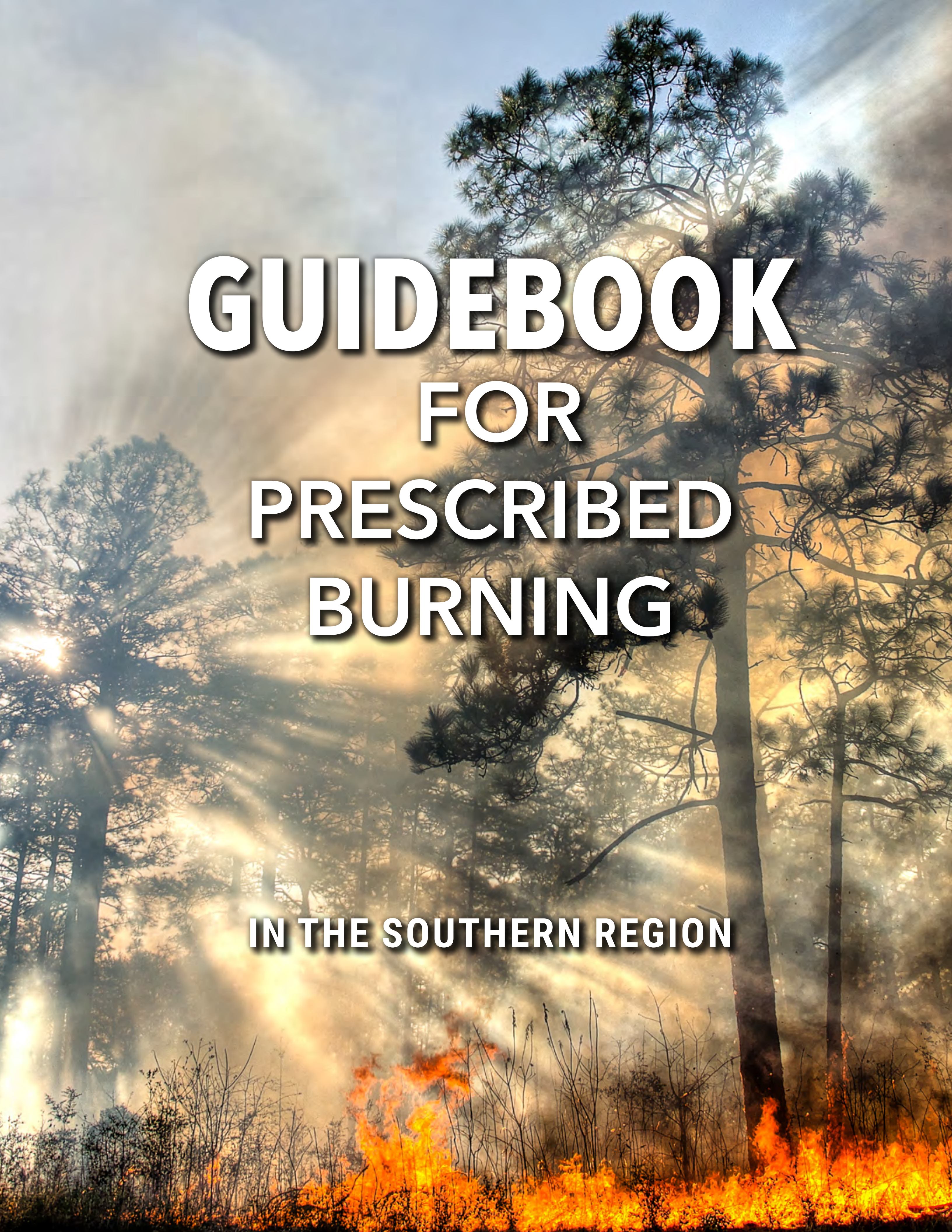

GUIDEBOOK FOR PRESCRIBED BURNING

IN THE SOUTHERN REGION

Front cover image courtesy of James Johnson

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Image courtesy of Mark O'Leary

WHY THIS GUIDEBOOK?

Prescribed fire is a key tool for those who own or manage land in the Southeastern United States. It creates important habitat for game and nongame wildlife, clears out vegetation to reduce wildfire risk, connects people to their cultural heritage, and has many other important benefits.

However, learning to use prescribed fire safely can be challenging, especially for private landowners who have limited time and resources. Training and learning opportunities vary by state and are not always accessible to everyone. This guidebook is not intended to replace existing resources or training opportunities, but to serve as a reference, and to help fill the gap that exists for those who cannot access them or who wish to learn more than those opportunities have time to teach. This guidebook is primarily intended for private landowners who own natural land areas that would benefit from prescribed fire, especially those landowners with at least 5 acres of land. However, the principles and rules detailed in this book apply no matter the size of the land and will be useful for anyone interested in prescribed burning. Many natural resource professionals who burn occasionally as part of their work may find the book helpful too.

It is important to note that this guidebook was written with a focus on the Southeastern U.S. and covers what is needed for a landowner or burner in the South to create a burn plan and conduct a burn according to their state rules. Each section may seem complex and even intimidating, but the topic it covers, such as creating a burn plan, can be relatively simple in practice. This guidebook errs on the side of providing more information, with the intention that readers can just use the information that is helpful to them. Each state also has different regulations and requirements surrounding burning, and therefore may be slightly different than what is included here. Despite this, this guide provides sufficient information to help you complete your burn plan to meet the requirements for your state.

Image courtesy of Leslie Boby

HOW DO I USE THIS GUIDEBOOK?

This guidebook will take you step-by-step through the processes involved in planning, preparing for and conducting a prescribed fire on your land. Each section is color-coded and designed to provide you with "checklists" of activities that need to be done, along with the timeline for each step. This guidebook is comprehensive and will take you from the earliest planning stages to final evaluation of your burn.

This guide has two types of chapters: action and informational

Action chapters are focused on the steps involved in prescribed fire from start to finish and include checklists of information to be gathered or actions to take. Within the chapter, each step in the checklist is described in enough detail so that the reader can do what they need to do.

Action Chapters:

- Getting Started
- Planning
- Conducting
- Evaluating

Informational chapters provide more in-depth information on important topics related to fire. These chapters include helpful diagrams, descriptions, and instructions for using tools.

Informational Chapters:

- Weather
- Smoke management
- Fuels
- Fire behavior

We strongly recommend that you seek guidance from your local state forestry agency who can provide you with advice and recommendations for your specific situation. A consulting forester, prescribed fire contractor, or Cooperative Extension Agent may also be able to provide helpful information.

INDEX *– CHAPTERS EXPANDED*

GETTING STARTED

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CONDUCTING THE BURN

EVALUATING THE BURN

WEATHER

SMOKE MANAGEMENT

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MASTER TIMELINE – *PRESCRIBED BURNING OVERVIEW*

STARTING → ← **PLANNING** →

6 MONTHS - 1 YEAR

Getting started
See page 19.

- ☐ Start the process of research
- ☐ Walk the proposed burn area
- ☐ Determine property objectives

Develop a burn plan
See page 34.

- ☐ Define burn & objectives
- ☐ Map burn areas
- ☐ Develop stand vegetation descriptions
- ☐ Determine acceptable weather parameters for burn

Pre-burn preparation
See page 44.

- ☐ Determine manpower
- ☐ Fire equipment needs
- ☐ Identify neighbors to notify
- ☐ Establish firebreaks

1-3 MONTHS BEFORE

Weeks before the burn
See page 63.

- ☐ Monitor weather
- ☐ Review the burn plan
- ☐ Check firebreaks
- ☐ Begin gathering equipment
- ☐ Notify neighbors you are planning to burn in the coming weeks

CONDUCTING

EVALUATING

DAY OF THE BURN

MONTHS AFTER BURN

Days before the burn

See page 64.

- ☐ Monitor weather
- ☐ Review the burn prescription
- ☐ Walk the burn unit
- ☐ Review your smoke management plan and best practices
- ☐ Confirm your burning team
- ☐ Prepare your fire equipment
- ☐ Make copies of the burn map for all
- ☐ Notify emergency services and neighbors that a burn is planned in the coming days

Morning

- ☐ Obtain fire weather forecast to print
- ☐ Burn permit

Immediately before

- ☐ Monitor and log weather onsite & several times during the day
- ☐ Test burn
- ☐ Evaluate smoke dispersion with test fire

During burn

- ☐ Follow ignition plans
- ☐ Adjust according to fire behavior
- ☐ Monitor Smoke Patterns & firebreaks

End of burn

- ☐ Mop-up
- ☐ After-action review

See page 68.

Initial post-burn evaluation

See page 85.

- ☐ Conduct after completing burn, within at least a week

Secondary evaluation

See page 88.

- ☐ Conduct after first growing season (~3-6 months) based on burn objectives

CHECKLIST FOR PRESCRIBED BURN PLANNING

GETTING STARTED

- [ ] **Start the process of research.** While this guidebook is a great reference for beginners, there are numerous other resources that can aid you in your prescribed fire journey.
- [ ] **Walk the proposed burn area** and get a feel for your property's needs.
- [ ] **Determine property objectives** that are measurable and achievable.

DEVELOP A BURN PLAN

- [ ] Define purpose and objectives of the burn
- [ ] Create a map of the areas to be burned
- [ ] Identify smoke-sensitive areas and locate on map
- [ ] Conduct smoke screening system
- [ ] Highlight special precautions
- [ ] Develop stand and vegetation descriptions
- [ ] Determine timing for burn
- [ ] Determine acceptable weather parameters for burn

PRE-BURN TASKS AND CONSIDERATIONS

- [ ] Determine manpower needs
- [ ] Determine fire equipment needs
- [ ] Estimate the number of hours needed to complete the burn
- [ ] Identify adjacent landowners to notify
- [ ] Establish firebreaks
- [ ] Develop contingency plans

FIRE AND SAFETY EQUIPMENT

- [ ] Assemble personal protective equipment (PPE)
- [ ] Obtain fire equipment

CHECKLIST FOR CONDUCTING PRESCRIBED FIRE – *PREPARATION*

WEEKS BEFORE THE BURN CHECKLIST

- [ ] **Review the burn plan**
- [ ] **Check firebreaks**
  - Create firebreaks, if needed
- [ ] **Monitor weather**
  - Be sure to review general weather trends, such as predicted rains and fronts
  - Check various parameters to compare to your burn prescriptions - (relative humidity, wind direction and speed, and temperature) this is a great opportunity to practice!
- [ ] **Develop a smoke management plan**
- [ ] **Walk the burn unit and look for safety hazards**
  - Look for any situations that have the potential to promote intense fire (i.e. snags)
  - Add any safety hazards to the burn unit map
- [ ] **Begin gathering necessary fire equipment**
- [ ] **Notify neighbors to let them know you are planning to burn in the coming weeks**

DAYS BEFORE THE BURN CHECKLIST

- [ ] **Review the burn prescription**
  - Make copies for your team
- [ ] **Walk the burn unit**
  - Check all firebreaks to ensure they are still clear
  - Check the duff, or soil layers, to assess dryness and general moisture content
- [ ] **Monitor weather**
  - Review the fire weather forecast, particularly the relative humidity, wind direction and speed, and temperature. Also, take note of anticipated dispersion indices. Compare all values to the burn prescription.
- [ ] **Review your smoke management plan and best practices**
- [ ] **Confirm you have enough people to complete a successful burn**
- [ ] **Prepare your fire equipment as needed**
  - Make sure your power tools are operable and are appropriately fueled
  - Check other tools to make sure they are functional (e.g. radios have fresh batteries, no loose toolheads, etc.)
- [ ] **Make copies of the burn map for all participants**
- [ ] **Notify emergency services and neighbors that a burn is planned in the coming days**

CHECKLIST FOR CONDUCTING PRESCRIBED FIRE – *DAY OF*

DAY OF THE BURN CHECKLIST – *MORNING*

- [ ] **Obtain fire weather forecast and print**
  - Compare fire weather forecast with the burn prescription
- [ ] **If weather conditions are acceptable, obtain burn permit and sign prescription**
- [ ] **Remind emergency services and neighbors that a burn is taking place**
- [ ] **Make sure you have copies of the burn plan and burn map available for all participants**

ON THE FIRELINE CHECKLIST

IMMEDIATELY BEFORE BURN

- [ ] **Monitor and log weather onsite**
  - Before and during the burn
- [ ] **Conduct crew briefing**
  - Familiarize the crew with the burn unit
  - Provide copies of the burn plans and map(s)
  - Review burn plan objectives
  - Review the map
  - Review the contingency plan
  - Review the fire weather forecast
  - Assign roles and responsibilities
  - Establish communications
  - Address safety and risk management
- [ ] **Review the *Go/No-Go* checklist**
- [ ] **Verify the downwind side**

TEST BURN

- [ ] **Complete a test fire**
  - Determine if the burn will proceed

BURN

- [ ] **Begin burn**
- [ ] **Observe fire behavior and adjust accordingly**
- [ ] **Monitor smoke patterns**
- [ ] **Monitor firebreaks**

END OF BURN

- [ ] **Mop-up**
- [ ] **After-action review**

EVALUATION CHECKLIST

- [ ] Conduct an initial evaluation after the burn is completed or the next morning, but at least within a week of the burn
- [ ] Conduct a secondary evaluation during or after the first growing season (~3-6 months later), depending on your burn objectives

GETTING STARTED

Image courtesy of Lindsay Thomas

Table of Contents

- [ ] Review your land management goals & objectives
- [ ] Determine the goal(s) of prescribed burning on your land
- [ ] List your prescribed fire objective(s)
- [ ] Determine the general timing of your burn

What is Prescribed Fire?

Prescribed fire is the controlled application of fire to natural land areas under particular environmental conditions to achieve specific land management goals. This distinguishes it from wildfire, which is unplanned.

Prescribed burns include the following set of characteristics:

- ✓ Planned
- ✓ Applied in set locations, under particular weather conditions and in a skillful manner
- ✓ Used to achieve specific results

> ***"Fire is so dominant a process that it determines, to an inordinate degree the composition, structure, and dynamics of many ecosystems. Fire as a process is complex; fire effects will vary among ecosystems and be a function of the timing and intensity of the fires."***

(Pyne, Andrews & Laven, 1996, p. 171)

You may hear the terms "**controlled burn**","**prescribed burn**", and "**prescribed fire**" used interchangeably. In this guidebook, prescribed fire and prescribed burn are the terms used.

Wildland Fire: A History

Natural areas, such as forests or grasslands, across the world are often dependent on repeated fire to maintain the plant and wildlife diversity. While wildland fires are started by natural causes such as lightning strikes, humans are the most common ignition source. For thousands of years, Native Americans intentionally set fire to the landscape in order to maintain desirable conditions for agriculture, clear areas for traveling, and promote hunting conditions and wildlife habitat. Subsequently, European colonizers continued the use of fire for similar reasons.

While there is a long history of prescribed fire use across the country, attitudes and practices in the 20th century changed. Beginning in the early 1900's, the United States Forest Service (USFS) and state forestry agencies developed the means to suppress and control wildfires and part of this strategy was to create crews of forest firefighters. In 1910, devastating wildfires burned 3 million acres in Montana, Idaho, and Washington in only two days, killing many forest fighters. Influenced by the effects of such events, the USFS adopted policies that all wildfires should be extinguished as soon as possible. These same policies strongly opposed the use of "light burning" (as it was called then) or prescribed fire. At the time, "light burning" was common practice for a variety of reasons for Native Americans, farmers, ranchers, forest landowners and timber companies. However, new scientific evidence, which emerged in the 1960's supported the importance and need for fires in forests and grasslands. Since the 1970's, federal and state agencies have gradually shifted practices to be more fire-friendly. Despite this shift in national policy, implementing changes has been challenging, as now many of these lands have gone decades without fire. Much local burning knowledge and experience has been lost over time. Currently, the general public, who have been exposed to the USFS' mascot Smokey Bear and his catchphrase ("only you can prevent forest fires") for generations, perceive any kind of fire as very dangerous. That view is now gradually changing, as is Smokey's message.

Image 1.1. Unidentified men carrying out a controlled burn in the 1950's (State Archives of Florida).

Nearly 100 years of wildfire suppression and lack of prescribed fire has, in many cases, altered the health and function of forest and grassland ecosystems. For example, without prescribed fire many grasslands across Oklahoma, Texas, Kansas, and Nebraska have had various shrubs and trees overtake fields. Frequent, low intensity fires in these grasslands kill such woody species and prevents them from drastically altering the ecosystem. Similarly, in many forested landscapes, pine needles, leaves, sticks and other organic matter accumulate. This can cover up the ground completely and suppress vegetation growth. In addition to crowding out new plant growth, this build-up of material can also pose more risks in the event of a wildfire, as there is more fuel to burn. Using prescribed fire on these lands can restore their health and function, as well as reduce the risk of wildfires.

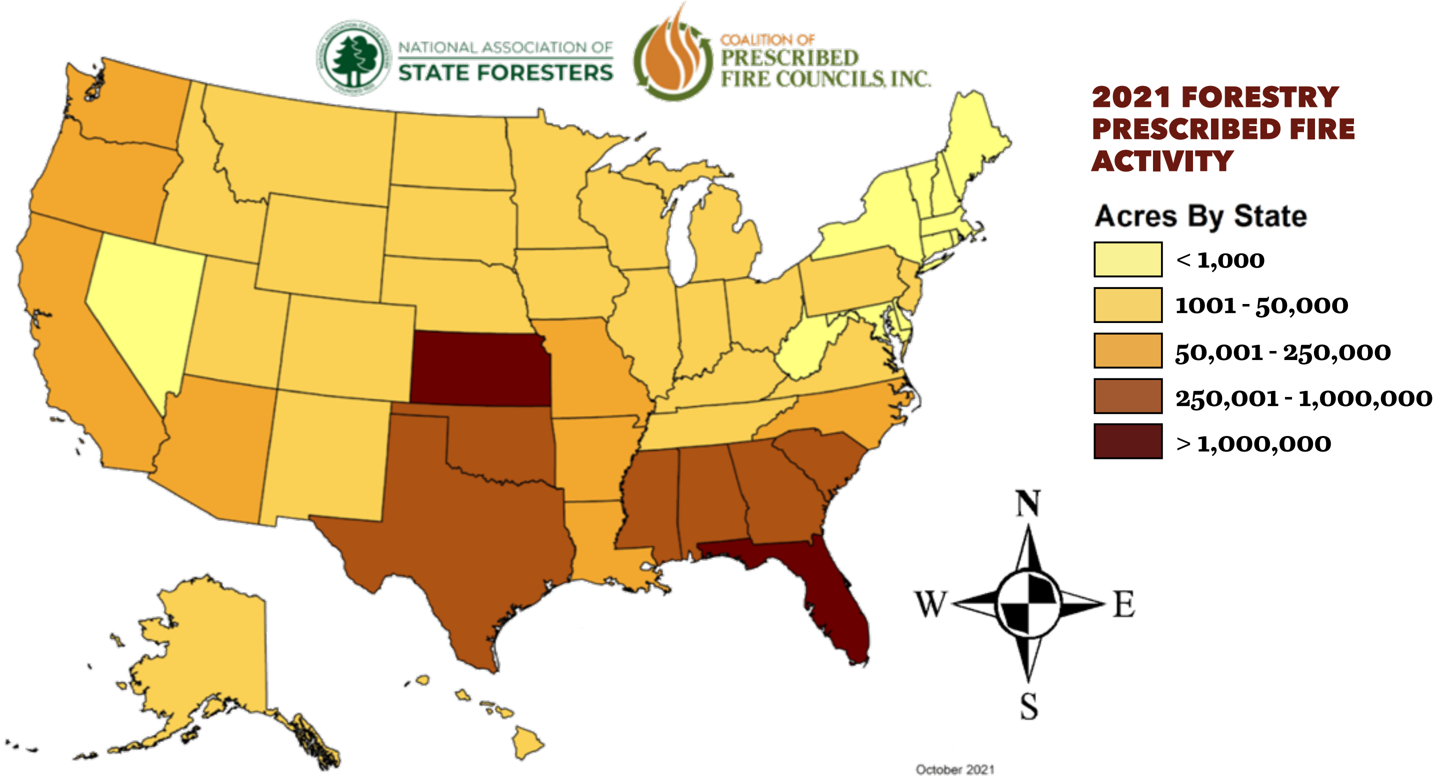
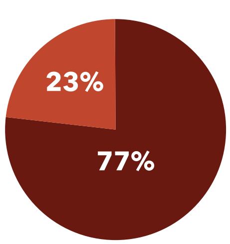


Figure 1.1. 2021 acreage of prescribed fire use for forestry and rangeland objectives by state (Melvin, 2021).

Prescribed Fire in the South

National policies from the USFS focused on putting out all wildfires. However, in many parts of the South "woods burning has a long unbroken history and was a widespread practice" (Johnson & Hale, 2002, p. 11). Researchers in the South have long recognized the important role prescribed fire plays in land management and have led the country in training and practice. As early as 1931, Herbert Stoddard was one of the first scientists to advocate for prescribed fire, as his research demonstrated bobwhite quail populations plummeted in areas without it. In 1971, the USFS hosted a scientific symposium on prescribed burning and the 400+ participants unanimously agreed that prescribed fire use in the South is "an almost indispensable management device having generally beneficial effects on the crop trees, on the soils on which they grow or on the flora or fauna of the area burned" (Johnson & Hale, 2002, p. 16). The strong support and understanding of prescribed fire in the South still persists to this day. More acres are burned in the South by prescribed fire than the rest of the country combined (Figure 1.1). In 2017, more than 7.5 million acres were burned in prescribed fires, three-fourths of which were forested land (Figure 1.2).



Forestry - 5,810,066 Acres

Agriculture - 1,766,694 Acres

Figure 1.2. Percentages of 2017 southeastern prescribed fire activity by resource objective (Melvin, 2018).

Why Burn?

Prescribed fire is a multifaceted management tool for forests, grasslands and other natural areas. It can be used for a variety of reasons; however, it is not the best tool for all situations. Nor can you accomplish all your land and property goals through one prescribed burn. Conducting prescribed burns should fit into your overall land management plan.

In the South, prescribed fire is commonly used **to improve forest health and resiliency, clear land, and dispose of debris** from logging or severe weather events. Removing forest litter and reducing dense duff layers can help lessen wildfire risk to trees and nearby communities in the wildland-urban interface (communities near forests that have the potential to burn). For production forestry, prescribed fire can provide an **economical way to manage vegetation** that competes for resources with marketable trees. It can also be used to **control insect and disease outbreaks**.

Habitat for wildlife, as well as forage for livestock grazing, can also be improved by prescribed fire. For example, regular fire tends to favor understory plant species that provide good browse. These plants benefit numerous game species, such as deer, dove, quail, and turkey. Prescribed fire also creates open habitat, and this type of habitat houses a variety of wildlife, such as red-cockaded woodpeckers, Bachman's sparrows, golden-winged warblers, painted buntings, timber rattlesnakes, northern pine snakes, gopher frogs, and gopher tortoises.

Many forests in the United States include plant communities that depend on periodic fire. Prescribed burns benefit these ecosystems through repeated low-intensity fires. Two examples of fire-adapted species in the Southeast include longleaf pine (*Pinus palustris*) and table mountain pine (*Pinus pungens*). Fire-adapted plants also have a variety of protective traits. For instance, some adaptations include thick scaly bark, re-sprouting from the root crown or underground stems, and seeds that germinate only after the seed coat is damaged in some way. Serotinous cones are another unique adaptation. Serotinous cones are covered with a resin that must be melted for the cone to open and release seeds.

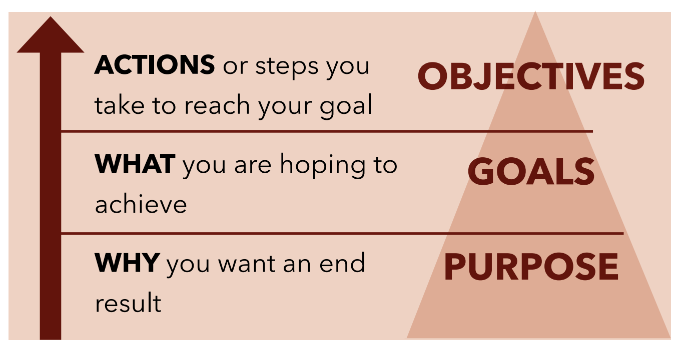
Finally, restoring land with prescribed fire can be rewarding and fun, and individuals often find themselves forming a community around their burning activities.

Getting Started on Your Burn Plan

1. REVIEW YOUR LAND MANAGEMENT GOALS & OBJECTIVES

Before you can plan a burn, you need to determine if prescribed fire will help you to meet the different goals that fit within your land management purpose. Land management plans also include information about objectives that will help you meet those goals. For example, you may have the goal of improving the health of a forested area on your land and prescribed fire may help you meet that goal. When determining the purpose of your burn, you may also think about how you expect the characteristics of that area to change following the burn. For instance, what will be eliminated or consumed, or what should be left following the burn? Once you know the purpose of the burn, the rest of your planning is shaped around your desired end result.

This process can take some time, but it is very important for determining where, when, and how prescribed fire can be used on your land.



It is extremely rare for wildlife to be killed by prescribed burns.
Most wildlife can leave an area before it burns, or can burrow underground to avoid the fire. After the burn, plants and shrubs emerge which provide new sources of food.

NOTE: Many organizations use the terms **purpose, goals** and **objectives** interchangeably, but all typically focus on what you want to achieve and how you will achieve it.

Do your best when identifying your goals and objectives, but do not worry about making them 'perfect.' It is better to have broad, achievable goals, than none at all.

2. DETERMINE YOUR PRESCRIBED FIRE GOALS

A goal is a description of what you hope to achieve or your desired results. Setting goals can help you describe your aspirations and/or determine the direction of your work. As you gain more experience, it will be easier to define your goals, but you can always ask for assistance from a seasoned fire professional.

Examples of Prescribed Fire Goals:

- Increase the numbers and sizes of fire-dependent trees
- Increase the populations of threatened and endangered plant species
- Reduce risks from wildfires
- Create a mosaic of habitat conditions for wildlife
- Create healthy, abundant populations of forage plants for grazing

3. LIST YOUR PRESCRIBED FIRE OBJECTIVES

Every prescribed burn should have a clear objective(s). Objectives refer to the actual steps or actions needed to achieve your goals. There are many different reasons for conducting a burn and so objectives can be singular or multiple, specific or broad, and could take weeks to years to achieve.

It can be helpful to be as specific as possible with your objectives and state exactly what you plan for the fire to accomplish (see S.M.A.R.T. Objectives on p. 27 for more information. Objectives can also be used to help you to evaluate the success of the burn. For instance, a simple way to evaluate your prescribed burn is by taking pictures before, directly after, and one year following the burn.

Objectives for a prescribed burn often include one or more of the following:

- Kill woody plants that compete with trees
- Reduce or setback, invasive plant species
- Reduce the amount of burnable fuel (grass, dead vegetation, pine straw and duff) on the forest floor
- Prepare seedbeds for planting

Table 1.1. Examples of the purposes, goals and objectives of a prescribed fire and how they relate to one another.

PURPOSE Why are you burning?	GOAL What do you hope to see?	OBJECTIVES What can you measure?
Restore forest understory to native plants	Increase populations of native understory plant species	■ Kill invasive plant species ■ Remove grass, dead vegetation & pine straw build-up ■ Prepare seedbed
Restore forest canopy to more functional conditions	Promote growth of fire-dependent trees	■ Kill trees & shrubs that compete with fire-dependent trees ■ Remove fuel build-up to create space for new tree seedlings

General objectives are better than no objectives, and the more you burn, the better you will be at defining these objectives.

In your burn plan, the objectives should not be so specific that they could limit your burn window.

Frequency and Timing of Burns

WHEN SHOULD I BURN?

When you conduct your prescribed burn will depend on your specific prescription and local weather conditions. Only conduct a burn when conditions fit your prescription and not necessarily at a specific season or time of year.

It is always better to burn when you can, than to skip a burn because it is a different season than you expected. Once you have started burning regularly, then you can focus on timing, but the most important thing is to burn.

HOW OFTEN SHOULD I BURN?

Prescribed fire is a process and not an event, and burns should be conducted on a regular basis. One of the most important factors in burning is the frequency of the burns. The frequency of the burns depends on the specific habitat. For example, an established longleaf pine forest might be burned every 1-3 years, whereas other forestland might only be burned every 3-5 years.

TIME SINCE LAST BURN

Note an approximate date for when an area was last burned. The amount of time since a burn occurred factors into how you conduct your burn, and helps you prioritize which unit to burn first. If you plan to conduct a prescribed burn on land that has not been burned in a long time, you should be aware of the amount of fuel present, and discover if it will cause any problems. Depending on when fire was last used on your land, you may need to complete management actions before you can burn.

Burning in Long Unburned Stands: Pre-burn Management Considerations

Burning in long-unburned stands poses additional challenges due to fuel build-up. Fuels such as leaf litter, pine needles, wood debris, plant stems, grass, etc., pile up on the forest floor after many years without fire. Duff (partially decomposed plant material that makes up the organic layer of the soil) is also a fuel of concern in long unburned stands. Thick layers of duff can accumulate around the base of desirable trees, and can put them at risk of dying if all of the duff were to be consumed in a fire. Assess fuel conditions as you plan your burn, and choose weather conditions that will reduce smoldering time and/or rake back leaf litter from the base of trees to protect them. If burning in grassland sites, mow any grasses taller than your waist. You can consult with natural resource professionals for specific recommendations for your fuel type and conditions.

Resources for Burning

ASSISTANCE

Multiple federal agencies, state agencies, university Cooperative Extension partners and non-governmental organizations (NGOs) provide outreach and educational support for prescribed fire in the form of webinars, workshops, and training. While federal agencies, such as the USDA Natural Resources Conservation Service (NRCS) and USDA Forest Service (USFS), can provide invaluable information, state forestry agencies are often better equipped to assist with developing burn plans and conducting prescribed burns due to their regional knowledge. Other area landowners or even your neighbors can also provide assistance, as can Prescribed Burn Associations (see pull-out box). State or federal agencies, NGOs, or PBAs may offer the following assistance:

- Development of a burn plan

- Construction of firebreaks
- Loan or rental of personal protection equipment (PPE)
- Loan or rental of standard prescribed burn equipment, such as rakes, shovels, and drip torches
- Personnel while a burn is being conducted
- Cost-share programs

Consulting foresters and prescribed burn contractors also exist throughout the Southeast and are a valuable source of expertise, particularly for landowners new to the concept of prescribed burning. Both can be hired to develop a prescribed burning plan and/or assist with the burn itself. Many states in the South provide online vendor databases for prescribed burning — typically on the state forestry agency website or through a Prescribed Fire Council. On these sites, consulting foresters and prescribed burn contractors can add their business to a list where private landowners can search the database for their contractor needs.

Tables 1.2 and 1.3 at the end of this chapter describe some of the organizations that offer prescribed burning information and assistance. All of these organizations can be found online with a simple Google search.

Prescribed Burn Association (PBA)

A **Prescribed Burn Association** (PBA) is a group of landowners and other interested citizens that form a partnership to conduct prescribed burns. Association members pool their knowledge, man-power and equipment to help other people in their association conduct prescribed burns. More than 100 PBAs are now found across the United States.

CONSIDERATIONS FOR HIRING CONSULTANT FORESTERS AND/OR PRESCRIBED BURN CONTRACTORS

- [ ] If possible, compare multiple service providers. Depending on the number of vendors in your area, this may be difficult.
- [ ] If you live in a state that provides a Burn Manager Certification, request a copy of their certificate.
- [ ] Request a list of 3-4 references and contact them to get a feel for the quality of work the contractor provides.
- [ ] Request a copy of their insurance policy. Make sure their policy is current and covers the activities they will be completing for you.
- [ ] Request a copy of the completed burn plan to ensure that it includes basic information such as: objectives, resources needed, burn parameters, maps, etc. You can typically find more information on what to expect in a burn plan on your state forestry agency website.

TRAINING

In-Person Training

Certified Burn Manager Program
Many state agencies offer programs to certify prescribed burn managers. While program curriculums will vary across states, the program within a state is considered standard for that area. Certified burners generally complete several training sessions where they receive a comprehensive study manual and instruction on subjects such as: fire behavior, fire weather and fire tactics. Most certification courses also require students to pass a written test and to complete a predetermined amount of field work. Find these from your state forestry agency.

Image 1.2. The best and most practical way to learn about prescribed burning is to participate or volunteer at an area burn. Prescribed burn associations, learn and burn events, and state-sponsored trainings are great opportunities to get your hands dirty. *Image courtesy of North Florida Prescribed Burn Association.*

Learn-n-Burn Workshops

Participants join these workshops for a hands-on opportunity to gain experience and knowledge. These workshops commonly include a half day in the classroom and a half day in the field burning. Find these events by contacting your local Extension or state forestry agency office.

Online Training

Free, online training is also available to landowners. For example, eFire is a virtual, interactive experience. After using this resource and completing section assessments, you should be able to:

- Explain why prescribed burns are used
- Summarize how to prepare for a prescribed burn
- Describe how a prescribed burn can be conducted
- Evaluate whether a prescribed burn can help meet property objectives

While eFire is not a substitute for state prescribed fire certification courses, it can provide you with the necessary information to feel more confident in your understanding of prescribed fires. By strengthening your foundational knowledge, you will be better prepared to take next steps, such as attending a prescribed fire workshop or joining a Prescribed Burn Association.

Smartphone technology can also play a role in prescribed burns. These on-the-go resources can be utilized by any landowner and downloads are often free or affordable.

Check with your state forestry agency to see how you can

BECOME A CERTIFIED PRESCRIBED BURN MANAGER

eFire Online Training

Click this link to access the North Carolina State University eFire page. Here you can immerse yourself in prescribed fire situations, the planning and evaluation process, and more

Access it here: https://efire.cnr.ncsu.edu/efire/

GO FARTHER USING S.M.A.R.T. OBJECTIVES

S Specific	M Measurable	A Achievable	R Realistic	T Timely
State what you will do with action words	Determine a way to evaluate your objective	Make sure you can accomplish the objective. Clearly identify steps that need to happen to guarantee a successful project.	Verify your ability to provide adequate time, funding, and knowledge	Set a date for when your objective needs to be completed

PUTTING S.M.A.R.T. INTO PRACTICE

Getting Specific Objectives

GENERAL		SPECIFIC
A. Prepare seedbed	➡	**A.** Prepare seedbed for native, warm-season grasses
B. Control insects or disease	➡	**B.** Burn a stand of timber to control brown spot needle blight
C. Reduce hazardous fuels	➡	**C.** Reduce loading material / slash from a previous timber cut
D. Improve wildlife habitat	➡	**D.** Create a burn-regime to benefit wildlife that thrives in early successional habitat

Following the SMART Process

SPECIFIC	I will conduct a prescribed burn on a recently logged site to prepare the seedbed for native, warm season grasses
MEASURABLE	*Debris left over from the previous cut will be reduced by 75% *The fire will consume 80% of fine fuels *Sapling growth of undesirable woody species will be reduced by 50%
ACHIEVABLE	I will work with my state forestry agency, as well as my local Prescribed Burn Association to learn more about best practices and what resources are available to me. I will also hire a prescribed burn contractor to create a burn plan and conduct the fire.
REALISTIC	This project is realistic because I have the resources (time, money, and enthusiasm) to support this project.
TIMELY	Conduct the burn in February or March to create space for grass seedlings to emerge. *The actual burn date is dependent on meeting all burn plan parameters.

RESOURCES FOR BEGINNING BURNERS

Table 1.2. Resources for beginner prescribed burners.

Resources for BEGINNING Burners	
About the Organization	**How Can They Help?**
The Cooperative Extension System provides unbiased, research-based information to individuals and communities to address challenges and find solutions. They are supported by your state land grant university.	» Access to prescribed fire research and publications » Educational resources, training, and webinars » Learn and Burn events
State forestry agencies have the responsibility of protecting and expanding forests through proper management, protection, and public education.	» Educational resources » Certified Prescribed Burner Courses » Expertise in writing land management plans » Fire equipment – varies by state » Burning regulations and permit information
Prescribed Burn Associations (PBAs) are comprised of landowners and other community members that form a partnership to conduct prescribed burns. They can be found throughout the country.	» Association members pool their knowledge, manpower, and equipment to help other members conduct prescribed burns » Great resource for first-time burners » Learn and Burn events
The Natural Resources Conservation Service (NRCS) provides technical expertise, conservation planning, and financial assistance for farmers, ranchers, and forest landowners wanting to make conservation improvements to their property.	» Educational material and publications » Financial assistance may be available through two programs: Environmental Quality Incentive Program (EQIP) and Conservation Reserve Program (CRP)
The Longleaf Alliance works to ensure a sustainable future for longleaf pine ecosystems through partnerships, landowner assistance, and science-based education and outreach.	» Publications and outreach material focused on longleaf restoration and management » Facilitates the Longleaf Academy Program for landowners and natural resource professionals
The American Forest Foundation (AFF) works on-the-ground with families, partners, and elected officials to promote forest stewardship and protect our nation's forest heritage.	» "**My Land Plan**" - This is an interactive resource that can help map your property, set goals, and connect you with other landowners in the area » Information on how to plan and conduct a burn » https://mylandplan.org

RESOURCES FOR ADVANCED BURNERS

Table 1.3. Resources for advanced prescribed burners.

Resources for ADVANCED Burners	
About the Organization	**How Can They Help?**
Prescribed Fire Councils (PFCs) offer information-sharing and networking opportunities for all parties interested in prescribed burns. They are organized at local & state levels.	» Forum for local and regional collaboration » Regular meetings for information-sharing, policy updates, and networking
The Southeast Prescribed Fire Update is a forum for stakeholders in the prescribed fire community to share information and ideas	» Current training opportunities » Upcoming events, workshops, and fire festivals » Educational resources
Tall Timbers is recognized as the home of fire ecology research and advocates for the right to use prescribed fire for land management. It is also recognized as one of the nation's leading land trusts.	» Publications and other relevant research » Historical context of prescribed burning in the Southeast
The Joint Fire Science Program funds scientific research on wildland fires and distributes results to help policymakers, fire managers, and practitioners make sound decisions. It is a national collaboration of 15 regional fire science exchanges. Explore your local exchange to learn more about regional resources (e.g., **Consortium of Appalachian Fire Managers** and **Southern Fire Exchange**).	» Regional newsletters, fact sheets, and research briefs » Webinars (live and archived) » Workshops and field tours » Models, tools, and maps
Prescribed Fire Training Exchanges (TREX) provide an experiential learning opportunity for professional fire practitioners	» Hands-on training completed through one to two-week events » Networking with fire beginners and experts
Volunteer fire departments (VFDs) consist of volunteers who perform fire suppression and other related emergency services for a local jurisdiction.	» Local VFDs may be willing to collaborate or assist on a burn event
The National Wildfire Coordinating Group (NWCG) provides national leadership to enable wildland fire operations amongst local, state and federal partners.	» Educational material and research briefs » Training material (primarily for wildland firefighters)

Image 1.3 (top) & 1.4 (bottom). Landowners working with PBAs to plan their burns. Prescribed burn associations, learn and burn events, and state-sponsored trainings are great opportunities to get your hands dirty. *Images courtesy of North Florida Prescribed Burn Association.*

References:

Clabo, D. & Campbell, H. (2020). Restoring fire to long-unburned pine dominated stands on Georgia private lands. University of Georgia Warnell School of Forestry & Natural Resources. Outreach Publication WSFNR-20-97A

Brose, P., Schuler, T., Van Lear, D., & Berst, J. (2001). Bringing fire back - The changing regimes of the Appalachian mixed-oak forest. *Journal of Forestry*, 99(11), 30-35.

Brown, H. (2000). Wildland burning by American Indians in Virginia. Fire Management Today, 60(3), 29-39. Fowler, C. & Konopik, E. (2007). The history of fire in the Southern United States. *Human Ecology Review*, 14(2), 165-176.

Johnson, A.S. & Hale, P.E. (2002). The historical foundations of prescribed burning for wildlife: A Southeastern perspective. In: W.M. Ford, K.R. Russell, & C.E. Moorman (Eds.), <u>The role of fire for nongame wildlife management and community restoration: traditional uses and new directions</u> (11-23). Newtown Square,PA: U.S. Dept. of Agriculture, Forest Service, Northeastern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_ne288/gtr_ne288_011.pdf

Melvin, M. A. (2020). 2020 National Prescribed Fire Use Survey Report (Ed. 04-20, pp. 1-9).

Pyne, S., Andrews, P., & Laven, R. (1996). <u>Introduction to Wildland Fire</u> (Second Edition). John Wiley & Sons, Inc., NY.

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). Introduction to prescribed fires in Southern ecosystems.Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

GETTING STARTED NOTES

GETTING STARTED NOTES

PLANNING THE BURN

Image courtesy of John Herbert

Table of Contents

Introduction to the Planning Process

Fire is a powerful management tool, and careful consideration is needed to use it safely and effectively. The planning process for a prescribed fire begins with your land management goals (your desired end result), which will determine the objectives (the steps to take to achieve your goal) for your prescribed fire (see chapter 1 for more details). Many different factors should be considered when planning a prescribed fire, as they will impact how you conduct it such as the purpose behind the burn (the reason why you want a particular end goal or result), the topography of the burn unit, the time of year, and other factors covered throughout this book. The development of a burn plan, often called a "prescription," is one of the most effective ways to ensure that all these factors have been identified and addressed.

This chapter includes detailed information about the different components involved in the entire burn planning and preparation process including detailed steps for developing the specific burn plan. Pre-burn tasks and considerations, and information on fire and safety equipment, as well as overall safety and liability are also covered here. Going through the process of planning for a burn and creating a burn plan will enable you to conduct your prescribed fire with confidence, reduce risks from your burn, and in some states, help limit liability.

Image 2.1. Landowners planning at Alabama Learn and Burn event. *Image courtesy of Leslie Boby.*

☐ *Develop a Burn Plan*

Conducting a prescribed fire, starts by developing a burn plan or prescription. While burn plans may vary in complexity, they all outline the parameters for the burn area, acceptable weather conditions for burning, timing, and recommended strategies to conduct the burns, and more. Burn plans are directly influenced by the characteristics of the burn unit, your objectives, your state or local fire regulations, and other related factors. Weather is a critical factor in the prescription, as the burn plan will include a range of variables for temperature, humidity, wind speed and wind direction. There is no wrong season for burning. A burn should be conducted when it is most likely to meet your management objectives and when the burn conditions are safe, as defined by your burn plan.

A written burn plan serves as a record of your prescribed fires and will provide guidance the next time you burn the same area. Many federal and state forestry, wildlife and natural resource agencies, non-governmental organizations, prescribed burn associations, and private consultants can develop a burn plan for you, or assist you as you do it yourself. Chapter 1 includes information on some of these organizations/individuals and other places to access resources or assistance. Some burn plans may be short, simple documents. Others are complex. The length or complexity of your burn plan will be dependent on your site, objectives, burn factors, state regulations, and personal preferences. The sections below list and describe the type of information commonly found in burn plans.

BURN PLANS WILL DIFFER FROM STATE TO STATE, SO YOUR BURN PLAN MAY INCLUDE A LITTLE MORE INFORMATION THAN IS LISTED IN THIS CHAPTER, OR A LITTLE LESS.

DOCUMENT INFORMATION ABOUT LAND OWNERSHIP AND LOCATION

Burn plans always include basic information about the area to be burned, such as listing the landowner, their contact information, and location of the area to be burned. This part of the burn plan will also include directions to the site, acres to be burned, and possibly a legal description of the site (using section, township and range), or may include the latitude/longitude of the site.

DESCRIBE THE BURN AREA INCLUDING VEGETATION TYPES AND FUELS

For planning purposes, you will need to include a description of the area to be burned including the vegetation that can be found there. If the area is forested, then you can describe the forest "stand," which includes identifying different main overstory tree types and the general sizes of those trees as well as the vegetation (low to the ground, shrubs, etc). Each of these components is part of the vertical forest stand structure. A brief overview of the fuel on the ground should also be included in this section. You can refer to your forest management plan for a stand description if one is available. As shown in Figure 2.1, a forest stand is made up of multiple layers of vegetation including an understory, a midstory, and an overstory. Your stand description may contain lists of the types of vegetation or trees found in the different canopy layers. Below are descriptions of each of the vegetation/canopy layers.

Understory Vegetation

- Herbaceous plants, small shrubs and trees found between the midstory canopy and the ground comprise the understory.

Midstory

- Large shrubs or young trees found between the understory vegetation and the overstory canopy. The types of shrubs or trees found in this layer.

Overstory or Canopy

- The tallest trees or vegetation that form the majority of the canopy are considered the overstory. The type of trees or vegetation should be listed, as well as the general height of the overstory.

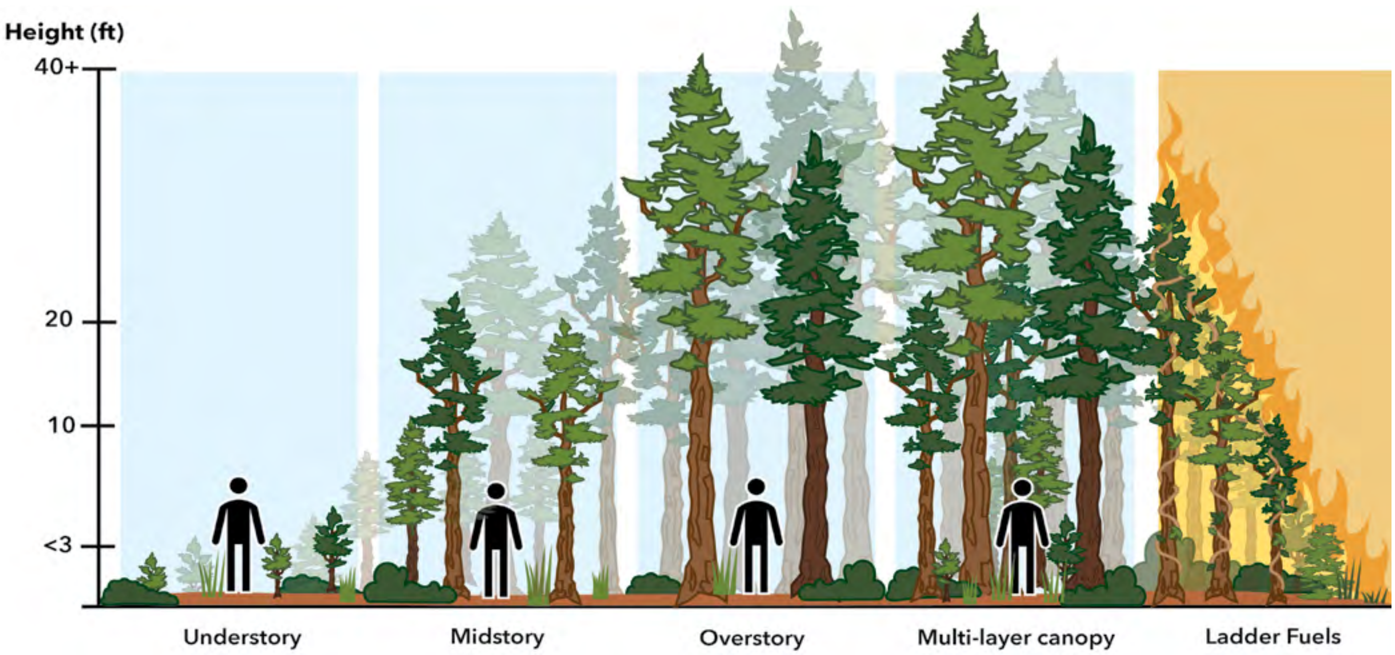


Figure 2.1. Forest stands are made of multiple vertical layers of vegetation, which can be fuels for fire. It is important to understand how the different layers of fuels interact to ensure all burn prescriptions can be met safely. *Diagram credit: Jessica Shaklee.*

Fuels Description and Amount

- Live fuels include trees, shrubs, herbaceous vegetation, and grasses. Some plants and shrubs are especially flammable, such as wax myrtle, saw palmettos, rhododendron, and gallberry, and should be noted in the stand/fuels description
- Fuel includes dead vegetation too, such as dried grass, pine needles, sticks, and timber slash, which are usually the primary source of ignition. Be sure to describe what can be found on the ground, as well as the general amount and how continuous the fuel is on the ground. This is important to note as different types of fuel burn differently, for example pine needles will burn differently than leaf litter and some vegetation are particularly flammable, such as wax myrtle, saw palmetto, rhododendron, and gallberry. More information on fuel can be found in chapter 7.

Ladder Fuel: Term used to describe live or dead vegetation that create a "ladder" or vertical continuity from the forest floor to the tree canopy or overstory. See Image 1 and Figure 1.

Fuel: Any combustible vegetation or material.

Image 2.2. In this picture, duff has built up around the base of the tree as it has not been burned in many, many years. This duff buildup can pose challenges when reintroducing prescribed fire. *Image courtesy of David Godwin.*

NOTE TIME SINCE LAST BURN

The amount of time that has passed since an area was last burned will factor into how you conduct your burn, and will help you prioritize which unit that you want to burn first. In fact, the time since the last burn was the number one factor in a burn prioritization model. Make a note in your burn plan of the approximate date that your land or burn unit was last burned. There is a little more preparation work and things to consider when burning in these stands, in order to protect trees or desired vegetation and to manage smoke. Chapter 1, Getting Started, as well as Chapter 7, Fuels have more information on burning in long unburned stands.

Burning in Long Unburned Stands

Duff is the partially decomposed plant material that composes the organic layer of the soil. Thick layers of duff can accumulate in forest stands that have gone without fire for many years. Significant duff build-up around desirable trees can put them at risk of dying, if the majority of the duff is consumed in the fire, as longer smoldering times can kill the tree's roots. While planning and before conducting a burn in a stand that has gone unburned for many years, consider doing the following:

- Assess the thickness of the duff layer at multiple spots
- Plan burn for weather conditions that will lead to a quicker fire that does not smolder long
- In some cases, you may need to manually remove large woody debris to ensure that the fire remains under control
- Rake back the leaf litter on top of the duff to protect important trees
- Consult with your state forestry agency or local Prescribed Burn Association (PBA)

RxBURN TRACKER: OKLAHOMA STATE UNIVERSITY

- Photograph burn units prior to and after burns are conducted
- Organize pictures and burn data chronologically
- Record burn data about each burn unit

Note: This example is not an endorsement of the application or its technologies.

DEFINE PURPOSE, GOALS AND OBJECTIVES OF THE BURN

The purpose of your burn should clearly outline the intent of the prescribed fire and how it will meet your overall land management objectives. The burn goal can be as simple as, “reduce fuel loads,” or may be more complex, such as “create a mosaic of habitat conditions for wildlife.” See Chapter 1, “Getting Started,” for more information on purpose, goals, and objectives.

When determining the objectives of your burn, you may think about how you expect the characteristics of that area to change following the burn. That is, what will be eliminated or consumed, or what should be left following the burn? Once you know the goal of the burn, the rest of your planning is shaped around your desired end result. Many organizations may use the terms purpose, goals, and objectives interchangeably, but all typically focus on what you want to achieve with your burn (goal) and if the steps or actions you need to take to achieve the goal (objectives). On your burn plan, you do not want to create objectives that are so specific that your burn window could be limited. Lastly, crafting objectives can be hard, so do your best, and as you gain experience, it will become easier.

IDENTIFY SMOKE-SENSITIVE AREAS

Smoke-sensitive areas include, but are not limited to: airports, highways, recreation areas, schools, hospitals, urbanized areas and large farming operations. If any of these areas, are adjacent to or downwind from the burn site, then there may be specific smoke management strategies that need to be taken. More information on identifying these smoke-sensitive areas and other considerations can be found in chapter 6, Smoke Management.

CONDUCT SMOKE SCREENING

A smoke screening system allows you to visualize the potential impacts of smoke on your burn unit and the surrounding area (Image 2.3). The Florida Forest Service hosts the Simple Smoke Screening Tool. Entering your burn location, acreage, fuels, ignition method, and wind direction into this virtual tool yields a map showing where smoke is likely to travel during a burn, and if any smoke-sensitive areas will be affected. This tool is available nationwide; however, your local forestry agency may have a tool specific to your region.

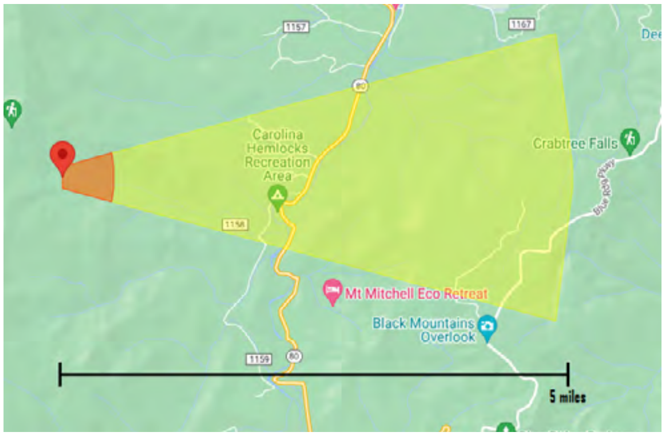
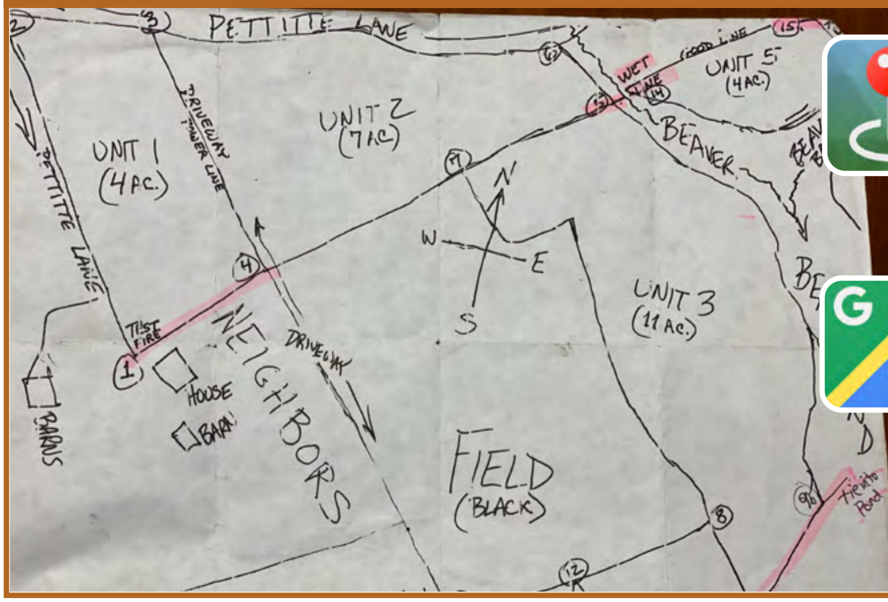


Image 2.3. Image taken from the Simple Smoke Screening Tool.

Hand-drawn burn map & tools to help



AVENZA MAPS: AVENZA SYSTEMS INC.

- Download georeferenced maps for offline use
- Use your phone's built-in GPS to track your location on any map
- Plot locations and photos
- Measure distance and area

GOOGLE MAPS: GOOGLE

- View satellite imagery
- Create and save maps for offline use
- Drop location points and measure distances between them
- Discover potential smoke-sensitive features with aerial view (homes, businesses, and roadways downwind of the proposed burn unit)

HIGHLIGHT SPECIAL PRECAUTIONS

Special precautions are site-specific conditions and/or situations that are pertinent to your burn and which should be noted and planned for. These special situations can be very specific to your management goals or general conditions on your land. For example, some special precaution areas may include land adjacent to the burn that has a high risk of catching fire or areas on the perimeter of the burn area that have a number of standing dead timber (snags). Pre-existing structures onsite such as old wells, cemeteries, abandoned buildings, buried or overhead utilities should also be highlighted in the burn plan as they can pose challenges. Sometimes conditions which have changed since the plan was written need to be highlighted, for example, characteristics of a fire break can be different. Figure 2.8, "Watch Out" situations on page 50 of this chapter has more information on special precautions.

CREATE A MAP OF THE AREAS TO BE BURNED

After determining the purpose of the burn, designate the burn area on a map of the property (Image 2.3). The map should include information that maximizes safety, while excluding details that could make the map littered or otherwise confusing. The map also needs to show all firebreaks and should highlight areas along the firebreaks where the fire could possibly escape, such as downwind areas that may have considerable fuels, or any sensitive areas near the boundary of the burn unit should be identified, such as crops, buildings, graveyards, or cultural sites. Adjacent land ownership may need to be noted on the map as well. Perimeters and map features with labels can be helpful when distinguishing where everyone is and how the fire is progressing. For example, "I'm carrying the drip torch from point A to point G" or "The area between points A and B has no active flames."

The map can be drawn by hand or created digitally. There are many tools to help create maps digitally, including online mapping tools (i.e., Google Maps; mylandplan.org) and mapping software, like Avenza (which offers a more limited free version available for both iPhone and Androids). The map should include the items in the component checklist.

MAP COMPONENT CHECKLIST

- ☐ Boundaries of the burn unit(s) with acreages
- ☐ Property boundary
- ☐ Topography
- ☐ Map orientation (compass)
- ☐ Fire breaks or natural barriers the act to contain the burn. The map should indicate existing fire breaks and those that need to be constructed and their lengths.
- ☐ Anticipated direction of the smoke plume
- ☐ Smoke-sensitive features
- ☐ Areas that will be excluded from fire such as structures
- ☐ Other essential information: known safety issues, specific wildlife, state required burn hours

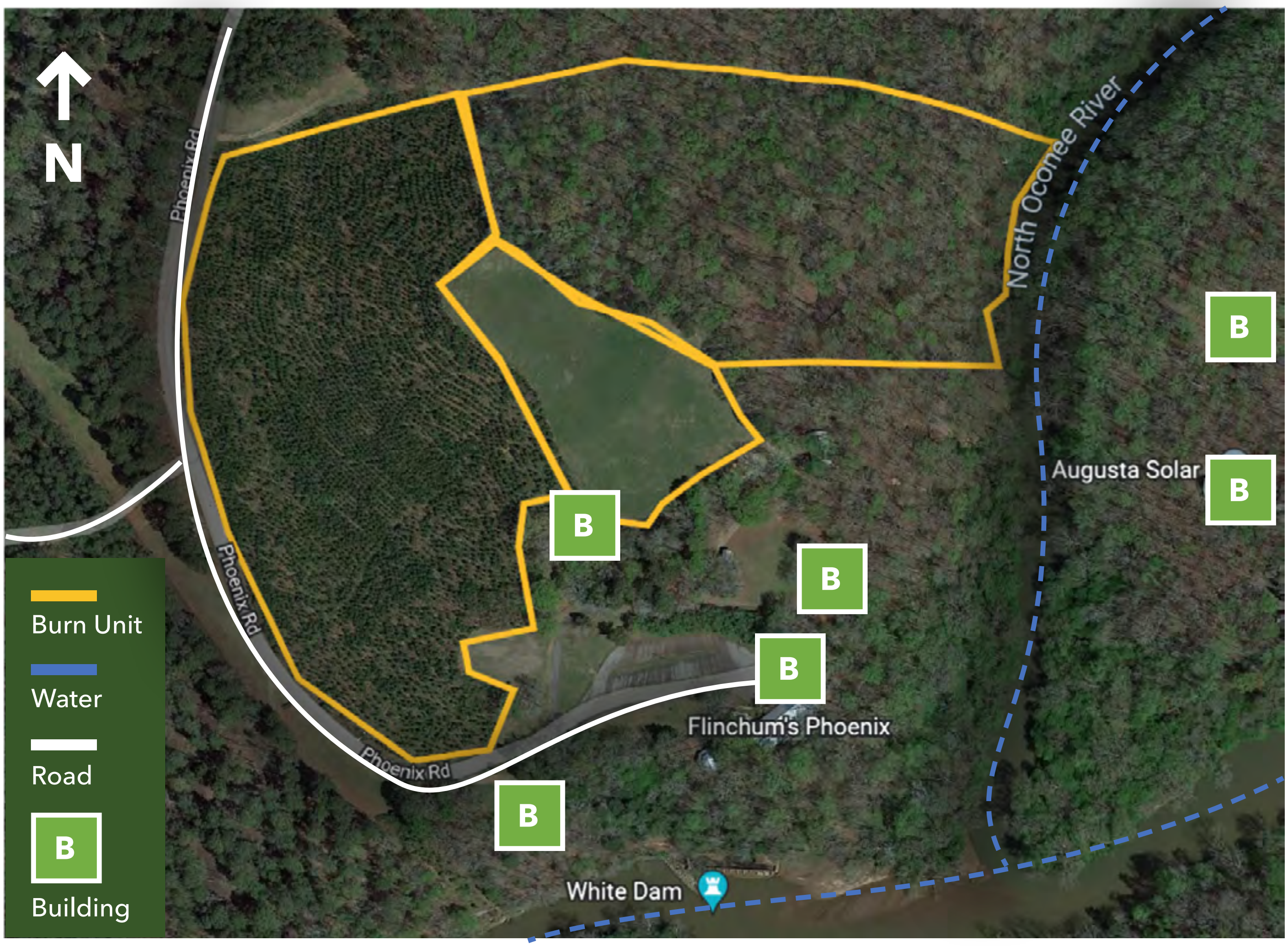


Figure 2.2. Example of a completed map of the property, burn unit, and other necessary components provided in the checklist. *Map courtesy of Sarah McNair.*

Burn Units

The land to be burned may also be subdivided into smaller burn units, depending on the size of the land, its complexity (i.e. topography, fuel load, nearness to roads, etc.) and previous burn cycles. Burn managers treat each burn unit as a separate entity. These smaller burn units can provide more options and flexibility for managing the burns, as burns can be conducted on each unit independent of any burning in other units. Depending on how well the burn is going on any given day and the amount of personnel available to help conduct the burn, the burn manager may burn each unit sequentially or simultaneously. There are no specific recommendations for burn unit size, as they are dependent on factors particular to the site such as the length of time since the area was last burned, or the complexity of the landscape. Identify the boundaries of any burn units on the map of your property.

