most likely to affect forest workers who receive high exposures to smoke at a wildland fire. This will be covered in more detail in the unit Fire Personnel Impacts.

EPA has developed a National Air Toxics Assessment for 33 of the 188 air toxics listed by Congress in the Federal Clean Air Act. This presents quantitative estimates of typical public exposures and health risks from pollutants known or suspected of causing cancer or other serious health problems. EPA has identified forest and wildfires as sources of 5 of the 33 including Acetaldehyde, acrolein, butadiene, formaldehyde, and polycyclic aromatic hydrocarbons.

These compounds are generally created in limited quantities and often disperse very quickly once away from the source. Very little is known about the risk from toxics emitted by wildland fires. There is good reason to believe firefighters and the public are at risk. Limited knowledge exists at this time about how much is produced from fires and the history of compounds once generated.

Toxics such as lead and mercury can be released from a fire. Although a very small amount might be a part of the natural vegetation, it is believed a majority is from industrial or automobile emissions deposited on the vegetation that burns.

These summary slides stress the primary components of smoke, secondary emissions, toxic emissions, what an emission factor is, and how to calculate the production of a pollutant of concern.

This is a midday photograph of the Los Angeles basin taken from about 4,000' northeast of LA. Not all of the visibility impairment can be attributed to particulate matter; much of LA's problems are from secondary emissions (formed in the atmosphere).

SUMMARY

Smoke from prescribed fires includes visible materials such as tar, soot, and water; components you cannot see include gases and organic vapors.

Some components of smoke are listed in the Clean Air Act as “criteria pollutants.” Of the criteria pollutants, smoke from wildland fires includes significant amounts of carbon monoxide as well as particulate matter.

Primary smoke products include carbon dioxide, carbon monoxide, water vapor, particulate matter, hydrocarbons, nitrogen oxides, and other “secondary” emissions.

Emission factors describe the “strength” of a particular smoke emission in terms of mass of smoke per mass of fuel consumed.

Particulate matter is the major pollutant of concern from prescribed burning. The extent of both the health and the visibility impacts of particulate matter is dependent upon the size of the particles. Respirable particulate matter is smaller than 10 microns. Nearly half of all particles smaller than 1 micron are deposited and diffused on the alveoli. Particles between 0.4 and 0.8 microns in diameter are near the wavelength of light, and are therefore excellent scatterers of light.

Small amounts of toxics are produced but generally they disperse quickly from the source of the fire.

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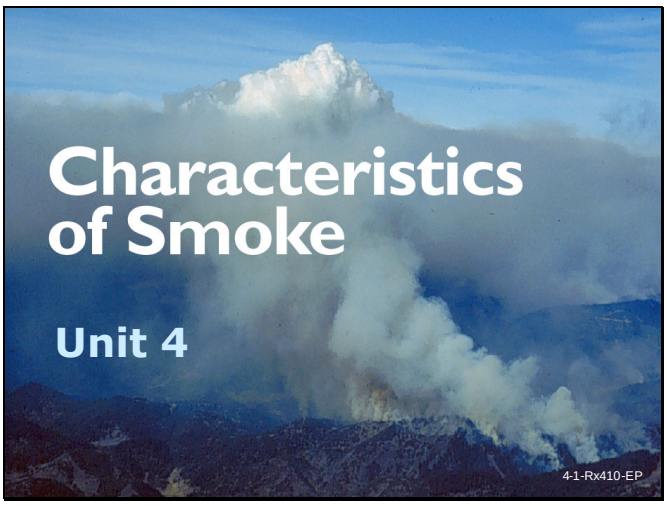

Slide 2

Unit 4 Objectives

- Describe the key components of smoke as a pollutant.
- Identify emission factors for various chemical compounds, particle size distribution, and possible air toxins.
- Relate major concerns about smoke to its physical and chemical characteristics.

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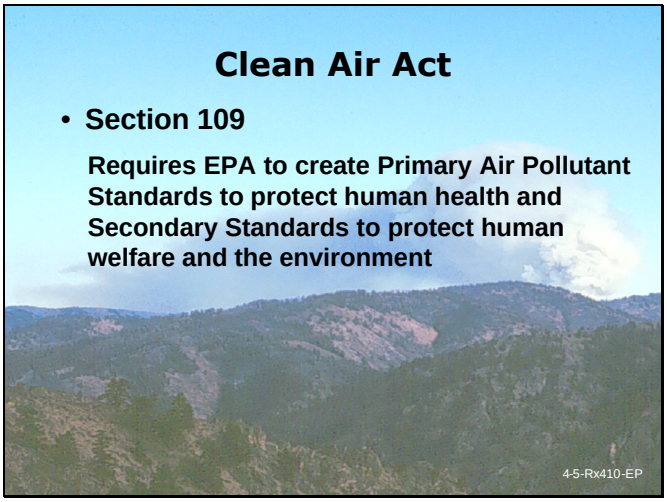
Slide 3

Slide 4

Slide 5



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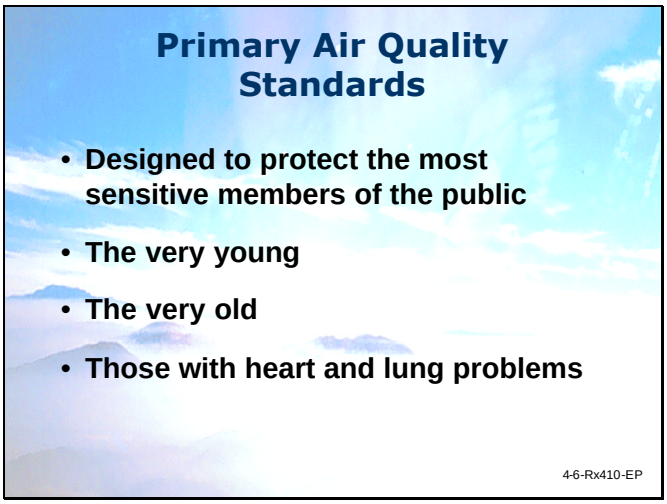

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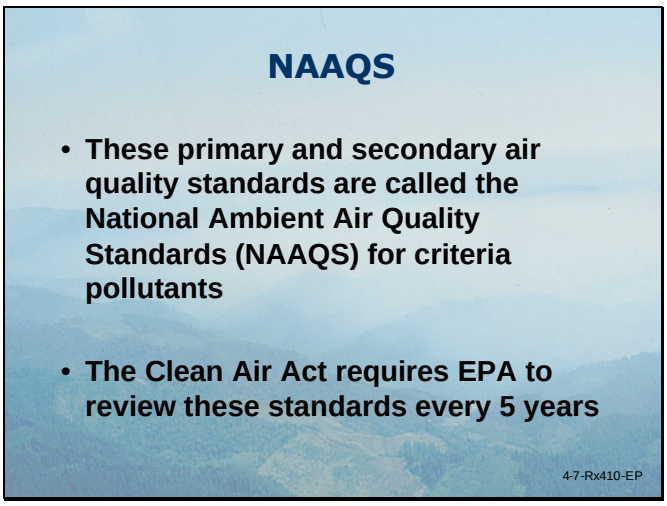

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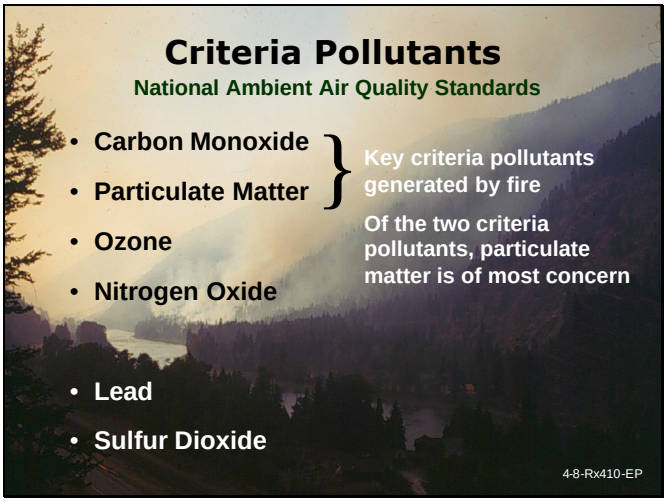

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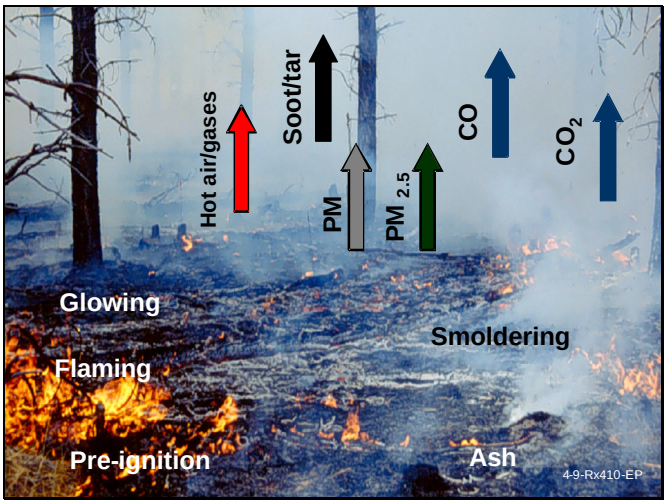

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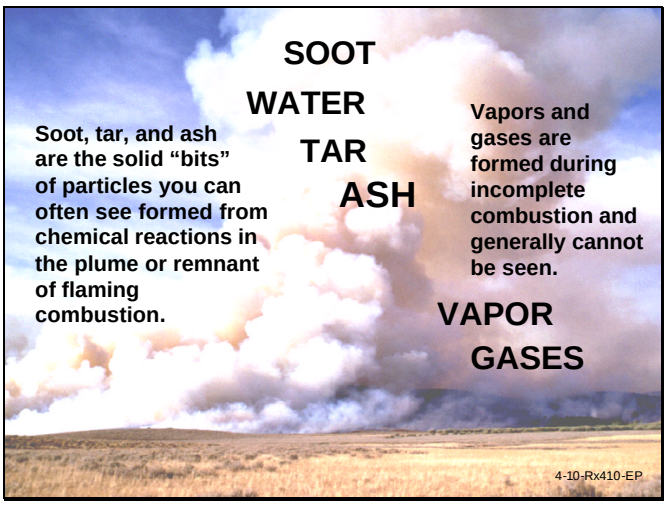

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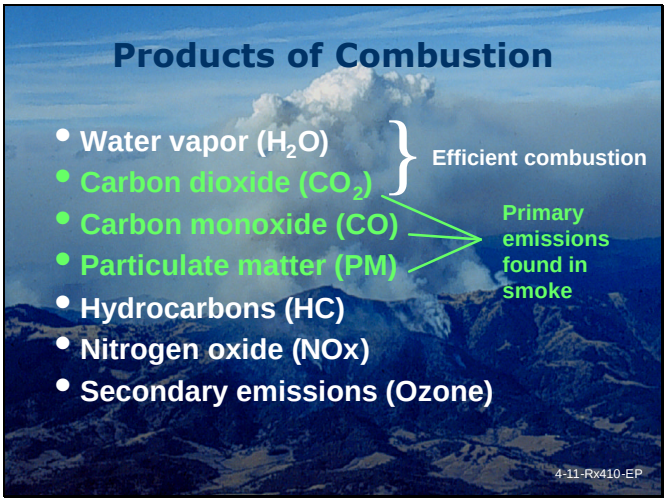

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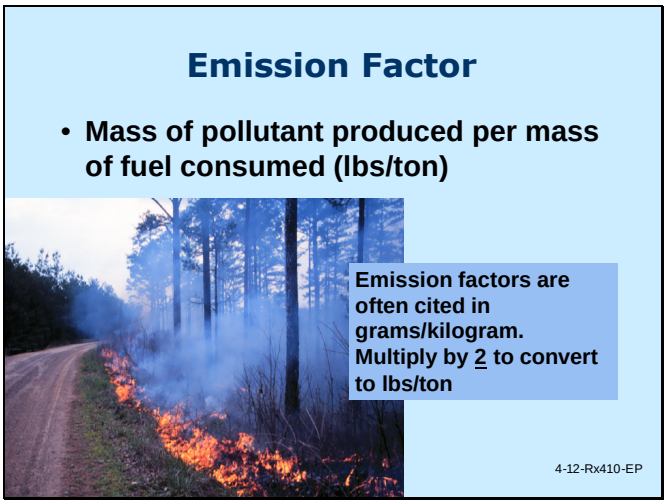

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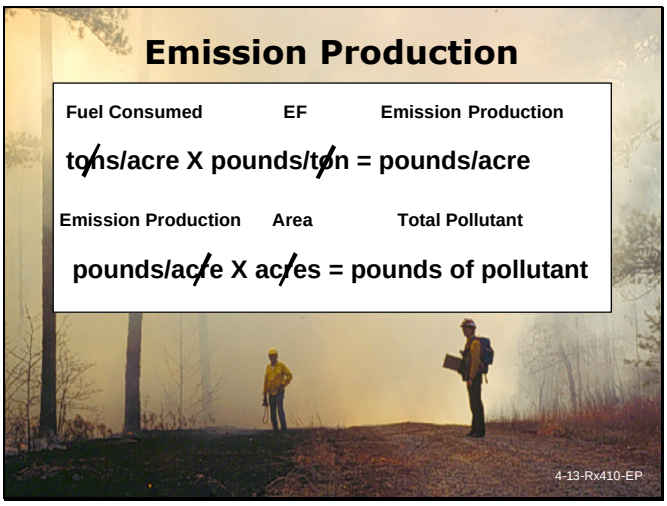

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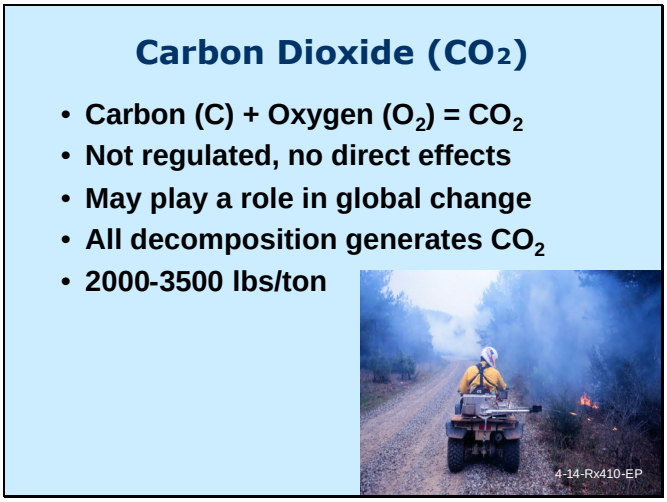

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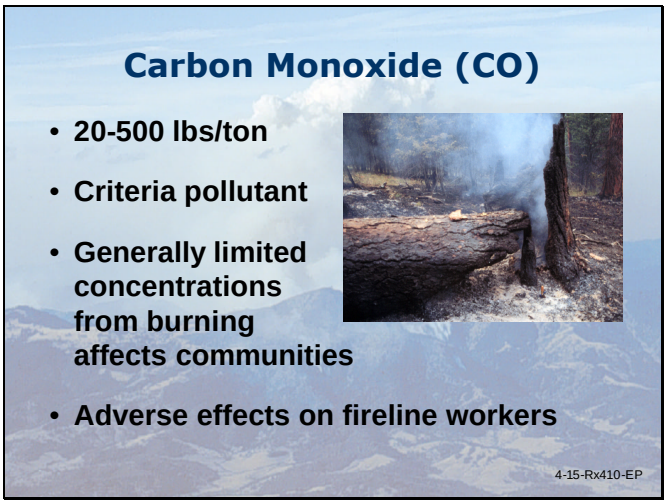

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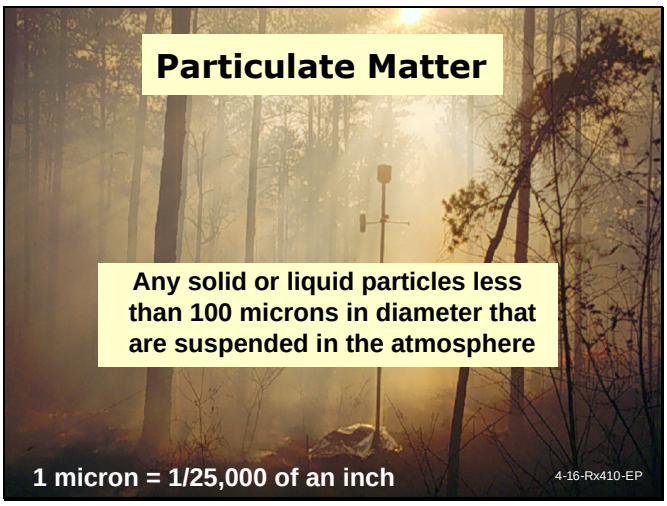

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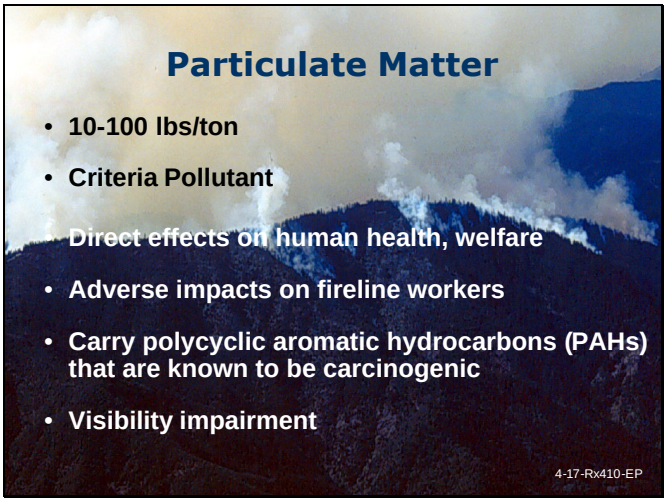

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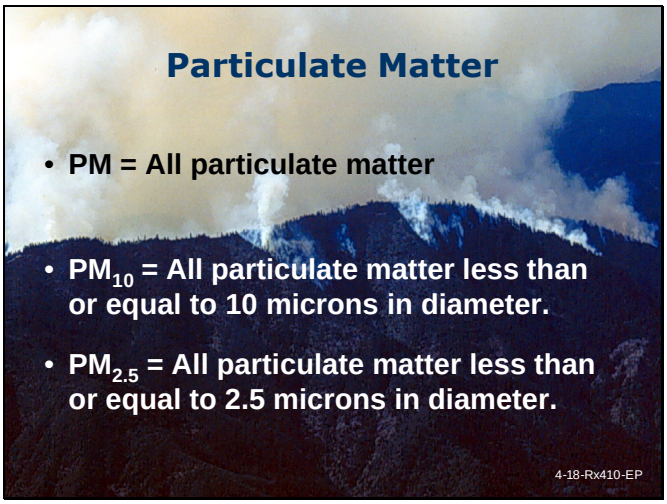

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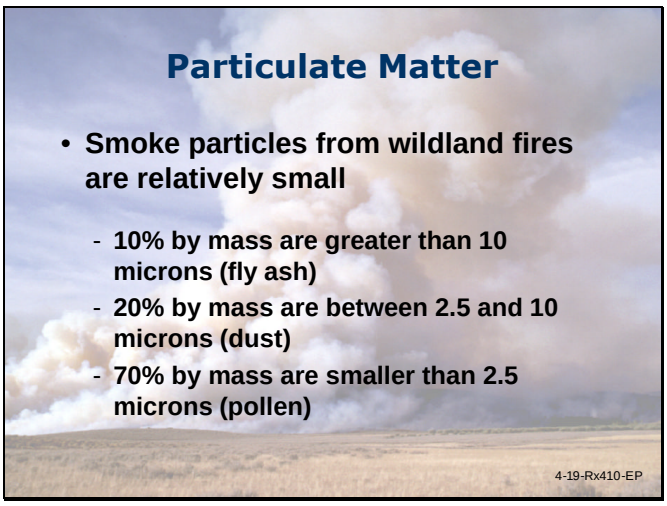

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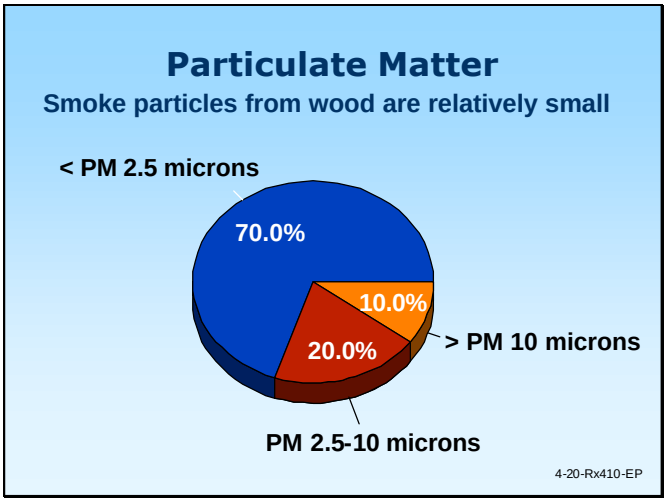

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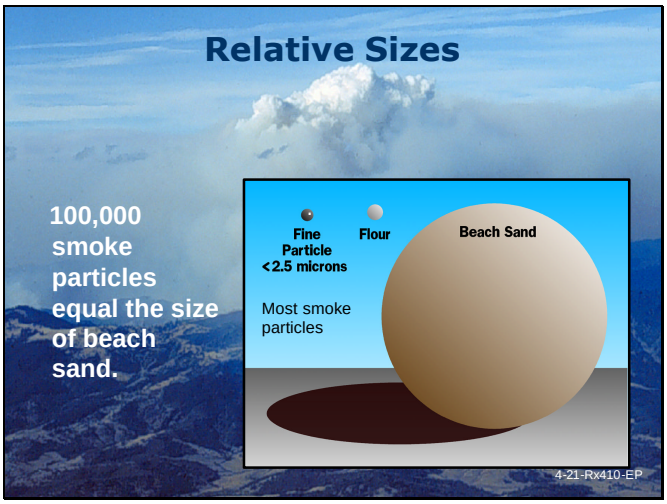

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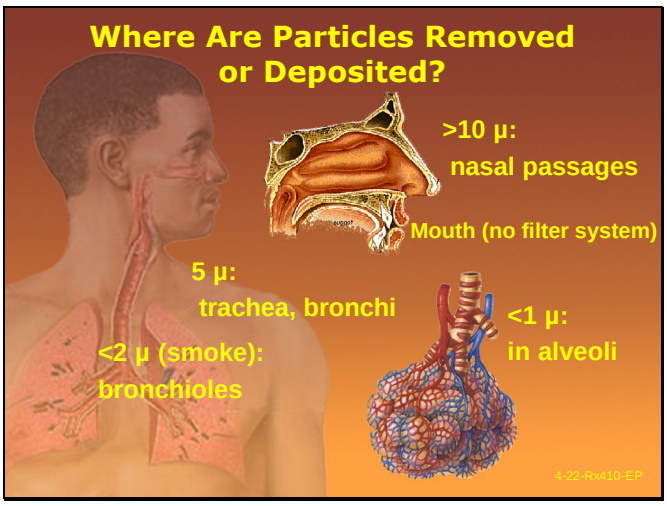

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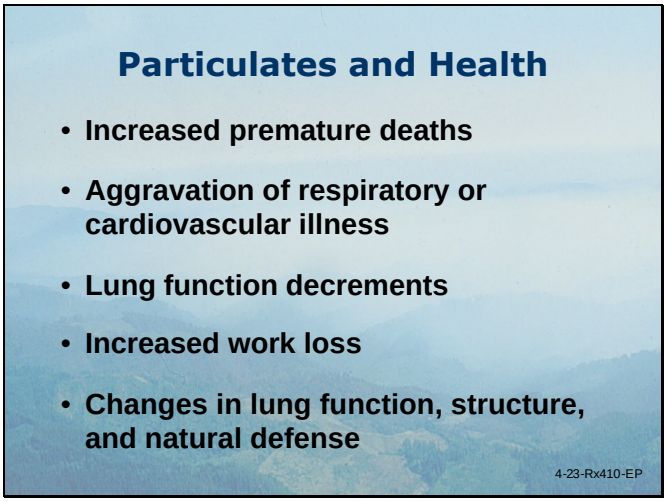

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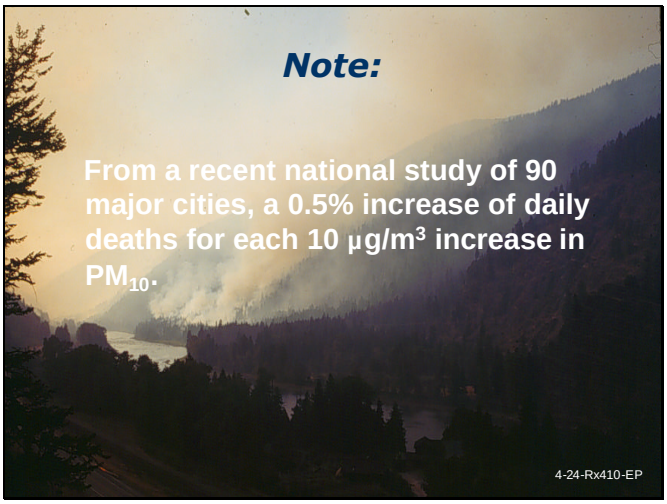

Slide 25

Revised Particulate Matter Standards

- PM 2.5 Standards
  - 15 µg/m³, annual arithmetic mean
  - 65 µg/m³, 24-hour average
- PM 10 Standards
  - retain annual standards of 50 µg/m³
  - retain level of 24-hour standards of 150 µg/m³

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Slide 26

In extreme cases, smoke from wildland burning can severely reduce visibility and be a high health risk, especially for those individuals with respiratory aliments.

- 1910 - Coeur d'Alene lights on by 3 PM
- 1987 - Happy Camp, CA. > 4000 µg/m³
- 1992 - Maraba, BZ. > 3500 µg/m³
- 2000 – Hamilton, MT > 1500 µg/m³

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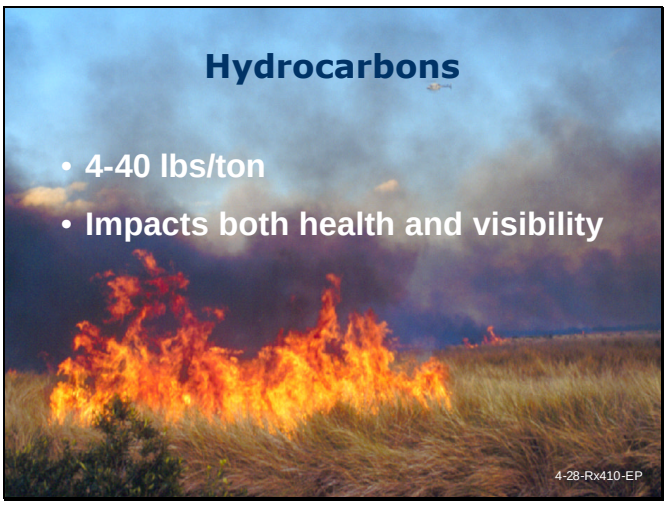
Slide 28



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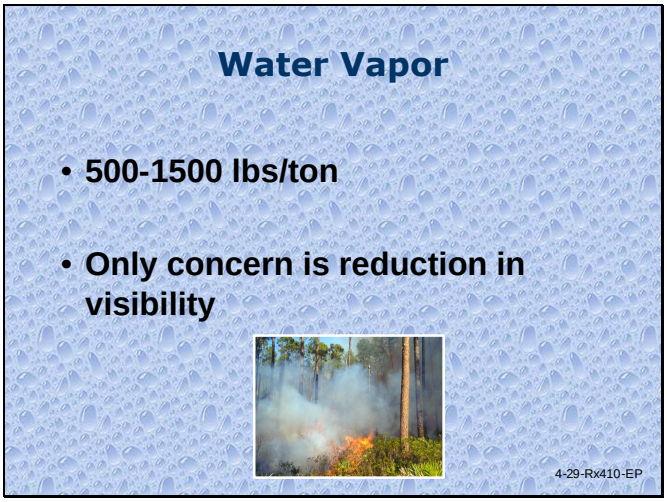

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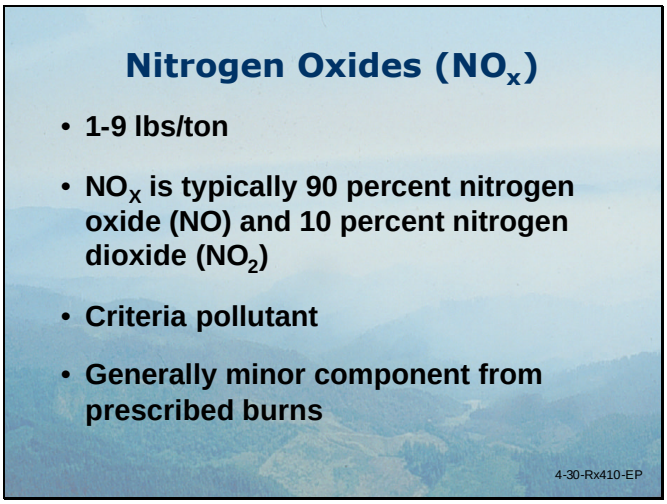

Slide 31

Secondary Emissions

- **Formed in the atmosphere**
- **Includes oxidants such as ozone**
- **Generally insignificant from prescribed burning**

4-31-Rx410-EP

Slide 32

Ozone

- Wildland fires produce nitrogen oxides (NOx) which are 90% nitogen oxide (NO) and 10% nitrogen dioxide (NO_2)
- In the presence of sunlight, oxygen (O_2) reacts with NO_x and Volatile Organic Compounds (VOCs) to produce ozone (O_3).

$$NO_x + VOCs = O_3 + NO$$

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Slide 33

Toxic Compounds

- **The EPA has developed a National Air Toxins Assessment for 33 of the 188 air toxins listed by Congress in the Federal Clean Air Act. It presents quantitative estimates of typical public exposures and health risks from pollutants known or suspected of causing cancer or other serious health problems.**
- **The EPA has identified wildfires as sources of five of the 33 including acetaldehyde, acrolein, butadiene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs).**

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Toxic Compounds

- These compounds are generally created in limited quantities and often disperse very quickly once away from the source. Limited knowledge exists about how much is produced from fires and the history of compounds once generated.
- Toxins such as lead and mercury can be released from a fire. Although a very small amount might be a part of the natural vegetation, most is from industrial or automobile emissions deposited on the vegetation that burns.

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Summary

- Smoke from fires includes visible materials such as tar, soot, ash, and water and gases and vapors you generally cannot see.
- Some components of smoke are criteria pollutants such as carbon monoxide and particulate matter.
- Primary smoke products include carbon dioxide, carbon monoxide, water vapor, particulate matter, hydrocarbons, nitrogen oxides and other secondary emissions.

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Summary

- Emission factors describe the strength of a particular smoke emission in terms of mass of smoke per mass of fuel consumed.
- Particulate matter is the major concern because of health and visibility impacts.
- Small amounts of toxins are produced.

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Unit 4 Objectives

- Describe key components of smoke as a pollutant.
- Identify emission factors for various chemical compounds, particle size distribution, and possible air toxins.
- Relate major concerns about smoke to its physical and chemical characteristics.

4-38-Rx410-EP

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Smoke Management Techniques, Rx-410

Unit 5 - Smoke Impacts

Lesson A - Public Health Impacts

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. List three human health impacts of wildland fire smoke to the public.

2. Describe common concerns voiced by the public during smoke episodes.

3. Discuss the land manager's role in mitigating and/or minimizing health impacts.

INTRODUCTION

Health Effects of Smoke

- Watery Eyes
- Irritated Respiratory Tract
- Reduced Lung Function
- Increased Hospital Visits
- Morbidity

Wildland fire smoke is one type of air pollution harmful to public health. The air is polluted at the same time by various other sources that contribute various pollutants. It is a cumulative effect.

Other sources

- Industrial
- Auto
- Mining
- Smelters
- Refineries
- Wood Stoves

Other pollutants

- Sulfates
- Nitrates
- Ozone
- Lead
- Carbon Monoxide
- Dust
- Elemental Carbon

What is "Public Health"?

- EPA definition – "incidence, prevalence and severity of diseases in *communities or populations* and the factors that account for them including *infections, exposure to pollutants and other exposures or activities.*

- Public health examples

  - 1948 Donora Smog Disaster where 19 people died in 24 hours. This incident is hailed as the reason for the 1970 Clean Air Act.

    1952 Great London Smog where as many as 4000 people died from breathing difficulties

"Air Pollution" Sensitive Populations

- Those with asthma and other respiratory problems (since they already have impaired or reduced lung function)

- Those with cardiovascular problems (since they already have impaired or reduced circulatory function).

- Elderly (since their systems may not be as resilient as younger persons and may have pre-existing heart and lung disease)

- Children (since they take in a greater ratio of air per body weight)

- Smokers (as they also have reduced lung function)

Statistics

- 74 million Americans (28%) are regularly exposed to harmful levels of air pollution

- 40,000 die prematurely

- Asthma in children has increased 118% (between 1980 and 1993)

So What's In Smoke and What are the Impacts?

Functioning of respiratory system

- In order to help us breathe, the respiratory system is built to help filter out particulates and pollutants. Air is filtered in the mouth and nose before traveling to the lungs. Many pollutants are filtered out in the upper respiratory system. As pollutants get deeper in the lungs, the lungs have less ability to defend themselves against their harmful effects.

Pollutants

Particulates

Coarse (generally greater than 5 microns): generally are deposited in the upper respiratory tract (nose, mouth, pharynx)

Fine (generally less than 2.5 microns) penetrate much deeper in the lungs. Deposited in the alveoli where body's defense mechanisms are ineffective in removing them.

Particulates can carry other toxics with them into the lungs.

Gases/Toxics

Acrolein
- Short term symptoms include stinging and tearing eyes, nausea and vomiting.
- Long term exposure risk is: Chronic respiratory disease

Formaldehyde
- Short term symptoms include irritated eyes, nose and throat.
- Long term exposure risk is nasal and nasopharyngeal cancer

Benzene

- Short term symptoms are headaches, dizziness, nausea and breathing difficulties.
- Long term exposure risks are anemia, liver and kidney damage, and cancer.

Carbon Monoxide

- Symptoms include dizziness, nausea and impaired mental function.
- Body typically recovers quickly from short-term exposure during smoke-free periods.
- High concentrations cause death.

Communicating the Impacts of Smoke (related to particulates)

EPA's Air Pollutant Index

- Can be used for a general assessment of health risks from monitored existing air quality (PM-2.5)
- Provides an adjective to describe air quality, the potential health effects at that level, and precautions the public should take to protect themselves.

Visibility Index

- Can be used where there are no air quality monitors.
- Uses visual range as a surrogate for air quality concentrations.
- Categories (descriptors) are the same as the EPA Index which allows the public to take proper precautions.

What Do These Concentrations Look Like?

- Within 10 minutes, four smokers in a 10' x 13' x 8' room can create particulate levels of 644 micrograms/cubic meter of PM2.5; exceeding EPA's "Hazardous Standard Index Category."

- Images represent concentrations in the Bitterroot Valley, MT measured during a wildfire episode in August of 1994:

  1st slide ~ 5 µg/m^3 PM-10
  2nd slide ~ 15 – 25 µg/m^3 PM-10
  3rd slide ~ 35 – 45 µg/m^3 PM-10
  4th slide ~ 65 µg/m^3 PM-10
  5th slide ~ 90 – 100 µg/m^3 PM-10

  (Note: Consider PM-2.5 to compose at least 70% of the PM-10. Therefore 100 µg/m3 of PM-10 is about 70 µg/m^3 PM-2.5)

Frequency of Occurrence

Wildfire Data

During an extreme fire year in Montana (2000), during two weeks in August, only 7% of the time were air quality levels considered in the "moderate" category. During the rest of the two weeks it ranged from unhealthy to hazardous.

Prescribed Fire Data

We do not have the same data on prescribed fire. Except in unusual circumstances, we would expect that concentrations are typically in the good to moderate category. If they are not, operations are likely ceased.

Common Concerns and Questions from the Public (or Regulators)

- It is normal for the public to want information so that they can take care of themselves and their families.

- We can provide information to help alleviate their concerns.

- Whether from wildfire or prescribed fire, be ready to answer questions related to:

  - What's in smoke from a wildfire?
  - Is smoke bad for me?
  - Do air filters help?
  - How long is the smoke going to last?
  - Are the smoke levels dangerous?
  - Do air filters help?

What is Your Role in Mitigating/Minimizing Health Impacts?

- If you are a land manager, your most important role is to provide to the regulatory agencies the necessary fire information and smoke projections they need to prepare for and respond to any public health concerns.

- Rely on health agencies to issue health advisories.

- Conduct or support particulate monitoring when appropriate

- Provide information to the public to help address common concerns (e.g., FAQ's)

Summary

- Health effects of wildland smoke are real.

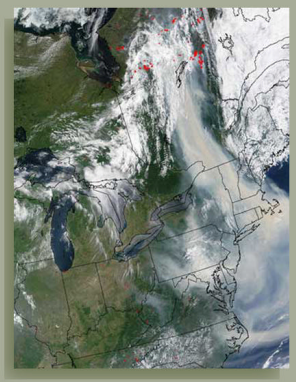
- Be aware of tools to help you communicate the impacts of smoke.

- Provide good fire/smoke information to the health agencies to help minimize the public's exposure.

Slide 1

The Impact of Smoke on Public Health

Unit 5A



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Slide 2

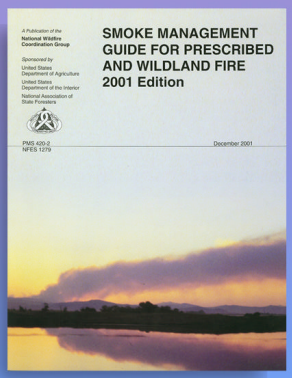
Unit 5A Objectives

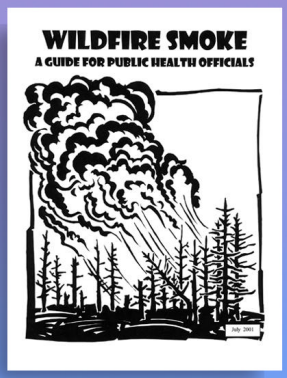
- List three human health impacts of wildland fire smoke to the public.
- Describe common concerns voiced by the public during smoke episodes.
- Discuss the land manager's role in mitigating and/or minimizing health impacts.

5A-2-Rx410-EP

Slide 3

Introduction





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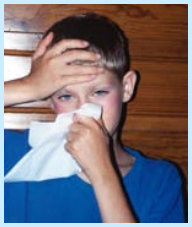
Slide 4

Health Effects of Smoke

- Watery Eyes
- Irritated Respiratory Tract
- Reduced Lung Function
- Increased Hospital Visits
- Morbidity



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Slide 5

Wildland Fire Smoke is only one type and source of pollutant

Source	Pollutant
• Industrial	Sulfates
• Auto	Nitrates
• Mining	Ozone
• Smelters	Lead
• Refineries	Dust
• Wood Stoves	Elemental Carbon

5A-5-Rx410-EP

Slide 6

EPA Defines Public Health as:

"Incidence, prevalence and severity of diseases in *communities or populations* and the factors that account for them."

- Infections
- Exposure to pollutants
- Other exposures or activities

5A-6-Rx410-EP

Slide 7

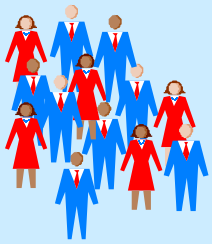
Public Health

- Communities can be a geographic location e.g., a town or a certain segment of the population such as:
  - Elderly
  - Children

5A-7-Rx410-EP

Slide 8

Public Health vs. Individual Health



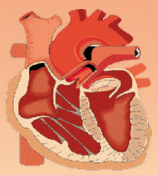
- Focusing on populations and not necessarily individuals

5A-8-Rx410-EP

Slide 9

Examples of Sensitive Populations

- Asthmatics
- Persons with coronary problems
- The elderly and children
- Smokers



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Slide 10

Statistics

- 28% of the American population is regularly exposed to harmful levels of particulate pollution.
- 40 thousand die early.
- 118% increase in asthma in children between 1980 and 1993.

5A-10-Rx410-EP

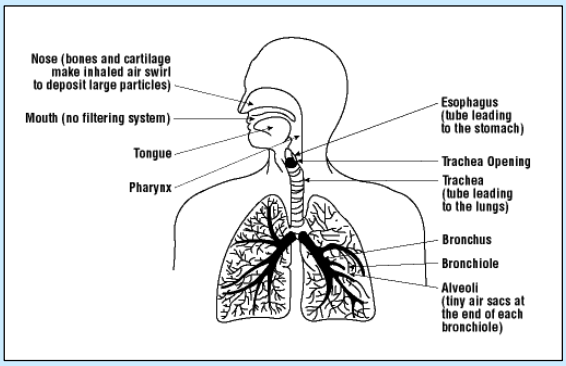
Slide 11

What's in Smoke and What are the Impacts?

5A-11-Rx410-EP

Slide 12

Respiratory System



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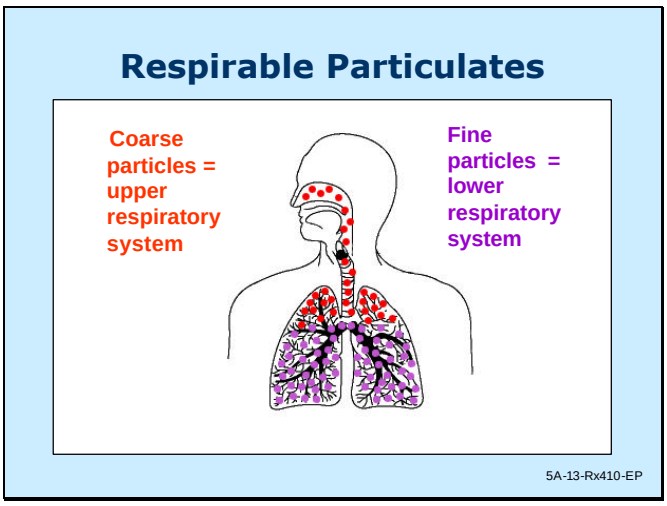

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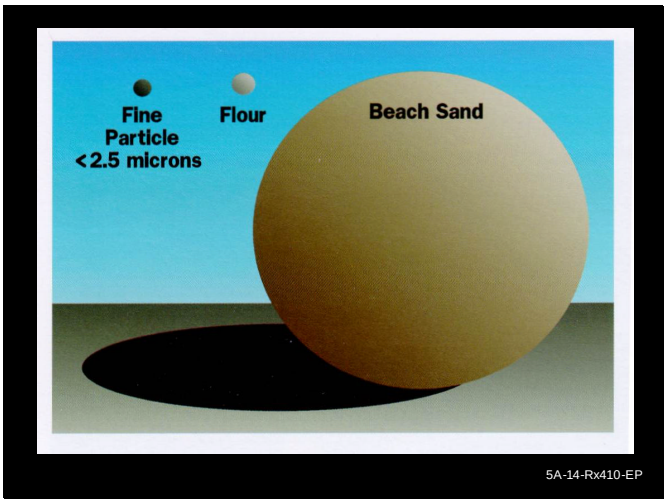

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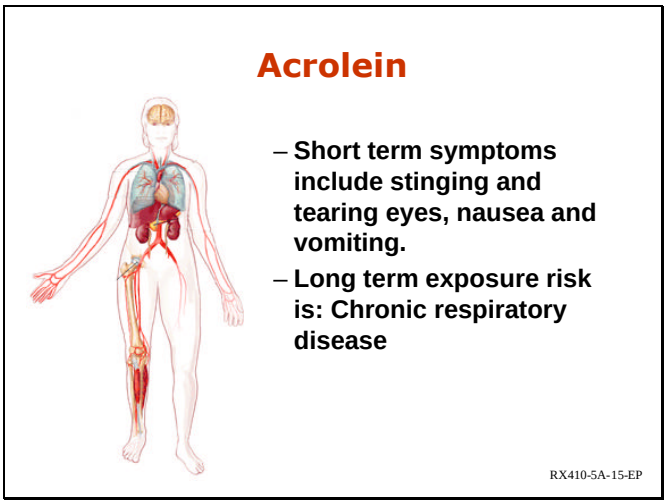


Slide 16

Formaldehyde

- Short term symptoms include irritated eyes, nose and throat.
- Long term exposure risk is nasal and nasopharyngeal cancer.

RX410-5A-16-EP

Slide 17

Benzene

- Short term symptoms are headaches, dizziness, nausea and breathing difficulties.
- Long term exposure risks are anemia, liver and kidney damage, and cancer.

RX410-5A-17-EP

Slide 18

Carbon Monoxide

- Symptoms include dizziness, nausea and impaired mental function.
- Body typically recovers quickly from short-term exposure during smoke-free periods.
- High concentrations cause death.

RX410-5A-18-EP

Slide 19

Communicating the Impacts of Smoke (related to particulates)

5A-19-Rx410-EP

Slide 20

EPA's Pollutant Standard Index for $PM_{2.5}$

Standard Index Category	PM2.5 24-hr concentration (μg/m³)	Health Effects	Cautionary Statements
Good	0-15.4	None	None
Moderate	15.5-40.4	None	None
Unhealthy for Sensitive Groups	40.5-65.4	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
Unhealthy	65.5-150.4	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion.
Very Unhealthy	150.5-250.4	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
Hazardous	>250.4	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

5A-20-Rx410-EP

Slide 21

Assessing Air Quality

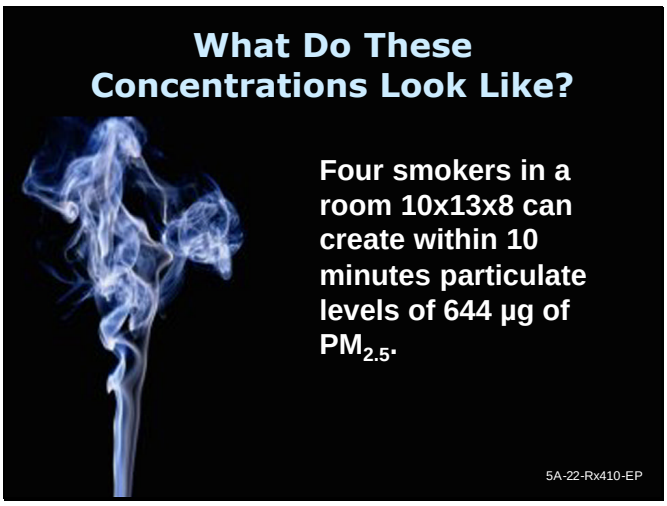
Category	PM2.5 1-hr avg. concentration (μg/m³)	Visibility Range (miles)
Good	0-40	10 miles and up
Moderate	41-80	6 to 9 miles
Unhealthy for Sensitive Groups	81-175	3 to 5 miles
Unhealthy	176-300	1 1/2 to 2 1/2 miles
Very Unhealthy	301-500	1 to 1 1/4 mile
Hazardous	Over 500	3/4 mile or less

The procedure for using personal observations to determine the approximate PM 2.5 concentration for local areas without official monitors is:

1. Face away from the sun.
2. Determine the limit of your visible range by looking for targets at known distance (miles). Visible range is that point at which even high contrast object totally disappear.
3. Use the values above to determine the local forest fire smoke category.

5A-21-Rx410-EP

Slide 22



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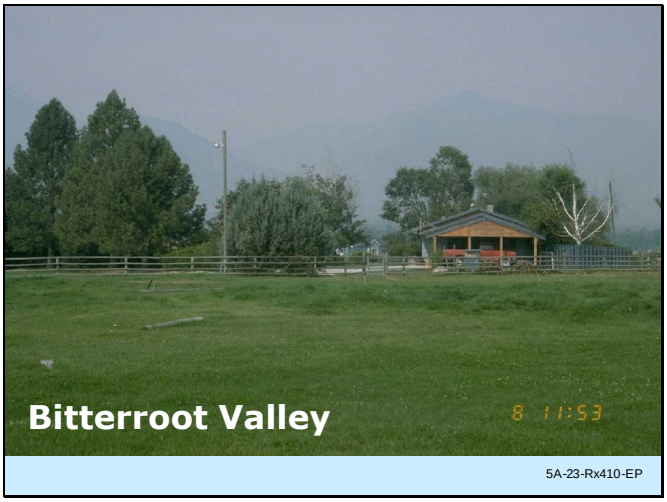

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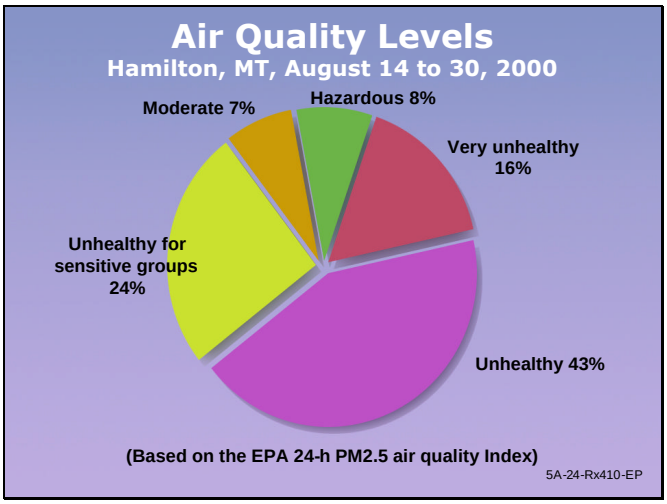


Slide 25

Common Concerns And Questions

– What's in smoke from a wildfire?
– Is smoke bad for me?
– Do air filters help?
– How long is the smoke going to last?

5A-25-Rx410-EP

Slide 26

Your Role in Mitigating/Minimizing Health Impacts

- Provide health agencies with necessary fire information to help formulate health advisories.
- Rely on health agencies to issue health advisories.
- Provide information to the public to help address common concerns (e.g. FAQ's)
- Conduct or support particulate monitoring when appropriate

5A-26-Rx410-EP

Slide 27

Summary

- Health effects of wildland smoke are real.
- Be aware of tools to help you communicate the impacts of smoke.
- Provide good fire/smoke information to the health agencies to help minimize the public's exposure.

5A-27-Rx410-EP

Slide 28

Unit 5A Objectives

- List three human health impacts of wildland fire smoke to the public.
- Describe common concerns voiced by the public during smoke episodes.
- Discuss the land manager's role in mitigating and/or minimizing health impacts.

5A-28-Rx410-EP

Wildfire Smoke

A guide for public health Officials

July 2001

introduction

Smoke rolls into town, blanketing the city, turning on street lights, creating an eerie and choking fog. Switch boards light up as people look for answers. Citizens want to know what they should do to protect themselves. Schools want to know if practices should be cancelled. The media wants to know how dangerous the smoke really is.

Smoke events often catch us off-guard. This guide is intended to provide local public health officials the information they need during a wildfire smoke event so they can adequately communicate health risks and precautions to the public. It is the result of a collaborative effort that brought together scientists, air quality specialists and public health professionals from national, state and local agencies.

Composition of smoke

Smoke is made up primarily of carbon dioxide, water vapor, carbon monoxide, particulate matter, hydrocarbons and other organics, nitrogen oxides and trace minerals. The composition of smoke varies with fuel type: different wood and vegetation are composed of varying amounts of cellulose, lignin, tannins and other polyphenolics, oils, fats, resins, waxes and starches which produce different compounds when burned.

In general, particulate matter is the major pollutant of concern from wildfire smoke. Particulate is a general term for a mixture of solid particles and liquid droplets found in the air. Particulate from smoke tends to be very small (less than one micron in diameter) and, as a result, is more of a health concern than the coarser particles that typically make up road dust. Particulate matter from wood smoke has a size range near the wavelength of visible light (0.4 – 0.7 micrometers). This makes the particles excellent scatterers of light and, therefore, excellent reducers of visibility.

Carbon monoxide is a colorless, odorless gas, produced as a product of incomplete combustion. It is produced in the largest amounts during the smoldering stages of the fire.

Hazardous air pollutants are present in smoke, but in far less concentrations than particulate and carbon monoxide. The most common are acrolein, benezene and formaldehyde.

Health effects of smoke

The effects of smoke run from irritation of the eyes and respiratory tract to more serious disorders, including asthma, bronchitis, reduced lung function and premature death. Studies have found that fine particulate matter is linked (alone or with other pollutants) with a number of significant respiratory and cardiovascular-related effects, including increased mortality and aggravation of existing respiratory and cardiovascular disease. In addition, airborne particles are respiratory irritants, and laboratory studies show that high concentrations of particulate matter cause persistent cough, phlegm, wheezing and physical discomfort in breathing. Particulate matter can also alter the body's immune system and affect removal of foreign materials from the lung, like pollen and bacteria.

Carbon monoxide enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. The health threat from lower levels of CO is most serious for those who suffer from cardiovascular disease. At higher levels, carbon monoxide exposure can cause headaches, dizziness, visual impairment, reduced work capacity, and reduced manual dexterity even in otherwise healthy individuals. At even higher levels (seldom associated solely with a fire), carbon monoxide can be deadly.

People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health problems. However, in general, it is believed that the long term risk from toxic air pollutants from forest fire smoke is very low. Some components of smoke, such as many polycyclic aromatic hydrocarbons (PAH) are carcinogenic. Probably the most carcinogenic is benzo-a-pyrene (BaP), which has been demonstrated to increase in toxicity when mixed with carbon particulate. Other components, such as the aldehydes, are acute irritants. Three air toxics are of most concern from wildfires:

1. Acrolein. An aldehyde with a piercing, choking odor. Even at low levels, acrolein can severely irritate the eyes and upper respiratory tract. Symptoms include stinging and tearing eyes, nausea and vomiting.
2. Formaldehyde. Low level exposure can cause irritation of the eyes, nose and throat. Higher levels cause irritation to spread to the lower respiratory tract. Long-term exposure is associated with nasal and nasopharyngeal cancer.
3. Benzene. Benzene causes headaches, dizziness, nausea and breathing difficulties, and is a very potent carcinogen. Benzene causes anemia, liver and kidney damage, and cancer.

Not everyone who is exposed to thick smoke will have health problems. Level, extent and duration of exposure, age, individual susceptibility and other factors play a significant role in determining whether or not someone will experience smoke-related health problems.

Sensitive populations

Most healthy adults will recover quickly from smoke exposures and will not suffer long-term consequences. However, certain sensitive populations may experience more severe acute and chronic symptoms from smoke exposure. Much of the information about how particulate effects these groups has come from studies done on urban particulate. More research is needed (and some of it is underway) to determine if particulate from wildfires affects these groups differently.

Individuals with asthma, and other respiratory diseases. Levels of pollutants which may not interfere with normal breathing affect people with asthma in more profound ways, causing greater inflammation or constriction of airways. Asthma, derived from the ancient Greek word for panting, is a chronic condition in which the airways temporarily become impeded, causing labored breathing, wheezing or coughing. During an asthma attack, the muscles tighten around the airways, constricting the free exchange of air. The lining of the airways becomes inflamed and swollen. Children's airways are narrower than those of adults, thus irritation that would produce only a slight response in an adult can result in significant obstruction in the airways of a young child. Older people with asthma experience higher mortality rates from asthma than other age groups.

Individuals with cardiovascular disease. Cardiovascular diseases include many ailments, such as hardening of the arteries, high blood pressure, angina pectoris, heart attacks and strokes. It is the leading cause of death in the United States, responsible for about 42% of all deaths each year. The vast majority of those deaths are in people over the age of 65. Studies have linked particulate pollution to increased heart attacks and symptoms in those with cardiovascular disease. The exact toxicological mechanisms are not well understood, but studies show that particulate matter causes respiratory symptoms, changes in lung function, alteration of mucociliary clearance and pulmonary inflammation that can lead to increased permeability of the lungs. This, in turn, can cause fluid to accumulate in the lungs. Mediators released during an inflammatory response could increase the risk of blood clot formation and strokes. Other studies have shown that the particles may trigger certain neurons in the respiratory tract, leading to effects on the nervous system.

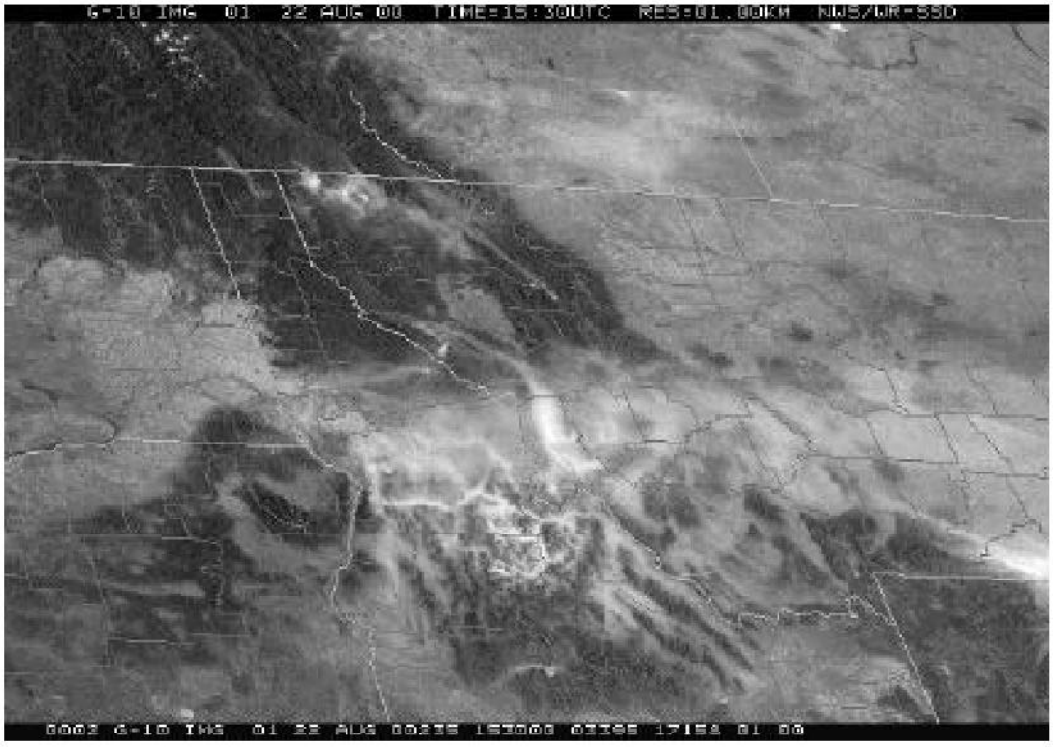
The elderly. Studies estimate that tens of thousands of elderly people die prematurely each year from exposure to particulate pollution. Part of that is due to the fact that the elderly are more likely to have pre-existing lung and heart diseases. In addition, the elderly seem to be more affected than other age groups because we lose important respiratory defense mechanisms as we age. Older individuals tend to have more difficulty clearing particles from their lungs. As a result, pollutants to irritate the lungs for longer periods of time and can cause more damage. In addition, particulate pollution can compromise the immune system, increasing the susceptibility to bacterial or viral respiratory infections. This can lead to an increase incidence of pneumonia and other complications among the elderly.

Children. Children, even those without any preexisting conditions, are considered a sensitive population because their lungs are still developing, making them more susceptible to environmental threats than healthy adults. Several factors lead to increased exposure in children: compared to adults, they tend to spend more time outside; they engage in about three times the vigorous activity, and they breathe about 50% more air per pound of body weight. Studies have shown that particulate pollution is associated with increased respiratory symptoms and decreased lung function in children, including symptoms such as aggravated coughing and difficulty or pain in breathing. These can result in school absences and limitation in normal childhood activities.

Smokers. People who smoke have already compromised their lung function. Exposure to high levels of particulate can exacerbate their condition, leading to chest pain, trouble breathing and other respiratory symptoms more quickly than in non-smokers. As a way to put smoking in context, in a 10′ by 13′ room with an 8′ ceiling, it takes only 10 minutes for the side stream smoke of 4 cigarettes to create ambient levels of particulate in the hazardous ranges (644 ug/m^3).

Characteristics of smoke

The behavior of smoke depends on many factors, including the fire's size, the fire's location, the topography of the area and the weather. In mountainous terrain, where inversions are common, smoke often fills the valleys, where, incidentally, people usually live. Smoke levels can be very hard to predict: a wind that usually clears out a valley, may simply blow more smoke in, or may fan the fires causing a worse episode the next day. Smoke concentrations tend to change constantly. (By the time you issue a warning, the smoke may have cleared out.) National Weather Service satellite photos, weather and wind forecasts, and knowledge of the area can all help in predicting how much smoke will come into an area, but predictions are rarely accurate for more than a few hours out. The National Weather Service's website has a lot of information, including satellite photos that are updated throughout the day. For the western United States, the web address is www.wrh.noaa.gov.



Judging particulate levels in smoke

Communities that have established air quality programs and alert systems traditionally base their advisements to the public on the 24 or 8 hour averages of particulate. However, it makes sense to approach smoke emergencies differently, for a couple of reasons. Smoke concentrations tend to be very high for a few hours, and then drop off dramatically. But, research has shown that the spikes may be what cause some of the most deleterious effects. In addition, the particulate from smoke is very small, and has more of an impact than PM_{10}, which is what most emergency plans are based upon. Another factor is public perception. Since smoke is such a good scatterer of light, visibility changes drastically as smoke concentrations increase. Even without being told, the public can tell when the smoke is getting worse, and they want authorities to respond to those changes as they are happening, instead of when they have been going on for eight hours, or when they are over.

Many places don't have real-time particulate monitors to help determine how thick the smoke is. (Real time monitors give an instant (and continuous) reading of particulate concentrations.) However, visibility can serve as a good surrogate. Even in areas with monitors, this index is useful, since smoke levels are ever-changing, giving the public a way to judge the smoke levels for themselves on a continual basis.

