

CHAPTER 7

FIRE BEHAVIOR

OBJECTIVES

- 1) Identify fire behavior terms.
- 2) Explain the fire triangle.
- 3) Discuss the major elements of the fire environment.
- 4) List and explain the three methods of heat transfer.
- 5) List fuel characteristics which govern combustion.
- 6) Identify fuel model categories and examples in Florida.
- 7) Explain the difference between fire intensity and severity and how both can be regulated and measured.
- 8) Define residence time and explain why it is significant in prescribed fire.
- 9) Discuss indicators of erratic or potentially erratic fire behavior.

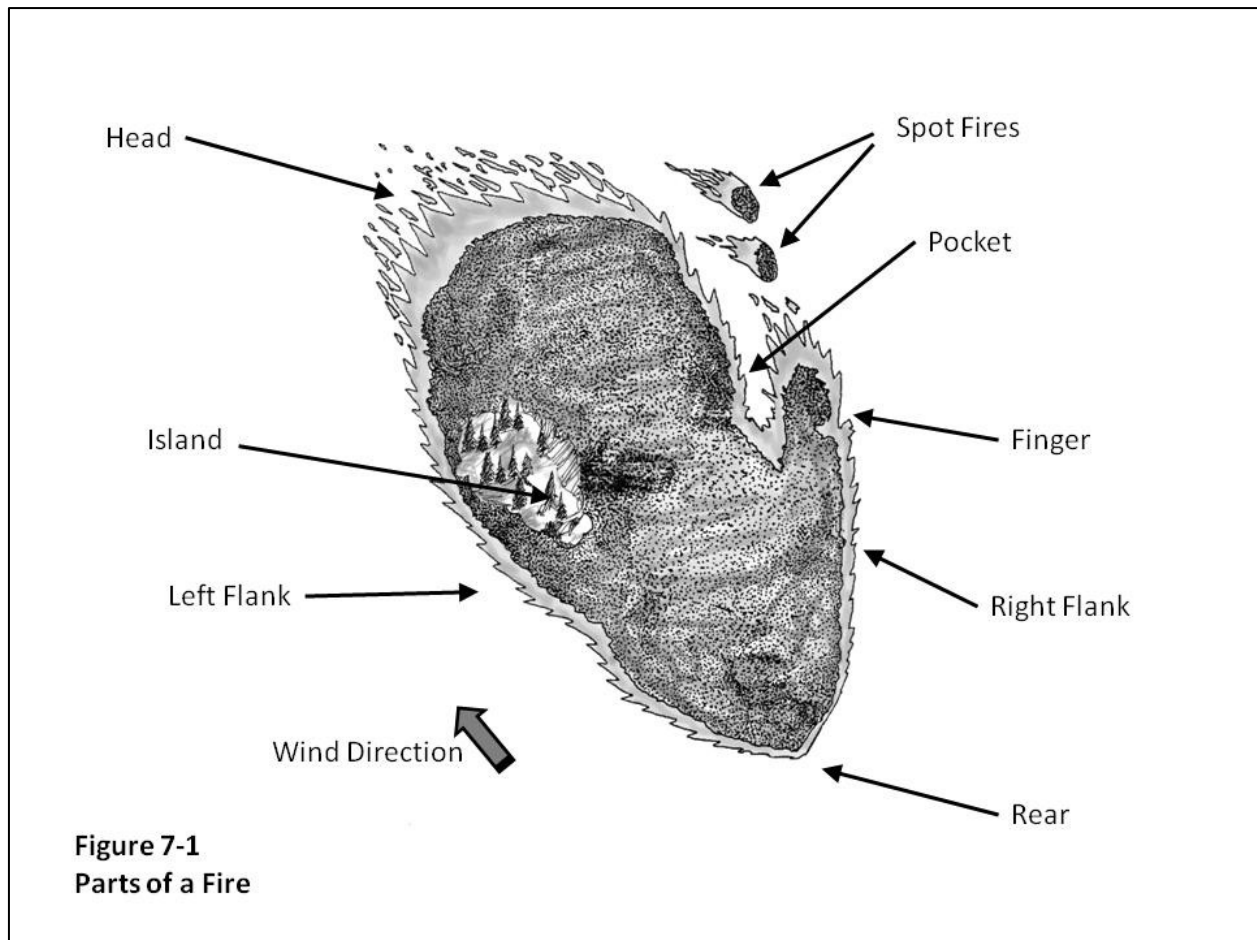
INTRODUCTION

Understanding fire behavior is an essential component of any successful prescribed fire. Without this basic knowledge, it is virtually impossible to prescribe the conditions and ignition patterns which will achieve the desired results. Unlike other courses which deal with wildfires in the western United States, this chapter deals with fire behavior associated with prescribed fire in Florida. The influences of Florida's climate, vegetation, topography, coastline and other factors unique to this state will be examined. Important details regarding the chemistry and physics of wildland fire will be explained.

FIRE BEHAVIOR TERMS

1. Parts of a fire (Figure 7-1):

- a. **Head** – The forward, wind driven edge of a fire; usually the hottest and fastest moving area with the highest flames
- b. **Flanks** – The parts of the fire burning perpendicular to the wind
- c. **Rear** – The part of the fire burning into the wind; usually the slowest moving area
- d. **Islands** – Unburned patches of fuel inside the fire perimeter
- e. **Fingers** – Projections of the fire perimeter separate from the head