Strategic planning for Prescribed Burns - Big picture view!

Creating a plan for conducting prescribed fires on your land focuses on particular burn units or sections of your land, but how do you decide which unit to burn and when? Prescribed fire is a process and not an event. Ideally, you will be burning your various units repeatedly over time. Depending on the size of your land, you can look at the whole landscape and think about how to "play chess" with your burn units over a period of years. Units may be prioritized for burning based on the time since the last burn, or on the complexity of the unit and its location in the landscape.

Topography refers to the forms and features of land surfaces. Learn more about how topography affects fire behavior in chapter 8.

DETERMINE DESIRED RANGE OF WEATHER FACTORS

Weather is the current or recent state of the atmosphere and strongly influences if it will be possible to burn or and if the burn will meet its objectives. Prescribed burn plans include a desired range of values for each weather factor, as well as maximum and minimum allowable values. (See Chapter 5: Weather on page 111 for more details).

Watching the weather and waiting for the right weather conditions are two important activities to prepare to burn! Some basic elements of weather that influence prescribed fire include the following:

Temperature

Measure of hotness or coldness of the air

Temperature is usually measured along one of two scales - in degrees Fahrenheit in the United States and degrees Celsius (other parts of the world).

Effects on vegetation & fuels – Heat from prescribed fire increases the ambient air temperature around live vegetation and dead fuels. Higher ambient air temperatures dry out dead fuels, especially fine or 1-hour fuels (see chapter 7 - for more information on fuels). Drier fuels are quicker to ignite and greater amounts of material can be burned by hotter and faster-moving fires. Some vegetation, which are live fuels, may also burn more easily in higher temperatures, especially vegetation that has characteristics that make it more flammable.

Topography – Elevation, slope, and aspect impact air temperature. Hilly or mountainous areas can create variable microclimate conditions within a burn. For example, the slope aspect influences how much sunlight an area gets, which in turn affects fuel moisture. East-facing slopes are warmer in the morning, while north-facing slopes tend to be cooler than south-facing slopes. Steeper terrain may also lead to increased fire intensity as heat rising from fire on slopes dries out the fuel before the flame reaches it.

Image 2.4. Topography should be considered when you plan your burn as it can influence fire behavior. *Image courtesy of David Godwin.*

Relative humidity (RH)

Refers to the amount of moisture in the air relative to the amount that could be in the air, at a specific temperature. RH values are percentages, and an RH of 100% means that the air is saturated with water (dew point). RH changes throughout the day. For example, at lower air temperatures, the amount of moisture in the air is much greater than the amount of moisture that could be in the air at a higher temperature. As such, the daily high temperature typically coincides with low RH. Common values for RH will vary based on the location, for example, the RH in the drier climate of the Southwest, will be significantly lower than in the much more humid Southeast. In general, as RH drops, fire intensity increases, which could make prescribed fires harder to contain. Therefore, burn plans typically designate a range of acceptable RH values.

Effects on fuel moisture levels – Generally, RH values are closely linked to fuel moisture levels in smaller fuels (1-hour fuels). As the RH decreases, smaller fuels dry out faster. When the RH is higher, 1-hour fuel moisture is also higher, so fuels may not burn as well, leading to a patchier burn, and less intense fire. However, fuel composition and physiology can affect this general rule. For example, a pine needle should dry quicker than a pine cone, based on size, but the waxy coating of a pine needle slows the drying process.

Micro-climate conditions – RH levels are typically higher under dense canopies because of increased fuel moisture due to shading.

As the temperature increases throughout the day, the relative humidity (RH) value will typically drop, and then will slowly increase again as the temperature cools down at night.

Precipitation

Moisture that falls to the ground as rain, snow, sleet or hail.

Effects on soil and fuel moisture levels – Precipitation increases moisture levels in soil and fuels. The impact that precipitation will have on soil and fuel moisture levels depends on the amount of precipitation and the number of days prior to burning. Smaller fuels become saturated faster than larger fuels. Fuels in more open areas become saturated faster than fuels located under denser canopies. This also means that fuels in open areas tend to dry much faster. If fuel moisture levels are too high, it can cause patchy burns and produce significant amounts of white smoke that reduce visibility.

In addition, fuel moisture can vary between fine fuels and the duff layer. The fine fuels will burn, but the duff may be too wet to burn. Duff moisture influences how it will burn.

Precipitation amounts and timing are part of the calculations used for several indices, primarily the Keetch-Byram Drought Index (KBDI). KBDI is a drought index based on a daily water balance, where a drought factor is balanced with precipitation and soil moisture. It is used to assess the level of fire risk.

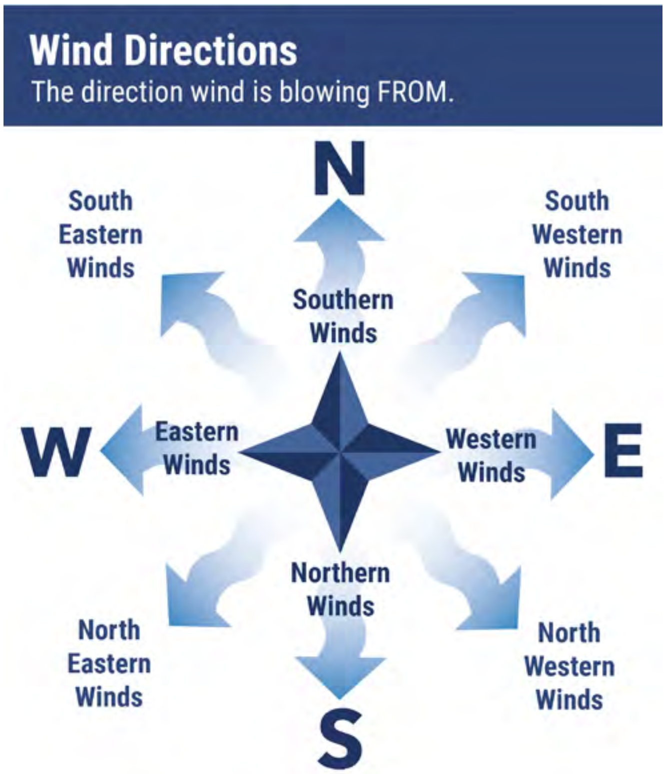


Figure 2.3. Wind direction is always expressed as the direction from which the wind is coming. *Diagram credit: Jessica Shaklee.*

Wind Speed & Direction

Wind is the movement of air. On maps, wind direction is expressed as the direction from which the wind is coming (Figure 2.3). The direction and speed of the wind are determined by the distribution of pressure centers and local topography. In a high pressure system, wind will flow down and away from the system. In a high pressure system, wind will flow clockwise when north of the equator and counterclockwise when south of the equator. The reverse is true of a low pressure system: wind will flow counterclockwise when north of the equator and clockwise when south of it. Wind influences the direction and rate of fire spread, along with smoke dispersion. It also helps to disperse heat from fire, reducing scorch. Two important types of wind to monitor during a burn are transport and surface winds.

Transport winds – Average wind speed and direction from the ground to mixing height. These winds carry smoke away from the burn unit.

Surface winds – Measured 20 feet above the average height of an obstruction, such as trees or buildings. Understory composition, the density of trees, and general canopy height can impact surface winds, particularly regarding wind direction and speed.

Atmospheric stability

Atmospheric stability refers to the resistance of the atmosphere to vertical motion. There can be stable or unstable atmospheric air conditions with mixing heights that change throughout the day (Figure 2.4). **Mixing height** is the height at which smoke will be diluted and dispersed. Low mixing heights keep smoke close to the ground surface, whereas high mixing heights allow for more smoke dispersion.

Several weather indices use atmospheric stability measurements in their calculations. For example, the Haines Index value indicates the potential for wildfire growth by measuring the stability and dryness of the air over a fire. Other indices that utilize atmospheric stability include the Atmospheric Dispersion Index (ADI) and the Low Visibility Occurrence Risk Index (LVORI).

Image 2.5. Landowner burning as part of an Alachua Conservation Trust event. *Image courtesy of John Herbert.*

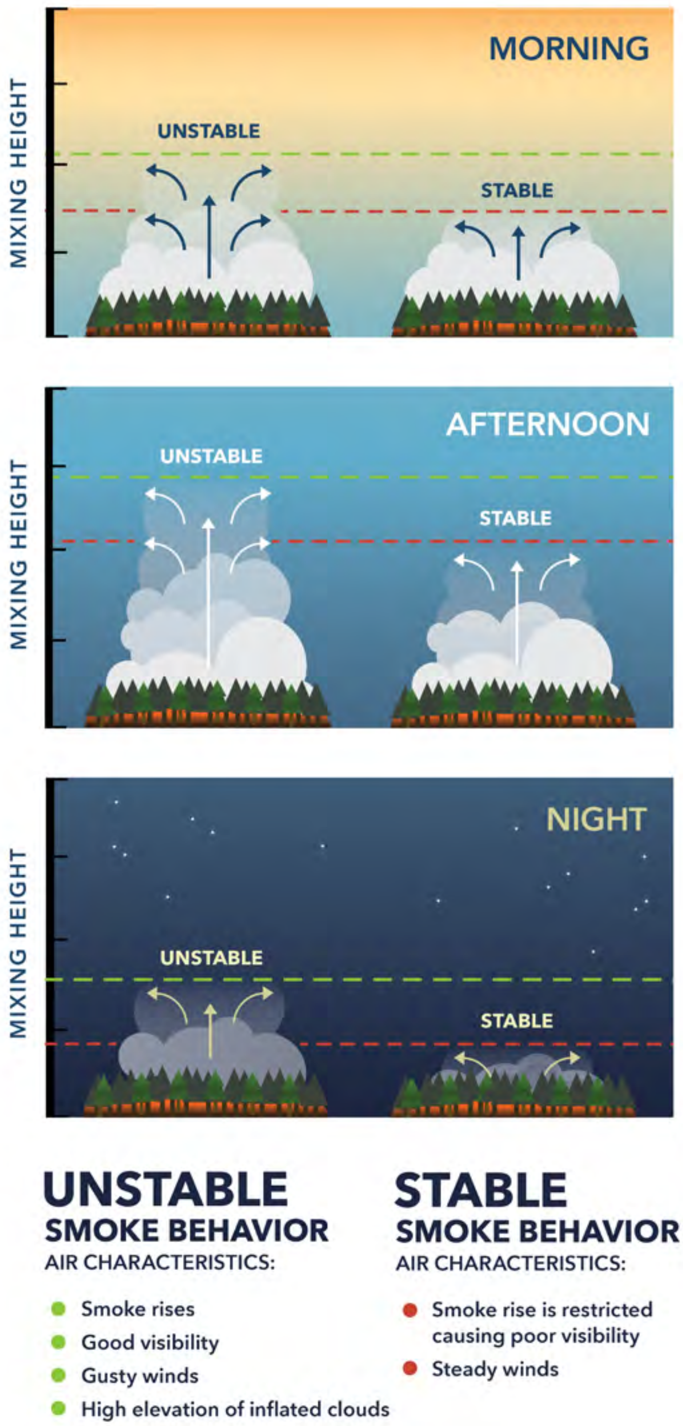


Figure 2.4. Stable and unstable atmospheric conditions at different times of day and the corresponding changes in mixing height. *Diagram credit: Jessica Shaklee.*

Stable atmospheric conditions – This restricts upward movement of air, causing the mixing height to be lower due to cooler air at the ground level. This can cause a low layer of fog and/or clouds. When this occurs, smoke remains low to the ground and dispersion is limited. During the morning hours, mixing height is low due to lower ground temperatures and less movement from winds and heat in the atmosphere. Typically, in the afternoon, the ground temperature has increased from the sun and mixing height is at its highest. Smoke is able to rise easily when mixing height is higher. At night, mixing height is lower than its afternoon peak due to decreased vertical mixing in the atmosphere and decreased temperatures.

Unstable atmospheric conditions – Unstable atmospheric conditions mean that upward movement of air is unrestricted and there is a higher mixing height as compared to stable air conditions. Unstable atmospheres result in high levels of vertical mixing between winds and heat, and can create good conditions for smoke dispersion. However, if the atmospheric conditions are too unstable, it can encourage more volatile fire conditions.

Watching the weather and waiting for the right weather conditions are two important activities in preparing to burn!

THINK ABOUT THE TIMING FOR YOUR BURN

Prescribed fires should generally be planned so that the entire burn or burn unit can be completed within the same time period or day. There may be state regulations that also specify the maximum length of a burn. Most burns are conducted during daylight hours due to favorable visibility, weather conditions, and smoke dispersion. Night burns are less common but may be conducted when conditions are right and cooler temperatures are desired to meet the objectives of the burn. Timing will be dependent on many factors such as available assistance or the complexity of the burn.

Day-time burns are typically ignited between 10 am to 12 pm, with some starting later (1 or 2 pm). By these times, the morning dew has evaporated, fuel is drier, and mixing height has increased for better smoke dispersion. Mixing height is the height to which relatively vigorous mixing of the atmosphere occurs. When atmospheric mixing height is lower, it causes a low layer of fog and/or clouds and smoke will begin to move horizontally. Mixing height will typically be highest during the day, working well with faster burn-off times and increased smoke dispersion.

Night-time burns are typically ignited when cooler temperatures are required to reach burn objectives or if strong winds and low relative humidity remain throughout the day and into the evening. Smoke dispersion is generally poorer at night, thus limiting opportunities for night burning. Weather conditions and smoke drift need special attention when burning at night. There are also additional safety concerns for night burning such as reduced visibility and slower response times should help be needed from an outside agency. Although night-time burning may be desired specifically for burn objectives, sometimes nighttime burning is done for the convenience of the landowner or burn team. For forest landowners with full-time jobs or other time conflicts, night burns may be the only options.

Image 2.6. Tall Timbers' prescribed burn of the Wade Tract Preserve at night. *Image courtesy of Kevin Robertson.*

While most agency-lead prescribed fires will be conducted during the day, night-time burns may be more feasible for landowners who have full-time jobs or other conflicts during the day on weekdays.

Pre-Burn Preparation

Once you have developed a burn plan, then you will need to assess other factors that will affect how you implement the burn. For instance, estimate the number of people and the kind of equipment needed to conduct the burn. You will need to identify if there are any special considerations for your burn, build or check your firebreaks, decide which neighbors you should tell about your burn, and create a plan for holding the fire within the burn area and for any unexpected contingencies. Continue reading for more information.

IDENTIFY APPROPRIATE PARTIES TO NOTIFY

Courteous burners will often notify neighbors and other affected parties 2-3 days to one week in advance of the anticipated burn day. Neighbors who live or have property adjacent to the burn site should *always* be notified on the day of the burn. In addition, it is a good practice to contact your neighbors during the planning phase some months before you burn, to let them know of the general plan. This will help prevent unnecessary calls to local emergency personnel should they mistake your prescribed fire for a wildfire. **In most states, it is mandatory that you notify your state forestry agency and obtain a burn permit.** Other appropriate parties to notify on the day of the burn may include public safety representatives including local forestry personnel, fire department, 911 non-emergency number, as well as the local air quality regulatory agency (if required).

ESTABLISH FIREBREAKS

Firebreaks are natural or man-made areas that contain no vegetation or fuels and prevent fire from spreading. They are used to contain the fire within the boundaries of the burn unit (Figure 2.5) and can also serve as travel paths for personnel and equipment. There needs to be some type of firebreak present around the entire perimeter of the burn unit. Often burn units are planned to make use of pre-existing fire breaks such as roads, streams, lakes, and/or cultivated fields. Firebreaks can be created by using hand tools, power tools, and/or heavy equipment to remove vegetation and fuels until bare ground or mineral soil are exposed. (Image 2.4). In some areas, a firebreak can be created by mowing grass or other vegetation as short as possible, and then wetting the full width of the firebreak area.

There are no set standards for widths of firebreaks. Their width is dependent upon fuel characteristics, such as fuel type, loading, and moisture content (drier fuels are more likely to ignite). In some cases, a 2-to-4-foot firebreak is sufficient, whereas in other cases, the firebreak may be as wide as 100+ feet. Width of the firebreak will be dependent on the fuel type, local regulations and more. One rule of thumb that is often used to decide width of firebreaks is to create a firebreak that is two times the height of the nearest vegetation. Others plan firebreak width based on the expected length of the flames. For example, prescribed fires in grasslands will move fast and may have tall flames.

The ignition plan for the burn will also influence the expected flame lengths as well. Firebreaks must be checked before the burn, to ensure they have not been compromised since their establishment. For example, a stream bed may dry out, leaves may accumulate across a road or break, or a snag may fall over the line. Leaf blowers are useful for removing leaf litter and other small debris from fire breaks. Although there is no set standard for firebreaks, it is a good practice to be generous with firebreak sizes.

The terms firebreak and control line are interchangeable. It is up to the burn boss to determine the most appropriate term to avoid any confusion among team members.

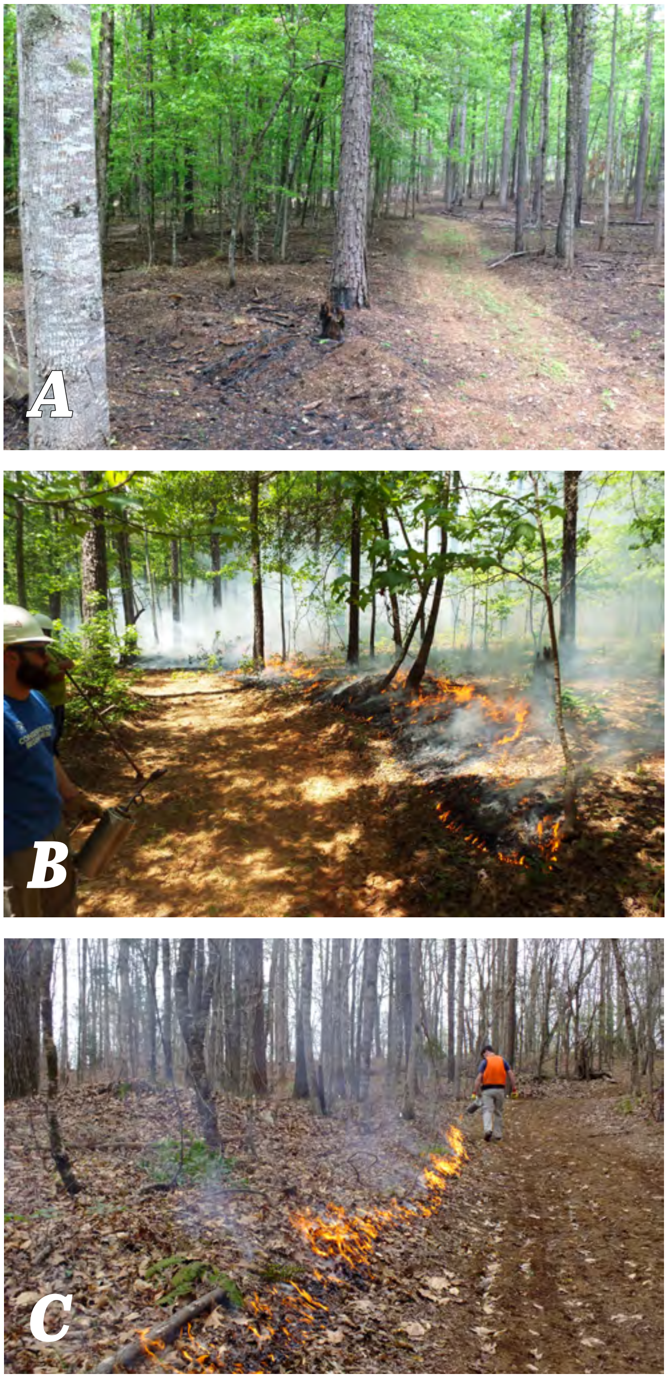


Figure 2.5. Firelines can be established through a variety of methods and techniques a.) Hand tools and leaf blower, b.) disked lines, c.) flat blade.

Image 2.7. Example of a flooded roadway being used as a firebreak. *Image courtesy of David Godwin.*

DO PRE-BURN MANAGEMENT PREPARATION

Some of your pre-burn on the ground work may likely include creating or checking firebreaks, but there may also be a need to do other preparation. For example, there may be some dead trees or snags that are close to the firebreak that should be cut down. Your land management plan may also include mechanical treatments or grazing management that would reduce the complexity of the burn and make it safer. Some areas within your burn unit may need to be treated in order to protect them before the burn.

CREATE AN IGNITION PLAN OR STRATEGY FOR LIGHTING THE BURN

There are many different ways to start burning and your burn technique or ignition plan will be based on the physical conditions of the particular unit such as fuels, topography, location of firebreaks, etc. The ignition plan will also be based on the prescription weather conditions for the unit and the desired burn objectives. Ignition plans typically include a combination of ignition patterns that include backing fires, headfires, strip headfires, flanking fires and more. Most prescribed fires start by "blacklining," or burning a strip of the unburned section along the firebreak. Blacklining bolsters the firebreaks and reduces the chance that the fire may cross the firebreak. More information on ignition patterns can be found in the fire behavior section of this guidebook. While your plan may contain a general ignition plan, it may change on the day of the burn, depending on the conditions.

Image 2.8. Habitat management burn, as viewed from a UTV. *Image courtesy of Corey May.*

Estimate the number of hours needed to complete the burn.

A variety of factors, such as humidity and wind speed/direction, change throughout the day and affect fire behavior. Having an estimate of the number of hours needed to complete the burn is helpful, in case weather conditions go out of prescription and you need to change how you are burning or stop altogether.

DEVELOP A PLAN FOR "HOLDING" AND FOR CONTINGENCIES

While an ignition plan focuses on how to meet objectives, holding and contingency plans focus on how to prevent escapes and keep the fire within the overall objectives and parameters. Planning for holding and contingency is critical to the successful completion of a burn. These plans should feed back into the ignition plans and tactics throughout the burn day, since weather, staff capabilities, and equipment operation often change during this time. Good holding and contingency plans should anticipate potential issues and state the resources needed to mitigate problems as they arise.

Image 2.9. Landowner practicing drip torch use at a Long Leaf Alliance event. *Image courtesy of Susan French.*

It is important to know who you will call for assistance should a fire escape from the planned burn area or if there is an injury onsite. It is helpful to identify high risk areas on your burn map and ensure that your crew are aware of such risks. Although good plans can mitigate much of the risk from prescribed fires, a back-up or contingency plan is important in case something unexpected happens. In your prescribed fire plan you should:

- Identify potential problem areas and actions to take place in the event of an escaped fire
- Identify personnel and equipment needs and availability if a fire were to escape the planned burn area
- Contact your local state agency in the case of an escape. They can provide the expertise and equipment to contain the escape safely and efficiently.

A holding plan is focused on maintaining prescribed fire within the planned burn area by identifying resources and staff needed for all operational phases (pre-ignition, during the burn, and mop-up). Escapes can occur days or weeks after primary ignition has been completed. For example, if there are deep organic layers that continue smoldering, or if there are dead trees or snags that have unseen embers, etc., they could start a fire later. It is critical to assign resources to monitor your fire for as long as you think is appropriate, based on your site's specific holding challenges.

Sometimes burns do not go exactly as planned.

Sometimes burns go outside of the planned burn unit too, but that is why there are back-up plans!

Contingency Plan – In prescribed fire, we all recognize that our plans written days or weeks in advance of the burn day will be impacted by changes that occur in weather, staffing or equipment during the day. Contingency actions are then required to be taken when the fire behavior deviates from what was expected. It is important to consider what staff or outside resources you might need when considering the following actions. Contingency actions are taken to return the fire behavior to its planned parameters, and to reduce the chances of unfavorable consequences from unanticipated events.

Contingency actions or changes in tactics can be used when:

- Established **prescription parameters**, trigger points, or limits are exceeded
- **Prescription elements** not being met (over- or underachieving fire behavior or other objectives)
- **Safety** violations or accidents occur
- **Smoke** sensitive sites impacted
- Historic/**archeological**/hazmat sites discovered.
- Unplanned, independent events such as wildfire activity that requires **contingency resources such as state forestry equipment to be pulled.**
- **Insufficient time** to complete prescribed fire operations

Actions include:

- Changing ignition patterns if fire behavior is to intense or conversely too low
- Changing amount of ignition if smoke distribution is not what was expected
- Reducing the planned unit size by burning off of an interior road or trail
- Moving crews or equipment to a different part of the unit than they were first assigned to
- Longer mop-up period if smoldering is greater than anticipated
- Shutting down the fire altogether if possible

Contingency plans or actions can be implemented anytime during a prescribed fire and do not constitute a wildfire declaration.

Image 2.10. Example of a firebreak cut in soil. *Image courtesy of Southern Fire Exchange.*

Figure 2.6. Agency wildland firefighters wear specific personal protective equipment, or PPE. However, for most private landowners, 100% cotton long-sleeved shirts and pants, as well as leather boots and gloves will provide sufficient protection. *Diagram credit: Jessica Shaklee.*

☐ *Determine Personnel and Equipment Needs*

Maintain prescribed fire within the project boundary by identifying resources and staff needed for all operational phases (pre, during, post ignition). Determining how many people you will need to safely execute the burn will be based on the size and complexity of the burn area, experience of crew members, as well as any special conditions or challenging areas. You will also need to determine the equipment needed to conduct the burn safely. Common equipment needs include drip torches for ignition, a weather instrument for monitoring onsite weather conditions, personal protective equipment for burners, and tools, such as rakes or shovels, for suppression and mop-up. You should also consider having a source of water. You can get water onsite by utilizing a water sprayer or pumper unit.

ASSEMBLE PERSONAL PROTECTIVE EQUIPMENT (PPE)

When conducting a prescribed burn, it is important to wear clothes that will provide protection. Long pants and long-sleeved shirts must be worn, and it is crucial to wear clothing made only of natural fibers like cotton/wool or a fire-resistant material such as Nomex, which is what agency personnel use (Figure 2.6). Synthetic fibers like nylon and polyester will melt when exposed to high temperatures. Closed toed-shoes and gloves are also a must-have, preferably leather boots and leather gloves. Eye protection is beneficial to have on the line, as it will help prevent smoke, ash, and other debris from irritating your eyes. Finally, helmets are good for protecting your head especially if you are close to trees that may drop branches or snags.

1. **Alcohol Wipes**
2. **Pads/gauze** (Large Gauze pad, Rolled Gauze, Medium Nonstick Pad with adhesive tab, Small Nonstick Pad with adhesive tabs)
3. **Bandage tape**
4. **Nonsterile gloves, latex or non-latex**
5. **Self-adhesive wrap, also referred to as Vetwrap**
6. **Bandage scissors**
7. **Bandages** (Wound closure bandages, Waterproof bandages)
8. **Sterile Bandages**
9. **Ace bandages**
10. **Safety Pins**
11. **Tweezers**
12. **Poison Ivy & Oak Scrub**
13. **Epinephrine pen injection**
14. **Pain reliever** (Ibuprofen (NSAID), Bayer Chewable (NSAID), Aspirin liquid (NSAID), Naproxen Sodium)
15. **Eye saline**
16. **Allergy Relief**
17. **Antibiotic Ointment**
18. **Equate Anti-itch cream**
19. **Cold Pack**
20. **Liquid Skin or Moleskin**

Figure 2.7. First aid kit components. *Diagram credit: Jessica Shaklee.*

ASSEMBLE A FIRST AID KIT

Since small burns or injuries that occur in a prescribed fire can need more treatment than a basic first aid kit, consider getting an “enhanced” kit with larger compresses, ice packs, medical gloves, and more (Figure 2.7). Wilderness type first aid kits can be purchased at sporting goods or other outdoor stores. The kit should have enough bandages to secure a larger wound. It is also wise to include some type of antihistamine, such as Benadryl or Claritin, in your kit, in case of allergic reactions to stinging insects or plants. Other over-the-counter medications, like ibuprofen or tylenol, can reduce discomfort in the field.

Table 2.1. Prescribed Fire Equipment and Tools

Image	Prescribed fire tools	Description and how are they used in a prescribed fire
	Drip torches	This is the primary ignition tool and it is commonly filled with a mixture of diesel and gasoline fuels. The fuel mix ratio may change depending on conditions.
	Shovels	This common tool can be used to place soil on stumps, logs, or other burning material. It can also be used to mix water into soil to cool down hot spots.
	Leaf blowers	Leaf blowers are used to blow debris back into burn units along the edge of the firebreak. They are also effective in clearing out leaves and duff from under hard to reach areas.
	Chainsaws	Saws are used to fell snags, cut logs into manageable size pieces, or clear thick shrubs/brush from under trees.
	Axe / hatchet	While not as fast working as chainsaws, these alternatives can be effective on smaller trees or shrubs, and can be used in a pinch.
	Rakes / McLeods	Rakes can be used to pull debris to create a fuel break, cut down small shrubs and brush, and drag limbs and logs. This tool is useful to protect fire sensitive objects like signs, power poles and utility boxes.
	Radios	Radios are used for communication throughout the burn.
	Wildland fire pumper unit	This equipment is commonly used on agency prescribed burns to rapidly access areas of concern (as they are generally mounted onto smaller, 4-wheel drive vehicles). They are used to extinguish, soak, wet, or cool down fuels.
	Pulaski	This piece of equipment is a combination of an axe and adze in one head, with a rigid handle of wood, plastic, or fiberglass. The Pulaski is a versatile tool for constructing firebreaks, as it can be used to both dig soil and chop wood.
	ATV / utility vehicles	Oftentimes, reliable and swift mobility is needed on the fire line. ATVs and utility vehicles are used to patrol the burn unit and to transport equipment and personnel.
	Backpack pumps	These manual pumps are used to extinguish, soak, wet, or cool down fuels. They are especially important in that they can go where traditional water pumper units cannot go; making them a vital tool in quickly putting out hotspots.
	Fire swatters	Fire swatters are an effective tool for smothering small grass or brush fires. They should be dragged across and held on hot spots to smother them.

Figure 2.8

USING A DRIP TORCH

The most common method of ignition for prescribed fire is the **handheld drip torch**. A drip torch is a tool, which is a vessel for fuel and it is used to purposefully ignite fires by dripping flaming fuel onto the ground.

1 Fill the driptorch about 75% full with fuel

Extra space is needed to allow room for fuel to expand when temperatures increase. If the torch is filled to the top, then it is likely to leak as pressure builds up, wasting fuel and creating a safety concern.

2 Ignite the drip torch

- pour a *small* amount of fuel on some leaf litter/ pine needles
- make sure the fuel saturates the wick
- ignite the fuel on the ground with a lighter
- place the wick of the torch in the flames, avoid pouring too much fuel at once
- or use an existing source of fire to light it

Common Fuel Ratios for Drip torch Mix
4 parts diesel: 1 part gasoline
If there is too much diesel, then the torch will be difficult to light. If there is too much gas, then the fuel can burn up before reaching the vegetation. The exact ratio will depend on weather and fuels. Consult with your local expert for guidance on your area.

3 Control the flow of fuel released from the drip torch

Adjusting the Air Breather Valve (Figure 2.8, #5) controls the amount of fuel released and the speed that the fire flows. When it is closed, the drip torch will not pour fuel. It is important to note, when fully open, the stream of fuel can overshoot the wick and not ignite.

4 Extinguish the drip torch

Smother the drip torch flame by grabbing the wick while wearing a thick leather glove. The drip torch should be extinguished, when the drip torch is not in use, either when taking a break or when finished.

Do NOT blow a drip torch out as there is a high risk of your face getting burned.

1. **Wick** – Maintains a small ball of fire on the end of the drip torch for fuel to pass over and ignite from.
2. **Spout** – Fuel exits the canister through this nozzle and pours onto the wick.
3. **Fuel Trap Loop** – This loop prevents the fire from backing into the main canister. When a torch is assembled, this loop should always be facing the opposite direction of the handle.
4. **Locking Ring** – Holds the torch assembly together, whether it is configured upright or inverted for storage.
5. **Discharge Plug** – This plug prevents the flow of fuel during transport and storage when screwed into the fuel outlet at the base of the fuel trap. If your torch is assembled and not pouring fuel, double check this plug has been moved over to the parked position.
6. **Air Breather Valve** – Allows air to enter the canister while fuel is exiting and controls the flow of fuel.
7. **Handle** – For holding the drip torch. It is not advised to hold the drip torch by any other part.

Figure credit: Jasmin El Farnawany. Diagram adapted from Willis, K., 2023. Drip torches, deconstructed.

OBTAIN FIRE EQUIPMENT

Fire equipment ranges from simple tools, such as rakes and shovels, to full fire suppression machinery, like engines and tractor plows. The type and amount of equipment needed for a specific burn depends on the complexity, which is related to burn unit size and fuel characteristics. Drip torches are used to light the majority of prescribed fires. A drip torch has a reservoir for fuel, and a nozzle tip, which ignites when soaked with fuel. The nozzle allows drip torch fuel mix to slowly drip out to the end of the tip where it ignites. Carrying the drip torch by the handle with the tip pointed towards the ground and walking allows the fire to drop to the ground and ignite the fuels. Drip torch fuel is a 50:50 mixture of diesel and gasoline, though the ratio can change depending on conditions. In hotter temperatures the fuel may be a 60:40 mix or even as high as 70:30, as gasoline tends to burn too quickly, so greater amounts of diesel in the fuel mix reduces flare-ups and keeps the flame lit longer. Drip torch fuel mix ratios may differ depending on fuel type and weather conditions, experienced local burners may have their own preferred fuel mix ratios.

Firebreak equipment can vary greatly from a shovel to a tractor plow unit. Common equipment utilized by burners include ATVs and UTVs, though UTVs tend to be preferred over ATVs for their additional safety and stability. These vehicles allow individuals to quickly patrol fire breaks and they can also be outfitted with low volume sprayers that are very useful in controlling low-intensity spot fires, preventing things like snags from fully catching fire when sprayed early.

If you find yourself in need of certain equipment, some Prescribed Burn Associations (PBA) or state forestry agencies have equipment that can be borrowed or rented. You may also decide that you would like to purchase your own fire equipment and personal protective equipment. Such items can be purchased at specialty vendors, such as forestry or agricultural supply stores, or hardware/outdoor goods stores. Different types of prescribed fire equipment are shown in Table 2.1.

Overview of Safety - Extra Information

There are inherent risks associated with prescribed fire operations, but proper planning can minimize and reduce these risks. Recognizing the conditions and situations that pose a threat and can help you plan how to minimize and reduce these risks. While many safety concerns might have already been addressed in the burn plan, new hazards can arise that were either overlooked in the planning phase or arose due to evolving conditions at the burn

Image 2.12. Discussing safety at landowner learn and burn event. *Image courtesy of Leslie Boby.*

site. Having the right equipment is an important component of successfully conducting a prescribed fire and contributes to improved safety. It may be necessary to prepare a specific checklist that covers the required items and equipment. Additionally, safety on the fire line is a matter of following a series of common-sense procedures to protect people and the resources being managed.

PERSONAL SAFETY

While PPE offers some protection from fire line hazards, the most effective strategy to reduce exposure is by practicing sound **situational awareness.** Being aware of what is going on around you so that you can recognize new hazards as they arise and avoid tunnel vision. Personal hazards encountered during a prescribed fire include, but are not limited to: dehydration, heat exhaustion, cramps, and smoke inhalation. Most of these risks can be avoided by wearing appropriate attire, drinking enough water leading up to (and during) the burn, and minimizing exposure to smoke.

CREW SAFETY

Crew safety starts with choosing an individual to take charge of the burn (burn boss) who then provides direction for those helping. While each individual has to take personal responsibility for being safe on the fire, the burn boss is responsible for following recommended practices to keep everyone safe. The burn boss assigns tasks to crew members, checks that they have the necessary equipment for their role and develops a communication protocol that may include use of radios, cell phones, or staying within line of sight. It is important for the burn boss to assign clear instructions about crew safety to all individuals working on the fire and to ensure that these instructions are understood. The burn boss will conduct a briefing with the entire team before the burn to review the burn plan and map and to ensure they are clear about strategies and tactics to be used in the burn. Be sure to provide copies of the map to crew members. During the briefing, the burn boss will also discuss the risks and challenges for that location, as well as watch out situations (Figure 2.8), and any other safety concerns. Additionally, a back-up burn boss should be established, so that they may take over the burn should the original burn boss become unable to do so. Everyone should know the plan and be kept informed as new situations develop, and tactics change.

The list below highlights specific situations and/or conditions that could be dangerous for conducting prescribed fire or fighting wildfires. Each situation is based on an actual event which caused injuries, entrapments, or fatalities in wildlfire history. Watch out situations serve as warning to proceed with caution.

WATCH-OUT SITUATIONS
(GEORGIA FORESTRY COMMISSION)

1. An adjoining property that contains fuels with the potential to burn rapidly
2. Extensive periods of drought
3. More than three years since the property was burned
4. Moderate or high fog potential the night following the burn
5. Utility poles and other structures on site
6. Piles, windrows, heavy fuels or large amounts of dead/down fuel within the burn area
7. Standing dead snags along the fire breaks
8. Hazardous fuels = Any live or dead vegetation that can threaten ignition or the intensity and rate of spread, even under preferred prescribed burning weather conditions
9. Significant changes in topography, such as open fields, timber stand height, etc. that will cause winds to increase or change direction
10. Smoke sensitive areas (SSA) downwind or down drainage areas
11. Threatened and endangered habitat.

Figure 2.8. Important watch-out situations developed by the Georgia Forestry Commission.

Managing Liability

BASIC PRINCIPLES OF LIABILITY

All states in the South have laws or regulations that are supportive of prescribed fire and reduce liability risks for landowners. However, many landowners have misconceptions about prescribed fire liability and it is one of the main reasons listed for not using prescribed fire on private lands. Liability refers to the legal responsibility people hold for their acts or omissions. Liability, with respect to prescribed fire, means that a landowner or burner may be held accountable for damage to other people or society from an escaped fire or smoke.

Negligence is a standard based on what a "reasonable person" would do, or not do, in the same situation. This standard is applied to situations to determine if a person was negligent in their actions or inactions and would be liable for the damage caused. There are generally three types of liability under which the person responsible for the burn would be considered the defendant including gross, simple, or strict negligence (described below). All thirteen states in the South have either simple or gross negligence standards for fire and smoke (see Table 2.2).

a) **Gross negligence** means that the landowner is not considered negligent unless measurable damage was proven to result from the burner knowingly and willingly demonstrating a lack of care. This lack of care is known as reckless disregard. Under gross negligence law the opposing party must prove that the defendant was negligent in his/her actions. In states where gross negligence law applies, it is common to have legislative standards and certification requirements that a burner must adhere to when conducting a prescribed burn to receive the benefit of gross negligence.

b) **Simple negligence** means that a person is deemed negligent unless proven otherwise. Therefore, the person responsible for the burn is guilty until proven innocent. For example, an escaped fire that causes damage or injury to a neighbor(s) could fall under simple negligence. The person responsible for the burn must prove that due care was exercised. This is the most common type of liability law, but the specifics of the law vary from state to state.

c) **Strict or unlimited liability** refers to negligence that does not need to be proved and the defendant is liable for any damages regardless of any actions taken to avoid damages. None of the states in the South hold burners to strict liability standards.

Table 2.2. Civil liability standards for prescribed burning across the southeast.

STATE	FIRE	SMOKE
AL	Simple Negligence	Simple Negligence
AR	Simple Negligence	Simple Negligence
FL	Gross Negligence	Gross Negligence
GA	Gross Negligence	Gross Negligence
KY	Simple Negligence	Simple Negligence
LA	Simple Negligence	Simple Negligence
MS	Simple Negligence	Simple Negligence
NC	Simple Negligence	Simple Negligence
OK	Simple Negligence	Simple Negligence
SC	Simple Negligence	Gross Negligence/ Recklessness
TN	Simple Negligence	Simple Negligence
TX	Simple Negligence	Simple Negligence
VA	Simple Negligence	Simple Negligence

FOLLOW STATE PRESCRIBED BURNING LAWS OR STATUTES TO REDUCE LIABILITY

Following safe prescribed burning practices is one of the best ways to protect yourself from liability. Every state in the South has either laws, acts or statutes in place that support prescribed burning as being the right of a landowner and in the public interest. For example, Mississippi's Prescribed Burning Act defines it as a landowner's "property right and a land management tool that benefits the safety of the public, the environment and the economy of Mississippi." While these laws, statutes and acts are favorable to prescribed fire, they have specific requirements that a landowner must meet, to be in compliance. Some states have only two requirements while others have longer lists. Requirements for these state acts are consistent with recommended prescribed fire practices. Complying with the requirements of a state's prescribed burn acts (or laws/statutes) often protects landowners from liability. Since each state differs in its liability laws and regulations, consult with your state forestry agency to find information and recommendations specific to your area.

Common requirements to meet state prescribed burning acts/laws/statutes and reduce liability include:

- Obtaining a burn permit from the state forestry agency
- Written burn prescription
- Notifying neighbors about burn
- Certified Prescribed Burner supervising the burn
- Being onsite at the burn from ignition to completion

In addition to meeting the requirements of state laws and regulations, there are other best practices that can help you reduce your liability risks and protect you in the case that something does go wrong. For example, recording weather information during the burn and keeping that note and any other documents related to your burn is a good idea. General tips and recommendations for reducing prescribed fire liability are listed in Figure 2.9.

Find More Information about Prescribed Burning & State Liability Laws in these Publications

Prescribed Fire Liability Report for the Southern United States: A Summary of Statutes and Cases (2022)

Authors: Fawcett, J., Cary, B, Lowdermilk, J.
Find it on the Texas A&M University's Natural Resource Institute website: www.nri.tamu.edu

Prescribed Fire: Understanding Liability, Laws, and Risk (2020)

Authors: Weir, JR., P. Bauman, D. Cram, J.K. Kreye, C. Baldwin, J. Fawcett, M. Treadwell, J.D. Scasta, and D. Twidwell.
Oklahoma State University Cooperative Extension Service Publication: NREM-2950

Figure 2.9. Tips for liability considerations when prescribed burning. *Adapted from Baldwin, C., 2015. Prescribed Burn Notebook*

PRESCRIBED BURNING LIABILITY TIPS

- ☐ **Make sure you have a burn plan, but don't make it too complex.** If the burn plan is incredibly detailed, then there is less room for adaptation and a greater likelihood that prosecution could find you violated some portion of the burn plan through error in execution.
- ☐ **Be diligent about finding and recording information about weather conditions at the time of the burn and during the burn.** Print out the fire weather forecast at the same time as when you decide to burn.
- ☐ **Keep your documentation from the burn with the burn plan** and store both until after the statute of limitations has occured. However, it is always a good practice to keep your old burn plans for long-term evaluation purposes.
- ☐ **Connect with your neighbors to inform them of your plans well in advance of the burn.** Maintain communication with them and continue to let them know who the burn is likeliest to concern, especially anyone nearby that may have respiratory ailments.
- ☐ **Inform the local fire department of your plans and your preparation** and ensure that you have all appropriate permits.

References:

Baldwin, C. (2015). Prescribed Fire Notebook. Kansas State University.

Fawcett, J., Cary, B, Lowdermilk, J. (2022). Prescribed Fire Liability Report for the Southern United States: A Summary of Statutes and Cases. Retrieved from https://nri.tamu.edu/publications/extension-publications/2022/prescribed-fire-liability-report-for-the-southern-united-states-a-summary-of-statutes-and-cases/ on

National Wildfire Coordinating Group (NWCG). (May 2022). NWCG Standards for Prescribed Fire Planning and Implementation. PMS 484.

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

Weir, JR., P. Bauman, D. Cram, J.K. Kreye, C. Baldwin, J. Fawcett, M. Treadwell, J.D. Scasta, and D. Twidwell. (2020). Prescribed Fire: Understanding Liability, Laws, and Risk. NREM-2950 Cooperative Extension Service,Oklahoma State University, Stillwater, OK 12p.

Weir, JR. (2009). Conducting prescribed fires: a comprehensive manual. (Texas A&M University Press, College
Station, USA

Weir, J.R., Bidwell, T.G., Stevens, R. & Mustain, J. (2017). Firebreaks for Prescribed burning. OSU Extension Id: NREM-2890

Willis, K. (2023, February 16). Drip torches, deconstructed. Southeast Prescribed Fire Update. https://sites.cnr.ncsu.edu/southeast-fire-update/2023/02/16/drip-torches-deconstructed/

PLANNING NOTES

PLANNING NOTES

PLANNING NOTES

CONDUCTING THE BURN

Image courtesy of Corey May

Table of Contents

WEEKS BEFORE THE BURN

- [ ] Review the burn plan
- [ ] Check firebreaks (create firebreaks, if needed)
- [ ] Monitor weather
  - Pay attention to general weather trends, such as predicted rains and fronts
  - Check various weather parameter related to your prescription
- [ ] If needed, develop a smoke management plan
- [ ] Walk the burn unit and look for safety hazards
- [ ] Assemble and check equipment
- [ ] Organize people who can assist in the burn
- [ ] Notify neighbors to let them know you are planning to burn in the coming weeks

DAYS BEFORE THE BURN

- [ ] **Review the burn plan prescription**
  - Make copies of the burn map for all participants
- [ ] **Check onsite conditions**
  - Check all firebreaks to ensure they are still clear
  - Check the duff (organic soil layer) moisture
  - Look for any additional safety hazards
- [ ] **Monitor weather**
  - Review the fire weather forecast particularly RH, temperature, wind direction & speed
  - Note dispersion indice values
  - Compare values to burn prescription
- [ ] **Review your smoke management plan and best practices**
- [ ] **Confirm you have enough people to complete a successful burn**
- [ ] **Prepare your fire equipment as needed**
  - Make sure your power tools are operable and are appropriately fueled
  - Check other tools to make sure they are functional (e.g. radios have fresh batteries, no loose toolheads, etc.)
- [ ] **Notify emergency services and neighbors that a burn is planned in the coming days**

Image 3.1. A prescribed burn in a stand of Sugarcane Plume Grass. Prescribed fire is an important tool in the management of this species, which can be challenging to remove otherwise. *Image courtesy of Corey May.*

DAY OF THE BURN

- [ ] **Obtain the fire weather forecast and print**
  - Compare the forecast with the burn prescription
- [ ] **If weather conditions are acceptable, obtain a burn permit and sign the prescription**
- [ ] **Remind emergency services and neighbors that a burn is taking place**
- [ ] **Make sure you have copies of the burn plan and burn map available for all participants**

ON THE FIRELINE

- [ ] **Monitor and log weather onsite**
  - Before and during the burn
- [ ] **Conduct a crew briefing**
  - Familiarize the crew with the burn unit
  - Provide copies of the burn plan and map(s)
  - Review burn plan objectives
  - Review the map(s)
  - Address safety and risk management
  - Review the contingency plan
  - Review the fire weather forecast
  - Assign roles and responsibilities
  - Establish communications
- [ ] **Review the Go/No-Go checklist**
- [ ] **Verify the downwind side**
- [ ] **Complete a fire test**
  - Determine if the burn will proceed
- [ ] **Begin the burn**
- [ ] **Observe fire behavior and adjust accordingly**
- [ ] **Monitor smoke patterns**
- [ ] **Monitor firebreaks**
- [ ] **Mop-up**
- [ ] **After-action review**
- [ ] **Start the evaluation**

Introduction

Burn days are a culmination of all the preparation that has taken place in the previous weeks and months. At this point a burn plan should have been developed, firebreaks constructed, fire and safety equipment accounted for, and personnel ready on deck. This section will outline what to expect on the day of the burn, as well as tips to help you succeed.

☐ Weeks Before the Burn

REVIEW THE BURN PLAN

As you get closer to the day of the burn, you will want to review specific safety considerations and ignition techniques already outlined in the burn plan. You will also want to identify any new hazards that need to be mitigated and reevaluate the plan based on current conditions.

Check the following items that may have changed since the burn plan was developed and adjust the plan as needed (adapted from Waldrop and Goodrick):

The burning objectives - have they changed?

The amount and type of fuel within the burn unit. You may need to exclude the following areas when burning to promote the highest level of safety:

- Sawdust and slash piles, dry organic soils, snags, trash, old home sites, buildings, and other fuels that may produce a lot of smoke and/or require substantial mop-up.
- Fuels that might produce long flame lengths or lofted embers adjacent to control lines, such as tall grasses or flammable shrubs.

The degree of risk and hazard present. For example:

- Recent storm damage that may have downed trees.
- Construction of new structures or land improvements that need to be protected.

Are planned firing techniques still appropriate for current conditions?

CHECK FIREBREAKS

Verify that adequate firebreaks (often called control lines) have been established. In the weeks and days before the burn, you will want to monitor the condition of all firebreaks. Be especially aware of any new litter or plant growth that might carry fire across the established perimeter. All firebreaks should be clean and clear of flammable material.

What is a firebreak? It is a natural or constructed barrier used to stop or check fires.

Types of firebreaks:

- Pre-existing roads
- Natural breaks, particularly water ways
- Well-maintained trails
- Plow and tractor lines
- Hand dug lines
- Wet lines

MONITOR WEATHER – *WEEKS BEFORE*

In the weeks before the proposed burn date, it will be important to monitor weather patterns. Pay specific attention to temperature and moisture trends, for example, noting when it has rained or how much time has passed since it rained. Check various parameters to compare to your burn prescription.

DEVELOP A SMOKE MANAGEMENT PLAN, IF NEEDED

Prescriptions for burns account for smoke management concerns and are generally planned to minimize smoke production or hazards. However, depending on current conditions, you may need to re-assess if there are any potential new smoke hazards.

WALK THE BURN UNIT AND LOOK FOR SAFETY HAZARDS

Look for any situations that have the potential to promote escaped fire or human injury. For example, there may be snags or dead trees that could hurt someone, new debris from a storm, or there may be an area with more ladder fuels, etc. Add any safety hazards to the burn unit map.

ASSEMBLE AND CHECK EQUIPMENT

As you prepare for the burn, collect the equipment that you will need or make plans to borrow or acquire it. Ensure that tools are in good working order.

CONTACT PEOPLE WHO CAN ASSIST IN THE BURN

At this point, you may want to reach out to people who are willing to assist you in burning and let them know your proposed and alternate dates.

Image 3.2. Landowners at Virginia Learn and Burn. *Image courtesy of Leslie Boby.*

NOTIFY NEIGHBORS YOU ARE PLANNING TO BURN IN THE COMING WEEKS

As the time comes closer, it may be good to reach out to any neighbors to let them know of your impending burn.

☐ *Days before the burn*

REVIEW THE BURN PRESCRIPTION

Refamiliarize yourself with the burn plan and make a few copies for your helpers, if you'd like.

MAKE COPIES OF THE BURN MAP FOR ALL PARTICIPANTS

Ensure everyone will have a copy of the burn map and that all burn units are identified.

CHECK ONSITE CONDITIONS

- Check all firebreaks to ensure they are still clear of any branches or other material
- Check duff (organic soil layer) moisture
- Feel the duff for wetness. Go to chapter 7, fuels for more directions for estimating fuel and duff moisture onsite.
- Look for any additional safety hazards

MONITOR WEATHER – *DAYS BEFORE*

Check weather forecasts from multiple sources every day leading up to the burn. The National Weather Service (NWS) and other forecasting applications can be used on mobile devices for easy access. Watch for any developing weather fronts or storms that may halt your burn. Forecasts are generally predicted 7 to 10 days out but can change overnight. Weather forecasts including parameters for your prescription, will be more accurate closer to the day of the burn. The variables you need to track

Table 3.1. Prescribed burn weather variables.

Weather Variable	When to Check	General desired values (specific ranges vary by states)
Ambient air temperature	Day of burn	Temperature recommendations vary throughout the year and with burn objectives. Temperatures generally range from 65°F to 85°F.
Relative humidity (RH)	Day of burn	RH values for prescribed burning vary depending on location, but mostly range between 25 to 60 percent.
Wind direction	Day of burn	Wind is forecasted in the direction it is coming from. For example, a north wind would push smoke and fire to the south. Use the 8 intercardinal directions when assessing wind direction: N, NE, E, SE, S, SW, W, NW.
Wind speed	Day of burn	Surface wind speeds between 5-15 MPH are common for prescribed burning. Greater than 15 MPH may cause control issues.
Mixing height	Day of burn	A general mixing height value above 1650′ is recommended; less than 1650′ may indicate potential negative smoke impacts. A mixing height above 6500′ may indicate erratic fire behavior and control issues.
Atmospheric conditions	One week prior to and day of burn	Be aware of inversions, fronts, low humidities, and erratic weather patterns (thunderstorms).

Image 3.3. Wind speed may be higher in open environments, because there is nothing to block it. *Image courtesy of David Godwin.*

Image 3.4. Erratic weather patterns can occur with little to no warning. *Image courtesy of Sarah McNair.*

Image 3.5. Signage that notifies passerby of a prescribed burn. *Image courtesy of Marco Sanchez.*

or report will vary by location and regulations, but should always include the wind direction and speed, relative humidity (RH) and ambient air temperature. Table 3.1 lists various weather variables that can be reviewed prior to burning and weather indices that are commonly checked too. Furthermore, the "general desired values" column contains examples of ranges. These ranges will also vary due to state agency guidance, permit requirements, management objectives, and site conditions.

NOTIFY EMERGENCY SERVICES & NEIGHBORS THAT A BURN IS PLANNED IN THE COMING DAYS

If multiple forecasts are predicting weather that falls within the prescription parameters, then it is time to notify adjoining property owners the burn will be taking place very soon or immediately. You should have already informed your neighbors some months or weeks ago that you were planning a prescribed burn, as they may have some concerns, so this should just be a reminder.

REVIEW YOUR SMOKE MANAGEMENT & GENERAL BEST PRACTICES

Smoke management is a critical consideration for any prescribed burn and it can often create more challenges than the burn itself. By the day of the burn, a smoke management plan should be in place. This information can play a central role in protecting human health, preventing unnecessary air pollution, and mitigating visibility issues. Refer to Chapter 6 Smoke Management (pp. 131) for more detailed information on predicting smoke patterns and discovering what actions you can take to keep your smoke production to a minimum. If you have already evaluated your potential smoke impacts, take a look at the checklist below for day-of reminders:

- Ensure proper road signs are posted near the burn alerting drivers of the smoke; temporarily close roads if necessary (in coordination with the local transportation department) (Image 3.5).
- Begin mop-up along roads as soon as possible to reduce impacts on visibility.
- Try to burn after inversions have lifted and be done well before sunset, as dispersion conditions are generally best at this time.
- Limit the hours smoke is produced during the day; this may mean burning the unit in small sections or using firing techniques known to burn hot and quickly.

Image 3.6. Smoke management is a critical consideration for prescribed burns. *Image courtesy of David Godwin.*

PREPARE YOUR FIRE EQUIPMENT

- Make sure you have the proper equipment and sufficient fuel for ignition.
- Check power tools and make sure that they are operable and have fuel.
- Check other tools to make sure that they are functional. For example, if you have radios, make sure they are charged or have enough batteries.

NOTE: Most weather forecasts only predict weather 7-10 days out.

CHECKING WEATHER

Table 3.1 lists various weather variables that can be reviewed prior to burning. The variables you need to track or report will vary by location and regulations, but should always include the wind direction and speed, relative humidity (RH) and ambient air temperature. Furthermore, the “general desired values” column contains examples of ranges. These ranges will also vary due to state agency guidance, permit requirements, management objectives, and site conditions.

Image 3.7. Landowners fill drip torches with fuel. *Image courtesy of David Godwin.*

Image 3.8. Proper equipment varies depending on your burn. If your burn unit is large, you may want to utilize an ATV to travel quickly and carry large amounts of water. *Image courtesy of David Godwin.*

Day of the burn

OBTAIN FIRE WEATHER FORECAST

Once the burn manager has determined that the burn plans are satisfactory or has made the necessary adjustments, check weather conditions to ensure they are consistent with the hourly forecast. As previously mentioned, the top three observed weather factors that drive fire intensity are relative humidity (RH), wind direction, and speed and ambient air temperature.

A dependable source of forecast information can typically be obtained from the National Weather Service - Fire Weather Dashboard, which provides forecasts by zones across the United States. By visiting their website, you can click on a map and get a detailed forecast for the exact area you plan to burn. Other sources for weather information include state forestry agencies, private weather forecasting sites, and on-site observations. See chapter 5, weather for a sample fire weather forecast. The burn manager should monitor one or more forecasts before, during, and after a prescribed fire operation.

OBTAIN BURN PERMIT

Most states require you to obtain a burn permit, also called an authorization, from your state forestry agency prior to starting the burn. Before doing so, check the Fire Weather Forecast and Current Fire Danger Rating for your area which you can find from the National Weather Service. Class 4 and 5 days indicate very high or extreme fire danger, and it is unlikely that you would be granted a burn permit on those days.

To obtain a permit you must call your state forestry agency or use their online burn request forms. Burn permits may be good for 1 to 30 days once issued, depending on the state forestry agency. When contacting your forestry agency be prepared to provide information about your location and burn.

Table 3.2. An example of a fire danger rating system used in Georgia and based off of the National Fire Danger Rating System (NFDRS). Some states may use different systems.

Class Day	Adjective
1	Low fire danger
2	Moderate fire danger
3	High fire danger
4	Very high fire danger
5	Extreme fire danger

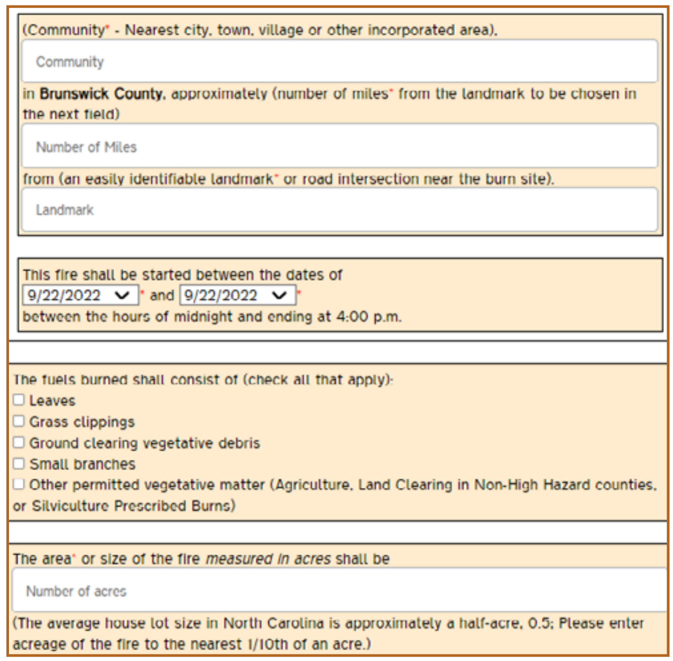

(Community* - Nearest city, town, village or other incorporated area).
Community
in **Brunswick County**, approximately (number of miles* from the landmark to be chosen in the next field)
Number of Miles
from (an easily identifiable landmark* or road intersection near the burn site).
Landmark
This fire shall be started between the dates of
9/22/2022 * and 9/22/2022 *
between the hours of midnight and ending at 4:00 p.m.
The fuels burned shall consist of (check all that apply):
☐ Leaves
☐ Grass clippings
☐ Ground clearing vegetative debris
☐ Small branches
☐ Other permitted vegetative matter (Agriculture, Land Clearing in Non-High Hazard counties, or Silviculture Prescribed Burns)
The area* or size of the fire *measured in acres* shall be
Number of acres
(The average house lot size in North Carolina is approximately a half-acre, 0.5; Please enter acreage of the fire to the nearest 1/10th of an acre.)

Figure 3.1. Example of an online burn permit application from North Carolina Forest Service.

Typical Information Needed for a Burn Permit:

- Location (Address, latitude/longitude, crossroads, section-range-township, etc.)
- Burn unit acreage
- Vegetation type to be burned
- Starting time and approximate duration of the burn
- Equipment and number of personnel
- Personal contact information (Typically a home address, phone number, and email)

Table 3.4. Burn permit requirements by state.

CHECK WITH YOUR STATE FORESTRY AGENCY FOR PERMITTING DETAILS *SUBJECT TO CHANGE*	
State	**Burn Permit Requirement**
Alabama	Required
Arkansas	Must notify, no permit
Florida	Required
Georgia	Required
Kentucky	Varies by county
Louisiana	Must be a "Certified Prescribed Burner" with written permission to burn
Mississippi	Required
Oklahoma	Required
North Carolina	Depends on local gov't
South Carolina	Must notify & get approved
Tennessee	Seasonal requirement
Texas	Required
Virginia	Varies by county

QUICK TIP:
GPS coordinates will ensure that emergency responders find the burn location quickly if needed. You can determine latitude and longitude by using Google Maps (https://www.google.com/maps). After navigating to the site, double-click the location of the burn. The coordinates will appear centered at the bottom of the page (Image 3.9).