Categories	**Visibility in Miles**	**Particulate levels (averaged 1 hour, $\mu g/m^3$)**
Good	10 miles and up	0 - 40
Moderate	6 to 9	41 - 80
Unhealthy for Sensitive Groups	3 to 5	81 - 175
Unhealthy	1 1/2 to 2 1/2	176 - 300
Very Unhealthy	1 to 1 1/4	301 - 500
Hazardous	3/4 mile or less	over 500

Procedure for Making Personal Observation to Determine Smoke Concentrations

- Face away from the sun
- Determine the limit of your visibility range by looking for targets at known distances (miles). Visible range is that point at which even the high contrast objects totally disappear
- After determining visibility in miles, use the chart to determine health effect and appropriate cautionary statement.

At times, even the visibility index may be hard to use, especially if specific landmarks of known distance are not available for judging distances. In such cases, individuals may have to rely on common sense in assessing smoke conditions (e.g., mild, moderate, heavy smoke) and the kinds of protective actions that might be necessary.

Recommendations for the public

The following table provides a general list of probable health effects at each level, and associated recommended cautionary statements. It is based on the EPA's Air Pollution Index, as well as some work done in Montana and Washington.

Categories	Health Effect	Cautionary Statement
Good	None	None
Moderate	Possibility of aggravation of heart or respiratory disease.	People with heart or lung disease should pay attention to symptoms.
Unhealthy for Sensitive Groups	Increasing likelihood of respiratory symptoms and aggravation of lung disease such as asthma.	People with respiratory or heart disease, the elderly and children should *limit* prolonged exertion and stay indoors when possible.
Unhealthy	Increased respiratory symptoms and aggravation of lung and heart diseases; possible respiratory effects to general population.	People with respiratory or heart disease, the elderly and children should *avoid* prolonged exertion and stay indoors when possible; everyone else should *limit* prolonged exertion.
Very Unhealthy	Significant increase in respiratory symptoms and aggravation of existing lung and heart disease; increasing likelihood of respiratory effects of general population.	People with respiratory or heart disease, the elderly and children should *avoid* any outdoor activity; everyone else should *avoid* any outdoor exertion.
Hazardous	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should *avoid* any indoor and outdoor exertion; everyone should remain indoors whenever possible.

Specific strategies

Staying Indoors

The most common advisory issued during a smoke pollution episode is to stay indoors. The usefulness of this strategy depends entirely on how clean the indoor air is. Studies (almost none of which were conducted during forest fire smoke episodes) indicate that this strategy can usually provide some protection, especially in a tightly closed, air conditioned house. Staying inside can usually reduce ambient air pollution by about a third. In non-air conditioned homes anywhere from 70 to 100% of fine particulate will penetrate indoors from the outside air. In very leaky homes and buildings, the guidance of staying inside with doors and windows closed may offer little protection. Certainly, if doors and windows are left open, indoor and outdoor air will be about the same.

One of the biggest problems with advising people to stay inside during smoke events is the risk of heat stress. The fire season is often accompanied by high outside temperatures and for those people who depend upon open windows and doors for ventilation, keeping windows and doors closed can be a problem. Older individuals and others in frail health run the risk of heat exhaustion or heat stroke which could have dire consequences. If outside temperatures are very high, it would be prudent to advise those without air conditioning to seek shelter in a clean air sanctuary. These are discussed later in this guide.

Smoke events can last several weeks or months. These longer events are usually punctuated by times with relatively clean air. When air quality improves, even temporarily, residents should "air out" their homes to reduce indoor air pollution.

Air conditioners

Little is known about the impact of using various types of air conditioners and air filters on indoor air pollutant concentrations. The conventional wisdom is that air conditioners reduce the amount of outside particulate to get indoors, if for no other reason than air conditioned homes usually have lower air exchange rates than homes that use open windows for ventilation. Some air conditioners can be fitted with HEPA filters (stands for High Efficiency Particulate) These filters can capture most of the tiny particles associated with smoke and can further reduce the amount of outside air pollution that gets indoors.

Specific strategies

Air cleaners

Air cleaners can be effective at reducing indoor particulate levels, provided the specific cleaner is adequately matched to the indoor environment in which it is placed. However, they tend to be expensive. Air cleaners can be either a portable unit to clean a single room ($50 - $300) or a larger central air cleaner to clean the whole house ($300 - $1000–). Most air cleaners are not effective at removing gases and odors. The two basic types of air cleaners for particle removal are:

(a) Mechanical cleaners, which contain a fiber or fabric filter. The filters need to be sealed tightly in their holders, and cleaned or replaced regularly.
(b) Electronic air cleaners, such as electrostatic precipitators (ESP) and ionizers. ESPs use a small electrical charge to collect particles from air pulled through the device. Ionizers, or negative ion generators, cause particles to stick to materials (such as carpet and walls) near the device. Electronic air cleaners usually produce small amounts of ozone as a byproduct.

The effectiveness of an air cleaner is usually reported in terms of efficiency, which can be misleading, as it only tells half of the story. The other important factor is air flow. Together, these two factors equal the Clean Air Delivery Rate (CADR), which is a better measure of how a device will actually perform. For example, 99.99% efficiency sounds great, if the flow is only 20 cfm, one would be better off at 90% efficiency and 100 cfm (CADR: 20 vs 90 cfm).

Room units should be sized to supply at least two or three times the room volume per hour. Most portable units will state on the package the unit's air flow rate, the size room it cleans and perhaps its particle removal efficiency and its CADR. Central system air units should handle at least 0.5 air changes per hour, the air exchange rate necessary to reasonably ventilate a house continuously under most conditions.

For central air conditioning systems, electrostatic precipitators, high efficiency media filters and medium-efficiency media filters can be added so that the particle level in the indoor air can be kept within acceptable levels during a prolonged smoke event. However, these filters create more air resistance in the system, and may not be able to be used without modifications to the system.

Devices that remove gases and odors are relatively costly, both to purchase and maintain. They force air through materials such as activated charcoal or alumina coated with potassium permanganate. However, the filtering medium can become quickly overloaded and may need to be replaced often.

(Continued)

Specific strategies

Some devices, known as ozone generators, personal ozone devices, "energized oxygen" generators, and "pure air" generators, are sold as air cleaners, but they probably do more harm than good. These devices intentionally produce ozone gas to react with pollutants in the air. Ozone is composed of three atoms of oxygen. The third atom can detach from the molecule and reattach to molecules of other substances, thereby altering their chemical composition. It is this ability to react with other substances that forms the basis of manufacturer's claims. However, the EPA has found that ozone is generally ineffective in controlling indoor air pollution at concentrations that do not greatly exceed public health standards. In addition, ozone does not remove particles from the air, so would not be effective during smoke events. (Some ozone generators include an ion generator to remove particles, but it would be far safer to buy the ionizer by itself.)

Ozone, whether in its pure form or mixed with other chemicals, can be harmful to health. When inhaled, ozone can damage the lungs. Relatively low amounts of ozone can cause chest pain, coughing, shortness of breath and throat irritation. It may also worsen chronic respiratory diseases such as asthma, as well as compromise the body's ability to fight respiratory infections. As a result, using an ozone generator during a smoke event may actually increase the adverse health effects from the smoke. For more information about ozone generators that are sold as air cleaners, see www.epa.gov/iaq/pubs/ozonegen.html.

Humidifiers are not technically air cleaners, and will not significantly reduce the amount of particulate in the air during a smoke event. Neither will they removed gases like carbon monoxide. However, humidifiers and dehumidifers (depending on the environment) may slightly reduce pollutants through condensation, absorption and other mechanisms. The greater benefit of running a humidifier in an arid environment during a smoke event would be to reduce stress on the respiratory system, by keeping the mucus membranes moist.

For more information about residential air cleaners, see www.epa.gov/iaq/pubs/residair.html.

Specific strategies

In vehicles

Individuals can reduce the amount of particulate in their vehicles by keeping the windows closed. However, cars heat up very quickly in warm weather, and heat stress can be an issue. Children and pets should never be left in a vehicle with the windows closed. The car's ventilation systems typically removes a portion of the particulate coming in from outside. For best results, most cars have the ability to recirculate the inside air, which will help keep the particulate levels lower.

Reduced activity

Reduction of physical activity reduces the dose of inhaled air pollutants, and may reduce the risk of health impacts during a smoke event. During exercise, people may increase their air intake as much as ten times their resting level. An endurance athlete can process as much as twenty times the normal intake. This brings more pollution deep into the lungs. While exercising, people tend to breathe through their mouths, bypassing the natural filtering ability of the nasal passages: again, delivering more pollution to the lungs. They also tend to breathe more deeply, causing the particulate to lodge deeper into the lungs where it can cause more damage.

Other sources of air pollution

Many indoor sources of air pollution can emit large amounts of the same pollutants present in forest fire smoke. Indoor sources such as cigarette smoke, gas, propane and woodburning stoves and furnaces, and activities such as cooking, burning candles and incense, and vacuuming can greatly increase the particulate levels in a home. Some of these sources can also increase the levels of polycyclic aromatic hydrocarbons (PAHs), carbon monoxide and nitrogen oxides. Besides cigarette smoke, combustion sources that do not vent to the outdoors contribute most to indoor pollutant levels and are of greatest concern. On average, reducing indoor air emissions as much as possible during smoke events may reduce indoor particulate levels by one quarter to one third or more, and levels of PAHs, VOCs and other pollutants by an even greater amount. These reductions can help compensate for the increased loading from the outdoor air.

Specific strategies

Masks

In order for a mask to provide protection during a smoke event, it must be able to filter very small particles (around 0.3 to 0.1 microns) and it must fit, providing an airtight seal around the wearer's face. Commonly available paper dust masks, which are designed to filter out larger particles such as dust created by sanding, typically offer little protection. The same is true for bandanas (wet or dry) and tissues held over the mouth and nose. In fact, they may actually be detrimental, giving the wearers a false sense of security and encouraging them to increase their physical activity and time outdoors.

Surgical masks that trap smaller particles are also available, but these masks are designed to filter air coming out of the wearer's mouth, and do not provide a good seal. As a result, these tend to be no better than dust masks.

Some masks (technically called respirators, but they look more like paper masks) are good enough to filter out 95% of the particulate that is 0.3 microns and larger. Smoke particulate averages about 0.3 microns, so these masks will filter out a significant portion of the smoke if they are properly fit to the wearer's face. These masks, which may include an exhale valve, do not require cartridge filters. They are marked with one of the following: "R95", "N95" or "P95." Soft masks with higher ratings (R, N or P 99 and R,N, or P100) are also available and will filter out even more particulate.

Respirators with purple HEPA (pronounced hee-pa and stands for high efficiency particulate air) filters offer the highest protection, but may be less comfortable and slightly more expensive than the flexible masks. Again, unless there is an airtight seal over the wearers face, it will provide little protection.

There are several drawbacks to recommending widespread mask use in an area affected by wildfire smoke. Most people won't use the masks correctly and won't understand the importance of having an airtight seal. For instance, it is impossible to get a good seal on individuals with beards. In addition, masks aren't designed for use by the general population (including children.) As a result, the masks will provide little if any protection. In addition, they may give the wearers a false sense of protection, leading them to ignore other recommendations, like reducing physical activity, which could actually increase their exposure.

Masks are uncomfortable (they are less uncomfortable when they are leaky – but then they do not provide protection.) They increase resistance to air flow. This makes breathing more difficult and leads to physiological stresses, such as increased respiratory and heart rates. Masks can also contribute to heat stress. Because of this, mask use by those with cardiopulmonary and respiratory diseases can be dangerous, and should only be done under a doctor's supervision. Even healthy adults may find that the increased effort required for breathing makes it uncomfortable to wear a mask for more than short periods of time. Breathing resistance increases with respirator efficiency. Most healthy adults can use a 95% efficient respirator without undue breathing resistance. At higher efficiencies, breathing resistance will increase and the user will experience more discomfort.

Another problem with masks is that most of them will not reduce CO.

Specific strategies

There are some instances where recommending mask use can be beneficial. For outdoor workers, or others that will be outside regardless of the smoke, masks (as long as they fit properly) can afford some protection. In cases where people are generally staying indoors, wearing a mask to go outside briefly might be useful. Masks can also be useful in conjunction with other methods of exposure reduction like staying indoors, reducing activity and using HEPA air cleaners, to reduce overall smoke exposure.

Clean Air Shelters

In many places, staying inside may not adequately protect susceptible individuals. Many homes do not have air conditioning, and depend on open windows and doors for cooling. Other homes may be so leaky, that the pollution levels will soon equal that of outside air. During severe smoke events, clean air shelters can be designated to provide residents with a place to get out of the smoke. These can be located in large commercial buildings, educational facilities, shopping malls or anyplace with effective air conditioning and particle filtration.

Closures

The decision to close or curtail business activities will depend upon predicted smoke levels, environmental and socioeconomic factors and other local conditions. It could be that exposure inside schools and businesses may be similar to or better than those in homes. Children's physical activity may also be better controlled in schools than in homes, making school closings a poor choice. In many areas it will not be practical to close businesses and schools, but partial closures may be beneficial. Closures and cancellations can target specific groups (like the sensitive populations) or specific, high risk activities, like outdoor sporting events and practices. Curtailing outside activities can reduce exposures by encouraging people to stay inside and reduce physical activity. The decision to restrict industrial emissions should be based on the local air pollution situation and the emission characteristics of particular industries. Curtailment may not be beneficial if eliminating industrial emissions will not noticeably reduce the air pollution load.

Evacuation

The most common call for evacuation during a wildfire is due to the direct threat of the fire instead of smoke. Leaving the area of thick smoke may be a good protective measure for members of sensitive groups, but it is often difficult to predict the duration, intensity and direction of smoke, making this an unattractive option to many people. For fires that go on for weeks, evacuation may not be possible for a large percentage of the population.

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Smoke Management Techniques, Rx-410

Unit 5 - Smoke Impacts

Lesson B - Fire Personnel Impacts

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Discuss the impact of smoke exposure on fire personnel.

2. Describe different techniques to reduce fire personnel exposure.

3. Describe methods for evaluating fire personnel exposure to smoke.

Firefighters are exposed to smoke toxics on both wildfires and prescribed fires. Firefighters and managers have been concerned about smoke exposure impacts on the health of employees for decades. Early research proved inconclusive and a survey conducted among the firefighter community in 1985 suggested studying the health effects was not a high priority.

That position changed drastically following the 1987 fires of northern California and southwest Oregon and the Yellowstone fires of 1988. Hundreds of firefighters reported respiratory problems. Safety and welfare of the workforce and exposure regulations are two reasons it is important to mitigate the exposure of personnel to smoke.

Each fire season, 20,000 to 30,000 firefighters are engaged in suppressing wildfires on federal lands, and many more are employed to battle fires on state and private lands. Wildfire suppression involves numerous risks, but most medical visits on fires result from over-exposure or chronic exposure to smoke. There always has been a concern about the exposure of firefighters to hazardous smoke concentrations. However, the 1987-88 fire seasons renewed concerns when hazardous exposures and respiratory problems were reported in large numbers. For example, there were 30,000 medical visits resulting from the Yellowstone Fires. Of these, 12,000 involved respiratory complaints; 600 of the 12,000 required subsequent medical attention. In 1994, fires in Idaho and Montana recorded over 8800 medical visits and nearly 50 percent were related to respiratory ailments.

Following the 1987 and 1988 wildfire seasons, concern expressed by firefighters themselves and the California Department of Forestry Employees Association reached Congress. A Congressional Committee brought together the National Wildfire Coordinating Group and Johns Hopkins University, to develop a comprehensive study plan to perform a full evaluation of the health hazards of exposure to forest fire smoke. The studies were divided into 3 major areas of research:

1) assessment of what and how much firefighters were exposed to
2) respirator trials, and
3) health effects.

These three pieces would provide the information needed to develop risk management strategies to mitigate the exposure of fireline workers to smoke.

The study plan lined out a research effort that would cost approximately $13,000,000, however, no money was available for the work. Through the efforts and support of the National Wildfire Coordinating Group, they assigned the project to the Missoula Technology and Development Center (MTDC). The USDA Forest Service PNW Research Station's Fire and Environmental Research Applications Team-Seattle (FERA) completed an exposure and risk assessment of firefighters on both prescribed fires and wildfires. MTDC produced the Health Hazards of Smoke newsletters, provided technical advice, and completed studies on respiratory use. A Consensus Conference was held in 1997 and studies were wrapped up by 2001 with several publications completed (see reference section). MTDC, Missoula Fire Lab, and FERA are working together to assist EPA and the Centers for Disease Control to continue new work in this area.

The smoke exposure study by the PNW Research Station was directed toward firefighters on the fire line. Other workers, such as those with fire camp duties, are also exposed to long episodes of smoke and need to be assessed.

The total annual suspended particulate matter (PM) produced from prescribed burning exceeds 100,000 tons in some states. In many more states, prescribed burning produces 10,000 to 100,000 tons of PM annually. This implies that ground-level concentrations must also be a significant concern among personnel at prescribed fires. In Region 6, the Vegetation Environmental Impact Statement states that firefighter exposure to air toxics must be considered and monitoring and mitigation steps be outlined before applying fire for vegetation management. This led to a smoke exposure assessment for individuals participating on prescribed fires. This was completed in 2001 by the USDA Forest Service PNW Research Station's Fire and Environmental Research Applications Team (FERA) culminating in a general technical report (see reference sections).

The studies assessing smoke exposure did not sample for unique toxics such as those associated with the burning of poison oak and tanoak. The photo is from a grass prescribed fire conducted in the Big Cypress National Preserve. An alga clings to the grass stems during the wet season when water covers the area. As the water evaporates, the alga residue is left and when burned, produces a smoke that irritates the respiratory tract. Unique toxics such as those associated with this Big Cypress burn or with the burning of poison oak and tanoak were not sampled during the wildland fire smoke assessment studies.

What inhalation toxics are found in smoke? Five primary air toxics have been assessed relative to the exposure of fireline workers to smoke from wildfires and prescribed fires. These include acrolein, formaldehyde, carbon monoxide, respirable particulates, and benzene.

· Acrolein

Acrolein is an aldehyde with a piercing, choking odor. The odor threshold is less than 0.1 ppm. Low-level exposures severely irritate the eyes and upper respiratory tract. Exposure indicators include stinging and tearing of the eyes, nausea, and vomiting.

· Formaldehyde

At low-level exposures, formaldehyde can cause irritation of the eyes, nose, and throat. The odor threshold is about 1.0 ppm. Higher levels of exposure can cause the lower respiratory tract to become irritated. Long-term exposure is associated with nasal and nasopharyngeal cancer.

· Respirable Particulates

Fine particulate matter (less than 10 microns in diameter) causes irritation of mucous membranes. Transport and deposition in the lower respiratory tract can occur. Fine particles transport carcinogenic and toxic polycyclic aromatic hydrocarbons (PAH). Workshift peak exposure level is 5 milligrams per meter cubed. Please note that this peak exposure level is in units of milligrams, which is 1,000 micrograms.

This slide illustrates size class distribution of particle matter in smoke from wildland fires. Smoke particles from wildland fires are relatively small. 100,000 smoke particles equal a piece of beach sand.

- 10% by mass are greater than 10 microns in diameter (fly ash)
- 20% by mass are between 2.5 and 10 microns in diameter (dust)
- 70 % by mass are smaller than 2.5 microns in diameter (pollen)

A clean and dirty filter mat showing particulate matter captured during a 15- minute sampling period.

The human body has defense mechanisms to reduce the impact of particulate matter entering the respiratory system. The nose hairs and mucous capture most of the large particles greater than 10 microns. The second line of defense is the trachea where mucous and cilia capture many of the particles greater than 5 microns. However, many of the smaller particles less than 5 microns will make it to the lower parts of the lung and be deposited. As seen in the previous slides, 70 percent of the particles generated by wildland fire are less than 2.5 microns in diameter and thus can enter the human airways and be deposited deep in the lungs thus causing respiratory problems.

Studies have linked particulate matter exposure to increased premature deaths, respiratory irritation, lung function decrements, increased work loss, and changes in lung function, structure, and natural defense.

Although we have been discussing particles generated from wildland fire, dust particulate matter can be generated that may impact firefighters' health and welfare. Very little research has been conducted to quantify the exposure of firefighters to dust. If the dust is made up of crystalline silica such as found in volcanic ash type soils, the particles are very small, sharp and jagged. If the particles reach the interior of the lung, they may cause irreversible damage to the lung.

- Carbon Monoxide

  Carbon Monoxide reduces the oxygen-carrying capacity of the blood (reversible effect). Low exposures can cause loss of time awareness, and reduction of motor skills and mental acuity. Symptoms include nausea, dizziness, and weakness. Carbon monoxide can lead to a heart attack, especially in persons with heart disease. High exposures cause death due to a lack of oxygen.

- Benzene

  Benzene causes headache, dizziness, nausea, and breathing difficulties. It is a very potent carcinogen. Benzene causes anemia, liver and kidney damage, and cancer. Benzene was detected only among firefighters close to a source of combusting petroleum such as firefighters carrying a drip torch or firefighters operating a pump.

Exposure Limits (Thresholds)

The American Conference of Governmental Industrial Hygienists (ACGIH) develops recommendations or guidelines for Threshold Limit Values (TLVs) for airborne concentrations of substances.

Three categories of TLVs are defined:

1. TWA—the time-weighted average concentration for an 8-hour workday and a 40-hour work week to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

2. STEL—the short-term exposure limit is the concentration to which workers can be exposed continuously for a short period of time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, or (3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency. The period of time without suffering assumes that the daily TWA is not exceeded. It is not a separate, independent exposure limit; it supplements the TWA limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. The STELs are recommended only where toxic effects have been reported from high, short-term exposures in either humans or animals.

   A STEL is defined as a 15-minute exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the threshold limit value. Exposures above the TWA, up to the STEL, should not be longer than 15 minutes and should not occur more than 4 times per day. There should be at least 60 minutes between successive exposures in this range. An average period, other than 15 minutes, may be recommended when warranted by observed biological effects.

3. Ceiling — The concentration that should not be exceeded during any part of the working exposure.

This table provides information on the permissible exposure limits for some health hazards of smoke. The carbon monoxide (CO) time weighted average (TWA) exposure limit for federal works is 50 parts per million (PPM). Some states have more strict laws and the TWA for CO is 35 or even as low as 25 PPM. The CO TWA limit will probably go down to 35 PPM for federal workers in the future.

Exposure Assessment

An extensive assessment of fire line worker exposure has been completed for prescribed burning activities and wildfires. The study has successfully documented hundreds of individual exposures on prescribed fires and wildfires in the western United States.

The smoke sampling device weighed about 9 pounds and contained 3 battery powered pumps, a filter for particulate matter, absorption tubes for acrolein and formaldehyde detection, and a large bag to collect samples for processing back at the laboratory. The exposure study measured smoke exposures on six firefighters at prescribed fires and wildfires by collecting consecutive 2-hour samples of the air in each worker's breathing zone. (The samples were analyzed both in the field and back at the laboratory).

The assessment monitored all types of crews and identified four discrete firefighter activities: lighting, holding, direct attack, and mopup. During breaks, sampling pumps were turned off if the individual smoked.

The County Line and Foothills fires in Idaho provided researchers from the Pacific Northwest Research Station (PNW) with opportunities to evaluate firefighter exposure to the health hazards of smoke. Crews of hotshot firefighters, experienced crews, and less experienced crews were monitored. Six firefighters per day were selected at random from each crew and outfitted with a special fire pack that contained removable smoke sampling instruments. Exposure was measured over their entire work shift, and TWA exposure was calculated for each pollutant measured. The crew began direct attack and digging line and ended the day gridding for hotspots.

This slide shows the levels of carbon monoxide (CO) exposure for a representative firefighter. Carbon monoxide exposure was high during the morning hours when firefighters were constructing an indirect line, well removed from nearby sources of smoke. As a result, the elevated CO values were due to the inversion.

The levels of CO and other trapped pollutants declined as the inversion broke up between 0900 and 1100. Thereafter, the firefighters worked in relatively clean air, even during mopup. Even though during the early part of the day the firefighter was exposed to high levels of CO that were close to or exceeded 50 PPM, the lower exposure levels later on during the day brought the TWA for the workshift to the blue line (12.2 ppm) well below the TWA recommended standard of 50ppm and the 20 ppm adjusted for elevation. The inversion appeared to be the dominant factor controlling exposure; all the firefighters had similar CO exposures.

The Libby Wildfire Complex in Montana during 1994 provided an opportunity to evaluate firefighters in a burnout situation. Again, six firefighters per day were selected at random from each crew and outfitted with a special fire pack that contained removable smoke sampling instruments. Exposure was measured over their entire work shift, and TWA exposure was calculated for each pollutant measured. The crew began mopup operations and ended the day with direct attack and mopup duties on a burnout operation.

This slide shows the levels of carbon monoxide (CO) exposure for a representative firefighter. Carbon monoxide exposure was low during the morning mopup operations. In the afternoon, the burnout operations began and following ignition, the wind shifted and exposure increased. The average TWA exposure was 28.8 ppm, below the 50 ppm standard for federal employees.

This is a real time chart of the CO exposure monitored by a CO data logger during the burnout operation described above. The instrument was attached near the firefighters breathing zone. The CO data matches the CO exposure during the burnout situation. The CO TWA was well below the recommended standard but the firefighter came close to exceeding the ceiling limit of 200 ppm. These data recorders are good instruments for monitoring CO and informing the firefighter when they may be reaching the recommended TWA standard or exceeding the ceiling limit. The graph output can also be used for training.

The CO average exposure during an initial attack wildland fire was similar for all work activities and ranged from 8.4 ppm for mopup to 16.3 ppm for sawyers.

The CO average exposure by work task was not similar. The holding and mopup activity exceeded all other activities by a considerable margin. The exposure ranged from 4.2 ppm for a sawyer to 45.1 ppm for holding and mopup.

Studies have also shown that there is a good correlation between exposure of firefighters to carbon monoxide and other more difficult to measure toxics. For example, if carbon monoxide exposure levels are known for a firefighter, the exposure level to formaldehyde or acrolein can be estimated from this relationship. Carbon monoxide is easy to measure. Formaldehyde and acrolein are very difficult to measure.

To determine firefighter risk, the amount of time a firefighter is on the fireline is needed. It was determined from firefighting records that initial attack crews averaged a 13-hour workshift but only 3 hours on the fireline. At a project fire, average workshift was 14 hours with 10 hours on the fireline. At prescribed fires, the workshift averaged 12 hours with 7 hours on the fireline.

Prescribed fire

A prescribed burn at Merritt Island, Florida where the ignition techniques used pulled the smoke away from fireline workers.

The study found a similar or slightly higher potential of smoke exposure during prescribed fires than wildfires. Many changes in tactics and ignition techniques over the past 15 years have reduced the exposure of fireline workers to smoke during prescribed fires.

These slides show a fireline worker overexposed to smoke during a mopup activity following a clearcut burn in Washington State. The monitored individual well exceeded the ceiling limit of 200 ppm of CO and had classic systems of CO poisoning. These situations should be avoided and generally are today.

This graph shows that about 3 percent of the 300 individuals monitored during prescribed fires exceeded the 50 ppm CO exposure limit.

A direct attack operation had the highest carbon monoxide exposure while the lighters were exposed the least.

To date, studies of breathing zone air samples collected on wildland firefighters and workers involved with both prescribed fires and wildfires indicate some potential for hazardous exposure (respirable particulate, carbon monoxide, formaldehyde, acrolein). Although these exposures have occasionally exceeded STEL or ceilings, (3 percent during prescribed fires and 1-10 percent during wildfires) very few cases have approached or exceeded allowable TWAs.

Firefighters can face unhealthy levels of smoke when patrolling or holding fire lines on the downwind edge of a wildfire or prescribed fire, during direct attack of an escaped prescribed fire, or while mopping up intense hot spots. In most cases however, there are mitigation measures that can be implemented to reduce exposure levels

Studies of the respiratory effects of smoke exposure on wildland firefighters indicate that exposure during a fire season may result in small, but statistically significant, changes in lung function (FVC, FEV1). The health implications of short-term exposure and the potential health effects of long-term exposure have not been quantified.

Lung function exceeds demand. Maximum lung capacity is about 180 liters/minute. During maximum exercise, the body requires about 120 liters/minute. During firefighting, the body requires about 40-60 liters/minute of lung capacity. A healthy lung has a remarkable ability to recover from exposure to toxic compounds and particulate matter. This ability increases if there is nutritional food, water, and adequate sleep.

A small lung function decrease immediately following the completion of a prescribed fire workshift was evident during this University of Washington lung function study. The lung function returned to normal after a good night rest in a clean air environment. It is surmised that continued exposure to smoke on a period basis throughout the fire season would cause the lung function to take longer to return to normal.

There are short, immediate, and long term health effects. Short term effects include eye irritation, headaches, nausea, lung function decrements both post shift, post season, and possibly long term.

Intermediate health effects include decreased cilia action, bronchitis, and decreased immune function. Tiny hair-like projections called cilia sweep particles up and out of the respiratory passages. Days and weeks of smoke exposure can deaden the cilia action and suppress the immune system setting the stage for particle build-up and bronchitis. The cilia action recovers when the smoke exposure ends.

Long-term health effects include lung and heart disease and cancer. While long-term risk of lung and heart disease and cancer is suggested by studies of smoking and air pollution, these effects have not been confirmed in wildland firefighters. An assessment of chronic smoke exposure for wildland firefighters indicated little increased risk for the average firefighter even though exposure can be several times higher that experienced by residents of communities exposed to smoke. While biomass smoke may be a potential carcinogen, it is much less so than motor vehicle exhaust or other known carcinogens.

Risk Management includes three general areas and includes managing exposure through tactics and training, monitoring exposure through data recorders, visual references (smoke photo series), and biomarkers (urine tests), and respiratory protection.

Because prescribed fire and wildfire exposure data found firefighters exceeded OSHA permissible exposure limits in a small percentage of cases (less than 5 percent), considerable attention was given to tactics that would further reduce the risk of exposure. In addition, firefighters were encouraged to practice nutrition and health habits that maintain the function of the immune system and minimize the effects of smoke exposure.

Prescribed fire tactics to manage smoke exposure include setting up sprinklers or foaming areas to eliminate the need for mopup operations, placing fireline in areas of lighter fuels, employing lighting techniques to draw the smoke away from the fireline, burn under conditions where the large woody fuels and duff are moist to reduce smoldering potential, rotate individuals out of smoke, reduce aggressive mopup, monitor one or two crew members for CO, and finally, train employees in smoke exposure awareness.

Wildfire tactics to manage smoke exposure include rotating individuals and crews out of the smoke periodically, locating fire camps in areas less prone to concentrating smoke, allowing crews to stay at less smoky camps or establishing clean air tents, reducing aggressive mopup, monitoring one crew member for CO, training employees in smoke exposure awareness, and improving accident reporting system.

Nutritional and health habits that maintain the function of the immune system can minimize the effects of smoke exposure. Adequate rest, intake of vitamins, antioxidants, and nutritional foods and good health habits need to be encouraged for all wildland firefighting and prescribed fire situations.

Carbon Monoxide Monitoring

Carbon monoxide is relatively easy to monitor and is a surrogate for other difficult-to-measure toxic compounds. Dosimeters (1) provide cumulative data; (2) are inexpensive and light; and, (3) work well.

Carbon monoxide data loggers provide (1) real-time data, (2) TWA peak, and (3) computer storage of data; they are also (4) lightweight, (5) expensive, and (6) correlate well with pack sampling.

There is a relationship between visibility and CO exposure. A simple smoke photo series has been produced so that observers can estimate smoke exposure.

Laboratory and field studies of respiratory protective devices have been conducted by the Missoula Technology and Development Center, led by Dr. Brian Sharkey. Lab studies have focused on the effect of air-purifying respirators on work performance and on ways to predict the ability to work while wearing a respirator. Field studies have included a survey to determine field use of respirators, other methods of risk management, and field trials to evaluate a wide range of respirators in actual working conditions.

There are three types of masks used for respiratory protection: (1) disposable, (2) half mask, and (3) full face. All have advantages and disadvantages. Full-face masks were generally preferred over disposable and half masks at prescribed fires under heavy smoke exposure. Full-face masks provided better eye protection and better fit, although they were heavy and bulky. Half masks provided respiratory protection but no eye protection. Disposable masks were light-weight but usually fit poorly and the protection they provided was limited. None of the respirators provided CO protection.

For maximum protection from respirable particles and acid gases, HEPA and OV/AG filter cartridges are recommended. However, breathing is more difficult. Powered air-purifying respirators help with breathing, but are heavy and noisy.

All personnel are required to complete an 11-point training course on the use and maintenance of respirators before using one.

A light weight mouth piece respirator has been tested that could be used to protect the respiratory system. However, it would need an OSHA program established, NIOSH approval, and agency approval.

Respirator trials led by Brian Sharkey were conducted by the University of Montana and the National Wildfire Coordinating Group. The trials found that respirators did protect the respiratory system but were hot and difficult to breathe through. A 20 percent reduction in work capacity was noted in some cases.

Where do we go from here?

- There are several research projects that need to be completed including:
  - Assessment of crystalline silica exposure
  - Assess exposure in other areas of the country
  - Assess long term health risk
  - Assess fire camp exposure
  - Develop a simple biomarker test to determine exposure

- There are several development projects that need further development:
  - Improve awareness training
  - Implement CO monitoring protocols
  - Improve health surveillance and record keeping
  - Implement risk management strategies

Summary

Hazardous air pollutants generated by fire that can cause health concerns to firefighters include acrolein, formaldehyde, carbon monoxide, particulate matter, and benzene.

Short term exposure includes headaches, eye irritation, nausea, and lung function decrements.

Intermediate effects include reduced cilia action, immune suppression, and bronchitis.

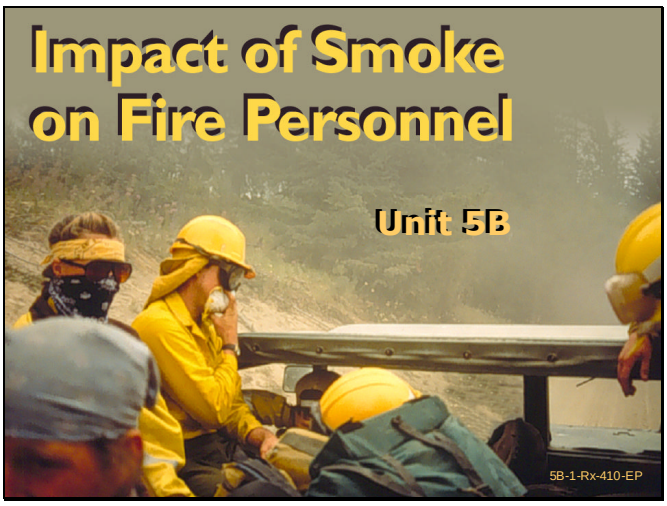
Long term effects have not been well assessed but could include pulmonary disease, heart disease, and cancer.

Prescribed fire and wildfire exposure data found firefighters exceeded OSHA permissible exposure limits in less than 5 percent of the cases.

Risk management strategies include:

- Tactics (rotation, lighting techniques, reduce mopup, etc.)
- Monitor (CO monitors, biomarkers, visual references)
- Respiratory protection

Slide 1



Slide 2

Unit 5B Objectives

- Discuss the impact of smoke exposure on fire personnel.
- Describe different techniques to reduce fire personnel exposure.
- Describe methods for evaluating fire personnel exposure to smoke.

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Slide 3

Previous Work

- Firefighters and managers have been concerned for decades about the health effects of smoke
- Early research proved inconclusive
- In 1985, studying the health effects from smoke was not a high priority

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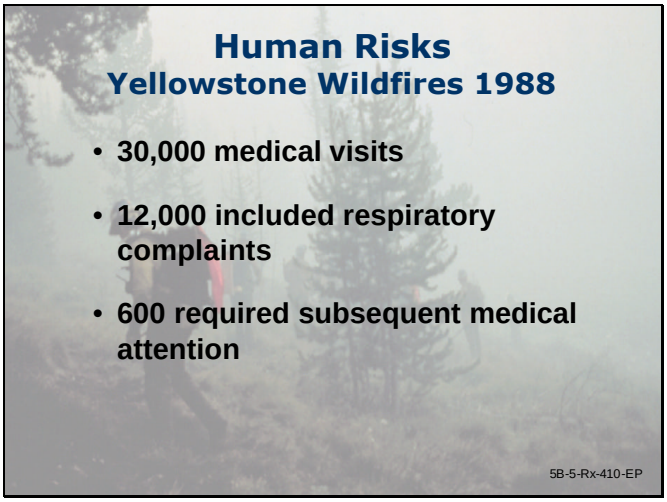
Slide 4

Slide 5



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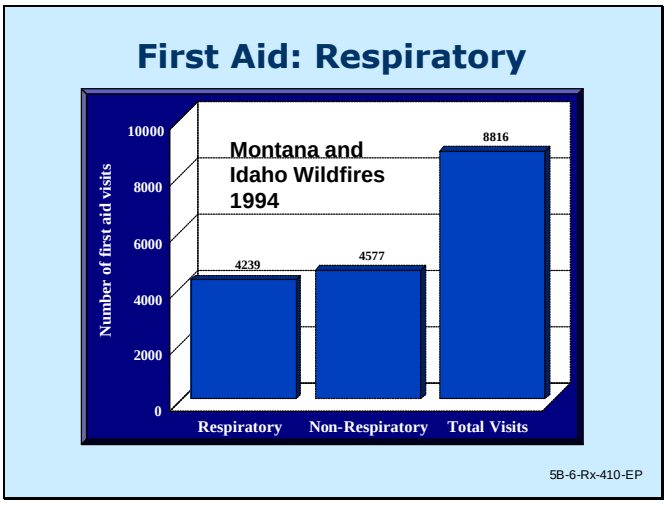


Slide 7

Health Hazards of Smoke Project
Research Needs - Study Plan of 1989

Exposure Assessment | Respirator Studies | Health Effects

Risk Management Strategies

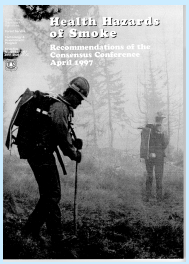
- Fireline Tactics
- Respirator Use
- Training
- Monitoring
- Medical Surveillance
- Future Research and Development

5B-7-Rx-410-EP

Slide 8

Recent Exposure Research

- NWCG assigns project to MTDC
- 1989-97 MTDC coordinates project
  - Technical advisory committee
  - HHS reports
  - PNW: prescribed fire and wildfire
- 1997 Consensus Conference
  - Recommendations
- 2000 fire season
  - MTDC, EPA, CDC



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Slide 9

Fire Camp

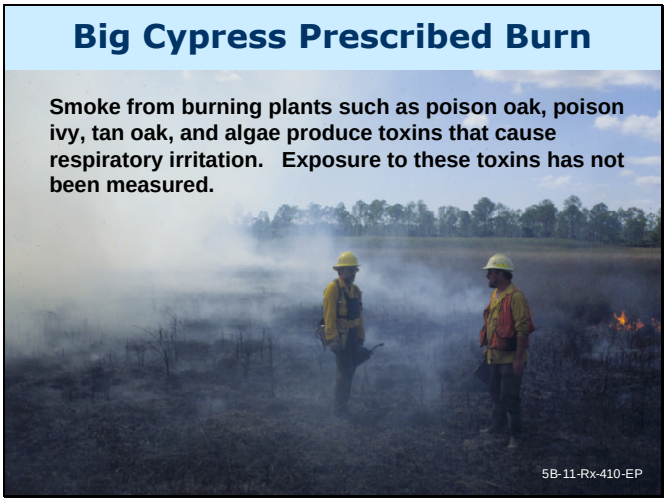
Exposure at fire camps is also a concern at Fire Camp

Leavenworth, Washington 1994

5B-9-Rx-410-EP

Slide 10

Slide 11



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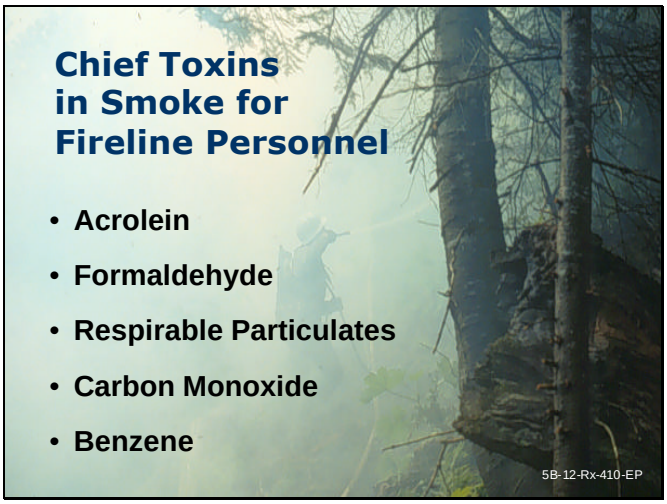

Slide 13

Acrolein

- Aldehyde with piercing, choking odor
- Irritates eyes, upper respiratory tract, causes nausea
- Severe exposure results in edema, abnormal lung function
- Long term exposure—chronic respiratory disease
- Workshift Peak Exposure Level: 0.1 ppm

5B-13-Rx-410-EP

Slide 14

Formaldehyde

- Low-level: irritates eyes, nose, throat
- Higher level: irritates respiratory tract
- Long-term exposure associated with cancer
- Workshift Peak Exposure Level: 0.75 ppm

5B-14-Rx-410-EP

Slide 15

Respirable Particles ($PM_{2.5}$)

- Irritation of mucous membranes
- Deposition in respiratory tract (alveoli)
- Transports carcinogenic policyclic Aromatic Hydrocarbons (PAHs)
- Defenses: cilia, macrophages
- Workshift Peak Exposure Level: 5,000 $\mu g/m^3$ (5 milligrams/m^3)

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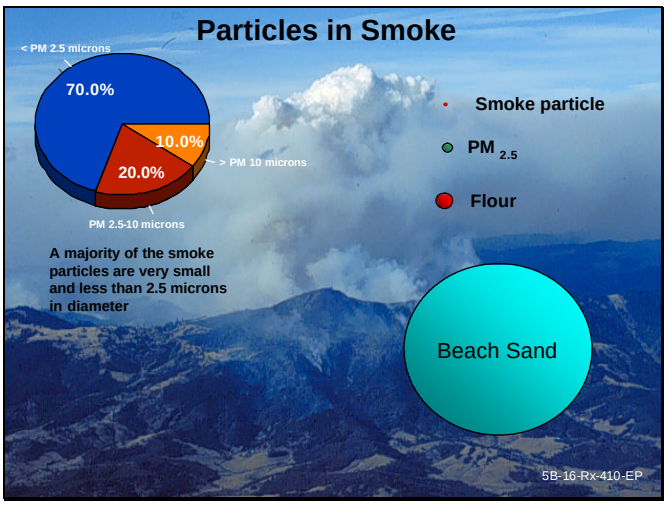
Slide 16



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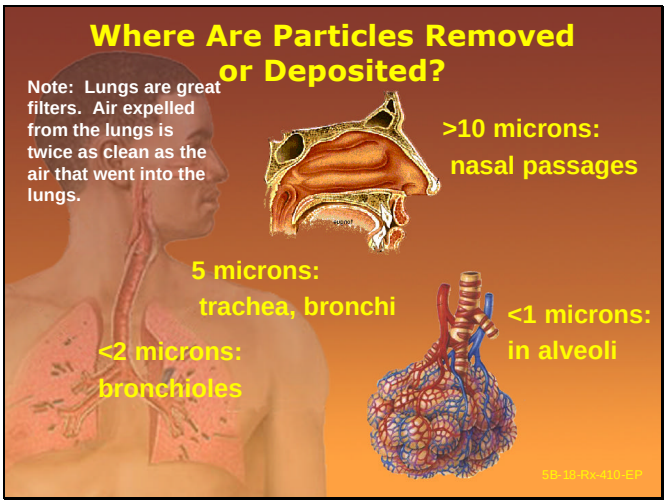

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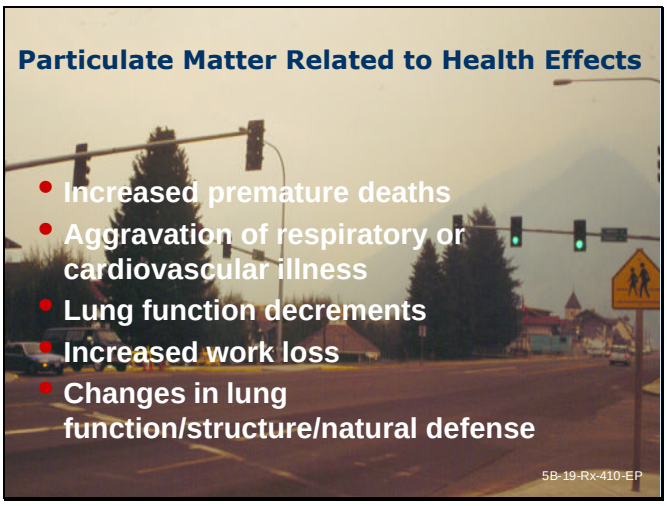

Slide 20

Slide 21

Carbon Monoxide (CO)

- Colorless and odorless
- Reduces oxygen transport in the blood
- Causes severe headaches
- Loss of mental acuity, motor skills, and time awareness
- Stresses heart
- May cause angina, coma, death
- Workshift Peak Exposure Level: 50ppm

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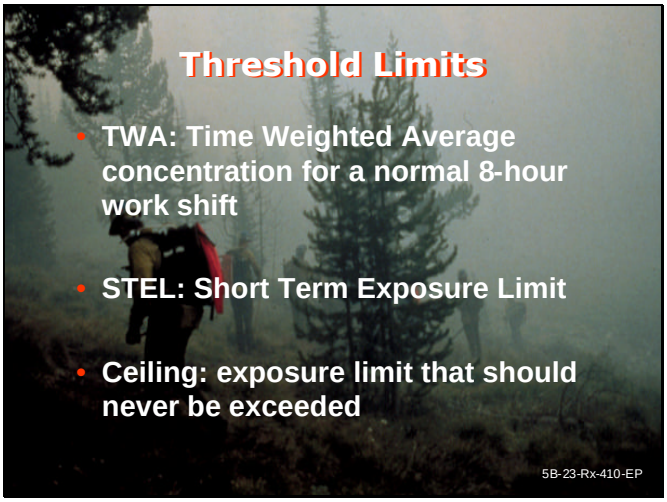
Slide 22

Slide 23



Slide 24

Exposure Limits

	CO ppm	Respirable Particles µ/m3	Acrolein ppm	Formalde-hyde ppm	Benzene ppm
TWA Current	50	5,000	0.1	0.75	1
TWA Past	35	5,000		1.5	10
TWA Future ??	35	3,000	0.1	0.75	0.3
Ceiling Current	200	none	none	none	5
Ceiling Past	200	none	none	none	5
Ceiling Future??	200	none	none	none	5

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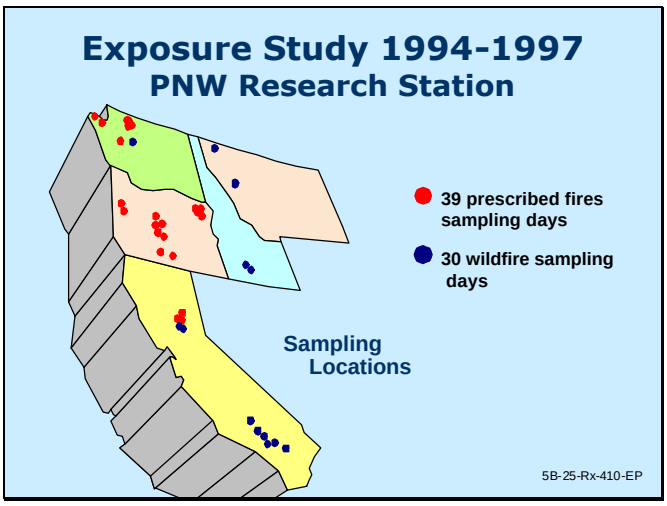
Slide 25



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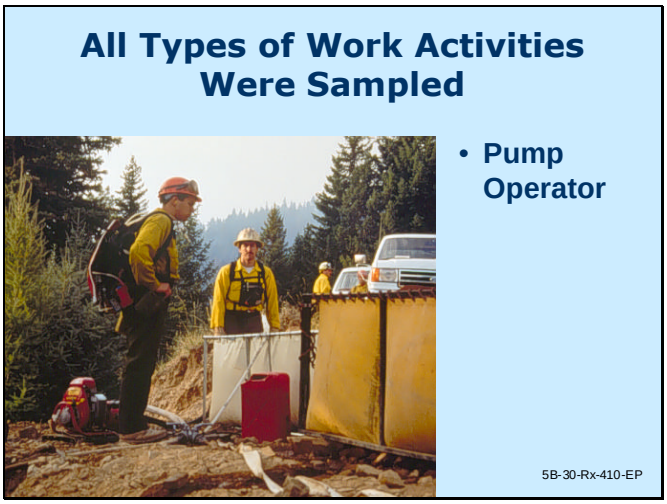

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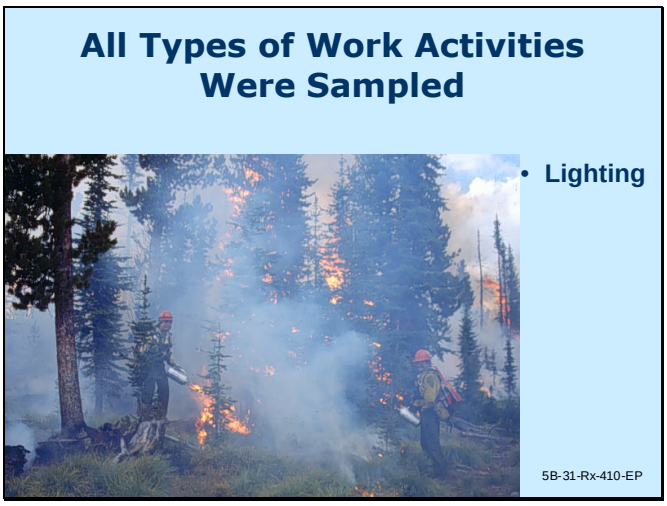

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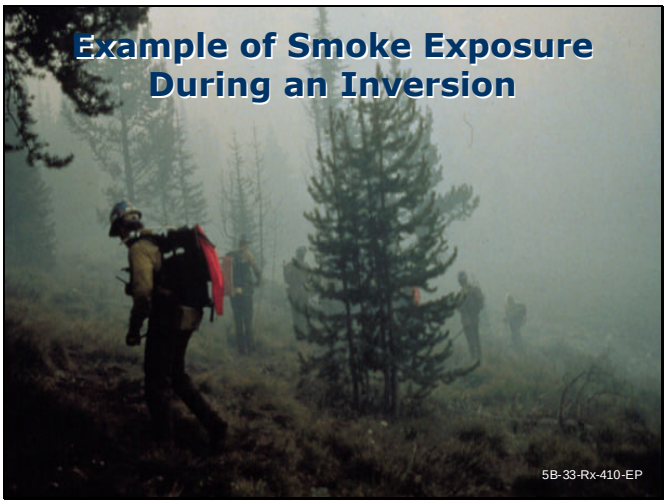

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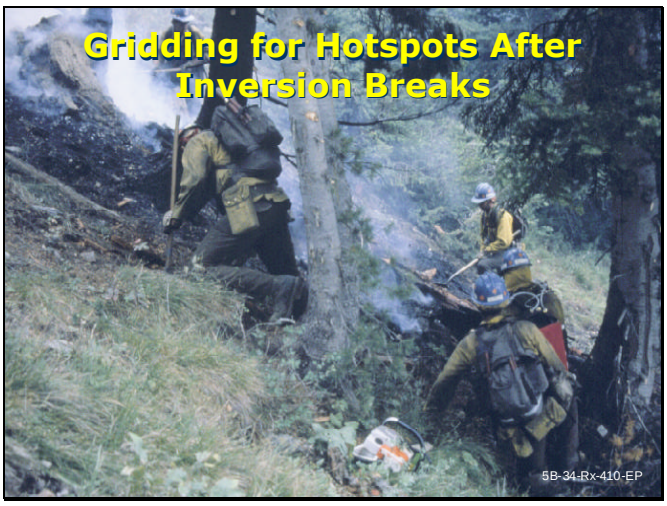

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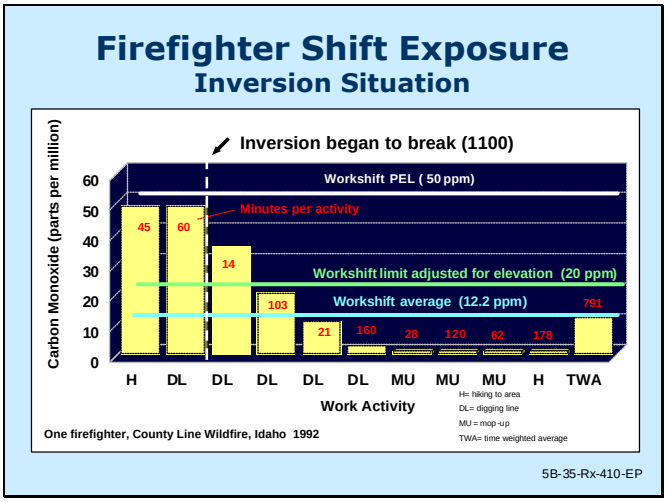

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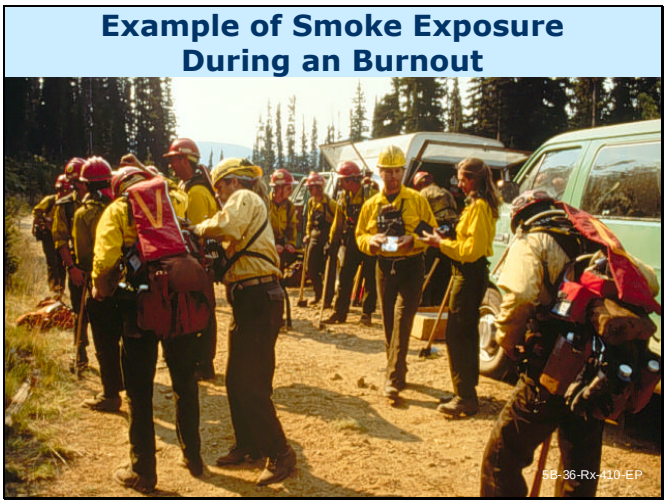

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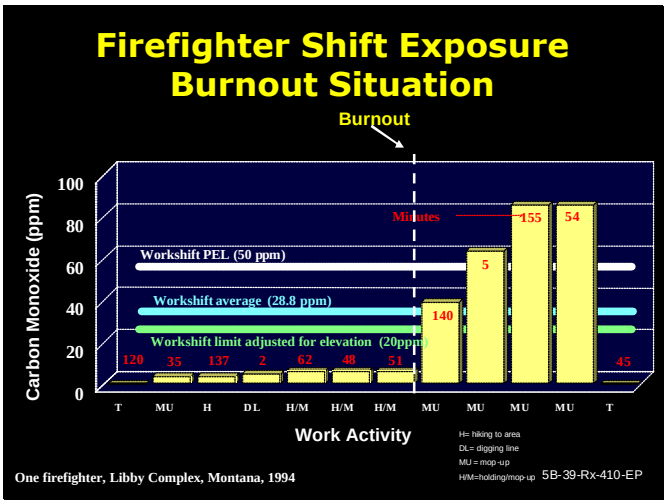
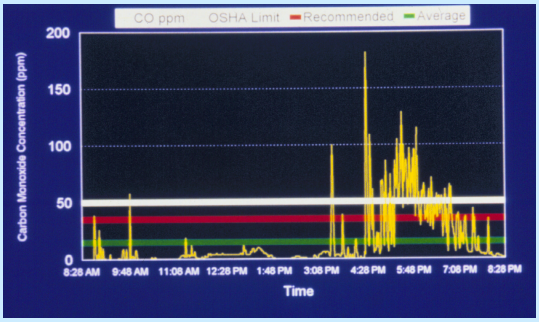


Slide 40

Actual Readout from CO Monitor During Burnout



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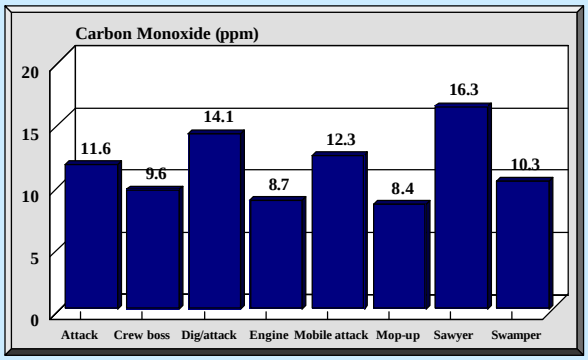
Slide 41

Carbon Monoxide Exposure
by wildfire work activity - initial attack



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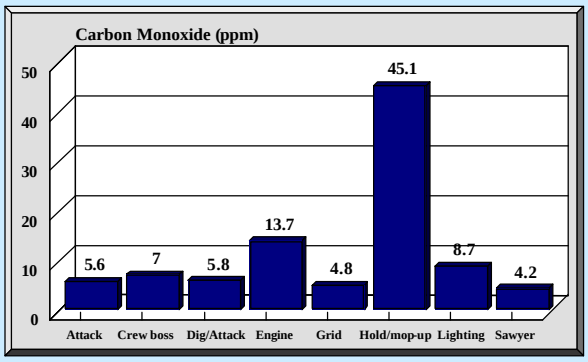
Slide 42

Carbon Monoxide Exposure
by wildfire work activity - project fire



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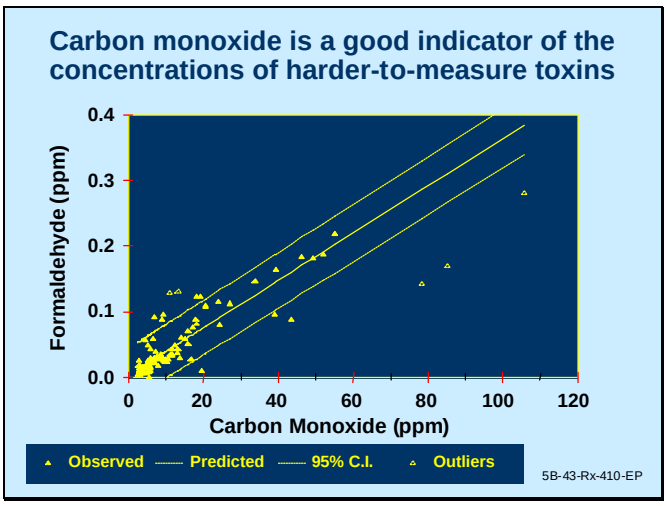

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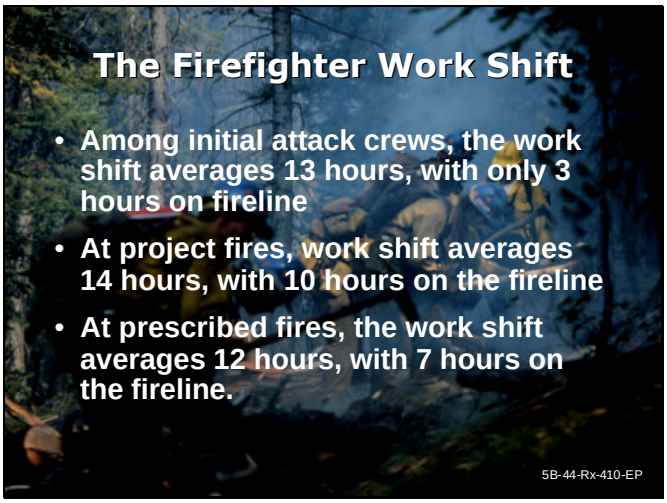

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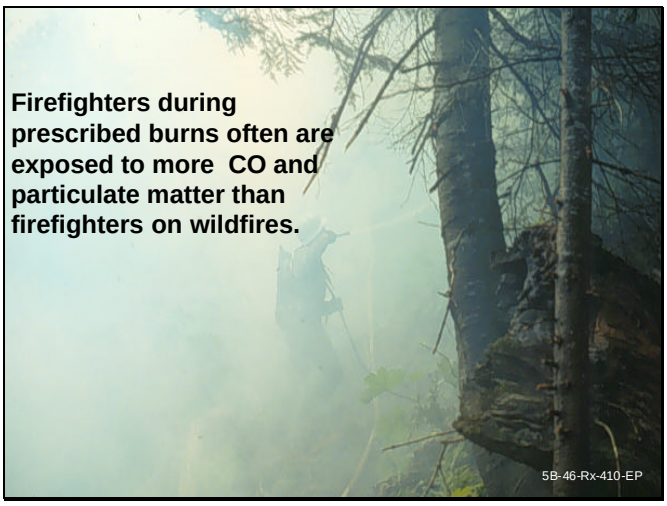
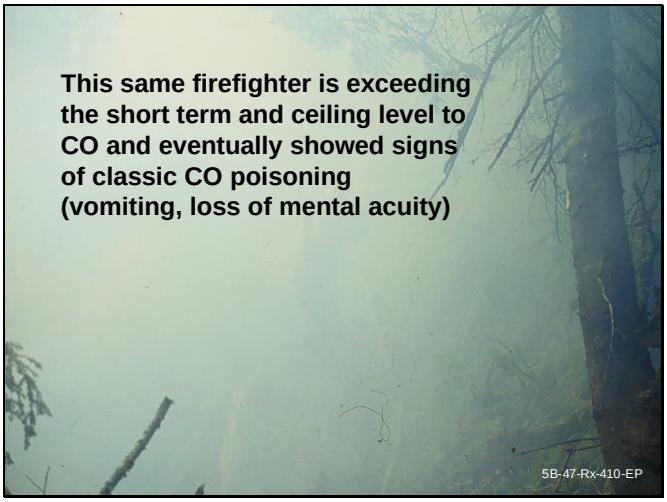


Slide 47



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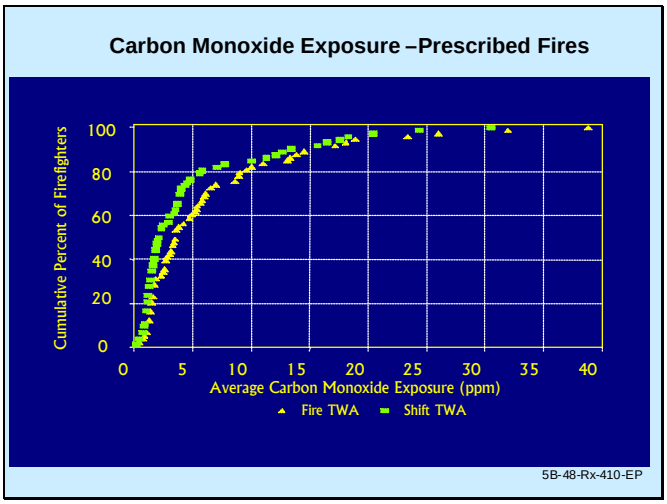
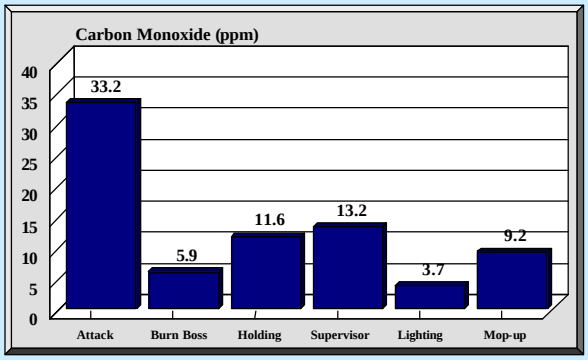


Slide 49

Carbon Monoxide Exposure
work activity - prescribed fire



5B-49-Rx-410-EP

Slide 50

Findings

- Smoke at 3% of prescribed fires and 1-10% of wildfires exceeds limits of CO and respiratory irritants (acrolein/formaldehyde, $PM_{3.5}$)
- Periods of low exposure may bring time-weighted average into compliance
- High-exposure work: direct attack, line holding, burnout, inversions
- Peak and short term exposures can exceed limits
- CO level is an indicator of $PM_{2.5}$, acrolein and formaldehyde
- Upper ranges of exposure may not have been captured and samples limited to West

5B-50-Rx-410-EP

Slide 51

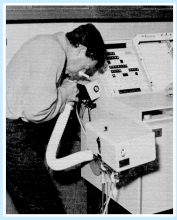
Lung Function

Maximum lung capacity: 180 L/min

Max exercise: 120 L/min

Average Firefighting: 40-60 L/min

L = Liters



5B-51-Rx-410-EP

Slide 52

Lung Function Test Results

- Decrease in lung function following prescribed fire work shift
- Lung function returned to normal following good night's rest in clean air
- The healthy lung has a remarkable ability to recover from exposure
- Continued daily exposure required longer periods in clean air before lung function returned to normal

5B-52-Rx-410-EP

Slide 53

Short-Term Health Effects

- Eye irritation
- Upper Respiratory Irritation
- Headache
- Nausea
- Lung function
  - Post-shift
  - Post-season
  - Long term?