- f. **Pockets** – Areas of unburned fuel outside the fire perimeter that occur between the fingers and the head
- g. **Spot Fires** – Fires ignited outside the perimeter of the main fire by a firebrand

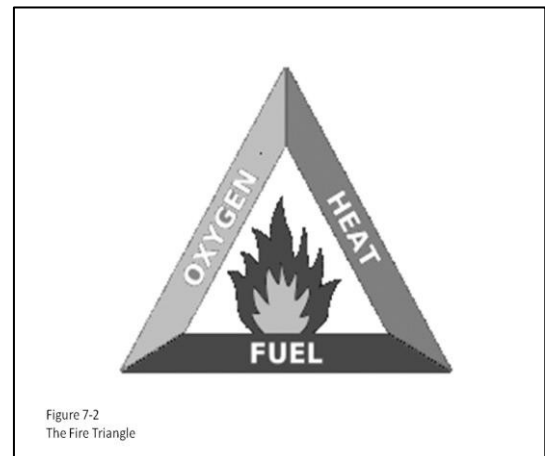


2. Description of fuels by location:
 - a. **Ground Fuels** – Organic material located in the duff and soil, such as peat, muck, duff, roots and stumps
 - b. **Surface Fuels** – Live and dead vegetation just above the ground, including grasses, shrubs, small trees, leaf litter and logging slash
 - c. **Aerial Fuels** – Crowns and/or canopy of the overstory
 - d. **Ladder Fuels** – Trees, vines and other fuels located between the surface and canopy
3. Descriptions of fire behavior:
 - a. **Smoldering** – Fire burning without flame and barely spreading
 - b. **Creeping** – Fire burning with a low flame and spreading slowly
 - c. **Backing** - Fire spreading slowly against the wind
 - d. **Running** – Fire spreading in a definite direction with a well defined head
 - e. **Spotting** – Fire spreading by lifting or transporting burning or glowing embers and igniting fuels in advance of the main fire
 - f. **Torching** – Fire racing upward from the ground to the crown or canopy and burning the top of one or several trees
 - g. **Flare-Up** – A sudden increase in a fire's rate of spread and intensity
 - h. **Surface Fire** – Fire burning above ground level but below the tree canopy
 - i. **Ground Fire** – Fire smoldering underground in organic soils or other fuels
 - j. **Crown Fire** – Fire advancing from treetop to treetop either in conjunction with or independently of a surface fire

THE FIRE TRIANGLE

Three elements make up the Fire Triangle, and must all be present for combustion to occur. Without any one of these elements, fire cannot exist. These elements are **Heat**, **Fuel** and **Oxygen**.