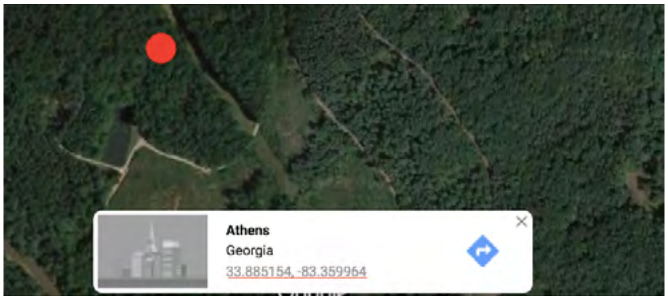


Image 3.9. An example of GPS coordinates obtained using Google to identify burn location. *Image courtesy of Google Maps.*

On the Fireline

CHECK FUEL & DUFF MOISTURE

Fuel moisture levels will determine how the fire burns. Fine fuels (1 hour fuels) need to be dry enough to burn while duff and logs (10-hour fuels) should be wet enough to avoid burning. At the burn unit, check the wetness of the duff at multiple spots, especially if it is a long, unburned stand. Estimate fine fuel moisture by touch or use the RH and fine fuel moisture tables. See Chapter 7 - Fuels for more information on estimating duff and fuel moisture.

MONITOR & LOG WEATHER ONSITE BEFORE & DURING THE BURN

While forecasts are helpful when planning, actual weather conditions should also be tested and recorded onsite. If one or more of the weather conditions do not fall within the prescribed parameters, then the burn should be postponed or canceled until values are acceptable. If there is a cell signal at the burn area, weather conditions can be monitored and documented via smartphone applications. Of course, cell signal in remote locations is never guaranteed.

Kestrel Weather Meter.
This tool calculates relative humidity, heat index, wind chill, wind speed, and temperature. It is available for purchase online.

A word of caution:
Be certain to calibrate meters for accuracy. An inaccurate meter can provide false readings – which can result in a hazardous field situation.

Image 3.10. Kestrel Weather Meter. *Image courtesy of Leslie Boby.*

To measure real-time weather conditions,use a portable, electronic weather meter. An entry level hand-held weather meter, such as the Kestrel in Image 3.10, can measure ambient air temperature, relative humidity (RH), and wind speed. You may want to have a compass to help orient yourself so you can correctly determine wind direction as well.

Relative humidity, temperature, and wind direction/speed readings can be logged approximately every hour in a notebook. Certain weather conditions may require that you monitor burn parameters more frequently such as every 30 minutes (shifting winds) or less frequently (cloud cover).

Assign one person to take onsite weather readings and announce conditions at regular intervals, approximately every hour throughout the burn.

Image 3.12. Ensure that you have spare batteries for radios, or walkie-talkies if you are using them. *Image courtesy of David Godwin.*

CREW BRIEFING

Once all necessary notifications have been made, the next step is to provide a thorough briefing for all individuals assisting with the prescribed burn (Image 3.13).

Remember, the burn boss or manager makes the final decision on all fire-related activities. While postponing or canceling a burn may be inconvenient, it is imperative to ensure the safety of life and property.

Image 3.11. Provide crew members with a map of the burn unit when briefing them. *Image courtesy of David Godwin.*

Image 3.13. Ensure that all crew members are present when reviewing the Go/No-Go checklist, so that you can address any concerns. *Image courtesy of David Godwin.*

Figure 3.2. Crew Briefing Checklist.

Y/N	Crew Briefing Checklist
	Familiarize the crew with the burn unit ■ Each crew member should have a map ■ Show crew the property if they are not familiar with it and point out hazardous or potentially hazardous areas
	Review burn plan objectives
	Review the map ■ Indicate where the fire is anticipated to begin and end ■ Point out labeled perimeters, locations, and landmarks that are of importance ■ Identify terrain or fuel features where fire behavior may change rapidly ■ Identify where smoke is likely to go ■ Identify travel routes and safety zones
	Address safety and risk management ■ Review known hazards and risks ■ Identify control measures to reduce/eliminate hazards and risks ■ Discuss procedures to follow under emergencies ■ Determine if crew members have specific health concerns or special medical training ■ Remind crew members to practice situational awareness, stay hydrated, and consume sufficient electrolytes (salts). ■ Ensure all crew members are outfitted in acceptable personal protective equipment (PPE)
	Review the contingency plan ■ Review safe zones and escape routes ■ Ensure that plans are in place for contacting emergency assistance in case of injuries ■ Review suppression strategy for an escaped fire

Y/N	Crew Briefing Checklist
	Review the fire weather forecast ■ Current and anticipated weather conditions ■ Alert crew of any likely changes in the weather (such as forecasted wind shifts, arrival of a front or increased cloud coverage) and the potential for altered fire behavior
	Discuss Fuels & Ignition plan ■ Discuss the type of fuels in the burn unit, moisture levels and how you will light it. ■ Mention any conditions that may be important
	Assign roles and responsibilities ■ Roll call – Get a headcount of all participants ■ Assign & describe burn crew roles including someone to take weather readings and another person to take over from the burn boss, if needed ■ Ensure that all crew members have and know how to use the appropriate tools for their assignment ■ Check that all tools are in working shape
	Establish Communications - The complexity of the burn will determine how you need to communicate ■ **Cell phones:** » Check if you have service, if not use radios or find another way to communicate » Ensure phones are charged » Exchange cell phone numbers ■ **Walkie-talkies or Radios:** » Distribute & test walk-talkies » Have extra batteries on hand » For radios, make sure everyone is on the same channel radio channel ■ On a small burn you may be able to communicate by shouting or using hand signals.

REVIEW GO/NO-GO CHECKLIST

Review the go/no-go checklist on below as a final checkpoint before starting ignitions. It can also be helpful to have this list attached to your burn plan for both reference and documentation.

Yes - No	National Wildfire Coordinating Group Prescribed Fire Go/No-Go Checklist Questions
	Are ALL fire prescription elements met?
	Are ALL smoke management specifications met?
	Has ALL required current and projected fire weather forecast been obtained and are they it favorable?
	Are ALL planned operations personnel and equipment on-site, available and operational?
	Has the availability of ALL contingency resources been checked, and are they available?
	Have ALL personnel been briefed on the project objectives, their assignment, safety hazards, escape routes, and safety zones?
	Have all the pre-burn considerations identified in the prescribed fire plan been completed or addressed?
	Have ALL the required notifications been made?
	Are ALL permits and clearances obtained?
	In your opinion, can the burn be carried out according to the prescribed fire plan and will it meet the planned objective?
If all the questions were answered "YES" proceed with a test fire. Document the current conditions, location, and results.	

Figure 3.3. NWCG Go/No-go checklist

Image 3.14. The burn manager leads the crew briefing to outline safety parameters and other essential information. *Image courtesy of Barry Coulliette.*

VERIFY THE DOWNWIND SIDE

Before starting a test fire, identify the downwind boundary of a burn unit. This boundary is important because it is typically used to create a wide, blackened fire line with a backing fire. You can easily recognize the downwind boundary by determining what direction the wind is blowing. For example, if the wind is blowing from the north, the downwind side will be the southern perimeter of the property (Figure 3.4).

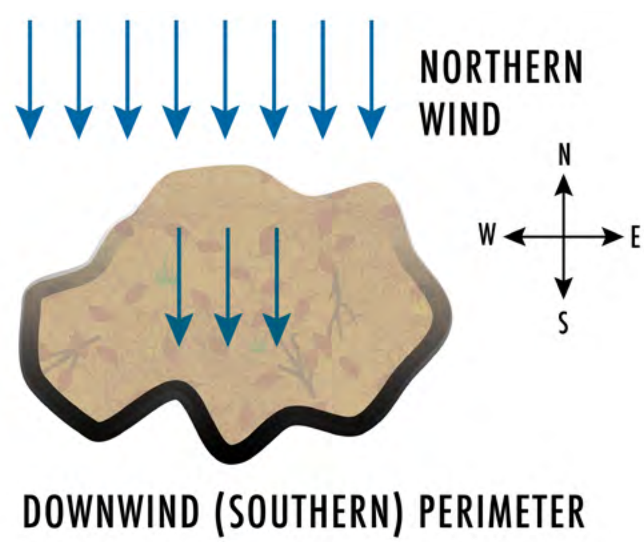


Figure 3.4. The downwind side of a burn is located opposite of the prevailing wind. *Diagram credit: Jessica Shaklee.*

Image 3.15. Crew personnel observe the test fire to gauge current conditions and to decide whether to proceed with the burn. *Image courtesy of John Herbert Ashton.*

Be open to canceling or postponing the burn!

COMPLETE A TEST FIRE

After the crew briefing is complete and conditions pass the go/no go checklist, then the burn manager or boss will light a test fire (Image 3.6). A test fire is a small fire set in a controlled area with fuels representative of the greater burn unit. This step is vital in determining whether conditions are favorable for fire behavior and smoke dispersion as outlined in the burn plan. Key considerations are wind (and smoke) direction and smoke lift, sufficient dryness of the fuel to carry fire, and fire behavior that is expected and acceptable for that time of day.

If the test fire meets your expectations for fire behavior and smoke dispersal, as outlined in the prescription parameters, then proceed with the burn as planned. If the test fire does not meet expectations, then the prescribed burn should be postponed until it can be safely conducted.

Reminder of Firing Techniques

Backing fire

- Move against the wind and much more slowly than heading fires.
- Typically lit along the downwind edge of a burn unit in order to slowly create burned areas or "blackline" close to the fire break.

Heading fire

- Move with the wind and move at faster speeds

Strip heading fire

- Set upwind of a fire break and are secured by either a firebreak or blackline created from a backing fire. Strips of fire are lit 150-250 feet from each other.

Flanking fire

- Set by simultaneously igniting multiple lines of fire directly into the wind. Requires multiple drip torches and fire crew members.

Point source fire

- Generally preceded by a backing fire on the downwind side of the burn unit. A line of 'spots,' differing in their intensities, are ignited upwind of the backing fire. This is repeated in a grid-like pattern until the entire burn unit has been consumed.

Ring fire

- Generally started with a backing fire on the downwind side of the burn unit. Burners ignite one or two spot fires in the center of the spot fire, and then ignite flank fires to surround the burn unit.

Find fire technique diagrams in Chapter 8, Fire Behavior: pages 190-196

START BURNING:

Burning objectives can be met through a variety of firing techniques. The burn typically includes multiple firing techniques and the firing pattern will be based on a combination of characteristics

MY FIRE ESCAPED! WHAT SHOULD I DO?

STOP all ignition activities. Evaluate potential fuel, size, rate of spread, location, and if additional suppression resources will be needed.

Consider your contingency plan. A good contingency plan should anticipate potential issues and state the resources needed to mitigate problems as they arise.

Contact your local forestry agency or fire department sooner rather than later!

including topography, fuels, and weather factors. For example, the burn boss will likely secure the downwind boundary with a backing fire, until the downwind burn unit boundary is secure, after which other ignition techniques might be used. Refer to Chapter 8 - Fire Behavior, pages 190-196 for diagrams and detailed explanations of each of the firing techniques.

Slopes and Fire

Care should be taken when conducting a burn on sloping or steep terrain. A fire traveling up a steep slope will move more quickly and burn more intensely than when on level terrain. Conversely, a headfire traveling down a hill may cause the fireline to move slowly and with less intensity. Fire behavior is more strongly influenced by topography when wind speed is low. Fuel moisture is also affected by slope. South-facing slopes tend to be drier, while north-facing areas are often cooler, moister, and have less fuel.

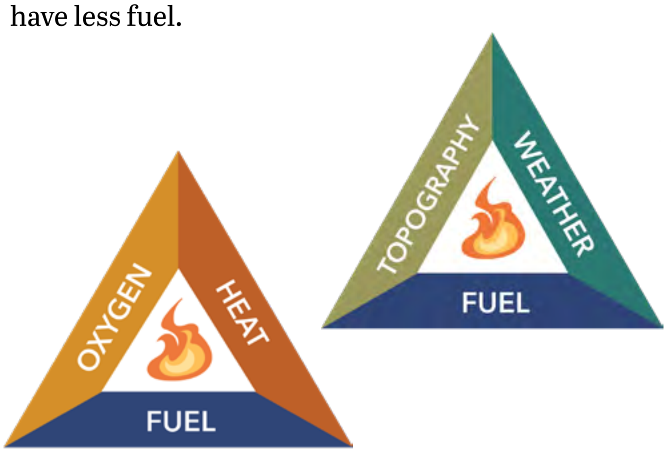


Figure 3.5. Fire Triangle & Fire Behavior Triange. Learn more about the fire behavior and fuel behavior triangles in chapters 7 (fuels) and 8 (fire behavior).

Fire behavior should be continuously observed throughout the burn

Additionally, monitor the amount & direction of smoke. Depending on your observations, firing techniques may need to be adjusted & people may need to move spots to safely meet burn objectives.

MONITOR FIREBREAKS

As soon as the burn has started, the fire perimeter should be patrolled by assigned crew members. This means all firebreaks should be monitored for spot fires outside of the intended burn unit and within areas of concern (downwind firebreaks, snags, adjacent fuels, large debris piles close to firebreaks, etc.).

Watch for Spot Fires

Spot fires occur when embers are transported across the firebreaks and create an ignition aerially outside of the intended burn unit. This can happen when wind gusts, convection columns, snags, or other fuels loft embers and carry them across the control line. These embers may land in an unburned receptive fuel, igniting small spot fires outside the control lines.

Watch for Rolling Debris

Burning debris on steep terrain may roll downhill and across constructed lines, igniting unburned fuels on the other side. Position firebreaks to avoid these hazards or dig cup trenches to minimize the risk of a rollout ignition.

Watch for Creeping
Creeping fires can follow buried root systems, peat, thick duff layers, and other organic soil infills. Firebreaks must be built to mineral soil (or water) levels to prevent fire from creeping beneath breaks. Also, an accumulation of light litter (dried leaves, twigs, etc.) have enough continuity to encourage creeping.

Image 3.16. Firebreaks can be constructed for the burn, or can be preexisting, such as a roadway. *Image courtesy of Leslie Boby.*

MOP-UP

Once it is confirmed that the firebreak lines are secure, and the active fire progression is no longer along the fire break, mop up becomes the next task. **Mop up is the slow and sometimes tedious work of mitigating residual heated or unburned fuels.** It is one of the most important jobs, as it can be crucial in preventing fire escapes and smoke problems (Image 3.17).

Mop up operations should begin as soon as possible along firebreaks and target hot spots on the downwind side of the burn unit. Mop-up operations should progressively work inward from the firebreak

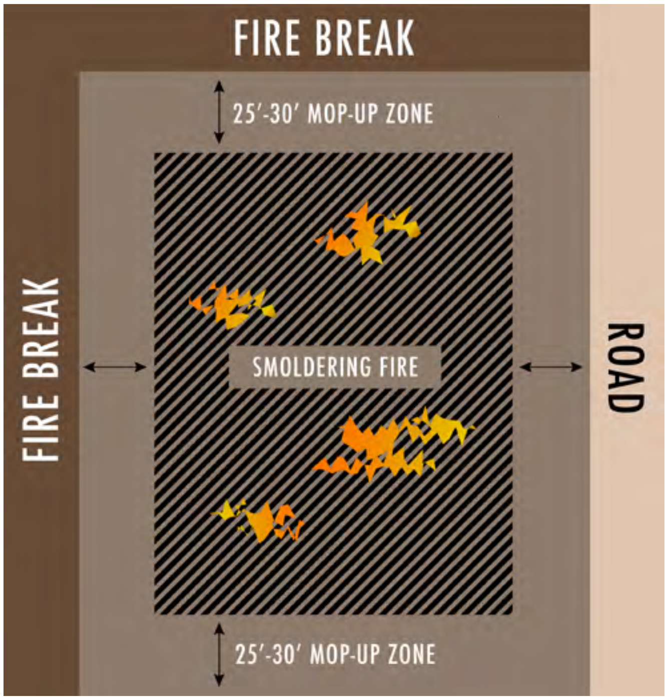


Figure 3.6. Mop-up breakdown. *Diagram credit: Melanie Quinton, Jessica Shaklee.*

Mop up is extinguishing or removing burning material near firebreaks. Generally, it is good to create a a 25′ to 30′ mop up zone parallel to fire breaks (figure 3.6).

until the area has been secured at a designated distance along the edge of the entire burn unit. Mop up may be required throughout the entire burn unit to some degree to prevent excessive smoke, especially during the night when inversion layers are low and there is little vertical lift. Burn crew members working on mop-up should be rotated frequently to mitigate smoke exposure. If there are filtered masks available, first priority should go to those working downwind of the fire.

There are both dry and wet mop-up techniques, but mop-up is easiest to do with water. In wet mop-up, first separate and expose burning materials using hand tools, and then douse the materials with water, and soil. A water supply can come from a variety of sources ranging from a backpack pump,

Table 3.4. Various mop-up techniques, wet and dry. Courtesy of the National Wildfire Coordinating Group (NWCG).

Wet Mop-Up Techniques
Apply a fine water spray from the firebreak inward
Use a straight stream to penetrate or reach a target
Spray, stir, and spray again as necessary
Use foam or another wetting agent
Break apart and spread fuel concentrations to lower fire intensity
Dry Mop-Up Techniques
Boneyarding: Place small, unburned limbs and logs in the black (previously burned area)
Chunking and piling: Allow materials to completely burn themselves out
Spreading: Spread out heavy concentrations of materials to lower fire intensity
Banking: Cover fuels temporarily to prevent them from igniting
Turning: Move materials that could roll so they are perpendicular to the slope, and then placing a cup trench below them

mobile fire apparatus, or industrial tank sprayer. Oftentimes, a small tank can be mounted on an ATV or a large tank can be pulled by a farm tractor. If water is not available, common or specialty hand tools can be used to do a dry mop-up. Dry mop-up is extinguishing smoldering material by scraping, stirring/mixing, and piling and it works best when combined with soil. Also, dry mop-up may not be sufficient under drier conditions when ground fuels, such as duff and roots, are still available to burn.

Image 3.17. Fire crew personnel conduct wet mop-up with a fire hose to extinguish hot spots. *Image courtesy of North Florida Prescribed Burn Association.*

Review Table 3.4 to learn more about wet and dry mop-up techniques.

Ultimately, final mop-up ensures that the fire has exhausted most, if not all, of the available fuel and that remaining hot or smoldering spots are within an acceptable level of risk. Remember to never leave a burn until all firebreak are secure. Continue to regularly check the fire until no visible smoke or ignitions are present for 24 hours. While the burn crew may leave a fire after mop-up is completed, the burn manager is responsible for ensuring that the fire is contained – even after normal “work hours.”

If strong winds or weather fronts are predicted post-burn, then more monitoring of the burn site will be needed, as these conditions can jeopardize the integrity of control efforts and lead to an escape. It may be helpful to visit the burn unit at night to identify remaining hot spots. Once the fire is officially declared out, then it is time to congratulate yourself and your crew on a job well done!

HOLD A POST-FIRE WRAP-UP DISCUSSION

As you wrap up the burn, it is a good practice to bring the crew together and briefly review how the burn went. Did everything go as expected? Were there any unwelcome surprises? Did you achieve burn objectives for the day? What could be done differently next time? This discussion will assist you to evaluate the burn.

Evaluations can be as simple as some short notes and a few pictures.

START THE EVALUATION

Conduct an evaluation of your burned area the same day of the burn, or soon after. Evaluations can be as simple as listing the date of the burn, recording some notes, and compiling a few photographs. Evaluations can also be more detailed and it's important to note that certain objectives can only be assessed weeks to months after a burn. The "Evaluating the Burn" chapter has more information on how to formally evaluate your burn.

References:

Baldwin, C. (2015). Prescribed Burning Notebook. Kansas State University.

Waldrop, T.A., and Goodrick, S.L. (2012) Introduction to prescribed fire in southern ecosystems. Science Update SRS-054. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 80 p.

Weir, JR., P. Bauman, D. Cram, J.K. Kreye, C. Baldwin, J. Fawcett, M. Treadwell, J.D. Scasta, and D. Twidwell. (2020). Prescribed Fire: Understanding Liability, Laws, and Risk. NREM-2950 Cooperative Extension Service, Oklahoma State University, Stillwater, OK 12 p.

Weir, JR. (2009). Conducting prescribed fires: a comprehensive manual. Texas A&M University Press, College Station, USA.

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

QUICK TIP:
Feel for heat in burned materials by using the back of your hand. After removing your glove, place the back side of your uncovered hand approximately 1" away from the item. If you don't feel any heat, then touch the item with the back of your hand to confirm that it is fully extinguished.

Image 3.18. Conducting a prescribed burn takes time, but is worth the effort. *Image courtesy of Corey May.*

Sourced from the U.S. Forest Service Introduction to Prescribed Fire in Southern Ecosystems (August 2012).

SIMPLE UNDERSTORY PRESCRIBED BURNING UNIT PLAN

Landowner ______________________ Permit no. __________
Address ______________________ Phone no. __________
S ______ T ______ R ______ County ________ Acres to burn ________ Previous burn date __________
Purpose of the burn ______________________

(Draw map on back or attach)

Stand Description
Overstory type & size ______________________ Height to bottom of crown __________
Understory type & height ______________________
Dead fuels: description and amount ______________________
____

Preburn Factors
Manpower & equipment needs ______________________
List smoke-sentitive areas & locate on map ______________________
Special precautions ______________________
____
Estimated no. hours to complete ______________ Passed smoke screening system ______________
Adjacent landowners to notify ______________________
____

Weather Factors:	**Desired Range**	**Predicted**	**Actual**
Surface winds (speed & dir.)	______	______	______
Transport winds (speed & dir.)	______	______	______
Minimum mixing height	______	______	______
Dispersion/stagnation index	______	______	______
Minimum relative humidity	______	______	______
Maximum temperature	______	______	______
Fine-fuel moisture (%)	______	______	______
Days since rain ______	Amount ______	______	______

Fire Behavior: Desired Range
Type fire ______________
Best month to burn ______________
Flame length ______________
Rate of spread ______________
Inches of litter to leave ______________

Future
Evaluation by ______________________
Date burned ______________________
____
____
____

Evaluation: Immediate
Any escapes? ______ Acreage ______
Objective met ______________
Smoke problems ______________
% of area with crown discoloration of
5-25% ___ 26-50% ___ 51-75% ___ 76%+___
Live crown consumption ______________
% understory veg. consumed ______________
Adverse publicity ______________
Technique used OK ______________
Remarks ______________
____
____
____
____

Future
Evaluation by ______________________
Date ______________________
Insect/disease dam. ______________________
% understory kill ______________________
Date burned ______________________
Soil movement ______________________
Other adverse effects ______________________
____
Remarks ______________________
____
____
____
____
____

Prescription made by ______________________
Title ______________________ Date _____/______/______

UNDERSTORY PRESCRIBED BURNING UNIT PLAN

Prepared by ____________ Signature ____________ Date ________ Permit no. ______
State __________ County ____________ District ____________ Comp't ____________
Burning Unit no. ________ S _____ T _____ R _____ Gross acres __________ Net acres __________
Landowner ____________________ Address & phone no. ____________________________
Person responsible & how to contact day & night ____

(Drawn map on back or attach)

A. Record of Previous Burning: Date __________ Fire Type ___________ Results ___________

B. Description of Stand:

1. Overstory: Type, density, size _______________ Height to bottom of crown _______________
2. Understory: Type, density, height ____
3. Dead fuels: Type, density, age, volume ____
4. Soil type and topography ____

C. Puropse(s) of Burn: ____

D. Specific Objectives: ____

E. Preburn factors:

1. Chains to plow (see map): Exterior: __________ Interior __________ Total __________
2. Chains to fire (see map): Exterior: __________ Interior __________ Total __________
3. Crew Size: ____________ Equip, needs ______________________________
4. Estimated tons/acres ____________________ Total tons to be burned ____________________
5. Ignition procedure (see map) ____
6. Passed screening system? _____ Special Precautions ______________________________
7. Notify: ____

____

8. Regulations that apply ____
9. List smoke-sensitive areas & critical targets (see map): ______________________________

____

F. Weather Factors: **Desired Range**	**Predicted**	**Actual**
1. Surface wind (speed & dir.) _______	____________	____________
2. Transport wind (speed & dir.) _____	____________	____________
3. Stability/stagnation index _________	____________	____________
4. Minimum mixing height __________	____________	____________
5. Dispersion index _ ____________	____________	____________
6. Minimum relative humidity _______	____________	____________
7. Maximum temperature ___________	____________	____________
8. Fine-fuel moisture _____________	____________	____________
9. Days since rain _____ Amount _____		____________
10. Burning Index __ Drought Index __		____________

G. Fire Behavior: **Desired Range**	
1. Type fire ______________	____________________
2. Best month to burn ___________	Date Burned ____________________
3. Time of the day to start __________	Time set ____________________
4. No. of hours to complete __________	Completed ____________________
5. Flame length ______________	____________________
6. Rate of spread ______________	____________________
7. Fireline intensity ___________	____________________
8. Inches of litter to leave __________	Litter left ____________________

H. Evaluation Immediately After Burn	
1. Acres burned ______________	Evaluation by ____________________
2. Spotting ______ Distance ______	Date made ____________________
3. Any escapes ______________	Insect/disease dam. ____________________
4. Objects met ______________	____________________
5. Smoke Problems ____________	Crop tree morality ____________________
6. % understory veg. consumed ___	____________________
7. % of area with crown discoloration of	% Understory kill
5-25% __ 26-50% __ 51-75 __ 76%+ __	Soil movement
8. Live crown consumption ______	Other adverse effects
9. Adverse publicity ___________	____________________
10. Remarks ______________	Remarks ____________________

CONDUCTING NOTES

CONDUCTING NOTES

CONDUCTING NOTES

Image courtesy of Holly Campbell

Table of Contents

EVALUATION CHECKLIST

- [ ] Conduct an initial evaluation after the burn is completed or the next morning, but at least within a week of the burn
- [ ] Conduct a secondary evaluation during or after the first growing season (~3-6 months later), depending on your burn objectives

Introduction

Prescribed burns are evaluated to determine how well the stated objectives of the burn were met and to gain information to be used in future burns. Following a prescribed burn, both initial (immediately after the burn) and secondary (3-6 months later) evaluations should be conducted. Post-burn evaluations help landowners and managers to keep accurate records of prescribed burn successes and failures. These evaluations can also serve as a baseline for future management activities.

Evaluations can range from simple notes and pictures to more detailed assessments which include notes on each burn objective, and considerations for future burns. Many burners will use evaluation forms while others may choose to take notes in a dedicated journal. Those who take notes in a journal may prefer having all of their notes in one notebook for easy access, while others may store their evaluations in a folder. There is no universal evaluation form used by landowners or agency personnel. However it is strongly recommended that your evaluation, at a minimum, include: date, time, location, and photographs of the burn, whether burn objectives were met and notes pertaining to the burn. Most state forestry agencies have their own evaluation forms that can be found on their respective websites. We have provided a few example completed evaluation forms within this section, as well as evaluation form templates in the appendix.

The first half of this section includes brief descriptions and examples of initial and secondary evaluations. These will help guide you in the process of completing your post prescribed burn evaluations. There are also detailed descriptions of the different components assessed in each evaluation type. Each component of these evaluations is not necessary for everyone to include.

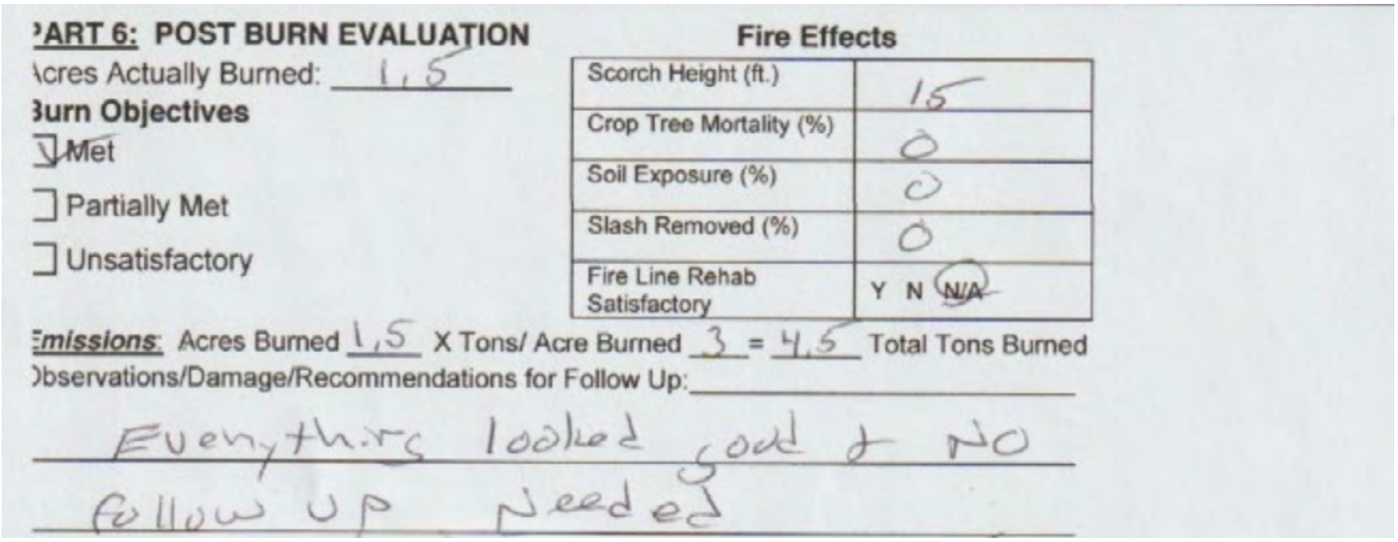
The second half of this section includes additional detailed information about fire effects on woody plants (including pine and hardwood trees), herbaceous vegetation, roots, and soil. It is important that you consider your management and prescribed burn goals, to decide how detailed your evaluation should be. There is no right or wrong way to evaluate the success of your burn. Any notes, pictures, or observations that you make will be of help to any future prescribed burn endeavors.

Any evaluation is better than no evaluation.

Any notes, pictures, or observations that you take will be helpful for any future prescribed burns.

PICTURES ARE AN IMPORTANT VISUAL RECORD OF BURNS

Take and date photographs of your burn unit to maintain a visual record. The top left photo shows a pine stand two days after burning. The top right photo shows a loblolly pine stand four months after a prescribed fire. The bottom left photo shows a loblolly pine stand two years after a prescribed burn. The bottom right photo shows a pine stand on a three-year burn interval. *Image courtesy of John Kush.*



PART 6: POST BURN EVALUATION

Acres Actually Burned: 1.5

Burn Objectives

- [x] Met
- [ ] Partially Met
- [ ] Unsatisfactory

Fire Effects

Scorch Height (ft.)	15
Crop Tree Mortality (%)	0
Soil Exposure (%)	0
Slash Removed (%)	0
Fire Line Rehab Satisfactory	Y N N/A

Emissions: Acres Burned 1.5 X Tons/ Acre Burned 3 = 4.5 Total Tons Burned

Observations/Damage/Recommendations for Follow Up:

Everything looked good & no follow up needed

Figure 4.1. An example post-burn evaluation form, in which burn objectives were met. *Evaluations courtesy of John Weir.*

An initial evaluation can be documented immediately after the burn (often the following morning) and no later than one week after the burn. A second evaluation can be made during or after the first post-fire growing season. The burn evaluation components and examples provided in this guide contain a range of components to consider based on how detailed you want your evaluation to be. In addition, examples of completed evaluations are included to show the differing levels of detail.

Complete evaluations to the best of your ability and be sure to add any relevant observations or items of note. Store all evaluations in a folder with your prescribed fire records as permanent accounts of all that went correctly and incorrectly. These evaluations and records can be a helpful tool for planning future burns.

LABEL AND TRACK YOUR RX BURN PICTURES

RxBURN TRACKER APP — OKLAHOMA STATE UNIVERSITY

- Photograph burn units prior to and after burns are conducted
- Organize pictures and burn data chronologically
- Record burn data about each burn unit

Initial Post-Burn Evaluation

Conduct an initial post-burn evaluation at the end of the burning day or the following morning. Complete this evaluation by the end of the week at the latest. You may use your own evaluation notebook or form, one from your state forestry agency or another source as well as the one found in the appendix of this book. Any evaluation is better than no evaluation, however; a recommended minimum evaluation should include the following:

- Date
- Location of burn
- Time of burn
- Take pre- and post-burn pictures
- Were burn objectives met?
- Notes

Questions to think about or answer when conducting an initial evaluation are below. It is not necessary to answer all of the questions, but these questions provide you some guidance to think about what you may want to look at and/or note.

Initial Post-Burn Evaluation Checklist

√	Basic Components of an Initial Evaluation
	Total acreage successfully burned: ___
	Were the burn objectives accomplished? ■ List which objectives were met fully, partially, or not at all.
	Were photographs taken prior to the burn?
	Was pre-burn preparation work satisfactorily completed?
	Was the burn plan followed? ■ If not, which parts and why?
	Were the following factors within planned limits? If not, were all deviations documented on the burn plan? ■ Weather conditions ■ Fuel conditions ■ Expected fire behavior ■ Smoke dispersion
	Did the fire behave as expected? If not, why? Did fire escape containment lines? ■ Did smoke disperse as expected and were you successful in avoiding smoke-sensitive features or areas? ■ Were the burning techniques used successful or did they result in control issues or damage?
	Were there injuries, equipment malfunctions, or complaints?
	When will the next burn be needed?
	Will the burn plan need adjustment for the next burn?

This information can be found as a form in the appendix.

√	Additional Components to Consider
	Fire Effects ■ What is the percentage of overstory leaf or needle discoloration (i.e., crown scorch)? ■ What is the percentage of consumption and top-kill of understory vegetation? ■ Approximately, what amount of litter or duff (decomposing organic material between tree litter layer and mineral soil) is remaining on the ground? ■ What impacts to non-target species (plant and animal) are present?
	Was the burn plan followed?
	Costs / Benefits ■ Briefly summarize the costs for manpower, equipment, and supplies
	Public Comments ■ Were there any adverse public comments or reactions prior to, during, or immediately after the burn? ■ Social, cultural, or training benefits
	Additional observations and comments: ■ Describe anything you see that may be noteworthy ■ What could be done to improve future, similar burns? ■ It can also be helpful to provide a post-burn map that indicates areas of success and complication.

Figure 4.2. Initial Post-Burn Evaluation Checklist

*More information can be found on page 85 of this chapter

Remember you can add as little or as much detail as you want. These questions and prompts to help you make notes about your burn that can help you in the future.

Secondary Evaluation Checklist

√	Basic Components of the Secondary Evaluation
	Does it appear that the prescribed fire was beneficial in aiding your overall land management objectives?
	How did the fire affect trees? ■ What is the estimated tree mortality? ■ Is any sap seeping from trees in the burned area, particularly pine? If yes, this is an indicator of cambium damage or insect attack.

	How did the fire affect vegetation?
	■ What is the estimated vegetation mortality?
	■ Is any undesirable vegetation growth present?
	  ■ If so, how quickly is the growth occurring?
	  ■ Are any of the species invasive/ exotic? If yes, describe which species were observed and where.
	■ Have any new desirable woody shrubs, vines, or herbacious plants been observed that were not present or notibable prior to the burn? If so, estimate the percent coverage.

	Was the burn plan followed? ■ If not, what parts and why?
	Have there been any complaints or support for the burn from the public since the burn's completion?
	Was the pre-burn preparation thoroughly and satisfactorly completed?
	Were the costs of the burn on par with the benefits derived?

Figure 4.3. Secondary Evaluation Checklist

√	Additional Components to Consider for Secondary Evaluation
	Other Fire Effects ■ Are regenerating pine and/or hardwood stems (i.e. seedlings and saplings) more or less prevelant in the stand? Quantify regeneration by counting these stems by species in circular, 1/100th acre (11.8 ft radius) plots. ■ What is the percentage of litter/duff on the forest floor? ■ Is there any evidence of disease or insect damage?
	Additional observations and comments: ■ Take and date additional photographs of your burn unit to maintain a visual record.

DEFINITIONS

Crown Scorch - Browning of needles or leaves in the crown of a tree or shrub caused by heat from a fire. Scorched needles and leaves will remain in the crown for up to a month with obvious discoloration.

Consumption - Needles and leaves are completely consumed by fire; branches are left bare.

Cambium - A very thin layer of growing tissue that produces new cells that become either xylem, phloem or more cambium. The cambium is responsible for an increase in tree girth.

Burn Severity - Refers to the degree to which a site has been altered, or the biological and ecological impacts of the fire on the environment. Severity is a product of fire intensity and is usually evaluated as light, moderate, or high on an evaluation. Burn severity can only be assessed after the fire.

CREATE A REMINDER ON YOUR CALENDAR TO CONDUCT THE SECONDARY EVALUATION

Secondary Evaluation

While it is easy to overlook, the secondary evaluation is important because it documents how well the disturbed areas responded to the burn in relation to your land management objectives over a longer period of time. Secondary evaluations should take place during or after the next growing season, which may be 3-6 months later.

The focus of this evaluation is to determine positive or negative effects the burn had on vegetation and site and note any potential public opinions towards the burn (Figure 4.1). Information from the secondary evaluation can improve the planning process for future burns. Also, if repeat burns are conducted in the same stand, the secondary evaluation(s) conducted after prior burns can help track progress towards meeting long-term stand management objectives. A blank secondary evaluation form is provided in the Appendix, though you can make your own notes or find another form from another source. Some descriptive items in this form can be quantitatively assessed using basic forest measurement and inventory methods. Evaluation forms are meant to be used as a template and may not include all variables relevant to a site or that potentially impact burn or stand objectives. Complete the evaluation forms to the best of your abilities, though you can find resources on any of this information, in Chapter 1: Getting Started.

At a minimum, take pictures of the site and record the date and any other notes for a secondary evaluation:

- Date
- Location of burn
- Take post-burn pictures

Questions to think about or answer when conducting an evaluation can be found on Figure 4.3. It is not necessary to answer all of the questions, but these questions provide you some guidance on what you may want to look at more closely and/or note.

Fire Effects

Fire effects on vegetation can vary based on fire intensity and the characteristics and arrangement of the vegetation on site and the time. High severity burns can injure and kill even the most fire-adapted species and modify ecosystems by consuming plants, altering successional patterns, and changing vegetation composition and structure. Many different terms are used to describe various aspects of wildfire or prescribed fire including fire intensity, and fire or burn severity.

Fire intensity is related to the energy released from organic matter (vegetation, leaf litter, etc.) burning. The intensity of a fire or burn is related to many factors such as the length of flames and scorching height during the burn as well as the overall fire behavior, and fire duration or residence time.

Burn or fire severity refers to the degree which a site has been altered, or the biological and ecological impacts of the fire on the environment. Burn or fire severity are often quantified as the amount of organic matter burned during a fire.

Thus, fire intensity refers to how the fire burned (energy released per unit of time per unit length of fire front), while burn severity refers to how the burn affected the area. Burn severity is influenced by the season of burning, sub-surface heating, and duff consumption, etc. Table 1 provides descriptions of low, medium, and high burn severity for three categories of vegetation as well as stumps and erosion potential.

Ultimately, a plant community's recovery following a burn is dependent on the fire intensity and burn severity. This section includes information on fire effects on woody plant species including pines and hardwoods specifically, as well as soil, roots, and general vegetation.

Table 4.1. Post-burn evaluation burn severity classification guide. *Compiled from Hungerford (1996) and Debano et al. (1998)*

Soil & Litter Parameters	Burn Severity		
	Low	**Moderate**	**High**
Surface Organic Horizons (litter, humus, & rotten wood)	Charred and blackened but with definable plant parts; 40-85% litter cover remains.	Partially consumed; less than 40% litter cover remaining, much covered with black char.	No surface litter remains.
Small Woody Debris (<3" diameter)	Surface burned; some unburned areas.	Charred; partially to wholly consumed	Fully consumed.
Large Woody Debris (>3" diameter)	Blackened with unburned areas.	All blackened; char goes into wood.	Only large, deeply charred logs are left.
Stumps	Stumps intact but black.	Burned deep enough to form charcoal.	Stumps gone, hole in ground where stumps and root systems were.
Indicates:			
Erosion Potential	Low.	Erosion possible on susceptible soils (e.g. soils that easily form water repellent layers).	Susceptible to overland flows and catastrophic erosion events.

FIRE EFFECTS ON WOODY PLANTS

Preparing a comprehensive post-burn evaluation requires some background knowledge about how fire can affect woody plants. The following section outlines how woody plants in the Southeast often respond to fire.

Certain woody plant species, particularly in the South, have unique adaptations that enable them to survive and recover effectively after burns. Some plant species are even dependent on fire. **Heat tolerance** and **fire resistance** refer to the ability of a woody plant species to survive high temperatures associated with the passage of fire. Depending on the moisture content and insulating properties of plant tissues, plant cells are killed if heated to 122-131 °F for several minutes, and the instantaneous lethal threshold is considered to be about 141 °F (Hare, 1961; Hare, 1965). Longer heat exposures can kill plants at lower burn temperatures and short exposures at higher burn temperatures. Actively growing tissues on plants such as tree buds are more susceptible to heat damage than dormant tissues because they have higher moisture content. Woody plant injury or death is usually a result of damage to a combination of tissues such as the foliage, buds, and the vascular cambium. Heat related injuries can also lead to delayed mortality due to the effects of secondary agents such as insects, disease, or fungus that weaken the tree further after it has been injured.

Woody plants are provided with fire resistance from insulating features that protect actively growing tissues such as buds and traits that add to or conserve food reserves of a plant (Image 4.1 & 4.2 and Table 4.2). **Bark thickness** is an important factor that affects fire resistance. This trait varies by species, tree size and age, distance above the ground, site characteristics, and health and vigor of the tree. When bark thickness is about 0.5 inches or more, tree survival tends to improve with lower severity fires. Bark tends to be thinner in young, small trees and shrubs, becomes thicker as they mature, and then declines with age. The structure, composition, density, and moisture content of bark also affect its insulating capabilities and vary by species. For similar sized trees, southern yellow pines tend to have thicker bark than most hardwoods. **Sprouting** is another fire adaptation of many hardwood species and some pine species, such as shortleaf pine (Images 4.1 & 4.2) and to a lesser extent loblolly pine. Dormant buds located near ground level begin to grow into a new stem when foliage and/or the stem is killed by fire. The degree of **re-sprouting** after fire is dependent on species, tree age, size, season of injury, fire frequency, and fire severity. **Serotinous cones**, found on some species of conifers, require the melting of resins for mature seeds to be released and are an additional fire-dependent adaptation of some species. Though some seeds in the forest floor are consumed by fire, some can remain viable and germinate after fires such as certain species of oaks and hickories. Their germination strategy results in the root collars (where dormant buds are located) remaining slightly below the soil surface, providing thermal insulation if a prescribed fire were to occur. The exposure of bare mineral soil following a burn and removing the duff layer by fire can improve **germination rates** of species with wind dispersed seed. Other fire adaptive traits include tree longevity, **natural limb pruning**, time to initial flowering, and nature of leaf shedding.

Each tree species differs in its fire tolerance, but the difference between pines and hardwoods is especially apparent. Certain characteristics can be observed post-burn to assess individual trees and the site. Unless a fire is particularly severe, mortality of stems may not be evident for one or more growing seasons.

Table 4.2. Common fire adaptive traits observed in trees. *Adapted from Keeley et al. (2011)*

Common fire adaptive traits:	Description
Thick bark	Thicker bark does not catch fire or burn easily; it also has insulating properties to help protect the live tissue within the tree.
Fire-induced sprouts	Some species of tree re-sprout after a disturbance. The sprouts grow from buds that are present belowground. Re-sprouting, however, is not always guaranteed after a fire – particularly if the fire was intense and lingered.
Closed or serotinous cones	This type of cone often remains on a tree after maturation and remains alive by staying connected to the tree's vascular system. When a fire disturbance occurs heat from the flames will melt the hardened sap that is keeping the cone closed. Cone opening can also be triggered by the tree's death, as the cone is no longer receiving nutrients.
Fire-activated seeds	Some plants have adapted to fire by producing seeds that remain dormant (viable, but not germinating) until they are exposed to fire. They only germinate when the seed's outer coating has been exposed to fire, a process called scarifying.
Natural limb pruning	Natural limb pruning occurs when a tree sheds its lower branches. Fewer lower branches decrease the probablitiy of leaf scorch, as well as the potential for crown fires.


Image 4.1 & 4.2. Woody species such as pines have several fire adaptive traits such as shortleaf pine's sprouting response when the stem is top killed (right photo), and thick insulating needles that protect the buds of longleaf pine (left photo). *Right Image courtesy of David Clabo. Left Image courtesy of Virginia Tech Dept. of Forest Resources and Environmental Conservation.*

FIRE EFFECTS ON PINE TREES

Southern pines are the favored commercial tree species throughout much of the South. As such, this section focuses heavily on proper evaluation techniques for pines.

Needle scorch is often the best indicator of pine tree fire damage. Brown needles in the crown of the tree following a burn are a sign of needle scorch. Assuming that buds and branches are not killed by radiation and convection heat transfer (not physical contact with flames), crown scorch approaching 100% will generally not kill pine trees outright. Secondary factors that materialize in response to the fire, such as insect attacks, disease, or drought, are often the deciding factors in individual tree mortality, after duff.

Total consumption of needles is inherently deadlier to pine trees – consumption occurs when needles have been completely burned off of branches. Pine trees that have 15% or more needle consumption have a low chance of survival, even if scorch damage is minimal. Seasonality of the burn also plays a role in tree health. For example, mortality is more likely to occur if significant needle loss occurs in the fall compared to other seasons. This applies particularly to younger trees which generally have less capacity to create and store energy reserves.

What can I look for when reviewing pine tree damage? *(Information adapted from Ripley, 2012).* Below are a series of questions to consider when reviewing pine tree damage.

1. Were any of the needles consumed or 'set' in one direction? If so, survival is unlikely.

The slash pine (*Pinus elliottii*) stand in Image 4.3 has 75% crown scorch and less than 5% of its needles consumed. In contrast, the sapling in Image 4.4 has needles "set" in one direction. This indicates that the heat from the fire was intense and moved quickly through the area and the sapling is unlikely to survive. Longleaf pine (*Pinus palustris*) seedlings may have needles consumed when burned during the grass stage or just after emerging from the grass stage, but unless the terminal bud is damaged, seedlings often survive (Image 4.5).

Image 4.3. Example of mature slash pine stand with crown scorch. *Image courtesy of David Clabo.*

Image 4.4. Pine sapling with needles set in one direction, which often is a good indicator the tree will not survive. *Image courtesy of Ripley, 2012.*

Image 4.5. Longleaf pine seedlings can survive most moderate to low intensity burns due to the insulation that its needles provide to the terminal bud. *Image courtesy of Barry Coulliette.*

2. What is the percentage of crown scorch?

The visuals in Figures 4.4 and 4.5 can be used to determine the percent crown scorch of trees. Remember, crown scorch is the percentage of brown discoloration caused by heat from a fire. Crown scorch may not always appear worse at the bottom of the crown compared to the top of the crown.

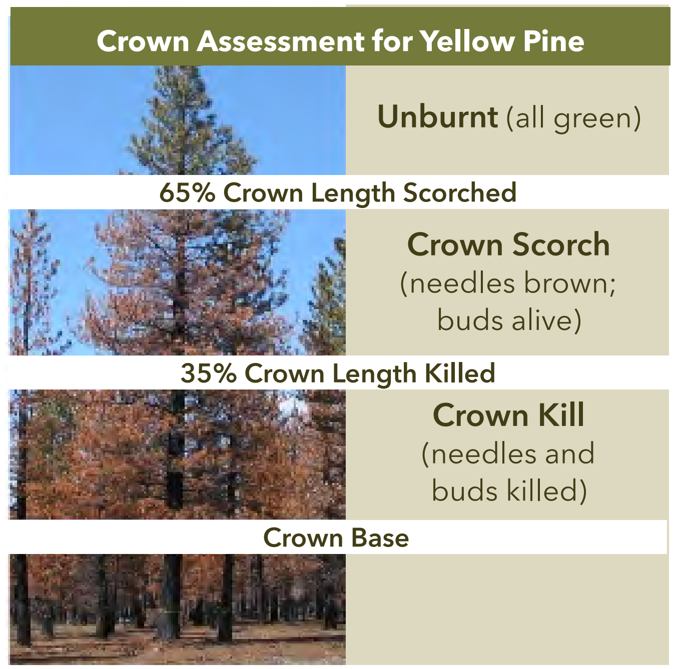


Figure 4.4. Crown assessment information for scorched pines. *Adapted from Smith & Cluck, 2011.*

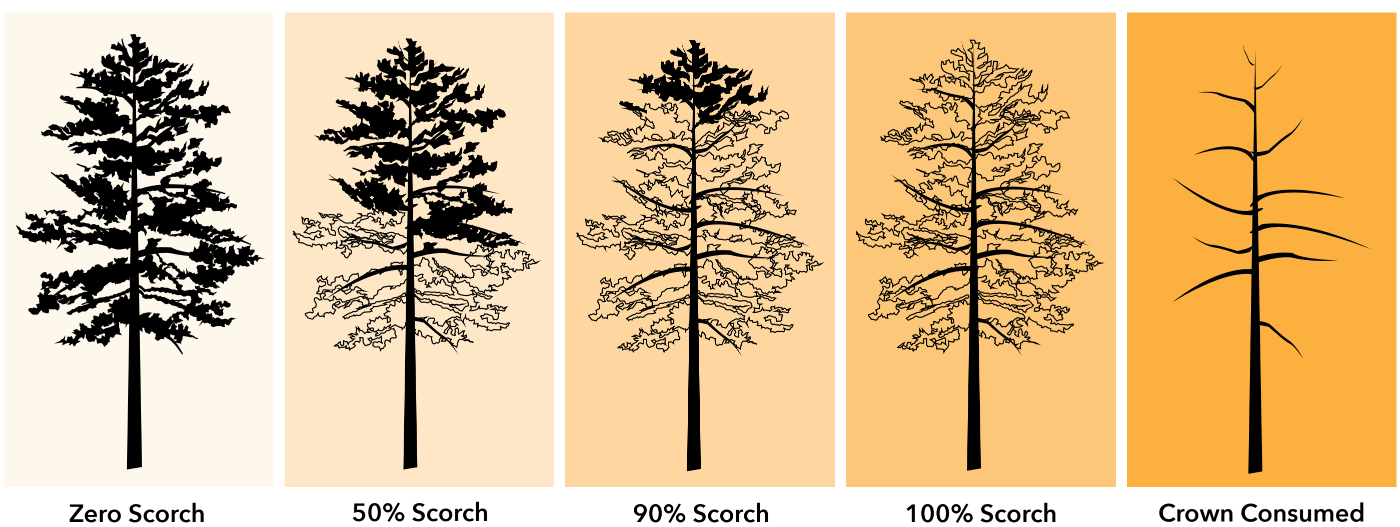


Figure 4.5. Examples of crown scorch percentages. *Diagram adapted from Oregon State University Extension Service.*

Table 4.3. In general, there is a direct relationship between annual diameter and height growth and the percentage of crown scorch. Live crown ratio is the length of the tree crown divided by the total height of the tree. Maintaining a live crown ratio greater than 35% maintains the health and growth of trees. The table below demonstrates potential growth loss in loblolly and slash pines over three inches diameter at breast height (DBH), assuming no crown consumption occurs (Wade and Lunsford, 1989).

Percent Crown Scorch	Damage
0 to 33	Some volume growth loss may occur the first postfire growing season but it will be minor.
34 to 66	Volume growth loss usually less than 40 percent and confined to the first postfire growing season.
67 to 100	Reduction may be as high as a full year's volume growth spread over 3 years.
As a general rule of thumb, pine trees with 2/3 or more crown scorch are less likely to survive, whereas trees with 1/3 or less scorch are likely to survive.	

Depending on fire behavior and fuels, scorch may be present at different levels of the crown and on different sides of the crown. Scorched needles and leaves can remain in the crown up to a month before dropping. General guidelines for crown scorch effects on tree growth are provided in Table 3.

3. Did a majority of terminal buds survive?

If a significant number of terminal buds survived the heat, indicated by green coloring and buds pointing straight up, then the trees have a greater chance of surviving (Image 4.6). This is particularly important to look for on younger trees.

Image 4.6. When pine terminal buds are green and point upward following a burn, the tree has a better chance of surviving. *Image courtesy of Irwin et. al (2007)*

4. Did severe charring occur on and around the base of the tree?

While southern pine bark has good insulating qualities, cambial damage (the living tissue under the bark of a tree) and consumption of fine roots crucial for water and nutrient uptake can occur from the extended smoldering of duff or woody debris around the root collar or base of the tree. Such damage is likely in previously unburned areas where a deep organic soil layer or duff has accumulated. This accumulation can be caused by many years of fire suppression, woody debris leftover following storm damage, or slash left behind from thinnings or partial harvests. Older trees are more likely to survive bark damage due to thicker bark. If charring is apparent on trees, it would be wise to check the condition of the inner bark and the main roots on a sample of trees 1 to 2 weeks post-burn. Four locations should be checked around the tree (Figure 4.4). If the inner bark is brown and dead at two of the four locations, then the tree will probably die from direct or indirect effects of the fire. Trees can survive less than 30% of fine root consumption, but will experience delayed mortality if more than 30% of fine roots are consumed (O'Brien et al., 2010).

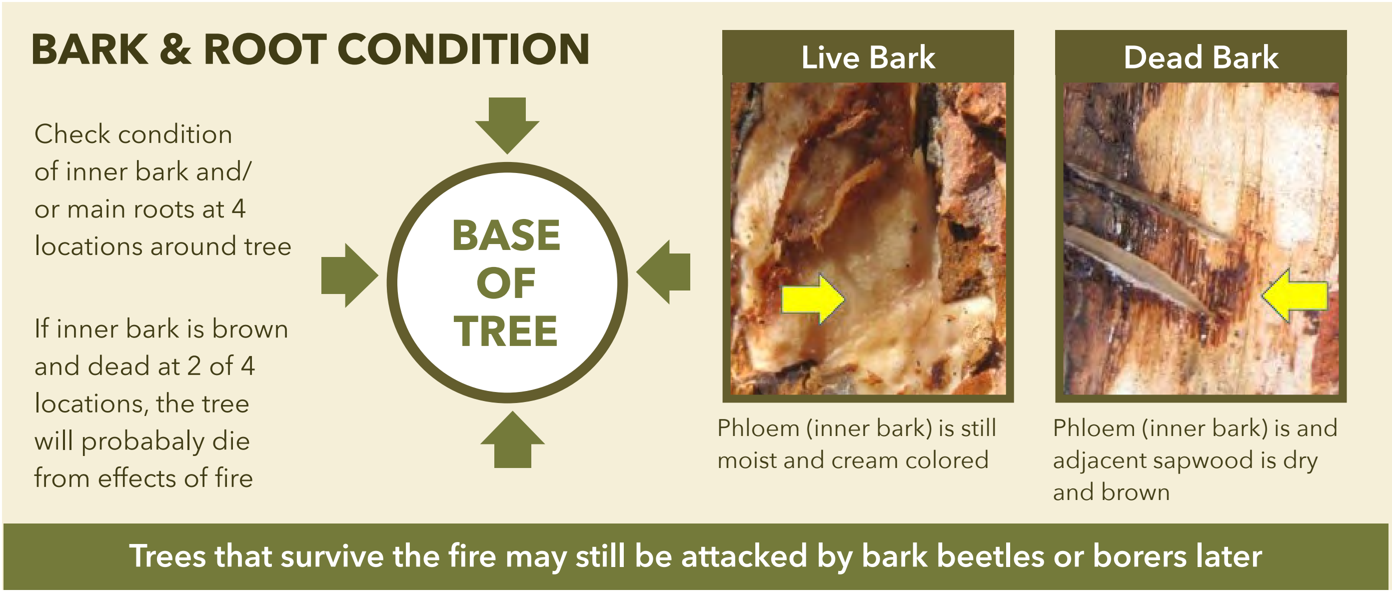


Figure 4.6. How to evaluate bark and root conditions post-burn. This method can also be applied to hardwood trees. *Information adapted from (Ripley, 2012).*

Questions to consider when reviewing pine tree damage:

- Were any of the needles consumed or 'set' in one direction?
- What is the percentage of crown scorch?
- Did a majority of terminal buds survive?
- Did severe charring occur on and around the tree?

PINE TREE FIRE FACTS

Check out fire facts below for a few different species: Loblolly pine (*Pinus taeda*) is the leading commercial timber species in the Southern United States.

Loblolly pine fire facts:

- Loblolly pines that are at least 3-4 inches in diameter, or about 15 feet in total height, are generally not damaged by low intensity fires.
- Saplings up to 2 inches in diameter are usually killed by moderate-severity fire, and trees up to 4 inches in diameter are usually only killed by high-intensity fire. Older, more established loblolly pines are generally tolerant of all but the most severe fires.
- Mortality is greatly increased if needles burn. If there is 25% or more needle consumption in loblolly pine crowns younger than nine years old, then at least 75% mortality can be expected.
- Prescribed fire is one of the primary methods for controlling the growth of hardwoods in loblolly stands. Periodic burns (are appropriate every 3-5 years) in order to provide acceptable hardwood control.

Longleaf pine (*Pinus palustris*) is a native species to the southeastern United States and was once one of the most extensive forest ecosystems in North America, covering an estimated 90 million acres. Efforts are now being made to restore this historically important tree species.

Longleaf pine fire facts:

- Open growth longleaf pine seedlings in the "grass stage," with a root collar diameter of 0.6 inches or greater, have a 50% chance of surviving moderate to high intensity prescribed burns. Seedlings located under a forest canopy have a less certain fate due to fine fuel (e.g. pine needles, dead herbaceous vegetation, etc.) accumulation from overstory trees.

- Fire may initiate or hasten seedling height growth out of the 'grass stage' due to reductions in competition and brown spot needle disease (Mycosphaerella dearnessii).
- After seedlings emerge from the 'grass stage' and reach 1-3 inches height, low to moderate intensity fires can decrease survival rate by 30% or more depending on fuel, season of burn, and weather conditions. After saplings reach taller height classes, survival rates increase.
- Trees over 10 feet tall are very fire tolerant.

Shortleaf pine (*Pinus echinata*) has the most extensive native range of any southern yellow pine species and occurs in 22 states. This fire-resistant species seldom occurs in pure stands except on drier sites in the western portion of its native range in Arkansas and Missouri. The species most often occurs in mixtures with upland hardwood species and other pines such as Loblolly, Virginia, and occasionally Longleaf pine.

Shortleaf pine fire facts:

- Trees greater than 5 feet tall seldom die if less than 70% of the crown is scorched; trees less than 5 feet usually are top-killed by most fires.
- Young shortleaf pine trees (up to 6-8 inches in diameter) may sprout if the stem is top-killed or injured by a fire. Shortleaf pine has a unique root system characteristic called the basal crook. It lowers dormant buds located near the root collar (point at or just below the ground surface) in the upper soil, which insulates the buds during a surface fire. These buds will often sprout when the tree is top-killed or damaged during a fire.
- Crown scorch that does not kill the stem often results in growth losses in young shortleaf pine trees. Some reports have found volume growth losses by as much as 75% after one burn in young stands. Diameter growth rates of older trees at least 4-10 inches diameter are typically not affected by moderate crown scorch.

FIRE EFFECTS ON HARDWOODS

Prescribed fire is not used as frequently for hardwood stands managed for timber objectives as it is for pines. Suitable burning conditions can be more challenging to attain in hardwood stands and can carry more risk of economic loss, tree topkill, or mortality than pines, but a variety of landowner objectives can be met or partially fulfilled when prescribed fire is conducted in hardwood stands. However, landowners may opt to use prescribed fire on drier, upland hardwood sites for various reasons (Image 4.7). Objectives may include site preparation in stands where hardwoods will be regenerated, favoring oak recruitment into larger size classes over competitor species, creating or maintaining habitat conditions suitable for certain wildlife, reducing the prevalence of undesirable, shade tolerant (also less fire tolerant) woody tree and shrub species, or to minimize fuel loading.

Image 4.7. Prescribed burn in an oak-hickory stand near Sewanee, TN. *Image courtesy of Elle Fowler.*

Image 4.8. Prescribed fire can be utilized in hardwood forest types to meet several management objectives. *Image courtesy of Martin Schubert.*

Image 4.9. Trunk scorch is more likely to top-kill smaller diameter hardwoods than larger diameter hardwoods (Image 4.8 & 4.10). Damage to the trunk can be an entry pathway to decay fungi and insects, which can contribute to delayed mortality of hardwoods. *Images courtesy of Elle Fowler and David Clabo.*

While fire may not kill large-diameter trees outright, fire can sometimes leave fire scars on mature trees (Images 4.8-4.11). Hardwood species differ in their fire tolerance; as an example, red oak species tend to be less tolerant of fire than white oak species. Tree size and age are also important characteristics to consider as suppressed and older trees are less tolerant of fire. The height of stem-bark char is highly related to stem or topkill rate in hardwood trees. Topkill rates for trees from 5-20 inches diameter tend to increase to over 50% when char height is greater than about 3-5 feet in previously long unburned stands). Damage to hardwoods can be indicated by a series of bark cracks extending into the cambium near ground level, as well as moderate to severe charring and consumption of the bark. Large woody debris and litter can be removed from around high-value hardwood trees to limit damage and potential mortality.