5B-53-Rx-410-EP

Slide 54

Intermediate Health Effects

- Decreased cilia action
- Bronchitis
- Suppressed immune function (also influenced by stress, exhaustion, diet, smoke, sleep, etc.)

5B-54-Rx-410-EP

Slide 55

Slide 56

Risk Management

- Manage exposure
  - ✓Tactics and training
- Monitor exposure
  - ✓Carbon monoxide data loggers
  - ✓Visual reference
  - ✓Biomarkers

- Respiratory protection

5B-56-Rx-410-EP

Slide 57

Smoke Exposure Management Tactics on Prescribed Fire

- High moisture content of the large fuel and duff
- Reduce aggressive mopup
- Fireline location, barriers
- Lighting techniques
- Sprinklers/foam
- Rotate crews
- Monitor
- Training
- Improve nutrition/ health habits

5B-57-Rx-410-EP

Slide 58

Smoke Exposure Management Tactics on Wildfire

- Rotate crews
- Camp location/clean air sites
- Allow firefighters to move
- Reduce aggressive mopup
- Monitor
- Training
- Improve nutrition/ health habits

5B-58-Rx-410-EP

Slide 59

Carbon Monoxide Exposure Monitoring

Pros:
- Light weight
- Real time CO, 2 seconds, TWA, Maximum
- Alarm
- Computer compatible

Cons:
- Expensive
- Requires calibration

Electronic Dosimeter
(Recommended)

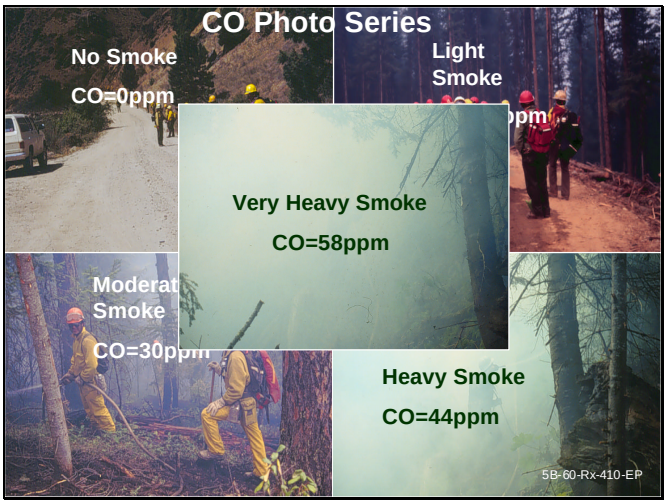
Tube Dosimeter
(Not recommended)

Pros:
- Light weight
- Inexpensive

Cons:
- Difficult to read
- Total CO only
- Requires cool temperature during storage

5B-59-Rx-410-EP

Slide 60



Slide 61

Respirators

Pros

- Protects respiratory system
- Less weight than SCBA
- Allows work in problem areas

Cons

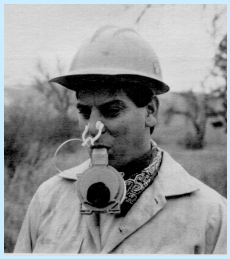
- Heat stress/ work reduction
- Training
- No CO protection
- Over-confidence

5B-61-Rx-410-EP

Slide 62

Mouthpiece Respirator

- Lightweight
- Easy on/off
- Self storing
- Beards, glasses OK
- But:
  - —OSHA program
  - —NIOSH approval?



5B-62-Rx-410-EP

Slide 63

Respirator Trial

- 20% reduction in work capacity was noted

5B-63-Rx-410-EP

Slide 64

Smoke Exposure

Where do we go from here?

Implement:
- Awareness training
- CO monitoring protocols
- Health surveillance/improved record keeping
- Risk management strategies

Research:
- Crystalline silica assessment
- Exposure in other geographic areas
- Long term health risk assessment
- Fire camp exposure

5B-64-Rx-410-EP

Slide 65

Summary

- Hazardous air pollutants include acrolein, formaldehyde, carbon monoxide, particulate matter, and benzene.
- Short-term exposure includes headaches, eye irritation, nausea, and short-term upper respiratory and lung function decrements.
- Intermediate effects include reduced cilia action, immune suppression, and bronchitis.
- Long-term effects have not been well assessed at this time.
- Firefighters exceeded OSHA permissible limits less than 5 percent of the time.
- Risk management strategies include tactics, monitoring and respiratory protection.

5B-65-Rx-410-EP

Slide 66

Unit 5B Objectives

- Discuss the impact of smoke exposure on fire personnel.
- Describe different techniques to reduce fire personnel exposure.
- Describe methods for evaluating fire personnel exposure to smoke.

5B-66-Rx-410-EP

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Smoke Management Techniques, Rx-410

Unit 5 - Smoke Impacts

Lesson C - Effects of Smoke on Visibility

OBJECTIVES:

Upon completion of this lesson, the student will:

1. Describe how smoke contributes to impaired visibility and regional haze.

2. Discuss how visibility impairment relates to the Clean Air Act, National Visibility Goals, and Class I areas.

This lesson will first describe how smoke causes visibility, regional haze, and safety concerns. The lesson will then focus on the visibility and regional haze and how it relates to regulations.

Why are we concerned about visibility? Here are a few reasons:

- Safety (visibility impairment can lead to automobile accidents)

- Visibility Protection (the 1977 Clean Air Amendment requires the prevention of any future and remedying of any existing impairment of visibility in Class I Federal areas)

- Regional Haze (This is haze and visibility impairment produced by a multitude of sources and the states are required by the Clean Air Amendment to show reasonable progress toward prevention and remedying)

- Other concerns such as social values (real estate, recreation, and tourism)

To begin the lesson, let's start off with a relatively clean air situation. This is the Shining Rock Wilderness area in North Carolina during a very clear day episode where a person can see over 100 miles (good visibility). The following pictures are from stationary cameras that periodically take pictures of mountain targets in the wilderness to monitor visibility and haze.

These mountains are obscured over 44 percent of the time from moisture in the air and clouds.

Regional haze conceals the mountain targets in the Shining Rock Wilderness 46 percent of the time.

This slide shows the visibility impairment from good, medium, poor, and bad days in the Shining Rock Wilderness.

Visibility impairment is associated with discoloration, haziness, and loss of detail and scenic features. How visibility impairment manifests itself depends on the extent and distribution of small particles in the atmosphere.

Visibility impairment can be classified into 3 general categories. These categories include layered haze, plume haze, and uniform haze.

Layered haze is when the atmosphere is stable (inversion) and pollution can be trapped near the ground and the haze will be in a layer. This photograph is of layered haze from wildfires near Missoula, Montana.

A plume haze occurs when pollution is emitted from a single source into an elevated stable layer. This photograph of a plume haze is from a prescribed fire near Mt. Shasta.

Uniform haze occurs when pollution degrades visibility uniformly throughout the atmosphere. A uniform haze that moves through the atmosphere from one region to another and extends across a large geographical region, is called regional haze. Regional haze causes most of the visibility impairment. This is a photograph of uniform haze in the Shining Rock Wilderness.

In order to understand visibility impairment, you need to understand the physics of light. Visible light is the vibration of electric and magnetic fields in the .4 to .7 micron wavelength range. The energy in light is carried by discrete packages called photons. The wavelength is similar to the length between the crest of two ocean waves. Blue light has a wavelength of about 0.45mm, green light has a wavelength of about 0.55 mm, and red light wave length of about 0.65mm. X-rays have smaller wavelengths than light and infrared, microwaves, and radar waves have wavelengths much longer than light waves.

Surface molecules of objects absorb and reflect photons of visible light. White light, which is composed of all “colors” of photons, strikes an object. If the object is white, photons of every color are reflected such as with this egg. However, if some of the photons are absorbed while others are reflected, the object will appear to be colored. Surface molecules of this apple captured all visible light photons except red.

Atmospheric visibility is influenced by scattering and absorption by light particles and gases. The particles absorb, refract, reflect, and diffract light. In certain instances, the light supplies energy to the particle and the particle will release thermal energy and/or fluorescence.

When a beam of white light (consisting of all colored photons) passes through a haze of small particles, it is generally the blue photons that are scattered in various directions and give the particles a bluish tint. Smoke contains very small particles that are often the diameter that is equal to or smaller than blue light and they will have a bluish appearance. When particles are near or larger than the wavelength of light, photons of all colors are scattered and a whitish appearance will occur.

The upper left photo is of smoke with very small particles that are less that the wavelength of light and refract blue light.

The lower right photograph shows smoke particles that have grown to about the size of the wavelength of visible light in a humid environment. The larger wavelength particles refract visible light thus appearing whitish.

As shown by this graph, most smoke particles have a diameter around 0.1 ¼m with a range of 0.08 ¼m to 0.7 ¼m. Visible light wavelengths: ~.4 -.7 ¼m.

Particles having a diameter about the same as the wavelength are the most effective at scattering light. Consequently since smoke particles are about the same diameter as the wavelength of light, they scatter about 85% of the light that strikes them.

Wildland fire smoke is primarily made up of elemental carbon and organic carbon (particulate matter).

Fine particles most responsible for visibility impairments are sulfates, nitrates, soil dust, organic compounds, and elemental carbon (soot).

Sulfates, nitrates, soil, organic carbon, and soil dust scatter light. Elemental carbon absorbs light. Since wildland fire smoke is primarily made up of elemental carbon and organic carbon, smoke is an excellent scatterer and absorber of light.

This slide shows the organic carbon that scatters visible light and is white in color. The elemental carbon absorbs light and is black in color.

What happens to smoke particles once lofted into the atmosphere? Smoke is made of very small particles less than 1 micron in size. It takes approximately 35 days for a particle less than 1 micron in size to drop 1000 feet. It has been estimated that the life span of a smoke particle is about 2 to 3 weeks. Note: Particles in this diameter range form excellent cloud condensation nuclei and may assist in the formation of rain droplets and can be removed from the atmosphere.

Since the particles provide excellent condensation nuclei, they also assist in the formation of fog. Thus, the smoke particles not only cause visibility impairment by scattering and absorbing light, but may also cause fog to be formed before the dew point is reached, thus causing visibility and automobile safety concerns.

Visibility/Visual Range: Visibility is most often thought of in terms of visual range or the furthest distance a person can see a landscape feature. The scientific definition of visual range is the farthest distance at which one can see a large black object against the sky. Maximum visual range with only air molecules in the air is 240 miles. Even without the influence of human caused air pollution, visibility would not reach the 240-mile limit because light extinction can occur naturally due to scattering caused by molecules that make up the atmosphere. This is called Rayleigh scattering and is the reason the sky is blue.

In the real world, people sense reduced visibility if a distant object that is usually visible cannot be seen; nearby objects look hazy; and if a layer of white, gray, or brown "pollutant" is seen.

Visibility is the process of how light is absorbed, scattered, and perceiving the environment through the human eye and brain. This hiker sees a landscape feature as light is reflected to form an image, however, particles and gases suspended in the view path can scatter or redirect image forming light as it travels to the eye. Sunlight, light from the clouds, and ground reflected light all impinge on and scatter from particulates located in the site path. Some of the scattered light remains in the sight path and at times it can become so bright that the image essentially disappears. Through this scattering process, some image forming light is removed from the site path and some light is scattered into the light path interfering with the view. Scattered light has a significant impact on the view. In addition, image-forming light is absorbed by particles and gases and taken out of the light path before reaching the viewer's eye. Absorption processes contribute less to visibility impairment than the scattering processes. The sum of scattering and absorption processes is called light extinction.

Extinction or loss of light is directly related to the concentration of gases and particles in the atmosphere.

These four pictures show the effect of progressively shifting sun angle on the appearance of a vista as seen from Island in the Sky, Canyonlands National Park. At 0600, the sun-angle-observer vista geometry results in a large amount of scattered light with a limited amount of reflected light from the vista. At 1200 noon, the opposite occurs. Scattered light is minimized and reflected light from the vista is at its maximum.

This slide shows the 1996-1998 average visual range over the United States. Currently, average visual range in the eastern United States is about 15-30 miles, or about one-third of the estimated natural background for the East. In the West, visual range currently averages about 60-90 miles, or about one-half of the estimated natural background for the West. Notice how much more impaired visibility is in the East versus the West. The current visual range was measured from the Interagency Monitoring of PROtected Visual Environments (IMPROVE) network.

National Visibility Goals

The 1977 amendments to the Clean Air Act established a national goal of "the prevention of any future, and remedying of any existing impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution."

States are required to develop implementation plans that make "reasonable progress" toward the national visibility goal**.** This is similar to the requirement by the Clean Air Act that requires the states to manage smoke for the health and welfare of the public.

The visibility regulations require states to make "reasonable progress" toward the Clean Air Act goal of "prevention of further, and future remedying of any existing, impairment, of visibility…". The regional haze regulations did not define visibility targets, but gave the states flexibility in determining reasonable progress. The rules require states to establish goals for each affected Class I area to: 1) Improve visibility on the haziest 20 percent of the days and 2) ensure no degradation occurs on the clearest 20 percent of the days over the period of each implementation plan.

A visibility baseline will be determined from a national network of visibility monitors (IMPROVE) representing Class I areas.

This slide is a map of the mandatory class I Federal areas of the United States. These areas are subject to the tightest restrictions on how much additional pollution, or increment, can be added to the air. Class I areas include Forest Service wilderness, national memorial parks over 5,000 acres, national parks exceeding 6,000 acres, and international parks.

Federal land managers have somewhat conflicting roles when it comes to protecting visibility in the Class I areas they manage.

On the one hand, they are given the responsibility by the Clean Air Act for reviewing Prevent Significant Deterioration (PSD) permits of major new and modified stationary sources and commenting to the state on whether there is a concern for visibility impacts. On the other hand, the federal land managers also use wildland fire which emits visibility impairing pollutants.

How is this conflict resolved? Wildernesses are managed to preserve and protect natural areas. Smoke and visibility impairment from wildland fire that closely mimics what would occur naturally is generally viewed as acceptable; while visibility impairment from “unnatural” pollutants and unnatural pollution sources is not.

Regional haze is visibility impairment produced by a multitude of sources and activities that emit fine particulates and their precursors, and are located across a broad geographical region. This contrasts with visibility impairment that can usually be traced to a single, very large polluting source.

Natural and current regional visibility varies significantly due to humidity, natural and anthropogenic emissions

This slide shows the effect that different levels of regional haze or uniform haze have on a Glacier National Park, Montana vista. The photos were taken near Apgar on the southwestern end of Lake McDonald. The atmospheric particulate concentrations associated with the photographs correspond to 7.6, 12.0, 21.7, and 65.3 mm.

Summary

Visibility is the process of how light is absorbed, scattered, and perceiving the environment through the human eye and brain. Image-forming information from an object is reduced (scattered and absorbed) as it passes through the atmosphere to the human observer.

A majority of the particles generated by wildland fires are very small and are excellent scatterers of light.

Regional haze is visibility impairment produced by a multitude of sources and activities that emit fine particulates and their precursors, and are located across a broad geographical region.

The Clean Air Act establishes National Visibility Goals that are administered by the states.

Slide 1

Slide 2

Unit 5C Objectives

- Describe how smoke contributes to impaired visibility and regional haze.
- Discuss how visibility impairment relates to the Clean Air Act, National Visibility Goals, and Class I areas.

5C-2-Rx410-EP

Slide 3

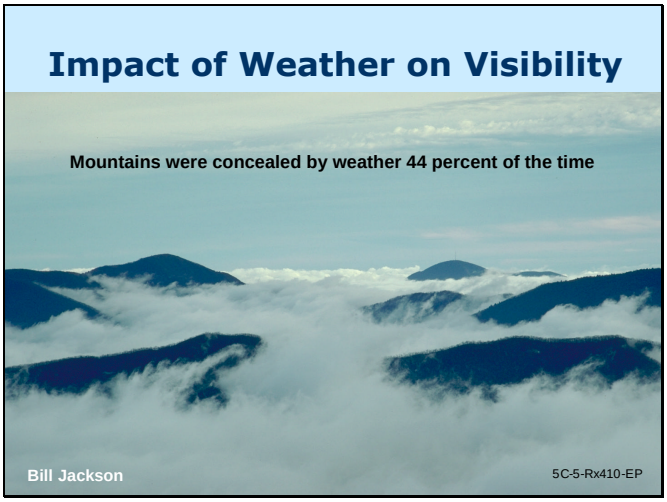
Why are we concerned about visibility?

- Safety
- It is the law (1977 Clean Air act Amendment)
- Regional Haze
- Scenic visibility protection

5C-3-Rx410-EP

Slide 4

Slide 5



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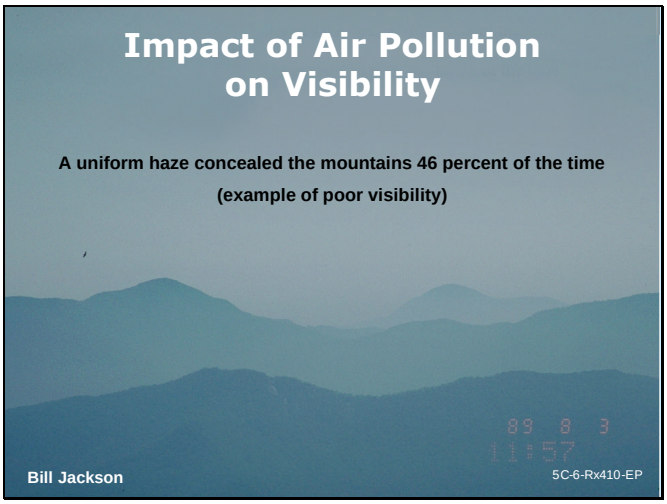

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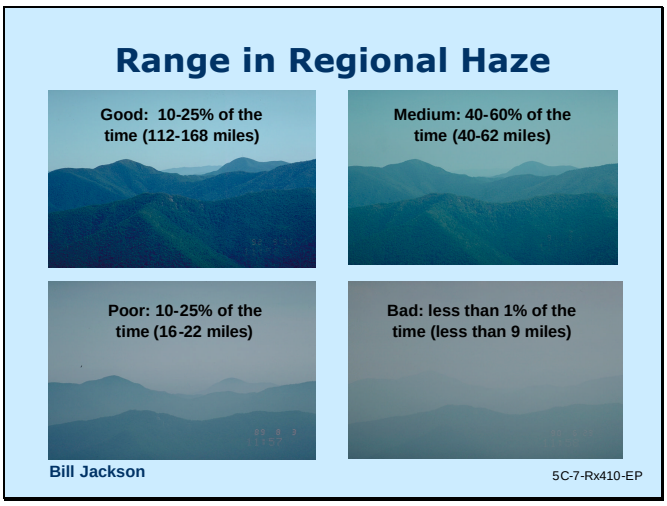

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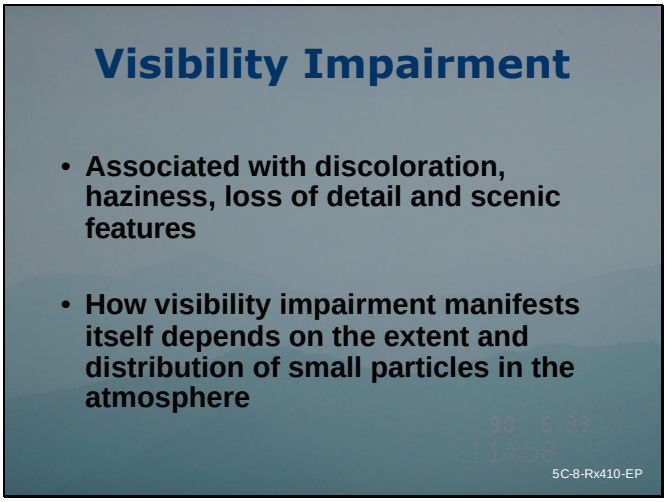

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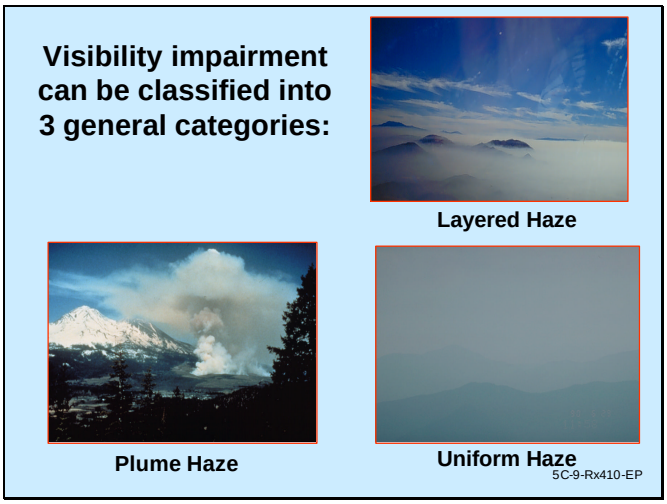
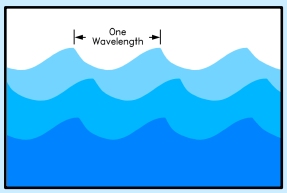
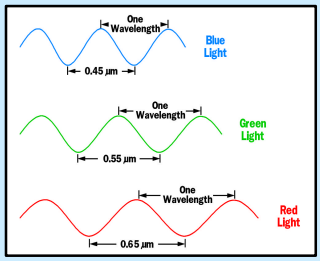


Slide 10

Visible Light

Visible light is the vibration of electric and magnetic fields in the .4 to .7 micron wavelength range. The energy in light is carried by discrete packages called photons.



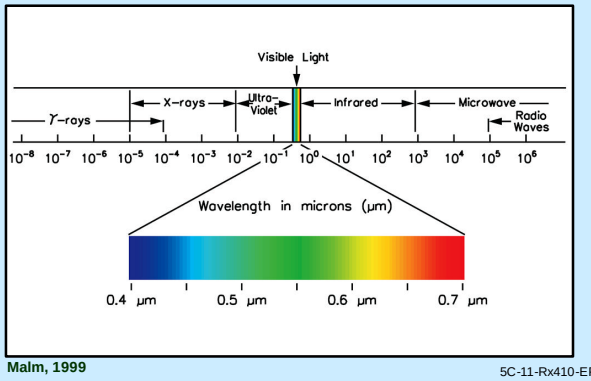


Malm, 1999

5C-10-Rx410-EP

Slide 11

Wavelength of Visible Light



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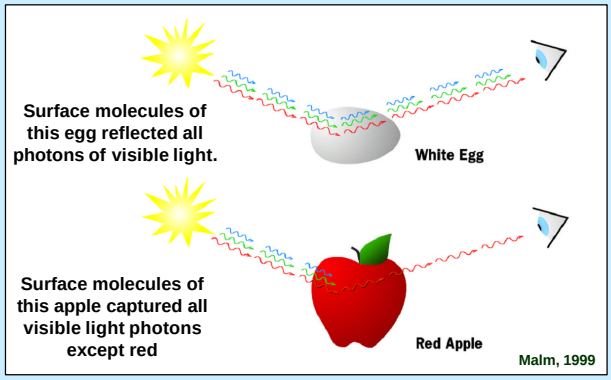
5C-11-Rx410-EP

Slide 12

Surface molecules of objects absorb and reflect photons of visible light



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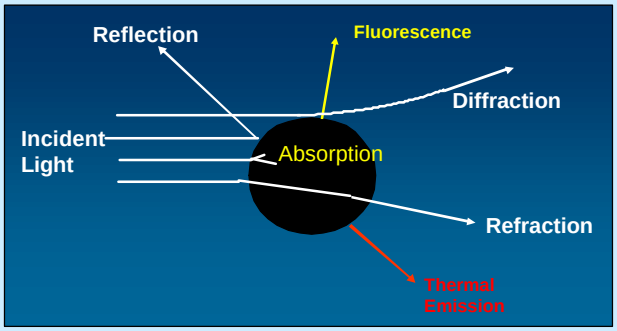
5C-12-Rx410-EP

Slide 13

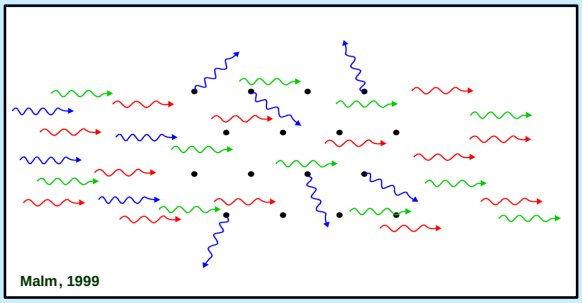
Atmospheric visibility is influenced by scattering and absorption of light particles and gases



5C-13-Rx410-EP

Slide 14

Blue Haze

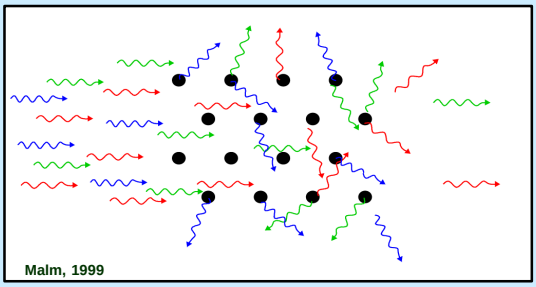


Small particles refract blue light and the resulting haze looks bluish

5C-14-Rx410-EP

Slide 15

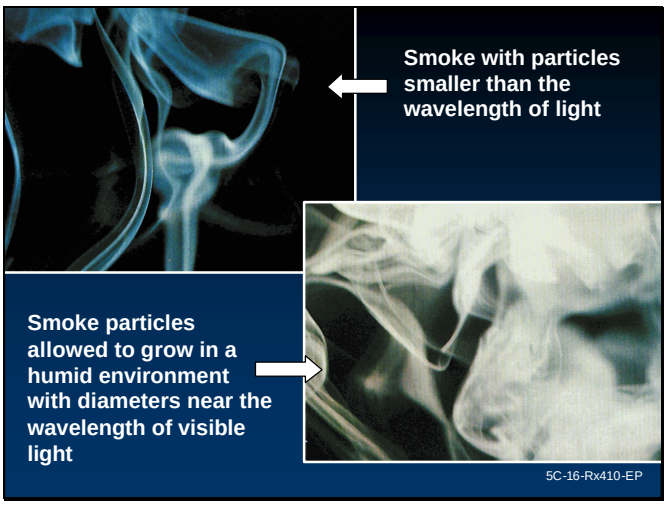
White Haze



Particles close to the size of visible light will scatter all photons equally, and the resulting haze looks whitish

5C-15-Rx410-EP

Slide 16



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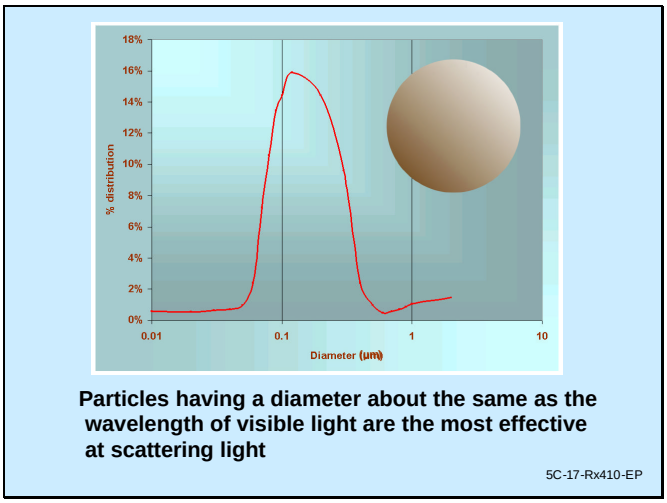

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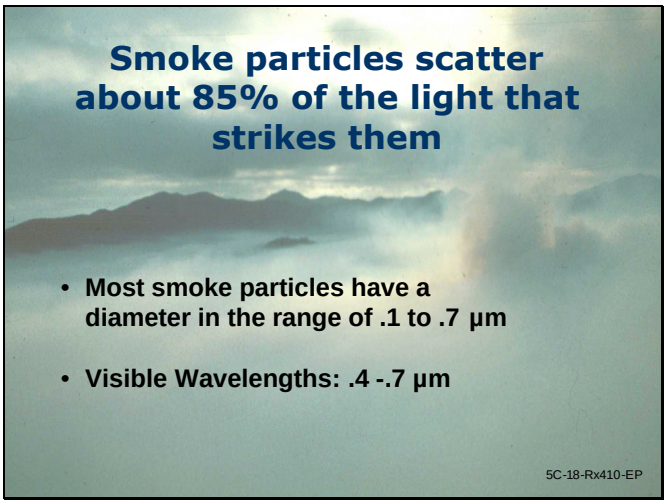

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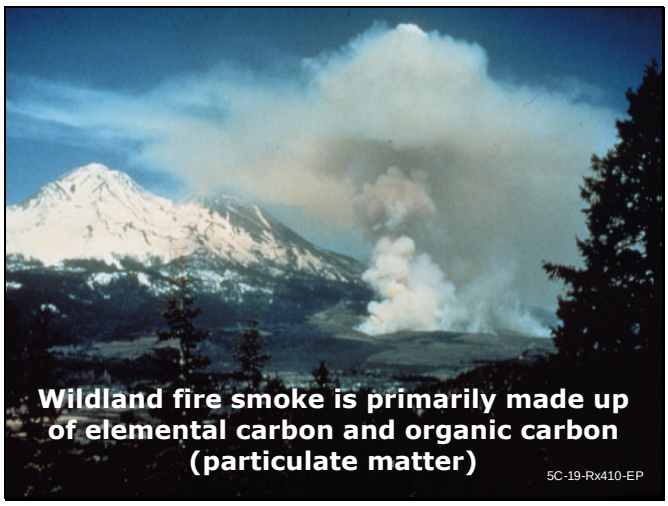
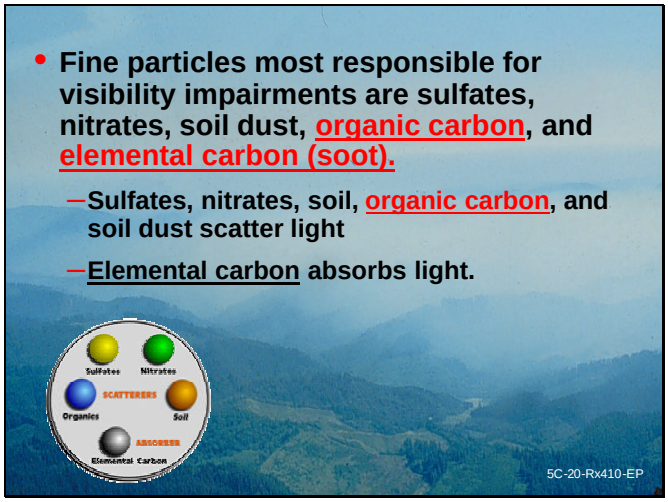


Slide 20



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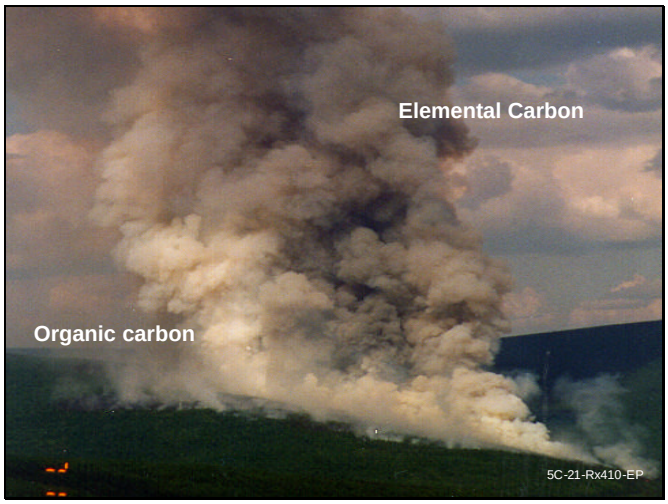

Slide 22

What Happens to Smoke Particles?

- It takes about 35 days for a particle between 0.1 and 1.0 µm to drop 1000 ft. (in still, dry air)
- Most smoke particles = .1 to .7 µm Particles of this size form excellent cloud condensation nuclei and may assist in the formation of rain or fog droplets and can be removed from the atmosphere.
- It has been estimated that smoke particles have an average "life-span" of 2-3 weeks.

Slide 23

Visibility - Visual Range

Definition - Visual range is defined to be the farthest distance at which one can see a large black object against the sky.

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Slide 24

Reduced Visibility

In the real world, people perceive reduced visibility if:

- a distant object that is usually visible cannot be seen
- a nearby object looks hazy or colors are washed out
- a layer of white, gray, or brown "pollutant" is seen

Maximum visual range with only elemental gas molecules in the air is 240 miles.

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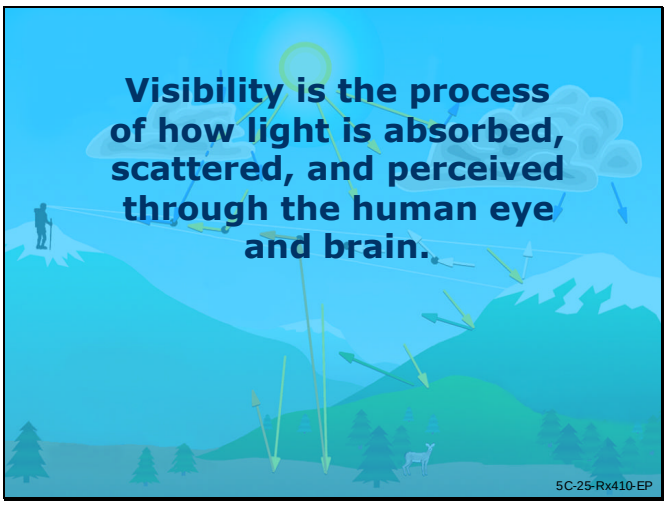

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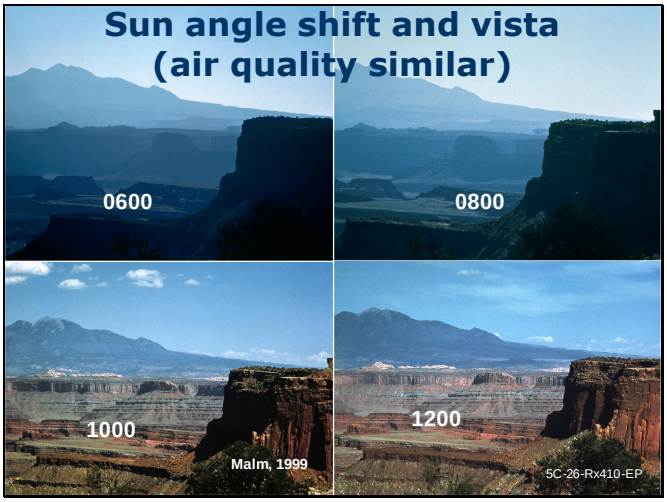

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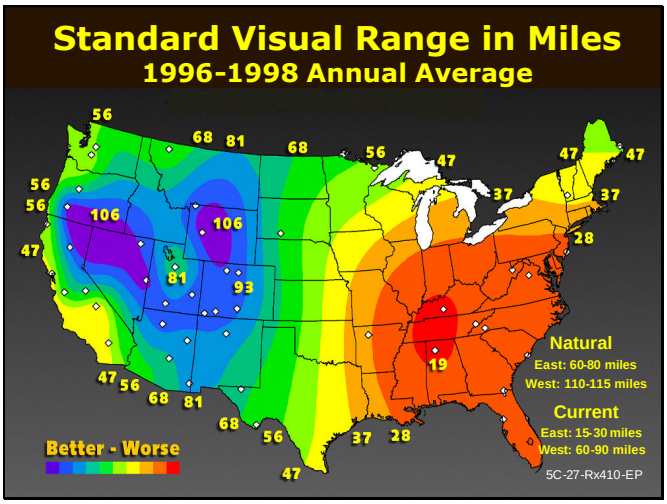

Slide 28

National Visibility Goals

- The 1977 amendments to the Clean Air Act established a national goal of "the prevention of any future, and remedying of any existing impairment of visibility in mandatory class I Federal areas from man made pollution."
- States are required to develop implementation plans that make "reasonable progress" toward the national visibility goal.

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What is Reasonable Progress?

State to establish goals for each Class I area to:

- Improve visibility on the haziest 20 percent of the days
- Ensure no degradation occurs on the clearest 20 percent of the days over the period of each implementation plan
- Determine a visibility baseline from a national network of visibility monitors representing Class I areas

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Mandatory Class I Federal Areas

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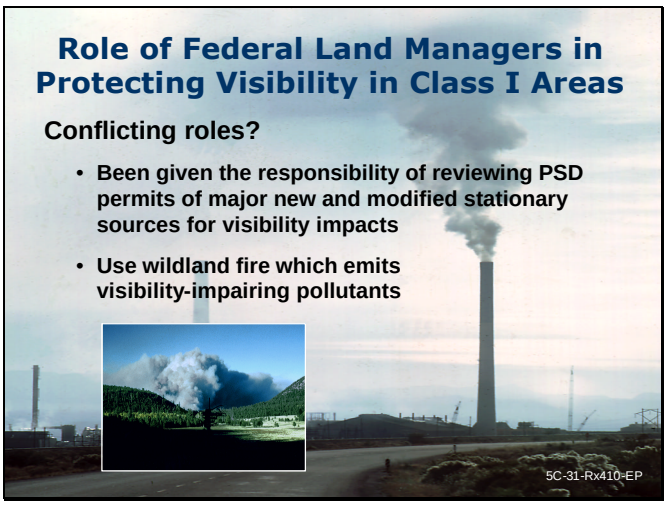

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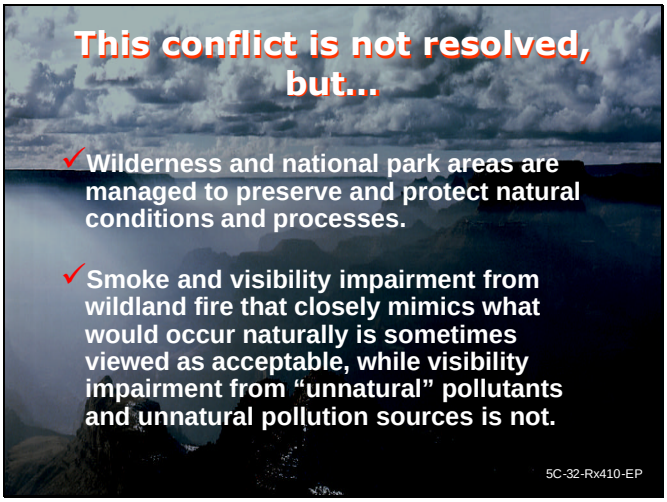

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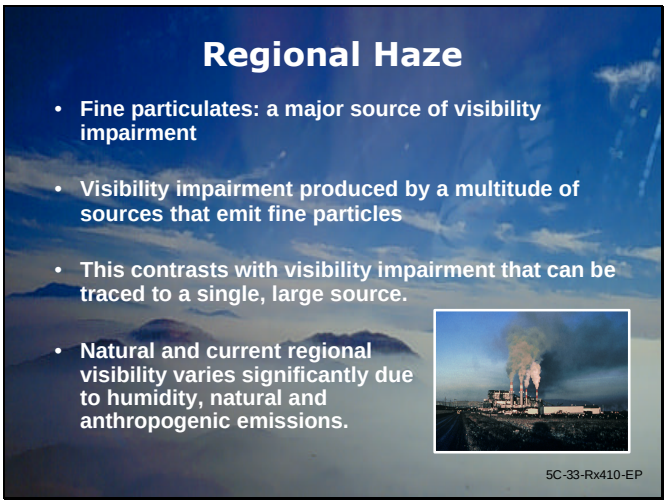

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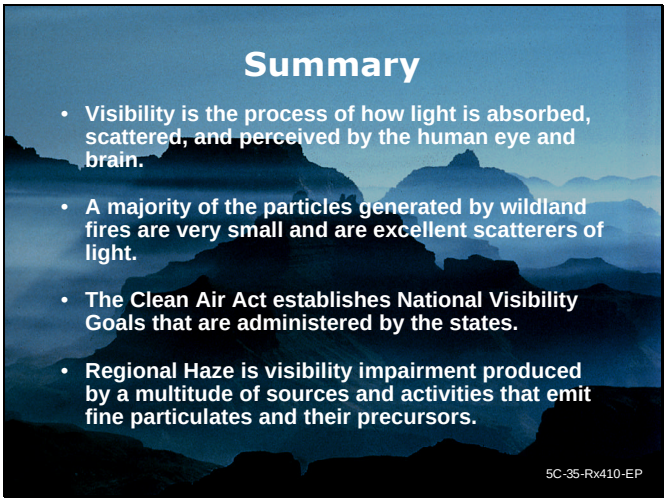

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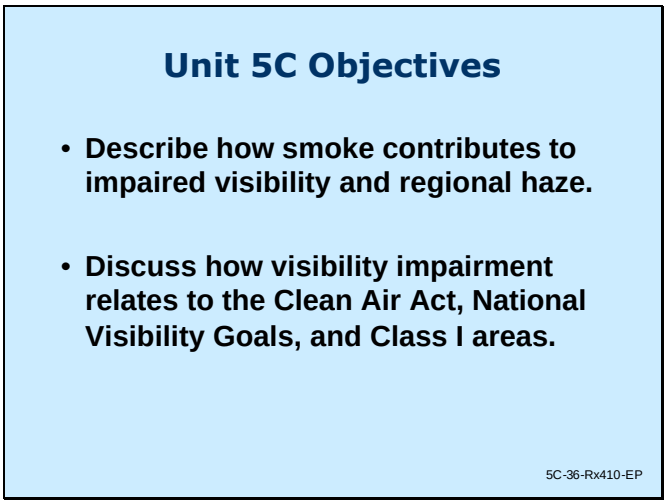

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Malm, William C. 1999. Introduction to visibility. Cooperative Agreement Number CA2350-97-001: T097-04, T098-06, Cooperative Institute for Research in the Atmosphere, NPS Visibility Program, Colorado Sate University, Fort Collins, CO. 68 p.

Smoke Management Techniques, Rx-410

Unit 5 - Smoke Impacts

Lesson D - Safety and Nuisance Impacts

OBJECTIVES:

Upon completion of this unit, students will be able to:

1. Define nuisance smoke impacts and list five examples.

2. List three public safety issues related to smoke.

3. Describe the current guidance for determining highway safety relative to visibility.

4. List three ways to monitor nuisance smoke impacts

5. List two ways to document nuisance smoke impacts.

I. WILDLAND FIRE SMOKE MAY HAVE NEGATIVE CONSEQUENCES WITHOUT VIOLATING AIR QUALITY STANDARDS.

A. Smoke may interfere with activities of the public, or present a safety hazard.

B. These consequences may have negative impacts on a burn program. Many programs are more severely restricted by these types of impacts than from restrictions from air quality regulations.

C. Even the perception of a problem by the public can result in restrictions on a burn program.

II. NUISANCE SMOKE AND SAFETY IMPACTS

A. Definition: The US Environmental Protection Agency defines nuisance smoke as the amount of smoke in the ambient air that interferes with a right or privilege common to members of the public, including the use or enjoyment of public or private resources (US EPA 1990).

1. Note that this definition is unrelated to the National Ambient Air Quality Standards.

2. In many parts of the country, NAAQS are not the chief smoke management concern. Nuisance smoke is far more problematic.

B. Nuisance smoke may be long or short term, impacting an entire town, or only a few individuals.

1. Impacts may occur during the burn, the following night, or as long as combustion continues.

2. Examples of nuisance impacts.

3. Even a few complaints can shut down a burn program.

C. Safety Impacts

1. Nuisance smoke becomes a safety hazard when it impairs visibility, or impacts public health.

2. Smoke may drift across roadways or settle on smoke-sensitive receptors

3. Particulate matter may serve as nuclei for condensation of water vapor, causing fog formation at a higher temperature than the dew point. This results in pockets of unexpected fog on roadways, presenting dangerous driving conditions.

4. Other examples of safety hazards

III. LEGAL CONSIDERATIONS

A. A private nuisance was defined by a state supreme court as an actionable invasion of interests in the use and enjoyment of private land. An invasion that constitutes a nuisance is usually by intangible substances, such as noises, odors, or smoke. (This is differentiated from trespass, which is a physical invasion by tangible matter.)

B. Nuisance smoke is most often regulated at the state or local level

1. Often based on public complaints and highway accidents

2. Some states (e.g., OR, FL, SC) take into account potential nuisance and safety impacts when deciding whether to issue a burn permit.

3. In 1991 in Sarasota County, FL, a state park protected its ability to burn by working with the county to incorporate a policy into the Comprehensive Plan for a new housing development. A “Notice of Proximity” was attached to all deeds and rental agreements for residents of the development, notifying them of possible impacts from resource management, including prescribed fire. Renters and landowners gave their consent by signing the Notice.

C. Federal and state regional haze regulations also protect visibility. Consult with local air quality regulators for information that may apply to your situation. (Discussed under Effects of Smoke on Visibility.)

IV. WHAT FACTORS CONTRIBUTE TO THE NUISANCE SMOKE PROBLEM?

A. Topography (valleys, low-lying areas)

B. Land forms (streams, lakes, ponds; clear-cuts)

C. Meteorology (inversions, low mixing heights, low transport wind speed, sea/land breezes)

D. Human considerations (Urban/wildland interface; land use such as recreation, agriculture, or housing; population density; infrastructure; cultural acceptance of prescribed fire and smoke)

E. Fuel conditions (Drought conditions promote ignition and smoldering of large fuels and duff or organic layers. Very high fuel moistures result in white, billowy smoke which may obscure visibility for short durations.)

V. ANTICIPATING AND MINIMIZING NUISANCE SMOKE IMPACTS

A. The burn plan should include provisions for dealing with nuisance smoke.

1. Incorporate operational strategies for preventing or minimizing smoke. Include strategies to minimize impacts on the crew. (Discussed in Operational Smoke Management Strategies.)

2. Plan to have a sufficient crew size to carry out strategies and to monitor for smoke impacts.

3. Set “trigger points” for terminating a prescribed burn because of smoke impacts. Have a contingency plan prepared for shutting down the burn quickly and safely.

4. Have proper road signs in place, and know whom to contact if a road must be closed. In most states, the authority to close roads is highly restricted.

   Consider acquiring a copy of the "Manual of Uniform Traffic Control Devices." This manual is mandated by the Federal Highway Administration and outlines the requirements for safety and warning signs, and flagger clothing and sign design standards. Be sure to coordinate with your local agencies who are responsible for managing traffic on public roadways (highway patrol, county sheriff, etc.).

VI. MONITORING FOR POTENTIAL NUISANCE SMOKE IMPACTS

A. When burning at a unit or site with smoke concerns, it is important to monitor for potential impacts and to document smoke observations, whether or not a nuisance problem occurs.

1. Set out stakes or flags on sensitive roadways at predetermined distances, and monitor visibility at time intervals.

2. Record number of nuisance complaints.

3. Set up air quality monitors or automated cameras.

4. Patrol smoke-sensitive areas to monitor for impacts. The presence of a crew member/firefighter can reassure the public that their welfare is being considered.

B. Use CA DOT highway visibility guidelines.

1. The CA DOT uses a safety factor of 1.75, i.e., Minimum Acceptable Visibility During Rx Burn = Acceptable Visibility x 1.75

Posted Speed Limit (mph)	Acceptable Visibility Adjusted for Rx Burn Conditions (feet)*
25	108
35	185
45	282
55	399
65	534
* DOUBLE adjusted visibility distance if smoke is present at night or if the highway is not divided.	

2. Note that the Minimum Acceptable Visibility should be doubled if smoke is present at night, or if it is not a divided road (which increases the risk of head-on collision).

3. Prior to burn, set out flags or stakes at set intervals along sensitive roadways, and assign crewmember to monitor.

VII. DOCUMENT SMOKE BEHAVIOR DURING THE BURN.

It is important to make written smoke observations during a prescribed burn, especially at sites where there is a significant risk of smoke management impacts. These notes may be useful as documentation of smoke behavior if an incident occurs.

· Have designated smoke observer make notes at the same time weather observations are taken. The weather observer may serve as the smoke observer if the person is in a position to make observations on the areas of concern.

Use the Smoke Monitoring Data Sheet

- Continue making written observations if smoke is a concern after sunset.

- Take photographs of the smoke plume, and of roadways, houses, or other sensitive areas, in order to document extent of smoke impacts.

VIII. CASE EXAMPLE: ALBANY PINE BUSH PRESERVE, NY

The Albany Pine Bush Preserve is a fire-managed natural area highly susceptible to negative impacts from smoke. The 2750-acre preserve is within the city limits of Albany, NY. The NY State Thruway bisects the preserve, and it is bordered by the Adirondack Northway and Thruway interchange. Adjacent to the property are three nursing homes (including a high-rise that specializes in respiratory care), a methane-emitting landfill, and hundreds of private homes and commercial structures. The site is managed for the rare natural communities that occur there, and as habitat for the federally endangered Karner Blue butterfly. Despite enormous challenges, the staff carries out a successful prescribed fire program. How do they do it?

First and foremost, they have cultivated the respect and trust of the community. They use various means to continually educate the public, including mailings, town meetings, newspaper and television media, conveying the message that fire is essential to the health of the Pine Bush. They also keep neighbors informed through an annual pre-burn mailing to over 1800 households and businesses, giving approximate dates of their upcoming burns. On the day of the burn, several members of the fire crew establish a phone bank, calling up to 100 individuals who have asked to be notified before burns occur in their local area. Neighbors have an opportunity to comment at the end of the burn season through a post-burn mailing that lists burns and accomplishments, and asks for feedback. Typically, only two or three negative comments are received at the end of the season.

The fire crew also uses a number of techniques to reduce emissions, such as burning small units (no greater than 30 acres) and conducting 100% mopup. They practice avoidance and dilution techniques by strictly adhering to meteorological parameters for wind direction and dispersion. The crew also recognizes situations when they must close down a burn because of smoke impacts, and are prepared with the staff and equipment to do so.

Although the cost of the burn program is high relative to more remote sites, the benefits are substantial. The vitality of the fire-adapted ecosystem, home to an endangered species and several other species of concern, is improving as a result of persistence and careful fire application. Fuel hazards are reduced in urban interface areas, and recreational opportunities have increased as dense stands are thinned by fire, allowing neighbors greater ease of access. The support of the community remains high for continuation of the prescribed fire program.

Slide 1

Slide 2

Unit 5D Objectives

- Define nuisance smoke impacts and list five examples
- List three public safety issues related to smoke
- Describe the current guidance for determining highway safety relative to visibility

5D-2-Rx410-EP

Slide 3

Unit 5D Objectives

- List three ways to monitor nuisance smoke impacts.
- List two ways to document nuisance smoke impacts.

5D-3-Rx410-EP

Slide 4

Nuisance Smoke

- **Smoke may cause problems without violating air quality standards.**
  - **May interfere with public's activities**
  - **Many burn programs are more severely restricted by these impacts than from air quality regulations.**
- **Even the *perception* of a problem can result in restrictions on a burn program.**

5D-4-Rx410-EP

Slide 5

What is Nuisance Smoke?

- **The amount of smoke in the ambient air that interferes with a right or privilege common to members of the public, including the use or enjoyment of public or private resources (US EPA 1990).**
- ***Not* defined by National Ambient Air Quality Standards.**
- **In some states nuisance smoke is defined by law or regulation.**

5D-5-Rx410-EP

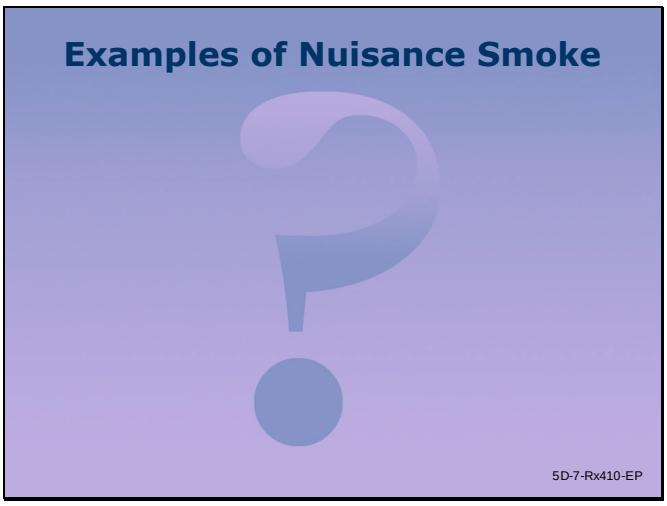
Slide 6

Scale of the Impact

- **May be short- or long-term**
- **May affect a few individuals, or entire towns**
- **Can occur during the daytime and nighttime hours**
- **A concern as long as combustion continues**

5D-6-Rx410-EP

Slide 7



Slide 8

Slide 9

Slide 10

Safety Related Episodes

- May result from direct plume impacts
- May result from continued smoldering after the burn, especially at night
- Presence of smoke particles promotes fog formation at temperatures above the dew point.

5D-10-Rx410-EP

Slide 11

Examples of Safety Impacts

5D-11-Rx410-EP

Slide 12

Legal Considerations

Nuisance smoke is usually regulated at the state or local level

- Burn permits or authorizations may be issued based on potential nuisance and safety impacts
- Counties or towns may have local smoke ordinances
- Supreme Court of Iowa ruled smoke intrusion may be a violation of private property rights (Fifth Amendment)

5D-12-Rx410-EP

Slide 13

Nuisance and Safety Smoke Factors: Topography

Topography, such as canyons, valleys or other low-lying areas

- High concentrations of low, smoldering smoke accumulate near the ground as air cools and wind speed declines after sunset

5D-13-Rx410-EP

Slide 14

Nuisance and Safety Smoke Factors: Land Forms

Land Forms

- streams
- lakes
- ponds
- clear-cuts

5D-14-Rx410-EP

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Nuisance and Safety Smoke Factors: Meteorology

Meteorology

- inversions
- low mixing height
- low transport windspeed
- sea/land breezes

5D-15-Rx410-EP

Slide 16

Nuisance Smoke Factors:
Human Considerations

- ✓ Urban interface
- ✓ Population density
- ✓ Land use
- ✓ Cultural Acceptance

5D-16-Rx410-EP

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Nuisance and Safety Smoke Factors:
Fuel Conditions

Drought conditions

- smoldering of large fuels
- smoldering of organic soils/duff

Very high fuel moisture

- may not produce more emissions but produces more water vapor
- smoke becomes less buoyant

5D-17-Rx410-EP

Slide 18

Anticipating Smoke Impacts

Fire Management or Burn Unit Plan should address nuisance and safety related smoke issues in the Smoke Management section.

- Incorporate operational strategies for preventing or minimizing impacts (discussed in Operational Smoke Management Strategies unit). Include strategies to minimize impacts on crew

5D-18-Rx410-EP

Slide 19

Anticipating Smoke Impacts

- Plan for sufficient crew size to carry out strategies and monitor.
- Set "trigger points" for terminating a burn because of smoke impacts, and have contingency plan for shutting the burn down.
- Have proper road signs and know whom to contact to close a road.

5D-19-Rx410-EP

Slide 20

Monitoring Smoke

When dealing with a smoke-sensitive site, it is important to monitor for nuisance and safety related smoke impacts, and document smoke observations.

- Set out stakes or flags on roadways at predetermined distances and monitor visibility
- Record number of nuisance complaints
- Use air quality monitors or cameras
- Patrol smoke-sensitive areas to monitor for impacts and reassure the public

5D-20-Rx410-EP

Slide 21

Monitoring Smoke

Use recommended minimum highway visibility guidelines

Posted Speed Limit (mph)	Minimum Acceptable Visibility Adjusted for RX Burn Conditions (feet)	Minimum Acceptable Visibility at night
25	108	216
35	185	370
45	282	564
55	399	798
65	534	1068

Acceptable Visibility During Burn = 1.75 x Normal Acceptable Highway Visibility

Double the distance at night

Source: CA DOT

5D-21-Rx410-EP

Slide 22

Document Smoke Behavior

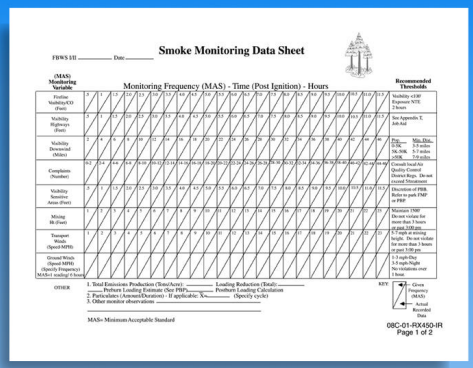
Make written observations on smoke behavior, nuisance and safety impacts, especially at smoke-sensitive sites or units

- **Have designated smoke observer make notes at the same time weather observations are taken; use Smoke Monitoring Data Sheet**
- **Continue if monitoring the burn through the night**
- **Take photographs of sensitive roadways, housing or commercial areas, and the smoke plume to show either impacts or lack of impacts**

5D-22-Rx410-EP

Slide 23

Smoke Monitoring Data Sheet



Smoke Monitoring Data Sheet

FBWS I/II _____ Date _____

(MAS) Monitoring Variable	Monitoring Frequency (MAS) - Time (Post Ignition) - Hours																								Recommended Thresholds
Frontline Visibility/CO (Feet)	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	Visibility <1SF Exposure NTE 2 hours
Visibility Highways (Feet)	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	See Appendix T, Job Aid
Visibility Downwind (Miles)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	Post-Ignition: Min. Dist. 0-5K: 2-5 miles 5K-50K: 5-7 miles >50K: 7-10 miles
Complaints (Number)	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	Consult local Air Quality Control District Regs. Do not exceed Structure
Visibility Sensitive Areas (Feet)	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	Discretion of PHB Refer to pack FMP or PBP
Mixing Ht (Feet)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Minimum 1500' Do not vacate for more than 3 hours at mid-200 pm
Transport Winds (Speed-MPH)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mixing ht. < 1500' ceiling height: Do not vacate for more than 3 hours at past 3:00 pm
Ground Winds (Speed-MPH) (Specify Frequency) MAS=1 reading/ 6 hours																									0-3 mph-Day 3-5 mph-Night No rotation over 3 hours

OTHER

1. Total Emissions Production (Tons/Acre) _____ Loading Reduction (Total) _____
_____ Prefuro Loading Estimate (See PBP) _____ Postburn Loading Calculation
2. Particulates (Amount/Duration) - If applicable: X= _____ (Specify cycle)
3. Other monitor observations _____
_____

MAS= Minimum Acceptable Standard

KEY: Given Frequency (MAS) / Actual Recorded Data

08C-01-RX450-IR
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Slide 24

Case Example: Smoke Management

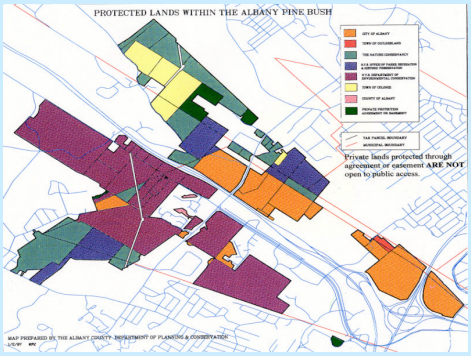
Albany Pine Bush Preserve

- **2750 acres within city limits of Albany, NY**
- **Three major roadways**
- **Three nursing homes**
  - **one high-rise specializes in respiratory care**
- **Methane-emitting landfill**
- **Hundreds of private homes**
- **Federally endangered species**

5D-24-Rx410-EP

Slide 25

Multiple Land Ownerships Increase Complexity



5D-25-Rx410-EP

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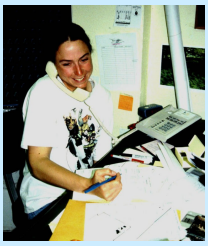
Case Example: Albany Pine Bush

Smoke Mitigation Measures

- **Community Relations**
  - **pre- and post-season mailings to 1800 neighbors**
  - **town meetings**
  - **media articles and reports**
  - **phone calls to all who request notice on day of burn (as many as 100)**



5D-26-Rx410-EP

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Case Example: Albany Pine Bush

Smoke Mitigation Measures

- **Fire Operations**
  - **Burn small units (<30 acres)**
  - **Strict adherence to wind and dispersion parameters**
  - **100% mopup**
  - **Terminate burns when smoke becomes a problem**

5D-27-Rx410-EP

Slide 28

Case Example:
Albany Pine Bush

Results = Program Success

- Ecosystem health is improving
- Butterfly habitat has increased
- Hazard is reduced
- Community support remains high

Slide 29

Summary

- Smoke is a nuisance if it interferes with a right or privilege common to the public.
- Smoke is a safety hazard when it impairs visibility on highways and airports etc.
- Anticipate, monitor and document smoke behavior.
- Be proactive to build community support.