Heat must come from an external source (lightning or man). Once a fire is started, it will provide enough heat to maintain the combustion process. Oxygen is available within the atmosphere and accounts for 21% of the air we breathe. Fuel is the material that actually has stored energy which is released during combustion. For prescribed burns, this is the available vegetative materials, both living and dead, that is consumed during the burn.



When planning a prescribed burn, all three elements must be considered. By understanding the role of each element and its relationship to time, the prescribed burner will enhance the quality and success of prescribed burns.

PHASES OF COMBUSTION

The process of combustion is divided into four distinct phases. Understanding these phases, their interactions and relative importance on each fire is essential for the burn manager during every prescribed fire. Actual fire behavior must be compared to expected fire behavior, ability to control the fire, meeting objectives and other potential problems.

1. **Pre-ignition** – During this phase, fuels are heated to the point that water and organic gases are released. This phase prepares fuels for the next phase when actual combustion occurs. Some fuels, often those in the canopy, may reach this phase, but due to the fire's velocity, may not actually ignite. Under these conditions, leaves or needles will scorch or brown, but will not burn.
2. **Flaming** – This, the most dramatic phase of combustion, is characterized by flames consuming fuels. Under extreme conditions, crown fires may support a broad flaming front reaching a hundred feet or more into the air. In contrast, Florida prescribed fires often rely on ignition patterns which generate flame lengths of two to six feet. Regardless of flame length, it is this highly visible process that consumes the available surface fuels. Major products during this phase are water, carbon dioxide and visible smoke particulates. The amount of fuel consumed depends on the speed and intensity of the fire.
3. **Smoldering** – During this phase, visible smoke is the primary product. This phase is important due to the continued consumption of available fuels and heat transferred to both the soil and surrounding vegetation. Extensive smoldering after the flaming front has passed produces residual smoke which is a major factor in many smoke management incidents.
4. **Glowing** – Carbon dioxide and carbon monoxide are the primary products of this phase. This continues to transfer heat to the area as well as consuming available fuel.

Management of all these phases is essential. The pre-ignition phase must be regulated and focused on those fuels which have been targeted for consumption or on undesirable vegetation components. For most prescribed burns, it is the flaming phase that is desirable for most combustion. With proper wind speed, this phase can be completed quickly while allowing for

proper smoke dispersal, minimizing damage to non-target species and providing efficient control. Extensive smoldering can cause a variety of problems, including residual smoke, damage to non-target species, increased monitoring and extensive mop-up. When the objective is to reduce large or bulky fuels, prescription parameters should be adjusted to emphasize both the flaming and glowing phases of combustion.

THE FIRE ENVIRONMENT

Prescribed fires are conducted within a specific range of conditions described as the fire environment. There are three major components or factors that make up the fire environment:

- 1. Fuels**
- 2. Weather**
- 3. Topography**

Of the three, topography is the least important in Florida, although wetlands readily alter the orientation of an advancing fire, thus modifying fire behavior and fire effects. For the purposes of this course, the student only needs to know that fire burns faster uphill. This can be observed in the sandy hills of north and central Florida, and in the rolling clay hills of the panhandle.

Fuels and weather exert the strongest influences on the Florida fire environment and will be examined in detail later in this chapter.

HEAT TRANSFER AND RELEASE

A fire spreads by transferring heat from one piece of fuel to another. Listed by order of importance for Florida fires are the three methods of heat transfer:

- 1. Convection** – The movement of heat through a liquid or gas (such as air). An example of convective heat transfer is heat rising in a column above a fire. Convective heat pre-heats fuels quickly, raising them to their ignition temperature. Convective heat rises, but it may also be pushed laterally by the wind.
- 2. Radiation** – Radiant heat occurs when a hot object, such as burning fuels, warms nearby objects, such as surrounding vegetation. The heat we feel and absorb from the sun is radiant heat. Radiation spreads in all directions, preheating fuels in the immediate vicinity of a fire.