Nearly all healthy hardwood trees less than 8 inches diameter at breast height (DBH) and less than 40 years old will sprout from the stump

Image 4.10. Trunk scorch and basal sprout response of maple. *Image courtesy of Elle Fowler.*

(most hardwoods and some pines) or along roots (primarily sweetgum, sassafras, and black locust in the Southeast), yet this sprouting response can vary widely due to fire intensity, site conditions, vegetation composition, and individual species' sprouting strategies. Some species (such as oaks and hickories) input more resources into root development, whereas some species (such as yellow-poplar and red maple) input more resources into stem growth. The success of these growth strategies differs the most with respect to fire frequency, with the root development strategy being more suited to regularly occurring prescribed fire (and reliable sprouting after multiple burns in younger stems).

FIRE EFFECTS ON SOIL AND ROOTS

Soil and root damage is affected by the amount of surface and ground fuels consumed in the burn. Burning under prescribed conditions in the South rarely results in extreme mineral soil exposure. If a duff layer is present after a burn, then it is likely that the soil beneath was not harmed (Figure 4.7). However, if bare mineral soil is present, erosion may occur due to a loss of soil structure and porosity when organic matter is lost. When under-burning mature pine stands, consumption of the duff layer is undesirable. Duff can be ignited directly through low fuel moisture or ignited at higher fuel moisture levels when larger woody fuels such as downed branches or pine cones burn on top of or within the duff layer (Dixon and Robertson 2018). Burning in the duff layer can be hard to detect because of a slow rate of spread and visible flames often do not occur. This combustion phase is termed "smoldering combustion." Smoldering combustion in the duff layer can lead to the death of the vascular cambium (conducting tissues responsible for movement of food and water) through girdling, death of fine roots (which are responsible for most nutrient and water absorption), increased tree stress, and susceptibility to death by secondary agents such as drought and bark beetles.

Low intensity fires are likely to encourage increased soil fertility by speeding up mineralization rates, whereas high intensity fires are more likely to cause nutrient losses through volatilization – which is when nutrients are essentially vaporized into the atmosphere. Important soil nutrients most often affected or altered by fire are nitrogen, phosphorus, and sulfur.

Root damage (especially fine, feeder roots) is likely to occur whenever the organic layer is completely consumed. When burns are conducted on dry soils or when a deep litter layer is present (as there is more opportunity for fuel to smolder and remain hot) root damage should be expected (Image 4.11 and Table 4.4). The chances of root damage after long periods of fire exclusion are also possible due to smoldering around the base of trees.

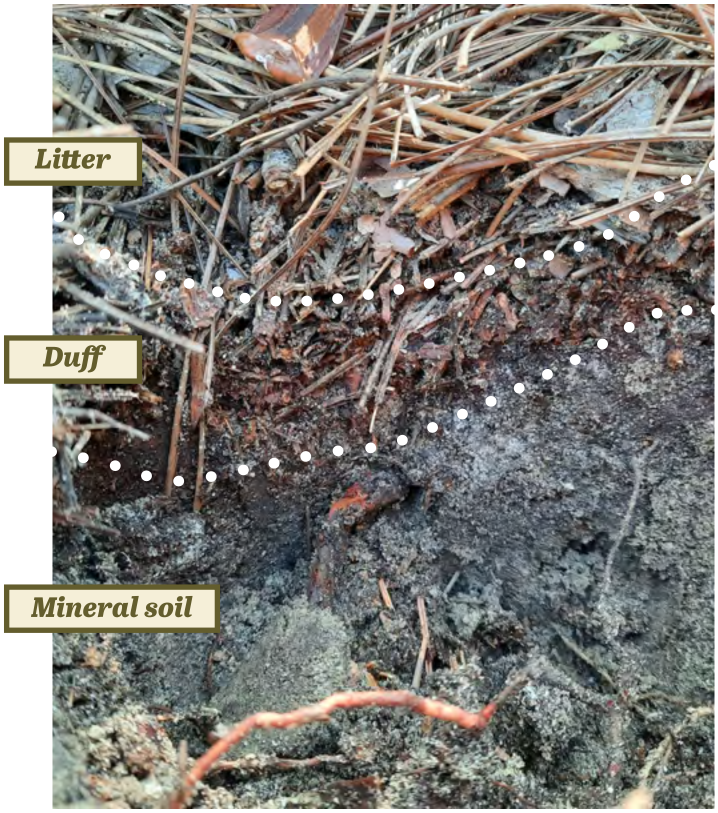


Image 4.11. Example of a Coastal Plain soil with a one to two-inch-thick duff layer, or O horizon. *Image courtesy of David Clabo.*

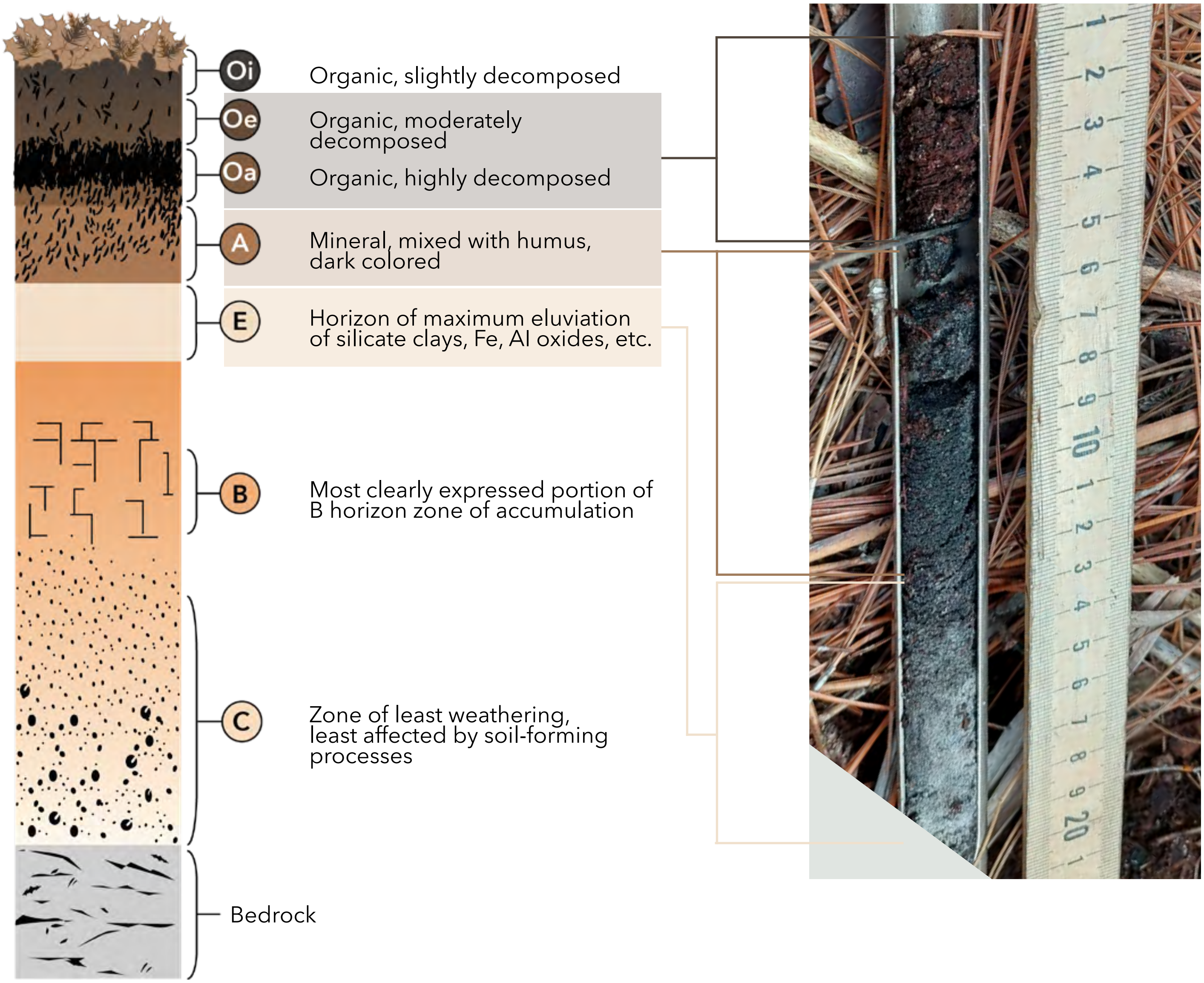


Figure 4.7. On the left side is a diagram of a soil profile with organic soil horizons (O horizons) on top of mineral soil. The O and A horizons play a significant role in post-fire regeneration; their disappearance will delay future vegetation growth. Adapted from NRCS Official Soil Series Descriptions. The right side of Figure 4.7 is a picture of a soil probe sample which shows the fluffy, dark brown duff and the darker mineral soil beneath it. *Image courtesy of Mac Callaham. Diagram adapted by Jasmin El Farnawany.*

Younger trees are more likely to survive root damage due to their vigorous growth; whereas, older, more mature trees can experience delayed mortality six months to a year later due to undetectable injuries. The amount of root damage also correlates with the fire tolerance of the tree species and fire intensity – as previously mentioned, some species in the South have fire adaptive traits which allow them to rebound quickly after a burn.

The Duff Layer(Oe-Oa Horizons) is decomposing organic material, decomposed to the point at which there is no identifiable organic materials (pine straw, leaves, twigs, etc.).

The Litter Layer (Oi Horizon) undecomposed or slightly decomposed organic material that can be readily identified (e.g. plant leaves, needles, twigs, etc.).

Table 4.4. Refer to the chart below to evaluate potential root damage after a fire. Adapted from the Georgia Forestry Commission.

Fire Damage Rating System for the Lower Trunk and Roots of Southern Pine Trees

Indicator	DAMAGE		
	low	medium	high
Lower Trunk	Bark partially charred; example - one side of tree or outer portions of bark plates	Bark completely charred, all sides of tree and all plates and fissures of bark	Bark completely charred and noticeable consumed
Litter and Duff around Tree	Litter charred to partially consumed; remains recognizable; upper duff layer burned to partially consumed	Litter mostly to entirely consumed; duff partially consumed; fine or feeder roots burned in duff layer	Litter and duff entirely consumed leaving ash or exposed mineral soil, and crater effect around rounds
Roots	Concealed; damage not evident	Slight exposure and charring, particularly on one side or at tree base; feeder or fine roots burned in duff layer	Abundant exposure and charring (in direction and distance) to partial or complete combustion

FIRE EFFECTS ON HERBACEOUS VEGETATION

Fire effects on herbaceous vegetation or forage, such as grasses and forbs, can be dramatic following prescribed burns. On sites that were historically forested or never in agricultural production, an increase in forage production and diversity can often be achieved through prescribed fire or prescribed fire in combination with timber thinnings or harvests (Image 4.12).

Gains in forage abundance and diversity following prescribed fire may not be as noticeable on sites that were previously agricultural fields or sites with long histories of livestock grazing even if sunlight was amply available due to depleted seed banks. Greater sunlight levels combined with prescribed burning stimulates sprouting and seed germination of forage vegetation. Some grasses produce sprouts from basal meristems and many forb species produce sprouts from dormant buds at or beneath ground level.

Image 4.12. Regular, periodic prescribed fire that occurs in this shortleaf pine savanna can stimulate herbaceous vegetation production and increase plant diversity. *Image courtesy of David Clabo.*

Soil temperatures often increase after a prescribed burn which can promote the germination of certain herbaceous species. Reductions in litter and duff layer thickness also occur, which increases light and water availability for seeds and sprouts. Forage plants are more likely to benefit from brief increases in soil nutrients than woody plants. The mortality and consumption of older plants that are consumed by the fire can promote greater forage growth, vigor, and nutrient content for wildlife and livestock. These increases in productivity may only occur for one or two years without recurrent prescribed fire. In most southeastern forests and vegetation cover types, shorter fire return intervals over long periods will result in a transition to grass and forb dominance. Woody vegetation is not able to colonize or recover adequately with perpetual, short (1-2 year) fire return intervals.

The season of burning can also impact forage species composition (Figures 4.6 & 4.7). Dormant season burns tend to favor forbs and cool-season grasses, such as kentucky bluegrass and fescue; whereas, early spring to summer burns often favor native warm season grasses, such as big bluestem and switchgrass, by promoting flowering and seedling of some species. Cool-season grasses, also known as C3, have an optimum photosynthesis and growth temperature range between 65-75 °F and can begin growth with cooler soil temperatures than warm-season grasses. Grasses and other plants that fall in this category have reduced growth during hot and/or dry conditions that frequently occur in the Coastal Plain of the southeastern U.S. Growth and productivity of these plants is greatest during the fall and spring. Warm-season grasses, or C4 plants, are most productive when temperatures are 85-95 °F and are more water efficient during dry, hot conditions than cool-season grasses. Growth of warm-season grasses is triggered by daylength, and they are most prevalent during the summer months in the southeastern U.S. Fires during the dormant season tend to reduce cool-season species and favor many warm-season species and vice versa since mature plants are more susceptible to burns than dormant or plants in early stages of development. Forbs such as composites and legumes may increase in response to burns conducted during the growing season depending on fire intensity, fuel characteristics, and land-use history (e.g. Sparks et al. 1998). Longer return intervals between prescribed burns usually diminish the influence of season of burn on forage species composition and diversity. In general, the more frequent an area can be burned, the greater the herbaceous species richness will be in stands or areas that were never in agricultural production as frequent burning tends to limit development and colonization of woody plants. Seasonal burn influences are also dependent on other factors such as fire severity and vegetation stage of development.

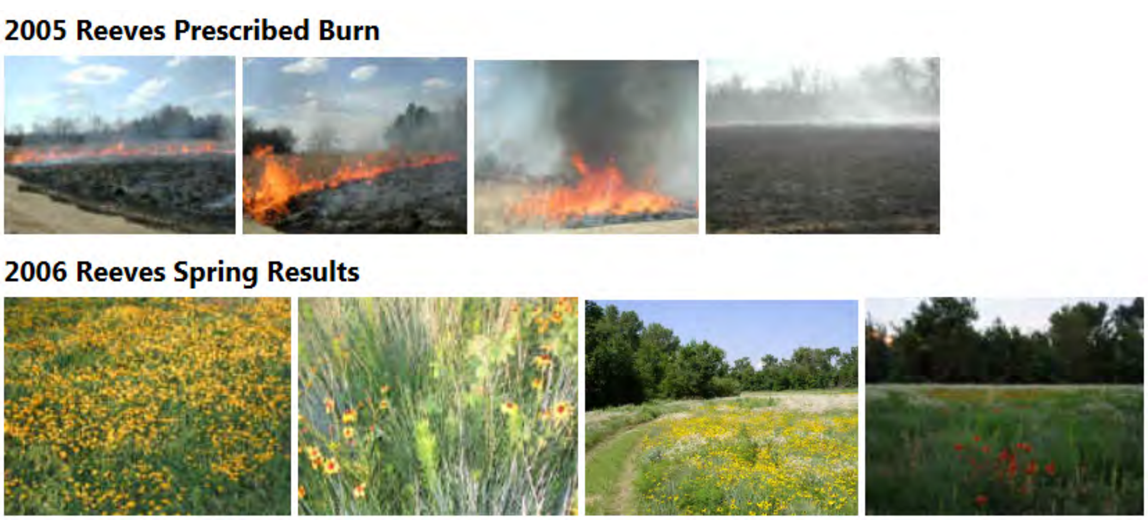


Figure 4.8. Images in this figure include pictures of the prescribed burn in one year (top) and then the bottom pictures show results of that burn the next year. Herbaceous vegetation species composition can be changed utilizing prescribed fire and by altering season of burn. *Figure courtesy of David Clabo.*

BEFORE AND AFTER TIMELINE

June 21, 2013

July 3, 2013

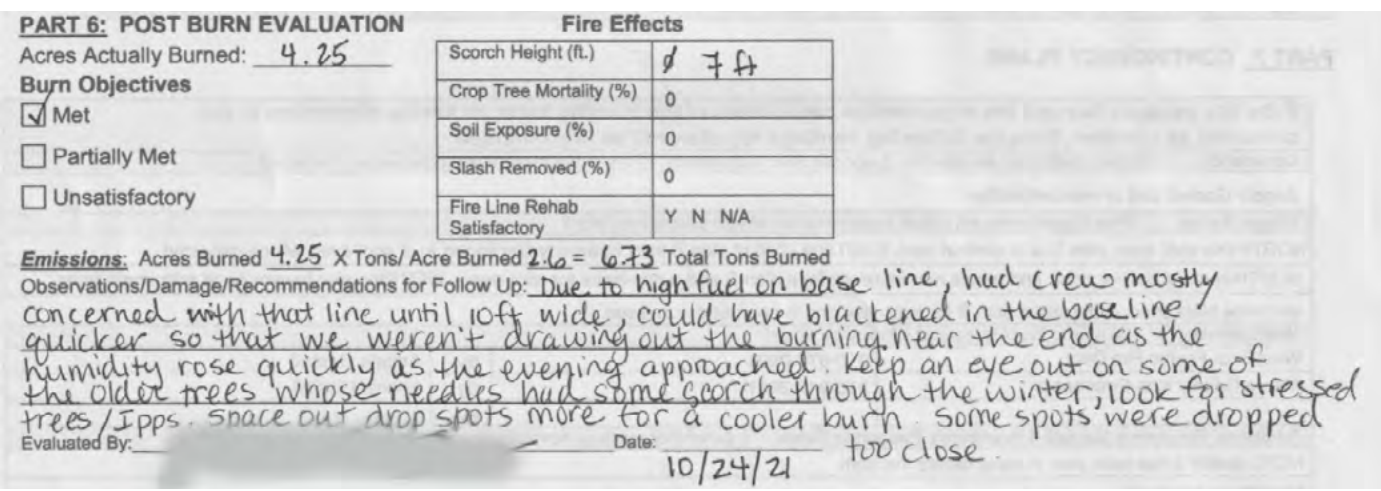
September 5, 2013

July 29, 2015

Figure 4.9. Photo time series of herbaceous vegetation changes starting immediately after the burn up to two years later. *Images courtesy of Kevin Robertson.*

Evaluation Examples

Evaluations can be done in many different ways, while still incorporating the components listed earlier in this section. Below are two examples of initial evaluations (Figures 4.10 & 4.11).



PART 6: POST BURN EVALUATION

Acres Actually Burned: 4.25

Burn Objectives

☑ Met

☐ Partially Met

☐ Unsatisfactory

Fire Effects

Scorch Height (ft.)	~~8~~ 7 ft
Crop Tree Mortality (%)	0
Soil Exposure (%)	0
Slash Removed (%)	0
Fire Line Rehab Satisfactory	Y N N/A

Emissions: Acres Burned 4.25 X Tons/ Acre Burned 2.6 = 6.73 Total Tons Burned

Observations/Damage/Recommendations for Follow Up: Due to high fuel on base line, had crew mostly concerned with that line until 10ft wide, could have blackened in the baseline quicker so that we weren't drawing out the burning near the end as the humidity rose quickly as the evening approached. Keep an eye out on some of the older trees whose needles had some scorch through the winter, look for stressed trees/Ipps. Space out drop spots more for a cooler burn. Some spots were dropped too close.

Evaluated By: Date: 10/24/21

Figure 4.10. A simple example post burn evaluation form, in which objectives were met, and comments are made regarding the crew's thoughts. *Evaluations courtesy of John Weir.*

Item	Response	Item	Response
Prepared by:	John Doe	**Signature:**	*John Doe*
Date & Time of the burn:	3-9-2020; 1-4:00 pm	**Date of evaluation:**	4-24-2020 (1.5 months post-burn)
Permit #:		**County & State:**	CRP Slash Pine Stand, Tift County, GA

Component	Description (*Example text below*)
Understory hardwood and shrub top-kill	Most understory hardwoods and shrubs <3" groundline diameter post-burn have been top-kill (>80%). Stem cracks and char provided evidence of top-kill (Image 4.13).
Minimize pine crown scorch	Prior to burning the goal was to keep crown scorch <33% for individual pines. Some trees were less than 33% but many feel into the 34-66% (Image 4.14).
Improve stand visibility	Improved sight lines and visibility throughout the stand by 30-40 yards due to top-killing understory hardwoods (Image 4.15).

Figure 4.11. A simple example post burn evaluation form, in which objectives were met, and comments are made regarding the crew's thoughts.

Image 4.13.

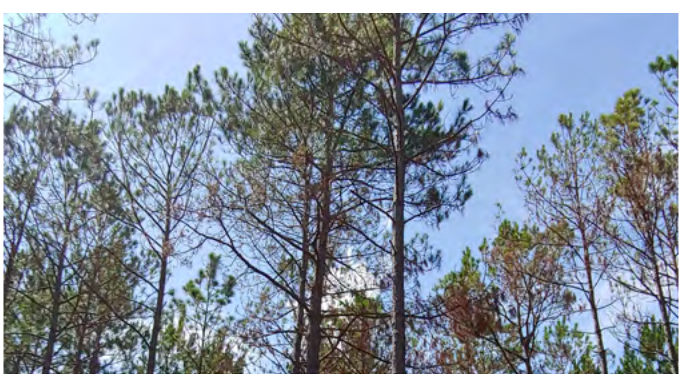


Image 4.14.

Image 4.15.

Captions for 4.15, 4.16 & 4.17 are listed in the description section of Figure 4.11.

References:

Brose, P.H., and D.H. Van Lear, D.H. (1998). *Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands.* Canadian Journal of Forest Research 28(3): 331-339.

Burger, G., P.D. Keyser, and A.L. Vander Yacht. (2013). *Ecology and management of oak woodlands and savannahs.* University of Tennessee Institute of Agriculture. PB-1812. 8 p.

Carey, Jennifer H. (1992). Pinus taeda. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.
DeBano, L.F., D.G. Neary, and P.F. Ffolliot. (1998). *Fire's effects on ecosystems*. John Wiley & Sons, Inc., New York. 333 p.

Dixon, A.K., and K.M. Robertson. (2018). *Reintroducing fire to long-unburned pine stands: the duff problem*. Southern Fire Exchange Fact Sheet 2018-4. 4 p.

Flinn, K. and M. Vellend. (2005). *Recovery of forest plant communities in post-agricultural landscapes*. Frontiers in Ecology and the Environment 3: 243-250.

Hare, R.C. (1961). *Heat effects on living plants*. Occasional Paper 183. USDA Forest Service Southern Forest Experiment Station, 32 pp.

Hare, R.C. (1965). *Contribution of bark to fire resistance*. Journal of Forestry 63(4): 248-251

Hungerford, R.D. (1996). *Soils: fire in ecosystem notes: Unit II-i*: Marana, AZ. U.S. Department of Agriculture, Forest Service, National Advanced Resource Technology.

Irwin, K., Dickens, D., McElvany, B., Moorhead, D., and Lanier. (2007). *Determining Survival in Young Slash , Loblolly , and Longleaf Pinestands after a fire in Bulloch County, GA.* Warnell Publication 004R-07

Keeley, J.E. (2009). *Fire intensity, fire severity and burn severity: a brief review and suggested usage*. International Journal of Wildland Fire, 18, 116-126.

Keeley, J.E. (2012). E*cology and evolution of pine life histories*. Annals of Forest Science 69: 445-453.

Keeley, J.E., J.G. Pausas, P.W. Rundel, P.W., W.J. Bond, and R.A. Bradstock. (2011). *Fire as an evolutionary pressure shaping plant traits*. Trends in Plant Science 16(8), 406-411.

Loomis, R.M. (1973). *Estimating fire-caused mortality and injury in oak-hickory forests*. Res. Paper 94. East Lansing, MI. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 9 p.

Moskal E. (2013). *Log it or leave it - post-fire debate over burned trees*. Bay Nature. Retrieved January 2022, from https://baynature.org/article/log-leave-post-fire-debate-over-burned-trees/

O'Brien, J.J., J.K. Hiers, P.J. Mitchell, J.M. Varner III, and K. Mordecai. (2010). *Acute Physiological Stress and Mortality Following Fire in a Long-Unburned Longleaf Pine Ecosystem*. Fire Ecology 6: 1-12.

Prescribed-Fire. (2020). *Using prescribed fire in loblolly pine stands*. Prescribed Fire. Retrieved January 11, 2022, from https://prescribed-fire.extension.org/using-prescribed-fire-in-loblolly-pine-stands/

Regelbrugge, J.C., and D.W. Smith. (1994). *Postfire tree mortality in relation to wildfire severity in mixed oak forests in the Blue Ridge of Virginia*. Northern Journal of Applied Forestry 11(3): 90-97.

Ripley, K. (2012). *Fire Injured Trees: Making an Initial Assessment of Whether a Tree is Likely to Die.* Washington State Department of Natural Resources. https://afterthefirewa.org/wp-content/uploads/2014/07/assessingtreeinjury_ripley_2012.pdf

Seiler, J., Niemiera, A., Jensen, E., & Peterson, J. (2021). *Longleaf pine*. Virginia Tech Dendrology Fact Sheet. Retrieved January 18, 2022, from http://dendro.cnre.vt.edu/dendrology/syllabus/factsheet.cfm?ID=107

Smith, S., & Cluck, D. (2011). *Marking Guidelines for Fire-Injured Trees in California*. United States Forest Service. Retrieved January 18, 2022, from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5331724.pdf

Soil Development. Geography. (n.d.). Retrieved January 12, 2022, from http://geography.name/soil-development/ '

Sparks, J.C., R.E. Masters, D.M. Engle, M.W. Palmer, and G.A. Bukenhofer. (1998). *Effects of late growing-season and late dormant-season prescribed fire on herbaceous vegetation in restored pine-grassland communities*. Journal of Vegetation Science 9(1): 133-142.

USFS. (n.d.). *Index of Species Information: Pine taeda. Fire Effects Information System (FEIS)*. Retrieved January 11, 2022, from https://www.fs.fed.us/database/feis/plants/tree/pintae/all.html

Vellend, M., K. Verheyen, K. Flinn, H. Jaquemyn, A. Kolb, H.V. Calster, G. Peterken, B.J. Graae, J. Bellemare, O. Honnay, J. Brunet, M. Wulf, F. Gerhardt, and M. Hermy. (2007). *Homogenization of forest plant communities and weakening of species-environment relationships via agricultural land use*. Journal of Ecology 95: 566-573.

Wade, D.D., and J.D. Lunsford. (1989). *A guide for prescribed fire in southern forests.* Technical Publication R*-TP 11. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 56 p.

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

Weise, D.R., R.W. Johansen, and D.D. Wade. (1987). *Effects of spring defoliation on first-year growth of young loblolly and slash pines*. Research Note SE-347. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 4 p.

Weise, D.R., D.D. Wade, R.W. Johansen, H.K. Preisten, D.D. Combs, and E.E. Arch. (2016). *Defoliation effects growth and mortality of three young southern pine species.* Research Paper PSW-RP-267. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 70 p.

Initial Post-Burn Evaluation

Item	Response	Item	Response
Prepared by:			
Date of the burn:		Date of evaluation:	
Permit #:		County & State:	
Acres burned:		Do you have pre-burn pictures?	
		Did you take pictures today?	

Component	Notes
Were the burn objectives accomplished? ■ List which objectives were met fully, partially, or not at all.	
Was the pre-burn preparation thoroughly and satisfactorily completed?	
Was the burn plan followed? ■ If not, what parts changed and why?	
Were the following factors within planned limits? ■ If not, were all deviations documented on the burn plan? Consider: ■ Weather conditions ■ Fuel conditions ■ Expected fire behavior ■ Smoke dispersion	
Did the fire behave as expected? If not, why? ■ Did it escape containment? ■ Did smoke disperse as expected and were you successful in avoiding smoke-sensitive features or areas? ■ Were the burning techniques used successful or did they result in control issues or damage?	

Component	Notes
Fire Effects ■ Add anything of note about each component below: ■ Crown (was there any crown scorch) ■ Understory vegetation (estimate of how much was burned and/or killed) ■ Litter/duff (about how much is left on the forest floor?) ■ Any other impacts?	
Costs / Benefits ■ Briefly summarize the costs for manpower, equipment, and supplies	
Notes for Future burns ■ When will the next burn be needed? ■ Will the burn plan need to be adjusted for the next burn? ■ What could be done to improve future, similar burns?	
Additional observations and comments ■ It can be good to sketch up a map showing the areas burned	

Figure 4.13. Advanced initial evaluation worksheet.

Secondary Post-Burn Evaluation *Page 1 of 2*

Item	Response	Item	Response
Prepared by:			
Date of the burn:		Date of evaluation:	
Permit #:		County & State:	
Acres burned:		Do you have pre-burn pictures?	
		Did you take pictures today?	

Component	Notes
Does it appear that the prescribed fire was beneficial in aiding your overall land management objectives?	
How did the fire affect trees? ■ What is the estimated tree mortality? ■ Is any sap seeping from trees in the burned area, particularly pine? If yes, this is an indicator	

How did the fire affect vegetation?
■ What is the estimated vegetation mortality?
■ Is any undesirable vegetation growth present?
    ■ If so, how quickly is the growth occurring?
    ■ Are any of the species invasive/exotic? If yes describe which species were observed and where.
■ Have any new desirable woody shrubs, vines, or herbacious plants been observed that were not present or notibable prior to the burn? If so, estimate the percent coverage.	

Was the burn plan followed? ■ If not, what parts and why?	

Figure 4.14. Secondary Evaluation form

Page 2 of 2

Component	Notes
Have there been any complaints or support for the burn from the public since the burn's completion?	
Was the pre-burn preparation thoroughly and satisfactorily completed?	
Were the costs of the burn on par with the benefits derived?	
Additional Components to Consider for Secondary Evaluation	
Other Fire Effects ■ Are regenerating (i.e. seedlings and saplings) pine and/or hardwood stems more or less prevelant in the stand? Quantify regeneration by counting these stems by species in circular, 1/100th acre (11.8 ft radius) plots. ■ What is the percentage of litter/duff on the forest floor? ■ Is there any evidence of disease or insect damage?	
Additional observations and comments: ■ Take and date additional photographs of your burn unit to maintain a visual record.	

Figure 4.14. Continued. Secondary Evaluation form

EVALUATING THE BURN NOTES

EVALUATING THE BURN NOTES

WEATHER

Image courtesy of James Johnson

Table of Contents

Introduction to Fire Weather

Knowledge of weather and its effects on fire behavior is crucial to conducting prescribed burns effectively and safely. Understanding how these weather factors affect fire starts with the most pertinent basic weather principles. While you can't manipulate or control weather elements, being aware of their influence on prescribed fire will help set you up for success.

Prescribed burns are influenced by many variables such as fuel conditions and arrangement, time since last burn, topography, and land features. Weather conditions, however, are one of the most important factors impacting a prescribed burn. Weather conditions influence how much smoke is produced, how long the smoke lingers in the atmosphere and the direction of its path. If smoke does not disperse, or travels over major roads, hospitals, airports or heavily populated areas, it can cause serious problems. For example, large plumes of smoke may cause health problems due to poor air quality, particularly for vulnerable populations. When burn prescriptions are developed, the range of values for different weather conditions are selected to meet prescribed burn objectives and to minimize production of smoke and the time it takes to disperse.

Weather conditions are not static and change from day to day and hour to hour, thus monitoring these conditions is also an ongoing task. Generally, temperatures will likely rise, and humidity levels will likely drop from morning to afternoon. Wind speed can increase or decrease or change direction and cloud cover can allow more or less solar exposure. These fluctuations in daily and hourly weather conditions will influence if you can burn on a particular day, when you start your burn, your ignition techniques, and fire behavior. Weather forecasts will provide information and probabilities of general weather conditions. However, weather conditions (temperature, wind direction/speed, relative humidity, etc.) must be measured and documented on the site of the burn and throughout the burn. Luckily, there are many tools for quantifying weather conditions and resources for accessing weather forecasts.

In preparation for burning, weather forecasts will need to be monitored in the weeks and days before a likely date(s). You will need to follow general weather forecasts, to watch for the right general set of weather conditions for your burn. In addition, there are many different indices which provide information about general weather conditions for burning, such as the fire danger index, or the Keetch-Byram Index which measures drought conditions. Your burn plan will likely include a range of values for some of these indices. If the general forecast conditions and index values are suitable for your burn, then you will need to obtain more accurate and specific fire weather forecasts and on the ground observations. There are many resources for obtaining accurate weather forecasts, such as the National Weather Service (NWS), and state forestry agency websites, among others, which provide information specific to burning. Only federal and state agencies can access "spot weather forecasts" for burning. On the ground observations can be captured through tools ranging from a basic thermometer and rain gauge to more sophisticated tools such as portable weather stations. This section provides information and a checklist on weather factors, weather observations and indices, smoke management and fire behavior (Table 5.1).

Table 5.1. The range of possible values for relative humidity (RH) and temperature for prescribed burns varies across the Southeast and across sites, but this table includes the lowest and highest likely values.

Common Range of Values for RH & Temperature for Burn Prescriptions Across the South	
Relative Humidity	25% - 60%
Temperature	30°F - 80°F

Weather Factors: Definitions and Descriptions

Temperature, relative humidity (RH) and wind are the three most important weather factors for prescribed fires. These weather measurements are affected by each other, as well as a variety of other physical and geographical variables, ranging from season of the year and cloud cover, to topography or vegetation and more. See Table 5.2 for a more comprehensive list. Other weather factors to consider include atmospheric stability as well as cold and warm fronts. It is important to be familiar and comfortable with these essential weather variables when conducting a prescribed burn. Definitions for each are included below and they are described in greater detail in the following pages.

Table 5.2. Lists of the variables that affect each of the three main weather conditions. *Adapted from Weir, J. (2009).*

Weather Condition	What affects it?
Temperature	▪ Air Mass ▪ Shading Vegetation ▪ Wind ▪ Humidity ▪ Temperature Inversions ▪ Season of the Year ▪ Cloud cover ▪ Topography ▪ Aspect ▪ Elevation ▪ Proximity to Large Bodies of Water ▪ Inversions
Relative Humidity	▪ Topography ▪ Wind ▪ Clouds ▪ Vegetation ▪ Air Masses or Fronts ▪ Temperature
Wind	▪ Topography and Water ▪ Diurnal Variation ▪ Vegetation ▪ Eddies ▪ Frontal Boundary ▪ Slope Effect ▪ Thunderstorms ▪ Sea Breezes

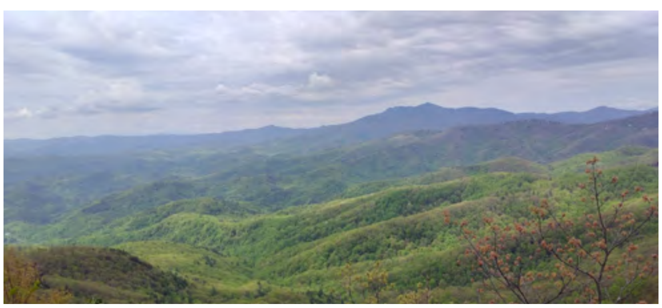


Image 5.1. Topography can impact all weather variables. Burns in the mountains will differ from burns in a marshland. *Image courtesy of Sarah McNair.*

Temperature: a measure of how hot or cold the air is.

Relative Humidity (RH): a value used to capture the amount of moisture content in the air and is recorded as a percentage of the total possible water that the air can hold at a given temperature. Complete saturation at a given temperature is equivalent to an RH of 100%.

Wind: the natural movement of any air of any speed or direction, caused by the earth's unequal heating.

Weather Front: a boundary separating two masses of air with different densities.

Atmospheric Stability: refers to how "active" weather patterns are a measure of how a parcel of air moves when it is pushed upwards by day-time heating or topography.

TEMPERATURE

Atmospheric temperature is a measure of the hotness or coldness of the air and can be calculated with a standard thermometer onsite. Be certain to measure temperature in a location that is consistent with the rest of the burn unit. For example, do not measure temperature in direct sunlight, on nearby pavement, or under a shade tree if you are burning in a field, as this will provide unrepresentative readings.

Burn prescriptions often start with selection of a desired range of values for temperature, as temperature influences the moisture of forest fuels. Higher air temperatures will dry fuels out faster, even if the RH levels stay the same. Exposure to sun can also impact the temperature of vegetation as vegetation in direct sunlight can be 40°F or more above that of the surrounding air. If fuels are already warm from air temperature, then less energy from a fire is necessary for them to ignite. Water in fuels evaporates more rapidly when the air is warm, which means less heat energy from a fire is needed to reduce the fuel moisture, and then preheat and ignite the fuel. Air temperature also affects personal and crew safety – extreme temperatures can cause dehydration and heat exhaustion/stroke.

Risks to Vegetation from Higher or Lower Ambient Temperatures

High air temperatures increase the probability of crown scorch during a fire. When air temperatures are already high, then it is easier for the fire to increase the temperature of the live foliage above its lethal threshold (considered to be almost instantaneous at 145°F). Avoiding the unsightly appearance of excessive crown scorch is often a major consideration, when conducting prescribed burns. At the other end of the spectrum, burning when the temperature is below 30°F requires additional heat to melt any ice crystals that have formed in plant cells (live and dead) before this moisture can be evaporated. However, burning during these conditions can significantly increase dead fuel loading for 2 to 3 years.

RELATIVE HUMIDITY

Relative humidity (RH) is the relative measure of the moisture content of the air as a percentage, of the total possible amount of moisture saturation for a given air temperature and ambient air pressure. It is the single most important weather factor in the drying of fine fuels.

The lower the relative humidity, the faster fuels will dry (Figure 5.1). The relative humidity is typically highest at daybreak and then decreases as the day gets hotter. Warm air holds more moisture at saturation than cold air. Thus, RH decreases as the temperature of a given parcel of air increases.

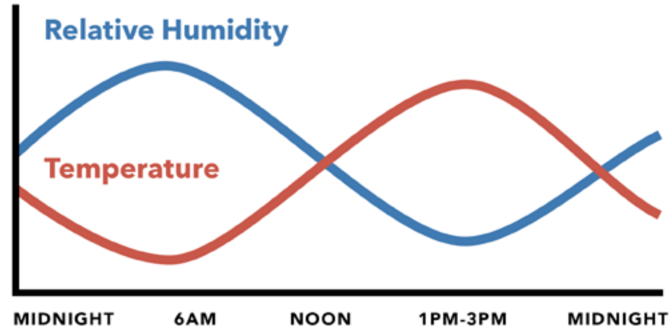


Figure 5.1. The relationship between relative humidity values and the temperature changes throughout the day and night.

For every 20˚F increase in temperature, the RH will be reduced by about one-half. Conversely, the RH roughly doubles with every 20˚F decrease in temperature until the air becomes saturated. The minimum RH is generally reached in the early afternoon and coincides with the maximum temperature.

The temperature at which saturation of air is reached is called the dew point (RH=100%). If the air continues to cool, moisture will change from a vapor to a liquid and heat will be released (called the heat of condensation). This is the process that causes dew to form. If the dew point is below freezing, then frost will form instead of dew. Clouds form when rising air cools and reaches the dew point temperature. Fog is simply a cloud in contact with the ground.

Fine fuel moisture is closely tied to the RH value. Moist air has a cooling effect on fuels. As RH increases, the fine-fuel moisture also increases, since these fuels absorb the water from the air. Moist fuels need more heat to burn than dry

1 Hour or Fine Fuels are fuels such as grass, pine, needles, moss, twigs and slash that is less than ¼ inch in diameter. It dries out and burns quickly.

An increase in relative humidity results in an increase in fine-fuel moisture, the lower the relative humidity level is, the faster fuels will dry out.

fuels. Heat from a fire is required to change liquid water (in the moist fuels) into vapor first (heat of evaporation). Once the water in the fuels has evaporated, then the fuels will ignite. Relative humidity can therefore be used to help regulate fuel consumption through its effect on fine-fuel moisture content. As the RH exceeds 60%, a patchy burn should be expected, especially in hardwood fuels. On the other hand, under low RH conditions, moisture in the fuel is absorbed by the air rendering the fuels more flammable.

Cold air masses that form in the Arctic are generally dry, so even if rainfall occurs along this type of frontal boundary, the RH will decrease as cold air settles in behind the front. In general, the lower the RH, the better the burning conditions. However, spotting (where sparks or embers carried by the wind ignite a new fire) can become a major problem as the RH drops below 30% partially because there is no longer enough moisture in the air to extinguish small firebrands, but mainly because the top layer of litter becomes increasingly dry and receptive to ignition.

Image 5.2. Relative humidity is higher in the morning, hence weather events such as early-morning fog. *Image courtesy of Sarah McNair.*

WIND

Wind is defined as the movement of air, the direction and speed of which is determined by the distribution of pressure centers and local topography. Wind direction is always expressed as the direction from which the wind is coming (Figure 5.2).

Wind is the most difficult weather variable to forecast and it has a strong influence on fire behavior. Wind speed and direction will influence fire behavior including how quickly the fire spreads, where it travels, and the direction that smoke is transported. Therefore, determining the desirable range for your prescribed burn plan is important to ensure that you meet your objectives and that you avoid the “wrong” wind direction which might cause challenges in your burn and for smoke management. Wind is affected by many topographical factors such as slope or terrain and tall vegetation, such as trees, may lift the wind up. Wind direction can also change quickly when a front passes through.

Types of Wind & Measuring Wind Speed

There are two broad types of winds — general and local — although in practice it is difficult to separate them. **General winds** are those affecting a large area such as an entire state. Winds form as air moves from high towards low pressure and then the direction is bent by the rotation of the earth. **Local winds** occur on a much smaller scale and are generated by local weather and terrain. Essentially local winds are the ones that a person on the ground can measure or feel. These winds can also be caused by differing temperatures between land and water bodies, and some examples are a sea breeze or land breeze.

Wind speed is measured in miles per hour, and forecasts will also often include the speed of possible **gusts** of wind, which are short bursts of faster wind. Wind speeds at a burn site are usually measured at eye level. Because local effects on wind are

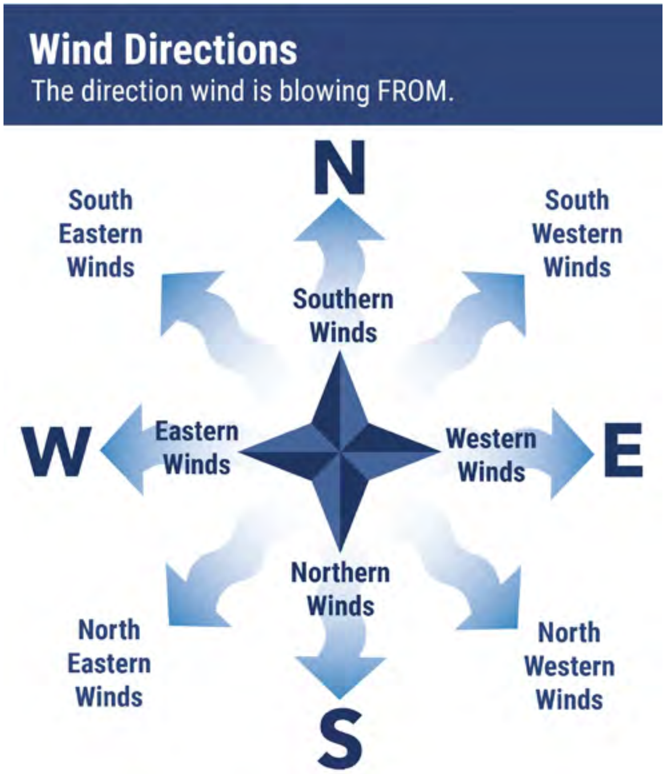


Figure 5.2. Wind direction is always expressed as the direction from which the wind is coming from. *Diagram credit: Jessica Shaklee.*

predictable, they may be used in assessing weather factors for a prescribed burn on a specific area. However, the wind speed listed in a standard fire weather forecast is a measure of wind speed ~33 feet above any vegetation, including the tree canopy. It is also called the **surface wind** speed or the ~33-foot wind speed. This difference generally results in a wind speed at the burn site, that is lower than the one listed in the fire weather forecast as there are obstructions that slow the wind speed. Weather forecasts differ on which winds they report. Most general National Weather Service forecasts share the surface wind speed.

Wind & Fire Behavior

Wind speed and direction strongly affects how a fire behaves. Wind influences oxygen input to a fire and smoke dispersal. Wind gusts and/or sudden changes in direction are responsible for most escaped prescribed fires. High wind speeds can result in spikes in oxygen, further contributing to erratic fire behavior. Higher wind speed can also increase smoke dispersal. Lower wind speed can result in smoke lingering over the burn for a prolonged period. Interestingly, when there is little to no wind, prescribed fires may be harder to control, as the fire will burn at its own pace, where there is fuel. When there is no wind, then approaches or ignition patterns for burning that require wind from specific directions may not be useful. For example, a backing fire is a line of fire that burns directly into the wind and moves slowly, whereas a heading fire burns in the same direction as the wind and moves more quickly.

It is imperative that the wind speed and direction on a prescribed burn fit within the prescription parameters to maintain control of the burn, achieve the desired fire effects, and satisfy smoke management constraints. Local wind patterns should be considered during the planning of firebreaks, burn unit boundaries, and throughout the ignition and mop up phases.

Image 5.3. *Image courtesy of James Johnson.*

Factors that Affect Wind Speed

Stand density and understory density can influence wind speed within a forest (Figure 5.3). **Stand density** refers to the number of canopy or mid-story trees found within a given area. **Understory density** refers to the density of the shrubs, small trees, and herbaceous plants that make up the forest understory.

Wind tends to change direction and speed as the airstream flows around and over ridges, swamps, lakes, and rivers. Winds are also influenced by urban areas and other large obstructions or constant heat sources such as airports and parking lots.

Hilly or mountainous terrain also affects wind flow. Valleys in between mountains or hills channel wind and influence wind direction. Wind flows upslope as solar radiation heats the slope during the day. However, wind flow on slopes changes from day to night independent of the general surface wind direction. On calm nights, wind flow is downslope because of radiational cooling. When burning in mountainous or hilly terrain, topography needs to be accounted for in the ignition plan. When there is no wind, then the slope can be used similarly as wind

Heading Fire: Fire that moves with the wind.
Backing Fire: Fire that moves against the wind.

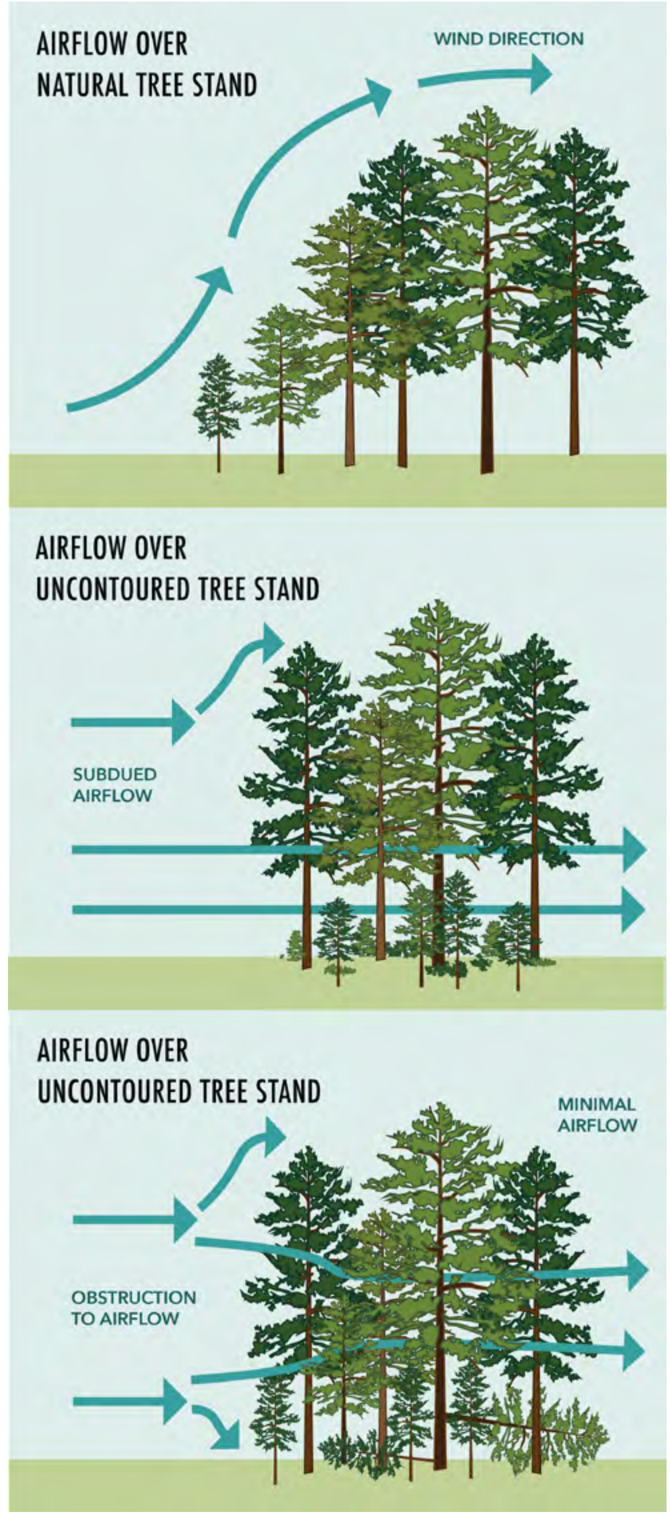


Figure 5.3. Airflow throughout and around stands is determined by stand structure and obstructions within the stand. *Diagram credit: Jessica Shaklee.*

Table 5.3. Description of terms for measuring and describing wind that are used for prescribed fire.

	Typical wind measurements that are used for prescribed fire Measured in miles per hour
Wind speed	The speed of wind and the speed of gusts if they are over 5mph higher than the average wind speed in the forecast.
Wind direction	The prevailing wind direction that the wind comes from. Wind direction may be a range such as, from north to northeast or south to southeast, etc.
Surface winds (33 foot winds)	A measure of wind speed 20 feet above any vegetation, including the tree canopy. It is also called the surface wind speed.
Mid-flame winds	Measured at the eye-level in the burn unit. As the wind becomes stronger (increases in speed), then fire intensity increases too.
Canopy wind	Canopy winds measured within a timber stand.

direction. If a fire is lit on the bottom of a hilly slope, then fire traveling up the slope will produce head fires, whereas a fire lit at the top of the slope will burn like a backing fire.

ATMOSPHERIC STABILITY

The atmosphere consists of multiple layers that are divided by their temperature characteristics and range from the troposphere, stratosphere, mesosphere, thermosphere and space. The troposphere is the lowest layer of the atmosphere (closest to the ground), and where weather is changeable. Temperature in this layer usually decreases with height and this temperature gradient or structure allows for vertical motion and atmospheric mixing. **The stability of the atmosphere is a measure of how a parcel of air moves when it is pushed upwards by daytime heating or topography.** Vertical motion is caused by heating a parcel of air which then rises because it is less dense than the surrounding cooler air. As this heated air rises, it cools until it reaches the temperature of the air it is passing through.

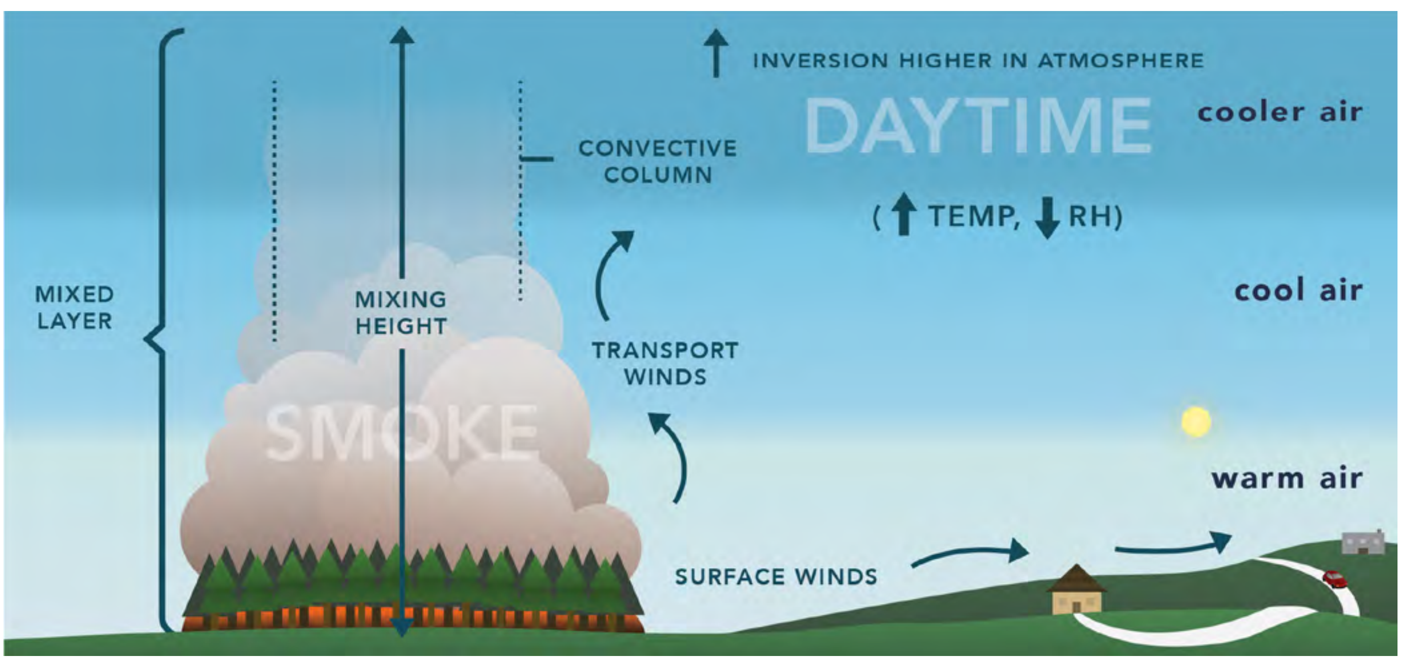


Figure 5.4. Atmospheric and weather conditions and how they may influence smoke behavior during the day
credit: Laura Costa, Southern Regional Extension Forestry (Campbell et al., 2020.)

Unstable atmosphere refers to a parcel of air that is warmer than the temperature of the environment and so it will rise. **Stable atmosphere** means that a parcel of air is equal in temperature to or cooler than the air around it, so it will either stay at the same level or sink when pushed upwards. Higher air temperatures near the earth's surface (in relation to the air above it), creates a more unstable parcel of air. Thus, sunny days usually result in more unstable atmospheric conditions near the ground. During the day as the air is heated by the sun, it rises, and displaces cooler air which sinks, setting up a vertical circulation pattern. Solar radiation near the ground is also part of the process that produces upslope winds on sunny days where slopes are present.

The height to which vigorous mixing due to convection occurs is called the **mixing height** (Figure 5.4). In general, **the more unstable the atmosphere, the higher the mixing height will be.** Mixing heights of 4,000 to 6,000 feet are common in the Southeastern U.S. during the summer and 2,000 to 4,000 feet during winter. Mixing heights also change during the course of the day since solar heating raises the mixing height and lack of sunshine at night allows a more stable, lower mixing height overnight (Figure 5.5). **Atmospheric dispersion** is the process by which the atmosphere mixes and transports particulates, such as smoke, away from their source.

Atmospheric stability strongly controls smoke dispersal and affects fire behavior (Table 5.4). An atmosphere that is more stable means that it is more resistant to air or smoke rising, whereas an unstable atmosphere is less resistant. An unstable atmosphere can be better for managing smoke from prescribed fires because smoke and combustion

	Unstable Atmospheric Conditions	Stable Atmospheric Conditions
Visual Indicators	▪ Good visibility ▪ Puffy clouds high in the sky ▪ Gusty winds	▪ Poor visibility, smoke, or haze ▪ Fog, thick layers of heavy clouds ▪ Inversion
Effects on Fire Behavior	▪ Smoke columns stay together, are tall and rising ▪ Increased likelihood of fire whirls and dust devils ▪ Gusty and erratic winds ▪ The height and strength of convection and smoke columns often increase significantly during unstable atmospheric conditions ▪ Increased likelihood of fire brands being lifted to great heights ▪ Higher intensity fires due to increased vertical motion and high inflow wind feeding the fire new oxygenated air	▪ Poor smoke dispersion as the smoke column does not rise, but drifts apart ▪ Decreased wind or activity or air movement, which limits fire growth and intensity ▪ Low intensity fires, as there is not much inflow of fresh air ▪ Low wind speeds & fire spread rates (except in hilly terrain)

Table 5.4. Stable and unstable atmospheric conditions at different times of day and the corresponding changes in mixing height.

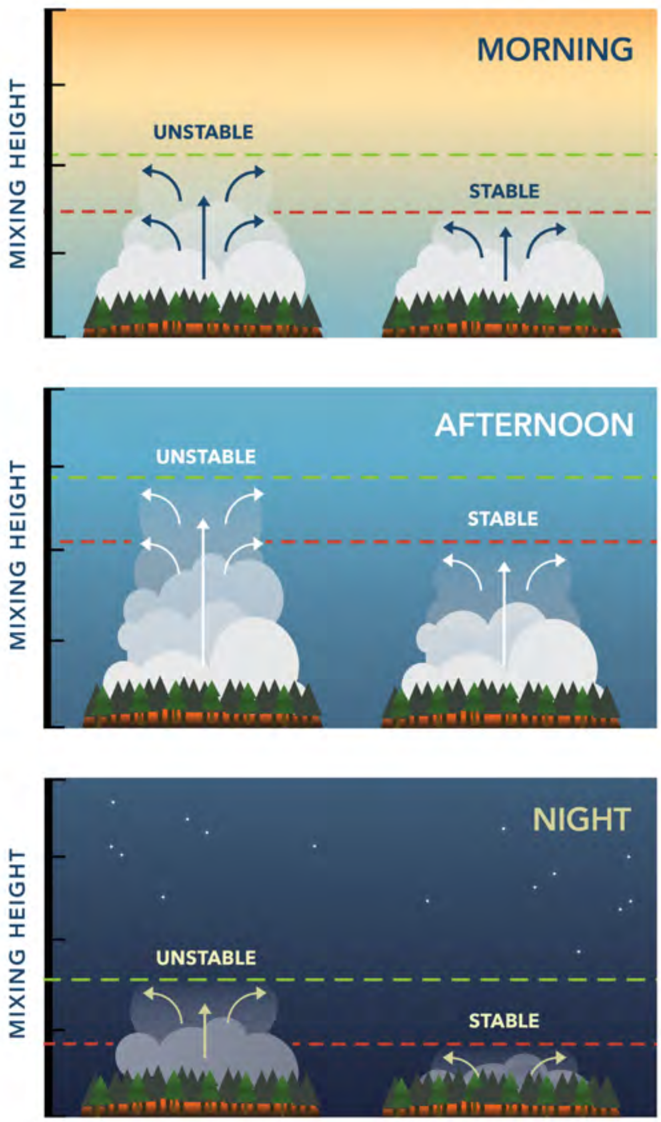


Figure 5.5. Stable and unstable atmospheric conditions at different times of day and the corresponding changes in mixing height. *Diagram credit: Jessica Shaklee.*

products can quickly rise, and the smoke will to stay in a column. However, a well-defined smoke column can also affect fire behavior and make it more difficult to contain the fire. If atmospheric conditions are extremely unstable, then there is a higher potential for unpredictable fire behavior.

As the sun sets, radiational cooling lowers the temperature of the earth's surface and, in turn, the adjacent air. This cooler air hugs the ground and flows downslope along drainages to lower elevations. Conditions such as these can result in a layer of warm air that forms at a higher elevation. This is called inversion. An inversion leads to stable atmospheric conditions. Inversions are often strongest during cold winter nights. In the South, stable conditions should be expected most nights, except immediately after passage of a cold front. The next day solar heating of the earth's surface warms the adjacent air which then rises breaking the nocturnal inversion, usually by mid-morning. There are dispersion index tools that are used to estimate daytime and nightime stability by assigning a value to the rate of dispersion in the mixing layer.

FRONTS

A front is defined as the boundary or zone separating two air masses of contrasting density. An air mass is a broad region of air with fairly uniform temperature and humidity. Fronts exist because the earth does not heat evenly, and warm air moves towards the north and south poles, while cold air moves towards the equator or tropical areas. Frontal systems are the main driver of winter weather in the South. Fronts are described as warm or cold depending on the temperature of the air mass relative to the temperature of the air that it is replacing. Cold fronts develop when cold (denser) air forces warm moist air aloft. The cold air, which is heavier, overtakes the warm air, moves forward by sliding underneath the warm air, forcing the warm air mass upward off the ground (Figure 5.6). Cold fronts usually occur every 5 to 7 days. Warm fronts, on the other hand, are warmer than the air they are replacing and are usually accompanied by a band of clouds and precipitation several hundred miles wide. Both types of fronts can occur year-round. Some fronts are stronger than others due to differences in humidity and temperature. Warm fronts are seldom associated with decent prescribed burning weather. Most winter burning is associated with passage of a cold front. Burns should take place after front has passed. Passage of cold fronts are often associated with increased wind gusts and winds almost always shift in a clockwise direction.