5D-29-Rx410-EP

Slide 30

Unit 5D Objectives

- Define nuisance smoke impacts and list five examples
- List three public safety issues related to smoke
- Describe the current guidance for determining highway safety relative to visibility

5D-30-Rx410-EP

Slide 31

Unit 5D Objectives

- List three ways to monitor nuisance smoke impacts.
- List two ways to document nuisance smoke impacts.

5D-31-Rx410-EP

Smoke Management Techniques, Rx-410

Unit 5 - Smoke Impacts

Lesson E - Public Relations

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Identify public relation opportunities for smoke management.

2. Develop public contact contingency plans and coordinate with the media.

3. Discuss the importance of being knowledgeable and proactive about smoke management issues to establish credibility with the public and air regulatory agencies.

I. PUBLIC RELATION OPPORTUNITIES

A. The public will most likely support a unit's prescribed fire program if there is better understanding of what the program will do for them.

1. Reduce the risk of catastrophic wildfire and the risk of health effects from catastrophic wildfire

2. Reestablish or maintain biodiversity

3. Maintain health of ecosystems

There will be tradeoffs. A short-term negative impact will be smoke production. The affected public needs to be involved in the planning efforts. Consider collaborative planning ahead of time.

Use opportunities that exist locally and regionally-

- Fire education programs
- Open houses and public meetings
- The agency planning process
- School environmental or ecology curriculums
- Civic organizations

B. Once the planning effort is underway, develop contingency plans and contact lists based on several scenarios. Plan for the worst case based on downwind receptors, inversions, and other unlikely events. Make these scenarios known and available to agency key staff, cooperators, and key public contacts. Project at what point these contingency plans need to be implemented.

Key Contacts:

1. Air regulatory agencies

2. Health agencies

3. Sensitive downwind receptors

4. Affected publics identified during planning

5. Public safety and transportation agencies

C. As the project is implemented, make sure that the contact list is used and keep key contacts informed at every stage of the project.

1. Ignition time

2. Progress

3. Whether the smoke management parameters and projections are within prescription.

4. Any deviations from prescription and required action "trigger points."

5. Finish of project

D. Contingencies need to be implemented as soon as a deviation from the plan is noted.

1. Notifications must be done as soon as possible when conditions change. Credibility and reputation are at risk if this is ignored.

2. Consider whether one or more of the contingencies must be implemented.

a. Issuing health advisories

b. Relocating smoke-sensitive people

c. Terminating project

d. Accelerating completion of project

3. Above all, be proactive! The short-term inconveniences will be of little consequence if the public realizes that in order to reach broader land management goals and objectives, some risk must be taken. If the "pre-work" is done and the public feels they have ownership in the program through participation in project planning, they could be more tolerant of smoke issues.

4. With a combined effort stressing the role of prescribed fire (acknowledging resulting smoke) and its effects on the public, the program will be accepted to a greater degree, and if by chance, the smoke parameters are exceeded the affected publics may be more forgiving.

II. NOTIFICATION

A. Early development of the project's notification plan will assist in communicating with local authorities and the public. Use a wide variety of methods:

1. Pamphlets or flyers

2. Public meetings

3. Newspaper, radio, and television announcements

4. Internet postings

Work well in advance of the proposed burn day and again within a few days prior to ignition. On the burn day, notify all key contacts.

B. Working with local, state, and regional authorities will be easier if you have the backing of the affected publics and have solid plans in place.

Enlist the help of your local public information personnel to "sell" your program not only to the public, but to the regulators as well.

C. Work with the air regulatory agencies in the development of your plans.

D. Be sure that you do what your burn plan and smoke management plan say you will do. Credibility is a primary consideration and maintaining it is vital to the success of your project and program.

SUMMARY

- Work closely within agency to identify positive smoke management methods
- Develop public contact plans and coordinate with local media, other agencies and affected publics.
- Do what you say you will do. Use every opportunity to enhance your credibility.

Slide 1

Slide 2

Unit 5E Objectives

- Identify public relations opportunities for smoke management
- Develop public contact contingency plans and coordinate with the media.
- Discuss the importance of being knowledgeable and proactive about smoke management issues to establish credibility with the public and air regulatory agencies.

5E-2-Rx410-EP

Slide 3

Slide 4

Public Relations Opportunities

Opportunities exist to teach the public about the need to:

- **Reduce the risk of catastrophic wildfire**
- **Reestablish or maintain biodiversity**

5E-4-Rx410-EP

Slide 5

Public Relations Opportunities

Use opportunities that exist locally and regionally

- **Fire education programs**
- **Open houses and public meetings**
- **The agency planning process**

- **School environmental or ecology curriculums**
- **Civic organizations**

5E-5-Rx410-EP

Slide 6

Public Relations Opportunities

- **Develop contingency plans**
- **Plan for the worst case**
- **Communicate scenarios to key staff and public**
- **Develop timelines to implement contingency plans**

5E-6-Rx410-EP

Slide 7

Key Contacts for Your Project

- Air regulatory agencies
- Health agencies
- Sensitive downwind receptors
  - Individuals, facilities, parks, recreation areas
- Affected publics identified during planning
- Public safety and transportation agencies

5E-7-Rx410-EP

Slide 8

Communicating the Plan

- Ignition time
- Progress
- Still in prescription?
- Approaching "trigger points"?
- Finish of project

5E-8-Rx410-EP

Slide 9

Contingencies

- Issuing health advisories
- Relocating smoke-sensitive people
- Terminating project
- Accelerating completion of project

BE PROACTIVE!!

5E-9-Rx410-EP

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Summary

- Work closely within agency to identify positive smoke management methods
- Develop public contact plans and coordinate with local media, other agencies and affected publics.
- Do what you say you will do. Use every opportunity to enhance your credibility.

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Unit 5E Objectives

- Identify public relations opportunities for smoke management
- Develop public contact contingency plans and coordinate with the media.
- Discuss the importance of being knowledgeable and proactive about smoke management issues to establish credibility with the public and air regulatory agencies.

5E-11-Rx410-EP

Smoke Management Techniques, Rx-410

Unit 6 - Regulations

Lesson A - Legal Requirements for Managing Smoke from Wildland Fire

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Discuss the present and potential air quality legal requirements for managing smoke from wildland fire.

2. Define regional planning organization (RPO) and how their activities may impact the use of wildland fire.

3. Describe how to become effectively involved in the development of air quality regulations at a local level.

I. FEDERAL LEGAL REQUIREMENTS

The Clean Air Act - The Clean Air Act (Public Law 95-95) as amended in 1977 and 1990 identifies standards and legal requirements that must be met by EPA, other federal agencies, the states, and private industry. Prior to 1990, the Federal Clean Air Act did not directly address prescribed burning. However, the latest amendments contain a number of sections which may result in both direct and indirect regulatory controls.

A. Section 109 requires EPA to develop primary air pollution standards to protect human health and secondary standards to protect welfare. The primary standards must be developed to protect the most sensitive portion of the population with an adequate margin of safety. The Supreme Court has held that EPA is not to consider costs of control when developing ambient air quality standards. However, EPA and states must consider the costs of control when developing regulations to implement the ambient air quality standards.

Fine Particulate Regulations

- In July of 1987, the Environmental Protection Agency promulgated ambient air quality standards for those particulates less than 10 microns in diameter (PM-10). The PM-10 standards were designed to protect that portion of the population which is most susceptible to effects of airborne respirable particulates. However, more recent research indicates that the PM-10 standard currently in place may not actually be protecting those people who already have existing respiratory problems. As a result EPA finalized a new standard in July, 1997 to regulate those particulates less than 2.5 microns (PM-2.5). Most current epidemiological studies indicate that there is a much stronger relationship between increases in PM-2.5 concentrations and mortality and morbidity.

- The PM 2.5 standards had been challenged by industry (the American Truckers Association) in a case that went to the U.S. Supreme Court. In the fall of 2001 the Supreme Court agreed with EPA for the most part and sent the case back to the DC Circuit Court of Appeals. On March 26, 2002 the DC Circuit upheld EPA which allows the agency to move ahead to require states to develop regulations to implement the PM 2.5 standards. These standards are of interest to the wildland fire community because approximately 70% of the particulates emitted from biomass burning are in this size range.

B. Section 110 requires states to develop State Implementation Plans (SIPs) which identify how the state will attain and maintain national ambient air quality standards and other federal air quality regulations.

C. Section 112 identifies 188 hazardous air pollutants. Those pollutants ("…which are known to be, or may be reasonably anticipated to be carcinogenic, mutagenic, teratogenic, neurotoxic, which may cause reproductive dysfunction, or which are [cause] acutely or chronically toxic or adverse environmental effects whether through ambient concentrations, bioaccumulation, deposition, or otherwise…"). EPA has focused their attention on 33 of those 188 pollutants including 5 emitted from biomass burning: acetaldehyde; acrolein; 1,3 butadiene; formaldehyde; and polycyclic organic matter (POM). POM includes 8 major categories of compounds including polycyclic aromatic hydrocarbons (PAHs) which include numerous chemicals emitted from fire. While this section focuses control requirements on major and minor stationary air pollution sources states and EPA are trying to determine the risk to the public from all air toxic emissions sources including biomass burning.

D. Section 116 allows states to develop standards and regulations which are more stringent than federal standards and regulations. States can not develop standards or regulations which are less stringent than federal standards or regulations.

E. Section 118 requires all federal agencies to comply with all federal, state, and local air quality regulations to the same degree as any non-governmental entity. This section was amended in 1990 so that the preceding applies to "(A) to any requirement whether substantive or procedural (including any record keeping or reporting requirement, any requirement respecting permits and any other requirement whatsoever), (B) to any requirement to pay a fee or charge imposed by any state or local agency to defray the costs of its air pollution regulatory program, (C) to the exercise of any Federal, State, or local administrative authority, and (D) to any process and sanction, whether enforced in Federal, State, or local courts or in any other manner."

F. Sections 160-169 provide for the prevention of significant deterioration of air quality in those areas of the country which have air quality concentrations which are better than the standards set under Section 109. Sections 160-169 provide specific protection for certain National Parks and Wildernesses. In most cases, this section of the Act does not apply to wildland fire.

G. Section 169A provides visibility protection for mandatory Federal Class I areas. Those areas include International Parks, National Memorial Parks which exceed 5,000 acres in size, National Parks which exceed 6,000 acres in size, and Wilderness Areas which exceed 5,000 acres in size and were in existence as of August 7, 1977 including any additions to those areas made after that date.

Visibility Regulations

- EPA and state visibility regulations are being developed to help meet the national visibility goal identified in Section 169A of the Clean Air Act; the prevention of any future and the remedying of any existing, impairment of visibility in mandatory Federal Class I areas from man-made air pollution. In some cases, states and EPA consider smoke from prescribed fire to be man-made.

- Research conducted in some wildernesses and national parks indicates that viewing the scenery through “clean, fresh air” is one of the most important attributes as determined by recreationists. This presents an interesting challenge for land managers who want to use prescribed fire in those same areas. Good visibility is also important to the tourism industry in many areas.

- All states with mandatory Class I areas are required to amend their State Implementation Plan (SIP) to identify how they will prevent future visibility impairment and remedy existing impairment of visibility. As a part of their visibility regulations EPA requires that states, in their State Implementation Plans, consider the impacts of prescribed burning on visibility and the adequacy of smoke management programs. The SIP must be reviewed every 3 years to determine if the state’s “Long Term Strategy” for meeting the national visibility goal is appropriate.

- EPA finalized their Regional Haze regulations on July1, 1999 (64 FR 35714). These regulations specifically address fire for many states in the West (see Section 309 of the RH regs).

- As required by Section 169(b) of the Federal Clean Air the Grand Canyon Visibility Transport Commission submitted recommendations to EPA in June, 1996 which identify a strategy to reduce visibility impairment in 16 National Parks and Wildernesses. These recommendations include a number of items which address prescribed fire. EPA included these recommendations in their development of the national Regional Haze regulations.

- Five Regional Planning Organizations (RPOs) have been established to help states develop programs to implement the Regional Haze Regulations. The RPO that has taken the lead nationally in developing technical programs is the Western Regional Air Partnership (WRAP). The WRAP was created to aid in the implementation of the Grand Canyon Visibility Transport Commission's recommendations. Under WRAP, wildland fire is being addressed by a specific forum (The Fire Emissions Joint Forum) whose activities can be reviewed at the web site www.wrapair.org. The WRAP has adopted a policy relative to the classification of fire as being either "natural" or "anthropogenic." Basically, the policy states that any wildfire or any fire being managed to maintain the natural fire frequency will be classified as natural. Any fire that is being ignited or managed to restore the natural fire frequency is anthropogenic. All fire such as slash burning or agricultural burning is also anthropogenic. The policy can be found at the WRAP web site.

H. Section 176(c) prohibits federal agencies from permitting, approving, providing financial assistance, or supporting in any way any activity which does not conform to a State Implementation Plan (SIP). This section may come in to play where an agency "finances or supports in any way" prescribed burning activities on its lands.

I. Section 190 directs EPA to issue technical guidance on reasonably available control measures and best available control measures for prescribed silvicultural and agricultural burning by May 1992. This document was developed with the assistance of NWCG but is, unfortunately, out of date and needs revision.

J. Section 310 provides that the Clean Air Act shall not be construed as superseding or limiting the authorities and responsibilities under any other provision of law, of any other federal officer, department or agency.

K. EPA Interim Air Quality Policy on Wildland and Prescribed Fire

In April, 1998 EPA released an Interim Air Quality Policy on Wildland and Prescribed Fire. The policy integrates two public policy goals, (1) to allow fire to function, as nearly as possible, in its natural role in maintaining healthy wildland ecosystems, and (2) to protect public health and welfare by mitigating the impacts of air pollution emissions on air quality and visibility. The document identifies significant procedural and legal benefits for states, tribes, and users of wildland fire if they develop smoke management programs that are state certified.

L. EPA Natural Events Policy

The EPA Natural Events Policy addresses emissions from three categories of natural events as they affect National Ambient Air Quality Standards: (1) volcanic and siesmic activity, (2) wildfires, and (3) high wind events. Basically, EPA believes that it is appropriate to exclude air quality data that are attributable to uncontrollable natural events from the decisions regarding an area's non-attainment status.

II. STATE AND LOCAL LEGAL REQUIREMENTS

There is an increasing number of examples where states or local agencies have developed regulations which directly address prescribed burning. These regulations may differ significantly between states. As a result, it is important that land managers identify (1) which state or local air regulatory agencies have jurisdiction over emissions from prescribed fire and (2) what regulations are currently in place or under development.

III. FIREFIGHTER HEALTH LEGAL REQUIREMENTS

Responsibility - The basic authority for safety and health standards is mandated by the Department of Labor, Occupational Safety and Health Administration (OSHA). That authority is contained in the Occupational Health and Safety Act of 1970; Executive Order 12196, February 26, 1980; CFR 1910 Occupational Safety and Health Standards; 29 CFR 1960 Basic Program Elements for Federal Employee Occupational Safety and Health Programs.

IV. LIABILITY ISSUES

The only way federal agencies, or "employees of the government" operating in an official capacity can be charged for tort liability is through the Federal Tort Claims Act (FTCA), 28 U.S.C 2671. There are no other "rights of action" under any state or local law. If an employee of the government is acting in an official capacity (and within his or her scope of duty) and smoke from a prescribed fire causes or contributes to an accident on a high-way, the agency will assume responsibility. Questions that will probably arise in determining the agency's liability are whether or not smoke management was adequately addressed in the burn plan and whether or not the plan was followed.

V. NEED FOR INVOLVEMENT WITH THE PUBLIC AND AIR REGULATORY AGENCIES

The general public's lack of knowledge about the role of fire in wildland ecosystems has the potential to result in more stringent air quality regulations which, in the long term, could create severe changes to ecosystems. The public understands the need for good air quality much better than they understand the natural and historic role of fire in ecosystem development. Few of the public are aware that many natural forest ecosystems exist because of periodic fire rather than in spite of it. Few understand the relationship of fire to wildlife habitat and populations, forest diseases, protection of rare and endangered species, management of national parks and wilderness, forest succession, and biological diversity. Unfortunately, the public is becoming more urban and, as a result, may have less of an understanding of biological processes and ecology than their rural counterparts.

Agency administrators need to communicate all acquired knowledge on the role of periodic fire in forest ecosystems as well as knowledge of wildfire effects to the public. This awareness and education of the public will increase public sensitivity to the role of fire in ecosystem maintenance. This message needs to be clear and concise for different ecosystems. Fire managers also need to let the public know that we are doing the best possible job (assuming that is the case) of managing our smoke, that we are aware of air quality concerns and that we take those concerns seriously.

Population and industrial growth in much of the country are increasing at the same time as the ecological need for the use of prescribed fire is increasing. However, given a finite atmosphere and a need to control air pollutants, the public must determine which sources will be allocated shares of the air resource. Public decisions on the allocation of the air resource will be based to some degree on the public's knowledge of the need for tolerating certain short-term pollutant sources. This has the potential to result in severe restriction on the use of prescribed fire as compared to restriction of other "more understood" air pollution sources. In short, the public's lack of knowledge on the ecological needs for fire could result in unnatural, unwanted, and potentially catastrophic fuel loadings and ecosystem changes. Land managers must effectively inform the public and regulatory agencies of the potential changes to ecosystem viability and productivity that may result from withholding fire from a fire dependent ecosystem.

Most environmental laws and protection programs managed by states and EPA are media specific (air, water, soil, etc). This situation does not provide for protection and management of ecosystems as a whole. Real solutions to environmental management problems cannot be solved through segmented and fragmented regulatory approaches. It is a major concern that control of one environmental problem such as air pollution might contribute to another environmental problem such as loss of biological diversity or catastrophic wildfire.

EPA is just beginning to develop multi-media environmental protection programs which, in the future, may be able to better consider issues such as fire in wildland ecosystems. However, comprehensive environmental decision making processes to truly address the problems caused by single media protection programs will require elimination of existing institutional and statutory constraints. Agency administrators have the opportunity to help support the elimination of these constraints.

VI. SUMMARY

In order to use fire as a land management tool managers need to be aware of both federal and state legal requirements for managing emissions of smoke. Federal land managers must comply with all federal, state and local air quality regulations to the same degree as any non-governmental entity. Air quality regulators are beginning to focus on the same very small airborne particulates as are emitted by fire because of those particulate's impacts on both human health and visibility. As a result, air quality regulations are becoming more stringent at the same time as the need to reduce fuels is becoming more necessary. Land managers will continue to be able to use fire if they apply appropriate smoke management techniques, are active in the development of new air quality regulations and active in groups such as the regional planning organizations.

Slide 1

Slide 2

Unit 6A Objectives

- Discuss the present and potential air quality legal requirements for managing smoke from wildland fire.
- Define regional planning organization (RPO) and how their activities may impact the use of wildland fire.
- Describe how to become effectively involved in the development of air quality regulations at a local level.

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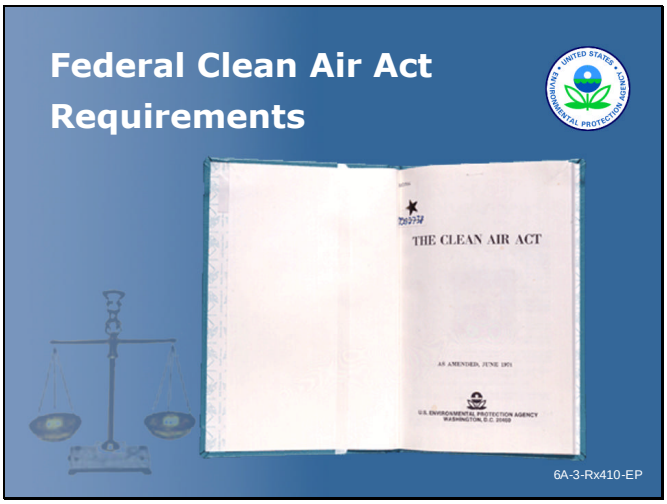
Slide 3



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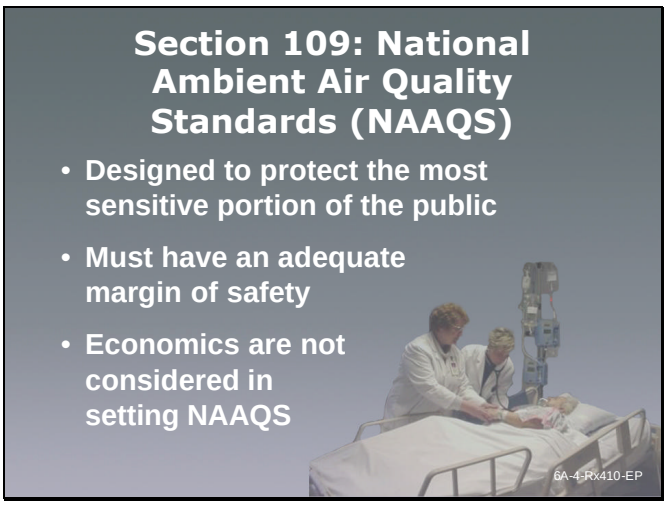

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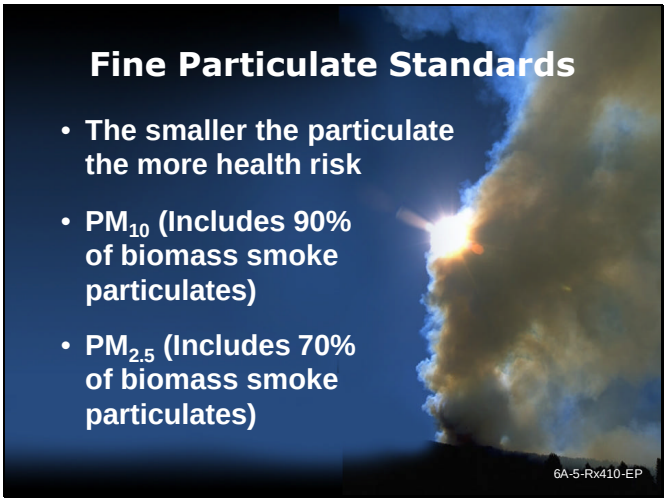

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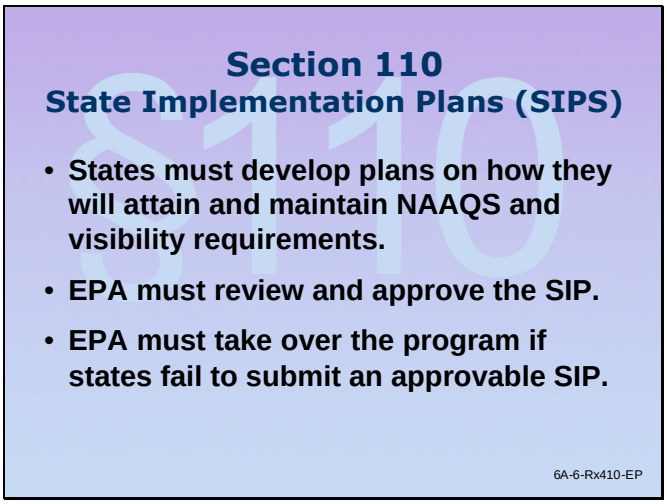

Slide 7

Section 116:
State Standards and Regulations

- States can develop standards and regulations more stringent than federal standards.
- States cannot develop standards and regulations less stringent than federal standards.

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Section 118:
Federal Compliance

- Federal agencies must comply with all substantive and procedural federal, state and local air pollution standards and regulations.
- Compliance will be to the same degree and in the same manner as any non-governmental agency.

6A-8-Rx410-EP

Slide 9

Section 118:
Federal Compliance

- Federal agencies must obtain permits and pay fees if required of other burners.
- There is a question if federal agencies may be required to pay civil penalties.

6A-9-Rx410-EP

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Section 160 - 169:
Prevention of Significant Deterioration (PSD)

- Provides specific protection for certain national parks and wildernesses.
- In most cases, PSD does not apply to wildland fire.

6A-10-Rx410-EP

Slide 11

Section 169A:
Visibility Protection

The National Visibility Goal

"…the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from man-made air pollution."

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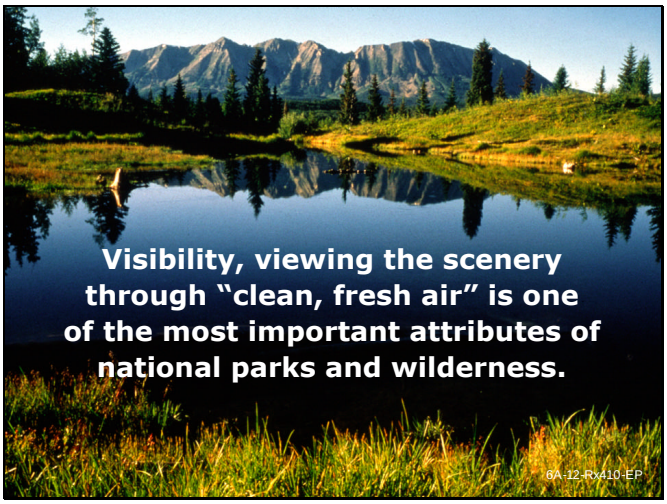

Slide 13

Regional Haze Regulations

- Finalized on July 1, 1999
- States are required to address all air pollution sources including fire.

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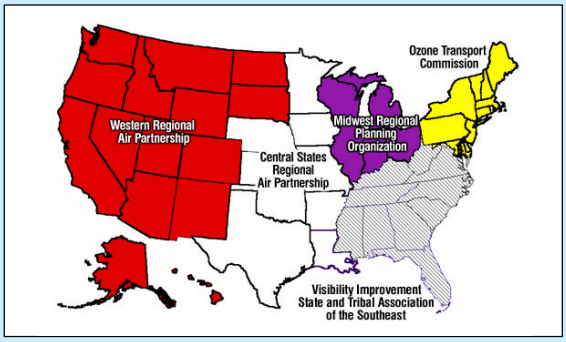
Regional Planning Organizations



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Section 176(c): Conformity

- Federal agencies may not permit, approve, provide financial assistance, or support in any way, any activity which does not conform to a State Implementation Plan.

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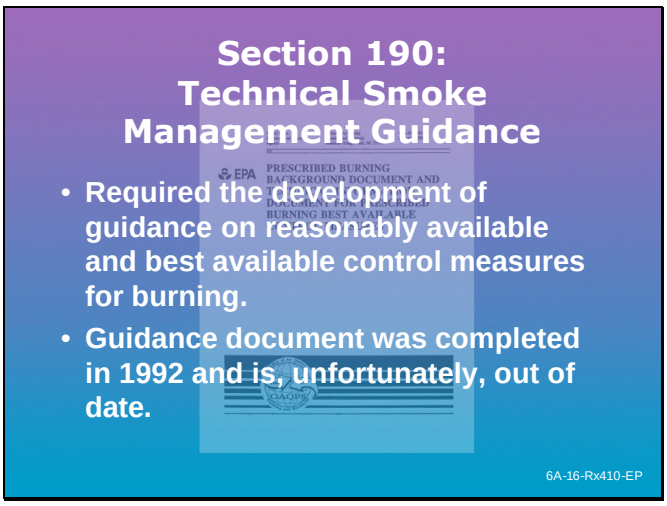

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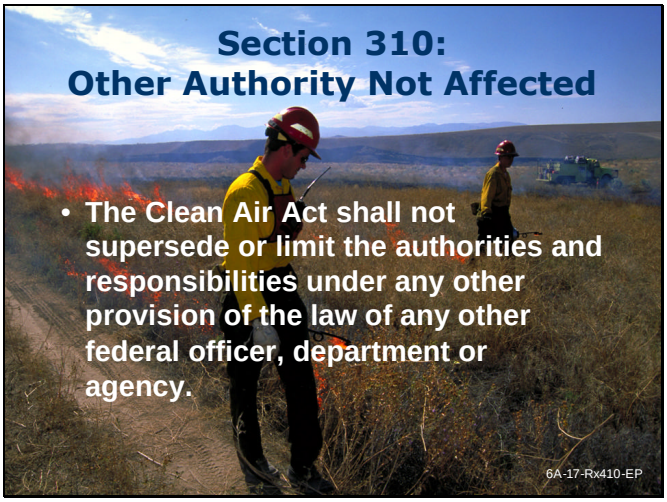

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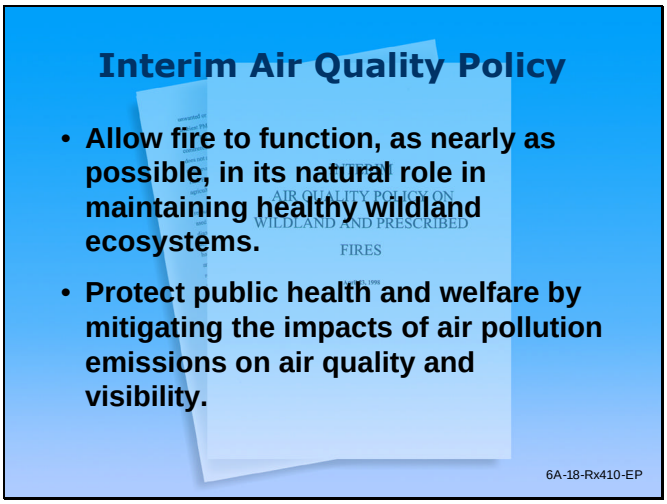

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Interim Air Quality Policy
on Wildland and Prescribed Fire

The Interim Air Quality Policy provides significant procedural and legal benefits for states, tribes, and users of wildland fire if they develop state-certified smoke management programs.

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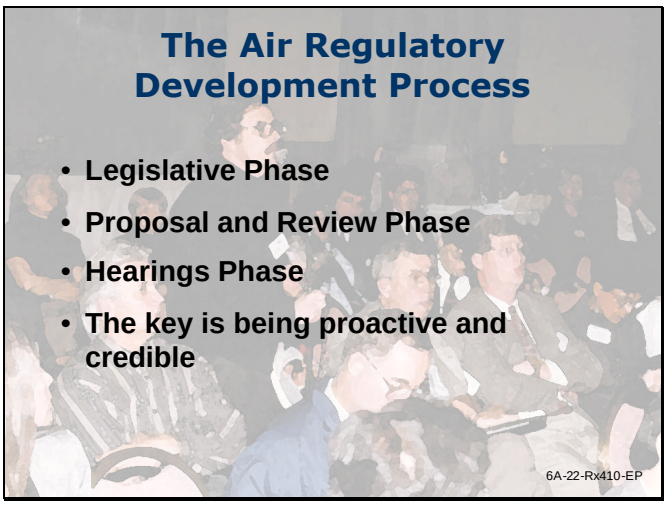

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Unit 6A Objectives

- Discuss the present and potential air quality legal requirements for managing smoke from wildland fire.
- Define regional planning organization (RPO) and how their activities may impact the use of wildland fire.
- Describe how to become effectively involved in the development of air quality regulations at a local level.

6A-25-Rx410-EP

THE REGULATORY DEVELOPMENT PROCESS

The Regulatory Development Process - In order to be effectively involved in the regulatory development process, land managers must understand how the process works and where involvement is most useful.

Administrative rule making is the exercise of quasi-legislative authority by a governmental agency to formulate, amend, or repeal a rule. The end product has the force of law. As required by section 118 of the Clean Air Act, federal agencies must comply with all substantive and procedural requirements of federal, state and local air quality regulations and standards. That is, federal agencies must comply with all parts of all regulations developed by administrative rule making at state and local levels.

Administrative rule making can be divided into 3 separate phases, the legislative phase, the proposal and review phase, and the hearing phase.

A. Legislative Phase - Prior to rule making by any administrative agency, statutory authority must be provided by the legislature. For air quality issues, the statutory authority is usually provided in the State Clean Air Act. When authority is inadequate, public and interest groups need to direct their efforts towards either lobbying the legislature or persuading the administrative agency to seek authority. Such lobbying is also appropriate when the public or interest group feels that the administrative agency has too much authority and is developing regulations that are not appropriate. It is very appropriate for land managers to be actively represented in the legislative phase.

B. Proposal and Review Phase - Administrative rule making requires a formal process for public review and comment. Land management agencies are an important part of the public that needs to be represented. Typically, an administrative agency develops proposed regulations in-house, notifies the public and interest groups of its proposal, provides a review period, and conducts a public hearing to solicit comments on the proposal. Administrative rule making procedures vary from state to state and sometimes from agency to agency within a state. It is important that land managers understand the appropriate administrative rule making procedures before the procedures begin.

Often, regulations are adopted exactly as proposed by the administrative agency. Therefore, the most effective time for land managers to become involved in the rule making process is before the agency develops the proposed regulations in-house. After proposed regulations are developed and proposed in draft form it is only natural that an administrative agency will feel that they have something to defend. Comments received after a draft is proposed are often considered in an adverse light. It is only human nature that administrative agency staff (or anyone else) might find it difficult to objectively review comments which are critical to their efforts. Again, the most effective time for land managers to become effectively involved in the rule making process is before it formally begins.

C. Hearing phase - After an air regulatory agency develops and proposes a regulation there is usually a time period for public review and a subsequent public hearing. Public hearings are probably one of the worst possible places to exchange new concepts and ideas. However, public hearings are a good place to reinforce concepts and ideas that are already established. Public hearings can be an excellent opportunity to bring in support and testimony from other groups which may support the land manager's position. Other groups may include industry, environmental organizations, and fish and wildlife agencies. Finally, the more supportive that land managers can be of the air regulatory agency during the public hearing, the better that the relationship between the groups will be in the future.

Education of the Public and Air Regulatory Agencies - A major problem that land management agencies must overcome is that air quality agency staff usually do not have an understanding of the needs and uses of prescribed fire. While air quality agency staff have excellent understanding of control equipment for stationary pollution sources, they often have little understanding of biological processes and the natural role of fire in driving those processes. As a result, it is possible that air quality regulations will be proposed for which the air quality staff does not understand the full consequences.

A good example is the possible restriction of the use of prescribed fire from unplanned ignitions in national parks and wildernesses. Many of these areas are mandatory Federal Class I areas where the national goal is to prevent any future and to remedy any existing impairment of visibility. However, in most wilderness ecosystems, exclusion of fire is presently the major man-caused impact. Carefully thought out and explained, there is no conflict between fire in wilderness and the national visibility goal.

In order to take care of this and other problems, it is necessary for land managers to educate air regulatory agencies on the uses and needs for prescribed fire. This education can be done in meetings initiated by the land manager or preferably by field trips and actual involvement in prescribed burning. One day in the field is usually worth ten days of meetings. However, it is important that meetings and field trips take place before the air regulatory agency proposes regulations.

Land managers also need to educate air regulatory agencies on smoke management techniques that are available and how various smoke management techniques relate to specific burning prescriptions. It is important that the air regulatory staff understand that the smoke management technique that is selected must fit the specific burn prescription.

It is also critical that land management agencies establish credibility with the air regulatory agency before regulations are proposed. It is much more difficult to develop credibility with any type of regulatory agency after the regulatory process has begun. In most cases, air regulatory agencies view land managers the same way that they view any other polluter. These same air regulatory agencies have heard hundreds of excuses of why specific polluters should be exempt from regulations, why it is too expensive to comply, why the polluter doesn't really cause any problem, why someone else is the real problem, and generally why the whole world will go to hell if the polluter is required to do anything. Rather than try to make lame excuses, land managers will develop credibility with air regulatory agencies if they can demonstrate how they are doing the best possible job of minimizing both the amount and impact of the smoke they emit into the air.

The key for land management agencies to be effectively involved in the regulatory development process is to be both proactive and credible. Being proactive and developing credibility takes time and effort. However, if land managers want to continue to use prescribed fire as a management tool then taking the time and effort is an absolute necessity.

Recommendations of the Grand Canyon Visibility Transport Commission Regarding Fire

1. Plan for the visibility impacts of smoke. The Commission recommends that the EPA require all federal, state, tribal, and private prescribed fire programs to incorporate smoke effects in planning and application by the year 2000.

2. Implement an emission tracking system for all fire activities. A consistent emissions tracking system for prescribed fire, wildfire, and agricultural burning should be implemented region-wide.

3. Improve integrated assessment of emissions. Federal, state, tribal and private land managers, in conjunction with relevant regulatory agencies and interested parties, should improve the current integrated assessment of emissions from prescribed fire, wildfire, and agricultural burning by 1999. This assessment should:

    a. identify specific areas where fire activities have or could have an adverse impact on health and visibility;

    b. identify areas where mechanical treatments could substantially reduce emissions and subsequent impacts on health and welfare.

    c. in the areas identified, assess the feasibility of biomass utilization (woody material use), market development, and non-statutory administrative barriers, and

    d. assess meteorological information needs, air quality monitoring needs, smoke dispersion model needs, interstate planning needs, wildfire/ prescribed fire trade-offs (economic, air quality, and other resource effects), and emission factor research (vegetation/fuels and effects of emission reduction techniques).

4. Enhance smoke management programs. The Commission recommends the development and implementation of criteria and requirements for the use of enhanced smoke management programs (including alternative management practices) and emission reduction strategies in the identified areas. Such programs should consider factors of efficiency, economics, law, land management objectives, and reduction of visibility impacts. States, tribes, state and federal land management agencies and private parties should create and implement smoke management programs that address public health, visibility and land management objectives by the year 2000, using the results of the assessment listed in #3 above.

5. Develop cooperative funding mechanisms. The Commission promotes the development of cooperative funding mechanisms between burners and regulatory agencies to implement costs of increased smoke management programs and integrated assessment costs.

6. Promote public education programs. The Commission supports the creation of a public education program regarding the role of fire in air quality, to be undertaken by land managers and other interested governmental and private groups.

7. Establish annual emission goals for fire programs. The Commission recommends that annual emission goals for all fire programs, where appropriate, be established by the year 2000. These goals will be set to minimize emission increases from such programs to the maximum extent feasible. The goals will be established cooperatively by states, tribes, state and federal land management agencies and their private sector counterparts.

8. Remove administrative barriers to the use of alternatives to burning. The Commission recommends that the federal land management agencies and their state, tribal, local, and private counterparts identify and remove non-statutory administrative barriers to emission reduction strategies by the year 2000 to the maximum extent feasible. In removing such barriers, the Commission intends that subsequent actions will be undertaken consistent with applicable laws and regulations.

RPO WEB SITES

CENRAP: Central Region Air Planning Organization (cenrap.org)

MANE-VU: Mid-Atlantic/Northeast Visibility Union (mane-vu.org)

Midwest RPO: (ladco.org/rpo/rpo.html)

VISTAS: Visibility Improvement – State and Tribal Association of the Southeast (vistas-sesarm.org)

WRAP: Western Regional Air Partnership (wrapair.org)

Smoke Management Techniques, Rx-410

Unit 6 - Regulations

Lesson B - State Smoke Management Programs

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Define the purpose of a state smoke management program.

2. Explain EPA's role in state smoke management programs.

3. Identify local air quality regulations and programs that impact prescribed fire operations.

1. What is a state smoke management program?

State smoke management programs establish a standard framework of procedures and requirements for managing smoke from prescribed fires.

The purposes of a state smoke management program are to:

- Minimize smoke entering populated areas
- Prevent public safety hazards (such as smoke impairment on roadways and runways)
- Avoid significant deterioration of air quality and National Ambient Air Quality Standards (NAAQS) violations
- Avoid visibility impacts in Class I areas.
- Process for nuisance mitigation

2. Who develops smoke management programs?

- States typically develop these programs, with cooperation and participation from stakeholders.
- Smoke management programs developed through partnerships are much more effective at reaching resource management goals, protecting public health and meeting air quality objectives.
- Tribes may develop smoke management programs for their lands.

3. Who is responsible for administering the smoke management program?

- Usually, state or tribal agencies administer these programs.
  - Give daily approval or denial of individual burns
  - Burning may be subject to a permit based on acres burned, tons consumed or emissions.
  - Multi-day burns may be subject to daily reassessment and reapproval to ensure smoke does not violate program goals.
- States should coordinate all prescribed fire activities in a region and consider cross boundary impacts of their programs.
  - Fire managers should coordinate with each other to share the air shed and minimize impacts. (Whether or not it's required by the state, it's the right thing to do.)

4. What is the U.S. EPA's role in smoke management programs?

To be recognized by EPA, a smoke management program should include the following basic components some of which are the responsibility of the administering agency and some of which are provided by the land manager:

- A process for assessing and authorizing burns (location, jurisdiction, fuel, area, tons/acre etc.).
- A plan for long-term minimization of emissions and impacts, including promotion of alternatives to burning and use of emission reduction techniques.
- Smoke management goals and procedures to be described in burn plans (when burn plan reporting is required) (Actions to minimize emissions, smoke dispersion evaluation, public notification and exposure reduction procedures, air quality monitoring).

- Public education and awareness.

- Surveillance and enforcement of smoke management program compliance.

- Program evaluation and plan for periodic review.

- Optional programs (special protection zones or buffers or performance standards).

5. Local and regional requirements and regulations.

   - Local governments such as counties or townships may pass air quality regulations that are stricter than state or federal regulations. They may also have their own smoke management programs.

   - There may also be recommendations at the regional level developed by regional air planning organizations.

Slide 1

Slide 2

Unit 6B Objectives

- Define the purpose of a state smoke management program.
- Explain EPA's role in state smoke management programs.
- Identify local air quality regulations and programs that impact prescribed fire operations.

6B-2-Rx410-EP

Slide 3

6B-3-Rx410-EP

Slide 4

What is a State Management Program (SMP)?

- Smoke Management Plan? Program?
- SMP's establish a standard framework for managing smoke from prescribed fire.
  - Standardized procedures
  - Standardized requirements

6A-4-Rx410-EP

Slide 5

What is the purpose of an SMP?

- Minimize smoke entering populated areas
- Prevent public safety hazards (such as smoke impairment on roadways and runways)
- Avoid significant deterioration of air quality and National Ambient Air Quality Standards (NAAQS) violations
- Avoid visibility impacts in Class I areas
- Process for nuisance mitigation

6B-5-Rx410-EP

Slide 6

Who develops SMPs?

- States typically develop these programs, with cooperation and participation from stakeholders.
- Tribes may develop smoke management programs for their lands.

6A-6-Rx410-EP

Slide 7

Who administers the SMP?

Usually, state or tribal agencies administer these programs.

- **Give daily approval or denial of individual burns**
- **Burning may be subject to a permit based on acres burned, tons consumed or emissions.**
- **Multi-day burns may be subject to daily reassessment and re-approval to ensure smoke does not violate program goals.**

6B-7-Rx410-EP

Slide 8

Coordination is the key!

States should coordinate all prescribed fire activities in a region and consider cross-boundary impacts of their programs.

6B-8-Rx410-EP

Slide 9

To be recognized by the EPA, SMPs must include:

- **A process for assessing and authorizing burns**
- **A plan for long-term minimization of emissions and impacts**
- **Smoke management goals and procedures**
- **Public education and awareness**

6A-9-Rx410-EP

Slide 10

To be recognized by the EPA, SMPs must include:

- Surveillance and enforcement of program compliance
- Program evaluation and review schedule
- Optional programs (special protection zones or buffers, etc.)

6A-10-Rx410-EP

Slide 11

Local and Regional Regulations

Local governments may pass air quality regulations that are stricter than state or federal regulations.

Local governments may also have their own smoke management programs.

6B-11-Rx410-EP

Slide 12

Summary

- SMPs establish standard procedures
- SMPs try to minimize smoke impacts to the public (nuisance, safety, NAAQS & visibility)
- Usually administered by state or tribal agencies
- Coordinate to share the airshed

6B-12-Rx410-EP

Slide 13

Unit 6B Objectives

- Define the purpose of a state smoke management program.
- Explain EPA's role in state smoke management programs.
- Identify local air quality regulations and programs that impact prescribed fire operations.

6B-13-Rx410-EP

Smoke Management Techniques, Rx-410

Unit 7 - Smoke Management Meteorology

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Define weather terms and concepts important to smoke management.

2. List three key weather factors that affect smoke behavior.

3. Verify smoke behavior forecasts using visual indicators and on-site measurements.

4. Describe the types of weather forecasts available and their limitations.

I. DISPERSION METEOROLOGY – TERMINOLOGY

A. Atmospheric Stability Definitions

1. Stable

When stable air is lifted, it becomes cooler than the surrounding air, and it then returns to its original level. Stable air hinders smoke dispersal

2. Unstable

When unstable air is lifted, it becomes warmer, and less dense than the surrounding air, and it continues to rise. Unstable air is ideal for smoke dispersal.

3. Neutral

When an air parcel is lifted and its temperature becomes the same as that of the surrounding air, the air has a neutral buoyancy. In other words it will tend to neither rise nor fall.

B. Movement of Air

1. Convection

The upward movement of air due to heating from below.

2. Advection

The horizontal movement of air from one region to another. Advection of warm or cold air at different levels can change the instability of the air. Wind will advect warm or cold air.

C. Lapse Rate

1. Definition

Lapse rate is a change of temperature with height.

2. Temperature normally decreases, but it can increase with height.

3. Soundings – The atmosphere can have a wide variation of temperature with height. Weather instruments carried aloft by balloon every 12 hours sample the upper air. The data are plotted on sounding charts. Forecasters use these charts to determine the stability of the atmosphere.

4. The normal or average lapse rate for the atmosphere is -3.5° F per 1,000 feet.

D. Adiabatic Lapse Rate

The rate at which a parcel of air cools as it moves up and expands. This is the result of thermodynamic laws. This cooling of the parcel is independent of the surrounding air. The air parcel cools at different rates depending on whether it is still water vapor or has condensed to form a cloud.

1. Dry adiabatic lapse rate.

The rate at which air cools without condensing any moisture. The rate is -5.4° F per 1,000 feet

2. Moist adiabatic lapse rate

If water vapor begins to condense inside the independent parcel as it ascends, the parcel will cool at the moist adiabatic rate. This is -3.0° F per 1,000 feet. This rate is different from the dry rate because heat is given off during condensation, and that heat warms the parcel so it doesn't cool as rapidly.

3. Neutral Stability

The air will be neither stable nor unstable when the ambient lapse rate is equal to -5.4° F per 1,000 feet. When an air parcel is moved up or down, its temperature will be the same as the surrounding air.

E. Determining Stability

1. Unstable

The atmosphere is unstable if the ambient lapse rate is greater than -5.4° F per 1,000 feet.

2. Stable

3. Neutral

F. Inversions

Question:

What do you notice about the clouds in this picture?

Answer:

Flat cloud tops
Settled at low elevation
Clear skies above.

1. Normally, temperature decreases with height. Sometimes, though, temperature increases with height, and this represents a very stable atmospheric condition, which inhibits smoke dispersal.

Definition – An inversion exists when temperature increases with height.

2. Inversions can form or intensify when cold or warm air is brought into an area.

An inversion will form or become stronger by warming the layer on top by means of warm air advection, or by cooling the layer from below through cold air advection.

3. Types of Inversions

a. Nocturnal

Nighttime inversions trap smoke in the lower 2,000 feet of the atmosphere.

Nighttime inversions form as the earth's surface radiates heat. The inversion begins very near the ground, and the stable layer deepens during the night.

Breaking a nocturnal inversion will happen only if:

- the sun can heat the earth's surface and have this heated air mix with the air above it, or

- the warm air above can mix down to the surface.

b. Subsidence

Subsidence inversions form as air sinks under high pressure air masses. As the air sinks, it warms by compression and creates an inversion that gradually lowers over time.

4. Marine Inversions

Cool ocean air flows inland during the day to cool the lower layers of the atmosphere, thus creating an inversion by cold advection. Cumulus clouds may form well inland where the air is warmer and more unstable.

This can happen around inland lakes during the spring. The greatest annual precipitation occurs over the higher terrain.

Note the cumulus clouds over the higher terrain in eastern and southern New York state, but clouds are suppressed along the downwind side of Lake Ontario and over the lake as well. Cold air flowing from the lake has produced an inversion downwind from the lake and has prevented convection in that region.

5. Frontal Inversions

As a warm front approaches, the cool high pressure retreats. Warm air advection aloft creates an inversion. This type of inversion lowers as the front approaches and can be difficult to break until the warm front passes.

After the warm front passes, the lower layers warm and mix to help dissipate the inversion.

Important:

Inversion heights are generally higher near low pressure areas than they are under high pressure areas.

Also, temperature inversions become lower with time after a cold front passes and as high pressure moves in.

G. Lifting Process

Good smoke dispersion requires the air to be lifted and then to be transported downwind.

1. Thermal

Sun hits the ground, heats it, and causes the heated parcels near the surface to rise.

2. Orographic

Air flowing into a terrain obstruction is forced to rise.

3. Frontal

The dense air behind a cold front can force the air aloft. Clouds have a greater vertical growth if the air is unstable, but will be layered and flatter if the air is stable.

4. Convergence

Air flowing into a region from different direction is forced to rise. Islands and peninsulas are good examples.

H. Mixing Heights

1. Definition - Mixing is a process by which there is an upward and downward exchange of air.

2. Mixing height (or depth) is the height above ground through which relatively vigorous vertical mixing occurs. The layer between the ground and the first inversion level is referred to as the mixing layer. Notice that a well mixed layer has a lapse rate nearly equal to the dry adiabatic lapse rate.

3. Mixing height varies throughout the day.

   a. Normally, it is lowest at night or early morning when the nocturnal inversion is present.

   b. Becomes highest during mid to late afternoon when the atmosphere is well mixed.

c. Forecasters determine the morning and afternoon mixing heights by using a sounding chart.

(1) The morning mixing height is calculated by forecasters by taking the morning sounding and adding 5° C. Then assuming a well mixed lower layer, the height of the inversion can be determined. Low morning mixing heights trap smoke near the ground.

(2) The afternoon mixing height is calculated by forecasters by starting at the afternoon maximum temperature, assuming a well mixed atmosphere, then projecting a line upward to where it meets the sounding.

d. Visual indicators of mixing.

(1) Clear sky or scattered cumulus clouds. In this case, high pressure over the area is likely.

(2) Smoke is drifting gently, and indicates light winds.

(3) Smoke has a flat top indicating the base of an inversion aloft.

(4) An aircraft with a responsive digital thermometer could find this inversion easily.

I. Winds

You learned in S-290 and S-490 about general, local, and free air, winds that affect fires. For smoke management, transport winds are the main concern.

1. Transport winds are the average speed and direction of the winds in the mixing layer, and represent the net effect of the winds in the mixing layer that work to move the smoke.

2. Wind shear can have dramatic effects on smoke dispersal and the area impacted. Wind shear is an abrupt change in wind speed and direction, or both, with height. It often is associated with temperature discontinuity at the base and/or top of an inversion.

Frontal passages also present wind shear problems. Winds may be blowing from different directions within a few hundred feet of the surface. Pilot balloon wind measurements or GPS winds aloft from aircraft are helpful.

In a very short period of time wind direction can change more than 90 degrees in the lowest layers of the atmosphere.

J. Dispersion

1. Definition – Dispersion is the distribution of a given quantity of pollutant throughout a volume of atmosphere. In other words, it is how smoke is distributed both vertically and horizontally.

2. Dispersion depends upon the depth of the mixing layer and the strength of the transport winds. Plumes can be characterized according to the atmospheric conditions.

3. Dispersion/ Ventilation Indices

Overall dispersion for any day can be expressed by a dispersion or ventilation index. The numerical value and its significance for smoke dispersal may vary throughout the country.

II. SITE MEASUREMENTS AND VISUAL INDICATORS

A. Sling psychrometers

1. Determine lapse rates if taken at several levels in the area

2. 80 percent RH implies fog

B. Hand held anemometer

C. Pilot Balloons (PIBALs) taken by Incident Meteorologist.

This has been the way local winds have been taken for many years. Although useful, they cannot be obtained until the IMET sets up the equipment, launches the balloon and then calculates the wind aloft.

D. Aircraft

1. GPS in spotter aircraft and air tankers provides instant readouts of wind speed and direction every few seconds. To get a profile of the winds upwind from a fire, just fly a path similar to a holding pattern. Have the pilots note the wind readout and the altitude every 500 feet or so. Or have tanker pilots note the winds inbound or outbound every 30 to 60 minutes.

2. Temperatures from a digital thermometer on board give a local temperature sounding, locate any inversions, and can help determine the stability of the atmosphere in the area.

3. Winds and temperatures can then be plotted just like a real upper air sounding.

E. Visual Indicators

1. Stable conditions

a. Stratus clouds

b. Layered clouds

c. Smoke drifts after limited rise

d. Poor visibility because inversion traps the smoke.

e. Fog

2. Unstable conditions

a. Good vertical growth of clouds

b. Cumulus type clouds with vertical extent

c. Gusty winds (good mixing)

d. Good visibilities

e. Dust devils

III. HOW WEATHER FACTORS AFFECT SMOKE – A REVIEW OF TOPICS SO FAR

A. Stability

1. Lower atmosphere stable at night and can trap smoke for a long time.

2. Inversions limit vertical motion and dispersion

   Marine air has higher moisture content and lower temperatures than continental air. This generally results in increased stability along coastlines.

3. Higher moisture content combined with smoke can reduce visibility.

4. The subsidence inversion under a stable high pressure becomes lower with time despite sunny skies.

5. Light winds provide little transport of pollutants

B. Mixing

1. Low Mixing Height = Limited dispersion

2. High Mixing Height = Allows smoke to rise higher so stronger winds can carry (transport) it away.

C. Winds

1. Transport winds carry the smoke.

2. Stronger winds lead to better dispersion

3. Burn intensity affects the height of the convective column and determines what wind (level) will carry the smoke.

4. Frontal passage

   a. Direction change

   b. Speed change

5. Local winds

   a. Topography

   b. Convergence

   c. Drainage at night and upvalley winds in the day.

   d. Seas breezes during the day and land breezes at night.

IV. WEATHER FORECASTS

A. General Narrative (FWF)

1. Synopsis

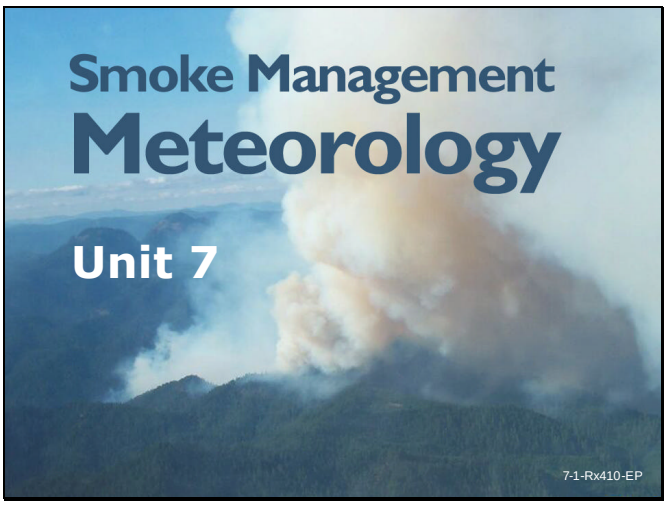
2. Winds

3. Haines

4. Smoke Management

B. Spot forecast

Slide 1



Slide 2

Unit 7 Objectives

- Define weather terms and concepts important to smoke management.
- List key weather factors that affect smoke behavior.
- Verify smoke behavior forecasts using visual indicators and on-site measurements.
- Describe the types of weather forecasts available and their limitations.

7-2-Rx410-EP

Slide 3

Dispersion Meteorology Terms

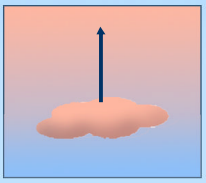
- Atmospheric Stability
- Lapse Rate
- Adiabatic Lapse Rate
- Stable air/unstable air
- Neutral stability
- Inversion
- Subsidence Inversion
- Lifting processes
- Winds: Transport, Surface/local, shear
- Dispersion/ventilation
- Mixing height/layer

7-3-Rx410-EP

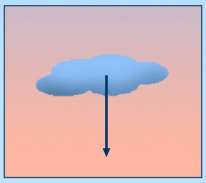
Slide 4

Atmospheric Stability

The degree to which vertical motion in the atmosphere is enhanced or suppressed



Air warmer than surrounding air rises



Air cooler than surrounding air sinks

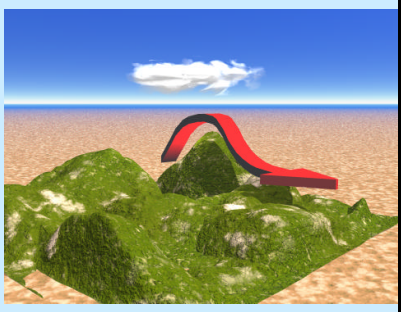
7-4-Rx410-EP

Slide 5

Stable Atmosphere

A stable atmosphere:

- **suppresses vertical motion**
- **limits mixing**
- **limits smoke dispersion**
- **may require a burn to be shut down**



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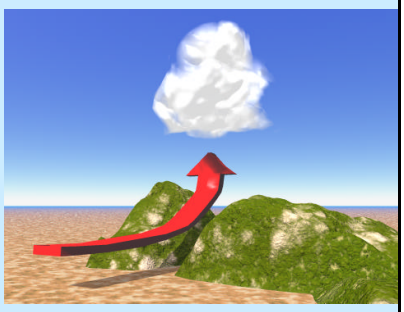
Slide 6

Unstable Atmosphere

An unstable atmosphere:

- **enhances vertical motion**
- **increases mixing**
- **increases smoke dispersion**
- **helps enhance burning**



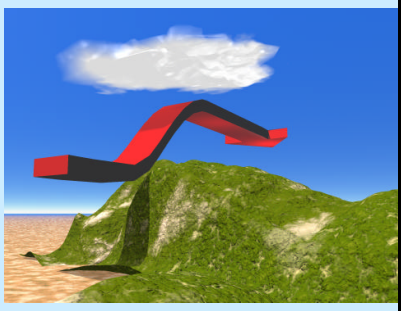
7-6-Rx410-EP

Slide 7

Neutral Atmosphere

Neutral stability

- Neither enhances nor hinders vertical motion
- Allows smoke to remain at current level



7-7-Rx410-EP

Slide 8

Convection

VERTICAL movement of air

Advection

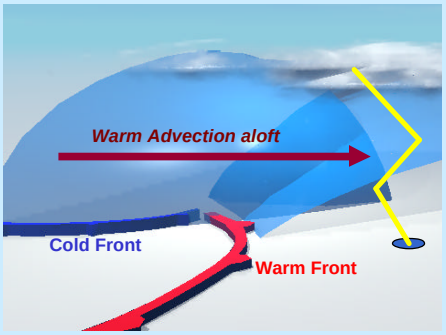
HORIZONTAL movement of air by the wind

7-8-Rx410-EP

Slide 9

Advection

The horizontal movement of air



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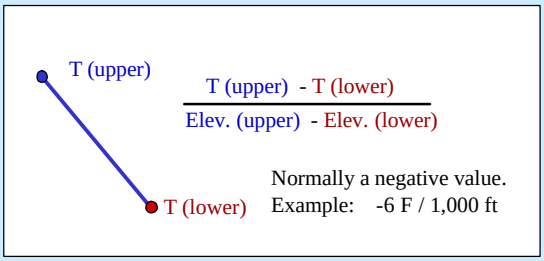
Slide 10

Lapse Rate

The change in temperature with increasing altitude.