3. **Conduction** – The movement of heat through solid objects. Examples include the transfer of heat through a copper pipe or a metal spoon in a hot liquid. In wildland fires, conduction usually takes place in large fuels, such as fallen logs or within the soil substrate. Because wood is a poor conductor of heat, this method has the least influence on the rate of spread in most fires. Conductive heat can have dramatic impacts on root systems and soils, especially with slow moving or smoldering fires.

On most fires, the only heat measurements usually recorded are within the flaming front. This includes backing, head fires and flanking fires. There are several ways to measure heat release from wildland fires, but the two most common are:

1. **Fireline Intensity** – The amount of heat released per second per linear foot of the flaming front. Fireline intensity varies dramatically in response to rate of spread. A fire moving rapidly will have much higher fireline intensity than one moving slowly. Flame length is directly related to fireline intensity. Fireline intensity is generally expressed as BTU/foot/second.
2. **Heat Per Unit Area** – The total heat released within a square foot of the flaming front independent of time. This measures the total heat released during the flaming phase of combustion and, unlike fireline intensity, is a result of the amount of fuels available to burn under given fuel moisture conditions. Heat Per Unit Area is generally expressed as BTU/square foot.

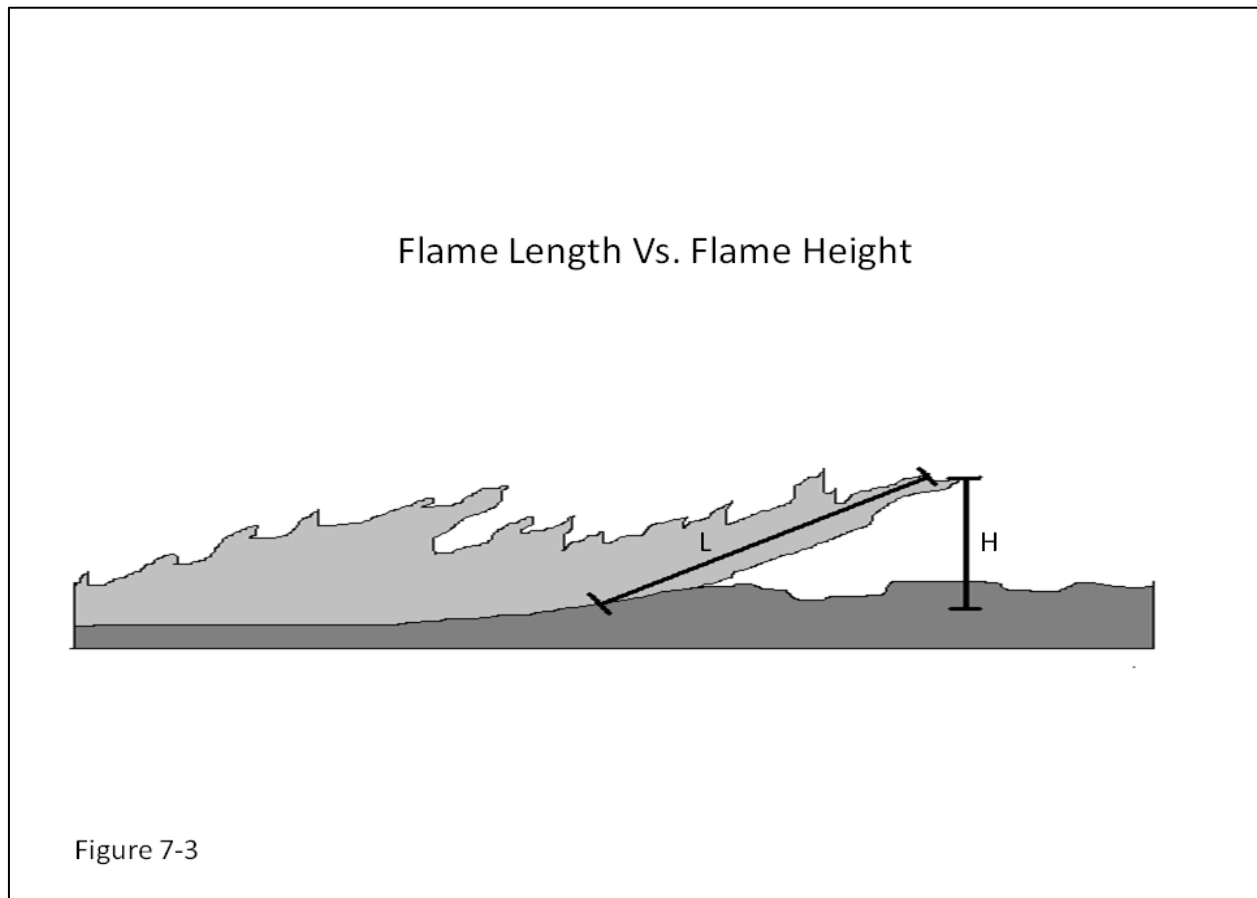
The important point to remember is that the total heat released and the total fuel consumed are not measured by either of these methods. While Heat Per Unit Area attempts to measure the total energy release during the flaming phase of combustion, the smoldering and glowing phases are not considered. Fireline intensity is important as it relates to crew safety and the ability of a given fireline to contain the prescribed fire.