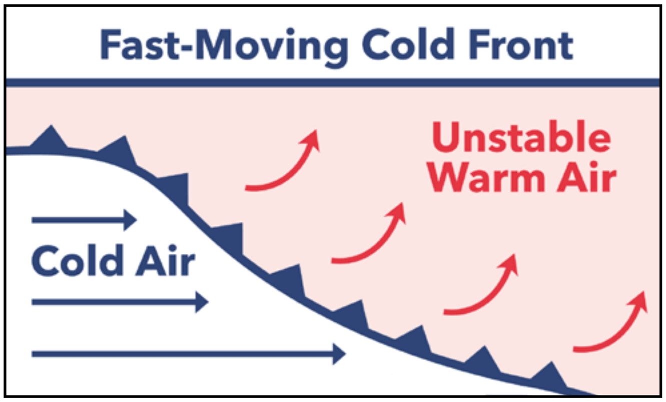


Figure 5.6. The heavier, cold air slides underneath the warm air forcing it upward. *Diagram credit: Jessica Shaklee.*

In the South, airflow ahead of an approaching cold front most commonly comes from the southwest. Such winds will generally dampen fine fuels in some southern states because they gather moisture over the Gulf of Mexico. Nonetheless, such winds are often used in prescribed burning when smoke management constraints require a southerly direction (smoke transport to the north), or when less intense heading fires are desired (the increased fine fuel moisture means more of the heat released is used to evaporate the water in the fuels and is thus not available to increase fire line intensity). If rain accompanies the front, smoldering fuels are likely to be extinguished thereby eliminating residual smoke problems.

ATMOSPHERIC PRESSURE SYSTEMS

Weather changes are caused by the different amounts of solar energy that regions of the planet receive at any given time. **Atmospheric pressure** results from the weight or mass of the atmosphere being affected by the force of gravity. The distribution of atmospheric pressure is closely linked to weather patterns, especially because air moves in response to differences in pressure. **Low pressure** centers are areas with lower pressure than the surrounding region. High pressure centers are the opposite. Low pressure systems have inward and rising air motion, spinning in a counterclockwise direction (in the northern hemisphere), leading to cooling and increased RH. When the air flows into a low-pressure system from all sides, it is called **convergence**, as the air must move, and it can only go upward because of the ground below. In **high pressure** systems, air flows outward, spinning in a clockwise direction in the northern hemisphere, and descending. Lines of low pressure are called **troughs**, while lines of high pressure are **ridges**.

In high pressure systems the air flows down and out and there tends to be clear skies and sunshine with few clouds. In low pressure systems the air flows in and up and the water in the air condenses forming clouds form that can grow big enough to storm. Temperature differentials and moisture content disparities generally produce more active fronts.

Cold fronts may cause these common weather changes

Weather Factor	Change
Wind direction	Can change drastically throughout a burn
Wind speed	Increases up to 20 mph – higher speeds often occur at higher elevations
Temperature	Decreases of 5 to 30°F as the front passes
Relative Humidity	Decreases 10 to 30%
Rainfall / Precipitation	May or may not be part of cold front depending on amount of moisture present and density differences

Table 5.5. Cold fronts can cause changes in wind direction, temperature, relative humidity, and other weather conditions.

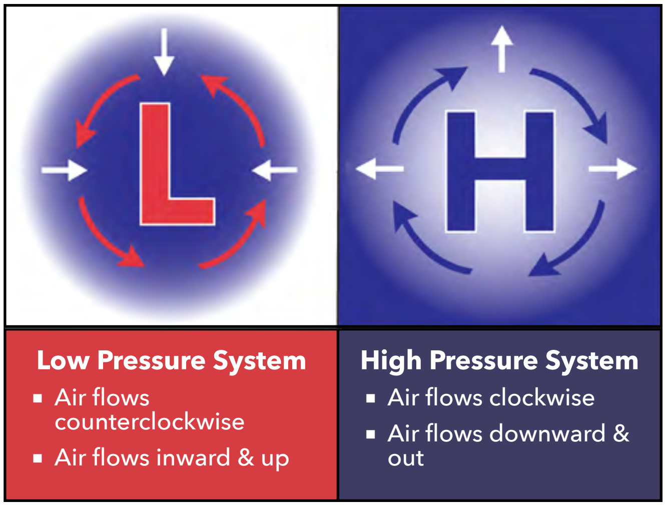


Figure 5.7. The formation of high- and low-pressure frontal systems.

Areas with low pressure tend to be associated with frontal weather (Figure 5.7).

Highs and lows have different types of weather associated with them that can also affect fire behavior. For example, when atmospheric pressure changes quickly, then wind speed increases. Typically, there are higher wind speeds in low pressure systems overall, and very strong wind speeds in the center of the lows. High pressure systems tend to have low wind speeds and weak pressure gradients near their centers. Areas with low pressure tend to be associated with fronts (described below), and the fronts tend to form in the troughs of lower pressure.

Weather Observations

ON-SITE

Many different weather variables can be measured on site and can be recorded before burns, and every 60 minutes or so, during burns. Since conditions can change, it is critical that someone continues to monitor weather conditions throughout the burn and even afterward if smoldering continues to produce smoke. Typically, air temperature, relative humidity, wind speed and direction are measured on site. Weather meters can be used to measure RH, wind speed, and temperature. In chapter 3, Conducting the Burn, see the weather checklist for a list of measurements to be made on site and a log for recording them, as it is good for your records.

When measuring on-site weather conditions, the measurements should be taken in the stand to be burned, not on a road, or in an area with

Kestrel Weather Meter

This tool calculates relative humidity, heat index, wind chill, wind speed, and temperature. It is available for purchase online.

Steps for measuring windspeed with a Kestrel

1. Let the unit become acclimated to surroundings (2 - 5 minutes)

2. Hold it about eye level facing into the wind and at arms length so your body does not interfere with the measurement

Do not stand directly behind a large shrub or tree bole that will block the wind

3. Do not just take a reading when the wind is gusting, although gusts maximums should be a part of the observation

A word of caution: Be certain to calibrate meters for accuracy (e.g. relative humidity). An inaccurate meter can provide false readings – which can result in a hazardous field situation.

Figure 5.7. Example forecast obtained from National Weather Service. *Diagram credit: Jasmin El Farnawany & Jessica Shaklee.*

obvious understory or overstory density or height differences, such as a clear-cut area versus a mature forest. While there are forms you can use to record your observations, the important thing is to record your notes. Typically, you will want to note time, temperature, RH, wind speed, and direction. Kestrel weather sensors should be checked frequently for accuracy as some RH sensors need to be calibrated often. Kestrels should not be the only weather instruments on a burn.

Continue to take weather observations at set intervals (one-hour intervals are often used) throughout the burn. Once the burn is underway, make sure observations are taken some distance upwind of the fire to assure the readings are not affected by indrafts, or by air warmed by fire or smoke.

For a more in depth weather forecast, visit the National Weather Service fire weather dashboard. **https://www.weather.gov/dlh/fwd**

Table 5.6. Fire weather timeline. Record weather observations (wind speed and direction temp RH) from before the burn starts through the end of the burn.

Timeline	What to review
Several days prior to burning	Long-term general weather
One or two days prior to burning	Weather forecasts & on-site weather observations
Day of the burn	Monitor on-site weather conditions before & during the burn to be aware of any deviations from expected conditions.
End of the burn	Record weather observations (wind speed & direction and temperature & RH immediately before leaving the site.

Weather Forecast Resources

There are many resources to obtain weather forecasts that can be particularly helpful. For example, you can likely obtain a fire weather forecast from the National Weather Service website (Figure 5.9). There are also many weather apps that will work well for your area.

- Fire weather forecast
- Weather apps
- Weather Underground App
- NC Fire weather portal

Fire Indices and Tools

There are a variety of indexes that estimate different potential fire behavior or weather-related factors (Table 5.8). It is not critical to understand all of the indices and tools, but it can be helpful to check them to see what values are appropriate for burn plan conditions. These indices include a range of values that are specific to each one; however, they also include information about what those values mean. For example, the fire danger index ranges from 1-5 with the values being described as low, moderate, high, very high, or extreme fire danger. They can also summarize multiple weather/fuel conditions as they are based on a variety of parameters that range from climate to atmospheric stability to fuels and topography.

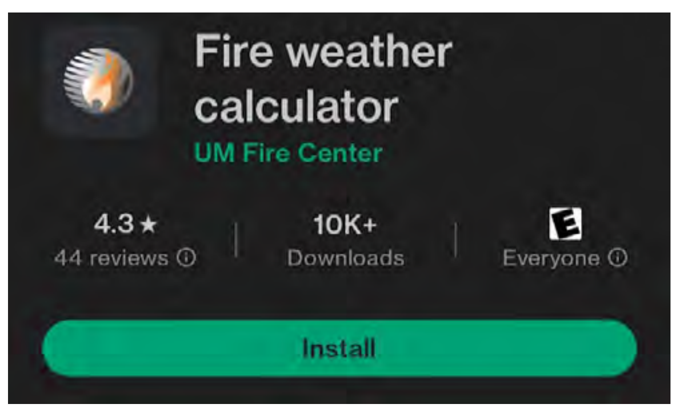
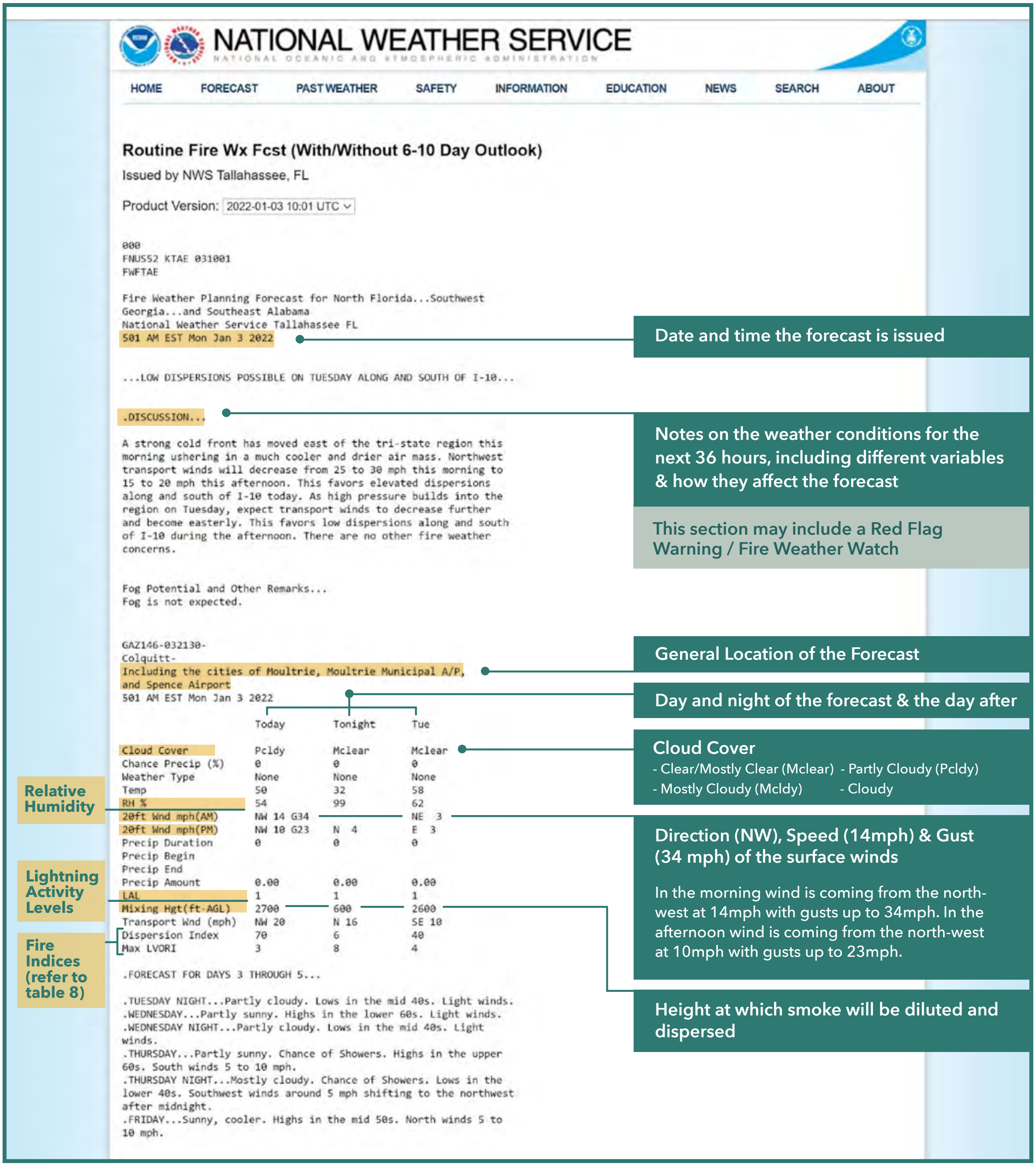


Image 5.4. Many phone applications exist where you can acquire weather forecasts, including the University of Montana calculator.



NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HOME FORECAST PAST WEATHER SAFETY INFORMATION EDUCATION NEWS SEARCH ABOUT

Routine Fire Wx Fcst (With/Without 6-10 Day Outlook)

Issued by NWS Tallahassee, FL

Product Version: 2022-01-03 10:01 UTC

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000
FNUS52 KTAE 031001
FWFTAE

Fire Weather Planning Forecast for North Florida...Southwest
Georgia...and Southeast Alabama
National Weather Service Tallahassee FL
501 AM EST Mon Jan 3 2022

...LOW DISPERSIONS POSSIBLE ON TUESDAY ALONG AND SOUTH OF I-10...

.DISCUSSION...

A strong cold front has moved east of the tri-state region this
morning ushering in a much cooler and drier air mass. Northwest
transport winds will decrease from 25 to 30 mph this morning to
15 to 20 mph this afternoon. This favors elevated dispersions
along and south of I-10 today. As high pressure builds into the
region on Tuesday, expect transport winds to decrease further
and become easterly. This favors low dispersions along and south
of I-10 during the afternoon. There are no other fire weather
concerns.

Fog Potential and Other Remarks...
Fog is not expected.

GAZ146-032130-
Colquitt-
Including the cities of Moultrie, Moultrie Municipal A/P,
and Spence Airport
501 AM EST Mon Jan 3 2022

                      Today        Tonight      Tue

Cloud Cover           Pcldy        Mclear       Mclear
Chance Precip (%)     0            0            0
Weather Type          None         None         None
Temp                  50           32           58
RH %                  54           99           62
20ft Wnd mph(AM)      NW 14 G34                 NE  3
20ft Wnd mph(PM)      NW 10 G23    N  4         E  3
Precip Duration       0            0            0
Precip Begin
Precip End
Precip Amount         0.00         0.00         0.00
LAL                   1            1            1
Mixing Hgt(ft-AGL)    2700         600          2600
Transport Wnd (mph)   NW 20        N 16         SE 10
Dispersion Index      70           6            40
Max LVORI             3            8            4

.FORECAST FOR DAYS 3 THROUGH 5...