Expressed in degrees F per 1,000 feet,
or degrees C per 100 m.



$$\frac{\text{T (upper)} - \text{T (lower)}}{\text{Elev. (upper)} - \text{Elev. (lower)}}$$

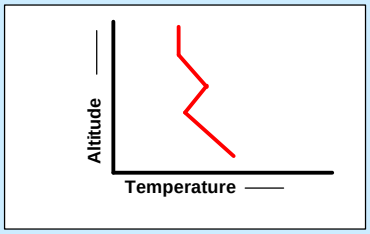
Normally a negative value.
Example: -6 F / 1,000 ft

7-10-Rx410-EP

Slide 11

Current or "Ambient" Temperature Structure

Temperature of the existing atmosphere can decrease or increase with altitude. These measurements are called "soundings."



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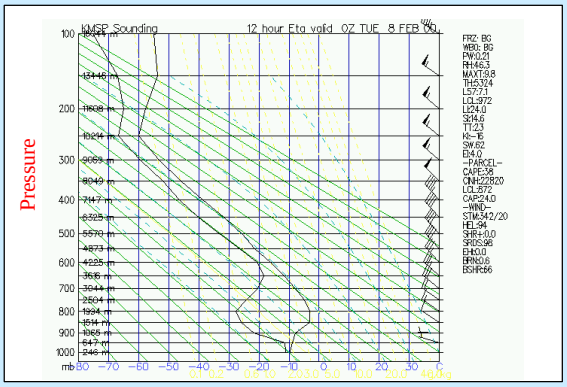
Slide 12

Forecast Soundings



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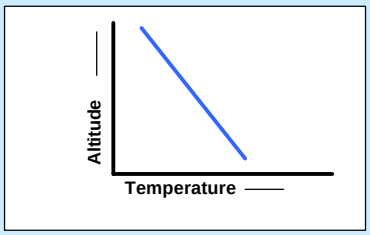
Slide 13

Average or Normal Lapse Rate

In the atmosphere, temperature normally decreases with increasing altitude at -3.5°F / 1,000 ft.



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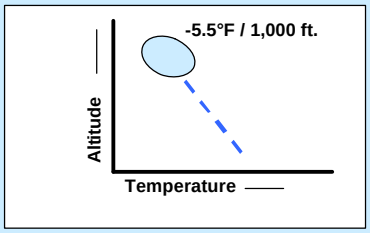
Slide 14

Dry "adiabatic" Lapse Rate

The Dry Lapse Rate is the rate at which the temperature of an unsaturated (invisible) air parcel would change if it were moved up or down in the atmosphere.



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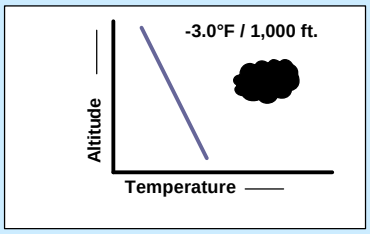
Slide 15

Moist "adiabatic" Lapse Rate

The Moist Lapse Rate is the rate at which the temperature of a saturated air parcel (a cloud) would change if it were moved up or down in the atmosphere.



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Slide 16

Determining Stability

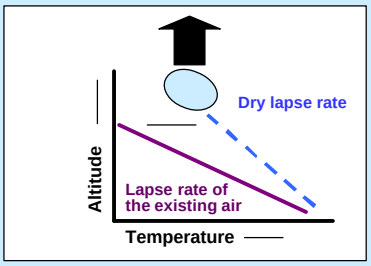
- The stability of an air mass or layer of air is determined by “moving” an air parcel upward.
- The resulting temperature of the parcel is then compared to that of the surrounding air.
- If the parcel is warmer than the surrounding air, then the air is unstable, because the air parcel is now more buoyant than the surrounding air and would continue to rise.
- Conversely, if the lifted parcel is cooler than the surrounding air, the air mass or layer of air is stable, because the air parcel would be more dense than the surrounding air and the parcel would sink.

7-16-Rx410-EP

Slide 17

Unstable Condition

The atmosphere or layer of air is unstable when the lapse rate of the existing air is GREATER than the dry lapse rate.



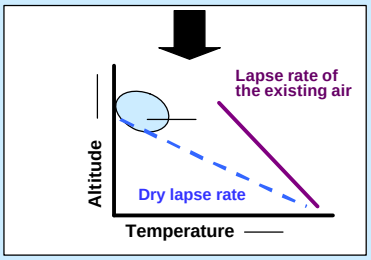
As an air parcel is forced to move up, it cools more slowly than the surrounding or ambient air. The parcel would be warmer than the surrounding air and would then continue to rise.

7-17-Rx410-EP

Slide 18

Stable Condition

The atmosphere or layer of air is stable when the lapse rate of the existing air is LESS than the dry lapse rate.



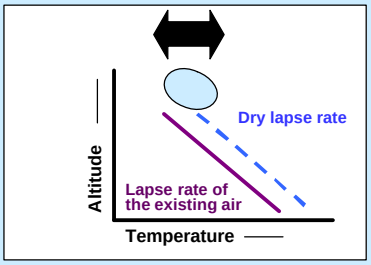
As an air parcel is forced to move up, it cools faster than the surrounding or ambient air. The parcel would then sink.

7-18-Rx410-EP

Slide 19

Neutral Condition

The atmosphere or layer of air has neutral stability when the lapse rate of the existing air is EQUAL TO the dry lapse rate.



As an air parcel is forced to move up, it cools at the same rate as the surrounding or ambient air. The parcel would then remain at that new level.

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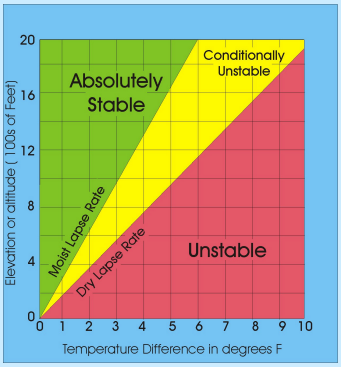
Slide 20

Determining Stability



Graph for determining stability of a layer of air.

Measure the temperature at the top and bottom of the layer and note the thickness of the layer.

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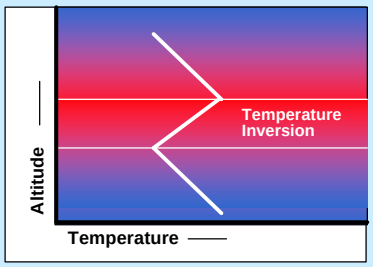
Temperature Inversion

When temperature increases with increasing altitude, a temperature inversion exists.



Inversions are stable layers which inhibit upward motion and smoke dispersal.

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Types of Inversions

- Radiation or nighttime (nocturnal)
- Subsidence
- Marine
- Frontal

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Nocturnal Inversion

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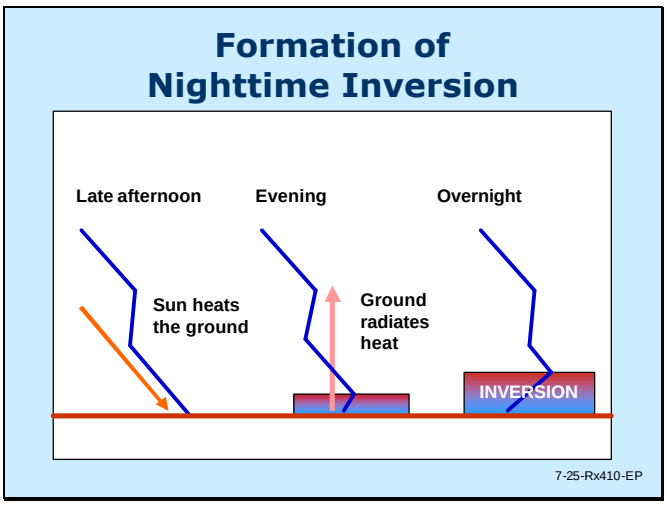

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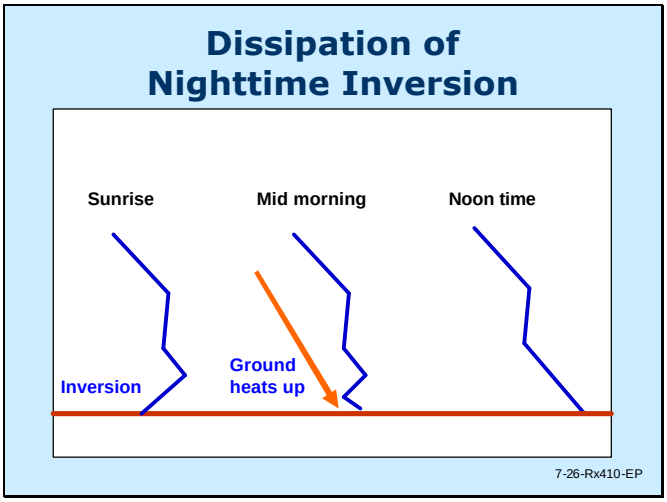

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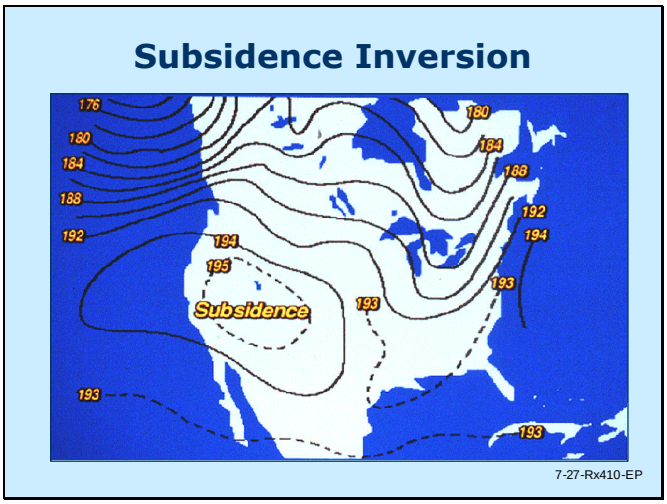

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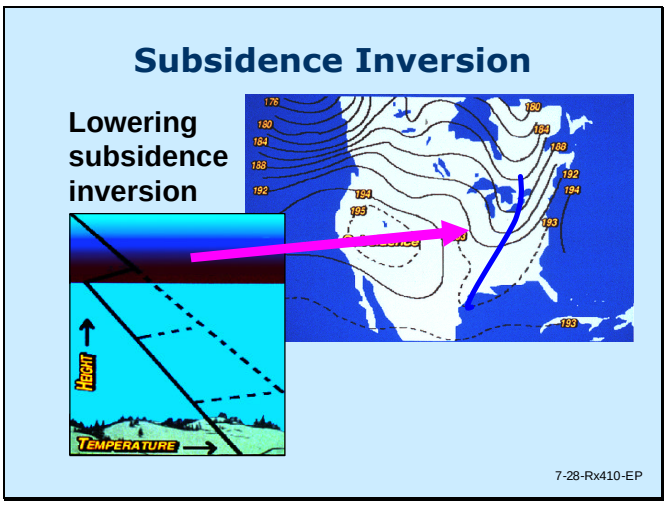

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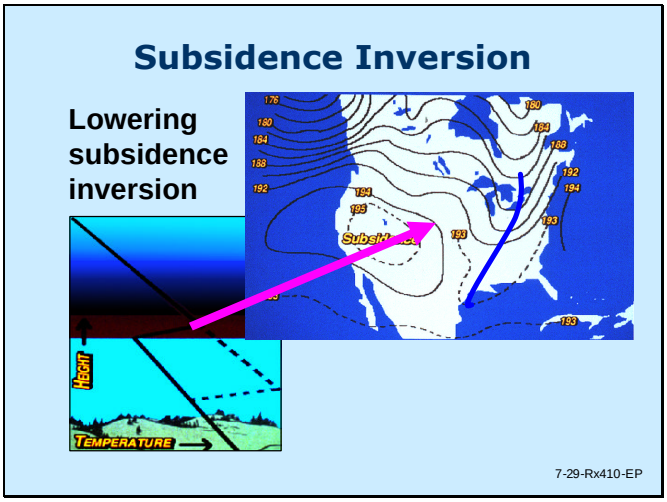

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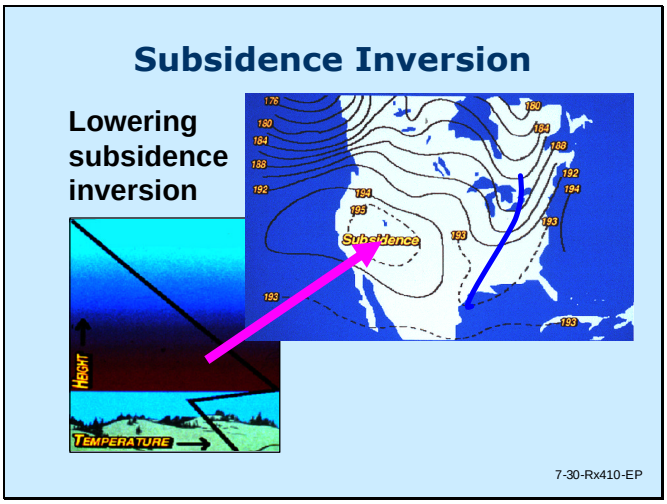

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High Pressure Subsidence Inversion

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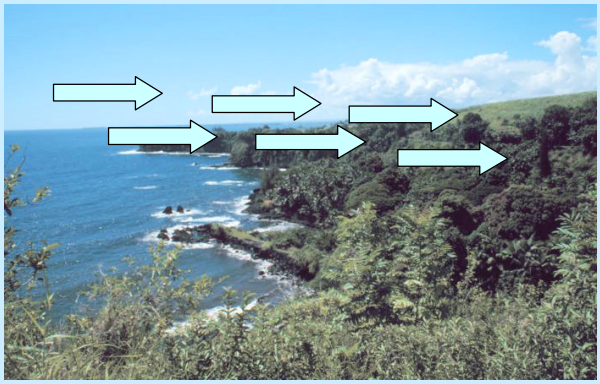
Marine Inversion



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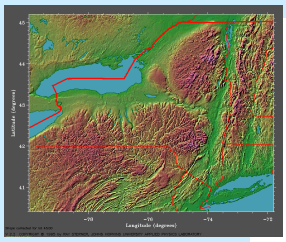
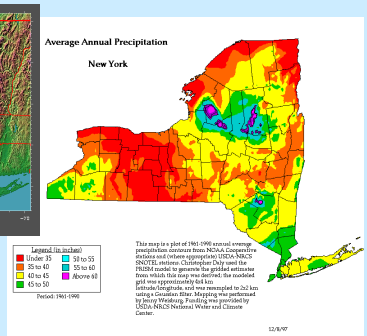
Precipitation and Topography

Marine inversions can occur at inland lakes





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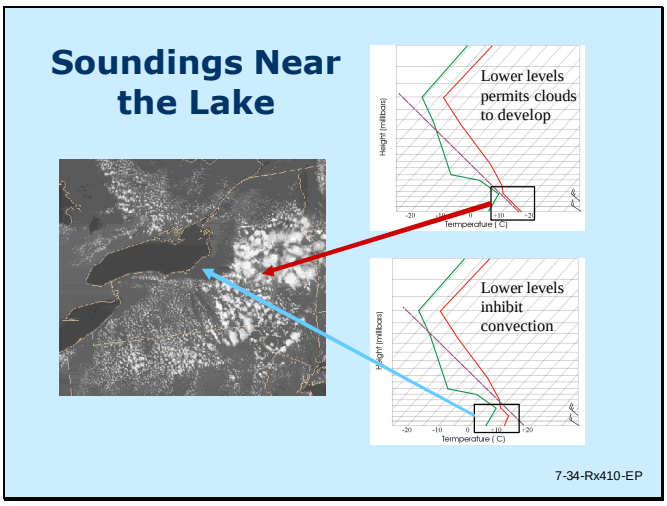

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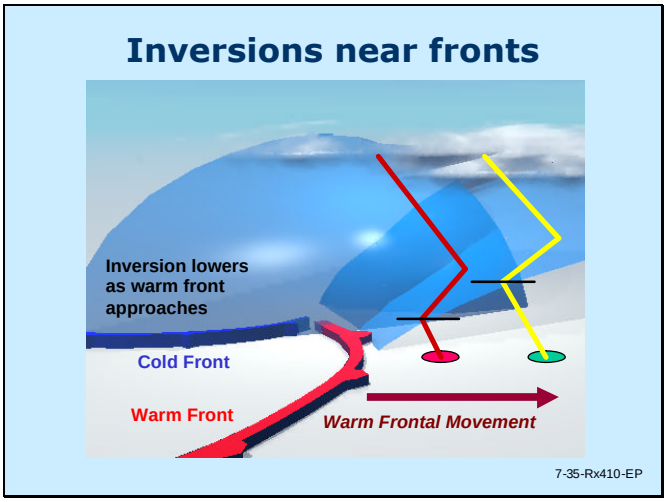

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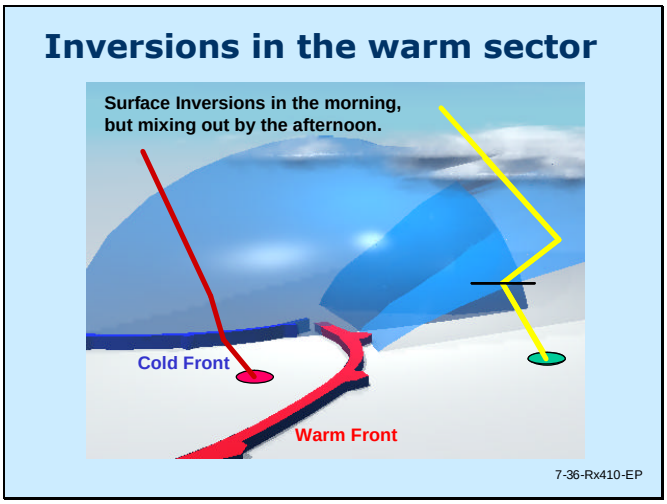

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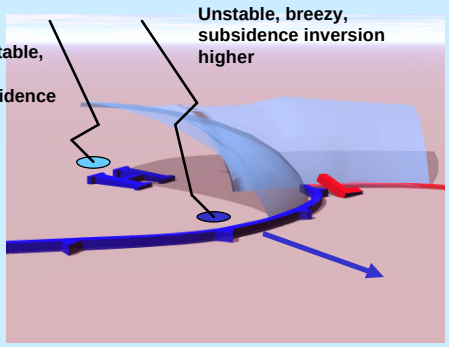
Soundings Behind Cold Fronts



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Lifting Process

- Surface heating
  - typical of summer days
- Orographic
  - air forced up a hill or mountain
- Frontal
  - Cold and Warm
- Convergence
  - Troughs
  - Local circulations

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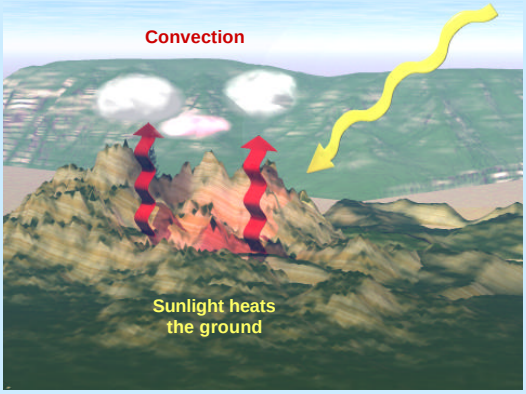
Thermal Lift



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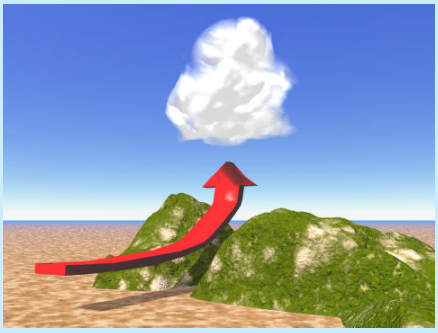
Orographic Lift

A function of topography, where air lifts as it passes over a higher elevation land mass



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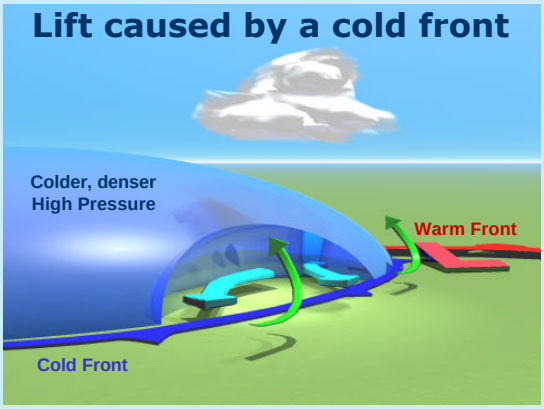

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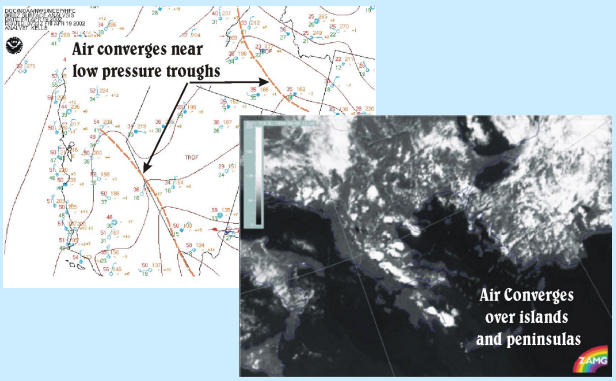
Convergence



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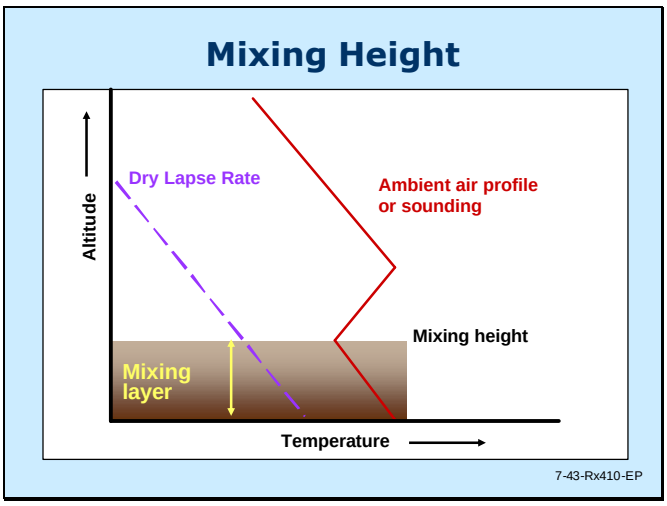

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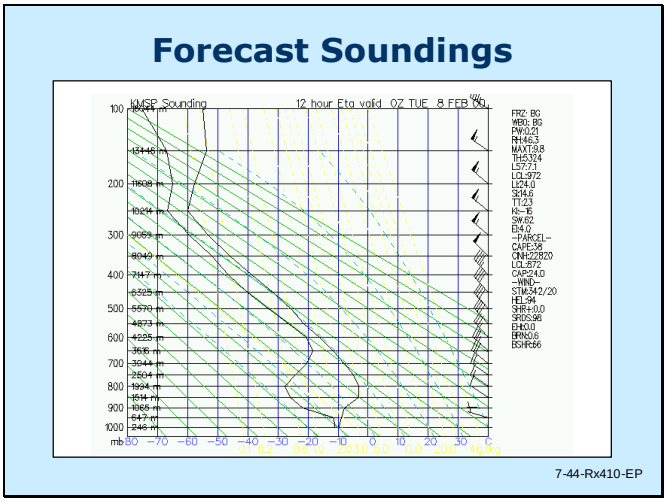

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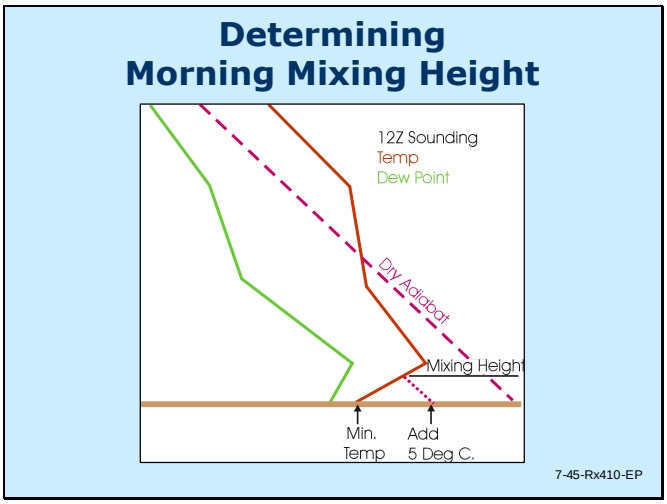

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Low Mixing Height

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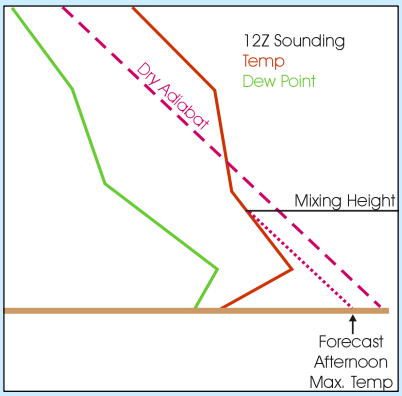
Determining Afternoon Mixing Height



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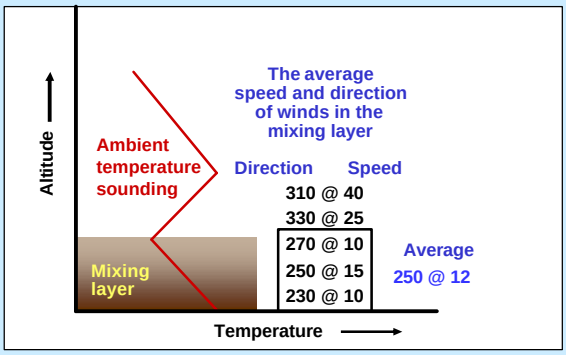
Transport Winds



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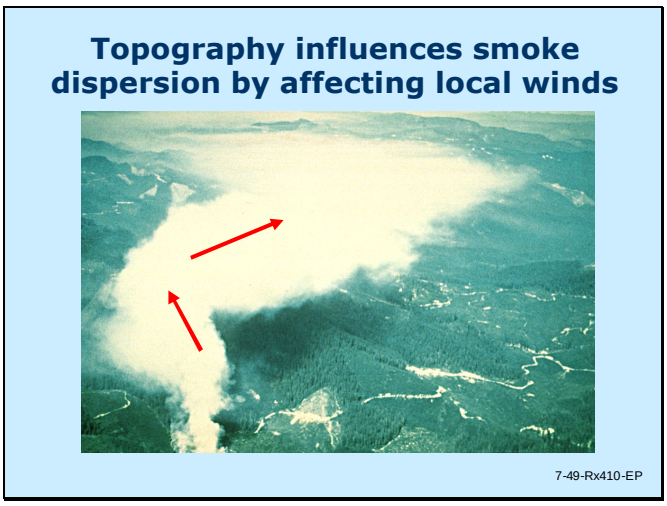

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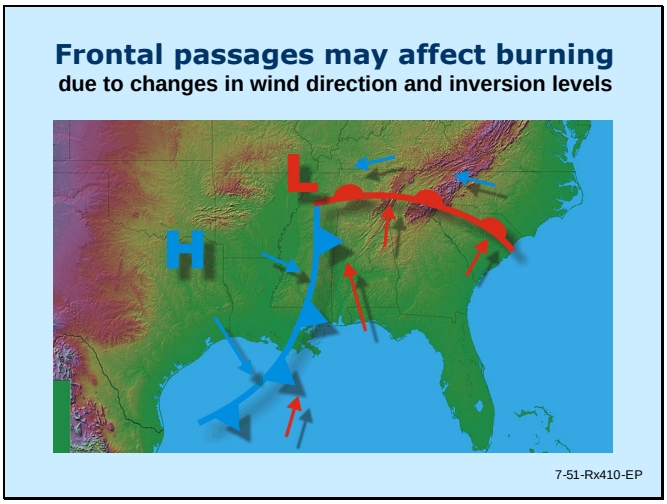

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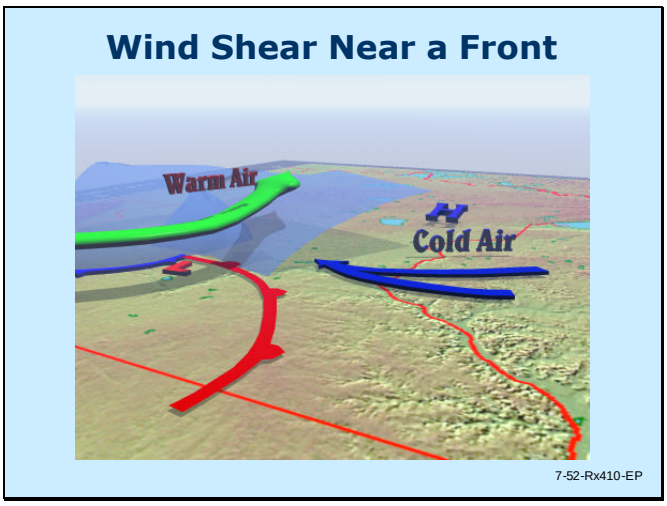

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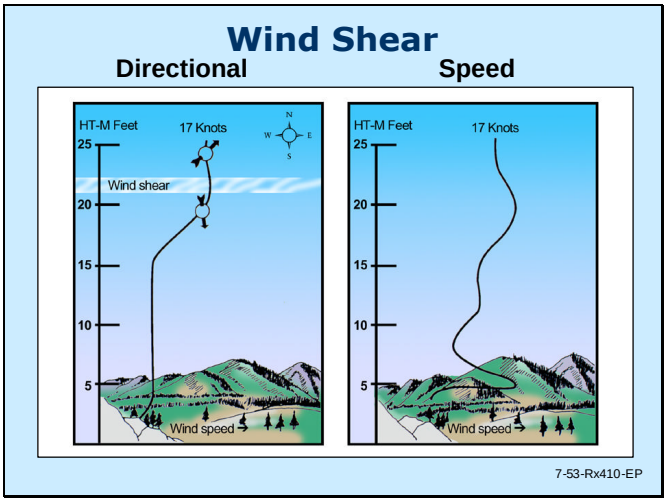

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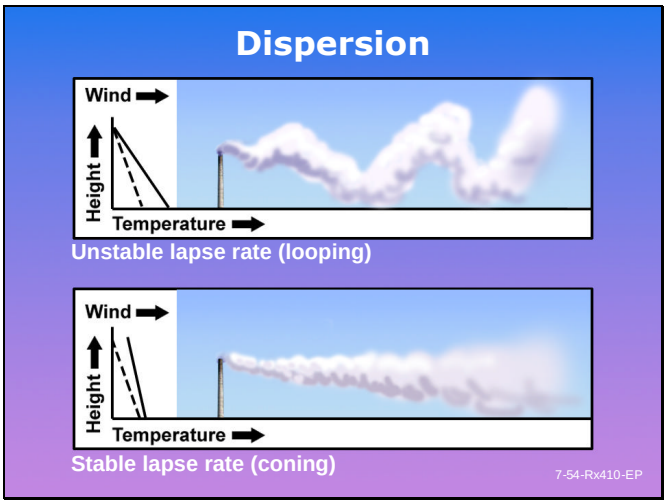

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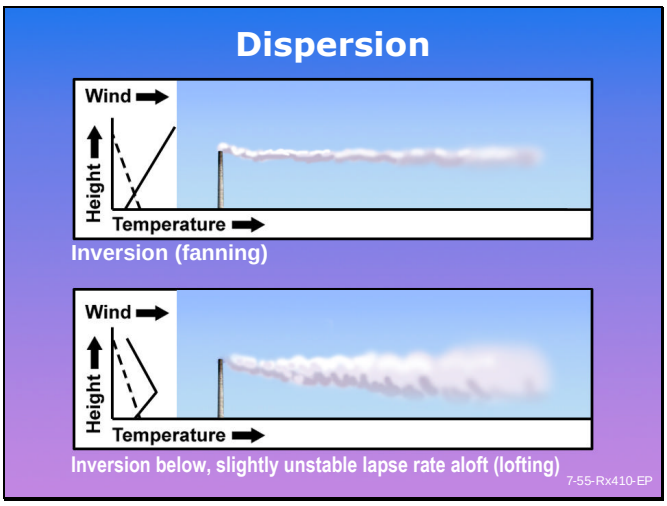

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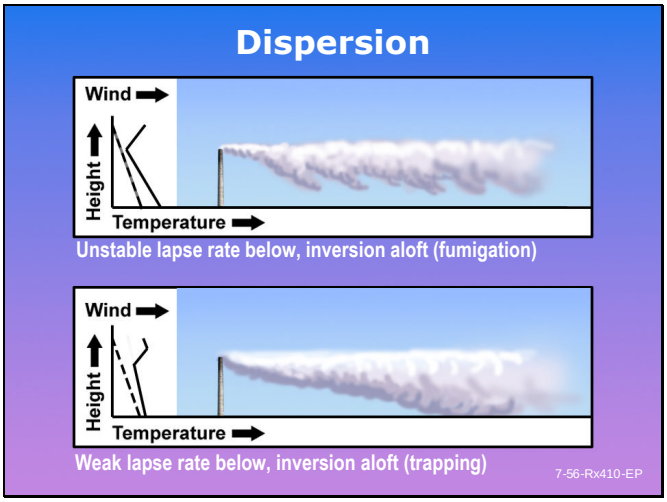

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Ventilation Index

a measure of the volume rate of horizontal transport of air within the mixing layer per unit distance.

$$\text{Index} = \frac{\text{Mixing height} \times \text{Transport Wind Speed}}{100}$$

Ventilation Index	Smoke Dispersion
>100	Excellent
60-99	Good
40-59	Fair
<40	Poor

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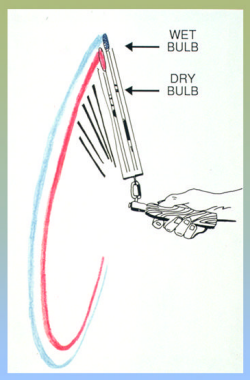
Sling Psychrometer



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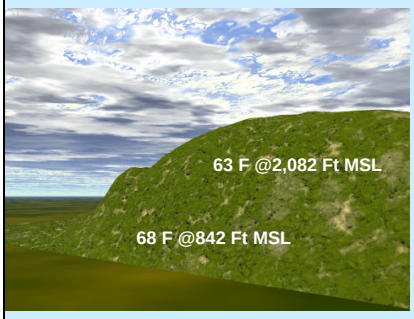
Calculating Stability
from field observations



Compare the observed temperature and elevation difference with that of the dry adiabatic lapse rate.

If the calculated value is greater than 5.4ºF, then the air is unstable.

$$\frac{X}{1{,}000\ \text{Ft}} = \frac{-5^{o}\text{F}}{1{,}240\ \text{Ft}} \qquad X = \frac{5^{o}\text{F} \times 1{,}000\ \text{Ft}}{1{,}240\text{Ft}} = -4.0^{o}\text{F}$$

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Weather balloons

released to sample the local winds

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Sampling the temperature lapse rate by airplane

GPS may also be a solution for measuring winds aloft

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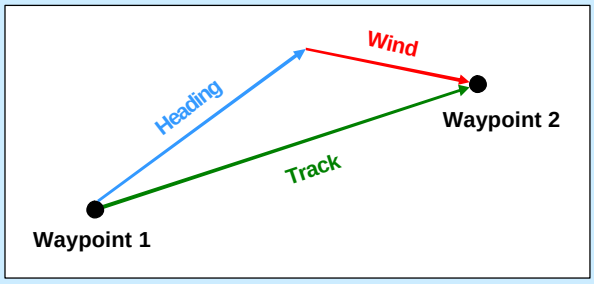
GPS Calculates Wind

GPS calculates wind every few seconds
Reading OAT as well can give you a sounding for the local area



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Winds aloft can be measured by onboard GPS in aircraft

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Visual Indicators of Stable Air

- Clouds in layers - No vertical motion
- Stratus-type clouds
- Smoke column drifts apart after limited rise
- Poor visibility in lower levels due to accumulation of smoke and haze
- Fog
- Light and steady winds

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Visual Indicators of Unstable Air

- Good vertical growth of clouds
- Cumulus clouds
- Gusty winds
- Upward and downward currents

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Visual Indicators of Unstable Air

- Good visibility
- Dust devils (vortices)

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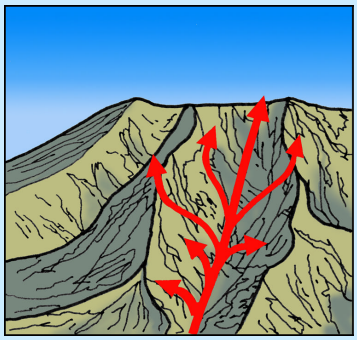
Valley Winds

Solar heating causes upslope wind during the day

Find out the wind direction at the ridge top



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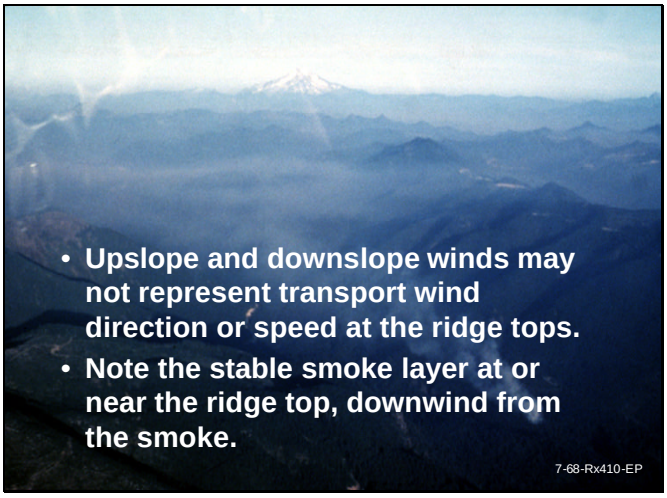

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Unit 7 Objectives

- Define weather terms and concepts important to smoke management.
- List key weather factors that affect smoke behavior.
- Verify smoke behavior forecasts using visual indicators and on-site measurements.
- Describe the types of weather forecasts available and their limitations.

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Smoke Management Techniques, Rx-410

Lesson 8A - Fuel Consumption and Smoke Production

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Describe the four phases of combustion.
2. Describe how different fuel characteristics affect combustion.
3. Describe how fuel moisture affects consumption.
4. Describe methods of estimating fuel consumption.
5. List five reasons why we need to estimate emissions.
6. Define an emission factor.
7. Predict emissions from wildland fires.

Why do we need to know fuel consumption?

Fuel consumption is the amount of biomass consumed during a fire and is another critical component required to estimate emissions production from wildland fire.

The amount of smoke produced can be derived from the knowledge of black (burned) area (acres), fuel loading (tons/acre), fuel consumption (tons/acre), and pollutant specific emission factors (lbs/ton). We will be estimating emissions using these variables later in the lesson. Dispersion models can then disperse the pollutants downwind and estimate potential ground level concentrations.

In the simplest terms, combustion of vegetative matter (cellulose) is a thermal/ chemical reaction when plant material is rapidly oxidized producing carbon dioxide, water, and energy. This is the reverse of plant photosynthesis when energy from the sun combines with carbon dioxide and water, producing cellulose.

It has been recognized that there are four major phases of combustion when fuel particles are consumed. These phases are: (1) pre-ignition; (2) flaming; (3) smoldering; and (4) glowing. Each phase will be described in more detail.

During the pre-ignition phase, fuels ahead of the fire front are heated and water vapor is driven to the surface of the fuels and expelled into the atmosphere. As fuels dry and are heated by radiation and convection to > 212°F, water vapor and noncombustible organics are distilled to the fuels surface and driven off into the air. As the fuel's internal temperature rises, cellulose and lignin of the fuel begin to decompose, releasing a stream of combustible organic gases and vapors. Since these gases and vapors are extremely hot, they rise and mix with the oxygen in the air and will ignite if temperatures between 617°F and 617°F are reached, leading to the flaming phase. This is a photograph of lighter igniting a large pile of logging debris. Note the white smoke coming off the pile. This is composed of water vapor and gases during the pre-ignition phase.

In the flaming phase, the fuel temperature rises rapidly. Pyrolysis accelerates and is accompanied by flaming of the combustible gases and vapors. The combustion efficiency during the flaming stage is relatively high in the majority of cases and the predominant products of flaming combustion are carbon dioxide (CO2) and water vapor (H2 O). The water vapor is a product of the combustion process and not from water vapor being driven from the fuel. Temperatures during the flaming stage range

between 932° F to 2552° F. During the flaming period, the average exterior diameter reduction of round wood material occurs at a rate of 1 inch per 8 minutes. For example, a dry limb 3 inches in diameter would take approximately 24 minutes to be completely consumed if flaming combustion is sustained during the entire time period.

During the smoldering phase, the emissions of combustible gases and vapors above the fuel are too low to support a vigorous combustion and a consistent flame envelope resulting in a fire spread decrease and significant temperature drop. Peak smoldering temperatures range from 572°F to 1112 ° F. The gases and vapors condense, appearing as visible smoke as they escape into the atmosphere. The smoke consists mostly of droplets less than a micrometer in size. The amount of particulate emissions generated per mass of fuel consumed during the smoldering phase is significantly greater than those of the flaming phase.

Smoldering combustion is more prevalent in certain fuel types such as duff, organic soils, and rotten logs and often less prevalent in fuels with high surface to volume ratios such as grasses, shrubs, and small diameter woody fuels. Since the heat generated from a smoldering phase is seldom sufficient to sustain a convection column, the smoke stays near the ground and often concentrates in nearby valley bottoms, compounding the impact of the fire on air quality. Near the end of the smoldering phase, the pyrolysis process nearly ceases, leaving the fuel that was not completely consumed with a layer of black char, high in carbon content.

In the glowing phase, most volatile gases have been driven off. Oxygen in the air can now reach the exposed surface of char left from the flaming and smoldering phase and it begins to glow with the characteristic orange color. Peak temperatures of the burning fuel during the glowing phase are similar to those found in the smoldering phase and range from 572°F to 1117 °F. There is little visible smoke. Carbon dioxide and carbon monoxide are the principal products of glowing combustion. This phase continues until the temperature of the fuel drops or until only noncombustible, mineral gray ash remains.

It is important to recognize that the combustion of fuels during a wildland fire is not an efficient process and many factors determine if and how efficiently a fuel complex will burn. First, moisture contained in the fuels absorbs some of the heat energy, thereby reducing the combustion temperature. Second, considerable heat is subsequently lost to the soil and surrounding air, consequently the amount, size, and arrangement, and continuity of fuel are critical to sustaining the combustion process.

Fuel Loading. Fuel loading is a very critical variable needed for determining total biomass consumed and emissions produced from wildland burning. Wildland fires in areas of light fuels will generally consume less fuel and produce less emissions than fires burning in heavy fuels given the same combustion parameters.

Fuel Size and Consumption. Since combustion generally takes place at the fuel/ atmosphere interface, the time necessary to ignite and consume an individual fuel particle with a given fuel moisture content, depends upon the smallest dimension of the particle. The surface area to volume ratio of a particle is often used to depict a particle's size and the greater the ratio, the smaller the particle. Small twigs and branches have a much larger surface to volume ratio and a much greater fuel surface exposed to the atmosphere than a large log. Consequently the small fuels will have a greater chance to burn and be consumed for a given fuel moisture.

Small fuels are consumed generally during the flaming stage and continue until there are too few to interact.

Flaming is sustained by smaller fuels and litter and ignites larger fuels.

The larger fuels have a small surface to volume ratio and once the large fuel is ignited, it will smolder until quenched by internal fuel moisture content in logging debris. In natural fuels, generally most of the larger material is rotten and once ignited, smoldering continues until the material is totally consumed or weather conditions extinguish combustion.

The arrangement of the particles is also important. The structuring of fuel particles and air spaces within a fuelbed can either enhance or retard fuel consumption and affect combustion efficiency. A measure of fuelbed porosity is called the packing ratio, or that fraction of the fuel volume occupied by the fuel. A loosely packed fuelbed (low packing ratio) will allow plenty of oxygen to be available for combustion, but may result in inefficient heat transfer between burning and adjacent unburned fuel particles. Many particles cannot be preheated to ignition temperature and are left unconsumed. On the other hand, a tightly packed fuelbed (high packing ratio) allows efficient heat transfer between the particles, but may restrict oxygen availability and reduce consumption and combustion efficiency. An efficient combusting fuelbed will have particles close enough for adequate heat transfer while at the same time large enough spaces between particles for oxygen availability.

Fuel discontinuity (both horizontal and vertically) isolates portions of the fuelbed from pre-ignition heating and ignition. Sustained ignition, and combustion will not occur when the spacing between the fuel particles is too large

Fuel moisture content is the most influential factor in the combustion and consumption processes. Live moisture content can vary by temperature, relative humidity, rainfall, soil moisture, seasonality and species. Dead fuel moisture content varies by temperature, relative humidity, rainfall, species, and decay class. Moisture within a fuel affects the flame temperature that in turn influences the ease of ignition, amount and rate of consumption, and the combustion efficiency (the ratio of energy produced compared to energy supplied) with which live and dead vegetation burn. In other words, the higher the fuel moisture content, the more energy required to drive off the moisture and enable the fuel to reach a point where pyrolysis begins. Generally, fuels with low fuel moisture content burn more efficiently and produce less emissions per unit of fuel consumed. On the other hand, even though the emissions per unit of fuel burned will be greater at higher fuel moistures, the total emissions may be less if some fraction of the fuels (typically, the large wood fuels and forest floor) do not totally burn.

This graph demonstrates how, during the pre-ignition phase, the fuel is heated to 212 degrees F and the energy releases the bound water and changes liquid water to vapor. The water is eventually removed from the fuel and the fuel temperature rises to ignition temperature.

This graph indicates the amount of energy it takes to remove moisture from a fuel particle. The higher the moisture content, the greater amount of energy it takes to remove the moisture from the fuels. Once the moisture is removed from the fuel and pre-ignition energy is still available, the fuel particle may reach ignition temperature and the flaming phase will begin.

Consumption is different by combustion phase. The major part of fuel consumption generally occurs during the flaming and smoldering phases.

Flaming Combustion. Flaming consumption generally occurs at the fuel surface and requires abundant oxygen. The flaming combustion is often very rapid, but for a relatively short duration of time. In the laboratory, it took approximately 8 minutes for the diameter of a wooden dowel to be reduced by 1-inch. During the flaming stage, the combustion efficiency is high and the emission factor associated with this phase is low.

Smoldering Combustion. Smoldering consumption generally occurs at the fuel surface or internally and can occur with limited oxygen. The smoldering phase rate is variable but often slower than the flaming stage and can occur over a very long duration. During the smoldering phase, combustion efficiency is low and the emission factor associated with this phase is high.

To determine total fuel consumed, the flaming and smoldering consumption are added together.

How is woody fuel and stump consumption determined? Wires are placed around each fuel type and pulled tight after the fire and a diameter reduction is determined.

How is litter and duff consumption determined? Metal nails or welding rod are placed flush with the litter surface. Following the fire, the amount of rod above the new consumed surface is measured. The litter and duff reduction is multiplied by a density factor (tons per acre per inch) to determine tons per acre of consumption.

How is grass and shrub consumption determined? Square plots are clipped before and after the fire and the biomass oven dried. The difference in biomass between the clipped plots is the amount of shrub and grass consumed.

Fuelbed categories and consumption predictability.

- Small woody fuels and dead grass—good.
- Large woody fuels—Good for sound material, improvements needed for rotten material.
- Litter and duff—Good, regionally specific
- Live fuels, shrubs, crowns—poor
- Break down of flaming and smoldering—poor

Equations for predicting biomass consumption in the flaming and smoldering combustion stages are widely available in two major software packages, Consume 2.1 (http://www.fs.fed.us/pnw/fera) and First Order Fire Effects Model (FOFEM 5.0) (http://www.fire.org). Both software packages are very easy to use and contain advanced fuel consumption models. Students should try each software package and determine for themselves which one they feel most comfortable with and provides the best estimates of fuel consumption for their fuelbed types.

Grasses and Shrubs. Generally the models assume:

Ninety to 100% consumption of grasses with a majority of the consumption occurring during the flaming stage.

Fifty - 70 percent consumption of shrubs with a majority of the consumption occurring during the flaming stage. Shrub consumption equations need improvements.

Both Consume 2.1 and First Order Fire Effects Model 5.0 (FOFEM) contain grass and shrub equations.

Small Woody (0-1-inch) fuel consumption.

- Generally assume 90-100 percent consumption during the flaming stages.
- Use local experience when available.
- Both Consume 2.1 and FOFEM 5.0 contain small woody fuel consumption equations.

Small Woody (1-3-inch) fuel consumption models.

- Fuel moisture, 10-hr fuel loading, and duff consumption are key variables for estimating consumption.
- Assume a majority of the consumption occurs during the flaming stage.
- Both Consume 2.1 and FOFEM 5.0 contain small woody (1-3-inch) fuel consumption models.

Large Woody Fuel Consumption.

- Woody fuel moisture (sound logs) and duff moisture (rotten logs) are the key variables.
- Flaming and smoldering ratio based on small fuel consumption.
- Both Consume 2.1 and FOFEM 5.0 contain large woody fuel consumption equations.

This is a photo of a clear-cut burn with logging slash. Fuel moisture is the key variable for determining the consumption of sound, woody fuels often found in fresh logging debris or recent blow down. Logs are ignited by the small fuels and will continue to be consumed until quenched by the internal fuel moisture.

This is a rotten ponderosa pine log with a measured fuel moisture content of 350 percent.

Sixty to eighty percent of the large woody debris found in natural fuels is often rotten and duff moisture content is the key variable used to determine fuel consumption. This is not the case in recent blow down. The duff moisture content determines if the fire will carry to the log and consume enough to ignite the rotten logs. Once ignited, the rotten logs are generally consumed unless a weather event stops the consumption. The internal fuel moisture content of a rotten log does not often play an important role in determining total consumption. Once fire has entered a rotten log, it often will totally consume the log whether it is wet or very dry. The moisture content does play an important role in determining the rate at which the log will be consumed. A dry, rotten log will be consumed faster than a wet log. The large log in the photograph is totally engulfed in flame even though the average fuel moisture content was measured at 350 percent. Even though this rotten log's fuel moisture content was 350 percent, once ignited, it was completely consumed and only an ash layer was left.

Litter and duff consumption.

Logging and blow down debris: The litter layer is assumed to be totally consumed in an area with logging debris, consequently, litter depth is the critical variable. The duff layer consumption is dependent upon the pre-burn duff depth, days since significant rain, and consumption of the larger woody fuels. Pre-burn duff depth determines how much duff is available to be consumed; days since significant rain is a surrogate for duff moisture content; and the large woody fuels determine the amount of heat that will be available to penetrate into the duff and dry the duff to a specific depth. The duff will be consumed to that depth.

Natural fuels: In natural fuels, the litter is assumed to be consumed 90 to 100% so pre-burn litter depth is the critical variable. The consumption of the duff is determined by pre-burn duff depth and duff moisture content. No surrogate for duff moisture content in natural fuels has been determined to date.

Extremely dry duff (<30 percent moisture content) will burn on its own once ignited. In the southern part of the United Sates, this is often related to a Keech-Byram index of greater than 500.

Litter and duff densities. Litter and duff have different densities depending on the material that generated the biomass. The densities are often variable. The average density for litter generated from needle and leaf fall is about 3 tons per acre per inch. Black duff (generated from the decay of needles and leaves) is about 12 tons per acre per inch. Red duff (generated from the decay of woody debris and logs) is most dense and averages 18.7 tons per acre per inch. Finally, moss generated duff averages about 3 tons per acre per inch.

Measuring the density of litter and duff is very time consuming and complex. The literature contains very few density figures. A known area square made of sharpened steel is pushed into the ground level with the litter layer. Fifteen metal rods are pushed into the litter and duff flush with the top of the litter layer. The litter layer is removed and placed in a bag. The distance between the top of the metal and the top of the duff layer is measured. The duff is then removed to mineral soil and placed in a bag. The distance between the top of the pin and mineral soil is measured. The litter and duff samples are oven dried and the known volume is calculated to determine density.

Emissions production. This lesson has been developed with a national perspective in mind. Many photos and comments will address smoke production in many areas of the United States.

Why do we need to know the amount of smoke produced from wildland fires?

- Landscape assessments
- Global change and carbon assessments.
- Wildfire and prescribed fire tradeoffs with regards to smoke
- Regulatory agency required emissions inventories
- State implementation plan requirements
- Meet regulation or impact reporting
- Assessing the potential of emission reduction techniques
- NEPA requirements and comparisons
- Wildland fire planning

This slide is an example of the Interior Columbia River basin landscape assessment of potential smoke production from fires burning in the 1930's (historical) and fires burning today (current). Note the increase in smoke potential in today's landscape. This is a result of a shift in forest type and structure from open ponderosa pine to more dense ponderosa pine and mixed conifer stands.

This slide is an example of a national emissions inventory completed by Darold Ward and Janice Peterson in 1989 at the request of the EPA. Note the large amount of burning that occurs in the southern United States.

This slide is an example of the State of Washington's emissions inventory to determine if they have met the State Implementation Plan requirements.

This slide is an example of $PM_{2.5}$ produced from wildfires between 1922 and 1994 and a comparison with prescribed burning projected smoke production and two large individual wildfire episodes. Emission production estimates can be used to compare tradeoffs between wildfires and prescribed fires.

This slide compares smoke impacts of wildfires and prescribed fires. Side 49 is the projected PM_{10} concentrations from several wildfires that occurred in 1990. Note the 24-hour PM_{10} exceedences from the wildfires. Slide 50 is the concentration of smoke generated from a 16 fold ramp-up of prescribed fire in eastern Oregon and Washington in 1990. Note there are no exceedences of the 150 ppm 24 hour average regulation for PM_{10}.

This slide compares the potential $PM_{2.5}$ reduction from various emission reduction techniques. Emission production allows land managers to show the potential emission reduction that is possible from various techniques.

This slide gives an example of the variability of fuel loading that can occur within a fuelbed type. This is why fuel loading has a large error associated with it when used to calculate smoke.

There are several methods to collect data on fuel loading including direct measurement, photo series, fuel characteristic classification system, assigning a fuel model, remote sensing, and expert guess. Remote sensing techniques are improving with such innovations as LIDAR (Light Detection And Ranging which measures distance, speed, chemical composition and concentration) but these techniques are not there yet. Generally, the more time consuming a method is, the more accurate your answer will be.

It is important to remember to include all fuelbed categories when determining fuel consumption. This includes the trees, shrubs, grasses, woody fuel, litter, and duff.

In certain cases, emission production estimates may justify the collection of detailed field data. This generally occurs if a prescribed burn is located near a smoke sensitive area.

Fuel consumption is also a variable that is associated with a large smoke estimation error. This slide shows a large variability in fuel consumption by loading category across a range of moisture conditions. This wide variation is why a large error in smoke production estimation can occur if poor fuel consumption prediction is evident.

Fuel consumption is the key to all effects. Small fuels, shrubs, and crown fires contribute to fire behavior, combustion efficiency, and are consumed generally during the flaming stage. The consumption of the large fuels can contribute to a large amount of mass consumed during both the flaming and smoldering stages producing large amounts of smoke. The organic layer can contribute both mass and large amounts of smoke. The organic layer can contribute 50 % or more of smoke produced that generally occurs during the smoldering phase.

There are several ways to estimate fuel consumption. Direct measurement is very difficult but most accurate. Modeling fuel consumption using Consume or FOFEM is relatively easy and accurate. One can estimate a percent consumption through expert knowledge. This is the least accurate method.

Emission factor: Mass of pollutant of interest produced per mass of fuel consumed. There are emission factors for the flaming and smoldering stage of a fire as well as a fire average emission factor.

There are several emission factor tables. These tables are updated periodically. In 1995, Dr. Darold Ward and Colin Hardy developed a table of emission factors associated with vegetation type and species (see 8A-01-Rx-410-SR). Dr. Ward later modified that emission factor table and based the emission factors on combustion efficiency. This table was similar to the earlier Ward and Hardy table since the combustion efficiency was related to fuelbed type and species. Finally, there is an EPA document called AP-42. This document needs to be updated since the emission factors are old and several tables have incorrect units associated with the emission factors. Note: emission factor units are generally in grams per kilogram, however, land managers prefer the units be in pounds per ton. If you multiply the emission factors that are in grams per kilogram by 2, you will convert the emission factor into pounds per ton.

This is a table of PM_{10} and $PM_{2.5}$ fire average emission factors. The grass emission factors are preliminary until new values are available. This is the best available table for United States fuelbed types at this time.

This is a table of $PM_{2.5}$ emission factors for the flaming and smoldering fire phase. Because the flaming phase is much more efficient than the smoldering phase, the emission factors for the flaming phase are much lower than the smoldering phase. This is why it is so important to separate consumption into the flaming and smoldering phases. The only exception to this generality is in the sagebrush fuelbed type. This could be an artifact of the limited amount of data acquired for this fuelbed type. The grass emission factors are preliminary until new values are available. Note the more efficient burning of the piles and the lower emission factor. This is the best table available table at this time.

Tower sampling system to measure smoke emissions between 1980s and 2000. The data was collected with large towers and cable systems in the mid 1980s and early 1990s. Later, the system was redesigned and miniaturized by the Missoula Fire Lab Fire Chemistry project in the mid to late 1990s and early 2000. For piles, a crane system was designed.

This is a summary slide of the fire average emission factors for 4 different fuelbed types. The grass and pile burning have the lowest emission factors because most of the consumption generally occurs during the flaming stage and is associated with a lower emission factor.

This is a slide of the fire average emission factors for various fuelbed types by species. Note the small variability between fuelbed types. This is why there is a relatively small error associated with the emission factor when predicting total emissions.

Emission production is very easy to calculate. Basically, you multiply the fuel consumed (tons per acre) by an emission factor (pounds per acre) for the pollutant of concern to obtain emission produced (pounds per acre). Once you have obtained the emissions produced per acre, one multiplies this by the number of acres burned (black acres) and obtain total emissions (pounds or tons).

Example of calculating $PM_{2.5}$ emissions for a grass prescribed burn in central Florida.

Example of calculating $PM_{2.5}$ emissions for a sagebrush prescribed burn in eastern Oregon.

Example of calculating $PM_{2.5}$ emissions for a ponderosa pine prescribed burn in eastern Oregon.

A comparison to demonstrate the difference in emissions produced from the grass, sagebrush, and ponderosa pine example units. The difference is due to total fuel loading and fuel consumed, and emission factors applied.

The simple approach for calculating total emissions was shown in the above examples. Total fuel consumption was multiplied by a fire average emission factor. A more accurate method is to determine the fuel consumption by combustion phase and multiply that consumption by the appropriate combustion phase emission factor. Add the pollutant produced during each phase together for total emissions. This complex approach is built into most emission production models such as Consume 2.1, FOFEM 5.0, and the Emissions Production Model (EPM).

Although reducing the amount of smoke through the use of emission reduction techniques is important, one must also consider the impacts of that smoke. For instance, in **slide79**, helicopter ignition reduced the amount of smoke produced, but the wind directed the smoke towards Mount Rainier National Park. In **slide 80**, emission reduction techniques were initiated, however, an inversion pooled the smoke in the valley and caused visibility and health concerns in a small community located in the valley bottom.

Consequently, as seen from **slides 79 and 80**, total smoke is not the only piece of information that is needed to regulate smoke. The smoke produced must be dispersed down wind to look at health and visibility impacts. This requires the variable of time to enter the equation and an emission rate be determined. Dispersion models require emission rates.

Emission rate (lbs per minute) = fuel consumption (tons per acre) X emission factor (pounds per ton) X rate of area burned (acres per minute).

This slide is an example of $PM_{2.5}$ emission production rate during a broadcast burn. The area under the red line is total $PM_{2.5}$ emissions produced during the flaming phase, the area under the green line is the total $PM_{2.5}$ produced during the smoldering period, and the area under the blue line is the total $PM_{2.5}$ produced smoothed for both phases. The black line is the actual $PM_{2.5}$ measured on site with the smoke emissions tower. The shape of these curves is very similar to fuel consumption rate curves.

This slide is an example of a sagebrush burn and the emission production rate. Note the burn is very quick and dominated by flaming combustion with very little smoldering.

This slide is an example of a ponderosa pine prescribed fire with a potential of long term smoldering. Note the smoldering emissions produced during afternoon burning periods of subsequent days. This smoke has low buoyancy and may cause health and visibility impacts.

Dispersion models estimate the transport of smoke downwind. Fuel consumption, emission factor, meteorological, and receptor data are required to operate the models. SASEM (west), NFSpuff (west), VSMOKE (south), and Calpuff (national) are some of the better known dispersion models used today. Bluesky is a new project that will bring together a common procedure to acquire the acres burned, fuel loading, consumption, emissions production, and meteorological data to run Calpuff and disperse the smoke downwind and estimate smoke impacts.

Summary:

- Four phases of combustion.
- Fuel characteristics and consumption.
- Fuel moisture and consumption.
- Methods for estimating fuel loading and fuel consumption.
- Why do we need to estimate emissions?
- Define an emissions factor.
- Predict emissions from wildland fires.
- Emission production rates.
- Dispersion.