OXYGEN AND WIND

Oxygen is necessary for any type of combustion, and the air around us contains sufficient oxygen to sustain fire. Air movement in and around the active fire can either accelerate or slow the combustion process. Providing additional oxygen facilitates combustion. While all of these factors discussed in this chapter can influence the combustion process, it is wind (the horizontal movement of air) in conjunction with fine dead fuel moisture that are the principal determinants of the rate of spread of a fire on a specific burn unit on any given day. If there is no wind, the fire “stands straight up” and the heat from the fire also goes straight up. Sustained wind with constant direction will “bend” the flames in the direction it is blowing. Wind also dissipates heat

laterally rather than “straight up.” This lateral movement of the heat reduces scorch and damage to the overstory. This can be especially important during spring and summer months, or whenever crown scorch may be critical.

The bending or leaning of flames makes the distinction between flame height and flame length critical. **Flame Height** is the vertical distance from the tip of the flame straight down to the middle of the fuel bed. **Flame Length** is the distance from the tip of the flame to the middle of the fuel bed at an angle equal to the leaning of the flame (Figure 7-3).



Another term applied to wind with respect to fire is the **Mid-Flame Wind Speed**. As the name implies, this is the wind speed at the mid-point of the flame. On many prescribed burns, field measurements of wind speed taken at eye level are used to approximate Mid-Flame Wind Speed, which is also referred to as Eye Level Wind.

Flame lean is important because it heats fuels and the air mass adjacent to the flame prior to ignition. In addition, the wind moves a fresh supply of oxygen to the fire.

Fires moving upslope travel much faster when the wind and slope are in the same direction. Flame lean and upslope elevated fuels provide faster and more complete preheating of the fuels and better oxygen mixing. Even in Florida, with relatively low rolling hills, these conditions can greatly increase the fire's rate of spread.

FUEL CHARACTERISTICS

Characteristics of fuels affecting fire behavior in Florida include:

- 1. Fuel Loading**
- 2. Fuel Size and Shape**
- 3. Fuel Arrangement**
- 4. Compactness**
- 5. Horizontal Continuity**
- 6. Vertical Arrangement**
- 7. Chemistry**

Fuel Loading

Fuel loading is the amount of fuel available to burn. It is usually measured in terms of tons of dry fuel per acre. Fuel loading may also be measured as bulk density in pounds per cubic foot. In Florida, biomass may vary from zero to 500 tons per acre in mature timber stands. Fuel loading includes both live and dead vegetative biomass, but it should only estimate fuel that is available to the fire and not necessarily the total biomass. For example, a low intensity prescribed fire in a mature timber stand may consume less than 5 tons per acre while total biomass could easily exceed 100 tons per acre.