.TUESDAY NIGHT...Partly cloudy. Lows in the mid 40s. Light winds.
.WEDNESDAY...Partly sunny. Highs in the lower 60s. Light winds.
.WEDNESDAY NIGHT...Partly cloudy. Lows in the mid 40s. Light
winds.
.THURSDAY...Partly sunny. Chance of showers. Highs in the upper
60s. South winds 5 to 10 mph.
.THURSDAY NIGHT...Mostly cloudy. Chance of showers. Lows in the
lower 40s. Southwest winds around 5 mph shifting to the northwest
after midnight.
.FRIDAY...Sunny, cooler. Highs in the mid 50s. North winds 5 to
10 mph.
```


Figure 5.8. Example forecast obtained from National Weather Service. *Diagram credit: Jessica Shaklee & Jasmin El Farnawany*

Fire Weather Calculator

National Center for landscape Fire Analysis

With Fire Weather Calculator, you can:

- Calculate relative humidity (RH), fine dead fuel moisture (FDFM), and probability of ignition (PIG) based on standard fire line weather observations
- Archive and share data observations via email

Fire Weather Calculator Mobile Application
The Fire Weather calculator is produced by the National Center for Landscape Fire Analysis and is for Android only. With this app, you can calculate relative humidity (RH), fine dead fuel moisture, and probability of ignition based on standard on site weather observations. In addition, you can save your records and share them in the app.

Precipitation/Drought Index - Keetch-Byram Drought Index - Drought is a measure of the relative dryness of an area. The **Ketch-Byram Drought Index (KBDI)** is commonly used in the Southeast. It depicts the degree of drought on a scale that ranges from 0 to 800. The KBDI includes assumptions that vegetation in an area will be at its wilting point when the index is 800 and that the area will reach field capacity with an effective rainfall of 8 inches. The index increases each rainless day, the amount depending upon the maximum ambient temperature reached. Conversely, the index value decreases with each rainy day, the amount depending upon the rainfall received during the 24-hour period. Rainfall amounts are much easier to predict in the winter because the rain is usually associated with the passage of region-wide pressure systems. In the summer, on the other hand, rainfall is generally the result of localized convective activity. Summer forecasts of probability of precipitation and precipitation amounts by the National Weather Service should be considered educated guesses. However, the KBDI is more site specific. In the absence of an onsite measurement the KBDI may be estimated.

Moisture in the lower litter and upper soil protects tree roots and soil microorganisms. When the KBDI exceeds 400, consider putting off scheduled burns where a duff layer is present. As a duff layer develops (in 4 or 5 years without fire on good sites with a closed canopy) tree roots quickly colonize it. Fires that consume this layer kill the feeder roots within it and often damage those roots just below the soil surface as well. Young fast-growing trees can generate a new feeder root system fairly quickly but as a tree matures this process takes longer and mortality becomes more likely. Those areas that have well established burn programs and short fire return intervals may have conditions that will accommodate burns with higher KBDI's.

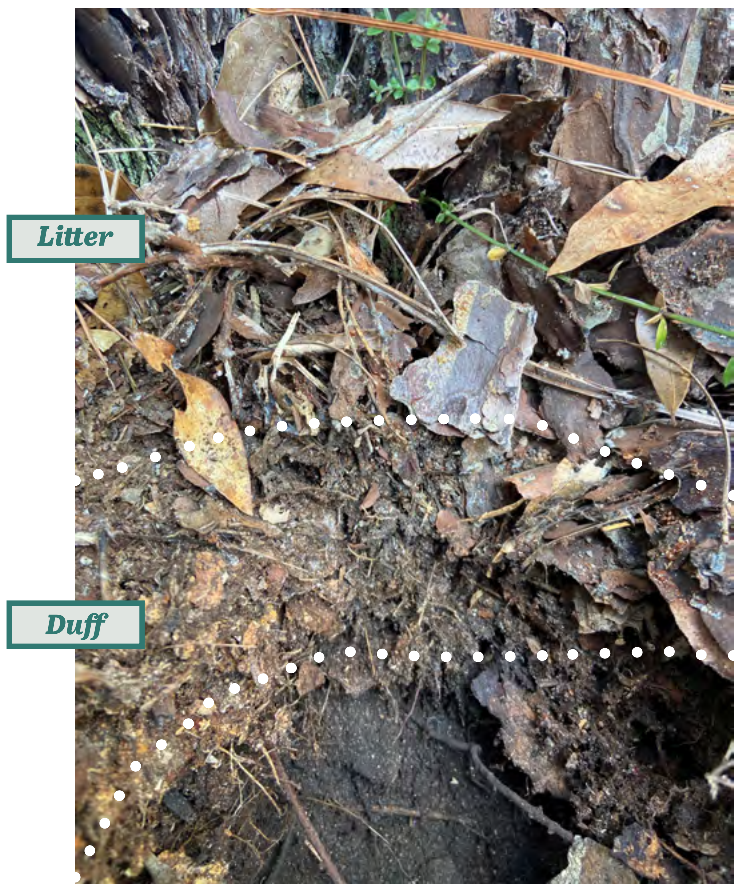


Image 5.5. The duff layer is decomposing organic material decomposed to the point at which there is no identifiable organic materials (pine straw, leaves, twigs, etc.). Duff is an important aspect of KBDI. *Image courtesy of David Godwin.*

Table 5.8. Various fire indices, their uses, and the range values used for each index.

Index	What is it?	Range of Values
Keech-Byram Drought Index	It is used to determine the potential for forest fire and is a drought index based on precipitation and soil moisture.	0-800 0 = Saturated soil 800 = Absolutely dry soil
Fire Danger Index	Ratings for this index are based on fuels, topography and weather. This index measures how readily a fire will ignite and provides an indication of potential fire behavior if it does ignite.	1-5; 1 = Low 2 = Moderate 3 = High 4 = Very High 5 = Extreme
LVORI (Low Visibility Occurrence Risk Index)	It is an index developed to estimate the potential for road accidents from smoke on the roadway at night.	1-10 1 = Few smoke/fog related accidents occurred under these conditions 10 = Majority of smoke/fog related accidents occurred under these conditions
Turner and Atmosphere Tendency	A measure of atmospheric stability that corresponds to expected fire behavior ranging from subdued to erratic.	1-7 1 = Extremely unstable atmosphere and erratic fire behavior 7 = Extremely stable atmosphere and subdued fire behavior
Atmospheric Dispersion Index (ADI Daytime)	Assesses the atmosphere's ability to disperse smoke or other pollutants away from a source based on the mixing height, transport winds, and atmospheric stability.	0-80+ 0-20 = Poor dispersion, stagnant, and persistent 21-40 = Poor to fair, stagnation may be indicated if accompanied by low wind speeds 41-60 = Generally good (for most rx fires) 61-80 = Good dispersion, control problems likely 80+ = Excellent dispersion, control problems expected
Atmospheric Dispersion Index (ADI Nighttime)		0-8+ 0-2 = Poor 3-4 = Poor to fair 5-8 = Good 8+ = Very good

Burn managers may proceed with caution when local knowledge and experience indicate that these conditions are suitable.

Don't be fooled by a hard shower when the KBDI is over about 500. Fire danger will be temporarily reduced but the interiors of large diameter fuels will still be very dry. After a day or two of sunshine, these fuels will be much drier than normal and are likely to ignite and could cause significant residual smoke. Check duff by hand to get a feel for moisture content.

The most important fire control concern when planning to burn vegetation growing on organic (peat/muck) soils such as a fresh-water marsh, is depth to the water table. It should be very close to, or above the surface to keep the organic soil from igniting. Once ignited, organic soils can cause significant nighttime smoke management problems and are extremely difficult to extinguish. Check with local officials if there are any questions.

The Fire Danger Index measures the potential risk of a wildfire starting, and the suppression effort it would require, on any given day. It is commonly posted by local fire stations, and can also be found online. The Fire Danger Index utilizes a color-coded, 0 to 100, scale. A green color, or a rating of 0, indicates low risk of a wildfire starting. A red color, or a rating of 100, indicates a very high chance of a wildfire starting.

The Low Visibility Occurrence Risk Index (LVORI) measures the risk of low visibility occurring. The risk dramatically increases when RH is high and ADI is low. This index is helpful in qualitatively estimating the likelihood of a vehicle accident occurring under a given set of conditions. This index is currently available from the National Weather Service and can also be ascertained by using the predicted nighttime DI, maximum RH, and the LVORI table.

Table 5.9. Turner Stability Index (Georgia Forestry Commission, n.d.).

Turner Class	Stability of the Atmosphere	Fire Behavior
1	Extremely unstable	Erratic
2	Moderately unstable	Intense
3	Slightly unstable	Normal
4	Neutral	Normal
5	Slightly stable	Normal
6	Moderately stable	Subdued
7	Extremely stable	Subdued

The Turner Stability Index is a measure of atmospheric stability. It is based on measurements of surface level wind speed and net solar radiation. Turner and Atmosphere Tendency values range between 1 and 7 (Table 5.9). Values 1-3 are only possible during daytime periods, and indicate atmospheric instability. Values 5-7 are only possible during nighttime periods and indicate atmospheric stability. A value of 4 can occur during both daytime and nighttime periods, and indicates moderate stability.

The Atmospheric Dispersion Index (ADI) is a forecasting tool that incorporates the Turner Stability Index into a measure of the atmosphere's ability to disperse smoke and other pollutants. It includes estimates for both daytime and nighttime atmospheric stability. It was developed by the U.S. Forest Service to assess the impact of prescribed burning activity on atmospheric smoke concentrations and air quality. The same processes responsible for good smoke dispersion also contribute to erratic fire behavior and may present very hazardous conditions.

The ADI incorporates the rate of dispersion within the mixing layer. The higher the ADI value, the better the dispersion but the more unstable the atmosphere. A doubling of the ADI results in a doubling of the amount of smoke the airshed can hold. Many burn prescriptions have daytime dispersion limits within the 41-60 range. Some prescribed burns may be acceptable with an ADI value as low as 30 but only when the burn unit size and proximity of Smoke Sensitive Areas' minimize smoke management concerns. As the ADI increases, so do fire control problems. Prudent prescribed burners double check fire behavior calculations and indices as the ADI approaches 70 due to increasing probability of resource damage and/or fire escape. Prescriptions with values outside the preferred range should be verified by past results and/or other experienced burners. It is important to note that what constitutes a good dispersion at night is fundamentally different than during the day as the atmosphere tends to be much more stable at night.

References

Baldwin, C. (2013). *Prescribed Burning Notebook. K-State Research and Extension.*

Barlow, B., Maggard, A., Armstrong, J. and Kush, J. (2022). Prescribed Fire: Weather. Alabama Cooperative Extension System Peer Reviewed publication, FOR-2070.

Fire Behavior Subcommittee, of the Fire Environment Committee. (2020). The Fire Behavior Field Reference Guide, PMS 437. National Wildfire Coordinating Group, retrieved on December 21, 2022, from: **https://www.nwcg.gov/publications/pms437**

Fire Weather Subcommittee of the Fire Environment Committee. (2021). Fire Weather, PMS 425-1. National Wildfire Coordinating Group, retrieved on December 21, 2022, from **https://www.nwcg.gov/publications/pms425-1**

Florida Department of Agriculture and Consumer Services. (2014, September 1). Chapter 6: Weather. FDACS. Retrieved January 10, 2022, from **https://www.fdacs.gov/content/download/39691/file/pft_chapter_06_weather.pdf**

Georgia Forestry Commission. (n.d.). Fire Weather Forecast Interpretation. Interpretation of Weather Forecast. Retrieved January 7, 2022, from **http://weather.gfc.state.ga.us/Info/WXexp.aspx**

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

Weir, J. R. (2009). Conducting prescribed fires: a comprehensive manual. Texas A&M University Press.

WEATHER NOTES

WEATHER NOTES

SMOKE MANAGEMENT

Image credit: Holly Campbell

Table of Contents

Introduction

Where there is fire, there will inevitably be smoke. Steps needed to manage smoke vary based on the size and complexity of the burn. For many prescribed burners, their burns are low complexity and smaller in size. In this case, smoke management may be a simple matter of checking out the area of the burn and paying attention to any sites that could be affected by the smoke, then choosing another direction. For example, if a school is located a couple of miles south of where you will burn, then you would not want to burn when there is a northerly wind (blowing south). In its simplest form, managing smoke is about taking common sense precautions. While this chapter includes recommendations that focus on managing smoke specifically, many of these actions are likely to already be incorporated into your prescribed burn plan.

Smoke is a known air pollutant that can impact human and animal health, lessen road visibility, and be a nuisance. Prescribed fires are planned and conducted in conditions selected to achieve specific results, and to minimize potential negative impacts. Potential impacts from the smoke depend on the burn site and what is located nearby.

Managing smoke during prescribed fires involves considering possible smoke impacts and ways to avoid them while planning the burn, during the burn, and after the burn is complete. Smoke management begins by understanding how different factors such as weather conditions, topography, fuel type, and management influence smoke behavior. This chapter highlights the factors that impact smoke production, dispersion, and direction as well as recommended basic smoke management practices. In addition, this chapter includes information about tools for estimating burn complexity and screening for smoke, as well as strategies for reducing smoke impacts.

Content and diagrams for this section were adapted from the Smoke Management Guidebook for Prescribed Burning in the Southern Region

Find the Smoke Management Guidebook Online: https://www.warnell.uga.edu/

On the Warnell School of Forestry and Natural Resources homepage, select the "Outreach" tab. On the top left side of the page select "Publications" and then scroll until you find the Smoke Management Guidebook.

Goals of Smoke Management:

1. Minimize the amount of smoke produced.
2. Move smoke away from sensitive areas or populations
3. Reduce the concentration of smoke through dispersal.
4. Handle smoke issues as they occur.

Prescribed burners have a responsibility to protect their communities' health and safety, and to manage the smoke from their burn. Smoke management is possible if the burn is carefully planned and executed. Ongoing training, planning, preparation, and practice by prescribed burners can help to support the continued use of this valuable land management tool. Your state may have specific statewide smoke management guidelines, so check with your state forestry agency to discover any recommendations specific to your state and situation.

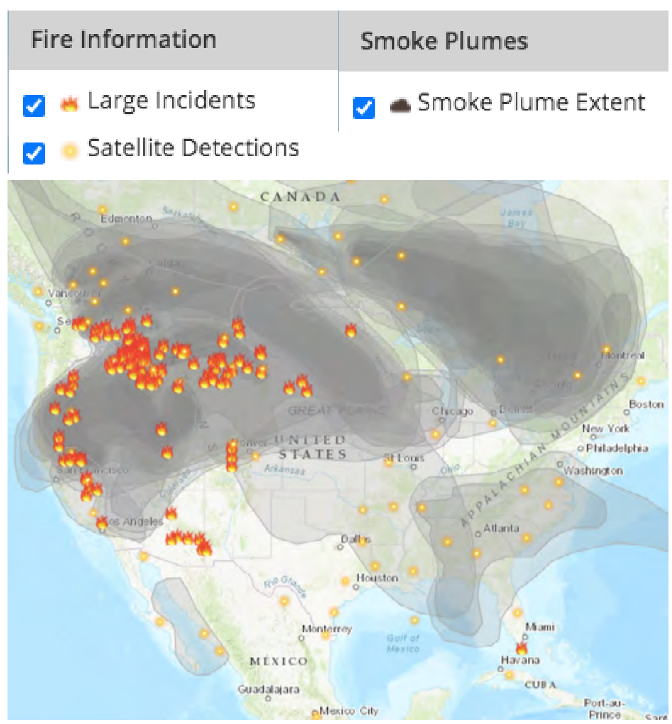


Figure 6.1. Modeled smoke plumes from summer wildland fires across the U.S. as seen on the AirNow website on July 27, 2021 (AirNow, n.d.).

Smoke Components & Stages of Combustion

Smoke forms when a fuel is burned (combusted) and is composed of the tiny particles, water vapor, and trace gases that are suspended in the air, visible to the naked eye. As a smoke plume travels away from the site, it may become harder to see, but will still carry tiny particles of soot (particulate matter) and gases, (such as ozone precursors). Smoke plumes from large fires or multiple burns in the same geographic region can travel for hundreds of miles before completely dispersing (Figure 6.1).

There are different types of smoke products (emissions) and amounts of smoke that are released at each stage of combustion (Figure 6.2). Smoke emissions include water vapor, particulate matter (PM), hot air, trace gases, carbon monoxide (CO) and carbon dioxide (CO2). Below are the four stages of combustion:

1. **Pre-ignition stage**: Fuel particles absorb heat, start to release water vapor, and the pyrolysis process begins.
2. **Flaming stage**: Active flames can be seen as combustible gases, and vapors that were created during pre-ignition begin to mix with oxygen.
3. **Smoldering stage**: Flames start to disappear as the fire temperature drops because there are fewer combustible gases and vapors produced.
4. **Glowing stage**: Materials at the surface glow from access to oxygen. Most burnable materials and volatile gases have already been combusted; this stage will continue until all available fuel has been burned.

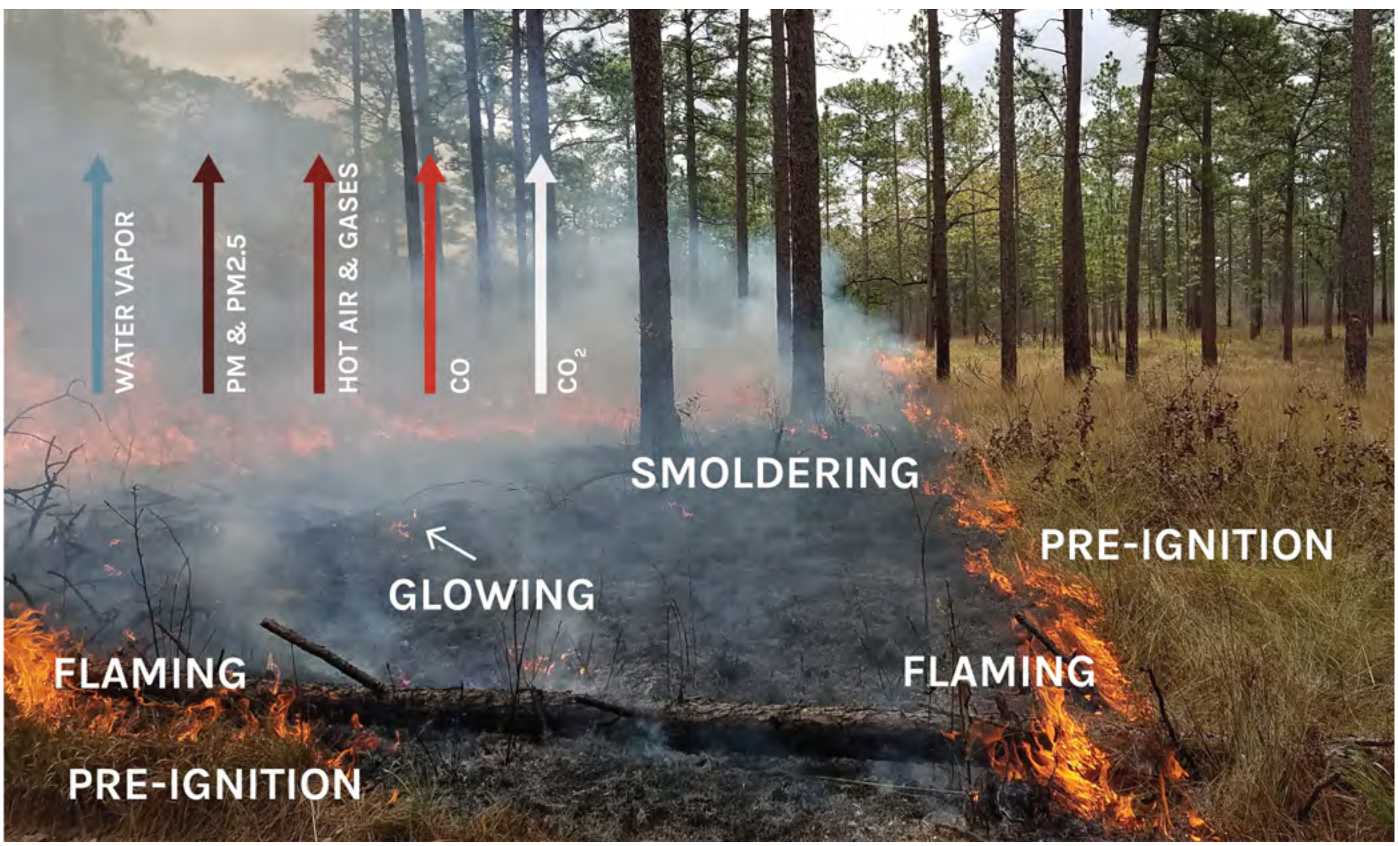


Figure 6.2. This image of a prescribed fire provides a visual representation of the four phases of combustion (pre-ignition, flaming, smoldering, glowing) and their emissions. *Credit: Smoke Management Guidebook for Prescribed Burning in the Southern Region (Campbell et. al., 2020)*

Smoke emissions at some stages of combustion can be more harmful to human health than at other stages. However, the types of fuel also influence how the fire will burn and the emissions produced. Overall, the greatest amounts of smoke are produced during the smoldering stage, which can often persist for hours or days after the flames are extinguished. This is especially true when the duff layer (partly decomposed material on the forest floor) burns during dry conditions.

Factors Affecting Smoke Production & Dispersal

There are many different factors that affect how much smoke is produced, how well it is dispersed, and where it travels (Figure 6.4). These factors can be categorized as burn site conditions (fuel characteristics, location, and topography), weather and atmospheric conditions, and finally burn timing and technique (how and when you burn). Burn site conditions are relatively constant, as location and topography do not change, while some fuel characteristics (type and load) do not change or change very slowly. Weather and atmospheric conditions, on the other hand, are always shifting. Fuel moisture content, which is impacted by weather, strongly affects smoke production too. Lastly, there are many options for when (timing) and how (technique) you burn that can affect smoke production and dispersal. Descriptions of the factors that affect smoke production and dispersal are below.

BURN SITE CONDITIONS

Fuel characteristics, geographic location, and topography at the burn site will strongly impact smoke production and dispersal. The burn site conditions are also known variables that do not change (with the exception of changes in fuel load and moisture content). The location of a burn and the topography at the burn site are the same from planning to implementation, and will inform how a plan develops and considerations for smoke management.

Fuel characteristics (type, load & moisture content) – The type of fuel, amount of fuel available to burn (load), and its moisture content will determine the amount of fuel that can be consumed in a fire and is directly related to the amount of smoke that can be produced. Fuel load will vary depending on the time since the last burn and the type of fuels. Smoke production is also influenced by the moisture content and size of the fuels. For example, dry grass will burn quickly, and produce a considerable amount of smoke during its active combustion phase, but will not smolder. Conversely, a stand of pine trees with a thick layer of surface fuels (litter) and a thick duff layer may produce more smoke if the duff layer starts to burn. Dry fuels will also produce less smoke, while wetter fuels, if they do burn, are likely to create considerable amounts of smoke.

Geographic Location – Geographical areas across the South contain differing climates, vegetation, and soils. These factors will play a role in the creation and dispersal of smoke. There may also be legal and social factors to consider based on the location of your burn. Burns located near an urban or suburban area may need greater consideration, whereas in a rural area where burning may be more commonplace, there will be greater community acceptance of the practice.

Topography – Topography influences where smoke moves. In areas that are flat, wind and atmospheric stability are the drivers of smoke dispersal and direction. In hilly or mountainous areas, however, smoke disperses differently. For example, smoke tends to move from higher points on the landscape, such as ridges, and collect in lower points on the landscape, such as valleys, drainages, and roadways. Winds are also affected by slopes and time of day, which will also factor into smoke dispersal.

Figure 6.3. Factors that affect smoke. *Credit: Smoke Management Guidebook for Prescribed Burning in the Southern Region (Campbell et. al., 2020)*

WEATHER AND ATMOSPHERIC CONDITIONS

Good smoke dispersion, or the scattering and dilution of smoke, is essential in a prescribed burn. Smoke is 90% carbon dioxide and water vapor; the remaining 10% is composed of particles and trace gases. Since it is in a gaseous state, it can move vertically and horizontally. When smoke enters the atmosphere, its concentration in any one place or at a specific time are dependent on the weather factors and atmospheric conditions that transport and disperse it. Depending on the stage of combustion, weather and atmospheric conditions may have a greater or lesser effect on smoke. See chapter 5, Weather, for more details on weather considerations. Several important weather factors that influence smoke behavior and are used to develop smoke management plans for most southern U.S. states are detailed below (and depicted in Figures 6.4 and 6.5).

Atmospheric Stability and Mixing Height
The stability of the atmosphere (a measure of how a parcel of air moves when pushed upwards) and the mixing height (height at which different parcels of air or smoke mix together due to convection) are highly correlated. Atmospheric conditions are more likely to be stable in the morning, evening, and through the night. When the atmosphere is more stable, then the mixing height is typically lower, which keeps smoke close to the ground surface and takes longer to disperse. When the atmosphere is more unstable (which is more common in the afternoon), there is typically a higher mixing height.

High mixing heights allow smoke to rise higher in the atmosphere to be vigorously diluted and dispersed by transport winds. Mixing heights are typically lowest in the morning and evening, and highest during the middle of the day. However, this varies due to weather and other factors, such as coastal influences on temperature, season, and high and low-pressure systems. There are a number of

Atmospheric stability: The stability of the atmosphere indicates how rapidly air is vertically mixed

Mixing Height: height at which smoke will be diluted and dispersed

Inversions: Inversions are a stable air mass or atmospheric layer that increase in air temperature as it moves higher, and are difficult for smoke to penetrate.

Transport winds are an average of the horizontal wind speed and direction from the Earth's surface to the mixing height.

Surface winds are measured at a height of 30 feet above the Earth's surface.

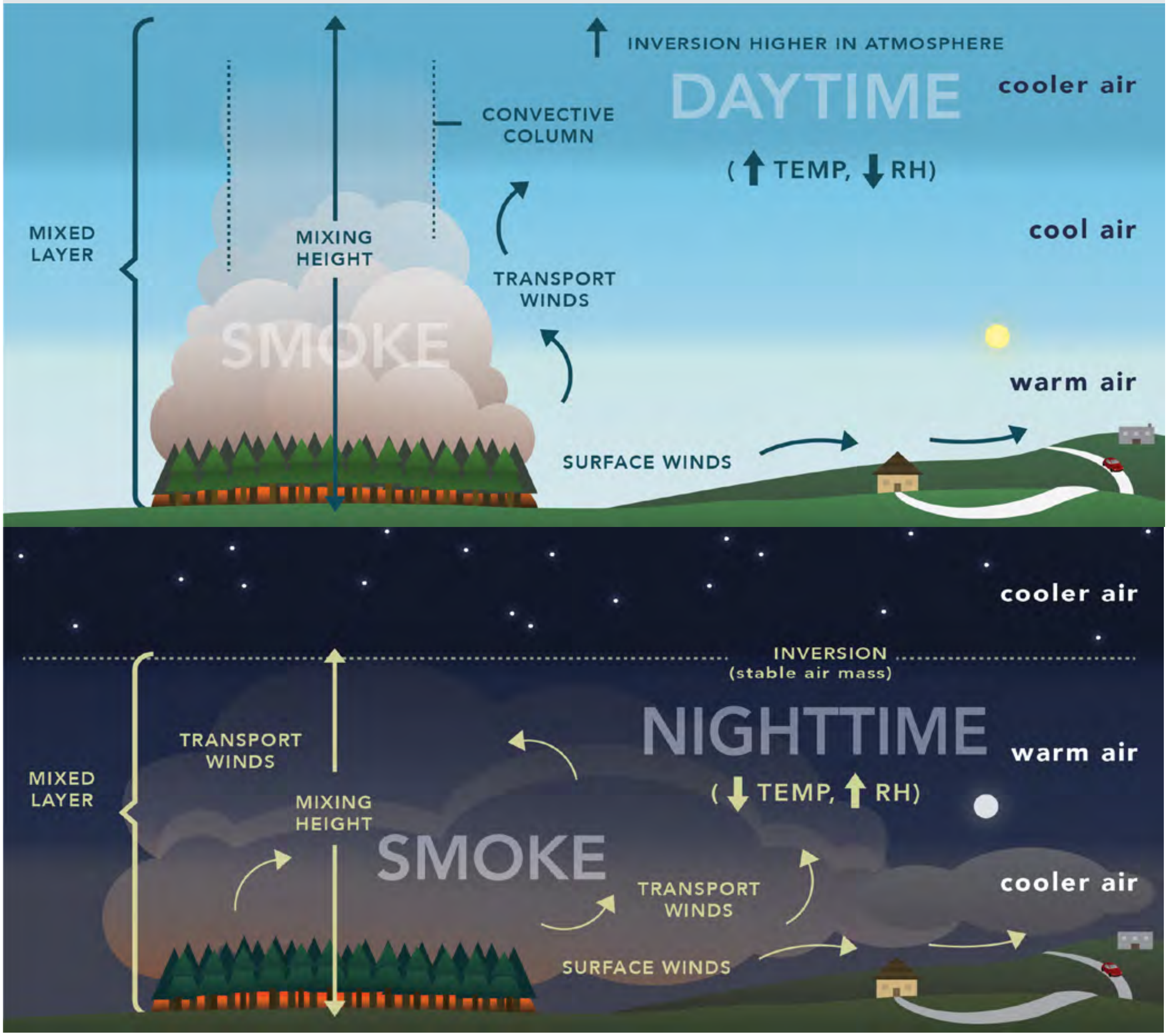


Figure 6.4 & 6.5. Atmospheric and weather conditions and how they may influence smoke behavior during the day and night. *Credit: Laura Costa, Southern Regional Extension Forestry (Campbell, et al., 2020.)*

indices that can be found on some general weather or fire weather forecasts that assign values to atmospheric stability and mixing height, such as the Atmospheric Dispersion Index (ADI). More details on these indices can be found in Chapter 5, Weather (table 5.8).

Wind – The direction and strength of the wind affect the movement and dispersion of smoke. Smoke is easier to manage, and more predictable when wind speed and direction are consistent. Fire weather forecasts from the National Weather Service provide expected wind conditions throughout the day.

Temperature Inversions – Inversions are an atmospheric layer where temperature increases with height, as opposed to typical atmospheric layers which become cooler as they rise. Inversions are a stable air mass that can be difficult for smoke to penetrate. During a temperature inversion, cooler air is closer to the ground and the warmer air is above. Since warm air rises, the air and smoke emissions, which are cooler, are trapped on the ground surface. This means that the smoke will linger and not disperse. Typically, temperature inversions occur in the evening and continue through the night and early parts of the following morning.

Relative Humidity (RH) – Drier fuels produce less smoke, and RH strongly influences moisture content in smaller fuels. While fine fuels will dry out quickly when there is a low RH, larger fuels are only affected by changes over longer periods of time. If RH values are high, then fuels may be too moist to efficiently burn, leading to higher smoke production (or they may not burn at all). Burns are often planned for times when the RH is low enough to dry out fine fuels (i.e., pine needles, grass), but is also high enough to prevent larger fuels, duff layers, or organic soils from burning. Duff is an important fuel type to consider in the South, and how (or if) it burns is connected to RH values. If conditions are dry enough that the duff layer burns, extra smoke will be produced. Fog can also form at higher RH values. Smoke and fog can also combine to form superfog in some instances. Superfog is especially dangerous as it reduces visibility even more than fog alone.

BURN TIMING & FIRING TECHNIQUES

When conducting a prescribed fire, there are many management approaches that affect smoke production. Some options must be determined when creating a prescribed burn plan, such as the size of the burn (or burn units) and the acceptable range of weather values. Other decisions are made the day of (and during) the burn, such as the burn start time and duration. The pattern of ignition (firing technique), duration of the burn, and steps taken when the fire is complete, are part of how the fire burns and ends. All of these decisions contribute to smoke management. Descriptions of these factors and how they affect smoke are below.

Size – Total acreage plays a role, but particularly the number of acres actively engaged in the fire phase. While different fuels and firing techniques may change how the area burns and increase its efficiency, more smoke is still produced from burning a larger area.

Time of year – In the South, burns are commonly conducted winter to early spring (dormant season) and late spring to summer (growing season). There are fewer daylight hours to burn during the winter, which may change the timing of the burn. During growing season burns, patches of new plant growth or "green" will not ignite, which can result in patchier burns.

Time of day – When you burn, can affect how much smoke is produced by your prescribed fire and how it disperses. Day and night have very different patterns of weather. In the morning, the temperature is lower, and the RH is higher, which may make it harder to start a burn. Temperature typically peaks during the afternoon and RH drops to its lowest levels during that same period. As the sun goes down, transport winds and mixing heights tend to decrease too. Daytime burns are typically conducted starting sometime from the later morning hours to completion by early evening time. Nighttime burns vary more for timing.

Firing technique – The approach that is used to light a prescribed fire (firing technique or ignition plan) can affect smoke production (Table 6.1). Firing technique impacts the rate that a fire's spread changes. For example, a backing fire is lit so that it travels against the wind, while a heading fire will move faster since it moves in the direction of the wind. For an explanation of different firing techniques, see chapter 8, Fire Behavior (Page 179).

Burn duration – Smoke production can be related to the size and duration of the burn, as the longer a prescribed fire lasts, the greater the smoke production will be. However, fuel type and moisture will more strongly impact smoke production than only burn size and duration. For example, a large grassy field will burn for a shorter period of time than a forested area that may be only one-third the size. In addition, grass will likely burn fast and hot, and will produce large amounts of smoke quickly, but it may be less likely to smolder. Fuel moisture will also affect how long the burn takes, as damp fuels will need to dry out before they can burn, meaning that the fire's energy will go towards drying first and then burning.

Mop-up – After a burn, logs, stumps, brush piles, duff, or snags (standing dead trees) that were ignited may smolder, which can continue to produce residual smoke. Mop-up is the process of walking the burned area (the black) and extinguishing any flames or smoldering fuels after the burn. Smoldering can continue for multiple days, if not addressed. Taking the time to mop-up, reduces the chances of smoldering and is critical for reducing the chances of smoke-related problems.

Table 6.1. Various types of prescribed burns and their effect on smoke.

Fire Type	Effect on smoke
Backing	Consumes more fuel in the flaming stage and produces less smoke over the course of the burn; however, backing fires move slowly and may limit how much acreage can be burned based on the burn plan.
Heading and Point-source	Often burns with a faster rate of spread than backing fires. A fire that moves very quickly, will have shorter residence time and result in less fuel overall burning, which could lower smoke production. However, if it burns very intensely, it could burn more fuel overall, which could increase smoke production.
Center and Circular (ring)	Convection from the interior fire pulls the flames of the perimeter fire towards the center of the burn unit, often creating a fast rate of spread and strong vertical lift of smoke.
Pile and Windrows	If not carefully planned, can result in significant and long-duration smoke production (especially if heavy fuels are mixed with soil, the pile is not stacked well, or woody debris is not sufficiently dry).

Smoke Impacts

AIR QUALITY

Air quality changes constantly based on local weather conditions, due to climatic conditions thousands of miles away (such as volcanic emissions), in addition to societal factors such as the number of cars on the road at a given time. The quality of the air (or concentration of pollutants) on any given day is being monitored by local, state and/or federal agencies. There are six major pollutants that the US Environmental Protection Agency (EPA) has established acceptable concentration limits for, due to their negative health effects and risks to the environment. These pollutants include particulate matter (PM), ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead. Smoke emissions from fires contain PM, carbon monoxide, and other trace gases, though the greatest concern is PM. PM, which is microscopic amounts of solid matter such as ash or dust, can result from incomplete burning of organic matter. The small size of PM allows it to be trapped in the nose or throat and then inhaled into the lungs where it can cause inflammation. It can also pass through the lungs and into the bloodstream. Tightened air quality standards in 1997, 2006, and 2013, along with implementation of a national monitoring program, have led to a significant reduction in PM concentration in the air. Over the past twenty years, the concentration of PM in the South has nearly been cut in half through reduced emissions from industrial and point sources. With the overall reduction in PM from other sources, prescribed fires now make up a larger proportion of PM emmissions. Therefore, smoke management during prescribed fires is especially important to reduce impacts to the public.

Image 6.1. *Image courtesy of Yuna Chitea.*

In urban and suburban areas that are highly populated, there are special challenges from smoke. If the burn is close to a large urban area, then smoke may not disperse before it reaches that area. Cities and other urban areas downwind of burn units often experience low-hanging residual smoke due to the urban heat island effect. Urban areas may already have impaired air quality. If an additional pollutant load from the prescribed fire's smoke is added, then air quality may approach or exceed regulatory levels for the reporting period.

HEALTH

Smoke can impact the health and safety of people and animals. Smoke has the greatest impact on individuals who are vulnerable, those who reside in locations downwind of the burn, prescribed burners, and firefighters. While exposure to smoke is not good for anyone's health, there are populations whom are more vulnerable to negative impacts from smoke such as infants, children, older adults, pregnant women (and their unborn children), people of low socioeconomic status, and individuals with impaired health. For this reason, it is important to limit the amount of smoke produced and/or prevent smoke from reaching areas where more vulnerable publications can be found (smoke sensitive areas). These Smoke Sensitive Areas (SSAs) include schools, daycares, nursing homes, hospitals, and agricultural operations with animals present. In addition to the vulnerable populations listed above, outdoor workers, and individuals outdoors are also more at risk.

SAFETY ISSUES

The presence of smoke can result in a variety of safety issues. Smoke that moves through and/or collects in roadways, airports or railways is a major public safety issue. Smoke can move into these areas quickly, which does not provide much time for motorists to respond or to be notified of danger. Reduced or zero visibility on roadways from smoke can cause fatalities and injuries, and carries a higher risk of liability and potential legal problems. Airports may postpone or even cancel flights if smoke is a safety concern. Fog can create hazardous conditions on the road by itself; however, smoke and fog can combine to form superfog, an extremely dangerous, dense mixture. "White-out" conditions can occur due to superfog during the day or night, further limiting visibility. Superfog has been responsible for massive pileups and related fatalities.

Basic Smoke Management Practices

One of the first steps to properly managing smoke is learning and understanding Basic Smoke Management Practices (BSMPs) (Table 6.2). Using BSMPs helps burners achieve three goals: (1) reducing the amount of smoke produced, (2) transporting smoke away from sensitive populations and other target areas, and (3) dispersing smoke to reduce its concentration. Most federal, state, and local agencies using prescribed fire must follow BSMPs, but private landowners are not required by all states to implement them. Even if they are not required, following BSMPs is highly recommended for safety and liability reasons. Many of the BSMP are likely to be part of your prescribed fire plan already, as they are best practice not just for smoke management, but for prescribed fire overall. For example, they include practices such as identifying smoke sensitive areas, conducting a test fire immediately before a burn, and identifying neighbors that you will be burning.

In addition to following these BSMPs, some states require that landowners use state-specific Smoke Management Plans (SMPs). Your state forestry agency can provide more information on BSMPs and SMPs relevant to your state. Be aware of possible additional rules governing prescribed burns near urban and suburban areas. Some states may have burn bans in counties surrounding major metropolitan areas, or on days when air quality is poor. Prior to burning, check the air quality index forecast for your area to ensure that there are no "Air Quality Alerts." Alerts are created when there are high levels of ozone being caused by other emissions sources in the area. These conditions typically only occur near large metropolitan areas such as Atlanta and during the hot summer months.

Some practices in the BSMP list may be more complicated and if you are new to burning, you may need assistance to determine if they are necessary for you and how to implement them. More information about how BSMPs can be implemented during the prescribed burning process can be found in the Smoke Management Guidebook.

Estimating Potential Smoke Impacts

Smoke management starts when planning a prescription for a burn, as potential smoke impacts should be evaluated. The first two steps of the BSMPs relate to estimating smoke impacts, which may only take a few steps and involve a simple smoke screening process for a less complex burn. For a more complex burn, there may be more data to input and additional tools to use that account for the complexity. Most prescribed burn plans include an important planning stage called smoke screening, which involves mapping the potential direction of smoke based on several weather variables. If

Table 6.2. A description of the twelve Basic Smoke Management Practices, and when they should be applied during the prescribed burn process. *Credit: Adapted from Campbell, H., et al. (2020).* Smoke Management Guidebook for Prescribed Burning in the Southern Region.

Basic Smoke Management Practice (BSMP)	When should the BSMP be applied?
1. Identify, map, and avoid impacting smoke sensitive areas	Before / During
2. Match appropriate smoke impact screening tools to burn complexity	Before
3. Use a test fire to verify expected smoke dispersion	During
4. Only burn when smoke dispersion conditions are favorable	During
5. Monitor changing weather conditions and respond to unintended smoke impacts	Before / During / After
6. Understand and follow local, state, federal, and tribal prescribed fire laws and regulations	Before / During / After
7. Notify appropriate parties (neighbors, public agencies, authorities) of intent to burn	Before
8. When feasible, use ignition patterns and methods which minimize smoke production	During
9. Minimize impacts from smoldering smoke	During / After
10. In high smoke risk areas, explore alternative methods to burning	Before
11. Enhance smoke management skills through training and experience	Before / During / After
12. Be aware of other burning activity and sources of pollution in your area	Before / During

Check Air Quality Index (AQI) Forecast Before Burning: https://airnow.gov

Avoid burning during Air Quality Alerts

smoke screening shows that a Smoke Sensitive Area (SSA) would be impacted by the smoke from a proposed fire, then a different wind direction should be chosen, or the burn plan should be altered in other ways that will not impact sensitive populations. Though it is imperative to protect SSAs, all populations should be considered in smoke management plans.

Evaluating potential smoke from nighttime burns is a much different procedure than daytime burns. Burns that continue or start in the period from around one hour before sunset through the night until one hour after sunrise are nighttime burns. There are many tools available for assessing burn complexity, smoke screening and more advanced smoke modeling for daytime and nighttime, which can be found in table 6.3 and are described in this section.

Evaluating Daytime Smoke

Burn size and duration, fuel load, topography, air quality, atmospheric dispersion, and proximity to urban areas are all elements that increase the complexity of a prescribed burn. A prescribed fire's complexity will vary depending on the number of these elements to consider, though some factors can be assessed in the planning phase, while others must be assessed on the day of the burn. More experienced burners will be able to assess these factors themselves, but less experienced burners may need assistance.

There are three levels of daytime burn complexity: low, moderate, and high. Low complexity burns produce the least amount of smoke, so simpler techniques can be used to estimate the plume pathway. High complexity burns will require more detailed smoke modeling due to the larger quantities of smoke expected to be produced. High complexity prescribed fires will also require more coordination with air quality and state forestry agencies, as well as the general public. Low complexity burns do not require that level of planning.

Instructions for estimating complexity are below (Table 6.3), though it may also be wise to consult with your state forestry agency or a local Prescribed Burn Association for help determining the complexity of your planned burn. These steps and the worksheet are sourced from the **Introduction to Prescribed Fire in Southern Ecosystems**. The worksheet uses many different estimates based on fuel type, load, estimated moisture content and more.
Smoke screening and/or modeling will need to be

Image 6.2.

Table 6.3. Daytime Smoke Management Complexity Worksheet (Source: USDA Forest Service Introduction to Prescribed Fire in Southern Ecosystems)

Process Steps	Value
1. Estimate the number of acres per hour that are actively burning	
A. Enter the size of the burn, in acres	
B. Enter how long you think the burn will be, in hours	
C. Divide value A by value B	
Select score based on C: <150 acres per hr = 0 150-300 acres/hr = 1 >300 acres/hr = 2	
2. Estimate fuel load consumed	
Score based on estimated tons per acre: <4 tons per acre = 0 4-8 tons per acre = 1 >8 tons per acre = 2	
3. Topography	
0 = flat terrain with no significant topography within 30 miles downwind of the burn 1 = flat terrain with significant topography within 30 miles downwind of the burn 2 = significant topography in burn unit	
4. Air Quality (based on Air Quality Index from https://airnow.org)	
Good dispersion = 0 Moderate dispersion = 2 Poor dispersion = do not burn!	
5. Atmospheric Dispersion (determine based on Atmospheric dispersion index)	
Good dispersion = 0 Moderate dispersion = 2 Poor dispersion = do not burn!	
6. Burn site location in relation to urban or suburban areas (wildland urban interface)	
No urban areas within 60 miles downwind of burn site = 0 Burn unit is not in an urban area, but urban areas are within 60 miles = 1 Burn unit is in an urban/suburban area = no score (special considerations)	
Total Score	

Table 6.4. Daytime Burn Complexity and Recommended Smoke Modeling tools

Daytime Smoke Management Complexity Worksheet Scores	Burn Complexity
0-2 (with no single factor receiving a score of 2)	**Low**
3-6 (no more than two factors receiving a score of 2)	**Moderate**
7 + (or 3 + factors receiving a score of 2)	**High**

done, regardless of the complexity of the burn. There are a number of methods and tools for smoke screening and modeling, which are listed below in relation to daytime burn complexity (table 6.3) and are described in greater detail later in this chapter. In addition, Table 6.4 summarizes each daytime smoke modeling tool.

Evaluating Nighttime Smoke

An evaluation of nighttime smoke dispersion conditions should take place prior to ignition. Dispersion conditions will be critical to deciding if firing operations should stop for the day or continue during the night. Weather patterns start to change to nighttime conditions about one hour after sunset and do not return to daytime conditions until one hour after sunrise. At night, winds and RH change, and topography has a larger impact on smoke. Nighttime smoke dispersion is also different as inversions are more likely to be present. Winds are often weaker at night than during the day and combined with an inversion, the smoke may linger on the ground for a long time. Any residual smoke from an earlier burn will flow downward towards drainages, or depressions in the landscape, or even cover flat areas such as fields. Relative humidity is another complicating factor for burning at night. If RH is very high or increases significantly throughout the night, fog conditions are more likely to form, due to a nighttime inversion and lighter winds. Smoke from burns can combine with the fog to form superfog as well.

Tools for evaluating smoke impacts for nighttime burns differ from daytime burns and include the Low Visibility Occurrence Risk Index (LVORI), hand-drawn maps (with different instructions than the simple smoke-screening tool), and the PB-Piedmont tool. The LVORI can be consulted to assess the potential for accidents, while the PB-Piedmont is used to model smoke behavior for nighttime burns. These tools are described more further on.

Introduction to Prescribed Fire in Southern Ecosystems Smoke Complexity Worksheet

You can download this on the USDA website (**https://www.fs.usda.gov/treesearch/**) under publications. Just search the title and then download the file.

Smoke and flames across the forest floor on a prescribed burn. *Image courtesy of Kevin Robertson*

Table 6.5. Tools for estimating potential smoke impacts in the daytime

Smoke Modeling Tool	Description	Inputs
DAYTIME		
Simple smoke screening tool (online)	■ Identifies smoke sensitive areas ■ Simple screening tool to help identify smoke sensitive areas that may be impacted	■ Fuel type (4 categories) ■ Burn size ■ Ignition method ■ Direction of the wind (assumed constant)
Simple smoke screening (instructions for drawing by hand)	■ Identifies smoke sensitive areas ■ Draw lines on a map to identify possible SSA impacts (instructions are below)	
VSmoke (easy to use web-based version)	■ Identifies smoke-sensitive areas ■ Projects expected downwind concentrations of PM relative to Air Quality Index and potential health impacts ■ Overlays a smoke plume on a satellite image or map to show expected PM concentrations at different distances from the burn ■ Works best in flat or rolling terrain	■ Location (lat/long or select point on map) ■ Fuel type (12 classes; it estimates fuel load for you) ■ Fuel moisture (wet, damp, dry, very dry) ■ Burn unit size ■ Ignition method (backing/spot or head/aerial) ■ From weather forecasts: wind direction (uniform), wind speed (constant), mixing height, atmospheric stability (extremely, moderately, or slightly unstable, or neutral)

BlueSky Playground (3.5) info.airfire.org	■ A modeling framework that integrates other tools and predicts cumulative smoke impacts. Includes tools for estimating:
	  ■ Fuel loading
	  ■ Fuel consumption
	  ■ Emissions calculations
	  ■ Trajectories
	  ■ Dispersion
		■ Location (lat/long or select point on map)
		■ Burn size (acres)
		■ Time zone (EDT, CDT, etc.)
		■ Fuels (1,200 choices which include fuel type plus management information)
		■ Fuel moisture (very wet to very dry)
		■ Consumption (you can select defaults)
		■ Number of days

Table 6.6. Tools for estimating potential smoke impacts in the nighttime.

Smoke Modeling Tool	Description	Inputs
NIGHTTIME		
Low Visibility Occurrence Risk Index (LVORI)	■ Indicates the potential that accidents may occur due to reduced visibility ■ Provides an estimate as a score from 1 (low) to 10 (high) of the likelihood that smoke or fog may contribute to an accident	■ Atmospheric Dispersion Index ■ RH

Basic Screening Process for nighttime smoke management
Instructions found in the Introduction to Prescribed Fire in Southern Ecosystems
	■ Identify smoke-sensitive features
	■ Provides an idea of where smoke is likely to go by identifying topographic features and drawing a range on a map
		■ Surface wind speed
		■ Screening distance based on 3 land types:
		  ■ Coastal plain (10 miles)
		  ■ Piedmont (15)
		  ■ Mountains (30)

Planned Burn (PB) - Piedmont	■ Models smoke movement in the Piedmont region during nighttime and early morning hours. ■ Predicts smoke movement patterns in the Piedmont region at nighttime and early morning, which helps to identify drainage areas that may be near Smoke Sensitive Areas	■ Location (lat/long or point on map) ■ Fire start time ■ Estimated burn duration (model is built for burn events that start at least 4 hours prior to sunset and that continue for a minimum of 6 hours after sunset) ■ Size of burn (acres) ■ Sample radius (distance from ignition source to edge of modeled area; default is 10 miles) ■ Grid spacing (set in 30-meter increments that connect to elevation) ■ Fuel type (3 types)

Smoke Screening & Modeling Tools

There are many different tools that can be used to model potential smoke impacts for both daytime and nighttime burns. Details about each tool and instructions for some are listed below. This list of tools are not comprehensive and there are additional tools that can be used (and may be prefered in your area).

SIMPLE SMOKE SCREENING TOOL (LOW COMPLEXITY BURNS)

If the daytime burn is determined to be low complexity, prescribed burners have the option to either hand-draw or use a web-based tool to complete their smoke screening. Below are instructions on how to use each. The Simple Smoke Screening Tool allows burners to make quick smoke preditions, essentially making a digital representation of the hand-drawn version. The directions below provide step-by-step instructions on how to use the tool.

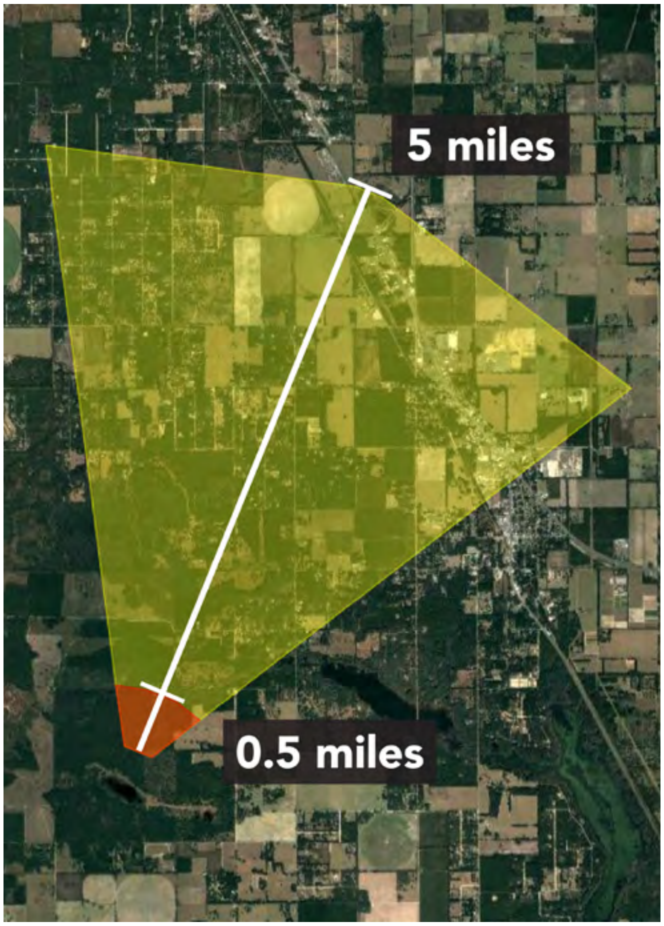


Figure 6.6. Output generated from the Simple Smoke Screening Tool using a satellite map. The red zone is used to identify critical smoke-sensitive areas. This is the most probable smoke impact area. The yellow zone shows an area of less severe impact.

ONLINE SIMPLE SMOKE SCREENING TOOL

1. Go to the online site: **http://fireweather.fdacs.gov/Simple-Smoke/**
2. Obtain input variables from the weather forecast and burn plan. (**NOTE: Make sure to input weather data specific to the time of the day of the burn)**. These include:
   - **a.** Latitude & Longitude
   - **b.** Burn acreage
   - **c.** Fuels
   - **d.** Ignition method
   - **e.** Transport wind direction & speed
3. Click on "**Update Map**"
4. Select **Map** or **Satellite view**
5. Examine the map to identify smoke sensitive targets, especially within critical smoke-sensitive areas (**identified in the red zone on the map**). This is the most probable smoke impact area. **If there are smoke-sensitive targets within this critical zone, burning is not recommended under the current prescription, additional screening must be used (using a different wind direction and speed), and a different burn day must be selected.**
6. Record all observations for planning and documentation purposes. This could include a screenshot, or saving the data for display in Google Earth by saving the KML output.
7. Add any necessary information from the output into your burn plan.

HAND-DRAWN INSTRUCTIONS

1. Locate and draw burn unit on a map.
2. Determine the distance(s) at which smoke could affect the surrounding area based on the size of your burn and the fuel load, then draw that distance as a circle on the map using a compass or protractor. Multiple rings could be drawn based on the predicted amount of smoke produced. Typically, rings could be ½ mile, 1 mile, 5 miles, 10 miles, etc.
3. Label the area on the map and determine if anything in the critical area is smoke sensitive.
4. Draw an additional circle for the smoke sensitive distance to ensure there is nothing that would be smoke sensitive.
5. Select a wind direction that would avoid anything in the critical smoke sensitive area.
6. Use smoke management considerations if something is in the smoke sensitive area or use a different wind direction.
7. Smoke plume lines should pass on the outside edges of the burn unit.

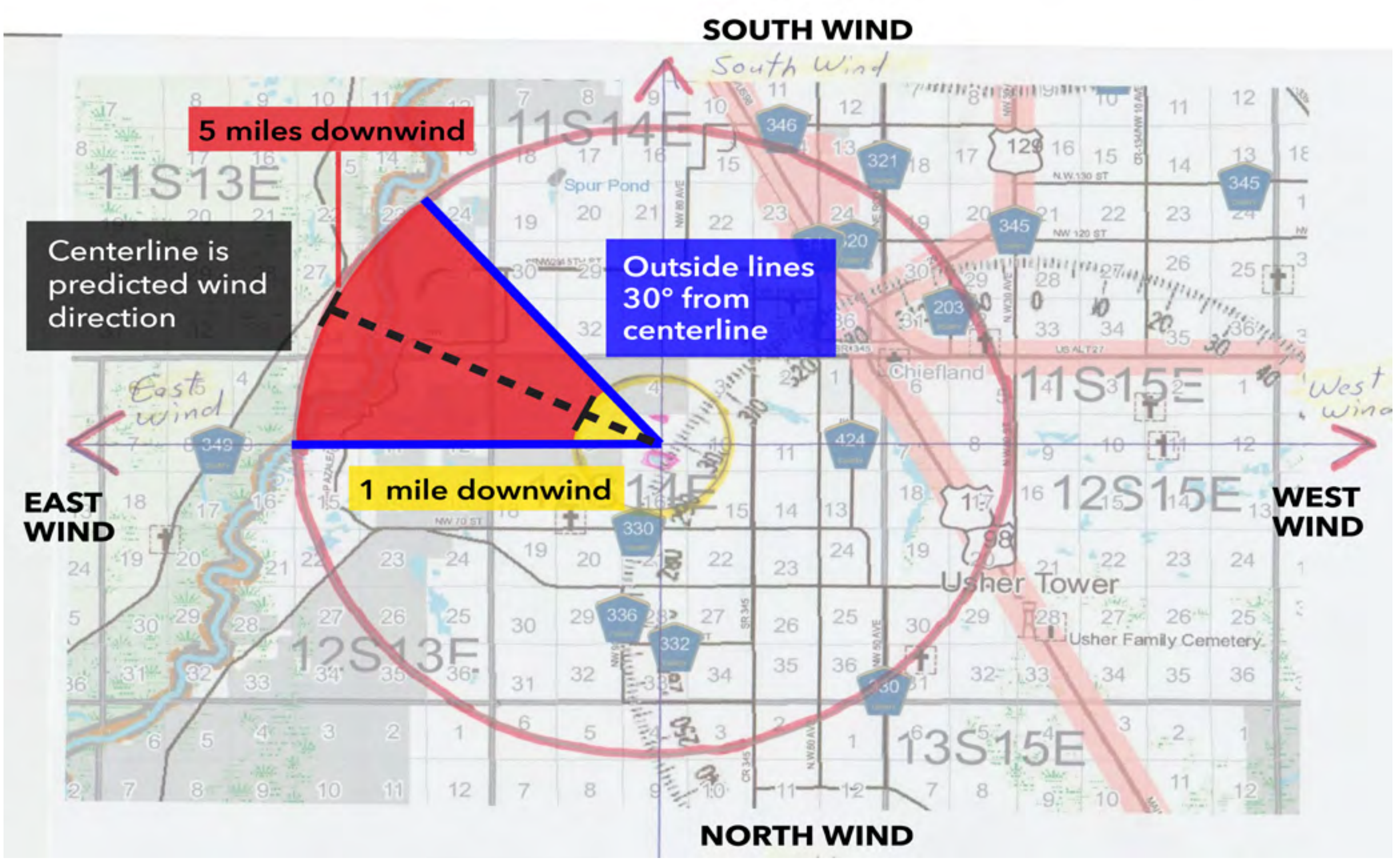


Figure 6.7. A hand-drawn smoke map showing the critical smoke sensitive area (1 mile radius yellow circle) and the smoke sensitive area (5 mile radius red circle). This burn's primary fuel source was grass, so the critical area is smaller than if it were burning larger fuels. Assigning a smoke plume of 30 degrees from the predicted centerline is a reasonable assumption, but the angle may be larger if sporadic weather conditions are expected. Though there are no smoke sensitive features within the critical area, there is a town and multiple roads to the northeast making a southwest wind unpreferable (but not impossible if favorable dispersion conditions and other mitigations are present).

ADVANCED SMOKE SCREENING FOR DAYTIME BURNS (MODERATE AND HIGH COMPLEXITY BURNS)

Moderate to high complexity daytime burns require more advanced smoke modeling, as they are likely to cause a greater smoke impact. A smoke model is particularly beneficial if the burn is considered to be of high complexity, or if known impacts are possible 10 to 15 miles downwind of the burn. These models combine fire information with meteorological information to predict where smoke from fire(s) may be transported.

For example, VSmoke-Web and BlueSky Playground are two computer-based models for modeling smoke. VSmoke-Web has been a popular tool for landowners, but has some limitations, such as fixed directions. BlueSky is another tool that is newer, easy to use and offers slightly more complex data.

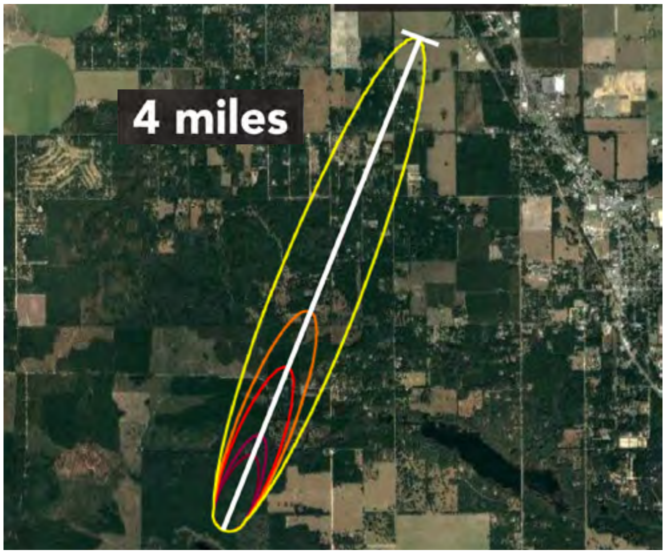


Figure 6.8. Output generated from VSmoke-Web using a satellite map. Concentric circles demonstrate areas with varying levels of AQI and smoke concern.

VSMOKE-WEB

Vsmoke-Web can be used to predict concentrations of fine particulate matter and cross-plume visibility from prescribed fires. It provides the user with a detailed assessment of smoke trajectory, but it requires more inputs than simple smoke screen methods. The directions below provide step-by-step instructions on how to use the VSmoke-Web (Figure 6.9).

1. Obtain input variables from the weather forecast and burn plan. These variables include:
   a. Location
   b. Fire size & estimated duration of fire
   c. Ignition method
   d. Fuel type & load
   e. Fuel consumption
      i. Fuel moisture scenario
         1. (wet, damp, dry, or very dry)
      ii. Estimate of percent consumption
   f. Emissions
   g. Weather (make sure to input weather data specific to the time of the day of the burn).
   h. Additional input options are available, if known.
   i. Note that VSmoke-Web assumes a constant wind direction.
2. Click on "Run Model"
3. Select Map or Satellite view
4. Examine the map to identify smoke sensitive areas.
5. Colors correspond to air quality index scores, levels of health concern and PM concentration (see table 6.7)
6. Record all observations for planning and documentation purposes.

Accessing VSmoke

Visit the Georgia Forestry Commission online site: **www.gatrees.org**

- Navigate to "Fire Weather" (not fire weather forecasts)
- VSmoke should be accessible: https://weather.gfc.state.ga.us/GoogleVsmoke/Vsmoke-Good2.html

Table 6.7. Output from the VSmoke model represents peak hourly concentrations of PM 2.5 or visibility. Contour values and their colors correspond to the PM 2.5 thresholds for the Air Quality Index (AQI) and reflect potential health impacts ranging from moderate to hazardous. *Sourced from the VSmoke-Website. Adapted by Jasmin El Farnawany.*

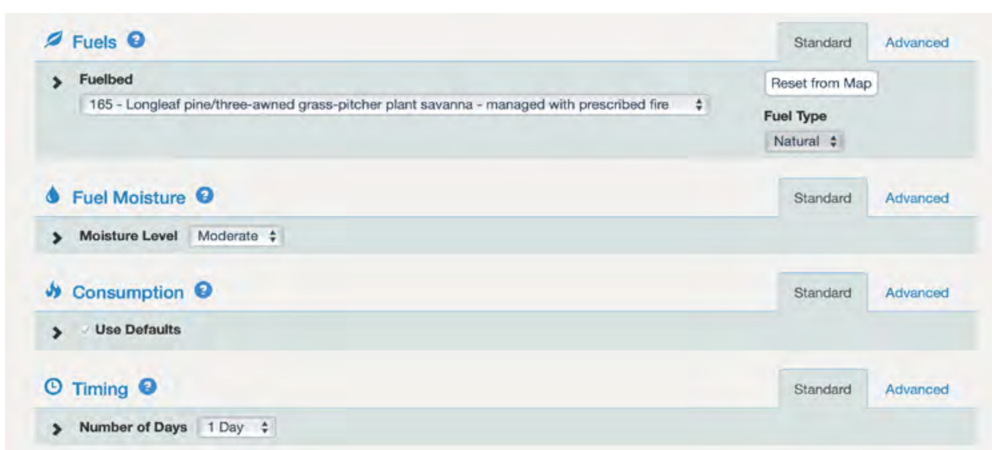
Levels of Health Concern	AQI Value	Hourly PM 2.5 Conc.	Meaning
Good	0 to 50	0 to 38	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 to 100	39 to 88	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are usually sensitive to air pollution
Unhealthy for Sensitive Group	101 to 150	89 to 138	Members of sensitive groups may experience health effects. The general public is not likely to be affected
Unhealthy	151 to 200	139 to 351	Everyone may begin to experience more serious health effects
Very Unhealthy	201 to 300	352 to 526	Health alert: everyone may experience more serious health effects
Hazardous	301 to 500	> 526	Health warnings of emergency conditions. The entire population is more likely to be affected.

BLUESKY PLAYGROUND

BlueSky is a modeling framework that integrates different tools to predict cumulative smoke impacts as well as forecasting ground concentration of smoke. The framework progresses through a series of tools and will assist you to estimate fuel loading, consumption, emissions estimates, trajectories and dispersion of smoke, and more. For details and examples for using BlueSky modeling software access, access it at: **info.airfire.org** , where you will also find detailed instructions.

BlueSky Playground

PGv3.5



SMOKE SCREENING TOOLS FOR NIGHTTIME BURNS

Low Visibility Occurrence Risk Index (LVORI)
Since nighttime conditions differ considerably from daytime conditions, there are different tools that are used to model smoke, or provide guidance. Leftover smoke from daytime burns and active smoke from nighttime burns can decrease visibility on the road. The Low Visibility Occurrence Risk Index (LVORI) provides burners with a probability of car accidents occurring due to low visibility. The LVORI was constructed based on Florida Highway Patrol data from accidents that mentioned smoke and/or fog as contributing to the accidents. The scores range from 1 (low likelihood) to 10 (high likelihood) of accidents and combines the RH with the Atmospheric Dispersion Index. LVORI numbers from 1-3 indicate low probability, and 6-7 indicates an increase in the chance of accidents by a factor of 10-40 over the low values. Finally, values from 8-10 have an even greater chance for accidents.

PB-Piedmont
Smoke screening smoke impacts in the Piedmont region of the South from the late afternoon (at least four hours before sunset) through the night (at least six hours after sunset), can be determined by using the online software: PB-Piedmont (https://piedmont.dri.edu/). PB-Piedmont can be used to forecast the likelihood of smoke and fog dispersing and then settling in areas of drainage that could, in turn, be close to smoke-sensitive areas. The tool is map-based and starts by entering the fire start time, expected duration of the burn, burn size, and then the terrain and fuel parameters (trees or grass). Output includes a projection of where smoke and fog will travel as a short animation (the file can be downloaded). For detailed instructions for using PB-Piedmont and an example, find the publication, "Planned Burn (PB) - Piedmont: Predicting Overnight Smoke Conditions in Complex Terrain," on the Southern Fire Exchange website (www.southernfireexchange.org).

Low Visibility Occurence Risk Index

	Atmospheric Dispersion Index (ADI)											
RH	1	2	3-4	5-6	7-8	9-10	11-12	13-16	17-25	26-30	31-40	> 40
< 55	2	2	2	2	2	2	2	2	2	2	1	1
55-59	3	3	3	3	3	2	2	2	2	2	1	1
60-64	3	3	3	3	3	3	2	2	2	2	1	1
65-69	4	3	3	3	3	3	3	3	3	3	3	1
70-74	4	3	3	3	3	3	3	3	3	3	3	3
75-79	4	4	4	4	4	4	4	4	3	3	3	3
80-82	6	5	5	4	4	4	4	4	3	3	3	3
83-85	6	5	5	5	4	4	4	4	4	4	4	4
86-88	6	6	6	5	5	5	5	4	4	4	4	4
89-91	7	7	6	6	5	5	5	5	4	4	4	4
92-94	8	7	6	6	6	6	5	5	5	4	4	4
95-97	9	8	8	7	6	6	6	5	5	4	4	4
> 97	10	10	9	9	8	8	7	5	5	4	4	4

Table 6.8. *Sourced from Lavdas and Achteimer, 1995.*

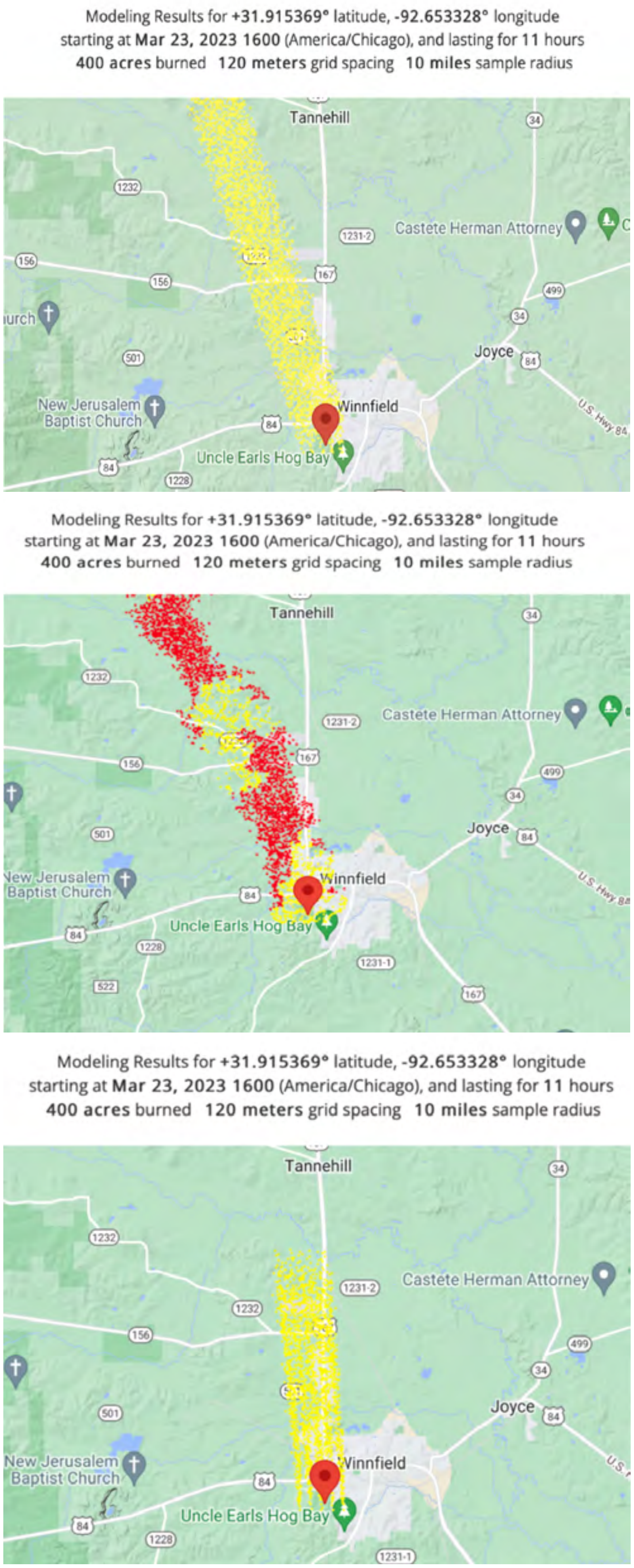


Figure 6.7. Three pictures of a simulation of projected trajectory of smoke at different times from the proposed start and duration of a burn using the PB-Piedmont tool.

Strategies to Reduce Smoke Impacts

While the effects of smoke cannot be completely eliminated, it is possible to reduce these impacts through various mitigation strategies/efforts. These mitigation strategies/efforts should first be considered during the planning stages and incorporated into a burn plan, but smoke mitigation techniques may also be employed during or after the burn. Mitigation techniques are important in both daytime and nighttime burns. While it is easiest to see the effects of smoke during a daytime burn, lower mixing heights and slower wind speeds are common with nighttime burns. These differing conditions at night, along with other variables, require more diligence in your smoke management approach.

Following BSMPs is highly recommended, and there are additional steps to consider which are helpful for reducing your potential smoke impacts. Some of the ways to mitigate the effects of smoke from your prescribed burn are listed below based on the **stage of burning**. All the suggestions listed below may not be feasible (or needed) for every burn, but they are still options to consider.

Smoke Mitigation Strategies by Stage of Burning
Planning the Burn:

- Explore other fuel reduction techniques (i.e., herbicides, mechanical treatments, mowing, grazing, etc.)
- Use a smoke screening tool to select a better smoke direction or dispersion
- Prepare multiple burn units, so you can match the best conditions to the best unit
- Create smaller burn units
- Understand how temperature changes affect smoke behavior (very important in nighttime burns)