Slide 1

Slide 2

Unit 8A Objectives

- Describe the four phases of combustion
- Describe how different fuel characteristics affect combustion
- Describe how fuel moisture affects consumption
- Describe methods of estimating fuel consumption
- List five reasons why we need to estimate emissions
- Define an emission factor
- Predict emissions from wildland fires

8A-2-Rx410-EP

Slide 3

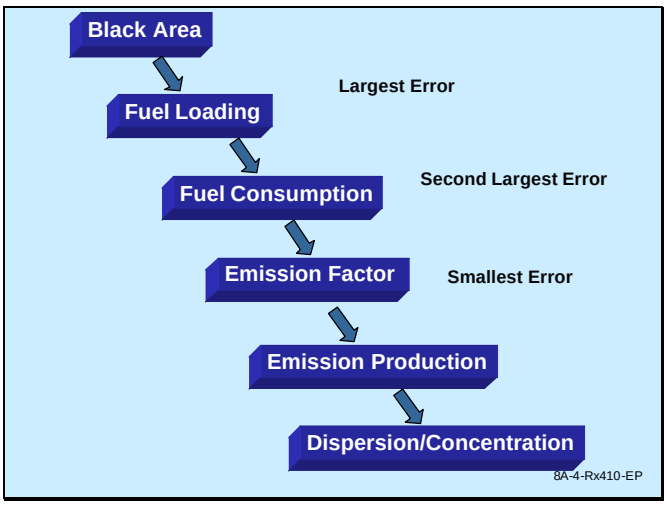
Fuel Consumption

Why do we need to know fuel consumption?

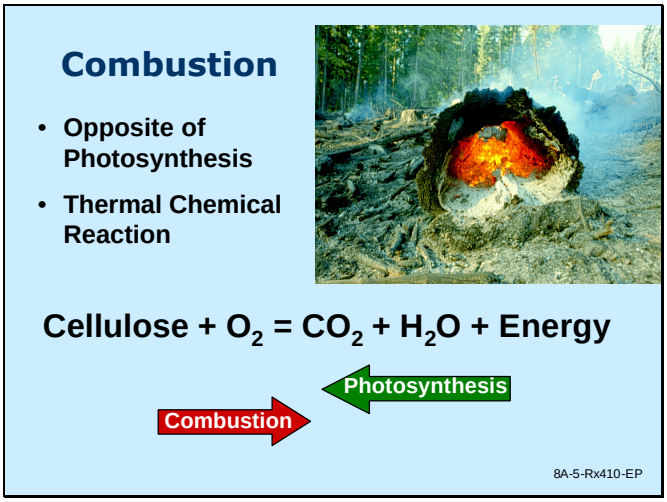
- Validate burn prescriptions
- Estimate emissions and impacts

8A-3-Rx410-EP

Slide 4



Slide 5



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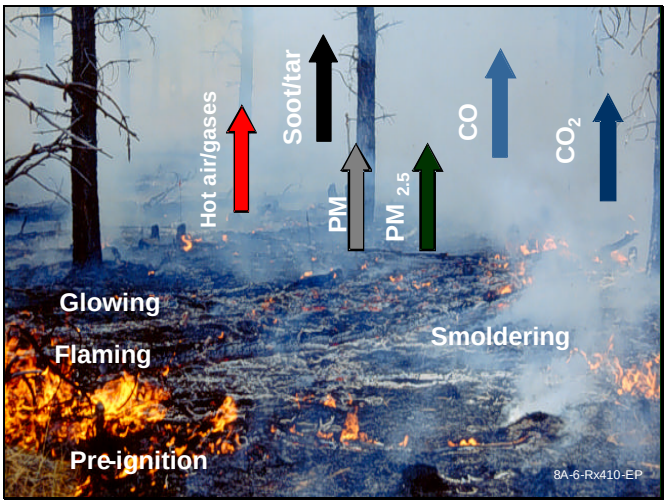


Slide 7

Pre-Ignition Phase

- Fuels are heated
- Fuel moisture is driven off and water vapor is released
- Pyrolysis begins: thermal decomposition of cellulose to combustible vapors

8A-7-Rx410-EP

Slide 8

Flaming Phase

- Combustible vapors reach 600° F and mix with sufficient oxygen
- Accelerates pyrolysis
- Rapid oxidation
- Produces primarily CO_2 and H_2O
- Partial oxidation causes a variety of emissions

8A-8-Rx410-EP

Slide 9

Smoldering Phase

- Temperature and combustible vapor mixture too low to support flaming
- Temperature drops, gases condense
- Emissions = 2X flaming stage
- Insufficient heat to maintain strong convection column

8A-9-Rx410-EP

Slide 10

Glowing Phase

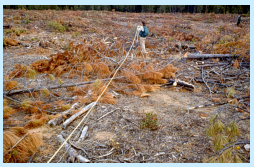
- All volatile gases driven off
- No visible smoke produced
- CO_2, CO and ash primary products

8A-10-Rx410-EP

Slide 11

Combustion and Consumption is Affected by Fuel

Loading
Size
Arrangement
Continuity
Fuel Moisture



8A-11-Rx410-EP

Slide 12

Fuel Loading and Consumption

If combustion factors remain constant and thus percent consumption remains constant: greater fuel loading = increased consumption

	Unit 1	Unit 2
Fuel Loading	8 t/a	30 t/a
Consumption	70%	70%
Fuel Consumed	5.6 t/a	21 t/a

8A-12-Rx410-EP

Slide 13

Fuel Size and Consumption

- Combustion occurs at fuel surface
- Smaller fuels = greater surface area per volume
- Smaller fuels consumption more dependent on current weather
- Larger fuels more dependent on climatic conditions

8A-13-Rx410-EP

Slide 14

Small Fuels

Small fuels are generally consumed during the flaming stage and burn out completely.

8A-14-Rx410-EP

Slide 15

Large Fuels

Flaming is sustained by smaller fuels and litter, which ignite the larger fuels

8A-15-Rx410-EP

Slide 16

Large Fuel Consumption

In l fuels with high percentage of rotten fuel, smoldering continues until log is completely consumed, or until weather conditions extinguish combustion.

In sound activity or recent blow down fuels, smoldering continues until quenched by internal fuel moisture content.

8A-16-Rx410-EP

Slide 17

Arrangement and Consumption

8A-17-Rx410-EP

Slide 18

Combustion Efficiency and Fuel Arrangement

Tightly packed
- ✓ excellent heat transfer
- ✓ poor oxygen availability

Loosely packed
- ✓ poor heat transfer
- ✓ excellent oxygen availability

Efficient fuel bed
- ✓ good heat transfer
- ✓ good oxygen availability

8A-18-Rx410-EP

Slide 19

Fuel Bed Continuity

Less continuity could result in less fuel consumption

8A-19-Rx410-EP

Slide 20

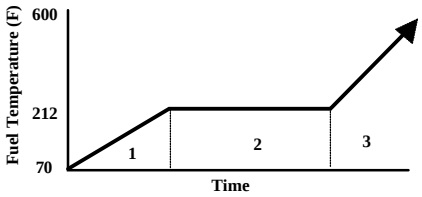
Fuel Moisture Content

- Often single most important variable
- Live and dead moisture
- Increased fuel moisture will generally decrease consumption

8A-20-Rx410-EP

Slide 21

Removing Water from Fuels

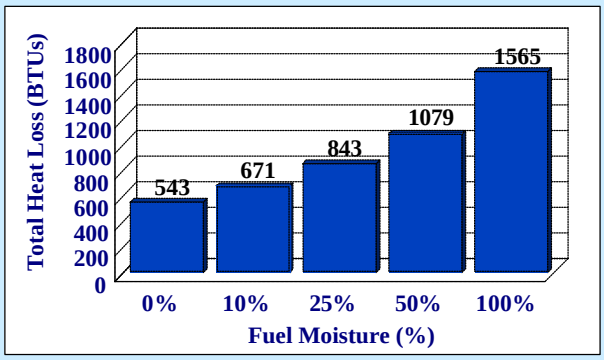


1. Energy raises temperature of liquid water and fuel.
2. Energy releases bound water and changes liquid water to vapor
3. Energy raises fuel temperature to ignition temperature

8A-21-Rx410-EP

Slide 22

Heat Loss During Combustion Varies with Fuels



8A-22-Rx410-EP

Slide 23

Combustion Phases and Fuel Consumption

- Consumption differs by combustion phase
- Most fuel consumption occurs during flaming and smoldering

8A-23-Rx410-EP

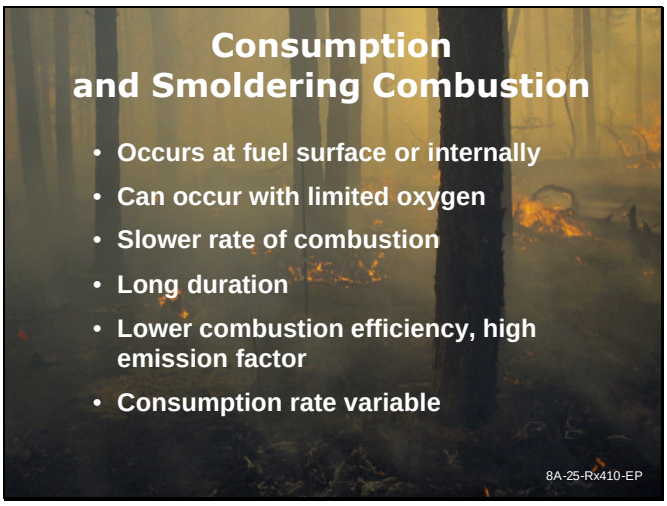
Slide 24

Consumption and Flaming Combustion

- Occurs at fuel surface
- Needs oxygen
- Rapid rate of combustion
- Short duration
- High combustion efficiency, low emission factor
- Consumption rate = 8 min/inch

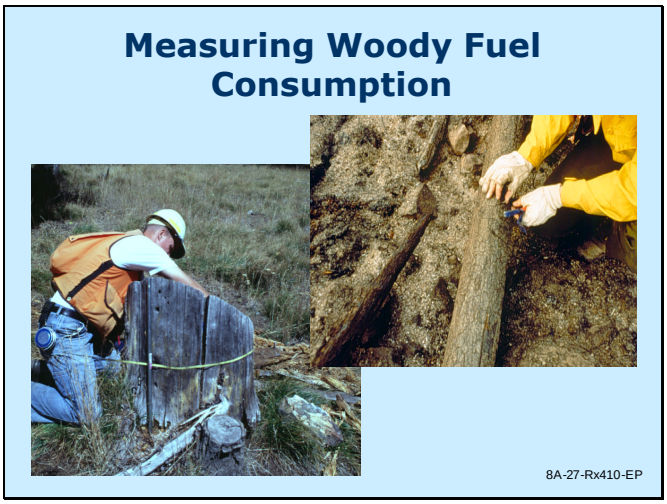
8A-24-Rx410-EP

Slide 25



Slide 26

Slide 27



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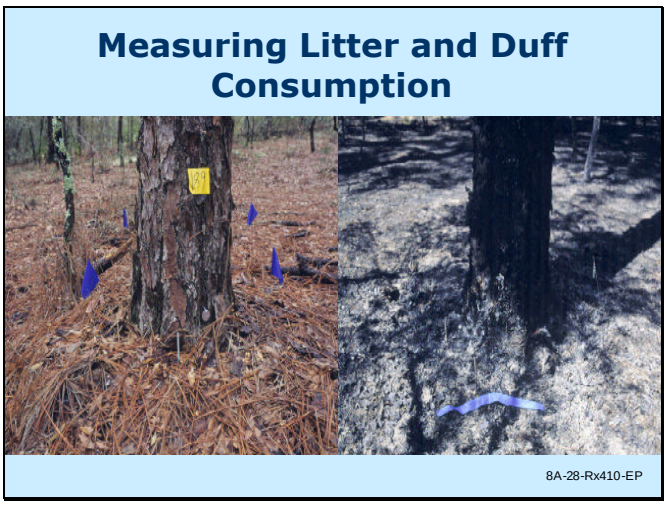
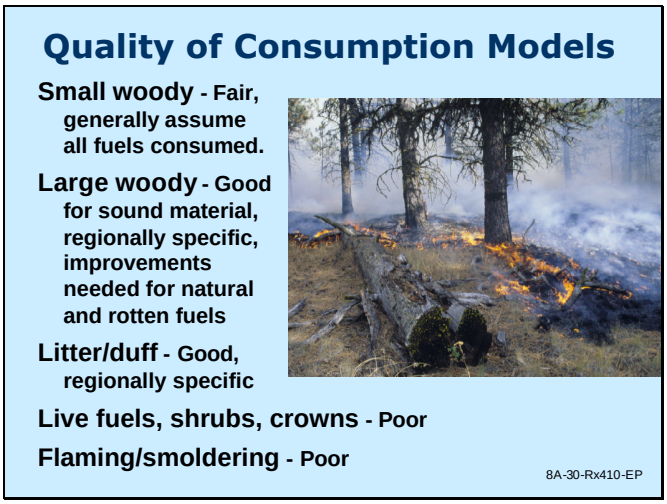


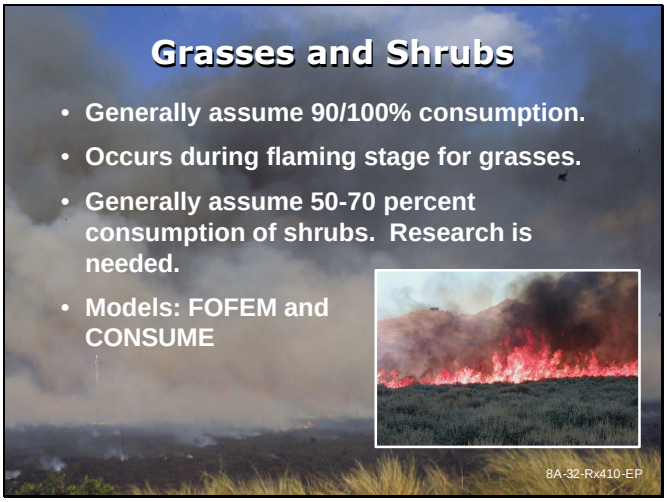
Slide 29

Slide 30

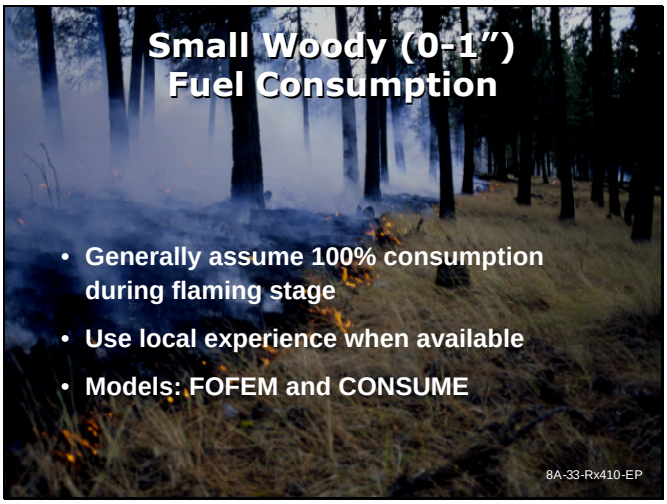


Slide 31

Slide 32



Slide 33



Slide 34

Small Woody (1-3”) Consumption Models

- Fuel moisture, 10-hr fuels and duff consumption key variables
- Assume consumption occurs during flaming
- Models: CONSUME/FOFEM

8A-34-Rx410-EP

Slide 35

Large Woody Fuel Consumption

- Key variables: Woody fuel moisture (sound/ activity fuels) and duff moisture content/ preburn loading (rotten/natural fuels)
- Output: diameter reduction, % consumption, or tons consumed
- Flaming/smoldering ratio based on small fuel consumption
- Models: CONSUME and FOFEM

8A-35-Rx410-EP

Slide 36

Sound Large Woody Fuels

(activity fuels or recent blow down)

Large woody fuel moisture key variable controlling fuel consumption

8A-36-Rx410-EP

Slide 37

Rotten Large Woody Fuels

Large, woody fuels that are rotten, duff moisture content is key variable controlling consumption

8A-37-Rx410-EP

Slide 38

Duff moisture determines if fire will carry to rotten log and maintain fire long enough to start log.

Once ignited with dry atmospheric conditions, the rotten log will consume regardless of moisture content.

8A-38-Rx410-EP

Slide 39

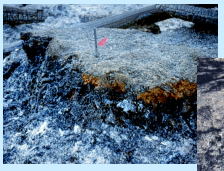
Litter and Duff Consumption

Activity Fuels

- Litter
  - Preburn litter depth
- Duff
  - Large fuel consumption
  - Days since rain
  - Preburn duff depth

Natural Fuels

- Litter
  - Preburn litter depth
- Duff
  - Prebun duff depth
  - Duff moisture content



Output

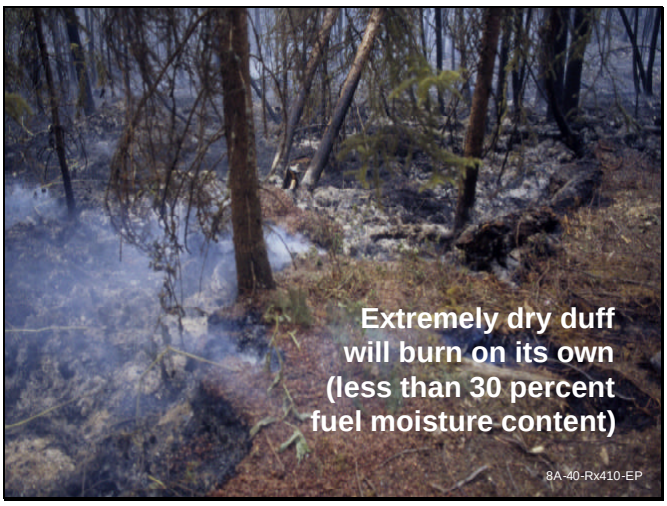
–Consumption (tons/acre)

–Reduction (inches)

–Models: Consume/FOEM

8A-39-Rx410-EP

Slide 40



Slide 41

Litter and Duff Densities

- Litter = 3 ton/acre/inch
- Black duff (formed from needle decay) = 12 tons/acre/inch
- Red duff (formed from wood decay) = 18.7 tons/acre/inch
- Moss/duff = 3 tons/acre/inch

8A-41-Rx410-EP

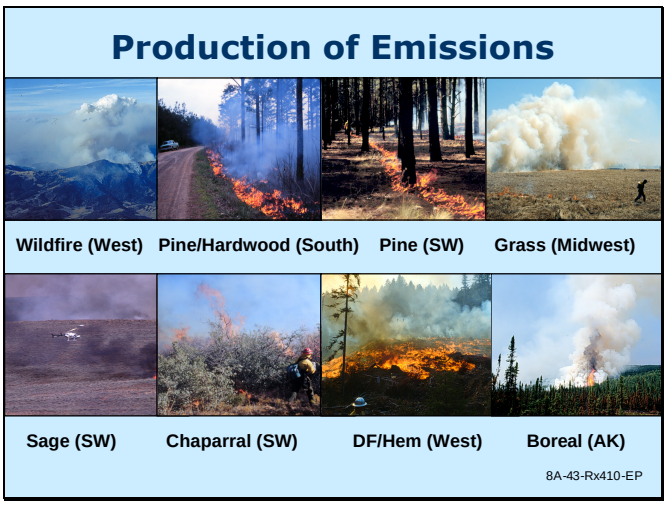
Slide 42

Measuring the Density of Litter and Duff

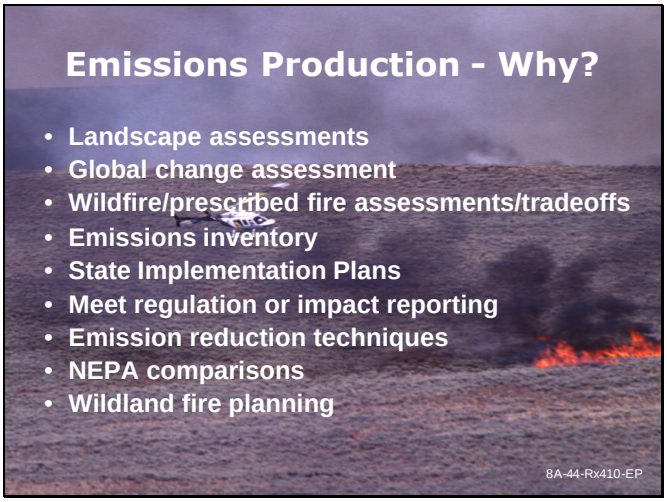
Representative litter and duff sample

8A-42-Rx410-EP

Slide 43



Slide 44



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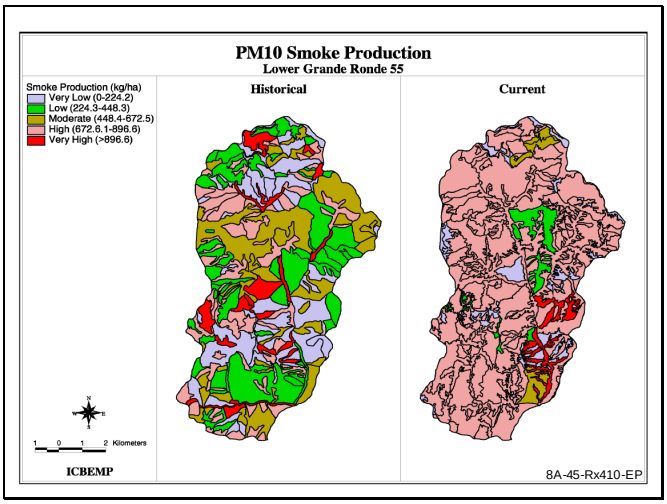

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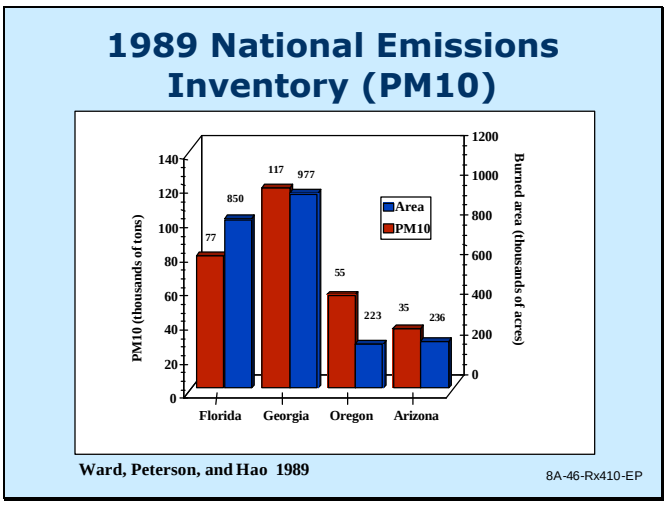

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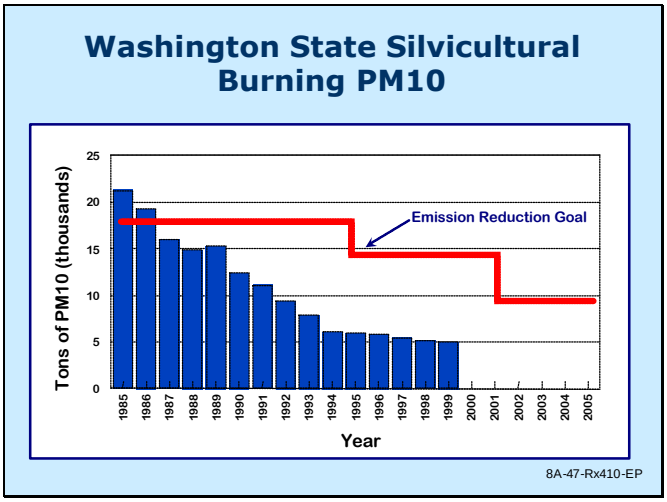

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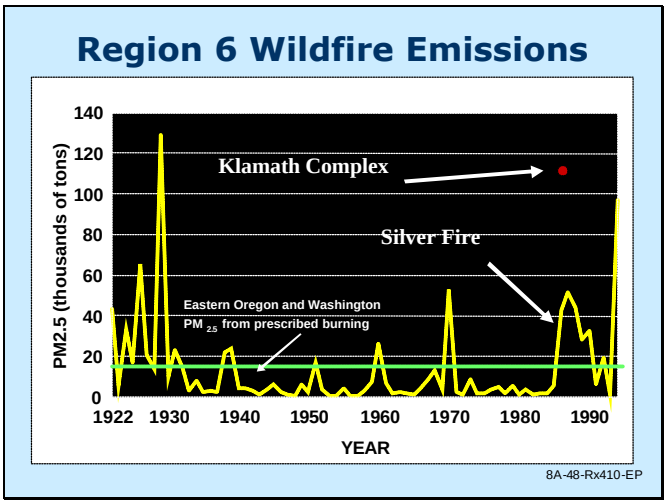

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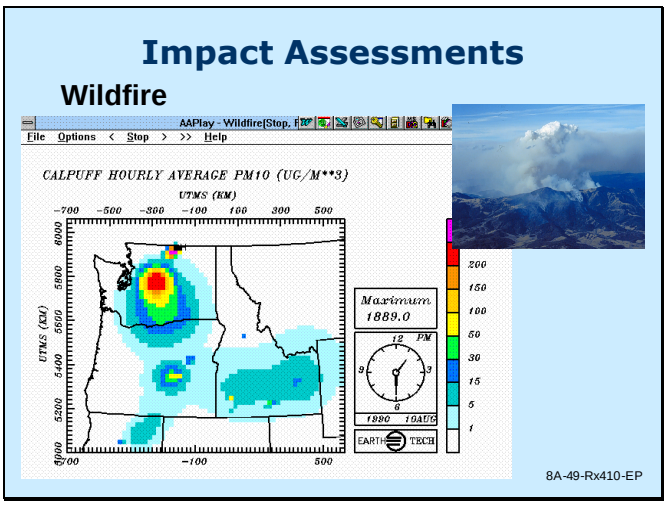

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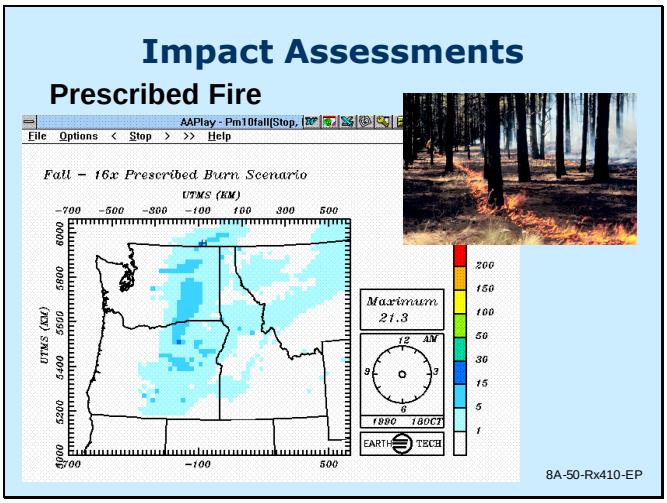

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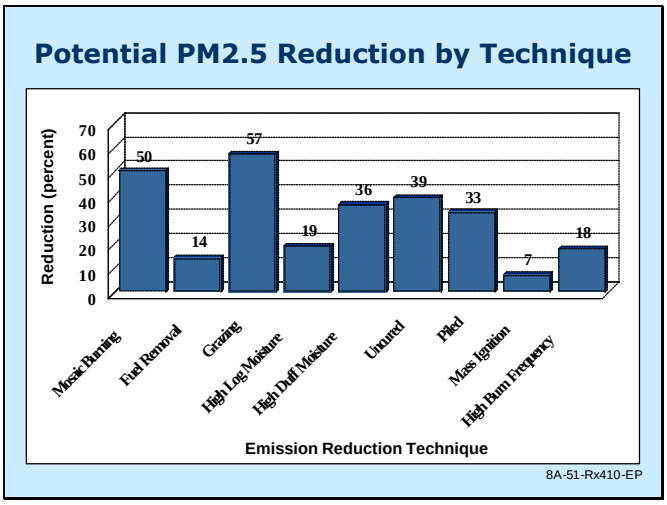

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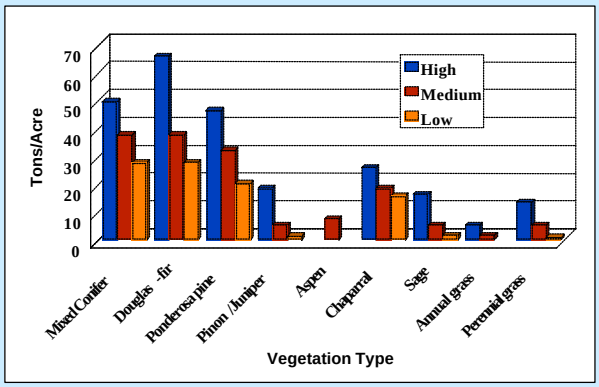
Variability of Fuel Loading



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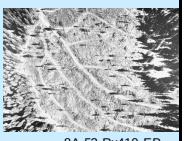
Fuels Data Collection

- **Measuring** (most accurate and time consuming)
  - **line intersect**
  - **clip/weighing**
  - **measuring/biometric equations**
- **Photo series** (good alternative to measuring)
- **Fuel Characteristic Class** (good, not ready)
- **Assign fuel model** (poor)
- **Remote sensing** (fair at this time)
- **Guess** (often used)



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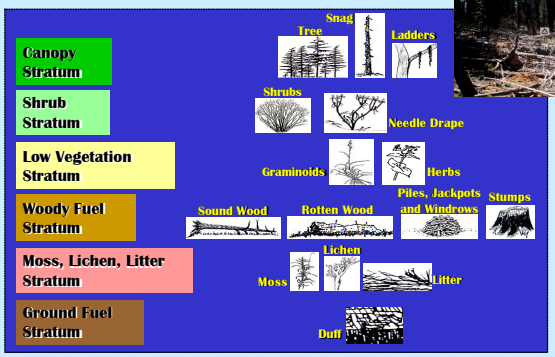
Include all fuelbed categories



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Emission Inventory Needs that May Justify Collection of Detailed Field Data

- Need to describe a localized risk of impact
- Ability to detect minor variations in emissions (+/- 15%)
- Need to verify progress toward emission reduction goals
- Burner motivation to reduce emissions without reducing acres

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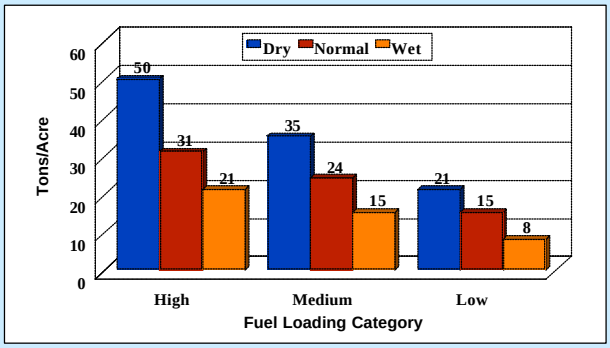
Variability of Fuel Consumption

for one vegetation type Douglas fir communities



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Fuel Consumption: Key to all Effects

- **Small fuels (grass/shrubs/crowns/fines):** Contribute to fire behavior and combustion efficiency/flaming
- **Large fuels:** Contribute to mass and smoke, often easily managed, flaming and smoldering
- **Forest floor:** Can contribute 50% of smoke and smoldering

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Fuel Consumption

- Measure (very difficult)
- Model (CONSUME, FOFEM, nomograms)
- Estimate percent

loading	% consumption	consumption
tons/acre X	percent =	tons/acre

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Emission Factor

Mass of pollutant produced per mass of fuel consumed

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Emission Factor Tables

- By species (Ward and Hardy)
- By combustion efficiency (Ward)
- AP 42 document (EPA)

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Emission Factors

Fuel Type/Fire Configuration	PM 10 (fire average) lbs/ton	PM 2.5 (fire average) lbs/ton
Douglas-fir/hemlock	23.1	21.8
Hardwoods	25.0	22.4
Ponderosa pine/lodgepole	25.0	22.0
Mixed conifer	20.5	18.8
Juniper	20.4	18.7
Piles	19.0	17.1
Sage	29.9	26.7
Chaparral	20.1	17.3
Grass	17.0	15.0
Wildfire	30.0	27.0

From Hardy, 05/29/96

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Emission Factors

Fuel Type/Fire Configuration	PM 2.5 (Flaming) lbs/ton	PM 2.5 (smoldering) lbs/ton
Douglas-fir/hemlock	14.9	26.1
Hardwoods	12.2	23.4
Ponderosa pine/lodgepole	10.0	34.2
Mixed conifer	9.6	23.6
Juniper	13.9	23.8
Piles	9.2	22.5
Sage	29.1 ?	26.4
Chaparral	13.5	21.6
Grass	10.0?	20.0?
Wildfire	15.0	35.0

From Hardy, 05/29/96

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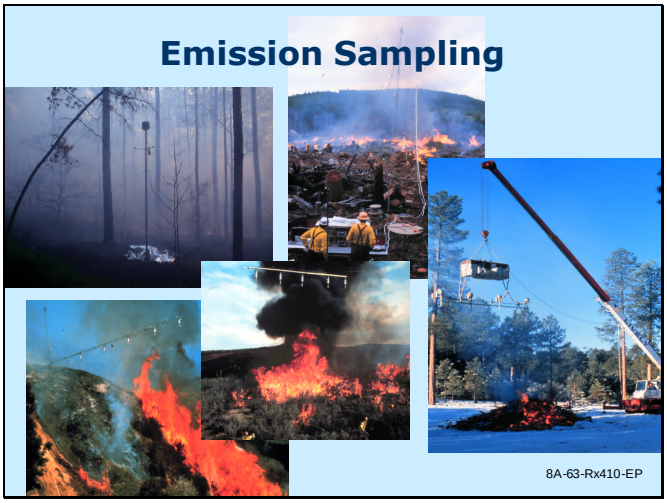
Emission Sampling



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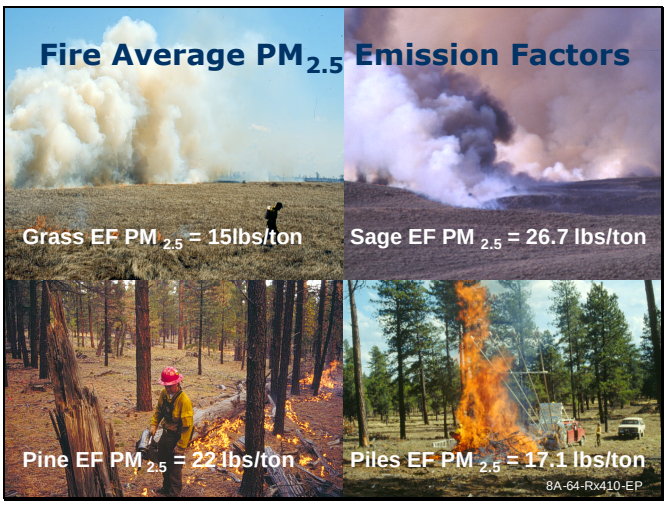

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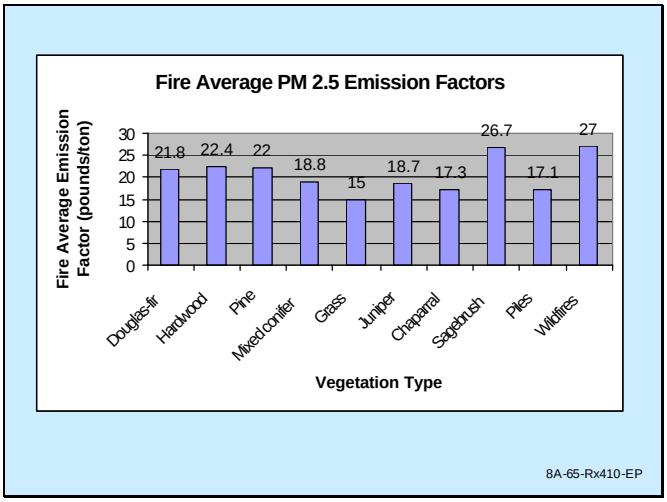

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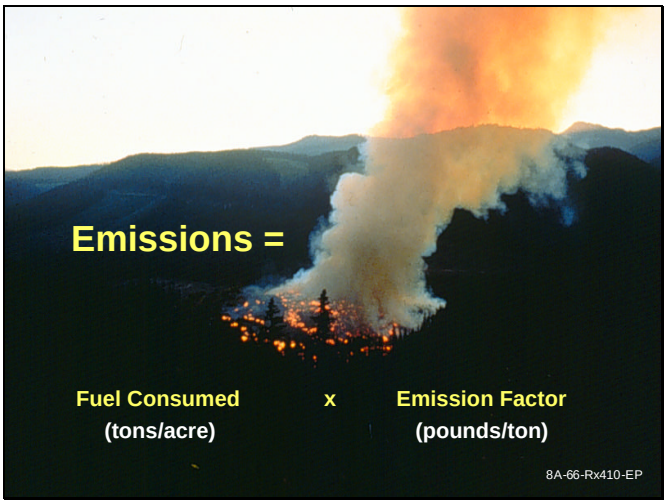

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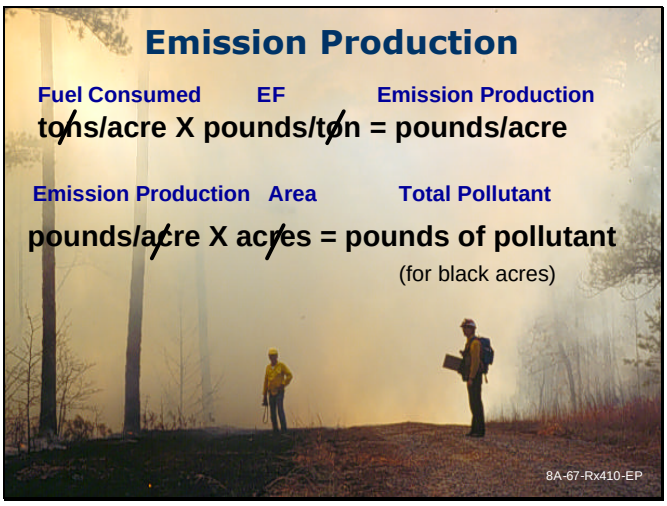

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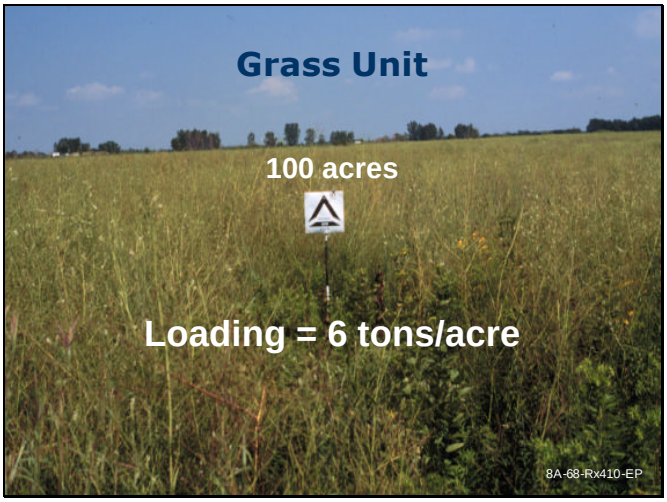

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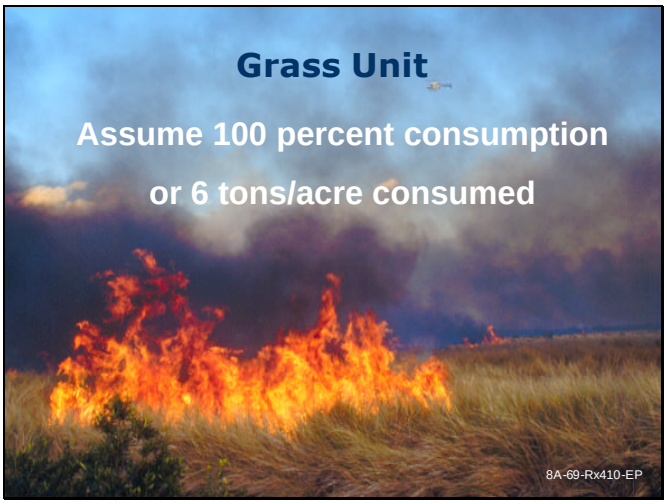

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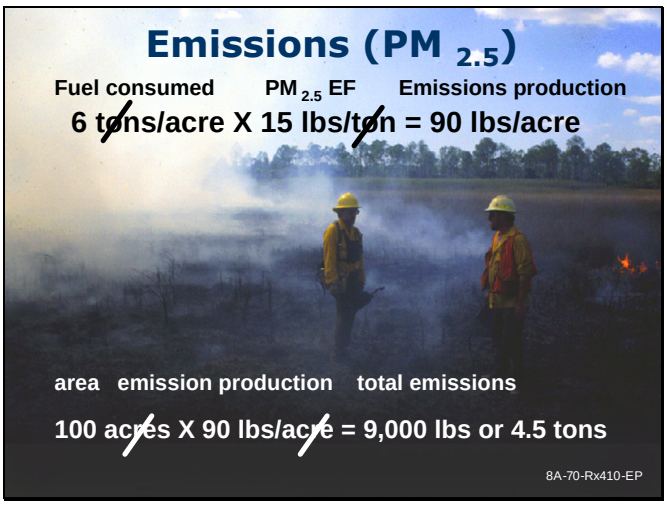

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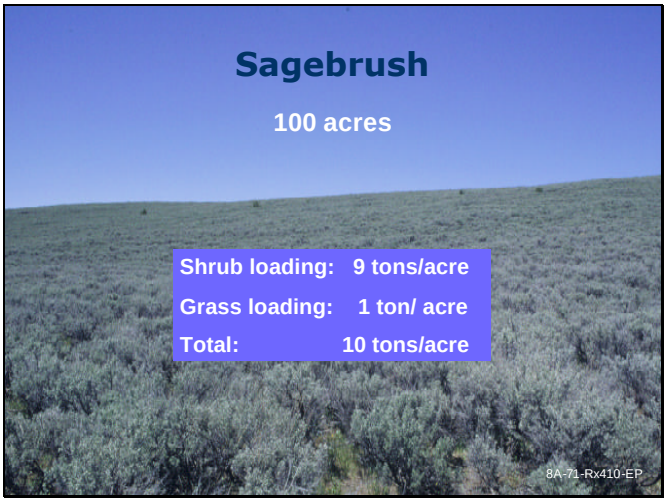

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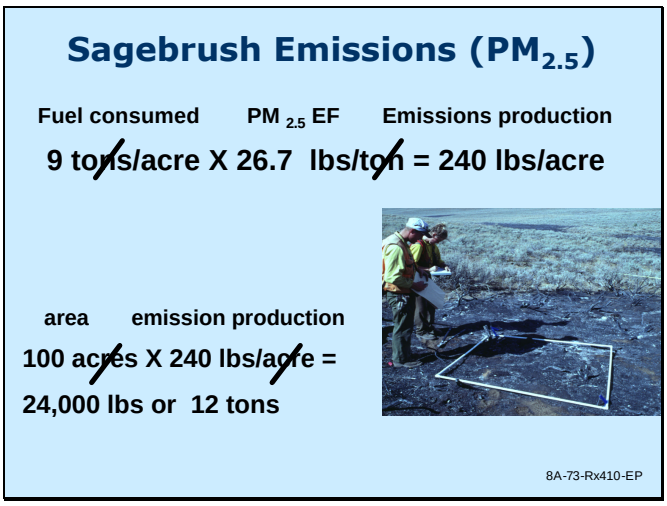

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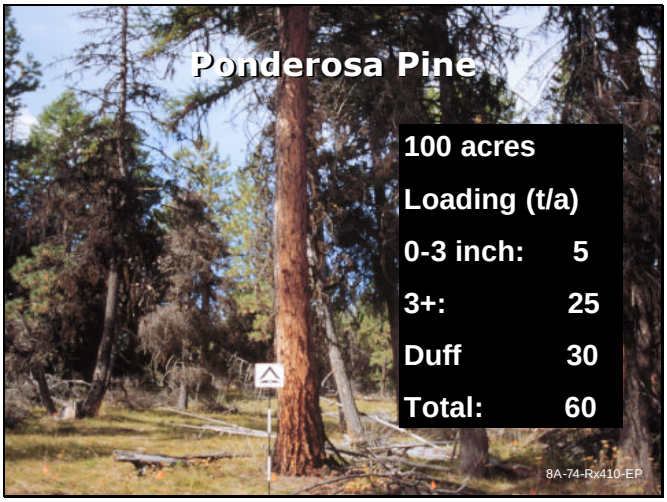

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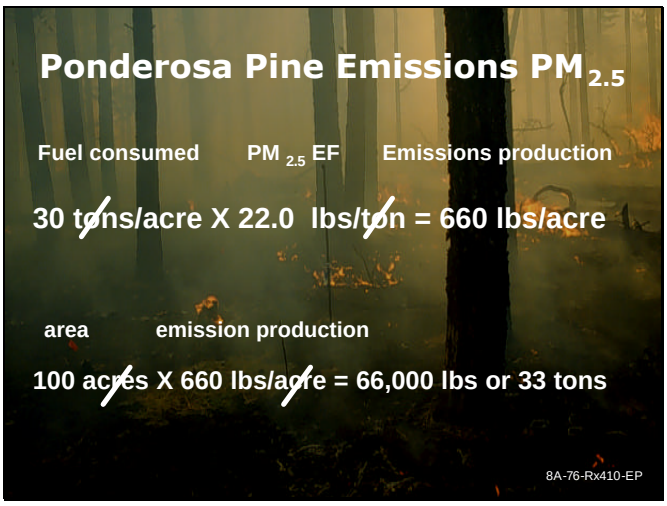

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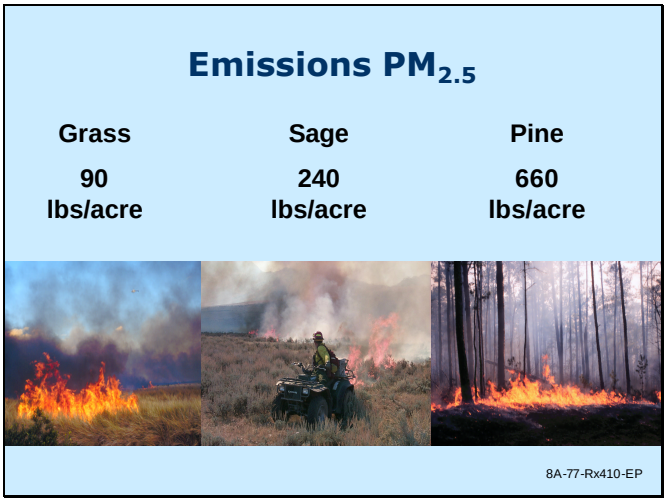

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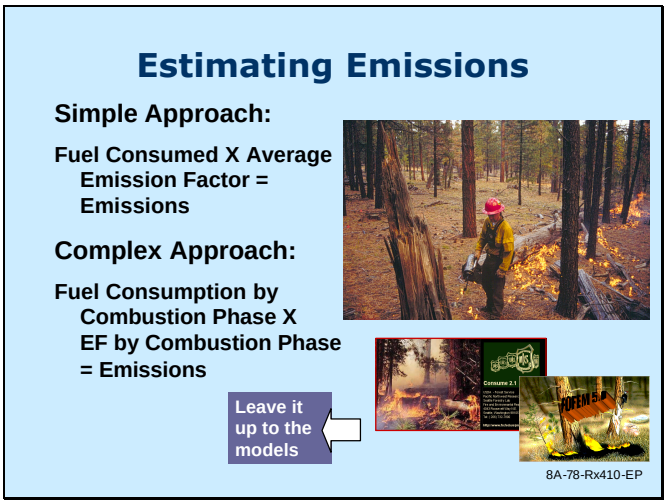

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Emission Rates

- **Amount of pollutant produced per unit of time (lbs/minute)**
- **Requires:**
  - fuel consumption
  - area burn rate
  - emission factor
- **Emission rate drives dispersion models that estimate concentration and impacts**

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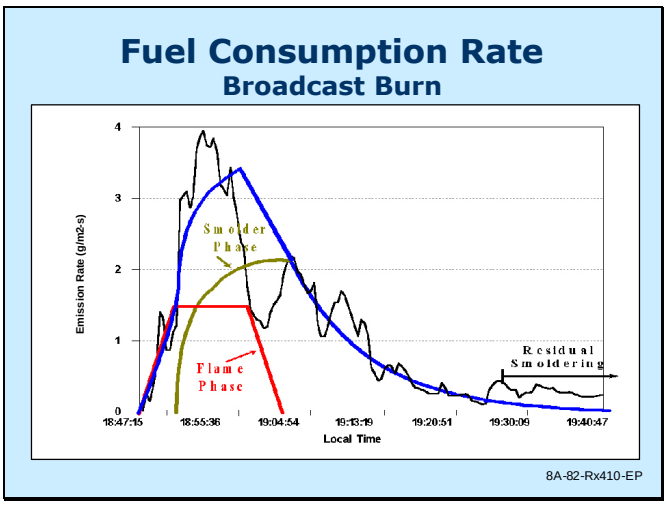

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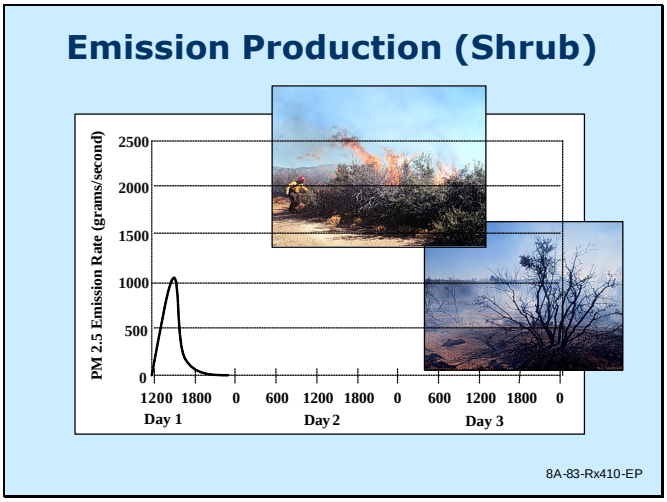

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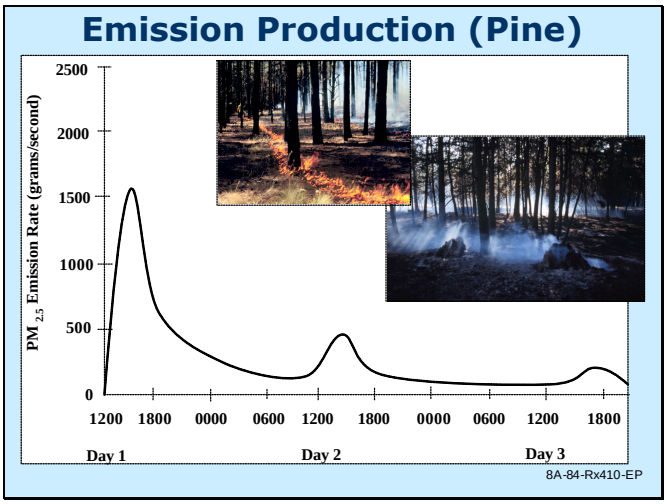

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Dispersion Models

- Estimate smoke plume transport
- Fuel consumption, emissions, meteorological, and receptor data needed
- SASEM (West), NFSPUFF (West)
- V-SMOKE (South), CALPUFF (national)
- Blue Sky

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Summary

- 4 phases of combustion
- Fuel Characteristics and consumption
- Fuel moisture and consumption
- Methods for estimating fuel loading and consumption
- Emission factors
- How to predict total emissions and rates
- Dispersion models

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Unit 8A Objectives

- Describe the four phases of combustion
- Describe how different fuel characteristics affect combustion
- Describe how fuel moisture affects consumption
- Describe methods of estimating fuel consumption
- List five reasons why we need to estimate emissions
- Define an emission factor
- Predict emissions from wildland fires

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TABLES

Table 5.1— Forest and rangeland emission factors ([1]Ward and others 1989; [2]Hardy and others 1996; [3]Hardy and Einfield 1992).

Fuel or Fire Configuration	Combustion Phase[a]	Emission Factors						
		PM	PM_{10}[b]	$PM_{2.5}$	CO	CO2	CH4	NMHC
		(Pounds emission per ton fuel consumed)						
BROADCAST BURNED SLASH[1]								
Douglas fir/	FLAMING	24.7	16.6	14.9	143	3385	4.6	4.2
hemlock	SMOLDERING	35.0	27.6	26.1	463	2804	15.2	8.4
(n=12)	FIRE AVERAGE	29.6	23.1	21.8	312	3082	11.0	7.2
Hardwoods	FLAMING	23.0	14.0	12.2	92	3389	4.4	5.2
(n=8)	SMOLDERING	38.0	25.9	23.4	366	2851	19.6	14.0
	FIRE-AVERAGE	37.4	25.0	22.4	256	3072	13.2	10.8
Ponderosa/	FLAMING	18.8	11.5	10.0	89	3401	3.0	3.6
l.pole pine	SMOLDERING	48.6	36.7	34.2	285	2971	14.6	9.6
(n=3)	FIRE AVERAGE	39.6	25.0	22.0	178	3202	8.2	6.4
Mixed conifer	FLAMING	22.0	11.7	9.6	53	3458	3.0	3.2
(n=3)	SMOLDERING	33.6	25.3	23.6	273	3023	17.6	13.2
	FIRE AVERAGE	29.0	20.5	18.8	201	3165	12.8	9.8
Juniper	FLAMING	21.9	15.3	13.9	82	3401	3.9	5.5
(n=6)	SMOLDERING	35.1	25.8	23.8	250	3050	20.5	15.5
	FIRE AVERAGE	28.3	20.4	18.7	163	3231	12.0	10.4
PILE-AND BURN SLASH[1]								
Tractor-piled	FLAMING	11.4	7.4	6.6	44	3492	2.4	2.2
(n=4)	SMOLDERING	25.0	15.9	14.0	232	3124	17.8	12.2
	FIRE AVERAGE	20.4	12.4	10.8	153	3271	11.4	8.0
Crane-piled	FLAMING	22.6	13.6	11.8	101	3349	9.4	8.2
(n=4)	SMOLDERING	44.2	33.2	31.0	232	3022	30.0	20.2
	FIRE AVERAGE	36.4	25.6	23.4	185	3143	21.7	15.2
"Average" Piles	FIRE AVERAGE	28.4	19.0	17.1	169	3207	16.6	11.6
	BROADCAST-BURNED BRUSH[2]							
Sagebrush	FLAMING	45.0	31.8	29.1	155	3197	7.4	6.8
(n=4)	SMOLDERING	45.3	29.6	26 4	212	3118	12.4	14.5
	FIRE-AVERAGE	45.3	29.9	26.7	206	3126	11.9	13.7
Chaparral	FLAMING	31.6	16.5	13.5	119	3326	3.4	17.2
(n=9)	SMOLDERING	40.0	24.7	21.6	197	3144	9.0	30.6
	FIRE AVERAGE	34.1	20.1	17.3	154	3257	5.7	19.6
WILDFIRES FIRES (IN FORESTS)[3]								
	Fire-average		30.0	27.0				

[a]Fire Average values are weighted-averages based on measured carbon flux.

[b]PM_{10} values are calculated, not measured, and are derived from known size-class distributions of particulates using PM and $PM_{2.5}$.

Smoke Management Techniques, Rx-410

Unit 9 - Smoke Emissions and Dispersion Modeling

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Identify common smoke emissions and dispersion modeling systems available to help the fire practitioner plan for and communicate the impacts of smoke.

2. Describe the difference between emission production and dispersion models.

3. Describe the data and expertise needed to run emissions and dispersion models.

4. Identify which models are most appropriate for your area and application.

I. SCENARIOS

A. You're a district fire management officer in Arizona in charge of conducting a burn next week. The county commissioners want to be assured that smoke will not impact their local festival. What do you do?

B. You're preparing a NEPA document for a burn close to a PM non-attainment area and a Class I area in the Southeast. You need to describe how smoke will impact these areas. What do you do?

C. You're the line officer determining whether or not to let a wildland fire use fire occur in Idaho. Smoke is a big concern. How do you talk to the press about potential smoke impacts?

D. You're an air quality regulator wanting to assess the effects of smoke on regional haze in the state. What do you do?

E. At the end of this lesson, you should be able to describe the tools and techniques available to you to answer the above questions.

II. DEFINITION OF SMOKE EMISSIONS AND/ OR DISPERSION MODELING

A well defined system for communicating the impact of smoke on ambient air quality (which can include visibility). Impacts can be communicated as:

- Mass (e.g., tons of particulate)
- Relative Index (e.g., ventilation)
- Concentrations (e.g., micrograms/cubic meter ¼ g/m3)

III. TYPES OF MODELS

Models can be categorized in many different ways (by outputs, complexity, application, hardware, etc.). Remember not all models are computer models. For this course, they are sorted into:

- Emissions Production Models
  - Mass (e.g., tons of particulate)
- Simple Approximation Systems
  - A relative index (e.g., ventilation)
- Dispersion Models
  - Concentrations (e.g., micrograms/cubic meter ¼ g/m3)

A. Emissions Production Models

Emissions production models (such as FOFEM or CONSUME presented in Unit 5) estimate emissions (usually in tons per year of pollutant or tons per year by project). Emissions models do NOT estimate where those emissions go or what will be their concentrations (e.g., impact) when they get there. **Therefore, one cannot compare emissions to any ambient air quality standard.**

So why estimate just emissions?

1. Can easily compare magnitude (e.g., tons per year) between actions, alternatives, years, types of fire etc.

2. Is a relative gauge for impacts to the atmosphere.

3. Some states may require it for permitting or regional haze planning

B. Simple Approximation Systems (for **approximating** the capacity of the atmosphere to handle smoke). These systems indicate the potential smoke impact at a site or across an area based on weather or topography. **They do not estimate emissions or predict concentrations**.

- Ventilation Indices
- Atmospheric Dispersion Index
- Geometric "Screening"

Why use an approximation system?

- Simple method to map the aerial extent of a smoke plume

- Simple method to assess potential impact to sensitive receptors

- As a first assessment (screen) to discern potential problems

1. Ventilation Indices

   a. A ventilation index is a product of the mixing height times the average wind within the mixed layer.

      - Different parts of the country use different ventilation indices.

      - Table 9.1 from the Smoke Management Guide compares common values of ventilation indices and associated smoke conditions.

   b. Dr. Sue Ferguson of the PNW Station developed an interactive database which displays patterns of ventilation across the country for morning and afternoon.

      - Ventilation is depicted in four categories from "poor" to "good."

- Index uses:
  - 30 years of data (1961 – 1990)
  - Averaged twice daily (7 a.m. and 7 p.m.)
  - On a 5 km grid (2.5 degrees latitude-longitude).

c. But there are caveats to using ventilation indices:

- Can not calculate a ventilation index when there is no mixing height (such as at night)
- The Ventilation Index calculated during very stable conditions may be too optimistic
  - Addressing these caveats led to development of **Atmospheric Dispersion Index (ADI).**

2. Atmospheric Dispersion Index (ADI)

a. Tool to help determine atmosphere's capacity to disperse smoke during all atmospheric conditions.

b. Combines Pasquill's stability class and ventilation indexes with a simple dispersion model.

c. Scale is typically interpreted as:

- 0 – 20: poor dispersion
- 21 – 100: fair to good dispersion
- >100: excellent dispersion

3. Geometric screening

a. Direction of smoke plume is estimated by considering size of fire and assuming 30 degrees of dispersion on either side of centerline trajectory if wind direction is planned or measured

b. Use 45 degrees if variable winds are forecasted. Then burners:

- Plot plume
- Identify smoke sensitive areas
- Identify existing air quality problems
- Estimate emissions
- Minimize risk

Do Emissions Production Models or Approximation Systems allow a user to compare the outputs directly to ambient air quality standards? NO. When that need is present the burner will need to use a numerical model which gives more refined, specific results.

C. Dispersion models estimate smoke and gas concentrations. Typically, you CAN compare their outputs to ambient air quality standards and sometimes visibility.

1. So why estimate concentrations?

a. Can be used to communicate potential impacts to health and visibility

b. May be required to obtain an air quality permit.

2. Modeling Terms

a. Source: Point of origin of emissions. Can be a single emission unit (e.g., a slash pile) or a combination of emission units (e.g., a burn unit)

b. Receptor - The theoretical point on a map at which pollutant concentrations are predicted to occur. Can be a distinct location defined by the user or a model-generated grid.

c. Simple Terrain: Flat or rolling

d. Complex Terrain: Hilly or mountainous

3. Types of Dispersion Models

a. Plume Models

b. Puff Model

c. Particle Model

d. Grid Model

Model inputs, outputs mechanics, and applications are different. Need to know what your application is and what degree of accuracy you need in order to select the most appropriate model.

4. Definition of Dispersion

The vertical and crosswind spread of a plume, measured over sufficiently long period of time, with increasing distance downwind of a source. “Dispersion” = “diffusion”

5. Description of Dispersion Model Types

a. Plume

(1) Definition of a Plume - A continuous stream of emissions from a source

(2) Description of Plume Model

(a) Assumes smoke travels in a straight line under steady state conditions (speed and direction of particles do not change during the model simulation period)

(b) Commonly used with flat or rolling terrain

(c) Examples: SASEM, VSMOKE-GIS, VSMOKE

b. Puff

(1) Definition- discrete volume (blob) of air representing a nearly instantaneous emission from a source. A series of "puffs" can be modeled to simulate a continuous plume.

Difference between a plume and a puff is that puffs can more accurately reflect changes in terrain or weather since they behave more independently within the plume.

(2) Description of Puff Model - this method simulates continuous plume by rapidly generating a series of puffs

(a) Puff models are used where trajectory winds may change or where underlying terrain controls smoke trajectory patterns

(b) Meteorological inputs are substantial

(c) NFSpuff, Calpuff are examples of puff models

(d) NFSpuff

Used in Western U.S. with complex terrain

Graphic outputs are time series of heat release and particulate emissions; Puff simulation with emission concentrations (1- hr and 24-hr); Plots of weather data and topography

(e) Calpuff

Can be used across U.S.