- Burn at a higher fuel moisture level (less fuel is consumed, so a lower quantity of smoke is produced)

Before the burn

- Do not burn until weather and fuel conditions are acceptable
- Do not burn during pollution alerts or stagnant conditions
- Contact all parties that could potentially be affected by your fire's smoke prior to and the day of the burn, including local authorities and neighbors
- Post signs on roads near the burn alerting drivers of the smoke, if needed
- Temporarily close roads if necessary (in coordination with the local transportation department)
- Establish a contingency plan to terminate the burn if smoke becomes a problem

During or after the burn

- Try to burn after inversions have lifted and be done well before sunset, as dispersion conditions are generally best at this time
- Complete burns as quickly as possible
- Limit the hours smoke is produced during the day; this may mean burning the unit in small sections or using firing techniques known to burn hot and quickly
- Consider different firing techniques
- Have sufficient burn crew members on hand to monitor smoke beyond the immediate burn unit
- Document smoke behavior through images and descriptions
- Monitor smoke on roads
- Contact emergency management if smoke encroaches on roadways or causes other hazardous conditions (i.e., additional signage, directing traffic)
- Shut down burn (if necessary)
- Begin mop-up along roads as soon as possible to reduce impacts on visibility.
- Mop-up across the burn unit to reduce smoldering, focus on areas where residual smoke is more likely, such as stumps, or snags

References

Campbell, J.H., Fawcett, J.E., Godwin, D.R. & L.A. Boby. (2020). *Smoke Management Guidebook for Prescribed Burning in the Southern Region.* University of Georgia Warnell School of Forestry and Natural Resources. Outreach Publication WSFNR-20-91A.

(EPA) United States Environmental Protection Agency. (2019). *Wildfire smoke: A guide for public health officials report*. https://www.airnow.gov/publications/wildfire-smoke-guide/wildfire-smoke-a-guide-for-public-health-officials/.

AirNow (n.d.). *Fire and Smoke Map v2.0*. Retrieved July 27, 2021, from https://fire.airnow.gov/#

Goodrick, S. (2014). *Introduction to VSmoke-Web*. [unpublished Power Point slides]. USDA Forest Service.

Hinnant, R. (2012). *Smoke management [Training presentation]. The Academy for Ranch Management: Prescribed Rangeland Burning School*. Agrilife Research and Texas A&M University.

Lavdas, L., & Achteimer, G. (1995). A Fog and Smoke Risk Index for Estimating Roadway Visibility Hazard. National Weather Digest, volume 20 (1).

Monroe, M., Dixon, A., Godwin, D., Watts, A., & Kobziar, L. (2022). Where There's Smoke: Air Quality and Prescribed Burning in Florida. UF IFAS Extension Publication FOR62.

NWCG. (2020). *NWCG smoke management guide for prescribed fire*. National Wildfire Coordinating Group. PMS 420-3. NFES 1279. 279 p. https://www.nwcg.gov/publications/420-3

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

Weir, J.R. (2009). *Conducting prescribed burns: A comprehensive manual.* Texas A&M University Press.

SMOKE MANAGEMENT NOTES

SMOKE MANAGEMENT NOTES

FUEL

Image credit: James Johnson

Table of Contents

Introduction

In order for a fire to occur, the three elements of the "**fire triangle**" must be present: fuel, oxygen, and heat (Figure 6.1). Fuel can be any material that could burn; however prescribed fire is focused on wildland fuels. Wildland fuels are defined as biomass made of dead or live vegetation that is potentially flammable. The types of the live or dead vegetation, the amount of material present (fuel load), and the moisture levels and arrangement of the materials in a given area are all part of the fuel characteristics. Fuel characteristics strongly influence both the prescribed burn plan parameters and the firing techniques used. While non-vegetative fuels, such as old tires, trash piles and abandoned structures may be found in a planned burn unit, they should be removed or separated from the burn unit (if possible). Non-vegetative fuels can create negative health impacts, fire control problems and legal issues if ignited.

Over time, fuel characteristics change through disturbance events, (such as storms, which can cause a blowdown of shrubs or trees and increase fuel loading) or through simple growth of the vegetation. Therefore, it is important to assess fuel characteristics when creating a burn plan and then to re-assess current conditions prior to burning.

Fuel characteristics are strongly linked to fire behavior. When more fuels and weather data are known prior to burning, burn objectives are more likely to be achieved and the risk of accidents decreases.

This section includes detailed descriptions of fuel characteristics, and information on different ways to estimate fuel loads and moisture levels.

Image 7.1. Fuels have many characteristics. An old, dry log will burn differently than fresh, moist grasses. *Image courtesy of Sarah McNair.*

Fuel Characteristics

Fuels are characterized by a number of physical factors that relate to how they will burn such as the type, vertical and horizontal arrangement, load or amount present, moisture levels, and the fuel's sizes and shapes. These fuel characteristics all interact with one another, as well as the climate, local weather patterns, and topography to impact fire behavior. While each of these fuel characteristics can be measured scientifically and precisely, an experienced burner can estimate them by walking the burn site and recording observations. General fuel characteristics will inform how your prescription burn plan is developed. Some fuel characteristics may change by the time you conduct your burn. Immediately before the burn, it will be important to walk the burn site and note if any of the fuel characteristics have changed and to estimate fuel moisture levels and loads. Check with your state forestry agency to ensure you meet the fuel documentation guidelines for your state.

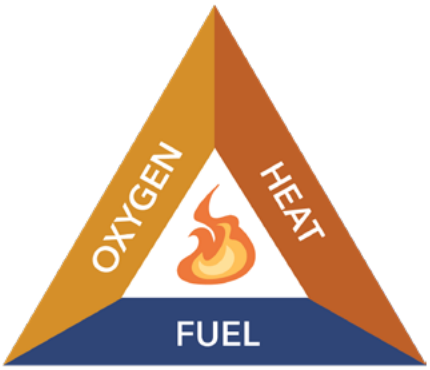


Figure 7.1. Fire Triangle

Fuel Type

Fuel Type refers to the different sizes/architecture of live vegetation types as well as sizes and arrangements of dead fuels on the ground, such as pine or hardwood leaf litter, limbs, and stems. It also can include herbaceous vegetation. Different types of fuels are then linked to predictable rates of spread or resistance to fire under specified weather conditions. The U.S. Forest Service uses four broad types of carrier fuels that are live vegetation or dead fuels including grass, shrub, tree litter, and slash/blowdown (Table 7.1). There are more detailed fuel model descriptions within these broad categories that address different specific fuel models applicable to the southeastern U.S. as well.

These fuel types are meant to describe the fuels that will be carrying a fire across the landscape. A longleaf pine stand with a continuous wiregrass understory may have some larger fuels present, but the grass is what will carry the fire and is the primary component contributing to fire behavior and spread. Therefore, the fuel type is considered grass. A similar longleaf pine stand with a scrub oak understory may be considered timber litter because the oak and pine litter would be the primary fuels contributing to fire behavior and spread. Figure 7.2 can be used to adequately assess fuel types in the South.

Burn plans and firing techniques will be influenced by the type of fuel present. For example, areas with thick organic soils or heavy logging slash can smolder for a very long time – this may require more intensive mop-up and more time spent working on and monitoring the burn area after the fire.

Table 7.1. The four broad fuel types and descriptions of the primary fire carriers within each fuel type.

Fuel Type	Primary carrier of fire
Grass	Solely grass or a combination of grass & herbaceous plants
Shrub	Live and dead shrub twigs & foliage in combination with dead and down shrub litter cover at least half of the site. Grass is sparse to nonexistent
Tree litter	Dead & down woody fuel (litter)
Slash/ blowndown	Limbs and materials remaining from timber harvest or management activities and/or blown down by storms

Image 7.2 & 7.3. Some live fuels such as mountain laurel and saw palmetto can burn intensely due to chemicals in their foliage. *Image courtesy of Martin Schubert (University of Tennessee) and Dale Wade (www.forestryimages.org)*

Live fuels can affect a burn based on the type of plant (woody or herbaceous), its development stage, and seasonal plant conditions (such as new vegetative growth, drought stressed vegetation, and dormant vegetation). Additionally, the chemical characteristics of live fuels are an important consideration. Plants may contain waxes, oils, fats, and terpenes that differ in concentrations by species or season. These chemicals can affect fuel flammability and fire behavior (Image 7.1).

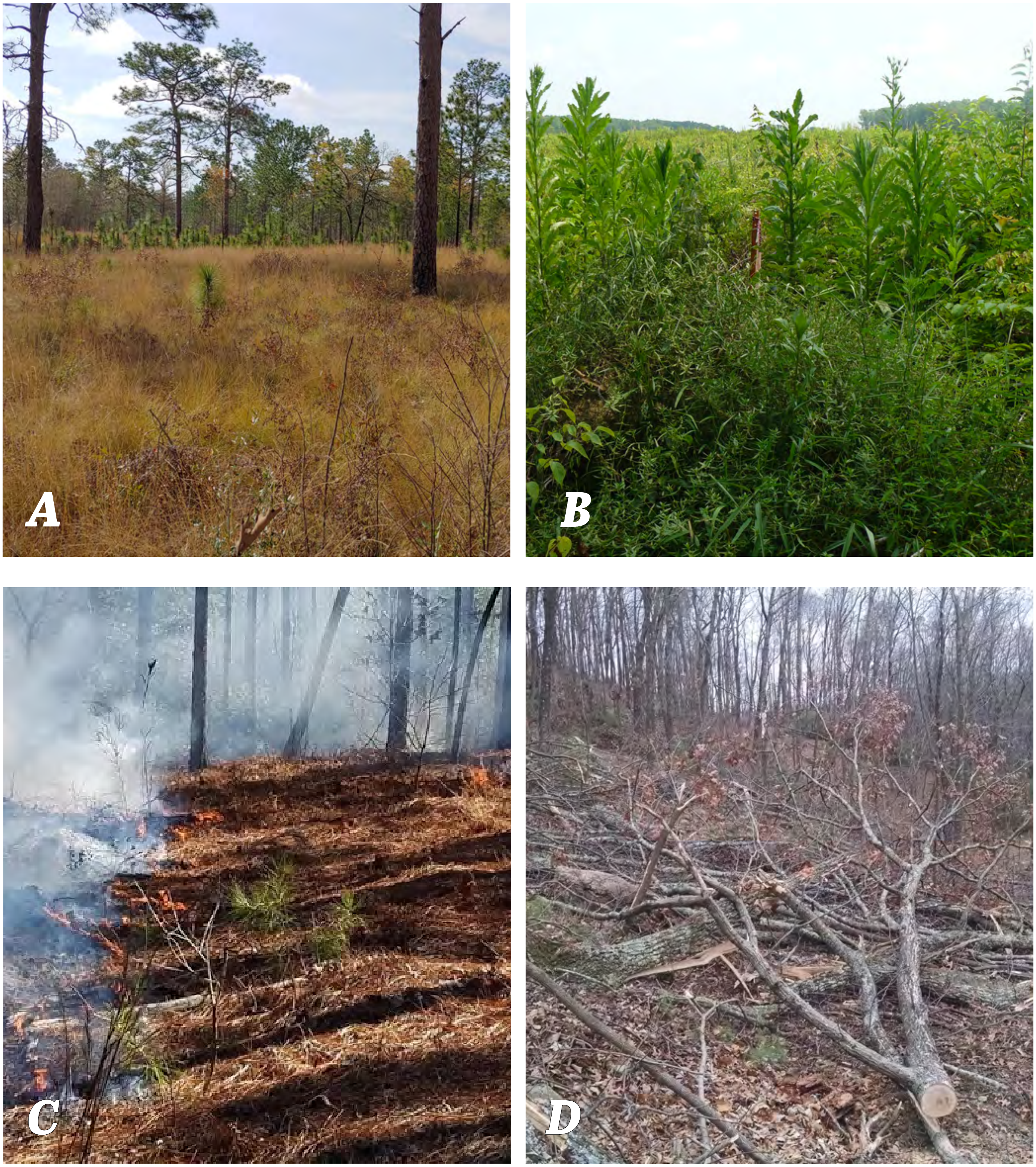


Figure 7.2. Four broad fuel types commonly used by the U.S. Forest Service to assess surface fuels in the southeastern United States. Fuel types include: a. grasses, b. brush, c. tree litter, and d. slash. *Image courtesy of David Clabo.*

Fuel Arrangement (Horizontal & Vertical)

Fuels can be classified by their vertical and horizontal arrangement as well as their type. The height of fuels can be used to classify them vertically (ground, surface, ladder or aerial fuels) (Figure 7.3). **Fuel continuity** refers to the horizontal distribution of fuels across the area, for example, patchy or continuous (Figure 7.4).

Fuel arrangement can affect how much of the fuel load can burn. An example of this is hardwood leaf litter arrangement. Leaves are more likely to burn in autumn, soon after falling, when they are arranged in loose layers. Leaves are less likely to burn when their arrangement is compressed and compacted after multiple rainfall events later in the dormant season. This is due to the ratio of surface area to volume. When vegetation is compressed its total mass remains unchanged, but its exposed surface and volume are reduced, thus requiring more heat/energy for it to ignite and sustain combustion. Think of starting a little campfire. Do we start it with large pieces of wood with a low surface to volume ratio, or with small leaves and twigs with higher surface to volume ratios? Will a tightly compressed handful of pine needles burn more readily, or would it ignite more easily if it were fluffed up to expose more surface area? Certain types of vegetation and even some plant species affect how well a fire will carry. For example, some oak species even curl and dry more quickly than other hardwoods, allowing them to burn more reliably.

VERTICAL FUEL CLASSIFICATIONS:

Ground Fuels
All combustible materials below the surface litter, including duff, tree or shrub roots, punch wood, peat, and sawdust, that normally support a glowing, smoldering combustion without flame.

Surface Fuels
All combustible materials lying on or near the surface of the ground, consisting of leaf and needle litter, dead branch material, downed logs, bark, tree, cones, and low stature living plants.

Ladder Fuels
All combustible materials which provide vertical continuity between the surface and canopy, thereby allowing fire to carry from surface fuels into the crowns of trees or shrubs with relative ease. They help initiate and assure the continuation of crowning.

Aerial or Canopy Fuels
All live and dead vegetation in the forest canopy or above surface fuels, including tree branches, twigs and cones, snags, moss, and high brush.

Image 7.4. Duff may not be immediately visible. It is often hidden under pinestraw. *Image courtesy of Barry Coulliette.*

Image 7.5. Dead tree limbs and vines create a "ladder" to the overstory, also called ladder fuels. *Image courtesy of Sarah McNair.*

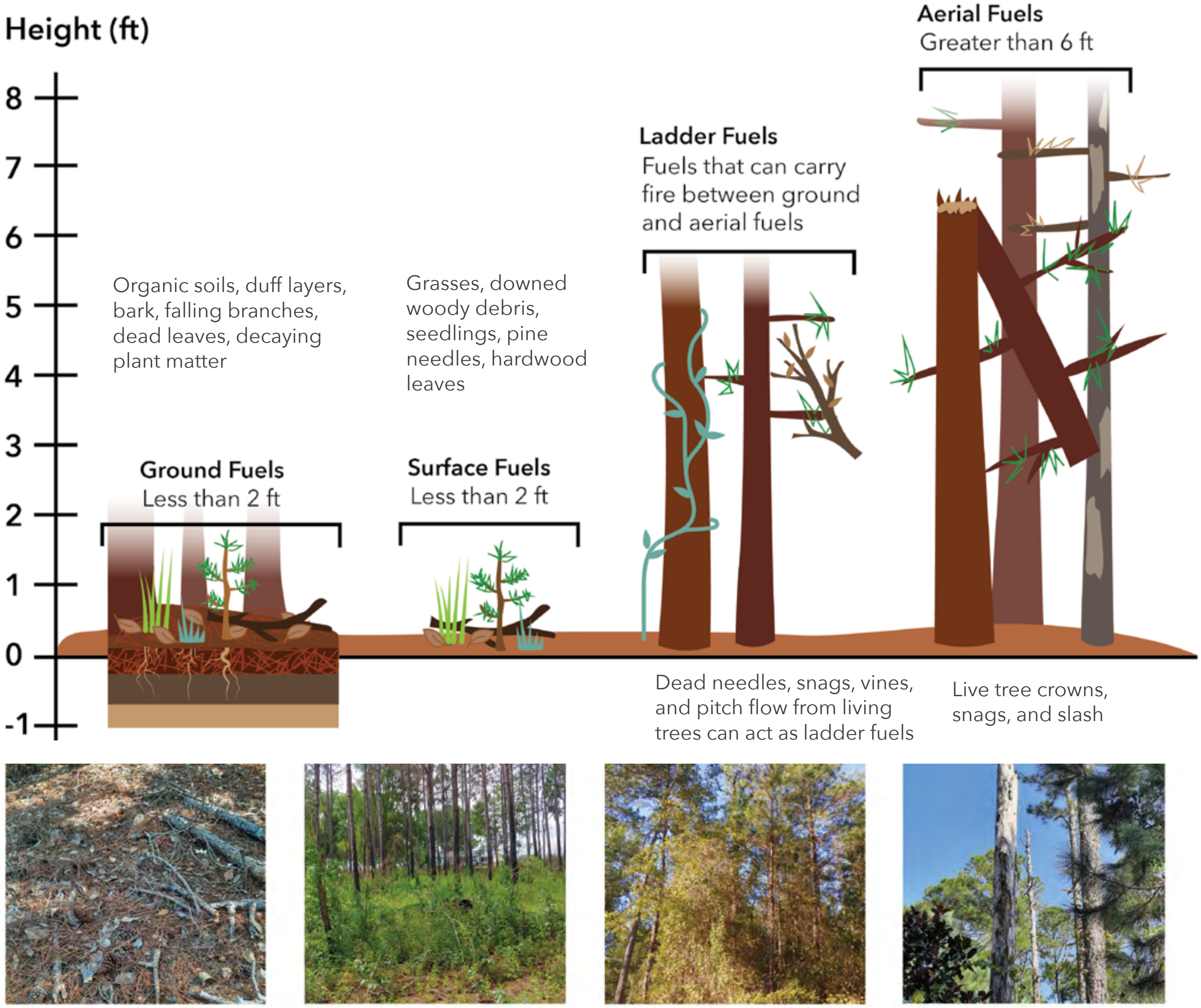


Figure 7.3. Diagram of vertical live and dead fuel classifications with example photos. *Images courtesy of David Clabo.*

Ladder and aerial fuels will be discussed in greater detail in the Fuel Continuity section. If your site has heavy ground fuels such as organic soils or thick duff layers, you should have your local forestry agent visit and assess your site before burning. Burning on sites with heavy ground fuels requires advanced knowledge and techniques beyond the scope of this guide.

Litter vs. duff: What's the difference?

Litter consists of undecomposed or slightly decomposed organic material that can be readily identified (e.g. plant leaves, needles, twigs, etc.). This is also referred to as the Oi horizon. Duff consists of intermediate or highly decomposed organic material beneath the litter or Oi layer but above mineral soil horizons. The duff layer (when present) consists of the Oe and Oa horizons.

HORIZONTAL ARRANGEMENT OR FUEL CONTINUITY

Fuel continuity specifically refers to the degree or extent of continuous or uninterrupted distribution of fuel in an area, and it will affect the ability of the fire to sustain combustion and spread. Some fuels, such as grasses and shrubs (which includes saplings, young trees, and vines), tend to naturally be oriented more vertically. Horizontally oriented fuels include timber litter and understory (dead hardwood and pine foliage) and logging slash (Image 7.6). A fire's rate of spread and fuel consumption are closely related to fuel continuity (Figures 7.4). Some tree species, due to their natural pruning characteristics, may also be more likely to have aerial fuels that could promote crown fires.

Image 7.6. An example of continuous, downed woody fuels. *Image courtesy of David Clabo.*

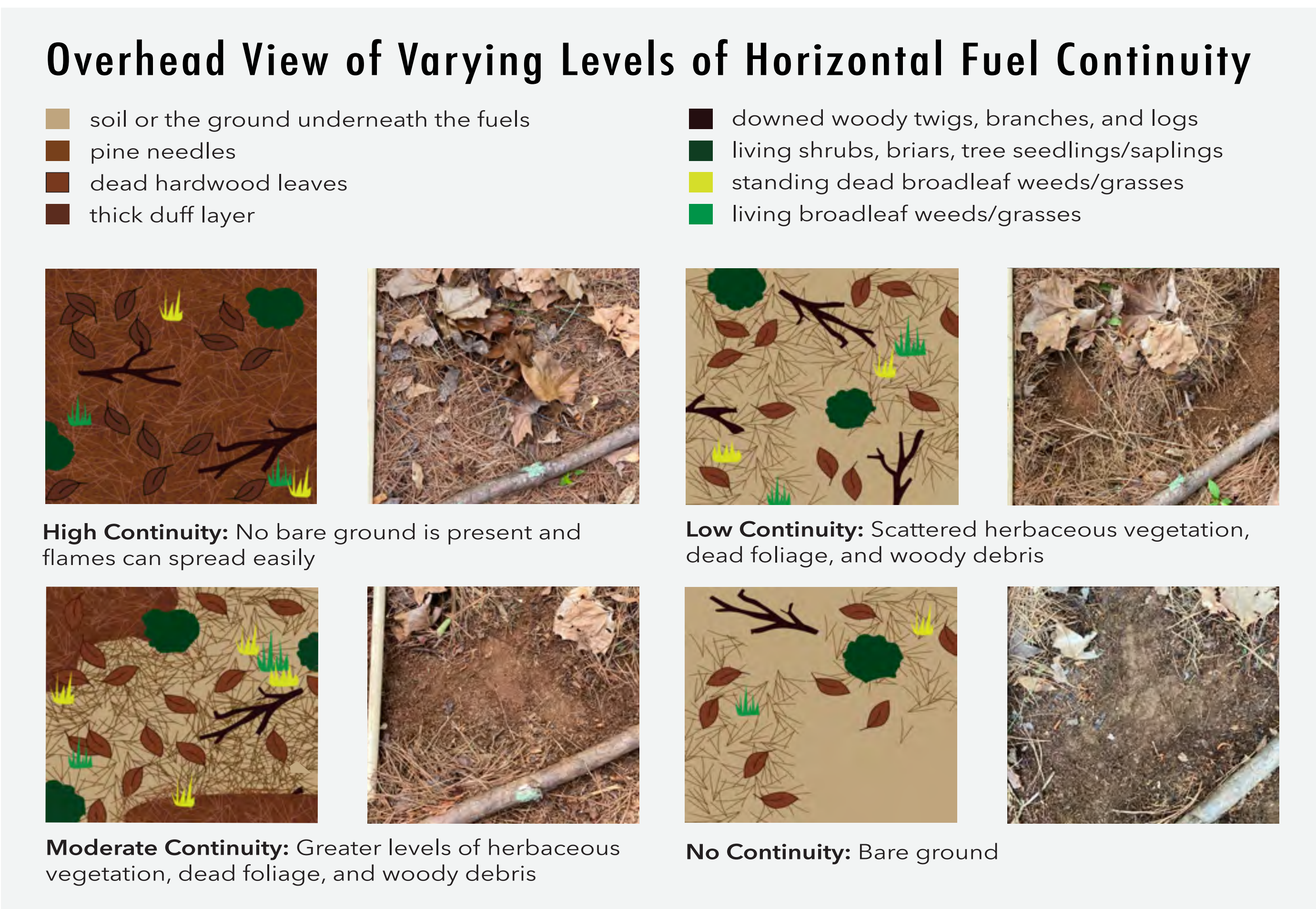


Figure 7.4. Aerial view diagram of horizontal fuel continuity. *Diagram credit: Melanie Quinton.*

Image 7.7 & 7.8. Longleaf pine (top photo) and sand pine may occur together on sandy textured soils of the Coastal Plain in the Southeast. Longleaf pine is a good natural pruner, whereas sand pine is not. Dead limbs on sand pine could act as ladder fuels. *Image courtesy of David Clabo.*

Fuel Size and Moisture

The size of the fuels will influence how easily they burn, how their moisture levels change, and how quickly they respond to weather conditions. Smaller sized and flatter shaped fuels ignite more readily and respond to changes in weather conditions rapidly. Larger and more evenly rounded fuels need more heat energy to ignite and are slow to adjust to changing weather conditions, but they will burn hotter and longer than smaller fuels if ignited.

Fuel Moisture The amount of moisture in a fuel class relative to its weight. This value is usually expressed as a percentage.

Dead fuel moisture content is assessed using timelag fuel classifications and is based on the amount of time required for a specific fuel size or time-lag class (Figure 7.5) to adjust to changes in environmental conditions such as rain, humidity, or periods of dryness. Under most prescribed fire conditions, dead fuels will be the predominant fuels carrying fire. Live fuel moistures are tricky to measure as they require weighing fuels while alive, drying them completely, and then weighing them again to determine the moisture content. Therefore, live fuel moisture is a variable that is not typically measured for prescribed fires; burners should be aware of their general condition. As fuel moisture content decreases and live fuels become available for consumption, fire behavior will become more erratic, making the fire more difficult to control. It is important to remember that wetter fuels produce greater amounts of smoke, which can lead to smoke issues. Fire behavior, rate of spread, and other factors are influenced by how dry fuels are at a given time. Most prescribed fires in the Southeast are conducted within an 8-20% fine fuel (1-hour) moisture range. Size or time-lag classes include 1-hour, 10-hour, 100-hour, 1,000-hour, and 10,000-hour dead woody fuels and are described below.

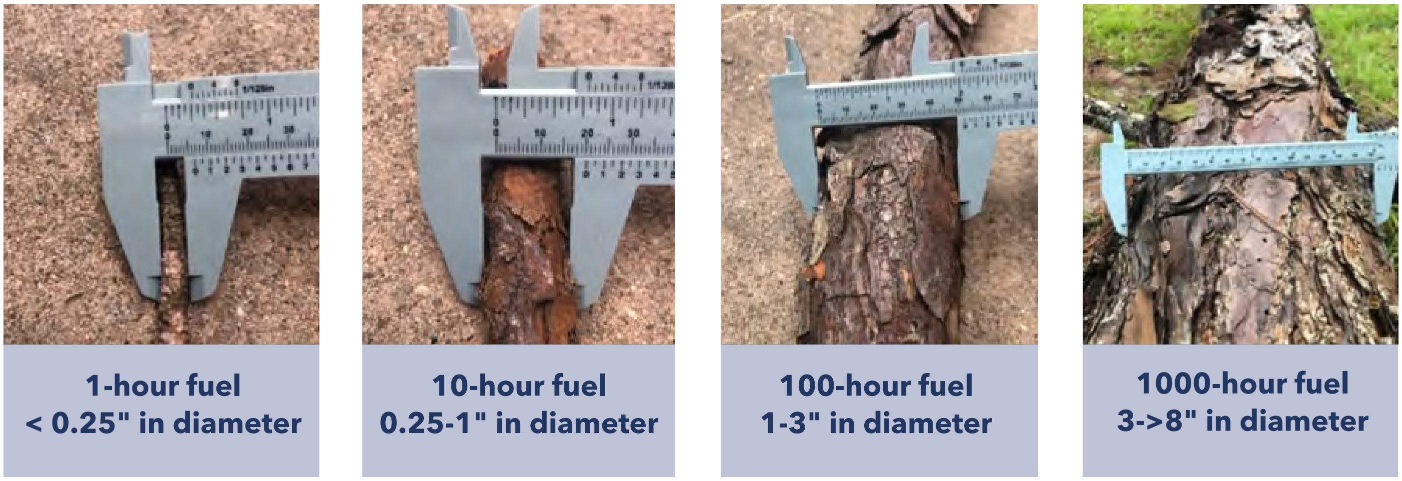


Figure 7.5. Fuel timelag classes for 1, 10, 100, and 1,000-hour fuels and their respective diameters are presented. *Images courtesy of David Clabo.*

1-hour fuels (<0.25" diameter) are the fine fuels that typically carry the fire such as leaves, needles and twigs narrower than the width of a pen or pencil (Figure 7.5). These are also the fuels that will react the fastest to changes in the environment. One-hour fuels are the reason that a fire may not burn during the morning hours when the air is cool and moist but burn readily a few hours later once temperatures increase and relative humidity drops. These fuels are

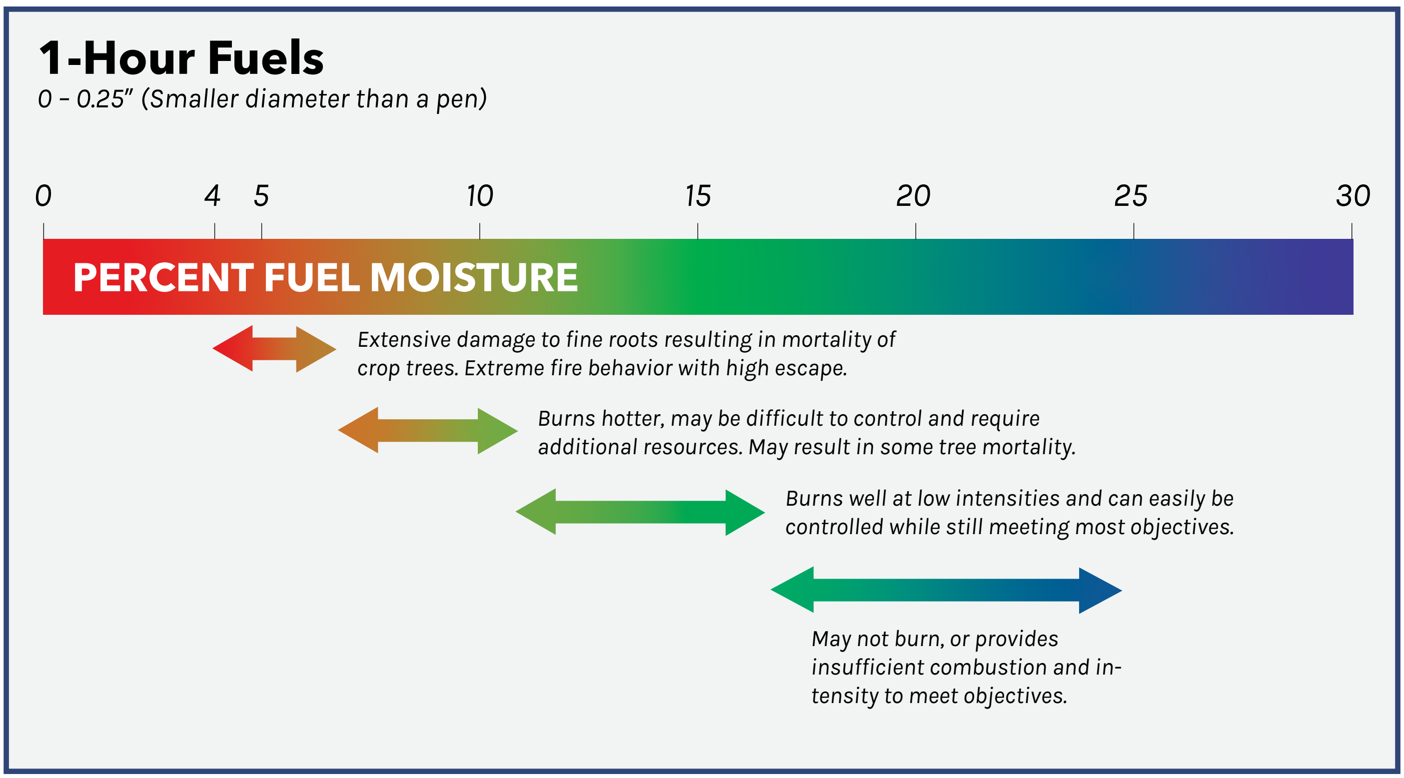


Figure 7.6. Percent of fuel moisture of 1-hour fuels and their effects on fire behavior. *Diagram credit: Melanie Quinton.*

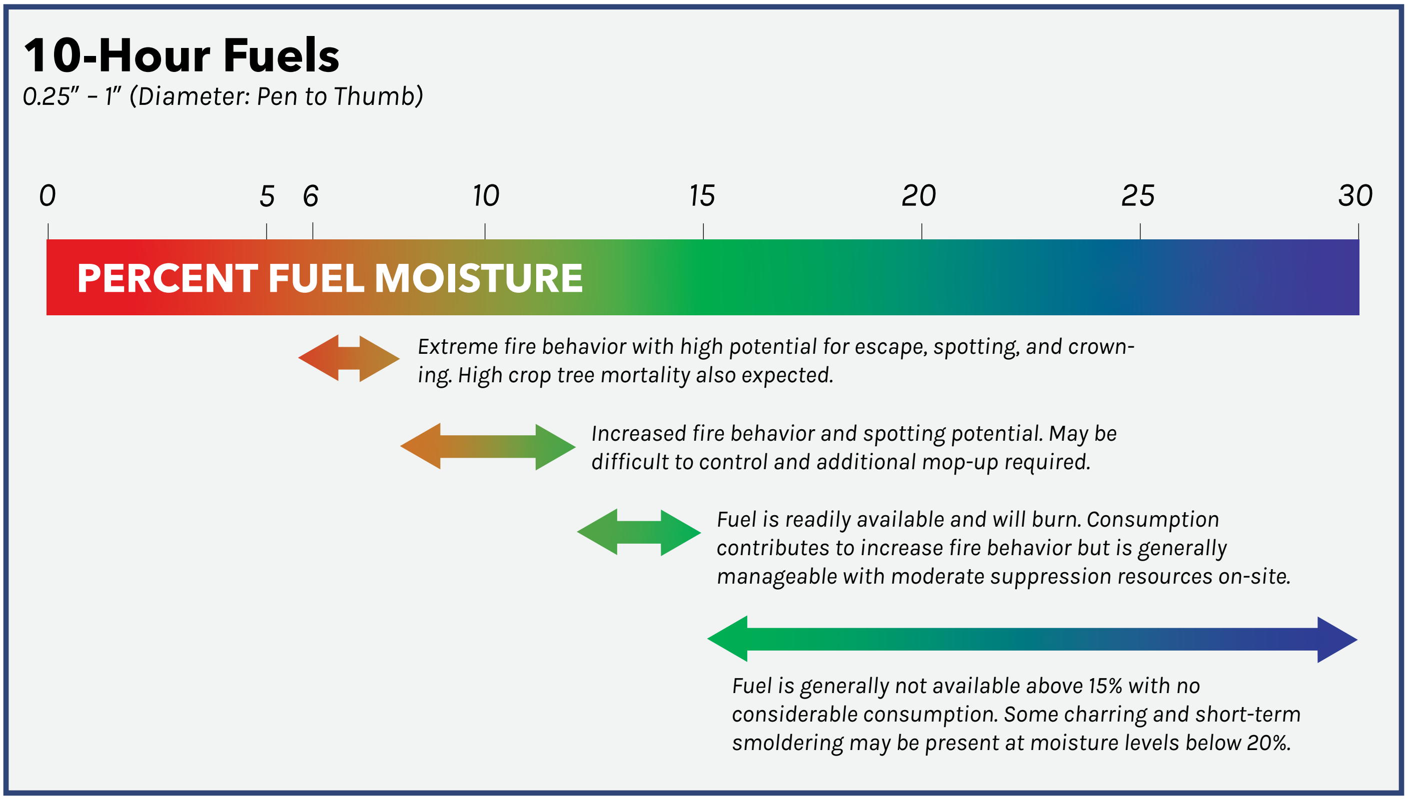


Figure 7.7. Percentage of fuel moisture of 10-hour fuels and their effects on fire behavior. *Diagram credit: Melanie Quinton.*

the most important to assess on the day of the burn.

10-hour fuels are slightly larger (0.25-1") and fall between the diameter of a pencil and a thumb width. These fuels may be partially or fully consumed depending on conditions. They are less susceptible to the environmental changes that take place in a single burning period but can change significantly over a 10-hour time span (Figure 7.7).

100 hour and 1,000 hour fuels range from 1 - >8" diameter. 100-hr fuels are 1-3" diameter, or from about the size of a thumb width to the size of a person's arm. 1,000 hr fuels are 3-8" diameter and approximately the size of a person's arm to the size of a person's thigh. These fuels take several days to respond to changes in their environment. They are not easily calculated in the field, but nearby readings can be easily obtained from the National Fire Danger Rating System, through your state's forestry agency, or from the Fire Weather Intelligence Portal. For most in-stand burning objectives, it is recommended to burn when moisture content levels of these fuels are above 17% and not available for combustion. Burning when these fuels are below 17% can result in needing additional holding and mop-up resources, increased fire behavior and intensity, increased smoldering and smoke production, heightened risk of crop tree damage, greater likelihood of escape, and a need for more vigilant monitoring that can last several days. Often these thresholds can be realized during the test fire phase before conditions deteriorate. With in-stand burning, if 100 and 1,000 hour fuels are igniting, it may be best to stop burning and plan for another day. However, there are instances where it may be desired to burn these (e.g. forestry site preparation burn).

Fuel Load & Duff Conditions

During the planning process, overall fuel loads and duff conditions should be estimated using some of the methods described at the end of this section, in addition to considering the age of the forest stand and prescribed fire history of the site, including time since last burn. An estimate of fuel loading and assessment of duff conditions can help with fire behavior and smoke production predictions.

FUEL LOAD

Fuel Load is the amount of available flammable material in a given area and can be measured in tons per acre or as a measure of the potential energy that could be released from a fire. This flammable material consists of living understory vegetation and dead fuels that could burn.

The total amount of fuel present is typically more than the material that will actually burn (available fuel). Higher fuel loads can result in greater intensity fires with conducive weather conditions as there is more material to burn when it is hotter and/or drier. Fuel loads are most commonly classified as low, medium, and high (Table 7.3). Fuel loads can also vary by vegetation cover type and disturbance (Tables 7.2 and 7.3).

Image 7.9. A burn site with a significant amount of buildup, including pine needles. *Image courtesy of Barry Coulliette.*

Table 7.2. Fuel loadings in tons per cover types and visual fuel loading assessments (low, medium and high).

Estimated Available Tons Per Acre*			
Assessment:	**Low**	**Medium**	**High**
Pine Litter	3	6	12
Hardwood Litter	3	5	7
Mixed Litter	4	6	8
Brush < 2 ft.	4	7	10
Brush 2-4 ft.	6	8	15
Brush > 4 ft.	10	20	30
Light (thin) Slash	5	10	20
Medium (chopped) Slash	10	20	40
Heavy (clearcut harvest) Slash	30	40	60
Short Grass (Wire Grass)	2	5	7
Tall Grass (Broomsedge/Marsh)	3	6	8

*This information is based on results of actual sample measurements and has represented accurately the fuel availability based on the selected loading range. Research studies and surveys that provide more accurate site-specific information concerning tonnage or fuel availability can be used.

Table 7.3. Fuel load descriptions and example photos of the grass/brush fuel type. Typical fuel loadings table courtesy of South Carolina Forestry Commission. Images below descriptions & tons per acre are examples. *Image courtesy of David Clabo.*

Item	Total Tons Per Acre		
Low and medium Grass/Brush	low	medium	high
Short grasses and light brush up to 2 feet high that burn rapidly. Moisture levels can change substantially in this category.	1	2.5	4
			
Moderate Grass/Brush	low	medium	high
Brush up to 6 feet high and often includes patchy fuels with grass. The rate of spread is usually slower, but it can burn at a moderate to very high intensity.	3	4.5	6
			
Heavy Grass/Brush with moderate to heavy slash in place	low	medium	high
Continuous brush more than 6 feet high including slash. The rate of spread is low to moderate but it is typically a high intensity type of burn if fuels are dry enough.	11	34.5	58
			

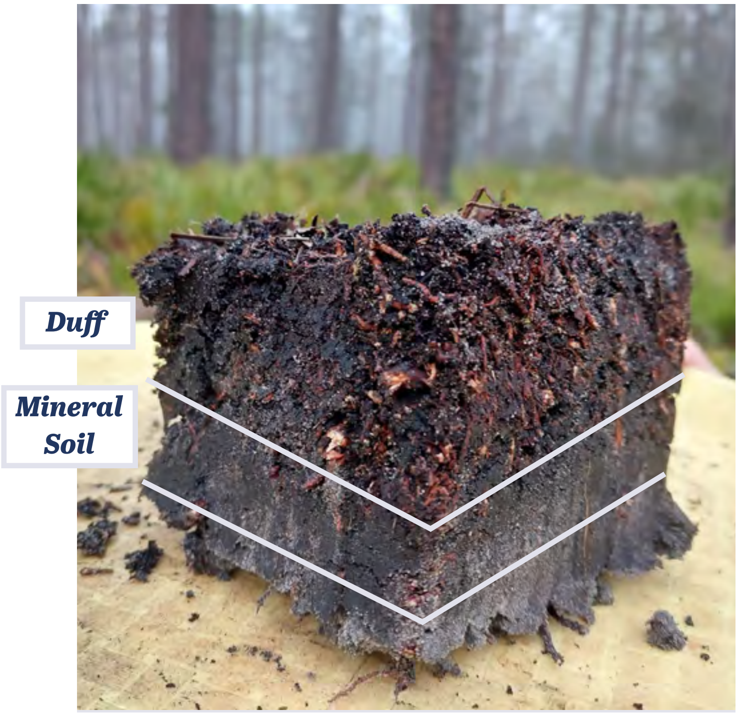


Image 7.10. Cubic soil sample, showing roots growing into the partly decomposed material (duff) on the forest floor. *Image courtesy of Mac Callaham.*

DUFF CONDITIONS

The **duff layer** is the upper layer of organic matter in the soil profile (part of the ground fuels), and it can be considered fuel, depending on moisture levels. Forest stands that are frequently burned are less likely to have a duff layer. For example, pine stands that are regularly burned (e.g. 1-3 year intervals) will not develop a duff layer; however, if you are planning a prescribed fire in a stand that has not been burned in a long time, it is especially important to be cognizant of the duff layer. This soil horizon tends to become deeper and accumulate near the base of large pine trees in fire suppressed pine forest types (Image 7.10). It is also **better to avoid burning this layer**, as it may lead to smoldering and smoke issues, plant feeder root damage, and possible erosion problems after the fire. Burning fine feeder roots of large, mature trees can cause mortality. This soil layer can be lightly burned or charred, but it should not be burned completely.

Assessing Your Fuel Loads, Duff Conditions & Moisture Levels

Fuel loads and moisture levels can be directly measured, but it is a very time-consuming and labor-intensive process, making it impractical outside of research applications or where more precise estimates are needed. Landowners and practitioners do not have time to precisely calculate fuel loads, perform detailed examinations of the duff layer, and measure fuel and duff moisture levels; however, there are many methods for estimating these values. Often fuel loads are estimated while planning the prescribed burn and then they should be assessed again for any changes immediately before the burn. Some states require you to submit fuel load values in order to obtain a burn permit. Duff conditions also need to be assessed during the planning process as the depth of the duff and time since last burn will influence the burn prescription. Since duff and fine fuel moisture content changes with the weather, moisture levels need to be estimated closer to the burn date. Fuel and duff moisture trends should be monitored during the days leading up to the scheduled burn day, with more stringent monitoring on-site, prior to ignition. Estimating fine fuel moisture provides a good idea of how fuels along with current weather conditions may affect fire behavior. Below are various methods for estimating and measuring your fuel loading and assessing duff and fuel moisture conditions.

Estimating & Measuring Fuel Load

Basic methods for estimating fuel loading involve using fuel charts and/or photo guides, while more advanced methods involve the use of fuel model aids and calculators. The more precise ways to measure fuel loads include direct measurements in the field using specialized sampling techniques. All three approaches for estimating/measuring fuel loads are covered here.

ESTIMATE FUEL LOAD USING FUEL CHARTS AND/OR PHOTO GUIDES

Walking the burn site and using a fuel loading photo guide or chart (like those shown in the fuel loading section) are the easiest ways to estimate fuel loads. There are many different publications that include pictures of fuel load estimates that are produced by the U.S. Forest Service, state forestry agencies, and others (see below for examples). Estimating fuel loads visually does require experience, so initially, it is recommended that you work with an experienced burner to hone your skills. If you do not have someone available to assist you, do the best you can and note your estimates in your burn plan and in your post-fire evaluation.

Fuel load estimates picture guides for area/fuel types

Photo guide for estimating fuel loading in the Southern Appalachian Mountains (2019)

U.S. Forest Service General technical report SRS-241. Asheville, NC: U.S. Department of Agricultural Service, Southern Research Station.

Fuel Load Estimation Guide for South Carolina (July 2014)

Find it on the South Carolina Forestry Commission website (scfc.gov), protection, fire resources & under 'burning information'

Texas Wildland Fuels: Fuel Model Guide (2016)
Texas Interagency Coordination Center

Fuel Treatments in Pine Flatwoods: A photo series guide for estimating vegetation and fuel biomass change over tie following mowing and burning in Southern Pine Flatwoods Forests (2016)

Find it on the Southern Fire Exchange (SFE) website (southernfireexchange.org), publications, prescribed fire, publications by SFE partners.

ESTIMATE FUEL LOAD USING ONLINE FUEL MODEL AIDS

Fuel model aids provide generalized estimates of fuel loading based on average conditions in various vegetation cover types and fuel types. They sometimes also consider fuel classification, continuity, and moisture. Fuel calculators such as the Available Fuel Calculator, predict how much fuel will be consumed under specified burning conditions. It should be noted that these aids are to be used as general references. Specific stands or burn units that are like one of the fuel classifications may exhibit fuel characteristics and fire behavior differently than expected.

Online Available Fuel Calculator

Access the tool here: http://smokeapp.serppas.org/
From the webpage above, select the "fuel calculator" option on the right-hand side of the page. This will bring you to the fuel moisture calculator.

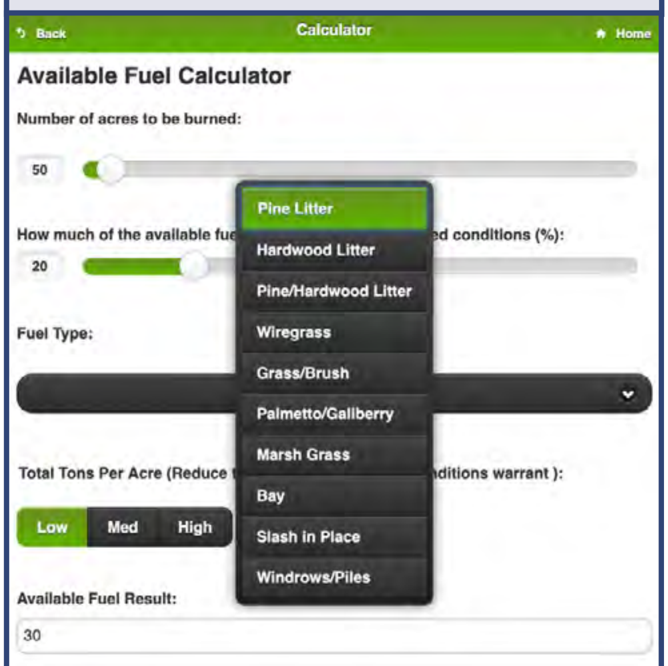


Image 7.11. Screenshot of Available Fuel Calculator.

MEASURING FUEL LOADING AND CONTINUITY VIA THE PLANAR INTERCEPT METHOD

Fuel loading and continuity (horizontal distribution of fuels) can be measured more precisely and accurately by using the planar intercept method described by Brown (1974). This sampling technique involves counting 1, 10, and 100-hour dead, woody debris that crosses established transect lines. Counts and measurements are necessary for intact and rotten 1,000-hour fuels. The planar intercept method is good for estimating tons per acre (fuel loading), horizontal continuity of downed woody fuels, litter depth, and duff depth. Calculating fuel-loading is straightforward and can be easily computed using spreadsheet computer software and equation constants. Equation constants for southern tree species are available in Anderson (1978). However, this method of calculating fuel loading does not provide an estimate of living fuel vegetation fuel amounts.

Image 7.11. Example of transect lines used with the planar intercept method to assess fuel loads, horizontal fuel continuity, litter depth and duff depth. *Image courtesy of Aaron Stottlemyer.*

Estimating Duff Moisture Levels Using Field Techniques and KBDI Index

ASSESS THE MOISTURE OF THE DUFF LAYER

In the field, feel the duff layer in several locations with different environmental conditions, such as in the shade and in full sunlight, in order to assess duff moisture conditions via the 'touch test.' Table 7.4 contains detailed instructions. A soil moisture probe can also be used to assess duff moisture, but take care to avoid compressing the duff when measuring.

Table 7.4. Step-by-step instructions for conducting the duff touch test are provided *(adapted from Dixon and Robertson 2018).*

Assessing Duff Moisture: The Touch Test
1. Rake back litter to expose upper duff.
2. Touch test A) Touch the duff B) Does the material stick to your skin? C) Does it feel wet?
3. Dig a little deeper and repeat step 2, as moisture levels can be different throughout the duff, as some deeper layers may be drier than upper layers and vice versa.
4. Repeat step 3 until you reach the mineral soil.
5. Repeat steps 1-4 at multiple trees and locations that represent the different conditions within the site.
6. If your samples of duff moisture across the burn site meet your desired conditions, then you are ready to burn.

Image 7.12. Duff layer accumulation in a 30-year-old slash pine stand with no history of burning since establishment with duff accumulation around the base of trees. Bare mineral soil is the gray color. Duff was approximately 5" deep in the photo. *Image courtesy of David Godwin.*

MONITOR THE TIME SINCE LAST RAIN

The moisture level of the duff is influenced by the number of days since the last rain event. Tracking the weather forecasts for locations as close to the burn site as possible will let you know about possible rain events; however, since rain can vary depending on exact site, it will only be an estimate. Rain events and inches of rain can be monitored directly on site by setting up rain gauges across your burn site and check during the week leading up to the burn. A portable weather station can also be set up in the weeks before the burn to track rain too, though these stations are expensive.

KEECH-BYRAM DROUGHT INDEX (KBDI)

The KBDI value can be related to soil and duff moisture content and provides supplemental information on how dry the soil or duff might be at a given time. KBDI ranges from 0-800 and represents a moisture regime from 0 to 8 inches of water throughout the soil layer. A zero value means that there is no moisture deficiency, while a value of 800 indicates maximum drought conditions. This index is available through some states' forestry commission fire weather websites and national maps of KBDI are also available online through the Wildland Fire Assessment System website (wfas.net). The KBDI should be below a value of about 400 (Table 7.5) to avoid duff consumption (note that duff ignition and fine root damage is still possible with values from 200 to 400), but values also need to be compared to recent rainfall patterns. More information can be found on KBDI in the weather section.

Table 7.5. Fuel characteristics and fire behavior associated with ascending ranges of KBDI (scale: 0-800). KBDI above 400 in heavy turf and organic soils can contribute to significant residual burning and smoke problems.

KBDI Value	Condition
0-200	Soil moisture and large class fuel moistures are high and do not contribute to fire intensity.
200-400	Lower litter and duff layers are drying and beginning to contribute to fire intensity.
400-600	Lower litter and duff layers actively contribute to fire intensity and will burn actively.
600-800	Often associated with more severe drought with increased wildfire occurence. Intense, deep burning fires with significant downwind spotting can be expected.

Estimate Fuel Moisture

Actual measurements of fuel moisture can be captured in the field using various techniques, however, realistically, very few people have time and reason to do so. Methods for estimating fuel moisture exist that are less involved and time consuming and provide more general values. Fine dead fuel moisture can be calculated using a table with data, or online on a website and possibly on some mobile applications. Another simple method for estimating fuel moisture in pine stands is the needle-bending test. The U.S. Forest Service maintains a website which can be used to check dead fuel moisture values online, though the information is for wide geographical areas. The most accurate (though impractical) fuel moisture measurements involve oven-drying samples or fuel moisture sticks. These four methods or references for estimating fuel moisture are discussed in this section.

CALCULATE FINE FUEL MOISTURE ESTIMATES USING TABLES

An easy way to estimate fine or 1-hour fuel moisture is to use a fine fuel moisture content calculator (Table 5). You will need to take on-site readings for temperature and relative humidity to complete the required calculations. These tables will provide a close estimate of the fine dead fuel moisture on your burn that is directly based on relative humidity (RH) and temperature measured on your site and then adjusted based on season, time of day, amount of shading, and a correction factor that is relevant for the southern U.S. If the burn site has a significant slope, then another adjustment factor should be added, which can be found on some dead fuel moisture tables. There are also several phone apps available that can calculate fuel moisture. Be sure that the calculation has a correction for shading or that you correct it yourself. If unsure, you can test your value against the calculator in Table 7.6.

Example Details for Table & Calculator

Date: 13 February 2019
Time: 10:30 AM
On-Site Temperature: 55°F
RH: 42%
Stand description: pine stand with about 75% canopy cover or trees covering about 3/4 of the area
Place: somewhere in the South

Directions for Using Tables

Calculate your Uncorrected or Reference Fuel Moisture

Find your dry bulb temperature (ambient air temperature) on the left side of table 7.6.a, then find your RH value for daytime or night-time across the horizontal axis and write that number.

Example: *the uncorrected fuel moisture would be 6, based on a temperature between 50-69°F & daytime RH between 40-44%.*

Find the specific correction value for the time of day and year and whether the site is exposed or shaded

On table 7.6.b, find the correct time of year and then time of day, then find the value in the same column as the time under either exposed or shaded, depending on site conditions

Example: *Time is between 10 am - 12 pm, and site is shaded, so correction factor is 4.*

Find the corrected fuel moisture value

Add values from steps #1 and #2 together

Example: *6+4=10 (adjusted value).*

Add the Southern U.S. Correction factor

If the adjusted value above is:

<10 then add 1

10 then add 2

Example: *adjusted value is 10, so add 2.*

The fine fuel moisture content estimate is: 12%.

Table 7.6. Example of a fine fuel moisture table for the southeastern U.S. Source: http://weather.state.ga.us/FineFuelMoistureTable.pdf.

Fine Fuel Moisture Table for Southeastern U.S.

7.6.a	Day time 8:00AM - 8:00PM												Night time 8:00AM - 8:00PM											
	Relative Humidity %												*Relative Humidity %*											
Dry Bulb * Temperature (°F)	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89
30-49	5	6	7	7	7	8	9	9	10	10	11	12	7	8	9	9	11	11	12	13	14	16	18	21
50-69	5	6	6	7	7	8	8	9	9	10	11	12	6	8	8	9	10	11	11	12	14	16	17	20
70-89	5	5	6	7	7	8	8	8	9	10	10	11	6	7	8	9	10	10	11	12	13	15	17	20
90-109	4	5	6	7	7	8	8	8	9	10	10	11	6	7	8	9	9	10	10	11	13	14	16	19

7.6.b **Note: dry bulb temperature is the ambient air temperature*

Nov-Jan						Feb- Apr, Aug-Oct						May-July						All Months
Daytime 8AM-8PM						Daytime 8AM-8PM						Daytime 8AM-8PM						Nighttime
8→	10→	12→	2→	4→	6→	8→	10→	12→	2→	4→	6→	8→	10→	12→	2→	4→	6→	No adjustment needed
Exposed - < 50 percent shading of surface fuel																		
5	4	3	2	4	5	4	2	1	1	2	4	3	1	0	0	1	3	
Shaded - > 50 percent shading of surface fuel																		
5	5	5	5	5	5	5	4	4	4	4	5	4	4	3	3	4	5	

CHECK GENERAL DEAD FUEL MOISTURE REPORTS ONLINE

Dead fuel moisture levels are dependent on ambient environmental conditions and are classified by size classes related to time needed for the moisture to change. The USDA Forest Service Wildland Fire Assessment System (WFAS) includes general information on dead fuel moisture for the entire country. The dead fuel moisture values are shown in a map that covers the entire country and includes values from less than 5%, to greater than 30% and water. Information on current conditions and forecasts for 10, 100 and 1,000-hour dead fuel moisture can be found there.

Dead Fuel Moisture Maps

Access the tool here: https://wfas.net
Find the 'dead fuel moisture' tab on the left side navigation under moisture/drought.

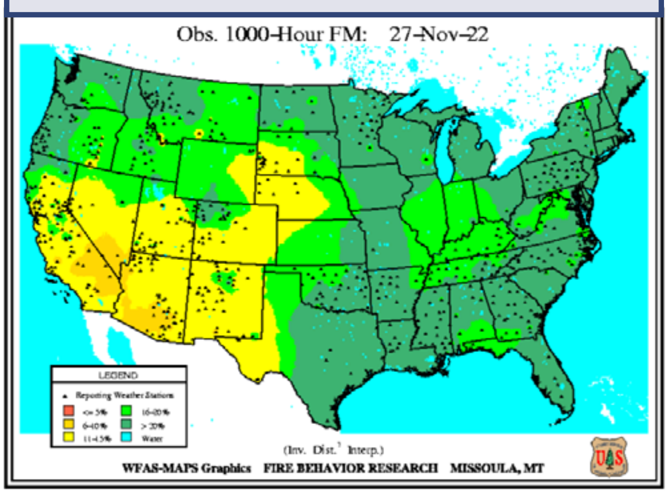


Image 7.13. Map of the observed 1,000 hour fuel moisture.

NEEDLE-BENDING TEST

A third method, that is restricted to fuel types with pine needles, is the needle-bending test. This test should be limited to pine needles that are recently fallen, cured, lack evidence of foliage disease, located on the upper litter layer, and unattached to a branch. Needles from throughout the burn unit are carefully selected and slowly bent into a loop over a ruler or measuring tape. The width of the axis or loop before the needle fractures or snaps has proven to be an indicator of dead, fine fuel moisture when suitable needles are used (Table 7.7). This method provides a general idea of dead fine fuel moisture and several tests should be conducted throughout the stand to obtain an average. Note that this method can be used for fine fuel moisture values between 10-35%, as values above and below this range, cannot be detected using this method.

Image 7.14. Longleaf pine needles being used for the needle-bending test. The width of the axis before the needle breaks indicates the dead, fine fuel moisture. *Image courtesy of Yuna Chitea.*

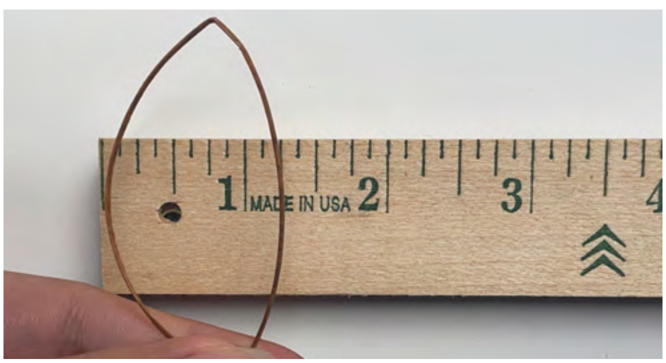


Table 7.7. Pine needle minor axis width after bending when fracture or snapping occurs as related to fuel moisture content (Johnson 1984).

Axis Width	Moisture Content ± (Percent)
1/8	23 ± 5
1/4	21 ± 4
1/2	16 ± 5
>5/8	13 ± 7

CALCULATE FINE FUEL MOISTURE USING THE ONLINE SIMPLE FFMC (ADVANCED*)

A second method is the online SimpleFFMC fine dead fuel moisture content calculator (http://www.wfas.net/ffmc/). This calculator requires field measurements of temperature and relative humidity, while also using values that are determined from reference tables. The calculation flowchart, reference tables and computation worksheet are available online at www.wfas.net/ffmc/docs.

Example Details for Table & Calculator

Date: 13 February 2019
Time: 10:30 AM
On-Site Temperature: 55°F
RH: 42%
Stand description: pine stand with about 75% canopy cover or trees covering about 3/4 of the area
Place: somewhere in the South

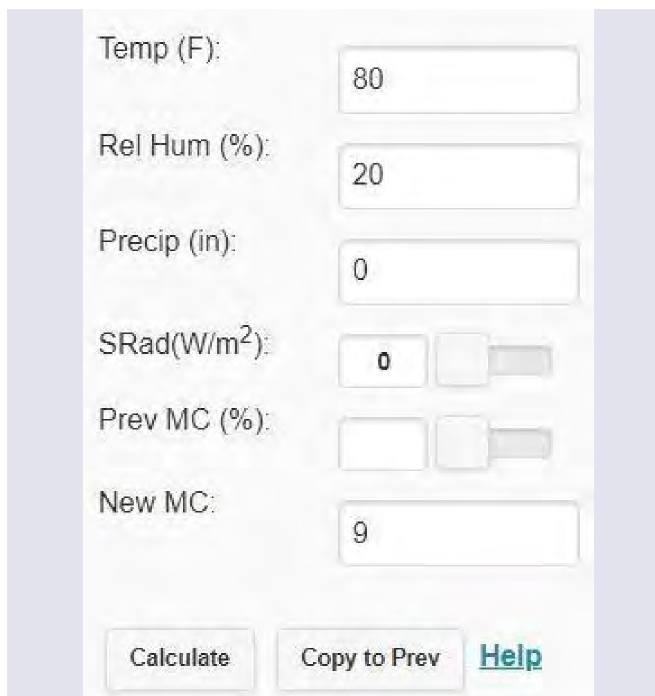


Figure 7.8. The SimpleFFMC calculator is a great online tool for determining dead fine fuel moisture percentages. http://www.southernfireexchange.org/SFE_Publications/factsheets/2016-1.pdf

References:

Anderson, H.E., (1982). Aids to Determining Fuel Models for Estimating Fire Behavior. United States Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report INT-122

Anderson, H.E. (1978). Graphic aids for field calculation of dead, down forest fuels. USDA Forest Service, General Technical Report INT-45. Intermountain Forest Range & Experiment Station, Ogden, UT. 21 p.

Brown, J.K. (1974). Handbook for inventorying downed woody material. USDA Forest Service, General Technical Report INT-16. Intermountain Forest & Range Experiment Station, Ogden, UT. 24 p.

Budny, M.L., Kreye, J.K., Kobziar, L.N. & Camp, J.M. (2017). Fuel Treatments in Pine Flatwoods: A Photo Series Guide for Estimating Vegetation and Fuel Biomass Change over Time Following Mowing and Burning in Southern Pine Flatwoods Forests. University of Florida, School of Forest Resources and Conservation, Southern Fire Exchange. Retrieved from: https://southernfireexchange.org/?s=fuel+treatments+photo+guide

Coalition of Prescribed Fire Councils, & Southeastern Regional Partnership for Planning and Sustainability. Available Fuel Calculator. Retrieved from: http://smokeapp.serppas.org/available-fuel-calculator.html

Dixon, A.K., and K.M. Robertson. (2018). Reintroducing fire into long-unburned pine stands: The duff problem. Southern Fire Exchange Fact Sheet 4. 4 p. http://southernfireexchange.org/SFE_Publications/factsheets/2018-4.pdf.

Johnson, V.J. (1984). Estimating moisture content of litter. Southern Journal of Applied Forestry 8(4): 197-201 pp.

Jolly, M., J. Brenner, and A. Long. (2016) SimpleFFMC: A new calculator for fine fuel moisture content. Southern Fire Exchange Fact Sheet 1. 2 p. http://www.southernfireexchange.org/SFE_Publications/factsheets/2016-1.pdf.

Lynch, C.M., and L.J. Horton. (1983). Photo series for quantifying residues in loblolly pine, eastern white pine, pitch pine, Virginia pine. USDA, Forest Service, NA-FR-25, Northeastern Area State and Private Forestry. Radnor, PA. 69 p.

National Wildfire Coordinating Group (NWCG). (2021). Fire Behavior Field Reference Guide, PMS 437, Dead Fuel Moisture Content, Retrieved from: https://www.nwcg.gov/publications/pms437/fuel-moisture/dead-fuel-moisture-content

Sanders, B.M., and D.H. Van Lear. (1988). Photos for estimating residue loadings before and after burning in southern Appalachian mixed pine-hardwood clearcuts. Asheville, NC: USDA, Forest Service, General Technical Report SE-49. Southeastern Forest Experiment Station. 21 p.

Scholl, E.R., and T.A. Waldrop. (1999). Photos for estimating fuel loadings before and after prescribed burning in the upper coastal plain of the southeast. USDA, Forest Service, General Technical Report SRS-26. Southern Research Station. Asheville, NC. 25 p.

South Carolina Forestry Commission, (July, 2014). Fuel Load Estimation Guide for South Carolina. Retrieved from: https://www.scfc.gov/wp-content/uploads/2021/07/fuelloads.pdf

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

Wade, D.D., K. Forbus, and J. Saveland. (1993). Photo series for estimating post-hurricane residues and fire behavior in southern pine. USDA, Forest Service, General Technical Report SE-82. Southeastern Forest Experiment Station. Asheville, NC. 19 ppd Southern Research Station.80 p.

FUEL NOTES

FUEL NOTES

FIRE BEHAVIOR

Image credit: David Godwin

Table of Contents

Introduction

Fire behavior is the “manner in which fuel ignites, flame develops, and fire spreads ... determined by the interaction of weather, fuels, and topography” (Alexander, M. n.d.). It can also be described by the fire’s rate and direction of spread and intensity. For a fire to burn, there must be fuel available to burn, a source to heat it and oxygen to fuel it, which is called the fire triangle (Figure 8.1). However, a fire behaves in reaction to its environment. This chapter will explore the components and factors that make up the fire triangle and those that influence fire behavior including fire type, season or month burned, flame length, rate of spread, duff thickness, fire intensity, and time of day. Firing techniques, which are the distinct patterns used to ignite a prescribed fire, will also be discussed in-depth. Burn prescriptions account for the variables listed above by including a range of acceptable values for weather. Fuels should also be assessed and then the burn should be ignited using firing techniques that will account for site conditions and topography.

Prescribed fires are planned to select for the conditions that will lead to desired fire behavior. While a prescribed fire can be conducted when weather conditions are within the range of acceptable values, actual fire behavior on the site will be the final test to determine if a burn should proceed. Prescribed fires all start with a test fire, where a small patch of fuels that are similar to conditions throughout the site are lit to see how the fire behaves. Based on the test fire, the burn manager or boss will decide if the prescribed burn should continue or stop. If the burn proceeds, then observing fire behavior and taking a few notes can provide reference for future burns, which is particularly helpful for areas with unique topography. While prescribed fires do not always behave as expected, a good prescription will increase the chances for success and reduce the risks.

The Fire Behavior Triangle

For a fire to burn, there must be fuel available to burn, a source to heat it and oxygen to fuel it, which is called the fire triangle (figure 8.1). However, a fire behaves in reaction to its environment. Fire behavior is a product of the interaction between the physical variables of fuel, weather and topography, also called the fire behavior triangle (figure 8.1). Fuel characteristics, weather conditions onsite and the lay of the land are the three elements that most directly influence how a fire will behave. Each of these factors in the fire behavior triangle are described below.

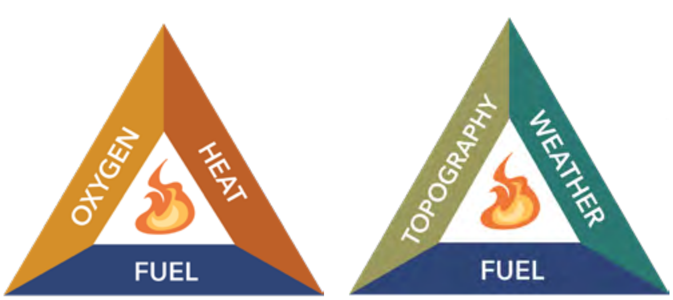


Figure 8.1. The fire triangle (left) & fire behavior triangle (right). These show the ingredients of fire & the 3 environmental factors that affect fire behavior. Fuel is the only one of these five factors that can be manipulated. Fuels managment is a primary objective in firescaping.

FUELS

Fuel characteristics will determine flammability (how easily a fire ignites) and behavior (how it will burn). Fires behave differently depending on the types of fuels present such as grasses, shrubs, trees and slash or blown down material. However, in most areas, there are more than one fuel type present and the vegetation types that are present also influence fire behavior. Different types of vegetation or plant communities have their own structure which influences moisture content and also affects how the vegetation will behave during fire. In addition to types of fuel and vegetation, the amounts present (fuel load), arrangement (vertical and horizontal) and moisture content are significant factors in fire behavior. The chemical make-up of fuels will also influence how they burn. For example, some vegetation, like saw palmettos, have oils, waxes or resins that are especially flammable. How fuels are arranged will influence fire behavior too, as fuels that are packed densely will be harder to ignite and keep burning. In addition, damp fuels with high moisture content will slow the burning process – as many who have tried to burn damp firewood know all too well.

Fuel continuity, sometimes also called fuel distribution, refers to the degree or extent of continuous or uninterrupted distribution of fuels. Fuel continuity typically refers to horizontal fuel distribution of surface fuels and helps determine a stand's ability to carry and sustain a prescribed fire. Vertical fuel arrangement refers to vertical fuel continuity and often to the presence of ladder fuels. Ladder fuels are live or dead vegetation that can carry a surface fire into the midstory and/or tree canopy. If ladder fuels are present and start to burn, they could carry fire to the tree canopy leading to individual trees torching and possibly causing a crown fire, in poor conditions.

Fuel type overall is important for prescribed fire behavior, but it is the surface fuels such as needles, hardwood leaf litter, sticks, bark, small shrubs, grasses, and other understory plants that carry the fire. Therefore, the types of surface fuels, amounts, arrangement, and their moisture content, wind, and other weather factors will all contribute to fire behavior. Ground fuels, which include the organic layer of soil, if ignited, can lead to fire behavior such as smoldering, for long periods of time. Smoldering can often cause damage to trees and smoke management issues. Before burning, fuels should be assessed and the burn should be ignited using firing techniques that will account for site conditions and topography.

1 Hour or Fine Fuels are fuels such as grass, pine, needles, moss, twigs and slash that is less than 1/4 inch in diameter. It dries out and burns quickly.

10 Hour fuels range from 1/4 inch to 1 inch in diameter and include twigs, sticks, etc. in that size range.

Spotting: Spot fire or spotting refers to the accidental creation of a new fire outside of your established unit, generally by embers traveling over the fireline.

Table 8.1. This Texas A&M relative humidity table explains the ranges of relative humidity and how it impacts fuels and fire behavior. Reference fuel moisture adjustment table. Sourced from the Texas A&M Agrilife Extension Prescribed Burn Handbook.

Fire Intensity Related to Fuel Moisture			
RH %	Fuel Moisture %		Relative ease of chance ignition and spotting, general burning conditions
	1-Hr	10-Hr	
>60	>20	>15	Very little ignition – some spotting may occur with winds in excess of 9mph
45-60	15-19	12-15	Low ignition hazard – campfires become dangerous; glowing brands cause ignition when RH is <50%
30-45	11-14	10-12	Medium ignitability, matches become dangerous; "easy" burning conditions
26-40	8-10	8-9	High ignition hazard – matches are always dangerous; occasional spotting or crowning caused by gusty winds; "moderate" burning conditions
15-30	5-7	5-7	Quick ignition, rapid-build up, extensive crowning; any increase in wind causes increased spotting, crowning, loss of control; fire moves up bark of trees igniting serial fuels; long distance spotting in pine stands; dangerous burning conditions
<15	<5	<5	All sources of ignition are dangerous; aggressive burning, spot fires occur often and spread rapidly, extreme fire behavior probable; critical burning conditions

WEATHER

Weather is the most dynamic of the three fire behavior triangle categories. Wind, temperature, and humidity, are the most important weather variables for a burn prescription and significantly affect fire behavior. Lack of wind or very low wind speed may slow the fire, while high wind speeds may lead to the fire spreading faster than wanted. If the wind changes direction significantly during a prescribed fire that is more complex, then firing technique may need to be changed or the burn stopped altogether. Some wind conditions such as unstable winds and updrafts (winds that flow from the bottom of a steep area to the top), can be responsible for blowing embers over firebreaks and igniting spot fires. The relative humidity (RH) values are connected to the moisture level of the smallest fuels (1-hour fuels) and too high of RH means that a fire may not burn, while too low of values can lead to more intense fire conditions (Table 8.1). Hot temperatures, low humidity levels, and wind can combine to dry fuels, increase fire behavior, and strongly increase spotting potential.

Image 8.1. *Image courtesy of Matt Jones.*

TOPOGRAPHY

Topography refers to the surface of the land and includes elevation, slope, aspect (the cardinal direction a slope faces), and geological features. Topographic features are generally permanent, unalterable, and may require special consideration when planning a burn. Slopes impact fire behavior in a number of ways, requiring the use of different firing techniques. Steep slopes increase the fire's spread across the terrain. Fires running up steep slopes are often more intense and move quickly due to rising hot air that dries and preheats fuels ahead of the flaming front. This is because heat rises as the sun warms the slope throughout the day creating an upward moving current, and the fire preheats the fuels upslope, allowing them to dry and ignite faster than they would on a flat area (Figure 8.2). Winds in hilly or mountainous areas may also impact fire behavior. For example, winds may blow upslope during the day but tend to blow downslope at night.

Image 8.2. Prescribed burns implemented on flat topography may spread slower than those on steep slopes. *Image courtesy of Matt Jones.*

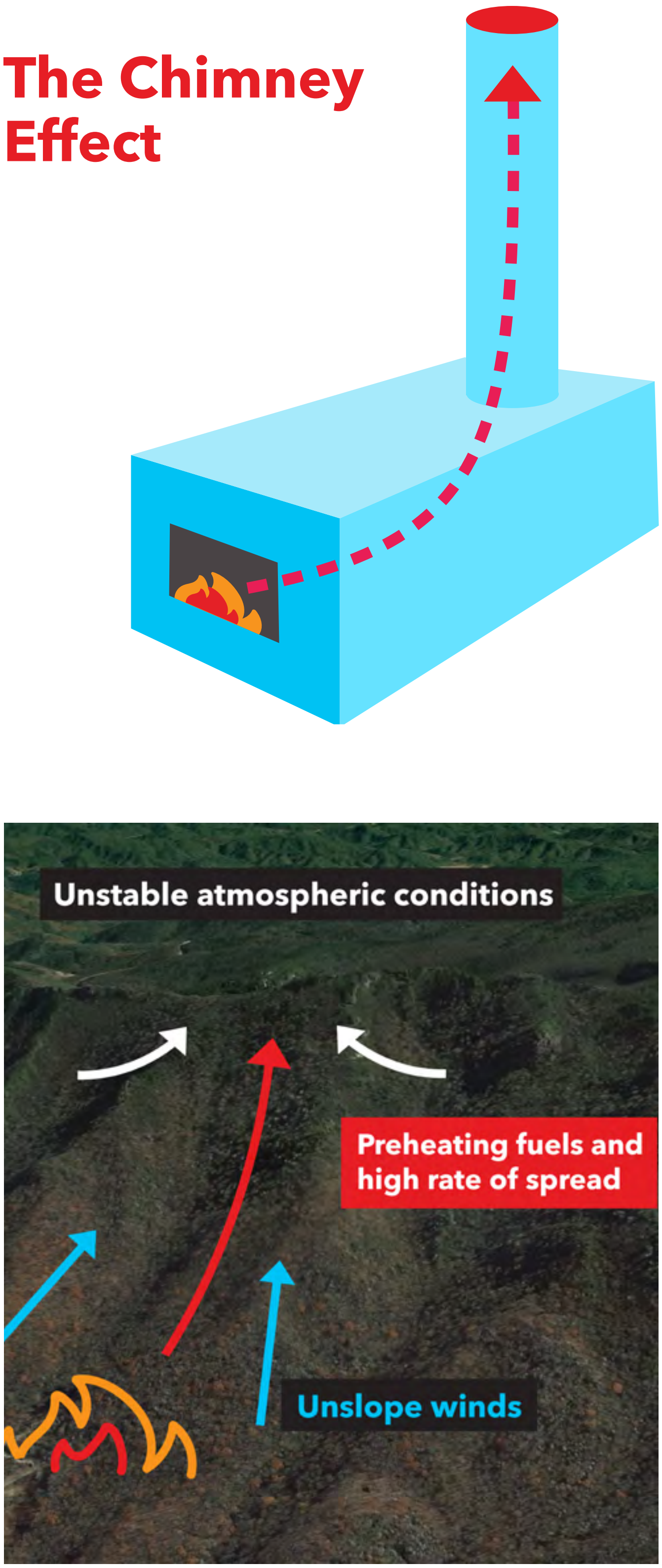


Figure 8.2. Demonstrating the nature of the chimney effect in a mountainous landscape. *Diagram credit: Jessica Shaklee.*

The shape of the slope and terrain impact fire behavior. For example, in areas in the Appalachian Mountains with deep hollows between slopes – known as draws – upslope winds often funnel through these draws to create what is called a chimney effect (Figure 8.2). The chimney effect occurs when unstable air conditions at the top of a draw create a strong convection current through the draw. When the chimney effect is combined with additional upslope winds, the resulting fire can move extremely fast. The aspect (or the compass direction that a slope faces) of an area also impacts fire behavior. South-facing slopes tend to be drier, while north-facing areas are often cooler and wetter. Burns on these south-facing slopes often burn with greater intensity due to the drier vegetation.

Measuring Fire Behavior

FLAME STRUCTURE

Flame structure consists of three values: flame length, height and zone depth (Image 8.3). **Flame length** is the distance from the ground at the leading edge of the flame to the flame tip. Flame length is important as it is an indicator of fire intensity. When Flames are longer than 4 feet, then they are too intense for a person to be close, and a handline (hand-dug fire break) is unlikely to contain the fire. Flame length is related to flame height. **Flame height** is the average height of flames as measured vertically, up and down. It may be less than flame length if the flames are angled in the horizontal direction, backward or forward. **Flame depth, or flame zone depth**, is the distance from the base of the flames to the trailing edge of the flaming front of the fire.

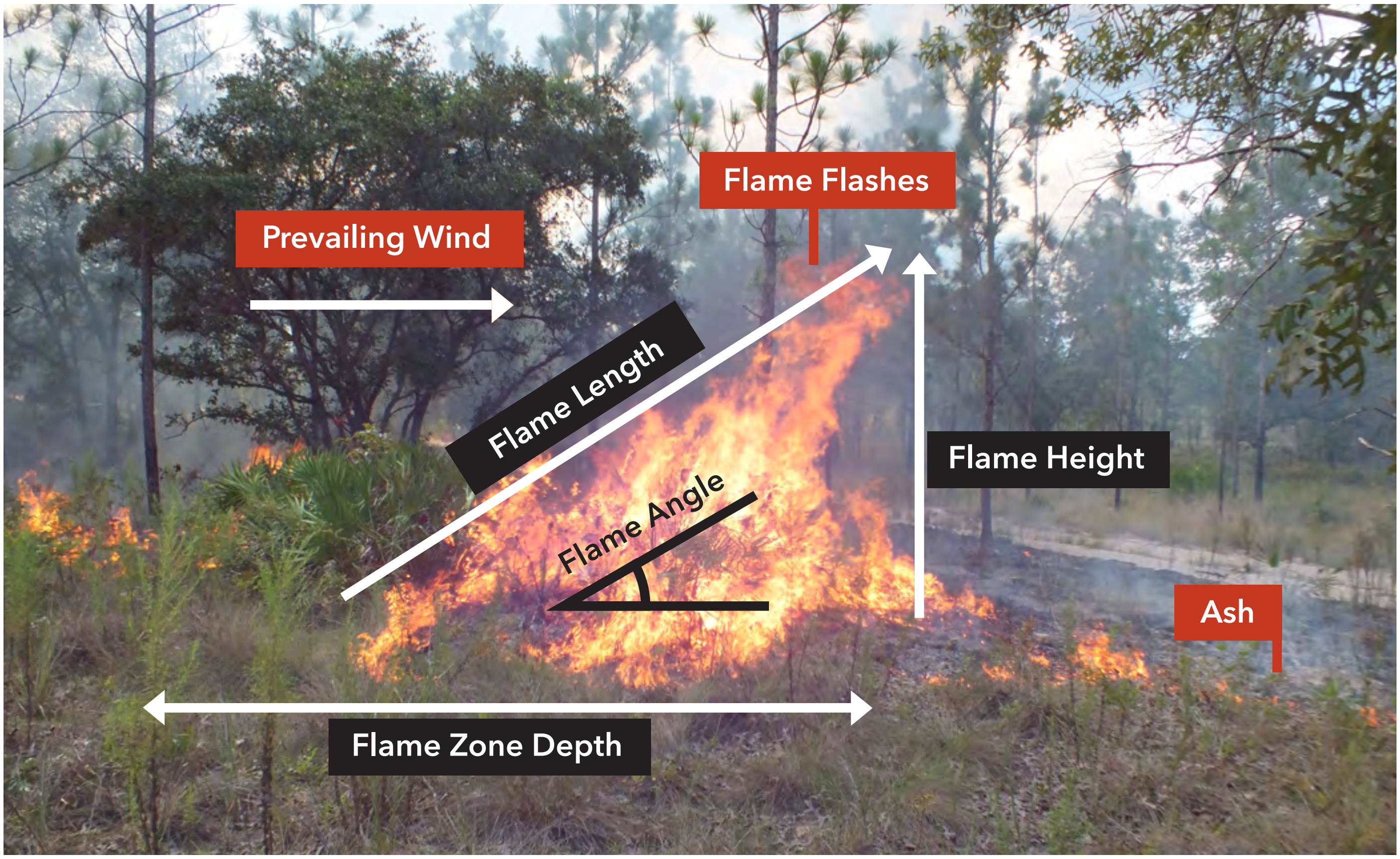


Image 8.3. Flame structure elements. *Image courtesy of John Herbert Ashton.*

RATE OF SPREAD

Rate of spread is the speed at which the fire moves across the landscape and can be measured in feet per minute, chains per hour, or miles per hour. It is affected by firing technique, fire intensity, fuel conditions, wind, topography, and vegetation. For example, a fire burning up a slope will spread faster than a fire burning in the same conditions across a flat area. Similarly, wind that drives the fire can increase the rate of spread, while wind blowing against the direction the fire is moving can decrease its rate of spread.

A chain is a unit of measurement commonly used in wildland firefighting and is equivalent to 66 feet (or 22 yards).

Image 8.4. Photographing your burn can allow you to assess flame structure at a later date. *Image courtesy of Barry Coulliette.*

Table 8.2. Descriptions of wildfire behavior observations and interpretations, *adapted from Fire Behavior Field Reference Guide, PMS 437*

Flame Length	Typical Fire Behavior	Rate of Spread	Interpretations
<1 foot	Very low, smoldering	0 - 132 ft/hr	Not spreading. Limited flaming. Handline holds.
1 to 4 feet	Low, creeping, spreading	132 - 330 ft/hr	Fire behavior is manageable. For these flame lengths, a hand dug firebreak should hold fire.
4 to 8 feet	Moderate, running	396 - 1320 ft/hr	Fires are too intense for people to be near, and a small hand-dug firebreak would not hold the fire.
8 to 11 feet	High, torching, and spotting	1320 - 3300 ft/hr	Fire may present serious control problems: torching, crowning, and spotting. Controlling this fire at the main point of spread or head will probably be ineffective.

Images 8.5 (top) & 8.6 (bottom). Flame length can be impacted by many factors, including fuel type and firing technique. Flame lengths in a backing fire in grass fuels (top) are typically much shorter than flame lengths and heights in more volatile fuels, such as palmetto (bottom). *Images courtesy of Leslie Boby & L. Ellie Fowler.*

Fire Intensity

Fire Intensity is the thermal energy released by fire per unit time per unit area and should be expressed in terms of kw / m2 / sec-1. It is influenced by the same factors as rate of spread. While fire intensity is often used interchangeably with fire severity, they are not the same. Fire severity describes the short, intermediate and long-term effects of fire on vegetation, litter, or soils. Severity is a variable that is often reviewed when conducting an evaluation after a burn.

Fire or Burn Severity

Fire or Burn Severity describes the short, intermediate and long-term effects of fire on vegetation, litter, or soils. Severity is a variable that is often reviewed when conducting an evaluation after a burn.

FIRE EFFECTS

Fire effects from previous prescribed burns (or wildfires), if they have occurred, will impact fire behavior. Fire effects are the physical, biological, and ecological impacts of fire on the environment. After a prescribed fire, the burn unit is evaluated to determine whether the objectives of the burn were met. The Evaluation section of this guide discusses fire effects and how to evaluate them in detail.

Fuels Management & Fire Timing

FUELS MANAGEMENT

Fuels are managed or treated in order to modify potential fire behavior or fire effects so that a desired objective can be reached. How a stand has been managed and the resulting site history are key factors in determining fire behavior. This topic is discussed in more detail in the Fuels section (page 157) of this guide. Prescribed fire is a fuel treatment by itself and the time since the last burn is one of the key factors that will affect the current prescribed fire. For example, a longleaf pine stand site that is routinely managed with fire will have very different fire behavior than a loblolly pine stand with a substantial hardwood midstory that has not been burned in many years. The loblolly pine stand is more likely to have thick layers of duff or other ground fuels. Burning stands with thick ground fuels require skill and precision, and if you are considering doing so, it would be wise to consult an experienced burner first. The frequently burned pine stand, in contrast, will be much easier to burn, as the fuel loading is smaller and it is likely that there are not many midstory fuels present.

In many cases, a site may include more than one kind of fuel treatment. Fuel treatments focus on vegetation removal, using mechanical means (thinning or mastication) or through chemical means (herbicides). In a thinning treatment, trees are cut down to 'thin' the canopy, so that the trees left will have more space between them to grow. Reducing the number and arrangement of trees can reduce fire risk as it may eliminate ladder fuels and open up the canopy. Herbicides are used to chemically treat unwanted plants and shrubs, and can kill midstory trees or shrubs that could change fire behavior, or reduce the number of plants in the understory. Mastication involves using a machine to cut, chop and chip vegetation mechanically and the resulting material is left on the ground. Mastication can remove fuels in the mid and understory, which again can remove fuels that could potentially carry fire into the canopy. However, since the chipped or ground fuels are left on the ground, they can increase fuel loads on the ground and contribute to more smoldering combustion.