Outputs include 1-hr averages of emissions and relative humidity

c. Particle

(1) Definition – each individual particle is tracked

(2) Description – simulates many particles released over the burn duration

(a) Atmospheric turbulence is considered by model

(b) Most accurate

(c) Examples: HySplit, PB-Piedmont. These are typically research or regulatory models.

d. Grid

(1) Definition - acts as a confined box (are like expanded box models).

(2) Description

(a) With grid models it is difficult to track individual plumes but extremely useful to look at cumulative impacts (e.g., regional haze)

(b) Range from simple (example Valbox) to complex (example REMSAD).

(3) Box Model – is like a simplified grid model used for a smaller geographic area (e.g., a valley)

(a) assume smoke fills box (e.g., a valley) instantaneously and concentrations vary over time

(b) No trajectory estimates

(c) Usually restricted to applications with low wind speeds and strong temperature inversions.

(d) VALBox is an example of a Box Model

IV. MODEL APPLICATIONS

No model does everything but different models are more appropriate for different applications.

A Plume models are most appropriate for:

- Relatively flat terrain
- When input data (such as weather, terrain, site information) are scarce
- Evaluating concentrations “near” a source (i.e., < 50 km)

B. Puff Models are most appropriate for:

- Complex terrain
- Variable weather (e.g., such as found in complex terrain or over a 24-hr period)
- Long-range transport

C. Particle Models are most appropriate for:

- Tracking pollution signatures

D. Grid Models are most appropriate for:

- Using across relatively large areas
- Modeling many sources at one time
- Modeling impacts to regional haze or ozone

V. COMPARING MODEL COMPLEXITY AND TYPICAL USERS

A. Just as situations range from simple to complex, so do models.

B. Model complexity is typically defined by the amount of input data it requires and its outputs. More complex models require greater skill level from the user to input the data and interpret results.

C. Simple (screening) models can typically meet the needs of local project managers.

D. More rigorous models are required to meet needs often related to cumulative impacts across a broad area from many sources which a regulator or research scientist may need to address.

E. The table ranks the models by their complexity and who might use them for what purpose. The table is not a definitive ranking i.e., any one model could slide a place or two up or down the scale.

VI. MODEL DEMONSTRATION (ONE FROM EACH CATEGORY I.E., EMISSIONS PRODUCTION, SIMPLE APPROXIMATION SYSTEMS, DISPERSION)

VII. SCENARIOS REVISITED

Based on the information presented in this unit, students should have more tools to address the scenarios.

A. You're a district fire management officer in Arizona in charge of conducting a burn next week. The county commissioners want to be assured that smoke will not impact their local festival. What do you do?

An answer: Use SASEM or NFSpuff to demonstrate distance, direction, and magnitude (e.g., air quality concentrations) of any potential smoke impacts.

B. You're preparing a NEPA document for a burn close to a PM non-attainment area and a Class I area in the Southeast. You need to describe how smoke will impact these areas. What do you do?

An answer: Use VSMOKE or VSMOKE-GIS to compare against ambient air quality standards and to judge impacts to Class I areas (e.g., distance, direction, and durations of plume)

An answer: Use geometric screening to discuss direction and spread of potential plume.

C. You're the line officer determining whether or not to let a wildland fire use fire occur in Idaho. Smoke is a big concern. How do you talk to the press about potential smoke impacts?

An answer: Use NFSpuff to demonstrate distance, direction and magnitude (e.g., air quality concentrations) of potential smoke impacts.

D. You're an air quality regulator wanting to assess the effects of smoke on regional haze in the state. What do you do?

Use Calpuff or REMSAD to assess effects to regional haze. These models are complex enough that they are within the purview of professional modelers.

VIII. SUMMARY

A. Models are a well defined system for communicating the impact of smoke on ambient air quality (which can include visibility) by:

- Quantifying total emissions
  - NEPA alternative comparisons
  - Regional haze planning
- Describing pattern of impact
  - Through approximations or refined modeling

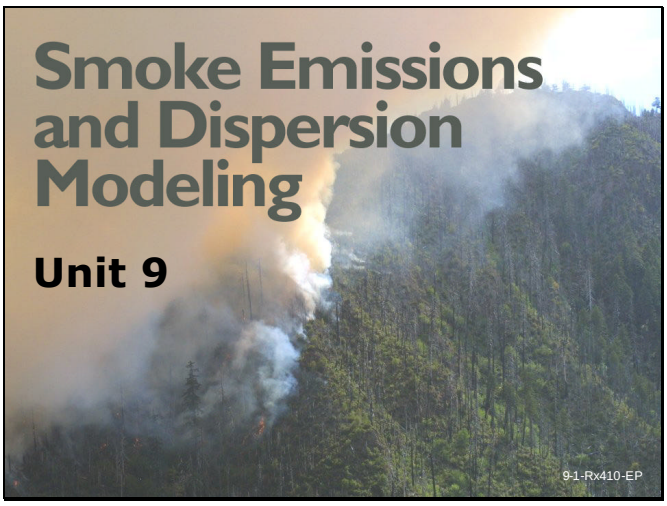
- Assessing impact to receptors
  - Highways, hospitals, airports, Class I
- Comparing to regulatory standards
  - Especially health standards for PM10, PM2.5
  - Regulatory agencies may require modeling

B. For many projects, a simple model often provides as good information as a more refined, or complex model. However, it may not get you through the permit process or meet information/communication needs.

C. Variability between states, tribes, and projects means there is no "blanket" recommendation on which prediction system to use for which application. Talk to your air quality regulators, air quality specialists and see the information in the tables to help assess what is the most appropriate method.

D. For example, if a simple indication of visibility impacts is required, plume models can be used or visual indexes can be approximated from concentrations out of box, plume, or puff models. If more detailed visibility impacts are required, a sophisticated puff model should be used.

Slide 1



Slide 2

Unit 9 Objectives

- Identify common smoke emissions and dispersion modeling systems available to help the fire practitioner plan for and communicate the impacts of smoke.
- Describe the difference between emission production and dispersion models.
- Describe the data and expertise needed to run emissions and dispersion models.
- Identify which models are most appropriate for your area and application.

9-2-Rx410-EP

Slide 3

What to do?

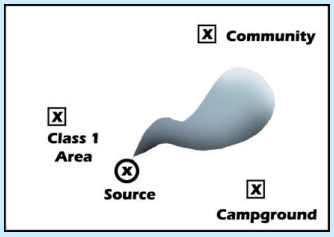
You're a District FMO in Arizona in charge of conducting a burn next week. County commissioners want to know how it will affect the local hot air balloon festival. What do you tell them?

9-3-Rx410-EP

Slide 4

What to do?

You're preparing a NEPA document for a burn close to a PM-non-attainment area and Class I area in the Southeast. You need to describe how smoke will impact these areas. What do you do?



9-4-Rx410-EP

Slide 5

What to do?

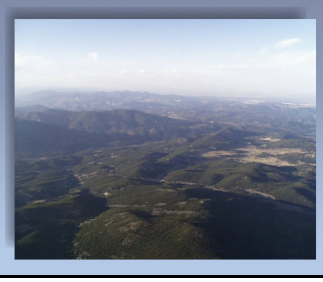
You're a line officer in Idaho deciding about a wildland fire use incident and how smoke may affect the local community. What do you tell the press about potential impacts?

9-5-Rx410-EP

Slide 6

What to do?

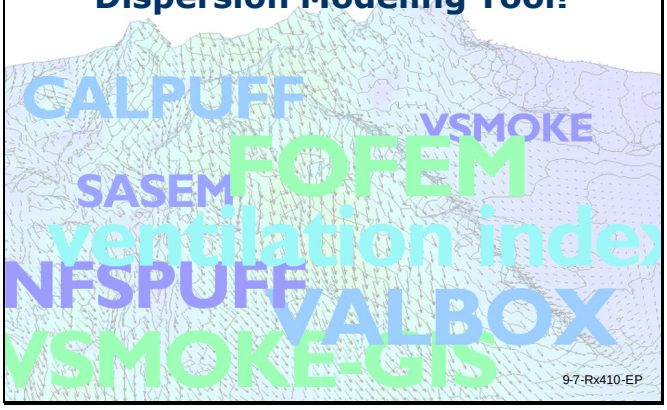
You're an air regulator wanting to assess the effects of smoke on regional haze in the state. What do you do?



9-6-Rx410-EP

Slide 7

Use a Smoke Emissions or Dispersion Modeling Tool!



9-7-Rx410-EP

Slide 8

What is smoke emission and/ or dispersion modeling?

A well defined system for *communicating* the impact of smoke on ambient air quality (which can include visibility).

Outputs can be:

- **Mass (e.g., tons of particulate);**
- **A relative index (e.g., ventilation)**
- **Concentration (e.g., micrograms/cubic meter)**

9-8-Rx410-EP

Slide 9

Types of Models

- **Emissions Production**
  - **Mass (e.g., tons of particulate);**
- **Simple Approximation Systems**
  - **A relative index (e.g., ventilation);**
- **Dispersion**
  - **Concentration (e.g., micrograms/cubic meter ug/m^3)**

9-9-Rx410-EP

Slide 10

What is Emissions Production Modeling?

- Predicts total amount (e.g., tons or pounds) of pollutants (e.g., PM-10 or PM-2.5) produced from a burn.
- Does not predict *where* emissions will disperse!

9-10-Rx410-EP

Slide 11

Simple Approximation Systems

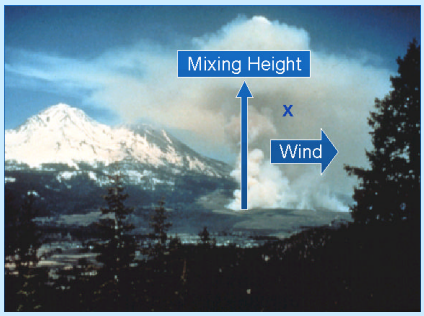
- Ventilation Indices
- Atmospheric Dispersion Index
- Geometric "Screening"

9-11-Rx410-EP

Slide 12

Ventilation Index

The product of a mixing height times the average wind speed through the mixing layer



9-12-Rx410-EP

Slide 13

Common values of ventilation indices and associated smoke conditions

VI (knot-ft) MH X traj *	VI (knot-ft)/100 MH x Avg **	VI (m2/sec) PBL x 40 m ***	Smoke Condition
0-28999	<200	< 2350	Poor
29,000 – 37,999	200 – 400	2,350 – 4,700	Marginal
38,000 – 49,999	400 – 500	4,700 – 7,050	Fair
50,000 – 94,999	> 500	> 7,050	Good
> 95,000			Excellent

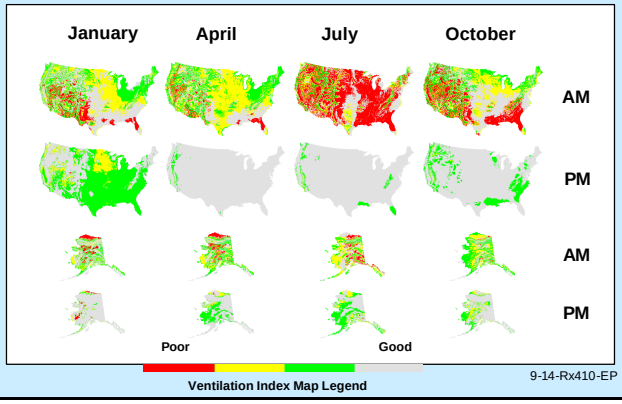
From Smoke Management Guide, Table 9.1
* Commonly used in the NW?
** Commonly used in Utah
*** Commonly used in South Carolina

VI = Ventilation Index
MH = Mixing Height
PBL = Planetary Boundary Layer

9-13-Rx410-EP

Slide 14

Ventilation Index Patterns Based on 30 Years of Data



9-14-Rx410-EP

Slide 15

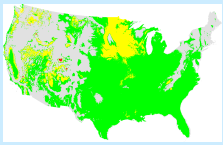
Ventilation Index Using High-Resolution Spatial Climate Data

- Surface wind
- Mixing height

x

= Ventilation index

- 2.5' latitude-longitude
- Twice daily (7 am and 7 pm EST)
- 30 years (1961-1990)



Dr. Sue Ferguson
PNW Research Station

9-15-Rx410-EP

Slide 16

Atmospheric Dispersion Index (ADI)
(Generally Used in the Southeast)

ADI	Interpretation
1-6	Very poor dispersion
7-12	Poor dispersion
13-20	Generally poor dispersion
21-40	Fair dispersion
41-60	Generally good dispersion
61-100	Good dispersion
>100	Very good dispersion

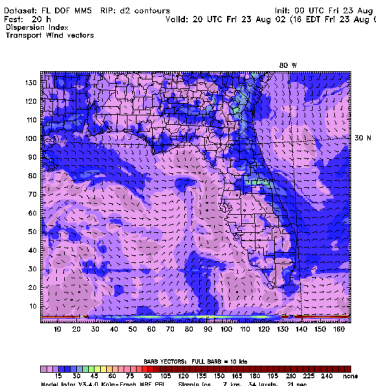
Generally burning not allowed

Table 9.2 from Smoke Guide

9-16-Rx410-EP

Slide 17

Atmospheric Dispersion Index

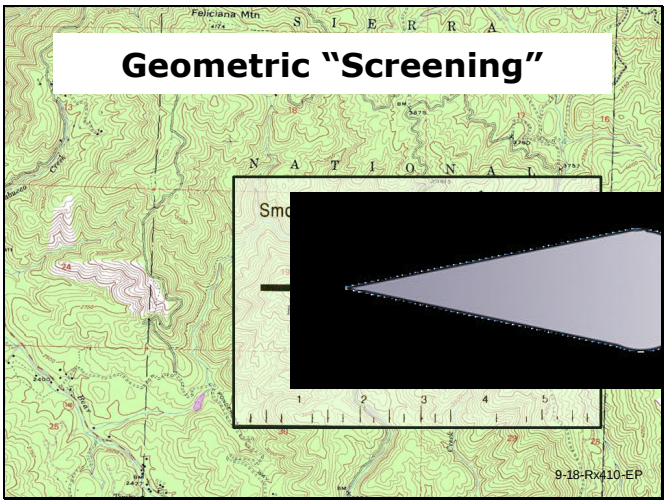


Generally excellent dispersion > 100

Generally poor dispersion < 20

9-17-Rx410-EP

Slide 18



9-18-Rx410-EP

Slide 19

Some Modeling Terms

- Source
- Receptor
- Simple Terrain
- Complex Terrain

9-19-Rx410-EP

Slide 20

Source

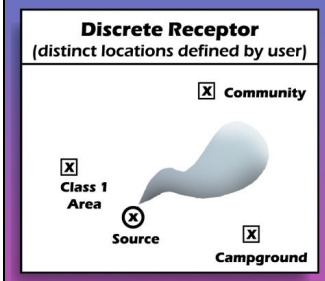
- Point of origin of emissions. Can be a single emission unit (e.g., a slash pile) or a combination of emission units (e.g., a burn unit)

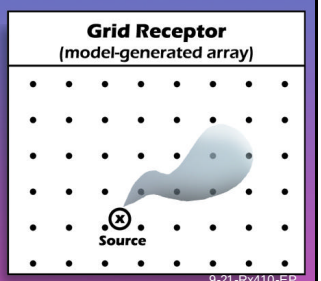
9-20-Rx410-EP

Slide 21

Receptor

- The point(s) where we think the smoke will go.
- Can be a geographic location (e.g., Class I area or community) or displayed as a grid.





9-21-Rx410-EP

Slide 22

Terrain

- Complex: Hilly or mountainous
- Simple: Flat or rolling

9-22-Rx410-EP

Slide 23

Dispersion Models

- Plume Models
- Puff Models
- Particle Models
- Grid Models

9-23-Rx410-EP

Slide 24

Dispersion

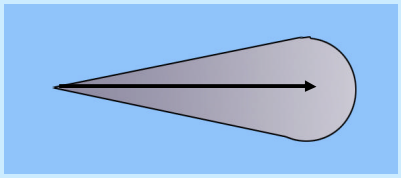
- The vertical and crosswind spread of a plume, measured over sufficiently long period of time, with increasing distance downwind of a source
- “Dispersion” = “diffusion”

9-24-Rx410-EP

Slide 25

Plume

- **A continuous stream of emissions from a source**



9-25-Rx410-EP

Slide 26

Plume Models

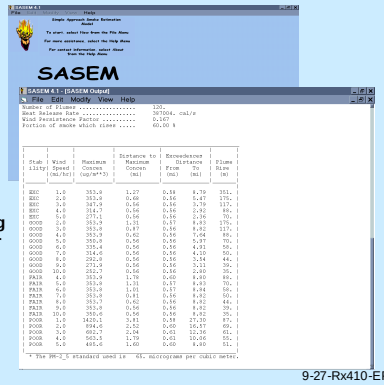
- **Assumes smoke travels in a straight line under steady state conditions (speed and direction of particles do not change during the model simulation period)**
- **Commonly used with flat or rolling terrain**
- **Examples: SASEM, VSMOKE, and VSMOKE-GIS**

9-26-Rx410-EP

Slide 27

Plume Models

- **Simple Approach Smoke Estimation Model (SASEM)**
  - **A simple screening model with tabular outputs of downwind concentrations**



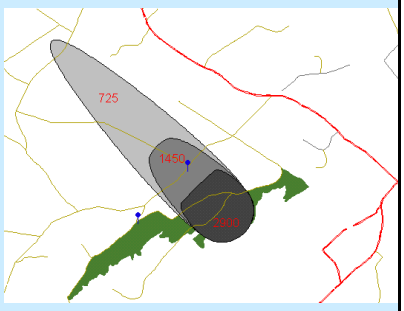
9-27-Rx410-EP

Slide 28

Plume Model

VSMOKE-GIS:

A simple screening model to show predicted downwind concentrations of particulate matter in graphic form.



9-28-Rx410-EP

Slide 29

Plume Model

- **VSMOKE – Displays in a table particulate matter, carbon monoxide, and visibility estimates at 31 logarithmically spaced distances (0.06 - 62 miles).**

Downwind Distance from Fire (miles)	Plume Height / Depth (feet)	Horizontal Dispersion Coefficient (feet)	Vertical Dispersion Coefficient (feet)	Particulate Matter (ug/m3)	Carbon monoxide (ppm)	Crossplume Visibility (miles)	Contrast Ratio (miles)
0.06	861.60	76.24	49.07	6,615.5120	48.1264	0.1102	0.0001
0.08	1,004.55	90.71	57.21	5,679.8860	42.7914	0.1203	0.0005
0.10	1,171.22	108.59	67.40	4,836.4350	37.8109	0.1506	0.0015
0.12	1,369.54	130.64	80.77	4,062.3450	33.3225	0.1793	0.0043
0.16	1,932.11	157.82	97.54	3,392.2500	29.4372	0.2147	0.0105
0.20	1,656.26	191.31	118.60	2,813.2020	26.1150	0.2583	0.0227
0.25	2,164.24	232.53	146.69	2,313.5090	23.1824	0.3146	0.0447
0.31	2,523.32	283.23	184.55	1,876.0740	20.6440	0.3878	0.0803
0.39	2,941.97	345.53	233.21	1,513.2580	18.5771	0.4786	0.1296
0.49	3,430.03	422.06	295.76	1,229.9110	16.8994	0.5908	0.1910
0.62	3,500.00	515.97	376.19	1,031.9720	15.7517	0.7036	0.2491
0.78	3,500.00	631.15	479.64	878.6840	14.8682	0.8240	0.3055
0.98	3,500.00	772.32	612.71	759.2600	14.1705	0.9550	0.3591
1.24	3,500.00	945.20	783.93	664.5260	13.6212	1.0928	0.4077
1.56	3,500.00	1,156.76	1,004.24	590.1310	13.1898	1.2452	0.4505
1.96	3,500.00	1,415.46	1,287.75	531.5280	12.8560	1.4202	0.4874
2.47	3,500.00	1,731.53	1,652.64	483.7950	12.5732	1.6019	0.5199
3.11	3,500.00	2,117.39	2,122.26	441.9730	12.3387	1.9581	0.5502
3.92	3,500.00	2,587.97	2,726.74	404.9810	12.1163	2.2759	0.5783
4.94	3,500.00	3,161.39	3,504.01	372.2230	11.9263	2.5424	0.6042
6.21	3,500.00	3,859.37	4,506.37	338.7540	11.7323	2.7826	0.6318
7.82	3,500.00	4,708.80	5,795.64	302.7580	11.5235	3.0589	0.6626
9.85	3,500.00	5,738.87	7,455.30	266.6230	11.3140	3.3881	0.6954
12.40	3,500.00	6,989.24	9,591.79	232.6830	11.1172	3.7713	0.7275
15.61	3,500.00	8,503.96	12,342.16	202.2120	10.9406	4.2093	0.7579
19.65	3,500.00	10,336.30	15,882.81	175.6680	10.7866	4.7015	0.7853
24.74	3,500.00	12,549.40	20,440.86	153.0020	10.6552	5.2461	0.8096
31.14	3,500.00	15,217.80	26,300.70	133.8980	10.5445	5.8368	0.8306
39.21	3,500.00	18,429.95	33,862.73	117.5380	10.4519	6.4669	0.8486
49.36	3,500.00	22,287.22	43,587.60	104.6750	10.3750	7.1274	0.8638
62.14	3,500.00	26,910.59	56,107.12	93.6320	10.3113	7.8077	0.8766

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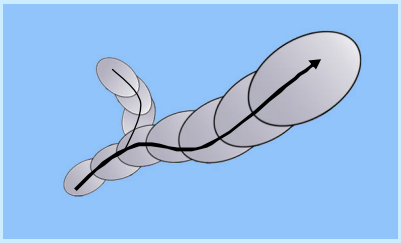
Slide 30

Puff

- **A discrete volume (parcel) of air representing a nearly instantaneous emission from a source. A series of puffs can be modeled to simulate a continuous plume.**



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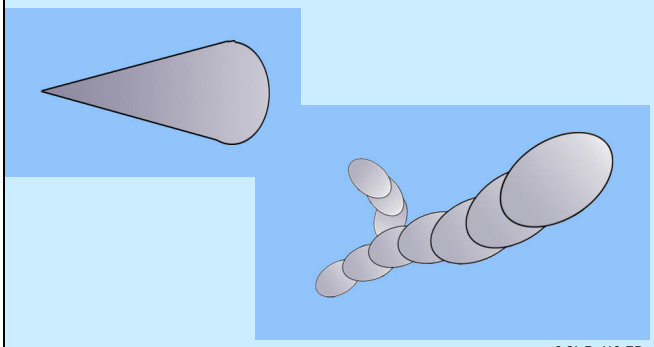
Slide 31

Comparing "Plumes" and "Puffs"



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Puff Models

- Simulates continuous plume by rapidly generating a series of puffs
- Used where trajectory winds may change or in areas of complex terrain
- Examples: NFSPuff, CALPUFF

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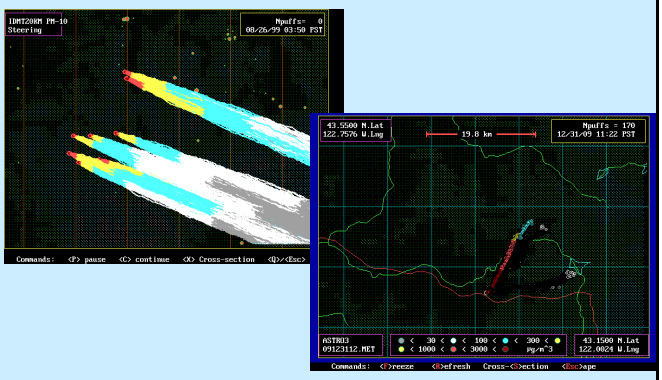
NFSPuff



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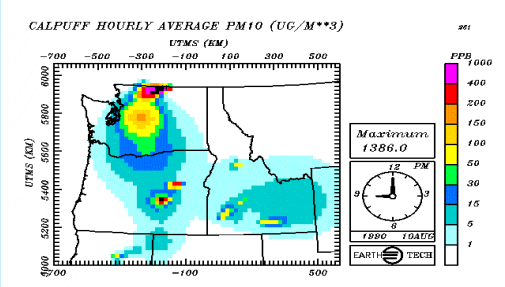
Calpuff



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Particle Models

- **Simulate many particles released over the burn duration**
- **Atmospheric "turbulence"considered**
- **Most accurate; research oriented**
- **Examples: Hysplit; PB-Piedmont**

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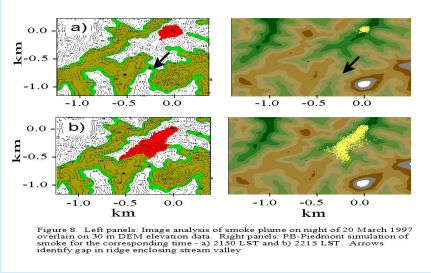
Particle Models



Output of PB-Piedmont Model

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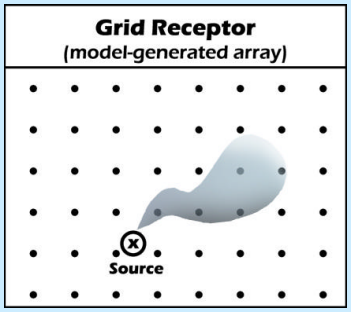
Grid Models

- Every grid acts as a confined box
- Difficult to track individual plumes but extremely useful to look at cumulative impacts (e.g., regional haze)
- Range from simple models (e.g., Valbox) to complex (e.g.,REMSAD)



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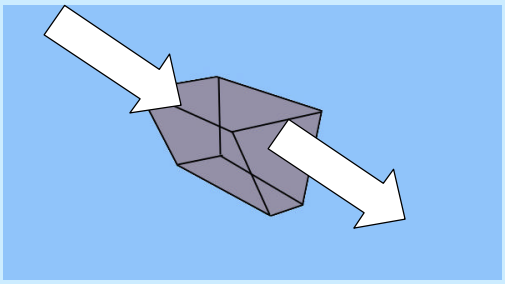
Box Model

Simple Box Models assume smoke fills a box (e.g., valley) instantaneously



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Box Model

- No trajectory estimates
- Usually restricted to low wind speeds
  - Flow is assumed to be downvalley
  - Meteorological inputs are substantial
- Example: Valbox

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Model Applications

- Plume models appropriate for:
  - Relatively flat terrain
  - When input data are scarce
  - Evaluating concentrations “near” a source
- Puff models appropriate for:
  - Complex terrain
  - Variable weather
  - Long-range transport

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Model Application (cont’d.)

- Particle Models appropriate for:
  - Tracking pollution “signatures”
- Grid Models appropriate for:
  - Relatively large domain
  - Modeling many sources
  - Impacts to regional haze or ozone

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Comparing Model Complexity and Users

Comparing Model Complexity and Typical Users

Relative Model Complexity to Use	Model or Type of Model	Typical Purpose	Typical User
Simple	• Emission Production • Ventilation Indices • Dispersion Indices • Geometric Screening • SASEM • ValBox • VSMOKE-GIS • Vsmoke	Screening/Relative Index	Local Project Manager
↓	• PB-Piedmont • CalPuff • Hy-Split	Planning	Reg'l Project Mgr or State Regulator
Complex	• Models3-CMAQ	Research	Research Scientist

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Scenarios Revisited

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What to do?

You're a District FMO in Arizona in charge of conducting a burn next week. County commissioners want to know how it will affect the local hot air balloon festival. What do you tell them?

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Answer

One Answer: Use SASEM or NFSPuff to demonstrate distance, direction and magnitude (e.g., air quality concentrations) of any potential smoke impacts.

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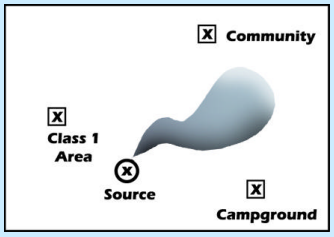
What to do?

You're preparing a NEPA document for a burn close to a PM-non-attainment area and Class I area in the Southeast. You need to describe how smoke will impact these areas. What do you do?



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Answer

One Answer: Use VSMOKE or VSMOKE-GIS to compare against ambient air quality standards and to judge impacts to Class I areas (e.g. distance, direction and duration of plume).

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What to do?

You're a line officer in Idaho deciding about a wildland fire use incident and how smoke may affect the local community. What do you tell the press about potential impacts?

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Answer

One Answer: Use NFSPuff to demonstrate distance, direction and magnitude (e.g., air quality concentrations) of potential smoke impacts.

Another answer: Use geometric screening to discuss direction of potential plume

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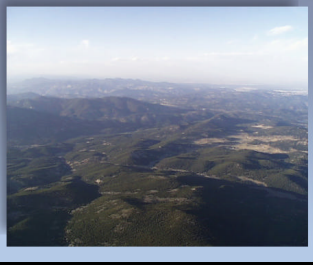
Slide 50

What to do?

You're an air regulator wanting to assess the effects of smoke on regional haze in the state. What do you do?



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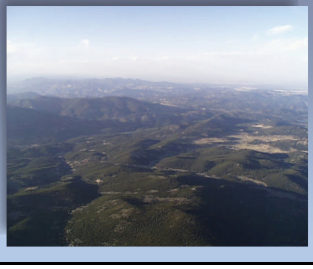
Answer

One Answer: Use CalPuff or RemSad to assess effects to Regional Haze. These complicated models are typically operated by EPA or the State air quality regulators (e.g., not land managers)



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What are your scenarios?

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Summary

- **Models are a well defined system for *communicating* the impact of smoke on ambient air quality (which can include visibility) by:**
  - **Quantifying total emissions**
    - NEPA Alternative comparisons
    - Regional Haze planning
  - **Describing pattern of impact**
    - Through approximations or refined modeling
  - **Assessing impact to receptors**
    - Highways, hospitals, airports, Class I
  - **Comparing to regulatory standards**
    - Especially health standards for PM10, PM2.5
    - Regulatory agencies may require modeling

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Unit 9 Objectives

- **Identify common smoke emissions and dispersion modeling systems available to help the fire practitioner plan for and communicate the impacts of smoke.**
- **Describe the difference between emission production and dispersion models.**
- **Describe the data and expertise needed to run emissions and dispersion models.**
- **Identify which models are most appropriate for your area and application.**

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Smoke Management

Smoke Screening Procedures: the “low tech” version

The following procedure was developed to aid the fire practitioner in limiting smoke impacts from prescribed burns. It does not offer the quantified emissions projections of some models, but its simplicity is attractive in many ways. Chiefly, there is no “black box” of assumptions en route to computing an answer. The direct, visual nature of the procedure makes judgements and assumptions more apparent to the user. It also does not require any expensive equipment.

This procedure was developed for use primarily in rural areas. In urban situations, the screening system may identify hundreds of critical smoke sensitive sites which cannot be entirely avoided if prescribed fires are to be conducted. In this situation, the system may be useful in identifying the most crucial sensitive areas, and in developing a list of neighbors and businesses to target for notification and education programs.

Additional steps can be added to this procedure that incorporate other fuel types and smoke-producing characteristics of the fuels. See: Wade, D.D. and J.D. Lunsford. 1989. A Guide for Prescribed Fire in Southern Forests. USDA Forest Service, Southeast Region. Technical Publication R8-TP 11.

To complete this procedure, you will need: an administrative map of the area, pencil, ruler, pencil compass (for drawing circles), and protractor or smoke plotter. A county map, showing roads, schools, churches, etc., is usually the appropriate scale for this procedure.

STEP 1. Determine Area Affected by Smoke Plume

A. Using an administrative map, plot wind direction from planned burn for the distance indicated:

   1. 5 miles for grass, any ignition technique
   2. 5 miles for backing fires in other fuels
   3. 10 miles for heading fires or large burns (>500 acres)

B. Draw lines from each end of fire at an angle of 30 degrees from wind direction and draw arcs at distance indicated above. This is your probable smoke impact area during the day (with variable winds, use 45 degrees).

C. Go down drainage for one-half the distance determined in A, spreading out over the valley or bottom. This is your probable impact area during the night.

STEP 2. Identify Smoke Sensitive Areas

A. Identify and mark any smoke-sensitive areas located within either probable impact areas plotted in STEP 1.

B. If no smoke-sensitive areas are found, you may burn as prescribed.

C. If any smoke-sensitive areas are found, continue screening procedure.

STEP 3. Identify Critical Smoke Sensitive Areas

A. Critical smoke sensitive areas are:

   1. Areas already with an air quality or visibility problem.
   2. Areas within the probable smoke impact areas as determined below:

      a. 5 miles - any sensitive area within one-half mile of burn is **critical**.

      b. 10 miles - any smoke-sensitive area within one mile is **critical**.

B. If any critical smoke-sensitive area is identified, DO NOT BURN without considering one of the following changes:

   1. Prescribe a new wind direction that will miss the critical smoke-sensitive area.

   2. If smoke sensitive area is in the outer half of the distance criteria, ensure burn area is small, and complete burn (including complete mop-up) by 5 pm.

   3. Consider alternatives to burning.

C. If no critical smoke-sensitive areas are found, or if criteria in “B” above are met, continue screening procedure.

STEP 4: Minimize Risk

If your planned burn meets all the criteria so far and you can answer yes to the following questions, you may burn as prescribed. If not, change prescription so all answers are “yes” or DO NOT BURN.

1. Is mixing height 1,700 feet or greater?

2. Is transport windspeed 9 mph or greater?

3. Is background visibility at least 5 miles?

4. If there are stumps and snags, are you taking steps to keep them from burning, or providing for adequate mop-up?

5. If smoke-sensitive area is in the overlapping trajectory of two smoke plumes, is it at least one mile from either source?

If your prescribed fire complies with all the conditions in the 4 steps, you should be able to safely burn without causing a smoke problem. If you have any marginal answers, areas extra sensitive to smoke, heavier than normal fuel loadings, or wet fuels, further adjustment may be in order.

Remember, this is a tool. *You* must make the final decision about when it is safe to burn.

Smoke Management Techniques, Rx-410

Unit 10 - Operational Smoke Management Strategies

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Define two general approaches to managing the impacts of wildland fire smoke (reduce emissions and redistribute emissions).

2. Discuss specific techniques within each approach and when they could be applied.

3. Discuss the tradeoffs between meeting planned objectives and applying smoke management strategies.

There are two basic approaches to minimizing the impact of wildland fire burning on air quality; (a) reducing the amount of pollutants emitted per ton of fuel burned or (b) reducing the impact of the pollutants emitted on sensitive locations or regional haze through smoke dilution or transport (redistributing emissions).

Although each method can be discussed independently, fire practitioners often choose firing and fuels manipulation techniques that complement or are at least consistent with meteorological scheduling for maximum smoke dispersion and favorable plume transport. The individual or combination use of these techniques is influenced by land management objectives, type and amount of vegetation being burned or treated, safety considerations, costs, and laws and regulations.

Within each of the two general categories, there are specific techniques that will be addressed next. To reduce the amount of pollutant emitted, these specific techniques include: reduce area burned, fuel load, fuel production, fuel consumed, burn before new fuel appears, and increase combustion efficiency. To reduce the impact of pollutant, the specific techniques include: burn when dispersion is good, avoid sensitive areas, share the airshed, and burn smaller units.

Reducing Emissions. First let's look at reducing the amount of smoke produced from a wildland fire. Assume the smoke that is generated from a wildland fire just fits inside the box shown in the slide. The volume of that box is dictated by the length of the three legs labeled fuel loading, fuel consumption, and emission factor. If any one of those factors or a combination of those factors is reduced, the volume of the box becomes smaller and for the smoke generated from the wildland fire to just fit in the box, less smoke would have to be produced. This is the basic idea behind techniques that reduce smoke from wildland fires.

Let's assume 30 people are in a restaurant that allows smoking and each person has lit up a Camel Straight cigarette. How can the smoke in that bar be reduced? First, you could reduce the number of cigarettes being smoked (reduce the fuel loading). Second, you could allow the smokers to only smoke ½ of the cigarette (reduce fuel consumed). Finally, you could require the individuals to smoke only Camel Light cigarettes (reduce emission factor).

There are 6 techniques that can be used to reduce the amount of smoke produced. Perhaps the most obvious method to reduce wildland fire emissions is to **reduce the area burned**. Area burned can be reduced by not burning at all or by burning a subset of the area within a designated perimeter. Caution must be applied though, and programs to reduce the area burned must not ultimately result in just a delay in the release of emissions either through prescribed burning at a later date or as the result of a wildland fire. Reducing the area burned should be accomplished by methods that truly result in reduced emissions over time rather than a deferral of emissions to some future date.

This technique can have detrimental effects on ecosystem function in fire-adapted vegetation community types and is least applicable when fire is needed for ecosystem or habitat management, or forest health enhancement. In some areas and some vegetation types, when fire is used to eliminate an undesirable species or dispose of biomass waste, alternative methods can be used to accomplish effects similar to what burning would accomplish. Examples of specific techniques include:

- **Burn concentrations:** Sometimes concentrations of fuels can be burned rather than using fire on 100 percent of an area requiring treatment. The fuel loading of the areas burned using this technique tends to be high. The total area burned under these circumstances can be very difficult to quantify.

- **Isolate fuels.** Large logs, snags, deep pockets of duff, sawdust piles, squirrel middens, or other fuel concentrations that have the potential to smolder for long periods of time can be isolated from burning. This can be accomplished by several techniques including: 1) constructing a fireline around the fuels of concern; 2) not lighting individual or concentrated fuels; 3) using natural barriers or snow; 4) scattering the fuels; and 5) spraying with foam or other fire retardant material. Eliminating these fuels from burning is often faster, safer, and less costly than mopup, and allows targeted fuels to remain following the prescribed burn.

- **Mosaic burning:** Landscapes often contain a variety of fuel types that are non-continuous and vary in fuel moisture content. Prescribed fire prescriptions and lighting patterns can be assigned to use this fuel and fuel moisture non-homogeneity to mimic a natural wildfire and create patches of burned and non-burned areas or burn only selected fuels. Areas or fuels that do not burn do not contribute to emissions. For example, an area may be continuously ignited

during a prescribed fire but because the fuels are not continuous, patches within the unit perimeter may not ignite and burn. Depressional wetlands, swamps, and hardwood stringers can be excluded by burning when soil moisture is abundant. Furthermore, if the burn prescription calls for low humidity and high live fuel moisture, continuous burning in the dead fuels may occur while the live fuels exceed the moisture of extinction. In both cases, the unburned live fuels may be available for future burning in a prescribed or wildland fire during droughts or dormant seasons.

- Graph showing the difference in emissions rate and total emissions from a unit that was 100 percent burned within the perimeter and one that was mosaic burned.

The second technique to reduce emissions is to reduce the fuel load. Some or all of the fuel can be permanently removed from the site, biologically decomposed, and/or prevented from being produced. Overall emissions can be reduced when fuel is permanently excluded from burning. This technique includes mechanical removal, mechanical processing, firewood sales, biomass for electrical generation, biomass utilization, and grazing.

- **Mechanical** removal. Mechanically removing fuels from a site reduces emissions proportionally to the amount of fuel removed. This is a broad category and can include such techniques as mechanical removal of logging debris from clearcuts, onsite chipping of woody material and/or brush for offsite utilization, and mechanical removal of fuels which may or may not be followed by offsite burning in a more controlled environment. Sometimes mechanical treatments (such as whole-tree harvesting or yarding of unmerchantable material (YUM)) may result in sufficient treatment so that burning is not needed. Mechanical treatments are applicable on lands where this activity is allowable (i.e., non-wilderness, etc.), supported by an access road network, and where there is an economic market for disposal of the removed fuel. This technique is most effective in forest fuel types and has some limited applicability in shrub and grass fuel types. A portion of the emission reduction gains from this technique may be offset by increased fossil fuel and particulate emissions from equipment used for harvest, transportation, and disposal operations. Mechanical treatments may cause undue soil disturbance or compaction, stimulate alien plant invasion, remove natural nutrient sources, or impair water quality.

Example of the removal of woody biomass from a mixed conifer stand.

Graph showing the emission rate over time for two units prescribed burned. One unit had fuels mechanically removed and the other unit did not. Note the shorter duration and less total emissions produced from the unit that had fuels removed.

- **Mechanical processing** - Mechanical processing of dead and live vegetation into wood chips or shredded biomass is effective in reducing emissions if the material is removed from the site or biologically decomposed. If the biomass is spread across the ground as additional small fuels, emission reductions are not achieved if the fuels are consumed either in a prescribed or wildland fire. Use of this technique may eliminate the need to burn; however, large piles of chips may cause other environmental problems or may pose a smoldering problem if burned.

- **Firewood sales**. Firewood sales may result in sufficient removal of woody debris making onsite burning unnecessary. This technique is particularly effective for piled material where the public has easy access. This technique is generally applicable in forest types with large diameter, woody biomass. The emissions from wildland fuels when burned for residential heating are not assessed as wildland fire emissions but as residential heating emissions. The impact of these emissions on the human environment is not attributed to wildland fire in the national or state emissions inventories.

- **Biomass for electrical generation**. Woody biomass can also be removed and used to provide electricity in regions with cogeneration facilities. Combustion efficiency in electricity production is greater than open burning and emissions from biomass fuel used offset fossil fuel emissions. Although this method of reducing fuel loading is cost-effective where there is a market for wood chips, there are significant administrative, logistical, and legal barriers that limit its use.

- Example of an electrical generation plant that uses chipped material and illustrates the utilization of biomass for soil production and landscaping material.

- **Biomass utilization**. Woody material can be used for many miscellaneous purposes including pulp for paper, methanol production, wood pellets, garden bedding, and specialty forest products. Demand for these products varies widely from place to place and year to year. Biomass utilization is most applicable in forest and shrub types that include large diameter woody biomass and where fuel density and accessibility makes biomass utilization economically viable.

- **Grazing**. Grazing and browsing live grassy or brushy fuels by sheep, cattle, or goats can reduce fuels prior to burning or reduce the burn frequency. Goats will sometimes consume even small, dead woody biomass. However, ungulates are selective, favoring some plants over others. The cumulative effect of this selectivity can significantly change plant species composition and long-term ecological processes on an area, eventually converting grass dominated areas to brush. On moderate to steep slopes, high populations of ungulates contribute to increased soil erosion.

Management techniques can be used to shift species composition to vegetation types that produce less biomass per acre per year, or produce biomass that is less likely to burn or burns more efficiently with less smoke. This third technique called reduce fuel production includes chemical treatment, site conversion, and land use change.

- **Chemical treatment:** Broad spectrum and selective herbicides can be used to reduce or remove live vegetation, or alter species diversity respectively. This often reduces or eliminates the need to use fire. Chemical production and application have their own emissions, environmental, and public relations problems. A NEPA (National Environmental Policy Act) analysis is generally required prior to any chemical use on public lands and states often require similar analyses prior to chemical use on state or private lands.

- **Site conversion**. Natural site productivity can be decreased by changing the vegetation composition. For example, frequent ground fires in southern pine forests will convert an understory of flammable shrubs (such as palmetto and gallberry) to open woodlands with less total fuel but also with more grass and herbs. Grass and herbs tend to burn cleaner than shrubs. Total fuel loading can also be reduced through conversion to species that are less productive.

Shows the removal of shrubs and trees to establish a grassland and Wal-Mart shopping area. The smaller pictures show an area converted to family homes. Although this area may never have prescribed fire applied because of the land use change, there is good evidence that some type of fuels treatment is required because of fire risk to the homes.

- **Land use change**. Changing wildlands to another land use category may result in elimination of the need to burn. Conversion of a wildland site to agriculture or an urbanized use significantly alters the ecological structure and function and presents numerous legal and philosophical issues. This alternative is probably not an option on federally managed lands.

The fourth technique to reduce emissions is to reduce fuel consumed. Emission reductions can be achieved when significant amounts of fuel are at or above the moisture of extinction, and therefore unavailable for combustion. Burning when fuels are wet may leave significant amounts of fuel in the treated area only to be burned in the future. This may not result in a real reduction in emissions then, but rather a delay of emissions to a later date. Real emission reductions are achieved only if the fuels left behind will biologically decompose or be otherwise sequestered at a time of subsequent burning. Even though wet fuels burn less efficiently and produce greater emissions relative to the amount of fuel consumed, emissions from a given event are significantly reduced because so much less fuel is consumed.

In the appropriate fuel types, the ability to target and burn only the fuels necessary to meet management objectives is one of the most effective methods of reducing emissions. When the objective of burning is to reduce wildfire hazard, removal of fine and intermediate diameter fuels may be sufficient. The opportunity to limit large fuel and organic layer consumption can significantly reduce emissions and includes burning when the moisture content is high in large logs and duff, burn before precipitation, and burn before large woody debris cures.

- **High moisture in large woody fuels**. Burning when large-diameter woody fuels (3+ inches in diameter or greater) are wet can result in lower fuel consumption and less smoldering. When large fuels are wet they will not sustain combustion on their own and are extinguished by their own internal moisture once the small twigs and branch-wood in the area finish burning. The large logs therefore consume less in total, they do not smolder as much, and they do not cause as much of the organic layer on the forest floor to burn. This

can be a very effective technique for reducing total emissions from a prescribed burn area and can have secondary benefits by leaving more large-woody debris in place for nutrient cycling. This technique can be effective in natural and activity fuels in forest types. When large fuel consumption is needed, burning under high moisture conditions is not a viable alternative.

Example of a pine unit that was burned under very high moisture contents with large woody fuels. It also illustrates a pine unit that was burned under very high duff moisture contents.

- **Moist litter and/or duff**. The organic layer that forms from decayed and partially decayed material on the forest floor often burns during the inefficient smoldering phase. Consequently, reducing the consumption of this material can be very effective at reducing emissions. Consumption of this litter and/or duff layer can be greatly reduced if the material is quite moist. The surface fuels can be burned and the organic layer left virtually intact. The appropriate conditions for use of this technique generally occur within a few days of a soaking rain or shortly after snowmelt. This technique is most effective in non-fire adapted forest and brush types. This technique may not be appropriate in areas where removal of the organic layer is desired. Burning litter and/or duff to expose mineral soil is often necessary in fire adapted ecosystems for plant regeneration.

- Comparison between the emission rate and total emission difference between a unit with a low large woody and duff fuel moisture content and a unit with high woody fuel and duff moisture content. Note that the unit with high fuel moisture content produces far less smoke and the production of smoke stops one day earlier with less smoldering.

- **Burning before precipitation.** Scheduling a prescribed fire before a precipitation event will often limit the consumption of large woody material, snags, stumps, and organic ground matter, thus reducing the potential for a long smoldering period and reducing the fire average emission factor. Successful application of this procedure depends on accurate meteorological forecasts for the area.

Example of a pine unit that was burned followed by a late season snow storm that eliminated smoldering of the large logs and duff. Also shows a clearcut unit that had been logged within the past 3 months. The large woody debris contains high fuel moisture contents and little consumption of this material would occur if burned.

- **Burn before large fuels cure**. Living trees contain very high internal fuel moistures, which take a number of months to dry after harvest. If an area can be burned within 3-4 drying months of timber harvest, many of the large fuels will still contain a significant amount of live fuel moisture. This technique is generally restricted to activity-generated fuels in forest-types.

Burning can sometimes be scheduled for times of the year before new fuels appear and includes burning before litter fall and before green-up. This may interfere with land management goals if burning is forced into seasons and moisture conditions where increased mortality of desirable species can result.

- **Burn before litter fall**. When deciduous trees and shrubs drop their leaves this ground litter contributes extra volume to the fuel bed. If burning takes place prior to litter fall there is less available fuel and therefore less fuel consumed and fewer emissions.

Example of sand pine/long leaf pine with a turkey oak understory before leaf fall from the turkey oak and a prescribed burn in a grassland area in the spring before green-up.

- **Burn before green-up**. Burning in cover types with a grass and/or herbaceous fuelbed component can produce fewer emissions if burning takes place before these fuels green-up for the year. Less fuel is available therefore fewer emissions are produced.

The sixth technique to reduce emissions is to increase the combustion efficiency and shift the majority of consumption away from the smoldering phase and into the more efficient flaming phase. This includes burning dry and clean piles and windrows, using a backing fire, and includes burning before litter fall, burning under dry conditions, rapid mopup, aerial ignition, and using lighting techniques to obtain a mass fire.

- **Burn piles or windrows**. Fuels concentrated into clean and dry piles or windrows generate greater heat, develop a better heat/oxygen mix, and burn more efficiently. A greater amount of the consumption occurs in the flaming phase and the emission factor is lower. This technique is primarily effective in forest fuel types but may have some applicability in brush types also. Concentrating fuels into piles or windrows generally requires the use of heavy equipment, which can negatively impact soils and water quality. Piles and windrows also cause temperature extremes in the soils directly underneath and can result in areas of soil sterilization. If fuels in piles or windrows are wet or mixed with dirt, extended smoldering of the debris can result in residual smoke problems.

Example of a pile burning very efficiently because the correct mix of compaction**.**

Graph showing the difference in emission rates between a pile burn and an underburn. The pile burn produces less smoke over a shorter period of time and most of the smoke is produced during the efficient flaming stage.

- **Backing fires**. Flaming combustion is cleaner than smoldering combustion. A backing fire takes advantage of this relationship by causing more fuel consumption to take place in the flaming phase than would occur if a heading fire were used. In applicable vegetation types where fuels are continuous and dry, the flaming front backs more slowly through the fuelbed and by the time it passes, most available fuel is consumed so the fire quickly dies out with very little smoldering. In a heading fire, the flaming front passes quickly and the ignited fuels continue to smolder until consumed. The opportunity to use backing fires is not always an option and often increases operational costs.

Examples of increasing combustion efficiency.

- Backing fire in a longleaf/turkey oak prescribed burn in Florida. Note little smoke from the flaming front.
- Burning under very dry conditions.

- **Dry conditions**. Burning under dry conditions increases combustion efficiency and less emissions may be produced. However, dryer conditions make fuel that was not available to burn (at or above the moisture of extinction) available to burn. The emissions from additional fuel burned generally more than offsets emission reduction advantages gained by greater combustion efficiency. This technique is effective only if all fuels will be consumed under either wet or dry conditions.

Example that shows the smoldering that can occur and the resulting smoldering smoke in a mixed conifer stand in the Pacific Northwest.

- **Rapid mopup**. Rapidly extinguishing a fire can reduce fuel consumption and smoldering emissions somewhat although this technique is not particularly effective at reducing total emissions and can be very costly. Rapid mopup primarily affects smoldering consumption of large-woody fuels, stumps, snags, and duff. Rapid mopup is more effective as an avoidance technique by reducing residual emissions that tend to get caught in drainage flows and end up in smoke sensitive areas**.**

Mopping up a smoldering stump which can eliminate the smoldering smoke production phase. This technique is often very expensive. Also a helicopter ignited lodge pole pine clear-cut that reached a mass fire condition.

- **Aerial ignition/mass ignition**. "Mass" ignition can occur through a combination of dry fine fuels and very rapid ignition, which can be achieved through a technique such as a helitorch. Mass ignition can shorten the duration of the smoldering phase of a fire and reduce the total amount of fuel consumed. When properly applied, mass ignition causes rapid consumption of dry, surface fuels and creates a very strong plume or convection column which draws much of the heat away from the fuel bed and prevents drying and preheating of larger, moister fuels. This strong plume may result in improved smoke dispersal. The fire dies out shortly after the fine fuels are fully consumed and there is little smoldering or consumption of the larger fuels and duff. The conditions necessary to create a true mass ignition situation include rapid ignition of a large, open area with continuous, dry fuels**.**

- **Air Curtain Incinerators**. Burning fuels in a large metal container or pit with the aid of a powerful fan-like device to force additional oxygen into the combustion process results in a very hot and efficient fire that produces little smoke. These devices are commonly used to burn land clearing, highway right-of-ways, or demolition debris in areas sensitive to smoke and may be required by air quality agency regulations in some areas.

Emissions can be spatially and temporally redistributed by burning during periods of good atmospheric dispersion (dilution) and when prevailing winds will transport smoke away from sensitive areas (avoidance) so that air quality standards are not violated. Redistribution of emissions does not necessarily reduce overall emissions. There are 6 techniques that fall under the large category of redistributing emissions. These include:

- **Burn when dispersion is good.** Smoke concentrations can be reduced by diluting the smoke through a greater volume of air, either by burning during good dispersion conditions when the atmosphere is unstable or burning at slower rates. If burning progresses too slowly, smoke accumulation due to evening atmospheric stability can occur.

A prescribed burn that occurred on a good dispersion day and a map showing the prescribed burns in southwest Oregon. The State of Oregon Smoke Management program requires individuals take turns and share the airshed.

- **Share the airshed.** Establishing a smoke management program that links both local and interstate jurisdictions will create opportunities to share the airshed and reduce the likelihood of smoke impacts.

- **Avoid sensitive areas**. The most obvious way to avoid smoke impacts is to burn when the wind is blowing away from all smoke-sensitive areas such as highways, airports, populated areas, and scenic vistas. Wind direction must be considered during all phases of burning. For example, the prevailing winds during the day time may move the smoke away from a major highway; however, at night, drainage winds can carry the smoke toward the highway**.**

Two plumes from large clearcut burns in western Washington that caused smoke problems at Mount Rainier National Park. Also burning a very small area within New York City to reduce the potential impact of smoke across the highway system and the local public.

- **Burn smaller units**. Short term emissions and impacts can be reduced by burning subsets of a large unit over multiple days or develop trigger points to stop a burn if unexpected smoke impacts are about to occur. Total emissions are not reduced if the entire area is eventually burned.

- **Burn more frequently**. Burning more frequently does not allow fuels to accumulate, thus there are less emissions with each burn. Frequent, low intensity fires can prevent unwanted vegetation from becoming established. If longer fire rotations are used, the vegetation has time to grow resulting in the production of extra biomass and extra fuel loading at the time of burning. This technique generally has positive effects on land management goals since it results in fire regimes that more closely mimic the frequency of natural fire in many ecosystems.

A prescribed burn in an area in Florida that is burned regularly on a 4-year rotation and a plume venting into a cloud.

- **Scavenging/vent into clouds**. Smoke particles are excellent condensation nuclei. If the smoke is vented into a moist atmosphere, often moisture will condense around the smoke particles. When the moisture droplet becomes heavy enough, it will fall from the sky, and scavenge the smoke particle from the atmosphere.

Smoke management strategies are not without potential negatives and must be prescribed and used with careful professional judgment and full awareness of possible tradeoffs. The use of smoke management techniques can:

1. Prevent the accomplishment of other objectives
2. Can increase future smoke episodes
3. Can cause negative impacts on other resource values
4. Can be expensive to implement.

Examples of conflicts are expressed in the following case studies.

Case Example 1: This is an under burn prescribed fire that occurred in a ponderosa pine fuel bed type in the southwestern part of the Untied States. One of the major objectives of this burn was to expose 60 percent mineral soil and increase the potential of natural regeneration. What are the smoke management and prescribed fire objective conflicts?

To obtain a 60 percent mineral exposure, the burn will have to be accomplished when the large woody fuels and duff layer are relatively dry. This will increase the fuel available for consumption and a majority of the fuel will be consumed during the less efficient smoldering phase producing more smoke per ton of fuel consumed and less buoyant smoke. Thus, there are tradeoffs the managers need to consider when completing burn prescriptions.

Case study 2 is an under burn in the Pacific Northwest in a mixed conifer stand. The objective was to reduce the small fuels but retain 60 percent of the large logs greater than 3 inches in diameter. What are the smoke management and prescribed fire objective conflicts?

To obtain the 60 percent retention of large logs, the fuel moisture content of both the duff and large logs will be high. Consequently, there is no conflict in meeting both the smoke management and prescribed fire objectives.

Case study 3 is an under burn in a 15 year rough long leaf pine site in the panhandle of Florida. The prescribed fire objective is to reduce the accumulation of large wood, litter, duff, shrubs, and grasses. The area is adjacent to a major highway. To reduce the potential of smoke crossing the highway and possibly causing a safety hazard, the prescribed fire plan calls for mopup and extinguishing all smoldering smokes within 2 hours of ignition. What are the smoke management and prescribed fire objective conflicts?

The prescribed fire plan calls for the consumption of a majority of the large woody fuels, duff, shrubs and grasses. In order to accomplish this, the Keech/Byram index will be above 500 and the duff and woody fuel moistures will be low. The potential for a large amount of smoldering will be large. This will create a situation where a large cost will be incurred to put out the smoldering duff and logs to reduce the smoke across the highway.

Case study 4. A prescribed burn is planned in a very dense mixed conifer site in western Montana. To reduce total smoke produced, a contract was let to thin the stand and chip the debris on site followed by the prescribed burn. What are the smoke management and prescribed fire objective conflicts?

There are no prescribed fire and smoke management objective conflicts. The thinning and chipping will reduce the fuel load, make the prescribed burn easier, and reduce the amount of smoke (if chips are removed from site). However, the thinning and chipper may cause soil compaction, negatively effect wildlife habitat and water quality. If chips are not removed and spread over site, may cause future fire problem and smoke problem and may cause impact on soil nutrients.

Smoke management and prescribed fire plan requirements.

Identify and comply with air quality and smoke management compliance actions that could include:

- Smoke management reporting/permitting
- Weather observations, plume trajectory and behavior
- Techniques to reduce consumption/smoke impacts
- Road visibility
- Public health/welfare/concerns/activities
- Monitoring of source, trajectory, and receptor
- Consider health and welfare of personnel with regards to smoke exposure
- Monitor
- Employ techniques to reduce impacts

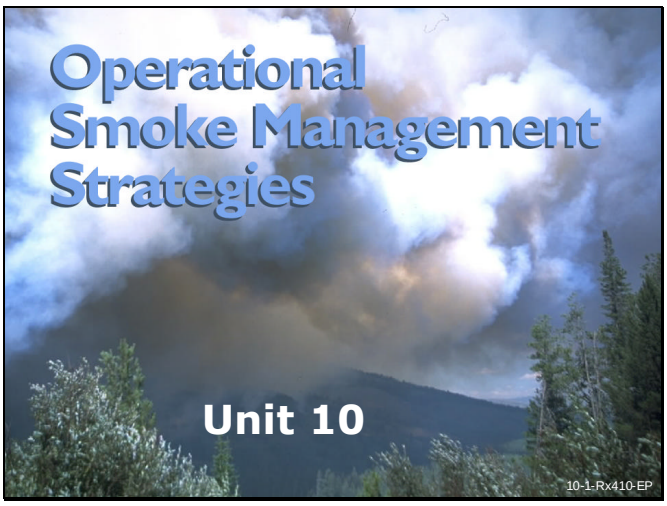
Summary

Two general approaches to managing the impacts of **wildland** fire smoke: reducing emissions and redistributing emissions

Specific techniques within each category: reduce area burned, fuel load, fuel production, fuel consumed, burn before new fuel appears, and increase combustion efficiency

Smoke objectives do not always meet prescribed fire objectives

Slide 1



Slide 2

Unit 10 Objectives

- Define two general approaches to managing the impacts of wildland fire smoke (reduce emissions and redistribute emissions)
- Discuss specific techniques within each approach and when they could be applied
- Discuss the tradeoffs between meeting planned objectives and applying smoke management strategies

10-2-Rx410-EP

Slide 3

Smoke Management Techniques

- There are two general approaches to managing the effects of wildland fire smoke on air quality:
  - Use techniques that reduce emissions produced for a given area treated
  - Redistribute the emissions through meteorological scheduling and by sharing the airshed to reduce impacts.