Overall, mechanical or chemical fuel treatments mostly decrease the amount of fuel present, remove undesirable vegetation and change the architecture of the remaining fuel. These treatments can reduce the chances of wildfire, and improve the health and ecosystem function of the forest or grasslands. For sites that have not been burned in a long time, these treatments may be necessary before prescribed fire can be used at the site. However, once fire is reintroduced and the area is burned at a regular frequency, then prescribed fire may be the only fuel treatment needed.

SEASON OR MONTH OF BURN

In many jurisdictions, burns can be conducted year-round, provided prescription conditions are met and no burn bans are in place. However, the time of year a burn is conducted can greatly impact the behavior and effects of prescribed fire. The best time of year to burn will depend on your location, burn objectives, and available burn windows. Fire behavior can vary significantly within a month or season depending on other factors such as fuels and weather.

Burns are often referred to as growing season or dormant season burns. Growing season burns are conducted in the late spring to early fall when vegetation is actively growing, and deciduous trees and shrubs have foliage. Dormant season burns are conducted in late fall to early spring when vegetation is not actively growing, and deciduous trees and shrubs generally have dropped their foliage.

Many landowners manage their land for wildlife habitat, and they may burn during a specific month or season in order to create conditions preferred by that wildlife species. While there may be some recommended seasons for burning for wildlife habitat improvement, it is better to burn when conditions fit rather than missing a burn window.

If weather conditions fit your burn prescription, it is best to burn, rather than waiting for a specific season or month.

Table 8.3. Information on burning for different objectives (adapted from Coordination of Burning table from https://www.srs.fs.usda.gov/pubs/su/su_srs054.pdf pg. 67-68). **These guidelines are general and will not fit all situations.**

PURPOSE	SIZE OF BURN	TYPE OF FIRE	FREQUENCY	REMARKS
REDUCE FUELS	Large enough to break fuel continuity	Not critical. Do not use a ring fire	2 to 4 years	Use line-backing fire, or point source fires under moist conditions for initial burn. Grid-firing techniques excellent for maintenance burns.
IMPROVE WILDLIFE HABITAT	–	Do not use a ring fire technique for wildlife habitat	–	General – Protect transitional or fringe areas. Do not burn stream bottoms.
Deer	Small or leave unburned areas	Backing or point-source	2 to 4 years	Want to promote sprouting and keep browse within reach. Repeat summer fires may kill some rootstocks.
Turkey	Small or leave unburned areas	Backing or point-source	2 to 4 years	Avoid burning during nesting season, which varies slightly depending on your location
Quail	~25+/- acres in patchwork	Not critical	1 to 2 years	Avoid nesting season, late April to June
Dove	Not critical	Not critical	Not critical	Leave unburned patches and thickets.
Waterfowl	Not critical	Heading fire	2+ years	Marshland only. Do not burn in hardwood swamps.
CONTROL COMPETING VEGETATION	Not critical	Not critical. Do not not use a ring fire	2 to 8 years	Summer burns result in higher rootstock kill and affect larger stems. Exclude fire from desirable hardwoods in pine-hardwood type.
IMPROVE FORAGE FOR GRAZING	Not critical, but will be "overgrazed" if too small for herd.	Not critical. Do not not use a ring fire	3 years	Split range and burn one-third each year. Individual herbs and grasses respond differently to fire season of burn. Consult expert.
IMPROVE ACCESSIBILITY	Varies with individual situation	Depends on amount of fuel present	As needed	Time with other resource objectives, which will dictate size, timing and frequency of burn.
CONTROL DISEASE	Depends on size of infected area. Include a buffer strip	Strip-heading or heading	2 to 3 years	Burn when humidity is above 50%. Avoid leaving unburned pockets of infected seedlings within of adjacent to burn.

Table 8.3. Information on burning for different objectives (adapted from Coordination of Burning table from https://www.srs.fs.usda.gov/pubs/su/su_srs054.pdf pg. 67-68) (Continued).

PURPOSE	SIZE OF BURN	TYPE OF FIRE	FREQUENCY	REMARKS
ENHANCE APPEARANCE	Varies with each situation	Backing or point-source	1+ years	Requires precise precription to protect vegetative type changes. Know effect of fire frequency and season of burn on both annual and biennial flowering plants. Provide pleasing visual lines.
PERPETUATE FIRE DEPENDENT SPECIES	Will vary with species	Will vary with fuel conditions and species requirements.	Will vary with species	Fire intensity, timing and frequency all dictated by species requirements.
YOUNG PINE STANDS	Varies with size of stand	Backing fire	2 to 4 years	Varies with pine species. Longleaf pine can be burned earlier, while other pines may need to be at least 3" in diameter & 10+ feet tall. Burn only after a strong cold front with rain.
DISPOSE OF LOGGING DEBRIS	Small areas mean fewer nighttime smoke problems	Not critical	–	Smoke management is a must! Take care not to damage soil or water resources with these hot fires. If a broadcast burn will not meet objectives, pile – do not windrow debris.
PREPARE SITES FOR SEEDING (NATURAL SEEDING)	Large enough to prevent concentrations of bird and rodents (usually 10 acres of more).	Not critical. Do not use a ring fire.	–	Be careful not to kill seed trees. If logging debris is present, manage your smoke. Burning is recommended in summer to early fall, prior to seed dispersal.
PREPARE SITES FOR SEEDING (DIRECT SEEDING)	Large enough to prevent concentrations of bird and rodents (usually 10 acres of more).	Not critical. Center firing with helicopter preferred if slash present.	–	If logging debris is present, smoke management is a must! Take care not to damage soil or water resources with these hot fires. Burning is recommended in fall to late winter in preparation for spring sowing, or in the previous winter for fall sowing of longleaf.
PREPARE SITES FOR PLANTING	Large enough to prevent concentrations of bird and rodents (usually 10 acres of more).	Not critical. Center firing with helicopter preferred if slash present.	–	If logging debris is present, smoke management is a must! Take care not to damage soil or water resources with these hot fires.

Image 8.7. Tall Timbers Prescribed Burn early morning. *Image courtesy of Kevin Robertson.*

FIRE TIMING (DAY/SEASON)

Time of day also plays a significant role in fire behavior; this is because some weather patterns often vary predictably at certain times of day (see Chapter 5 – Weather for more detailed information). These weather patterns can vary depending on location. For example, in coastal areas sea breezes may be important weather patterns that impact winds in the morning and evening.

Prescribed fires are often ignited in the morning after the dew has had a chance to evaporate. This timing allows surface inversions from the previous night to lift. Burning during the day has numerous advantages. Wind speeds are generally higher and wind directions are steadier. Higher wind speeds mean that ignited areas will be more likely to catch and carry fire quickly, while steady winds will aid in smoke dispersal. Day burning also generally has the advantage of an unstable atmosphere, which further aids smoke dispersal as it encourages vertical diffusion and prevents persistent smoke from lingering on the ground.

Smoke from night burns tends to remain for a longer period of time and collect in depressions because the atmosphere is more stable and less steady winds are present. Most night burning occurs during the winter to early spring months when a cold front pushes through. Cold fronts encourage strong, persistent winds and the relative humidity (RH) remains steady.

Inversions: Normally, as altitude increases, the temperature decreases due to changes in air pressure. An inversion is what occurs when it gets warmer at high altitudes instead of cooler.

Firing Techniques

Firing techniques refer to the pattern and method of lighting a prescribed fire. Without careful planning and the use of appropriate firing techniques, a fire can change its direction, speed, and intensity as it interacts with the elements of the fire behavior triangle (fuel, weather, and topography). Different firing techniques enable using these interactions to produce desired fire behavior and achieve burn objectives. Some firing techniques, such as backing and flanking fire, are both a technique and a direction of travel.

Firing techniques are selected based on burn objectives, fuels, topography, observed fire behavior, and weather factors (Table 8.4). For example, if the burn site has a significant buildup of surface fuels (such as heavily compacted pine needles or leaves) and the objective is to open up the forest floor to mineral soil, then the burn plan may include a backing fire for slow, steady consumption of those fuels. Conversely, another site may have surface fuels that have formed a substantial duff layer, and the burn plan may call for using techniques that create a fast-moving fire to consume the top layer of duff and avoid smoldering. The techniques

Image 8.8. *Image courtesy of James Johnson.*

Table 8.4. Types of firing techniques and fire spread.

Fire Type	Direction of fire	Intensity	Temperature	Rate of Spread	Ease of containment or control
Backing Fire	Against the wind, or downslope	Low	Generally, the coolest fire type	Slow	Easiest
Flanking Fire	Fire spreads at right angles (90°F) to the wind	Moderate	Cooler than heading fires, but can become hotter	Medium	Moderate - Difficult
Heading Fire	With the wind	High	Hottest	Fast	Difficult

Proceed with Caution When Lighting More Lines of Fire Inside the Burn Unit During the Fire – Internal Ignition

Strip-head fires, point-source fires and flanking fires all require burners to enter the burn unit while lighting, often called internal ignition. To safely ignite within the burn unit, ensure there is a way to communicate and coordinate with the burners, to avoid a burner becoming surrounded by fire (sometimes called entrapment).

Aerial Ignition

Aerial ignition refers to the use of aircraft such as helicopters and drones to ignite prescribed fires. These aircraft often drop small ping pong ball like devices injected with a chemical that causes them to ignite. Private landowners are unlikely to use these methods, but state agencies and contractors often have them available. Aerial ignition is usually used for prescribed burns on large, continuous areas.

described below will also vary in their relation to the wind. It is common for the burn boss to use more than one firing technique to achieve burn objectives, particularly as conditions change over the course of a burn.

Convergence - Some firing techniques will use convergence to control intensity and movement. Convergence fire occurs when two flames or flame fronts meet. As a flame burns and consumes oxygen, it creates a convection column where the heat rises and an area of low pressure around the base. Thus, around the base of the column, there is a resulting air void that is filled by the air rushing in around it. When two flames are near each other they will pull together, increasing in intensity and speed. When the flame fronts meet, expect an increase (often up to a tripling) of flame length and intensity.

Residence time - Residence time is the duration of contact a fuel has with a flame. While a backing fire may be less intense, it has a much longer residence time and can transfer more energy to surface and ground fuels, giving them a higher probability of ignition. Conversely, a head fire has a very short residence time and will tend to consume smaller, dry fuel rapidly but have a lower chance of igniting wetter larger fuels or duff. Note that if fuel moistures indicate that a given fuel is available prior to ignition then expect ignition regardless of the technique used.

Slopes and firing techniques - Burning in areas where slope is a factor can be complex. Burners should strongly consider working with an experienced burner when planning and conducting burns on significant slopes. On sites with significant slope, prescribed burners may want to consider starting their burns at the top of the slope and working their way down, so as to avoid the fast-moving fires that often occur when a fire burns from the bottom to the top of a slope.

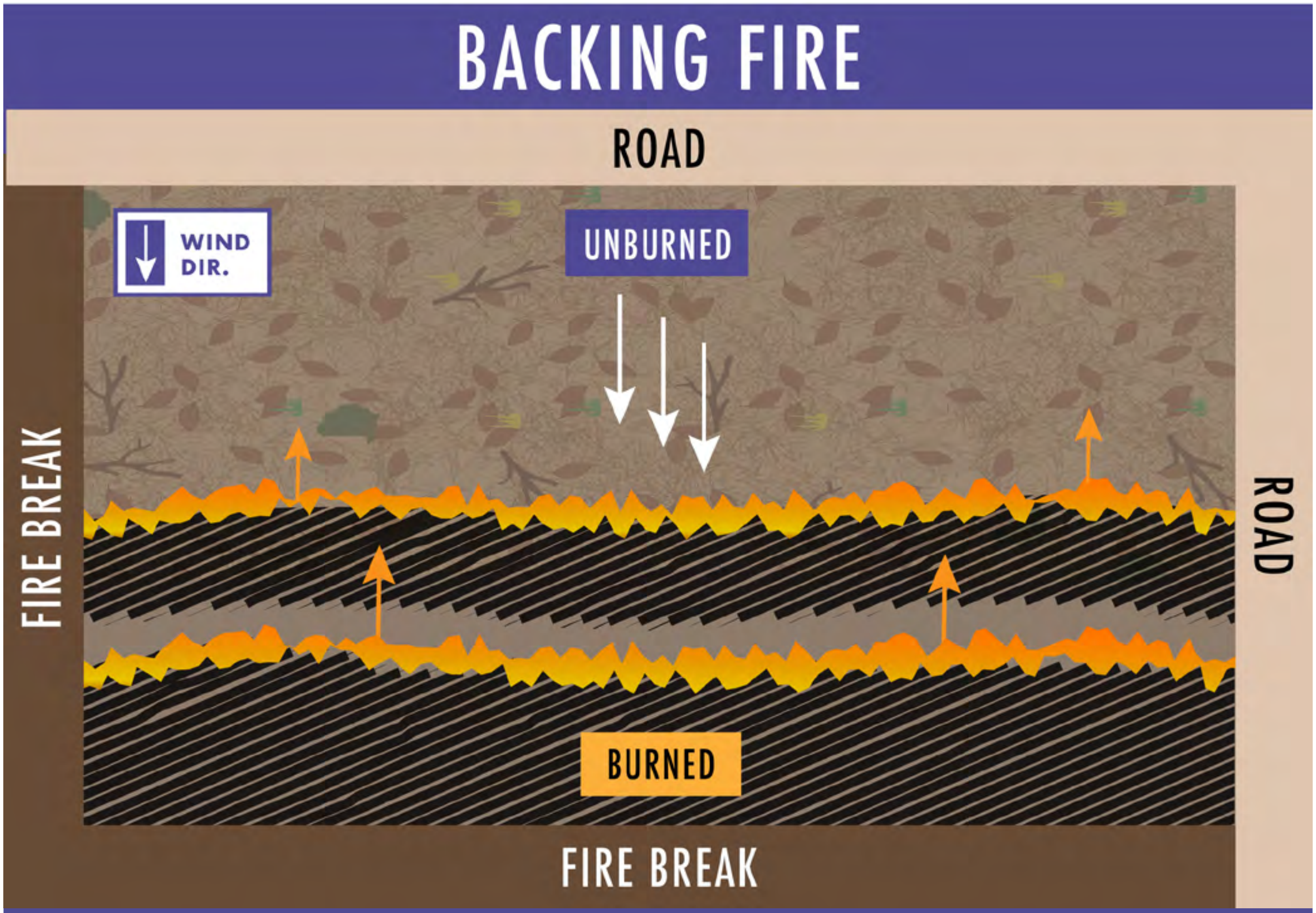


Figure 8.3. Backing Fire. *Diagram credit: Melanie Quinton & Jessica Shaklee.*

In a backing fire, the fire slowly burns fuels and moves against the wind. This encourages shorter flame lengths. Backing fires typically move about 60-200 feet, or about 1-3 chains, per hour – a relatively slow rate of spread and short flame lengths, among other factors, mean that backing fires are relatively easy to control and use – making them particularly useful when lower intensity and shorter flame lengths are desired. Backing fires play an important role in safety and are used to some extent on nearly every fire to burn out "blacklines" land safety zones before other firing techniques are implemented.

One challenge with backing fires is the possible extended residence time. If the fire is spreading slowly, (extended residence time), then the surface and ground fuels can ignite, damaging the small roots of trees, called feeder roots. Extended residence time can cause prolonged smoldering without sufficient moisture. This can be a major problem in forests with a substantial duff layer. See the Ground Fuels section on page 161 and chapter 7, for more information on measuring and managing duff.

Backing fires slow progression presents another challenge. Because they move slowly, they require a longer burning time. This means burners using a backing fire as their primary firing technique may be more likely to encounter weather shifts or run out of time before burning conditions change or become unfavorable. This is compounded by the fact that the technique is often used in the winter when larger fuels and duff moisture is high, but the days are shorter. Backing fires may also be more expensive to conduct than burning techniques that move faster, as they will require resources to be available for longer time periods.

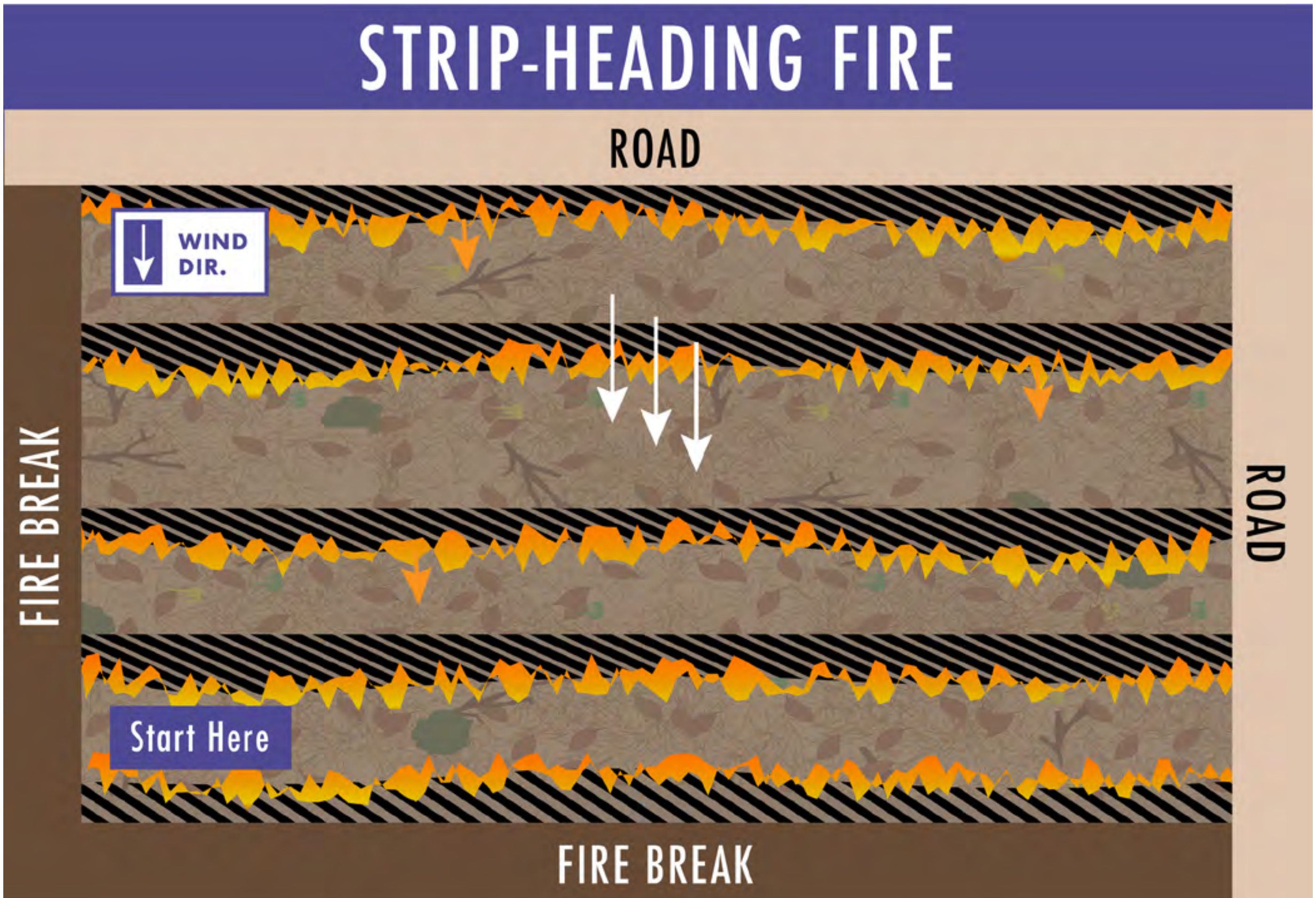


Figure 8.4. Strip-heading Fire. *Diagram credit: Melanie Quinton & Jessica Shaklee.*

As a type of head fire, strip-heading fires are ignited to burn in the direction of the prevailing wind – making them faster and more intense than other prescribed fire types. A strip-heading fire requires a series of lines of fire that are set progressively upwind of a firebreak. The purpose of these patterned lines is to prevent any individual line of fire from gaining too much energy before it reaches another line of fire or a firebreak. In general, a backing fire is first used to secure an anchor area. From there, strip heading fires are used to carry fire through the burn unit. The distance between strips can be adjusted while burning and should be based on anticipated and observed fire behavior. Strips that are farther apart will allow a headfire to burn for a longer distance, and generally become more intense than strips that are closer together. The burner can adjust the distance between strips to achieve desired flame length and mitigate fire intensity. Expect increased fire activity, scorch and fuel consumption where flame fronts meet due to convergence.

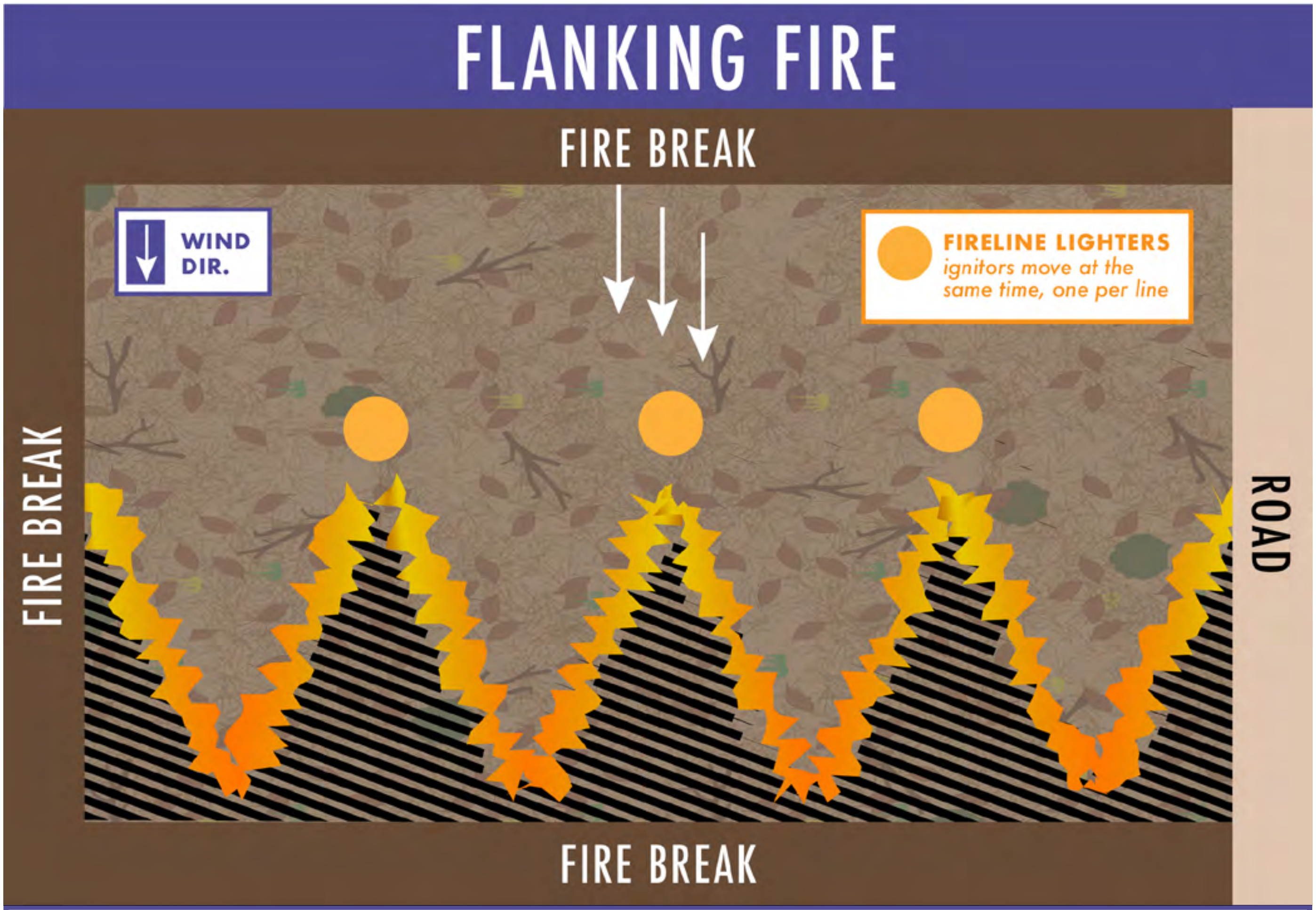


Figure 8.5. Flanking Fire. *Diagram credit: Melanie Quinton & Jessica Shaklee.*

Flanking fires are set by igniting multiple lines of fire directly into the wind, simultaneously. You will need multiple drip torches and enough people to light the lines at the same time. As with most techniques, a backing fire should be set first to secure the downwind area. Flanking fires move at 90-degree angles or parallel to the prevailing wind direction. They are considered the middle ground (with respect to intensity) between heading fires and backing fires. If flanking fire lines are set closer together, then the fire will burn more intensely, but if they are set farther apart, then it will be less intense.

Flanking fires are often used to secure the flanks of a backing or strip-heading fire as it progresses. They are most useful in small areas or to facilitate the quick burning of a large area. This method requires considerable knowledge of fire behavior and a consistent wind direction to be implemented safely. Wind shifts can cause a flanking fire to become a head fire – which will move more quickly and burn more intensely. This can cause dangerous conditions for burners, particularly on heavily wooded sites where personnel may find it difficult to ignite lines and move out of the way in a timely manner.

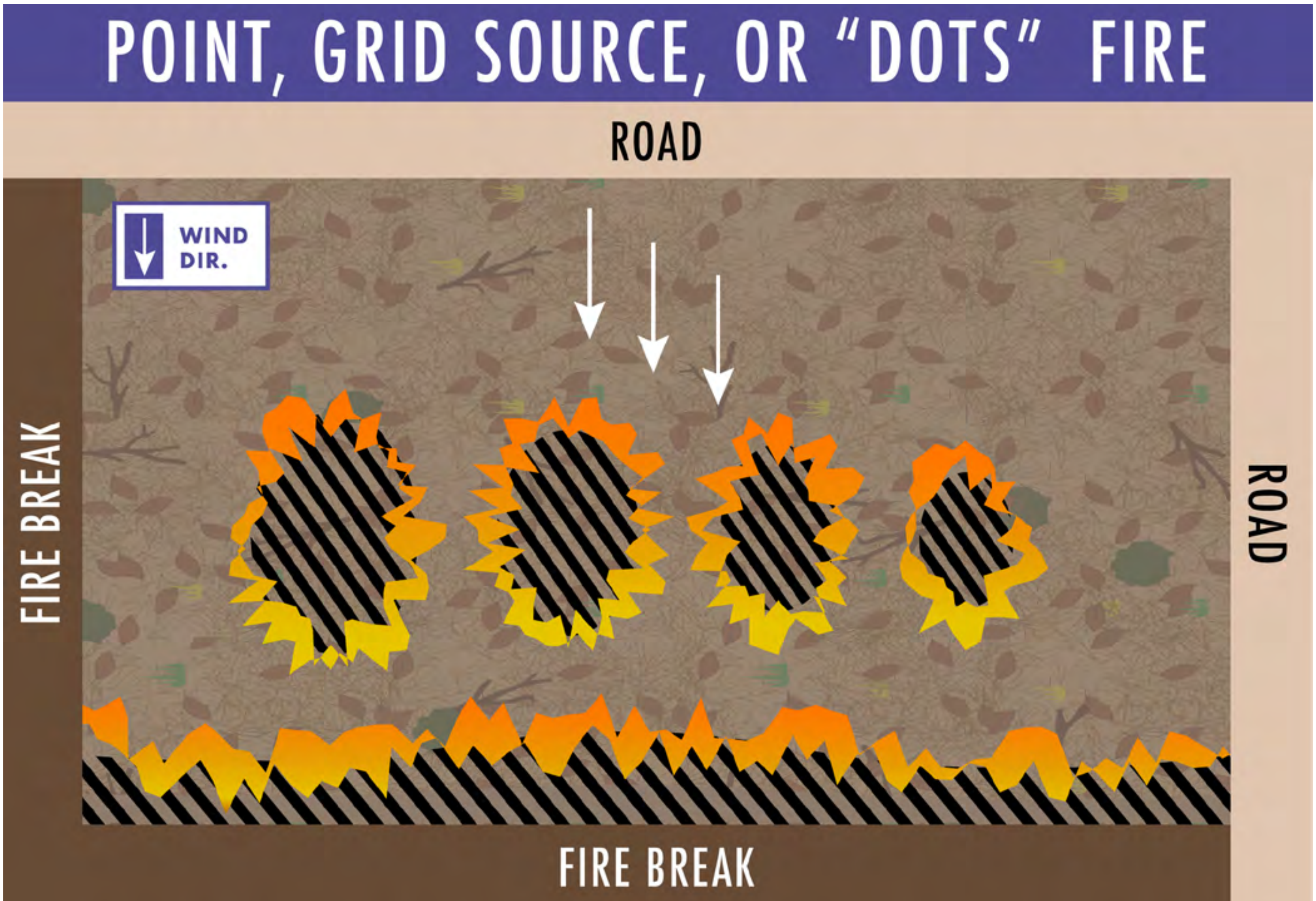


Figure 8.6. Point Source Fire. *Diagram credit: Melanie Quinton & Jessica Shaklee.*

Point source fires, also called dot or spot ignition, utilize convergence to create a mosaic of intensities across the landscape. This firing technique is generally first preceded by a backing fire on the downwind side of the burn unit that creates a secure firebreak. A line of spots is then ignited at a specified distance upwind of the backing fire. This process continues in a grid-like pattern until the entire burn unit is sufficiently consumed. The person in charge of the burn controls the intensity by adjusting ignition rates as differing fuels and weather variables are encountered. The spacing of the grid determines the intensity by controlling the amount of convergence and head fire. For example, the intensity of a point source fire can generally be lowered by widening the distance between ignition points. Spots should be spaced such that they reach the down wind backing fire before burning together. If spots burn together first, then a strip head fire is created, defeating the purpose of the grid. This technique is used to achieve less intense fire behavior than strip-heading fires and can be particularly useful when continuous strips of fire are too intense, or when weather conditions and fuels are leading to undesirable fire behavior.

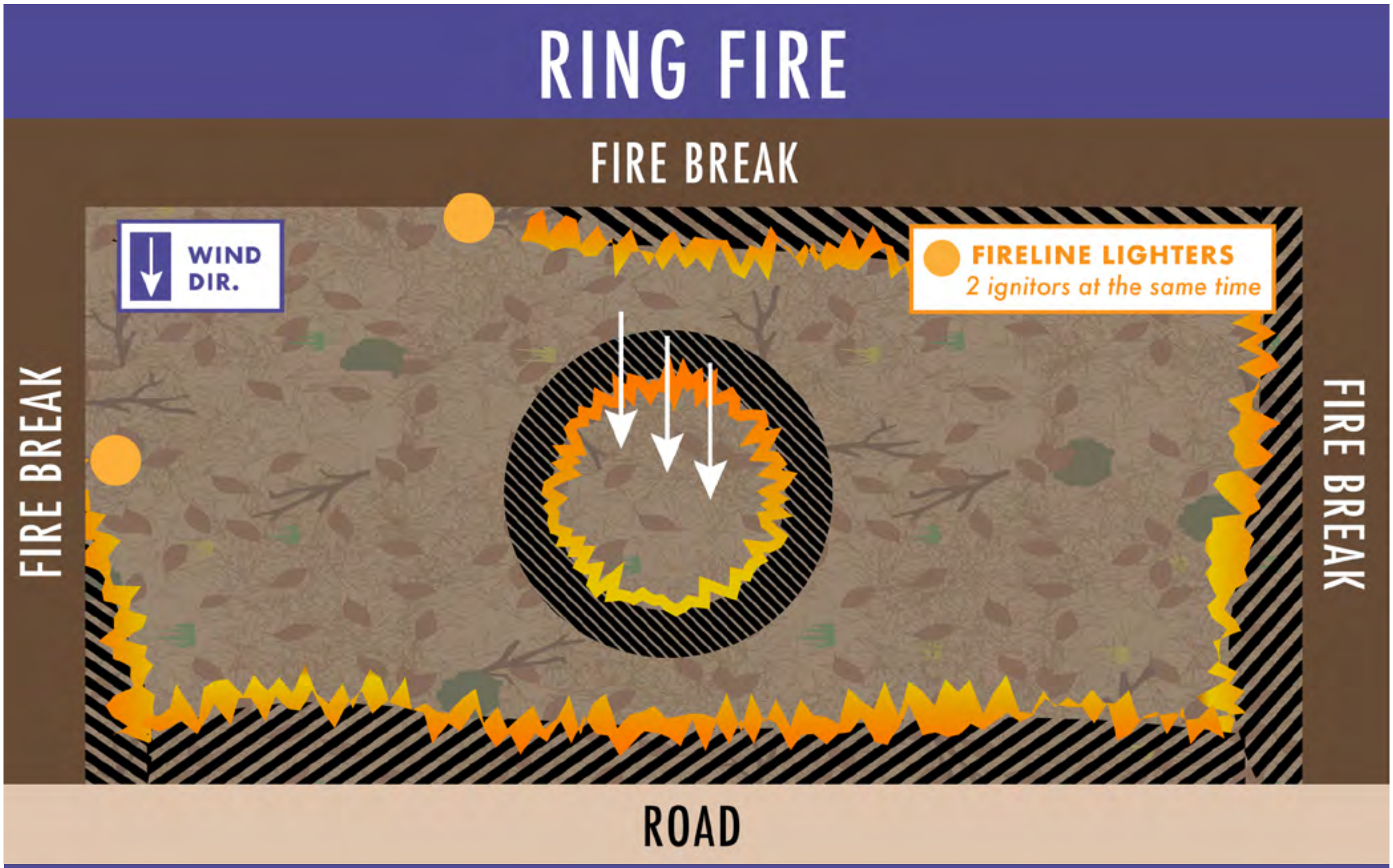


Figure 8.7. Ring Fire. *Diagram credit: Melanie Quinton & Jessica Shaklee.*

The ring or circular firing technique often burns hot and is useful on cutover areas where an intense fire is needed to reduce or eliminate logging debris. These techniques are not typically used in understory burns – they burn hot and will likely scorch, if not kill, trees in the stand. In these fires, a backing fire is used to secure a base line downwind. From there, burners will ignite one or two spot fires in the center of the burn unit and then the entire perimeter is lit. The inner fires should create sufficient vertical heat to pull the outer fire inward towards the center of the burn unit. Ring fires are generally started with a backfire along the downwind side, with two igniters working outwards from the center of the downwind side. Flank fires are ignited next, working sideways to the wind on either side. Residual smoke is a common product of center and ring firing. This technique is also the most dangerous for wildlife as there is little opportunity for them to escape.

Table 8.5. Advantages and disadvantages of the different firing techniques.

Firing Techniques	Advantages:	Disadvantages:
Backing Fire	■ Generally, results in minimal scorch ■ Produces less particulates ■ Can be used in all fuel types ■ Shorter flame lengths	■ Requires a steady wind ■ Likely to have extended burning periods resulting from slower movement of fire ■ Increased residence time and duration of heating
Flanking Fire	■ Helpful in securing the flanks of other firing techniques ■ Allows an area to be ignited quickly ■ Needs few control lines ■ Moderate intensity between backing and heading fires	■ Requires a steady wind ■ Knowledge of fire behavior is very critical, as fire intensity and wind changes need to be monitored closely ■ Need access to unit interior
Strip Head Fire	■ Permits quick firing and can cover large areas ■ Can be used with higher fuel moistures and relative humidity ■ Does not require many interior lines ■ One of the cheaper firing techniques due to production rate	■ Avoid use in heavy fuels and young stands (Closed canopies, high ambient temperatures, as well as low RH and moisture content values may lead to crown scorch) ■ Can produce high levels of particulate matter and smoke ■ Control can be difficult to maintain if wind speeds change drastically ■ Spotting potential ■ Can cause safety hazard for burners during internal ignition
Point Source Fire	■ Can burn units faster than a backing fire ■ Can easily switch to other firing techniques if needed ■ Intensity is generally between backing and head fires ■ Conserves drip torch fuel	■ Timing and spacing of spots is critical; scorch is likely if dot grid spacing is wrong ■ Previous burn experience is strongly recommended ■ Can cause safety hazard for burners during internal ignition
Center / Ring Fire	■ Produces a hot fire ■ Recommended in cutover stands to reduce or eliminate logging debris ■ Sometimes used near smoke sensitive features because it burns quickly, and the convection column moves smoke upwards	■ The convection column can cause spotting downwind of the fire ■ Can trap wildlife ■ On burn units with timber, it can result in undesirable fire intensity and canopy scorch within the interior of the ring

IGNITION DEVICES AND DESCRIPTIONS

There are many devices that can be used to ignite a prescribed fire, with the drip torch being the most common and well-known. Ignition devices, including drip torches, are covered in the table below.

Table 8.6. Ignition devices and descriptions.

Ignition Device	Description:	Image:
Drip Torch	■ Likely the most useful and widely used tool for prescribed burns ■ Proper training required to use, as it can be hazardous. ■ Understanding drip torch fuel mix ratios is important! ■ Works well on all types of fuels ■ Provides a reliable source of fire in hard to reach areas ■ Requires a fuel source nearby to operate over large acreages or long periods of time	
Matches / Lighter	■ Simplest and cheapest ignition device ■ Often used to ignite other devices, such as drip torches and flares ■ Not recommended to use exclusively on large acreages because the ignition process will likely be time-consuming; it is also difficult to achieve the continuous fireline that is generally desired.	
Fusee / Road Flare	■ Lightweight and portable – ideal for remote areas ■ Works best on continuous fuels ■ Can be re-lit if extinguished ■ Requires eye and hand protection (PPE)	
Propane Torch	■ Often used by ranchers ■ Works well on a variety of fuels ■ Can be used to ignite fuel from a moving vehicle ■ Needs to be connected to a fuel cylinder – this can prove to be cumbersome ■ Expensive to operate	
ATV Torch	■ Mounts on the back of an ATV or UTV ■ Can project flames 8-20' ■ Works well on all types and quantities of fuel ■ Caution should be taken when driving with an ATV torch – it is recommended to stay on established paths and open terrain to prevent rollovers ■ ATV torches can present unique hazards to ATV use, including the potential for vehicles to catch fire.	

Table 8.6. Ignition devices and descriptions continued.

Ignition Device	Description:	Image:
Hand Flares and Flare Guns	■ Used in areas that are hard to reach or unsafe for personnel to ignite by hand ■ Works best on dry and moderate to heavy continuous fuels ■ Flares would be impractical to use to ignite an entire burn unit	
Terra Torch	■ A mobile flamethrower that can project flames 50-150' ■ Only use if properly trained in its use and safety considerations. ■ Works well in all fuel types and conditions ■ As it is mixed with a gelling agent, it will stick to fuel and burn for a longer period of time ■ This tool can be more dangerous than other ignition devices, so exercise extreme caution	
Delayed Aerial Ignition Device (DAID) / Ping-pong Ball System	■ Most preferred aerial ignition tool ■ Often used on large burn units and remote terrain ■ Helipad does not need to be within the burn unit ■ Some ignitions can be mounted on a unmanned aerial system (UAS).	 

Image 8.8. Drip torches are an extremely common ignition tool. *Image courtesy of Leslie Boby.*

Image Citations:

"Creative Commons BIC Lighter" by Sun Ladder is licensed under CC 3.0.

"Creative Commons Matches" by Cilfa is licensed under CC0 1.0.

Steber, S. (n.d.). Transporting and disposing of fusees: Best management practices. United States Forest Service.

References:

Alexander, M. (n.d.). *Applied Wildland Fire Behavior Research & Development*. Retrieved from https://www.frames.gov/applied-fire-behavior/home

Husari, S., Nichols, H.T., Sugihara, N., and Stephens, S. (2018). *Fire and fuel management* in Fire in California's Ecosystems. University of California Press, Berkeley, CA.

Loudermilk, L., O'Brien, J., Goodrick, S., Linn, R., Skowronski, S. and Hiers, K. (2022). Vegetation's influence on fire behavior goes beyond just being fuel. *Fire Ecology*, volume 18(9).

NWCG. (2021). *NWCG User Guide for Glossary of Wildland Fire*. Retrieved from https://www.nwcg.gov/publications/pms205/about-the-nwcg-glossary-of-wildland-fire

Texas A&M. (n.d.). Reference fuel moisture adjustment table. Texas Prescribed Burn Handbook.. Retrieved January 3, 2022, from https://agrilife.org/rxburn/weather-fuel/reference-fuel-moisture-adjustment-table-2/

Wade, D. (2013). *Prescribed Fire Fact Sheet Series*. Retrieved from https://southernfireexchange.org/publications/

Waldrop, T.A., Goodrick, S.L. 2012. (Slightly revised 2018). *Introduction to prescribed fires in Southern ecosystems*. Science Update SRS-054. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station.80 p.

FIRE BEHAVIOR NOTES

GLOSSARY BY SECTION – *LISTED IN ORDER OF APPEARANCE*

GETTING STARTED

Prescribed fire = fire deliberately set under specific circumstances to achieve land management goals.

PLANNING THE BURN

Burn plan = a plan for your prescribed burn which includes parameters such as acceptable weather conditions, burn timing, a map, and recommended strategies to execute the burn.

Smoke sensitive areas = an area that is especially sensitive to smoke from a prescribed fire such as airports, highways, schools, hospitals, or farming operations.

Special precautions = Specific conditions and/or situations that are pertinent to your burn and which should be noted and planned for such as pre-existing structures (cemeteries, abandoned buildings) or unexpected weather conditions.

Stand = A collection of trees, generally of the same species, which are nearby one another.

Atmospheric stability = The atmosphere contains both vertical and horizontal motion, which is caused by several factors such as wind and heating of the Earth's surface. Stability is an indication of how rapidly vertical mixing is taking place. In the case of smoke, the more unstable the atmosphere, the more vigorously smoke is mixed, or lifted and dispersed into the atmosphere. Stable atmospheres disperse smoke less efficiently and can result in higher concentrations of smoke moving back to the ground some distance downwind.

Transport winds = Average wind speed and direction from the ground to mixing height. These winds carry smoke away from the burn unit.

Surface winds = Measured 20 feet above the average height of an obstruction, such as trees or buildings. Understory composition, the density of trees, and general canopy height can impact surface winds, particularly regarding wind direction and speed.

Firebreaks = A break in the fuel line meant to contain the fire within the boundary of the burn unit. Often created by using machinery to remove fuels, exposing bare soil. Sometimes referred to as a fire-line.

CONDUCTING THE BURN

Control line = a natural barrier or constructed barrier used to stop or check fires. Natural barriers include rivers, waterways, or rocky features. Constructed barriers include roadways and firelines.

Backing fire = A type of ignition technique where fire moves against the predominant wind direction. Flames during a backing fire tilt away from the direction of spread. Less smoke is produced during a backing fire because most fuel is consumed during the flaming stage, a stage of combustion where primary smoke products include water vapor and carbon dioxide.

Heading fire = A type of ignition technique where fire moves in the direction of the wind and flames tilt in the direction of the fire spread. Heading fires lead to more intense fires compared to backing fires.

GLOSSARY BY SECTION – *LISTED IN ORDER OF APPEARANCE*

CONDUCTING THE BURN

Flank fire = A fire progressing perpendicular to the wind.

Point-source fire = An ignition technique using a grid or spacing of spot/dot ignitions.

Ring fire = A fire started by igniting the full perimeter of the intended burn area so that the ensuing fire fronts converge toward the center of the burn. Set around the outer perimeter of a resource to establish a protective black-line-buffer.

Mop-up = the process of mitigating residual heated or unburned fuels, once active fire progression has stopped.

EVALUATING THE BURN

Crown scorch - Browning of needles or leaves in the crown of a tree or shrub caused by heat from a fire. Scorched needles and leaves will remain in the crown for up to a month with obvious discoloration.

Consumption - Needles and leaves are completely consumed (destroyed or severely damaged) by fire; branches are left bare.

Cambium - A very thin layer of growing tissue that produces new cells that become either xylem, phloem or more cambium. The cambium is responsible for an increase in tree girth.

Burn severity - Refers to the degree to which a site has been altered, or the biological and ecological impacts of the fire on the environment. Severity is a product of fire intensity and is usually evaluated as light, moderate, or high on an evaluation.

Heat tolerance and **fire resistance** refer to the ability of a woody plant species to survive high temperatures associated with the passage of fire.

A **terminal bud** is the primary growing point, typically at the top of the stem, of a plant. Many species of pine have a distinct terminal bud.

Re-sprouting is when a plant regrows a sprout or shoot that was previously damaged.

Serotinous cones are pine tree cones covered with thick resin, which must be exposed to fire before the internal seeds can be released.

Cool season grasses are those that grow best between 65-75 *F, such as Kentucky bluegrass and Fescue.

Warm season grasses are those that grow best between 85-95 *F. Such as Big Bluestem and Switchgrass.

GLOSSARY BY SECTION – *LISTED IN ORDER OF APPEARANCE*

WEATHER

Atmospheric temperature is a measure of the hotness or coldness of the air.

Relative humidity (RH) is the relative measure of the moisture content of the air as a percentage, of the total possible amount of moisture saturation for a given air temperature and ambient air pressure.

Dew point is the temperature at which saturation of air is reached.

Wind is defined as the movement of air, the direction and speed of which is determined by the distribution of pressure centers and local topography.

The **wind speed** listed in a standard fire weather forecast is a measure of the speed of the wind at a point 20 feet above any vegetative obstruction including the tree canopy in forest areas and is also called the surface wind speed or the 20-foot wind speed.

Stand density is the height to the bottom of the overstory canopy.

Understory density is the relative density of the forest understory.

A **front** is defined as the boundary or zone separating two air masses of contrasting density.

Low pressure systems spin in a counterclockwise direction and are associated with atmospheric instability.

High pressure systems spin in a clockwise direction and are associated with increased atmospheric stability.

Atmospheric stability is the "resistance of the atmosphere to vertical motion" (Waldrop and Goodrick, 2012). In general, the more unstable the atmosphere, the higher the mixing height will be.

Atmospheric dispersion is the process by which the atmosphere mixes and transports particulates, such as smoke, away from their source.

Fuel moisture percentage (F.M. %) refers to the percentage of moisture in a given fuel class, such as 1 hour fuel (<0.25 inches in diameter) or a 10 hour fuel (3-6 inches in diameter).

The **Keetch - Byram Drought Index (KBDI)** is commonly used in the Southeast. It depicts the degree of drought on a scale that ranges from 0 to 800.

The **Fire Danger Index** measures the potential risk of a wildfire starting, and the suppression effort it would require, on any given day.

The **Haines Index**, also called the **Lower Atmosphere Stability Index**, measures the potential for wildfire growth using the stability and dryness of air over a given wildfire.

The **Low Visibility Occurrence Risk Index (LVORI)** measures the risk of low visibility occurring.

The **Turner and Atmosphere Tendency** is a measure of atmospheric stability. It is based on measurements of surface level wind speed and net solar radiation.

The **Atmospheric Dispersion Index (ADI)** is a forecasting tool that estimates both daytime and nighttime atmospheric stability.

GLOSSARY BY SECTION *– LISTED IN ORDER OF APPEARANCE*

SMOKE MANAGEMENT

Smoke is the tiny particles and trace gases suspended in the air when a fuel is burned.

Inversions are atmospheric layers in which air temperature increases with height, effectively trapping smoke below them. Higher inversions, occurring during the afternoon, are preferable for smoke dispersion.

Mixing height is the height at which smoke will be diluted and dispersed. Low mixing heights keep smoke close to the ground surface, whereas high mixing heights allow for more smoke dispersion.

Duff is defined as a layer of decomposing organic matter sandwiched between freshly fallen debris (such as twigs, needles, and leaves) and mineral soil. It is an important fuel type in Southeastern forests as it can provide plants with fertilization.

Superfog is an extremely thick fog occurring at night created by the mixing of high RH and smoldering fuels.

FUEL

The **fire triangle** refers to three essential elements in a prescribed fire: fuel, oxygen, and heat.

Fuel type refers to the different vegetation and fuels on the ground, such as pine or hardwood leaf litter, limbs, and stems. It also can include herbaceous vegetation.

Fuel loading refers to the amount of consumable fuels. It is typically expressed as tons per acre.

Fuel continuity refers to the extent of continuous fuel particles within a given area.

Fuel moisture refers to the moisture content of a fuel, relative to its weight.

Surface fuels are fuels lying on or near the surface of the ground, consisting of leaf and needle litter, dead branch material, downed logs, bark, tree, cones, and low stature living plants.

Ladder fuels are combustible materials which provide vertical continuity between the surface and canopy, thereby allowing fire to carry from surface fuels into the crowns of trees or shrubs with relative ease.

Aerial fuels are any live and dead vegetation in the forest canopy or above surface fuels, including tree branches, twigs and cones, snags, moss, and high brush.

Timelag class refers to how readily a fuel will gain or lose moisture, relative to its size in a given environment. For example, a 1-hour fuel will react more quickly to changes in the environment than a 10-hour fuel.

GLOSSARY BY SECTION *– LISTED IN ORDER OF APPEARANCE*

FIRE BEHAVIOR

Topography refers to the lay of the land, including geological features, elevation, slope, and aspect.

Rate of speed spread is how fast the fire moves across the landscape and can be measured in feet per minute, chains (66 feet) per hour, or miles per hour.

Flame length is the distance from the ground at the leading edge of the flame to the flame tip.

Flame height is the average height of flames as measured vertically.

Chimney effect occurs when a fire burns between steep slopes, and smoke is drawn upslope.

Convergence is when two fires or flame fronts meet, causing a column of fire.

Residence time is the duration of contact between a fuel and a flame.

ACRONYMS *– ALPHABETICAL ORDER*

AFF = American Forest Foundation

CRP = Conservation Reserve Program

DBH = Diameter at Breast Height (or 4.5 feet)

EQIP = Environmental Quality Incentive Program

F.M. % = Fuel Moisture Percentage.

KBDI = Keetch-Bryam Drought Index

LVORI = Low Visibility Occurrence Risk Index

NFDRS = National Fire Danger Rating System

NRCS = Natural Resource Conservation Service

NWCG = National Wildfire Coordinating Group

NWS = National Weather Service

PBAs = Prescribed Burn Associations

PFCs = Prescribed Fire Councils

PPE = Personal Protection Equipment

RH = Relative Humidity

TREX = Prescribed Fire Training Exchanges

USFS = United States Forest Service

VFDs = Volunteer Fire Departments

APPENDIX – CHAPTER WORKSHEETS & CHECKLISTS TO PRINT

PLANNING THE BURN

PRESCRIBED BURNING LIABILITY TIPS
(ADAPTED FROM BALDWIN, C., 2015. PRESCRIBED BURN NOTEBOOK)

- [ ] **Make sure you have a burn plan, but don't make it too complex.** If the burn plan is incredibly detailed, then there is less room for adaptation and a greater likelihood that prosecution could find you violated some portion of the burn plan through error in execution.
- [ ] **Be diligent about finding and recording information about weather conditions at the time of the burn and during the burn.** Print out the fire weather forecast at the same time as when you decide to burn.
- [ ] **Keep your documentation from the burn with the burn plan** and store both until after the statute of limitations has occured. However, it is always a good practice to keep your old burn plans for long-term evaluation purposes.
- [ ] **Connect with your neighbors to inform them of your plans well in advance of the burn.** Maintain communication with them and continue to let them know who the burn is most likely to concern, especially anyone nearby that may have respiratory ailments.
- [ ] **Inform the local fire department of your plans and your preparation** and ensure that you have all appropriate permits.

MAP COMPONENT CHECKLIST

- [ ] Boundaries of the burn unit(s) with acreages
- [ ] Property boundary
- [ ] Topography
- [ ] Map orientation (compass)
- [ ] Fire breaks or natural barriers the act to contain the burn. The map should indicate existing fire breaks and those that need to be constructed and their lengths.
- [ ] Anticipated direction of the smoke plume
- [ ] Smoke-sensitive features
- [ ] Areas that will be excluded from fire such as structures
- [ ] Other essential information: known safety issues, specific wildlife, state required burn hours

CONDUCTING THE BURN

WEEKS BEFORE THE BURN

- ☐ **Review the burn plan**
- ☐ **Check firebreaks (create firebreaks, if needed)**
- ☐ **Monitor weather**
  - Pay attention to general weather trends, such as predicted rains and fronts
  - Check various weather parameter related to your prescription
- ☐ **If needed, develop a smoke management plan**
- ☐ **Walk the burn unit and look for safety hazards**
- ☐ **Assemble and check equipment**
- ☐ **Organize people who can assist in the burn**
- ☐ **Notify neighbors to let them know you are planning to burn in the coming weeks**

DAYS BEFORE THE BURN

- ☐ **Review the burn plan prescription**
  - Make copies for your team
- ☐ **Check onsite conditions**
  - Check all firebreaks to ensure they are still clear
  - Check the duff (organic soil layer) moisture
  - Look for any additional safety hazards
- ☐ **Monitor weather**
  - Review the fire weather forecast particularly RH, temperature, wind direction & speed
  - Note dispersion indice values
  - Compare values to burn prescription
- ☐ **Review your smoke management plan and best practices**
- ☐ **Confirm you have enough people to complete a successful burn**
- ☐ **Prepare your fire equipment as needed**
  - Make sure your power tools are operable and are appropriately fueled
  - Check other tools to make sure they are functional (e.g. radios have fresh batteries, no loose toolheads, etc.)
- ☐ **Prepare your fire equipment as needed**
- ☐ **Make copies of the burn map for all participants**
- ☐ **Notify emergency services and neighbors that a burn is planned in the coming days**

CONDUCTING THE BURN

DAY OF THE BURN

- [ ] **Obtain the fire weather forecast and print**
  - Compare the forecast with the burn prescription
- [ ] **If weather conditions are acceptable, obtain a burn permit and sign the prescription**
- [ ] **Remind emergency services and neighbors that a burn is taking place**
- [ ] **Make sure you have copies of the burn plan and burn map available for all participants**

ON THE FIRELINE

- [ ] **Monitor and log weather onsite**
  - Before and during the burn
- [ ] **Conduct a crew briefing**
  - Familiarize the crew with the burn unit
  - Provide copies of the burn plan and map(s)
  - Review burn plan objectives
  - Review the map(s)
  - Address safety and risk management
  - Review the contingency plan
  - Review the fire weather forecast
  - Assign roles and responsibilities
  - Establish communications
- [ ] **Review the Go/No-Go checklist**
- [ ] **Verify the downwind side**
- [ ] **Complete a fire test**
  - Determine if the burn will proceed
- [ ] **Begin the burn**
- [ ] **Observe fire behavior and adjust accordingly**
- [ ] **Monitor smoke patterns**
- [ ] **Monitor firebreaks**
- [ ] **Mop-up**
- [ ] **After-action review**
- [ ] **Start the evaluation**

CONDUCTING THE BURN

CREW BRIEFING CHECKLIST

- [ ] **Familiarize the crew with the burn unit**
  - Each crew member should have a map
  - Show crew the property if they are not familiar with it and point out hazardous or potentially hazardous areas
- [ ] **Review burn plan objectives**
- [ ] **Review the map**
  - Indicate where the fire is anticipated to begin and end
  - Point out labeled perimeters, locations, and landmarks that are of importance
  - Identify terrain or fuel features where fire behavior may change rapidly
  - Identify where smoke is likely to go
  - Identify travel routes and safety zones
- [ ] **Address safety and risk management**
  - Review known hazards and risks
  - Identify control measures to reduce/ eliminate hazards and risks
  - Discuss procedures to follow under emergencies
  - Determine if crew members have specific health concerns or special medical training
  - Remind crew members to practice situational awareness, stay hydrated, and consume sufficient electrolytes (salts).
  - Ensure all crew members are outfitted in acceptable personal protective equipment (PPE)
- [ ] **Review the contingency plan**
  - Review safe zones and escape routes
  - Ensure that plans are in place for contacting emergency assistance in case of injuries
  - Review suppression strategy for an escaped fire

CREW BRIEFING CHECKLIST

- [ ] **Review the fire weather forecast**
  - Current and anticipated weather conditions
  - Alert crew of any likely changes in the weather (such as forecasted wind shifts, arrival of a front or increased cloud coverage) and the potential for altered fire behavior
- [ ] **Discuss fuels & ignition plan**
  - Discuss the type of fuels in the burn unit, moisture levels and how you will light it
  - Mention any conditions that may be important
- [ ] **Assign roles and responsibilities**
  - Roll call – Get a headcount of all participants
  - Assign & describe burn crew roles including someone to take weather readings and another person to take over from the burn boss, if needed
  - Ensure that all crew members have and know how to use the appropriate tools for their assignment
  - Check that all tools are in working shape
- [ ] **Establish Communications - The complexity of the burn will determine how you need to communicate**
  - **Cell phones:**
    - Check if you have service, if not use radios or find another way to communicate
    - Ensure phones are charged
    - Exchange cell phone numbers
  - **Walkie-talkies or Radios:**
    - Distribute & test walk-talkies
    - Have extra batteries on hand
    - For radios, make sure everyone is on the same channel radio channel
  - On a small burn you may be able to communicate by shouting or using hand signals.

CONDUCTING THE BURN

Yes/No	National Wildfire Coordinating Group Prescribed Fire Go/No-Go Checklist Questions
	Are ALL fire prescription elements met?
	Are ALL smoke management specifications met?
	Has ALL required current and projected fire weather forecast been obtained and are they it favorable?
	Are ALL planned operations personnel and equipment on-site, available and operational?
	Has the availability of ALL contingency resources been checked, and are they available?
	Have ALL personnel been briefed on the project objectives, their assignment, safety hazards, escape routes, and safety zones?
	Have all the pre-burn considerations identified in the prescribed fire plan been completed or addressed?
	Have ALL the required notifications been made?
	Are ALL permits and clearances obtained?
	In your opinion, can the burn be carried out according to the prescribed fire plan and will it meet the planned objective?

If all the questions were answered "YES" proceed with a test fire. Document the current conditions, location, and results.

EVALUATING THE BURN

√	Basic Components of an Initial Evaluation
	Total acreage successfully burned: ___
	Were the burn objectives accomplished? ■ List which objectives were met fully, partially, or not at all.
	Were photographs taken prior to the burn?
	Was the pre-burn preparation work satisfactorily completed?
	Was the burn plan followed? ■ If not, what parts and why?
	Were the following factors within planned limits? If not, were all deviations documented on the burn plan? ■ Weather conditions ■ Fuel conditions ■ Expected fire behavior ■ Smoke dispersion
	Did the fire behave as expected? If not, why? Did fire escape containment lines? ■ Did smoke disperse as expected and were you successful in avoiding smoke-sensitive features or areas? ■ Were the burning techniques used successful or did they result in control issues or damage?
	Were there injuries, equipment malfunctions, or complaints?
	When will the next burn be needed (if applicable?)
	Will the burn plan need adjustment for the next burn?

√	Additional Comments to Consider
	Fire Effects ■ What is the percentage of overstory foliage discoloration (i.e., crown scorch)? ■ What is the percentage of consumption and top-kill of understory vegetation? ■ Approximately, what amount of litter or duff (decomposing organic material between tree litter layer and mineral soil) is remaining on the ground? ■ What impacts to non-target species (plant and animal) are present?
	Was the burn plan followed?
	Costs / Benefits ■ Briefly summarize the costs for manpower, equipment, and supplies
	Public Comments ■ Were there any adverse public comments or reactions prior to, during, or immediately after the burn? ■ Social, cultural, or training benefits
	Additional observations and comments: ■ Describe anything you see that may be notworthy. ■ What could be done to improve future, similar burns? ■ It can also be helpful to provide a post-burn map that indicates areas of success and complication.

EVALUATING THE BURN

√	Basic Components of the Secondary Evaluation
	Does it appear that the prescribed fire was beneficial in aiding your overall land management objectives?
	How did the fire affect trees? ■ What is the estimated tree mortality? ■ Is any sap seeping from trees in the burned area, particularly pine? If yes, this is an indicator of cambium damage or insect attack.

	How did the fire affect vegetation?
	■ What is the estimated vegetation mortality?
	■ Is any undesirable vegetation growth present?
	  ■ If so, how quickly is the growth occurring?
	  ■ Are any of the species invasive/ exotic? If yes, describe which species were observed and where.
	■ Have any new desirable woody shrubs, vines, or herbacious plants been observed that were not present or notibable prior to the burn? If so, estimate the percent coverage.

	Was the burn plan followed? ■ If not, what parts and why?
	Have there been any complaints or support for the burn from the public since the burn's completion?
	Was the pre-burn preparation thoroughly and satisfactorily completed?
	Were the costs of the burn on par with the benefits derived?

√	Additional Components to Consider for Secondary Evaluation
	Other Fire Effects ■ Are regenerating pine and/or hardwood stems (i.e. seedlings and saplings) more or less prevelant in the stand? Quantify regeneration by counting these stems by species in circular, 1/100th acre (11.8 ft radius) plots. ■ What is the percentage of litter/duff on the forest floor? ■ Is there any evidence of disease or insect damage?
	Additional observations and comments: ■ Take and date additional photographs of your burn unit to maintain a visual record..

INITIAL EVALUATION FORM, P.1

Item	Response	Item	Response
Prepared by:		Signature:	
Date of the burn:		Date of evaluation:	
Permit #:		County & State:	
Acres burned:		Do you have pre-burn pics?	
		Did you take pictures today?	

Component	Notes
Were the burn objectives accomplished? ■ List which objectives were met fully, partially, or not at all.	
Was the pre-burn preparation thoroughly and satisfactorily completed?	
Was the burn plan followed? ■ If not, what parts changed and why?	
Were the following factors within planned limits? ■ If not, were all deviations documented on the burn plan? Consider: ■ Weather conditions ■ Fuel conditions ■ Expected fire behavior ■ Smoke dispersion	
Did the fire behave as expected? If not, why? ■ Did it escape containment? ■ Did smoke disperse as expected and were you successful in avoiding smoke-sensitive features or areas? ■ Were the burning techniques used successful or did they result in control issues or damage to crop trees?	

INITIAL EVALUATION FORM, P.2

Component	Notes
Fire Effects ■ Add anything of note about each component below: ■ Crown (was there any crown scorch) ■ Understory vegetation (estimate of how much was burned and/or killed) ■ Litter/duff (about how much is left on the forest floor?) ■ Any other impacts?	
Costs / Benefits ■ Briefly summarize the costs for manpower, equipment, and supplies	
Notes for Future burns ■ When will the next burn be needed? ■ Will the burn plan need to be adjusted for the next burn? ■ What could be done to improve future, similar burns?	
Additional observations and comments ■ It can be good to sketch up a map showing the areas burned	

Figure 4.13. Advanced initial evaluation worksheet.

SECONDARY EVALUATION FORM, P.1

Item	Response	Item	Response
Prepared by:			
Date of the burn:		Date of evaluation:	
Permit #:		County & State:	
Acres burned:		Do you have pre-burn pictures?	
		Did you take pictures today?	

Component	Notes
Does it appear that the prescribed fire was beneficial in aiding your overall land management objectives?	
How did the fire affect trees? ■ What is the estimated tree mortality? ■ Is any sap seeping from trees in the burned area, particularly pine? If yes, this is an indicator	

How did the fire affect vegetation?
■ What is the estimated vegetation mortality?
■ Is any undesirable vegetation growth present?
  ■ If so, how quickly is the growth occurring?
  ■ Are any of the species invasive/exotic? If yes describe which species were observed and where.
■ Have any new desirable woody shrubs, vines, or herbacious plants been observed that were not present or notibable prior to the burn? If so, estimate the percent coverage.	

Was the burn plan followed? ■ If not, what parts and why?	

SECONDARY EVALUATION FORM, P.2

<table>
<tr><th>Component</th><th>Notes</th></tr>
<tr><td>Have there been any complaints or support for the burn from the public since the burn's completion?</td><td></td></tr>
<tr><td>Was the pre-burn preparation thoroughly and satisfactorily completed?</td><td></td></tr>
<tr><td>Were the costs of the burn on par with the benefits derived?</td><td></td></tr>
<tr><td colspan="2">Additional Components to Consider for Secondary Evaluation</td></tr>
<tr><td>Other Fire Effects
Are regenerating (i.e. seedlings and saplings) pine and/or hardwood stems more or less prevelant in the stand? Quantify regeneration by counting these stems by species in circular, 1/100th acre (11.8 ft radius) plots.
What is the percentage of litter/duff on the forest floor?
Is there any evidence of disease or insect damage?</td><td></td></tr>
<tr><td>Additional observations and comments:
Take and date additional photographs of your burn unit to maintain a visual record.</td><td></td></tr>
</table>

SMOKE MANAGEMENT

Table 6.3. Daytime Smoke Management Complexity Worksheet (Source: USDA Forest Service Introduction to Prescribed Fire in Southern Ecosystems)

Process Steps	Value
1. Estimate the number of acres per hour that are actively burning	
A. Enter the size of the burn, in acres	
B. Enter how long you think the burn will be, in hours	
C. Divide value A by value B	
Select score based on C: **<150 acres per hr = 0** **150-300 acres/hr = 1** **>300 acres/hr = 2**	
2. Estimate fuel load consumed	
Score based on estimated tons per acre: **<4 tons per acre = 0** **4-8 tons per acre = 1** **>8 tons per acre = 2**	
3. Topography	
0 = flat terrain with no significant topography within 30 miles downwind of the burn **1 = flat terrain with significant topography within 30 miles downwind of the burn** **2 = significant topography in burn unit**	
4. Air Quality (based on Air Quality Index from https://airnow.org)	
Good dispersion = 0 **Moderate dispersion = 2** **Poor dispersion = do not burn!**	
5. Atmospheric Dispersion (determine based on Atmospheric dispersion index)	
Good dispersion = 0 **Moderate dispersion = 2** **Poor dispersion = do not burn!**	
6. Burn site location in relation to urban or suburban areas (wildland urban interface)	
No urban areas within 60 miles downwind of burn site = 0 **Burn unit is not in an urban area, but urban areas are within 60 miles = 1** **Burn unit is in an urban/suburban area = no score (special considerations)**	
Total Score	

Table 6.6. Daytime Burn Complexity and Recommended Smoke Modeling tools

Burn Complexity	Recommended smoke modeling tool	Daytime Smoke Management Complexity Worksheet Scores
Low	Simple smoke screening	0-2 (with no single factor receiving a score of 2)
Moderate	Online software such as BlueSky or VSmoke	3-6 (no more than two factors receiving a score of 2)
High	Online software such as BlueSky or VSmoke. Contact your state forestry agency for further guidance	7 +

Table 6.7. Output from the VSmoke model represents peak hourly concentrations of PM 2.5 or visibility. Contour values and their colors correspond to the PM 2.5 thresholds for the Air Quality Index (AQI) and reflect potential health impacts ranging from moderate to hazardous. *Sourced from the VSmoke-Website. Adapted by Jasmin El Farnawany.*

Levels of Health Concern	AQI Value	Hourly PM 2.5 Conc.	Meaning
Good	0 to 50	0 to 38	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 to 100	39 to 88	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are usually sensitive to air pollution
Unhealthy for Sensitive Group	101 to 150	89 to 138	Members of sensitive groups may experience health effects. The general public is not likely to be affected
Unhealthy	151 to 200	139 to 351	Everyone may begin to experience more serious health effects
Very Unhealthy	201 to 300	352 to 526	Health alert: everyone may experience more serious health effects
Hazardous	301 to 500	> 526	Health warnings of emergency conditions. The entire population is more likely to be affected.

eFire Online Training

Click this link to access the North Carolina State University eFire page. Here you can immerse yourself in prescribed fire situations, the planning and evaluation process, and more
Access it here: https://efire.cnr.ncsu.edu/efire/

RxBURN TRACKER: OKLAHOMA STATE UNIVERSITY

- Photograph burn units prior to and after burns are conducted
- Organize pictures and burn data chronologically
- Record burn data about each burn unit

Note: This example is not an endorsement of the application or its technologies.

Kestrel Weather Meter

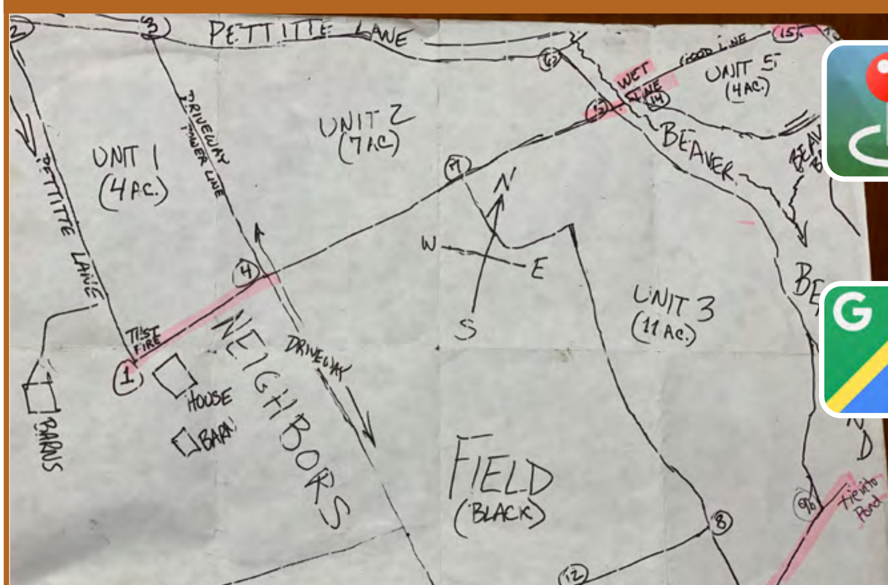
Kestrel Weather Meter: This tool calculates relative humidity, heat index, wind chill, wind speed, and temperature. It is available for purchase online.

A word of caution: Be certain to calibrate meters for accuracy (e.g. relative humidity). An inaccurate meter can provide false readings – which can result in a hazardous field situation.

Figure 5.8. The picture above is a Kestrel brand Weather Meter. Photo Source: National Wildfire Coordinating Group (NWCG).

For a more in depth weather forecast, visit the National Weather Service fire weather dashboard.
https://www.weather.gov/dlh/fwd

Hand-drawn burn map & tools to help



AVENZA MAPS: AVENZA SYSTEMS INC.

- Download georeferenced maps for offline use
- Use your phone's built-in GPS to track your location on any map
- Plot locations and photos
- Measure distance and area

GOOGLE MAPS: GOOGLE

- View satellite imagery
- Create and save maps for offline use
- Drop location points and measure distances between them
- Discover potential smoke-sensitive features with aerial view (homes, businesses, and roadways downwind of the proposed burn unit)

APPENDIX – *RESOURCES, TOOLS & APPS*

Fire Weather Calculator

National Center for landscape Fire Analysis

With Fire Weather Calculator, you can:

- Calculate relative humidity (RH), fine dead fuel moisture (FDFM), and probability of ignition (PIG) based on standard fire line weather observations
- Archive and share data observations via email

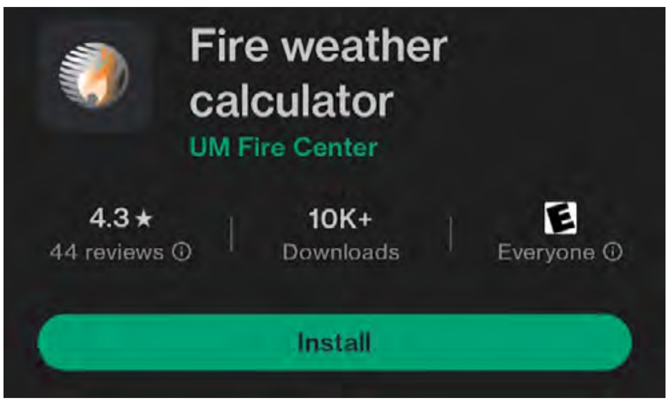


Image 5.4. Many phone applications exist where you can acquire weather forecasts, including the University of Montana calculator.

Find the Smoke Management Guidebook Online: https://www.warnell.uga.edu/

On the Warnell School of Forestry and Natural Resources homepage, select the Outreach tab. On the top left side of the page select "Publications" and then scroll until you find the Smoke Management Guidebook.

Check Air Quality Index (AQI) Forecast Before Burning: https://airnow.gov

Avoid burning during Air Quality Alerts

Introduction to Prescribed Fire in Southern Ecosystems Smoke Complexity Worksheet

You can download this on the USDA website (**https://www.fs.usda.gov/treesearch/**) under publications. Just search the title and then download the file.

Accessing VSmoke

Visit the Georgia Forestry Commission online site: **www.gatrees.org**

- Navigate to "Fire Weather" (not fire weather forecasts)
- VSmoke should be accessible: https://weather.gfc.state.ga.us/GoogleVsmoke/Vsmoke-Good2.html

Online Available Fuel Calculator

Access the tool here: http://smokeapp.serppas.org/
From the webpage above, select the "fuel calculator" option on the right-hand side of the page. This will bring you to the fuel moisture calculator.