10-3-Rx410-EP

Slide 4

Smoke Management Techniques

- May be used independently or in combination
- Influenced by:
  - Land management objectives
  - The type and amount of vegetation being burned or treated
  - Safety considerations
  - Cost
  - Laws and regulations

10-4-Rx410-EP

Slide 5

Smoke Management Techniques

- Reduce Emissions
  - Reduce area burned
  - Reduce fuel load
  - Reduce fuel production
  - Reduce fuel consumed
  - Schedule burning before new fuels appear
  - Increase combustion efficiency

backing fire

mosaic burning jackpot burning rapid mopup

10-5-Rx410-EP

Slide 6

Smoke Management Techniques

- Redistribute Emissions
  - Burn when dispersion is good
  - Avoid sensitive areas
  - Share the airshed
  - Burn smaller units

good dispersion avoid sensitive areas share airshed

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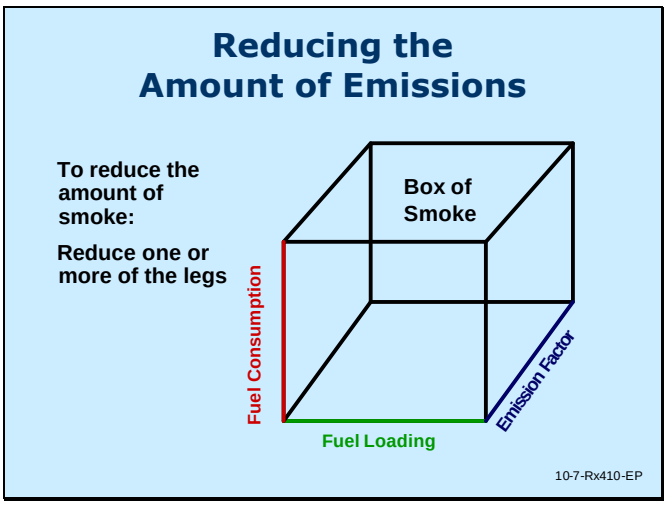
Slide 7



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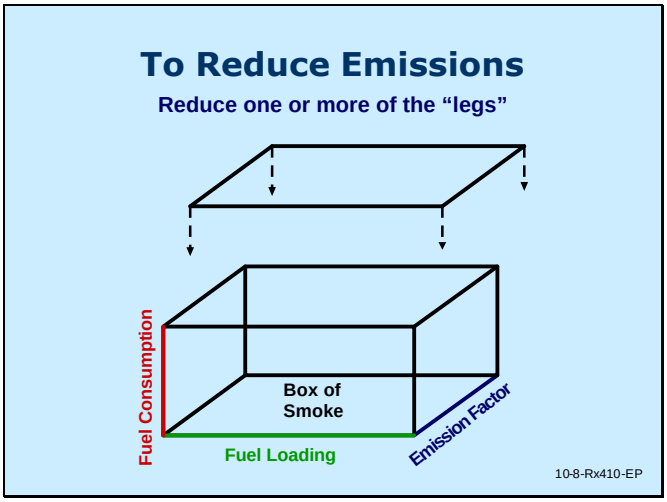

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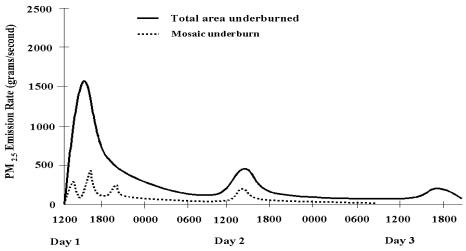

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Slide 11

Reducing the Amount of Emissions

- **Reduce Fuel Load**
  - Mechanical removal

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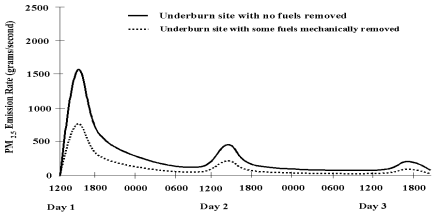
Slide 12



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Slide 13

Reducing the Amount of Emissions

- **Reduce Fuel Load**
  - Mechanical processing
  - Firewood sales

10-13-Rx410-EP

Slide 14

Reducing the Amount of Emissions

- **Reduce Fuel Load**
  - Biomass for electrical generation
  - Biomass utilization

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Slide 15

Reducing the Amount of Emissions

- **Reduce Fuel Load**
  - Grazing

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Slide 16

Reducing the Amount of Emissions

- **Reduce Fuel Production**
  - Chemical Treatment

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Slide 17

Reducing the Amount of Emissions

- **Reduce Fuel Production**
  - Site conversion
  - Land use change

10-17-Rx410-EP

Slide 18

Reducing the Amount of Emissions

- **Reduce Fuel Consumed**
  - High moisture in large woody fuels
  - Moist litter and duff

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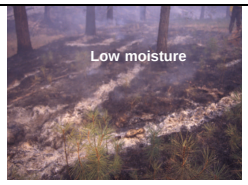
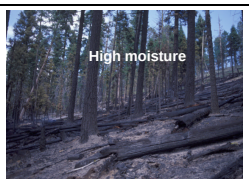
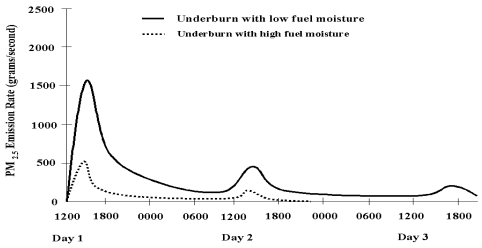
Slide 19







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Slide 20

Reducing the Amount of Emissions

- **Reduce Fuel Consumed**
  - Burn before precipitation
  - Burn before large fuels cure

10-20-Rx410-EP

Slide 21

Reducing the Amount of Emissions

- **Schedule Burn before New Fuels Appear**
  - Burn before litter fall
  - Burn before green-up

10-21-Rx410-EP

Slide 22

Reducing the Amount of Emissions

- **Increase Combustion Efficiency**
  - Burn piles or windrows

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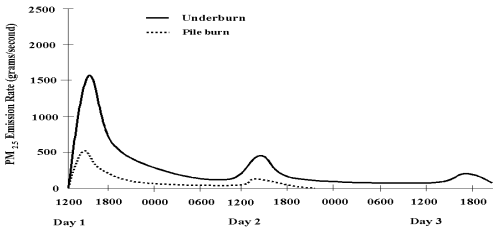
Slide 23



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Slide 24

Reducing the Amount of Emissions

- **Increase Combustion Efficiency**
  - Backing fires
  - Dry conditions

10-24-Rx410-EP

Slide 25

Dry conditions…

…lead to more efficient burning and less emissions may be produced.

However, more emissions may be produced because more large fuels and duff are available to burn.

10-25-Rx410-EP

Slide 26

Reducing the Amount of Emissions

- Increase Combustion Efficiency
  - Rapid mopup
  - Aerial ignition/ mass fire

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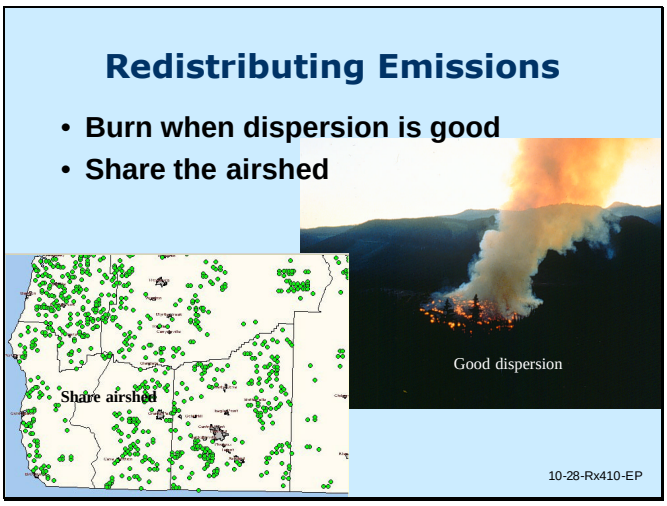
Slide 27

Reducing the Amount of Emissions

- Increase Combustion Efficiency
  - Air curtain incinerators

10-27-Rx410-EP

Slide 28



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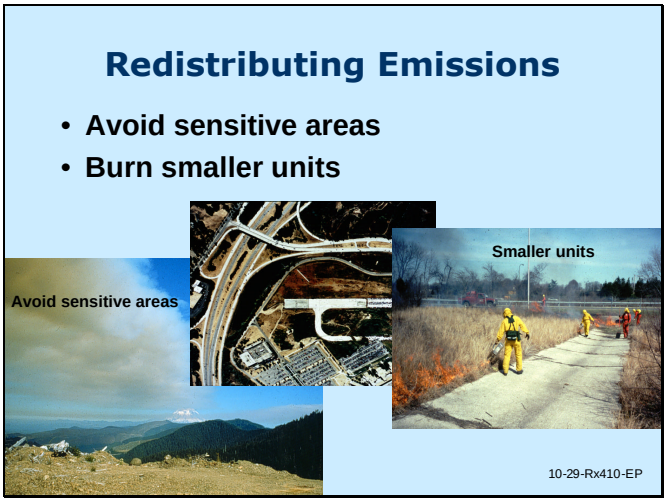

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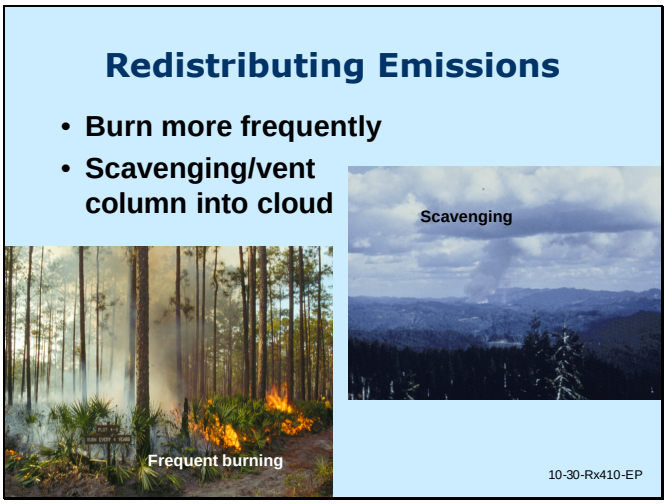

Slide 31

Smoke Management Techniques

Smoke Management strategies are not without potential negatives and must be prescribed and used with careful professional judgment and full awareness of possible tradeoffs.

- Can prevent accomplishment of objectives
- Can increase future smoke episodes
- Can cause negative impacts on other valuable resources through soil compaction, loss of nutrients, impaired water quality, etc.
- Can be expensive

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Slide 32

Case 1

This is a ponderosa pine stand. The prescribed fire objective is to prepare the site for natural regeneration by exposing 60 percent mineral soil.

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Case 1

What are the smoke management and prescribed fire objective conflicts?

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Case 1

Conflicts include:

- Low fuel moisture is required to consume litter and duff to expose 60% mineral soil. The tradeoff is producing large quantities of smoke.
- This results in less buoyant smoke.

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Case 2

This is a ponderosa pine/mixed conifer stand. The prescribed fire objective is to retain the large logs for wildlife and organic layer around the trees to reduce mortality.

What are the smoke management and prescribed fire objective conflicts?

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Case 2

Conflicts include:

- The fuels will be wet to reduce consumption, thus there will be little smoke produced and limited smoldering.
- May not meet fuel reduction objectives

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Case 3

This is a long leaf pine understory burn in a 5-year-old rough. The objective is to reduce accumulation of large wood, litter, duff, shrubs and grasses.

What are the smoke management and prescribed fire objective conflicts?

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Case 3

Conflicts include:

- To meet burn objective of reducing fuel accumulation, fuels will have to be dry. This creates the potential for fuels to smolder for a long time.
- Smoke across the highway
- High cost for mopup

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Case 4

This is a dense, partially dead mixed conifer site in Montana. A contract was let to thin the stand and chip the debris on site followed by a prescribed burn.

What are the smoke management and prescribed fire objective conflicts?

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Case 4

- **No prescribed fire and smoke management objective conflicts.**
- **Thinning and chipping with removal will reduce fuel load and reduce the amount of smoke.**
- **There may be an impact on soil, wildlife, water quality.**
- **If chips are not removed, may cause future fire and smoke problem.**

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Smoke Management and Prescribed Fire Plan Requirements

- **Identify and complete air quality and smoke management compliance actions which could include:**
  - smoke management reporting/permitting
  - consider techniques to reduce smoke production and impacts
  - weather observations, plume trajectory and behavior
  - road visibility
  - public health/welfare/concerns/activities
  - monitoring of source, trajectory, and receptor
- **Consider health and welfare of personnel with regard to smoke exposure**
  - monitor
  - reduce exposure

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Summary

- **Two general approaches to managing the impacts of wildland fire smoke: reducing emissions and redistributing emissions**
- **Specific techniques to reduce emissions: reduce area burned, fuel load, fuel production, fuel consumed; burn before new fuel appears, and increase combustion efficiency**
- **Specific techniques to redistribute emissions: burn when dispersion is good, avoid sensitive areas, share the airshed, burn smaller units.**
- **Smoke objectives do not always meet prescribed fire objectives.**

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Unit 10 Objectives

- Define two general approaches to managing the impacts of wildland fire smoke (reduce emissions and redistribute emissions)
- Discuss specific techniques within each approach and when they could be applied
- Discuss the tradeoffs between meeting planned objectives and applying smoke management strategies

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Smoke Management Techniques, Rx-410

Unit 11 - Smoke Monitoring and Evaluation of Impacts

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. List reasons wildland fire managers monitor smoke.

2. Clarify and list specific smoke monitoring objectives.

3. Describe particulate and visibility monitors and their availability.

4. Locate particulate matter and visibility data available through the Internet.

Reasons why we need to monitor

There are several reasons why a manager may want to establish a smoke monitoring program. These include:

1. Evaluate potential human health or nuisance impacts on communities and rural residences.

2. Provide feedback to public, regulators, smoke forecasters, and managers.

3. Verify assumptions and predictions from planning documents and modeled predictions.

4. Adjust lighting of burns and total burn acreages to avoid violations of ambient air quality standards.

5. Assess visibility in Class I areas.

Smoke Monitoring Equipment

There are two major categories of smoke monitoring equipment. These include particulate and visibility instruments.

Particulate Monitoring Equipment

Particulate monitoring instruments generally use one of two particulate concentration measurement techniques. These include gravimetric or optical.

The **gravimetric instruments** are filter based that collect particulates on ventilated filters. The filters are later weighed to determine the mass concentrations. This technique is very labor intensive and results may not be available for days or weeks. Also, airflow rates and elapsed sampling time must be carefully monitored. Gravimetric monitoring is best for projects where high-accuracy is needed and time delay of the data is not a problem. State monitoring networks designed to detect violations of air quality standards rely heavily on gravimetric monitors. Many federal reference method monitors are gravimetric. Gravimetric instruments include high volume samplers, IMPROVE Modular Aerosol Samplers, dichotomous samplers, and mini-volume samplers.

The **optical instruments** measure light-scattering (nephelometers) or light-absorbing (aethalometers) characteristics of the atmosphere. This measurement can then be converted to obtain an estimate of the concentration of airborne particulates. Optical instruments provide real time readings. Some are portable, require little power, and are relatively inexpensive. The main disadvantage is that optical instruments are generally less accurate than gravimetric instruments. Optical instruments are best for projects where real time data is needed, where portability is required, and when a high degree of accuracy is not essential. Optical instruments include Radiance nephelometer, MIE DataRam nephelometer, Laser photometers, Tapered Element Oscillating Microbalance (TEOM), and Beta Attenuation Monitor (BAM).

Visibility Monitoring Equipment

Complete visibility monitoring needs not only particulate concentrations but aerosol chemical composition and particulate light scattering and absorption as well. Monitoring of the visual quality of a vista (called scene monitoring) is often done at the same time using 35mm or digital cameras. Aerosol chemical analysis monitoring requires filter-based instrumentations.

Monitoring Program Objectives and Equipment

Both visibility data and PM 10 and PM 2.5 concentration data (particulates) are useful to smoke management program coordinators and regulatory agencies. The monitoring can be conducted at various temporal and spatial scales depending on the program objectives and instruments available. The program objectives must match the monitoring method.

There are three main program objectives to consider in determining monitoring instruments. These include 1) project impact monitoring; 2) NAAQS monitoring; and 3) visibility monitoring.

Project impact monitoring generally occurs in a real-time, short term or event-based situation, concentrating on a localized area such as a residential neighborhood. Applicable monitoring equipment includes:

- Radiance nephelometers
- MIE DataRAM nephelometer
- Laser photometers
- Tapered Element Oscillating Microbalance (TEOM)
- Beta Attenuation Monitor (BAM)

NAAQS monitoring generally occurs over a long time period, representing a large area such as an airshed. Applicable equipment includes:

- MiniVols
- Dichotomous samplers
- Other EPA FRM Monitor (e.g., high volume samplers)

If the program objective is visibility monitoring, sampling generally occurs over a long time period and represents a specific region. Applicable monitoring equipment includes:

- IMPROVE Aerosol Samplers
- Optec Nephelometer
- 35mm Camera
- Digital Camera System

Where to Monitor

Samplers used for smoke impact monitoring are normally paced at sensitive locations that have the greatest likelihood of impact. This may be a private residence, schools, hospitals, county fairs, airports, or recreational areas. Care must be taken to ensure that the instrument(s) are located in an open, exposed location removed from local pollution sources such as dirt roads, woodstoves, automobile traffic, etc.

When to monitor

The timing, frequency, and duration of sampling depends on the program objectives. Continuous hourly data is needed to monitor smoke impacts from a prescribed fire project several days before and after ignition. In contrast, PM10 NAAQS compliance monitoring using gravimetric based samplers is conducted once every six days in attainment areas.

Quality Assurance

Data integrity is essential in any monitoring program. Every monitoring project should have a quality assurance plan that addresses maintenance and calibration of each instrument.

Monitoring Data Websites

There are several websites that have examples of air quality monitoring. These include:

http://www.satguard.com/usdafs - remote wildland fire DataRAM particulate matter data via satellite telemetry

http://www.fsvisimages.com - real time and archived visibility images of class I areas in US. Digital web cameras tied to weather and air quality data affecting visibility will increase.

http://www.epa.gov/air/data/index.html - huge national database of all air pollution data. Local and state health and environmental quality agencies have Internet databases which may be more easily used than that of the EPA air database.

http://www.atmos.washington.edu/gcg/smokeandfire - weather, fire, and smoke prediction in real time for northwestern US

http://vista.cira.colostate.edu/improve/ - IMPROVE visibility database for class I areas in US. Archived data is a year behind.

Effectiveness of smoke management.

Monitoring is the means of evaluating smoke management effectiveness. Most air monitoring is EPA, state, and locally run and is used by smoke management programs in coordination with national, state, and local air resource management programs. Remote and portable DataRAMs may be used for specific cases of concern, giving relative index of PM levels. Remote digital cameras may be used for specific cases of visibility concerns for scenery and class I impairment concerns, and visibility impairment determination for sensitive areas like communities, recreational areas, airports, highways, hospitals, and schools, especially during times of high use.

Comparing particulate matter concentrations with NAAQS, and determining whether human health standards are met is an EPA and state role, working with local health and environmental agencies. The Federal Reference Method samplers require intensive quality assurance programs run by skilled EPA, state, and local health environmental quality agencies. Fire and smoke managers use the data.

Visibility evaluation, the degree of public acceptance, can be as simple as the number of phone calls and inquiries as to whether scenic views and sensitive areas like airports and highways are impaired. Visibility evaluation in terms of the Regional Haze Rule is a complex modeling of natural background atmospheric concentrations of air pollutants, compared with IMPROVE data over time, which needs to show continuing improvement over time, and which affects smoke management programs through the state implementation plans in which air and fire managers will be involved. The Regional Haze Rule and PM2.5 standards will affect burning and all sources of air pollution, with continued emphasis required on emission control technology implementation for point sources of pollution, and mandatory and carefully scrutinized smoke management programs for forestry burning, and, eventually, agricultural burning will be included in smoke management.

Integration into future burn plans

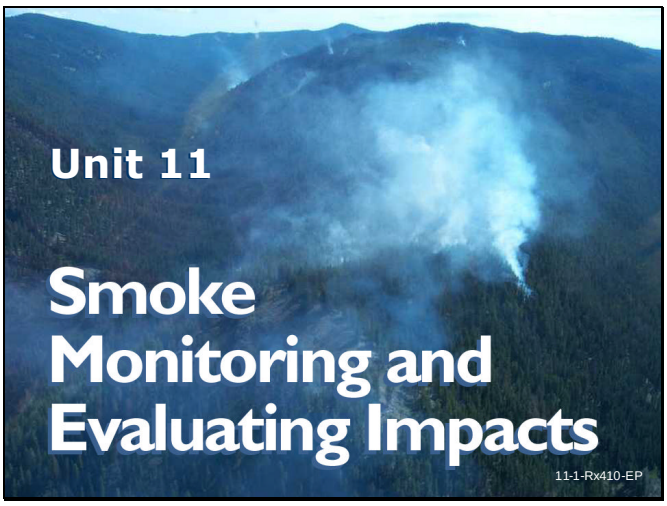
Some suggested procedures for integrating monitoring results into future prescribed burn plans and prescriptions (CH2MHILL 1997):

1. Define an acceptable particulate matter concentration threshold for nearby communities or Class I areas. A threshold particulate matter concentration is needed to measure the impact of prescribed understory burning operations on local communities.

2. Compare monitoring results and documented complaints to the established concentration thresholds

3. Modify future burn plans to produce lower particulate matter concentrations in nearby communities or Class I areas.

Slide 1



Slide 2

Objectives

- List reasons wildland fire managers monitor smoke.
- Clarify and list specific smoke monitoring objectives.
- Describe particulate and visibility monitors and their availability.
- Locate particulate matter and visibility data available through the Internet.

11-2-Rx410-EP

Slide 3

Reasons to Monitor

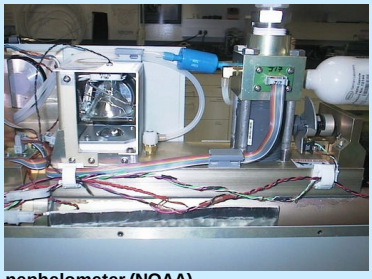
- Evaluate impacts on communities
- Provide feedback to public, regulators, smoke forecasters, and managers.
- Verify assumptions and predictions
- Avoid violations of air quality standards.
- Assess visibility in Class I areas.

11-3-Rx410-EP

Slide 4

Two Types of Smoke Monitoring Equipment

- Particulate
- Visibility



nephelometer (NOAA)

11-4-Rx410-EP

Slide 5

Particulate Monitoring Equipment

- Gravimetric
  - Filter based; weighs mass
  - Labor intensive
  - Very accurate but slow data return
  - Examples
    - High volume samplers
    - Dichotomous samplers
    - IMPROVE aerosol samplers

11-5-Rx410-EP

Slide 6

Particulate Monitoring Equipment

- Optical
  - Measure light scattering or light absorption
  - Converts to concentrations
  - Real-time data
  - Portable
  - Relatively inexpensive
  - Less accurate than gravimetric
  - Examples
    - Nephelometers
    - Photometers
    - TEOM

TEOM PM2.5 sampler

11-6-Rx410-EP

Slide 7

Visibility Monitoring Equipment

- Requires particulate concentrations
- Aerosol composition
- Light scattering and absorption
- Sometimes scene monitoring is incorporated

11-7-Rx410-EP

Slide 8

Clarifying Monitoring Objectives

- Three main objectives
  - Project impact monitoring
  - NAAQS monitoring
  - Visibility monitoring

11-8-Rx410-EP

Slide 9

Project Impact Monitoring

- Real-time
- Short term
- Event based
- Localized area
- Equipment
  - Nephelometers
  - Photometers
  - TEOM

photometer (NOAA)

11-9-Rx410-EP

Slide 10

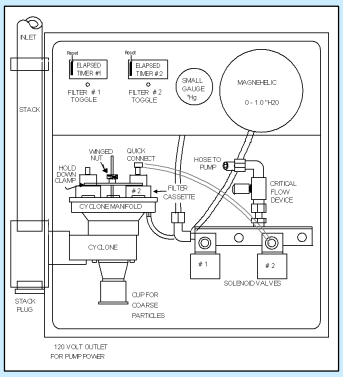
NAAQS Monitoring

- Long time period
- Large area
- Lag time monitoring
- Equipment
  - Federal reference method monitors

11-10-Rx410-EP

Slide 11

Visibility Monitoring



IMPROVE aerosol sampler

- IMPROVE aerosol samplers
- OPTEC nephelometers
- Camera systems

11-11-Rx410-EP

Slide 12

Where to Monitor

- Sensitive locations
  - Schools
  - Hospitals
  - County fairs
- Placed away from local pollution sources
  - Dirt roads
  - Wood stoves
  - Traffic

11-12-Rx410-EP

Slide 13

When to Monitor

- Depends on objectives
  - Project impact monitoring
    - May be hourly for several days before and after project
  - NAAQS monitoring
    - Once every six days

11-13-Rx410-EP

Slide 14

Quality Assurance

- Need to maintain and calibrate instruments

11-14-Rx410-EP

Slide 15

Monitoring Data Websites

- http://www.satguard.com/usdafs
- http://www.fsvisimages.com
- http://www.epa.gov/air/data/index.html
- http://www.atmos.washington.edu/gcg/smokeandfire
- http://vista.cira.colostate.edu/improve/

11-15-Rx410-EP

Slide 16

Effectiveness of Smoke Management

- Monitoring is the means to assess the effectiveness of a smoke management program
- Coordinate with other programs
  - Use EPA and state monitoring data
  - Locate monitors where no data is available
  - Use visibility data to evaluate impacts to class I areas

11-16-Rx410-EP

Slide 17

Integration Into Future Burn Plans

- Define an acceptable particulate matter concentration threshold for nearby communities or Class I areas.
- Compare monitoring results and documented complaints to the established concentration thresholds
- Modify future burn plans to produce lower particulate matter concentrations in nearby communities or Class I areas.

11-17-Rx410-EP

Slide 18

Summary

- Know why you are monitoring.
- Pick the appropriate piece of equipment.
- Know what to do with the data once you get it.

11-18-Rx410-EP

Slide 19

Objectives

- List reasons wildland fire managers monitor smoke.
- Clarify and list specific smoke monitoring objectives.
- Describe particulate and visibility monitors and their availability.
- Locate particulate matter and visibility data available through the Internet.

11-19-Rx410-EP

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Smoke guide
When and how to Monitor prescribed fire smoke CH2MHILL
Protocol and reference guides for monitoring equipment (MTDC)

Davies, Mary Ann. 2002. DataRAM4 particulate monitor: Forest Service user's guide. Tech. Rep. 0225-2810-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 26 p.

Davies, Mary Ann. 2002. User's guide for the DataRAM 2000 particulate monitor. Tech. Rep. 0225-2803-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 18 p.

Smoke Management Techniques, Rx-410

Unit 12 - Smoke Management Planning

Lesson A - NEPA Documentation

OBJECTIVE:

Upon completion of this lesson the student will be able to:

1. Discuss NEPA requirements in relationship to fire and air quality

2. List three criteria for identifying air quality as an issue in scoping.

3. Discuss a process to identify, describe, and quantify air impacts from prescribed fire and wildland fire use.

I. **Background:** The need for NEPA disclosure of air quality impacts associated with fire use activity is increasing in importance, as air quality regulations become more stringent. Smoke, whether from wild fire, wildland fire use, or prescribed fire affects air quality and therefore peoples' health and quality of life. Depending on agency terminology the effects of smoke from prescribed fire and wildland fire use should be considered in fire management plans and wildland fire use plans. Both types of documents should be tiered to the area's land and resource management plan. Smoke from prescribed fire and wildland fire use must meet federal, state, and local air quality regulations and are subject to NEPA. Wildfire is considered a "natural event" under EPA's Natural Events Policy and is not subject to NEPA.

· National Environmental Policy Act

A. **Background**: The National Environmental Policy Act, which was signed into law on January 1, 1970, is designed to:

"encourage productive and enjoyable harmony between man and his environment…promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man…enrich the understanding of the ecological systems and natural resources important to the nation."

NEPA applies to all federal agencies and to every major action taken by the agencies that significantly affects the quality of the human environment. NEPA supplements all statutes not in conflict with it. Not only does NEPA give federal agencies the power to consider the environmental effects of their proposed actions; it requires them to consider these impacts before implementing a plan.

B. Scope: NEPA is a procedural, not a substantive law. It prohibits uninformed rather than unwise decisions. Standards are set in other laws such as the Clean Air Act and Endangered Species Act. NEPA does not prohibit activities or projects, but establishes the decision-making process.

The Supreme Court has described NEPA as having two major purposes or aims. The first is to place "upon an agency the obligation to consider every significant aspect of the environmental impact of a proposed action." The second is to ensure "that the agency will inform the public that it has considered environmental concerns in its decision making process." This consideration of "every significant aspect of the environmental impact" must include, when appropriate, an analysis of direct and indirect air quality impacts.

NEPA (42 USC 4332) is specific in the type of analysis that must be conducted:

> Section 102. The Congress…directs that, all agencies of the Federal Government shall-
>
> (A) utilize a systematic, interdisciplinary approach [to] insure the integrated use of the natural and social sciences…in planning and in decision making which may [impact the] environment;
>
> (B) …develop methods and procedures…[to] ensure…environmental amenities [are considered] in decision making along with economic and technical considerations;
>
> (C) include…a detailed statement by the responsible official on-
>
> (i) the environmental impact of the proposed action,
> (ii) any [unavoidable] adverse environmental effect…,
> (iii) alternatives to the proposed action,
> (iv) …local short-term uses [and] long-term productivity, and
> (v) any irreversible and irretrievable [resource] commitments.

C. Elements of a NEPA Air Quality Analysis: The basic sections of either an Environmental Assessment or an Environmental Impact Statement are as follows:

1. Purpose and Need: The document should briefly specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action.

2. Alternatives: This section is the heart of the NEPA document. It should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decision maker and the public.

3. Affected Environment: The document should describe the environment of the area or areas to be affected by the alternatives under consideration. For air quality, the affected environment section should include the following:

   a. The general meteorology and climatology of the area, including temperature (average and range), precipitation (average and range), predominant wind directions, wind speeds, and occurrence of stagnation events.

   b. The location of sensitive receptors in the vicinity of the proposed project. Sensitive receptors may include but are not limited to roads, airports, residences, populated areas, schools, hospitals, non-attainment areas, class I areas, recreation areas, or popular vistas. (See 12A-01-Rx410-SR)

   c. The background air quality in the vicinity of the proposed project and identified sensitive receptors. Identify other sources of emissions that could affect the background air quality, such as industry, smoke from wood stoves, motor vehicles, urban centers, field burning, etc.

   d. A discussion of applicable air quality standards and regulations.

4. Environmental Consequences: This section should form the scientific and analytic basis for the comparison of alternatives in the document. For air quality the environmental consequences section should include the following for each alternative:

   a. Direct effects and their significance. For example, there may be an increase in short-term particulate matter concentrations resulting from a prescribed burn. The potential effects of particulate matter to public health and welfare including possible health effects, nuisance and soiling effects, and impairment of visibility in Class I areas will need to be addressed.

   b. Indirect effects and their significance. For example, there may be a decrease in wildfire emissions produced by a reduction in overall fuel loading following implementation of a prescribed burning program.

II. AGENCY RESPONSIBILITIES IN A NEPA AIR QUALITY ANALYSIS

All federal agencies have the responsibility to disclose possible air pollution impacts from land management activities including fire use.

EPA has been delegated responsibility by Section 309 of the Federal Clean Air Act to review certain proposed actions by other federal agencies. These EPA reviews are made public and, although EPA holds no authority to cancel or prohibit a specific project, the public may use their opinions. In cases where EPA has significant differences of opinion with the federal agency, EPA may refer the project to the Council on Environmental Quality.

III. IDENTIFYING AIR QUALITY AS AN ISSUE IN SCOPING:

Scoping should be designed to involve all affected and interested parties to determine the scope and significant issues to be analyzed. The following are some general guidelines when air quality issues and concerns are likely to be considered "significant" in the NEPA process.

- If the project by itself would not produce significant impacts but is associated with related projects that, taken together, would produce significant impacts. Significance cannot be avoided by terming an activity "temporary" or by breaking it down into smaller projects.

- If the project is within or near a Class I area.

- If the project might produce a significant amount of raw material whose primary use would reasonably be expected to produce significant amounts of air pollution emissions (i.e., firewood).

- If the project is within or in proximity to an area designated non-attainment for a pollutant emitted by fire.

- If the project or activity emits air pollutants and is located near historical or cultural resources, parks or campgrounds, vistas, high-use recreational areas, private inholdings, wild and scenic rivers, wilderness areas, scientific research areas, or other ecologically sensitive areas.

- If the project is viewed as "precedent setting" by the federal land manager, not necessarily in terms of air quality but for an element of the environment.

- If the project is near a public roadway or airport where visual range may be impaired.

- If the project is within or in proximity to an area where public complaints have previously been received.

- If the project is within or in proximity to populated areas.

The scoping process should be used to identify and eliminate issues that are not significant. **The line officer is the person who determines the significance of an issue**. "Significance", as used in NEPA, requires consideration of both context and intensity. Context refers to the temporal scales of the impacts (for example, short term or long term; site-specific, local, regional, or global). Intensity refers to the severity of the impacts at these varying scales (40 CFR 1508.27).

IV. DESCRIBING ALTERNATIVES

A. The use of fire as a tool to meet management objectives should be compared to non-fire alternatives. Document why fire is the preferred treatment alternative and why non-fire alternatives will not accomplish management objectives. Mix and match various scenarios for use of fire and non-fire alternatives to best meet management objectives while minimizing effects on air quality. Describe use of mitigation measures used to reduce impacts or total emissions. Be sure to include air quality protection benefits of standard practices such as compliance with smoke permitting requirements or burning when prevailing winds will take the smoke away from sensitive areas. The public and other environmental reviewers may not be aware of standard practices that protect air quality and that land managers often apply automatically.

1. Quantify the size of the area(s) to be treated and the amounts and types of material to be burned.

2. Estimate fuel consumption, and daily and annual particulate emission totals. Computer models that can help do this include CONSUME and FOFEM.

3. Describe mitigation measures that will be applied. Include compliance with local smoke management rules or regulations. Other mitigation measures include such things as burning when 1000-hr fuel moisture is high, piling fuels rather than broadcast burning, and burning concentrations of fuels rather than 100 percent of the treatment area. These and other mitigation measures are fully described in the Smoke Management Guide for Prescribed and Wildland Fire – 2001 Edition available through NWCG.

4. Identify the target season for burning. If burn objectives can be met in more than one season, consider air quality advantages of burning in a particular season. For example spring burning can result in reduced fuel consumption and better dispersion in some areas.

V. DESCRIBING ENVIRONMENTAL CONSEQUENCES

A. For each alternative quantify applicable emissions and perform dispersion model analysis. Numerous dispersion models are available for predicting downwind smoke concentrations including Calpuff, SASEM, VSMOKE, VSMOKE-GIS, NFSpuff, TSARS. Each model has unique applicability and features. More information is available in the 2001 Smoke Management Guide.

1. Compare predicted downwind concentrations of fine particulate matter (PM10 and PM2.5) to National Ambient Air Quality Standards or nuisance thresholds.

2. Describe potential visibility impacts in Class I or other potential smoke sensitive areas.

3. Mix and match burning scenarios for worst case emissions analysis to determine meteorological or other conditions where smoke accumulations could cause a problem.

4. Consider and describe the potential for other large emission sources to be impacting the air shed on the same day (for example other prescribed fire users or agricultural burning).

B. If an appropriate dispersion model is not available:

1. Describe qualitative impacts based on prevailing winds

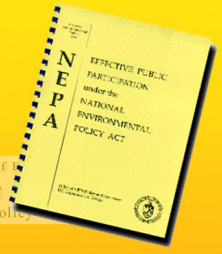
2. Include local knowledge of where smoke usually goes

Describe who or what may be impacted under specific conditions

Slide 1

NEPA Documentation

Unit 12A



U.S. Department of
Office of NEPA Policy
National Environmental Policy

12A-1-Rx410-EP

Slide 2

Unit 12A Objectives

1. Discuss NEPA requirements in relation to fire and air quality.
2. List three criteria for identifying air quality as an issue in scoping.
3. Discuss a process to identify, describe and quantify air impacts from prescribed fire and wildland fire use.

12A-2-Rx410-EP

Slide 3

National Environmental Policy Act

- Signed into law in 1970
- Applies to all federal agencies
- Requires all federal agencies to consider the environmental effects of their proposed actions before implementing them.

12A-3-Rx410-EP

Slide 4

NEPA

- Is Procedural, not Substantive Law
- Prohibits uninformed rather than unwise decisions
- Does not set standards
- Establishes the decision-making process

12A-4-Rx410-EP

Slide 5

Supreme Court on NEPA

NEPA has two major purposes:

1. Requires agencies "to consider every significant aspect of the environmental impact of a proposed action".
2. Requires that agencies "will inform the public that it has considered environmental concerns in its decision making process".

12A-5-Rx410-EP

Slide 6

NEPA is specific in the analysis that must be conducted

Agencies must:

- Utilize a systematic, interdisciplinary approach
- Ensure environmental amenities are considered along with economic and technical considerations

12A-6-Rx410-EP

Slide 7

NEPA is specific in the analysis that must be conducted

- Include a statement on:
  - the environmental impact of the proposed action
  - any unavoidable adverse environmental effects
  - alternatives to the proposed action
  - short-term uses and long-term productivity
  - Irreversible and irretrievable resource commitments.

12A-7-Rx410-EP

Slide 8

Elements of a NEPA Air Quality Analysis

- Purpose and Need
- Alternatives
- Affected Environment
- Environmental Consequences
  - Direct effects and their significance
  - Indirect effects and their significance

12A-8-Rx410-EP

Slide 9

EPA Responsibilities

Delegated responsibility under Section 309 of the Clean Air Act to:

- Review certain proposed actions by other Federal Agencies
- Where EPA and the agency have significant differences EPA may refer the project to the Council on Environmental Quality

12A-9-Rx410-EP

Slide 10

Identifying Air Quality as an Issue in Scoping

A project may be significant if it:

- **is associated with related projects that, taken together would produce significant impacts.**
- **is within or near a Class I area.**
- **may produce significant amounts of firewood**
- **is within or in proximity to a non-attainment area**
- **is located near high-use recreation areas**
- **is near a roadway or airport where visual range may be impaired**
- **is in an area where public complaints have been received**
- **is within or in proximity to populated areas**

12A-10-Rx410-EP

Slide 11

Scoping

Should be used to identify and eliminate non-significant issues. The line officer is the person who determines significance of an issue.

12A-11-Rx410-EP

Slide 12

"Significance" requires consideration of both context and intensity

- **Context – Temporal scales of impact (Short term or long term; site specific, local, regional or global)**
- **Intensity – Severity of impacts at these varying scales**

12A-12-Rx410-EP

Slide 13

Describing Alternatives

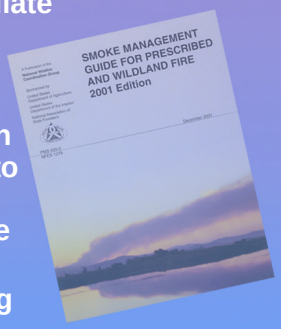
- Compare to the non-fire alternatives
- Mix and match various scenarios
- Describe mitigation measures to reduce impacts
- Describe air quality benefits of standard practices
- Quantify the size of the area and the amounts and types of material to be burned.

12A-13-Rx410-EP

Slide 14

Describing Alternatives (cont.)

- Estimate fuel consumption and daily and project particulate emission totals (CONSUME AND FOFEM may help)
- Describe mitigation measures – Refer to the 2001 Smoke Management Guide
- Identify target season for burning



12A-14-Rx410-EP

Slide 15

Describing Environmental Consequences

- For each alternative, quantify applicable emissions and perform dispersion model analysis. (See 2001 Smoke Management Guide for dispersion models available.)
- Compare downwind concentrations to ambient air quality standards
- Describe potential visibility impacts
- Determine when meteorological conditions may cause problems
- Consider the impact of other sources impacting the airshed on the same day

12A-15-Rx410-EP

Slide 16

If an appropriate dispersion model is not available:

- Describe qualitative impacts based on prevailing winds
- Include local knowledge of where smoke usually goes
- Describe who or what may be impacted under specific conditions

12A-16-Rx410-EP

Slide 17

Unit 12A Objectives

1. Discuss NEPA requirements in relation to fire and air quality.
2. List three criteria for identifying air quality as an issue in scoping.
3. Discuss a process to identify, describe and quantify air impacts from prescribed fire and wildland fire use.

12A-17-Rx410-EP

Sensitive Areas within 100 km (approx. 62 miles) Area of Consideration

Sensitive Areas		Direction from Project Area	Distance from Project Area	Prevailing Wind Direction for Smoke Transport	Potential for Residual Smoke 1/
Health/Nuisance	**Name**		**air miles**	**Y/N**	**Y/N**
Non-attainment and/ or Maintenance Areas	**Douglas County Non-Attainment Area**		**35**	**N**	**N**
Population Centers including Impact Zones	**Washington Hospital**	**NE**	**10**	**Y**	**?**
	Jefferson City	**NE**	**17**	**Y**	**?**
	Adams Park "Impact Zone"	**N**	**22**	**Y**	
	Lincoln City	**SSW**	**11**	**N**	**Y?**
	Davis Subdivision	**W**	**6**	**N**	**Y?**
	Hill City	**ENE**	**21**	**Y**	
	Banks Residence	**SSE**	**2**	**N**	**Y/N**
	Anderson "Impact Zone"	**SSE**	**3**	**N**	**Y/N**
Visibility	**Name**				
Class I Areas	**Clear View Wilderness**	**ESE**	**41**	**Y**	**N/A**
	Blue Sky Wilderness	**NNW**	**7**	**N**	**N/A**
Public Safety	**Name**				
Travel routes, airfields, campgrounds, etc.	**Deep Water Reservoir**	**ENE**	**19**	**Y**	**N**
	Highway 55	**E**	**4**	**Y**	**Y**
	FS Road 610, 618, 644	**ALL**	**1-19**	**Y**	**Y**

1/ Potential for residual smoke occurs primarily during the evening hours after day time transport winds and mixing height decrease and smoke from residual burning of fuels after ignition can continue to smolder. Smoke from residual burning can often be carried down drainage/canyon with nighttime flows of air or in close proximity along daytime plume trajectories

Smoke Management Techniques, Rx-410

Unit 12 - Smoke Management Planning

Lesson B - Incorporating Smoke Management into a Burn Plan

OBJECTIVES:

Upon completion of this lesson the student will be able to:

1. Describe how smoke management concerns are incorporated into a burn plan.

2. Describe how to integrate prescribed fire objectives and smoke management strategies to meet project objectives and minimize/mitigate air quality issues.

3. Identify the trigger points and contingency planning needed to mitigate impacts or terminate a burn due to smoke.

I. SMOKE MANAGEMENT

Smoke management should be considered throughout all phases of burn planning. Good decisions early in the planning process will make it easier to attain smoke management objectives during burns. Examples:

- Design of a burn unit, placement of firelines, firing sequences and patterns, can have a significant influence on personnel exposure and impact on roads.

- Being proactive with the community will pay great dividends in public acceptance.

- Other examples?

II. BURN PLANS

Burn plans should include quantified smoke management objectives.

A. Reasons for quantification are to:

1. Eliminate hasty or impulsive decision making by burn boss.

2. Establish a common, measurable level of acceptable impact on all individuals participating on burn. Important for communications, operations, crew health and safety.

3. Require periodic assessment and documentation of smoke behavior, such as column dissipation or monitoring personnel for exposure, to achieve burn plan compliance.

4. Add credibility to burn plan.

5. Provide opportunity for prescription refinement over long term (sequence of burns over time).

B. Use smoke management objectives as trigger points for assessing the severity of smoke impacts and whether to terminate the burn.

C. In burn plan development, include a contingency plan for terminating a prescribed fire because of smoke impacts.

Slide 1

Slide 2

Unit 12B Objectives

- **Describe how smoke management concerns are incorporated into a burn plan.**
- **Describe how to integrate prescribed fire objectives and smoke management strategies to meet project objectives and minimize/mitigate air quality issues.**

12B-2-Rx410-EP

Slide 3

Unit 12B Objectives

- **Identify the trigger points and contingency planning needed to mitigate impacts or terminate a burn due to smoke.**

12B-3-Rx410-EP

Slide 4

The Burn Plan

- How does the burn plan relate to other planning documents?
  - NEPA documents
  - State planning documents
  - Other programmatic documents

12B-4-Rx410-EP

Slide 5

Practice Good Planning

- Smoke management should be considered throughout all phases of burn planning.

12B-5-Rx410-EP

Slide 6

Plan Ahead

- Good decisions made early in the planning process will make it easier to attain smoke management objectives during burns.
  - Examples?

12B-6-Rx410-EP

Slide 7

- Burn plans should include quantified smoke management objectives.
  - Eliminate hasty decisions
  - Establish common, measurable acceptable impacts
  - Require assessment and documentation
  - Add credibility
  - Provide opportunity for prescription refinement

12B-7-Rx410-EP

Slide 8

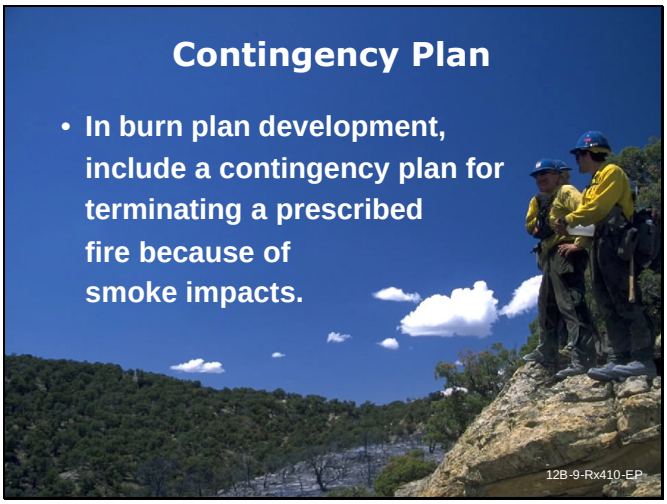
- Use smoke management objectives as trigger points for assessing the severity of smoke impacts and whether to terminate the burn.

12B-8-Rx410-EP

Slide 9

Contingency Plan

- In burn plan development, include a contingency plan for terminating a prescribed fire because of smoke impacts.



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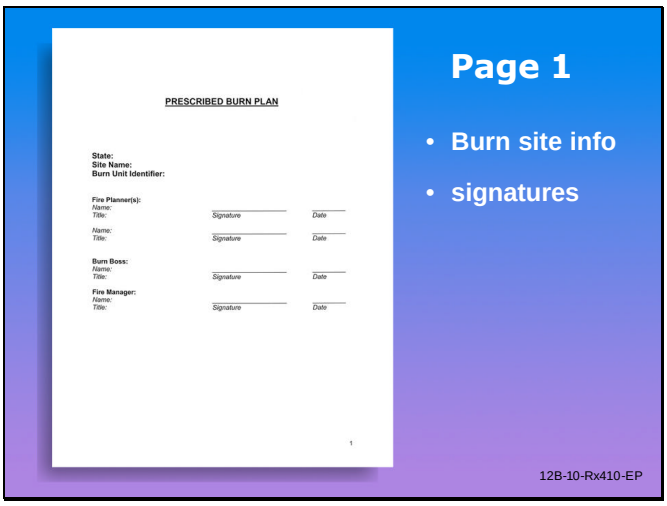

PRESCRIBED BURN PLAN

State:
Site Name:
Burn Unit Identifier:

Fire Planner(s):
Name:
Title: Signature Date

Name:
Title: Signature Date

Burn Boss:
Name:
Title: Signature Date

Fire Manager:
Name:
Title: Signature Date

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Page 1

- Burn site info
- signatures

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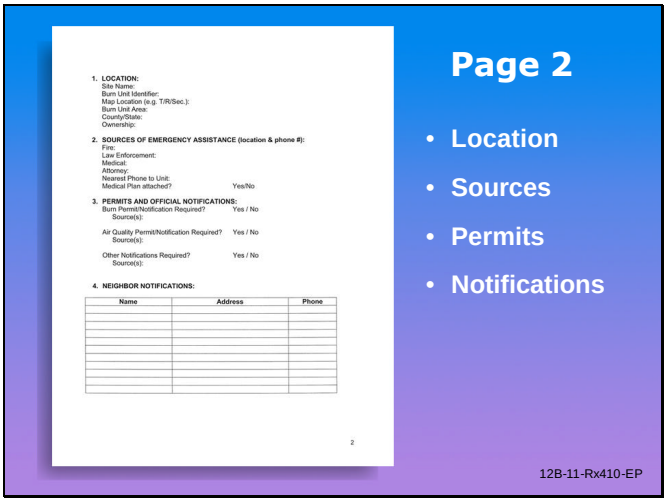

1. LOCATION:
   Site Name:
   Burn Unit Identifier:
   Map Location (e.g. T/R/Sec.):
   Burn Unit Area:
   County/State:
   Ownership:
2. SOURCES OF EMERGENCY ASSISTANCE (location & phone #):
   Fire:
   Law Enforcement:
   Medical:
   Attorney:
   Nearest Phone to Unit:
   Medical Plan attached? Yes/No
3. PERMITS AND OFFICIAL NOTIFICATIONS:
   Burn Permit/Notification Required? Yes / No
   Source(s):
   Air Quality Permit/Notification Required? Yes / No
   Source(s):
   Other Notifications Required? Yes / No
   Source(s):
4. NEIGHBOR NOTIFICATIONS:

Name	Address	Phone

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Page 2

- Location
- Sources
- Permits
- Notifications

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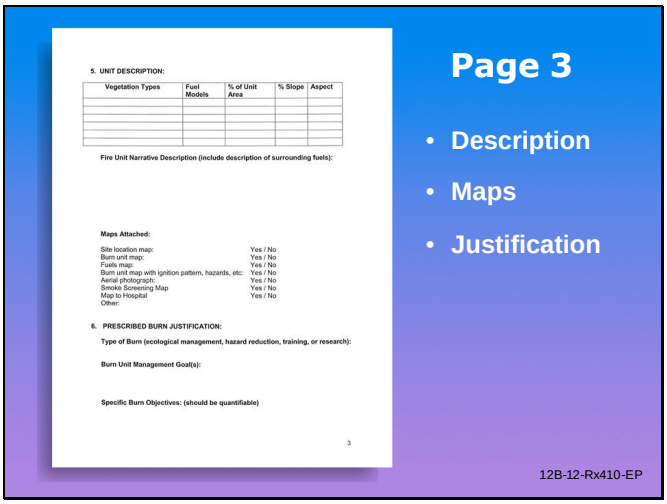

5. UNIT DESCRIPTION:

Vegetation Types	Fuel Models	% of Unit Area	% Slope	Aspect

Fire Unit Narrative Description (include description of surrounding fuels):

Maps Attached:

Site location map: Yes / No
Burn unit map: Yes / No
Fuels map: Yes / No
Burn unit map with ignition pattern, hazards, etc: Yes / No
Aerial photograph: Yes / No
Smoke Screening Map Yes / No
Map to Hospital Yes / No
Other:

6. PRESCRIBED BURN JUSTIFICATION:

Type of Burn (ecological management, hazard reduction, training, or research):

Burn Unit Management Goal(s):

Specific Burn Objectives: (should be quantifiable)

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Page 3

- Description
- Maps
- Justification

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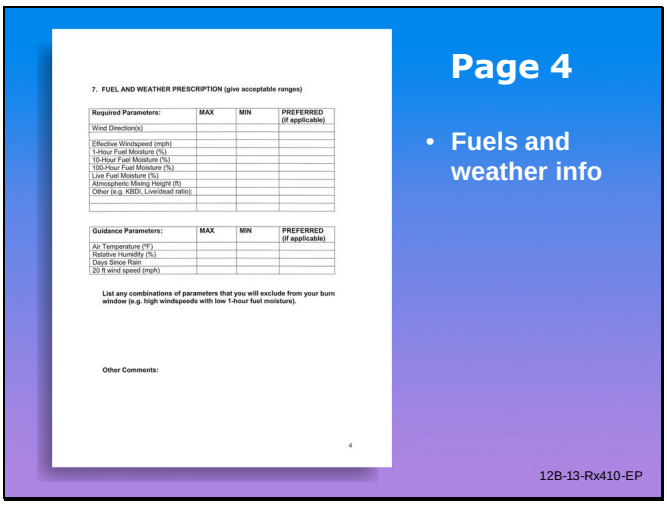

7. FUEL AND WEATHER PRESCRIPTION (give acceptable ranges)

Required Parameters:	MAX	MIN	PREFERRED (if applicable)
Wind Direction(s)			
Effective Windspeed (mph)			
1-Hour Fuel Moisture (%)			
10-Hour Fuel Moisture (%)			
100-Hour Fuel Moisture (%)			
Live Fuel Moisture (%)			
Atmospheric Mixing Height (ft)			
Other (e.g. KBDI, Live/dead ratio):			

Guidance Parameters:	MAX	MIN	PREFERRED (if applicable)
Air Temperature (°F)			
Relative Humidity (%)			
Days Since Rain			
20 ft wind speed (mph)			

List any combinations of parameters that you will exclude from your burn window (e.g. high windspeeds with low 1-hour fuel moisture).

Other Comments:

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- Fuels and weather info

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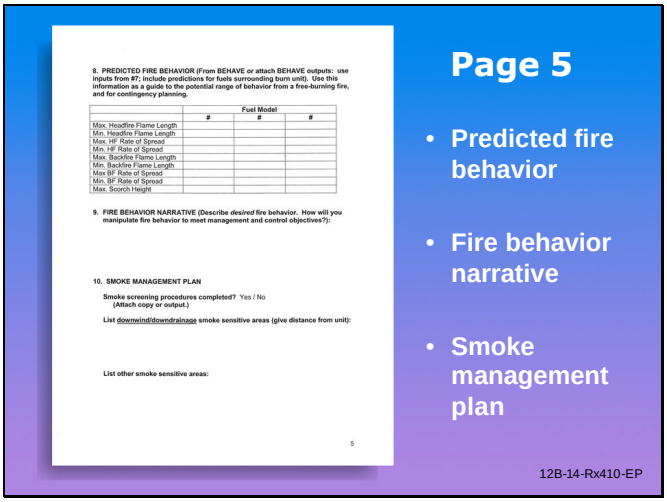

8. PREDICTED FIRE BEHAVIOR (From BEHAVE or attach BEHAVE outputs: use inputs from #7; include predictions for fuels surrounding burn unit). Use this information as a guide to the potential range of behavior from a free-burning fire, and for contingency planning.

	Fuel Model		
	#	#	#
Max. Headfire Flame Length			
Min. Headfire Flame Length			
Max. HF Rate of Spread			
Min. HF Rate of Spread			
Max. Backfire Flame Length			
Min. Backfire Flame Length			
Max BF Rate of Spread			
Min. BF Rate of Spread			
Max. Scorch Height			

9. FIRE BEHAVIOR NARRATIVE (Describe *desired* fire behavior. How will you manipulate fire behavior to meet management and control objectives?):

10. SMOKE MANAGEMENT PLAN

Smoke screening procedures completed? Yes / No
(Attach copy or output.)

List downwind/downdrainage smoke sensitive areas (give distance from unit):

List other smoke sensitive areas:

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- Predicted fire behavior
- Fire behavior narrative
- Smoke management plan

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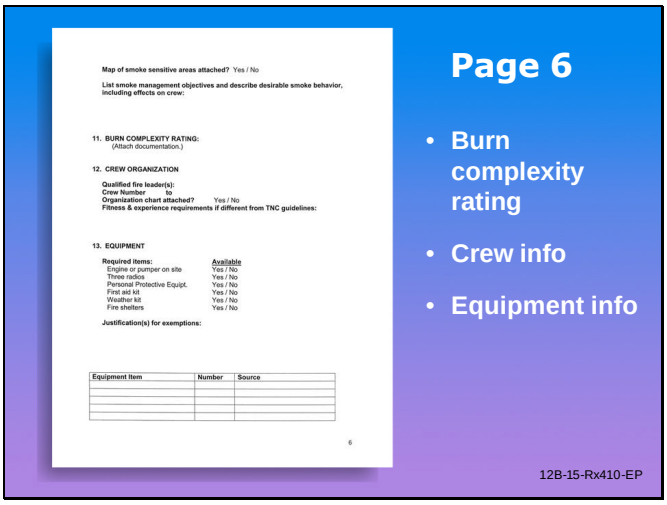

Map of smoke sensitive areas attached? Yes / No

List smoke management objectives and describe desirable smoke behavior, including effects on crew:

11. BURN COMPLEXITY RATING:
(Attach documentation.)

12. CREW ORGANIZATION

Qualified fire leader(s):
Crew Number to
Organization chart attached? Yes / No
Fitness & experience requirements if different from TNC guidelines:

13. EQUIPMENT

Required items:	Available
Engine or pumper on site	Yes / No
Three radios	Yes / No
Personal Protective Equipt.	Yes / No
First aid kit	Yes / No
Weather kit	Yes / No
Fire shelters	Yes / No

Justification(s) for exemptions:

Equipment Item	Number	Source

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Page 6

- Burn complexity rating
- Crew info
- Equipment info

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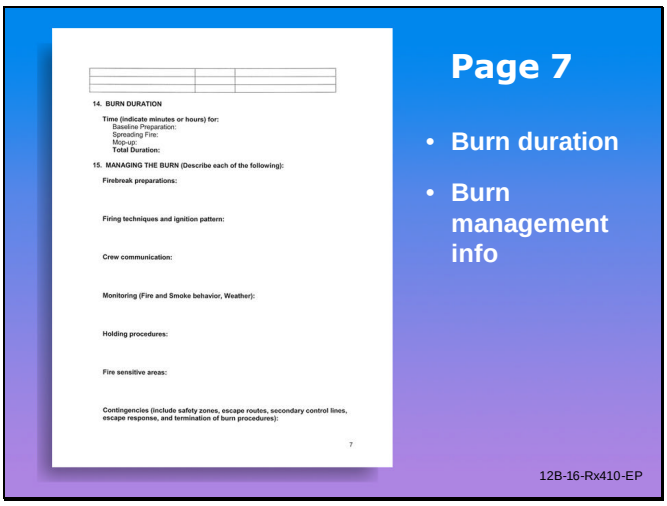

14. BURN DURATION

Time (indicate minutes or hours) for:
Baseline Preparation:
Spreading Fire:
Mop-up:
Total Duration:

15. MANAGING THE BURN (Describe each of the following):

Firebreak preparations:

Firing techniques and ignition pattern:

Crew communication:

Monitoring (Fire and Smoke behavior, Weather):

Holding procedures:

Fire sensitive areas:

Contingencies (include safety zones, escape routes, secondary control lines, escape response, and termination of burn procedures):

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- Burn duration
- Burn management info

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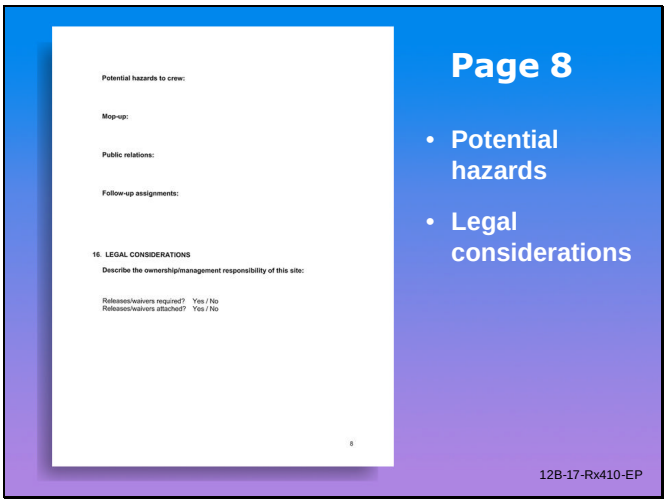

Potential hazards to crew:

Mop-up:

Public relations:

Follow-up assignments:

16. LEGAL CONSIDERATIONS

Describe the ownership/management responsibility of this site:

Releases/waivers required? Yes / No
Releases/waivers attached? Yes / No

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- Potential hazards
- Legal considerations

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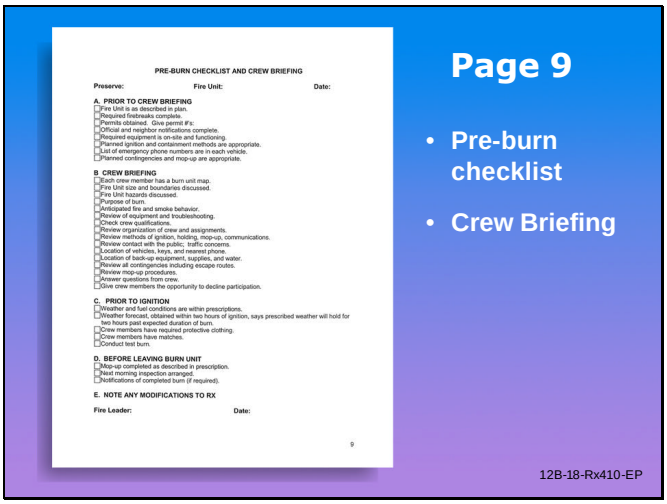

PRE-BURN CHECKLIST AND CREW BRIEFING

Preserve: **Fire Unit:** **Date:**

A. PRIOR TO CREW BRIEFING
- ☐ Fire Unit is as described in plan.
- ☐ Required firebreaks complete.
- ☐ Permits obtained. Give permit #'s:
- ☐ Official and neighbor notifications complete.
- ☐ Required equipment is on-site and functioning.
- ☐ Planned ignition and containment methods are appropriate.
- ☐ List of emergency phone numbers are in each vehicle.
- ☐ Planned contingencies and mop-up are appropriate.

B CREW BRIEFING
- ☐ Each crew member has a burn unit map.
- ☐ Fire Unit size and boundaries discussed.
- ☐ Fire Unit hazards discussed.
- ☐ Purpose of burn.
- ☐ Anticipated fire and smoke behavior.
- ☐ Review of equipment and troubleshooting.
- ☐ Check crew qualifications.
- ☐ Review organization of crew and assignments.
- ☐ Review methods of ignition, holding, mop-up, communications.
- ☐ Review contact with the public; traffic concerns.
- ☐ Location of vehicles, keys, and nearest phone.
- ☐ Location of back-up equipment, supplies, and water.
- ☐ Review all contingencies including escape routes.
- ☐ Review mop-up procedures.
- ☐ Answer questions from crew.
- ☐ Give crew members the opportunity to decline participation.

C. PRIOR TO IGNITION
- ☐ Weather and fuel conditions are within prescriptions.
- ☐ Weather forecast, obtained within two hours of ignition, says prescribed weather will hold for two hours past expected duration of burn.
- ☐ Crew members have required protective clothing.
- ☐ Crew members have matches.
- ☐ Conduct test burn.

D. BEFORE LEAVING BURN UNIT
- ☐ Mop-up completed as described in prescription.
- ☐ Next morning inspection arranged.
- ☐ Notifications of completed burn (if required).

E. NOTE ANY MODIFICATIONS TO RX

Fire Leader: **Date:**

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- Pre-burn checklist
- Crew Briefing

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Unit 12B Objectives

- Describe how smoke management concerns are incorporated into a burn plan.
- Describe how to integrate prescribed fire objectives and smoke management strategies to meet project objectives and minimize/mitigate air quality issues.

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Unit 12B Objectives

- Identify the trigger points and contingency planning needed to mitigate impacts or terminate a burn due to smoke.

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