Fuel Size and Shape

Fuel size and shape determines the ability of individual fuels to carry and sustain a fire. Typical Florida fuels that carry and sustain fires include pine needles, fine grasses, sawgrass and palmetto fronds. Typically it is the dead plant material within these types that actually carry and sustain fire. Larger tree limbs and logs are harder to ignite and do not normally sustain prescribed fires. Fuel size and shape is usually expressed as the surface area to volume ratio for individual pieces of fuel. Fine fuels such as wiregrass will have a ratio greater than 1000:1 while larger fuels like stumps and downed trees will have a ratio as low as 40:1. Fine fuels are easier to ignite because oxygen is readily available to all of the fuel and because the entire fuel mass dries and heats quickly.

Compactness

Fuel compactness may be simply defined as the percent of the fuel bed which is actually composed of fuel. This can be calculated by measuring the “packing ratio” which is the fuel volume divided by the total volume of the fuel bed. Typical ratios may range from 0.1 to 1.0 and, when multiplied by 100, represent a percent of the fuel bed. For illustration purposes, think of the pages of a phone book. Each page represents a fuel particle. With the phone book closed, the entire fuel bed is contained within the book. In this case, the volume of the book equals both the volume of the fuel and the volume of the fuel bed. The packing ratio is 1.0, meaning fuel (the pages) occupies 100% of the fuel bed. If, however, the individual pages are removed, crumpled and placed in a box, compactness has been altered. Now the volume of the box represents the fuel bed and the volume of the pages or fuel is only a small fraction of the fuel bed. In this case, fuel compactness would probably be less than 10%. Now the fine fuels (pages of the book) will ignite readily and burn rapidly.

Horizontal Continuity

Fuel continuity refers to the distribution of fuels within the burn unit. When fuels are continuous, they are evenly distributed throughout the area. Healthy, dense Everglades sawgrass strands are often thick and impenetrable. These strands often have complete horizontal continuity and fire moves evenly across such an area. Horizontal continuity applies to ground fuels, surface fuels and aerial fuels. In a closed canopy forest, aerial fuels would have horizontal continuity. When these same fuels are patchy or clustered, fire behaves much differently. Fire travels at different rates depending on fuel distribution and many areas may not burn at all.

Vertical Arrangement

Vertical arrangement refers to the distribution and spacing between surface and canopy fuels, or vertical continuity. Often, the space between these two fuel types is devoid of fuels and there is no vertical continuity. Ladder fuels provide vertical continuity and, when these fuels are abundant, there is a higher probability of a canopy fire, torching or severe canopy scorch. Crown fires are not a widespread, frequent problem in Florida. They are most likely to occur in thick cabbage palm forests, dense melaleuca stands, crowded pine plantations and forests where fire has been excluded. Common ladder fuels in Florida include cabbage palms, vines, Spanish moss, standing snags and mature wax myrtles.

Chemistry

Fuel chemistry is important when plants contain volatile chemicals. When abundant, these volatile oils or petroleum-like substances can cause fires to burn hotter, faster or both under

certain conditions. Two widespread Florida plants are well known for containing volatile oils. Saw palmetto and sand pine both have chemical properties that make prescribed burns a real challenge. Volatility is greater when live fuel moisture is lower. Tests have shown that sand pines have their lowest moisture in March. Palmetto moisture varies with geographical location and soil moisture. Dead palmetto fronds contain relatively low levels of volatile chemicals. “Lighter” pine is another fuel with unique chemical properties due to the high resin content. This fuel is found throughout Florida’s pine forests, especially where older trees are abundant and snags are left standing. Stumps of older trees and snags are major sources of “lighter” pine. Once ignited, this fuel is extremely difficult to extinguish. The high resin content also allows larger snags and stumps to burn for extended time periods. Snags can be critical when they are near the boundary of the burn unit. Not only can the snags burn and fall across the control line, but burning embers from dead limbs or “punky” soft wood on the main trunk can be transported across control lines as long as the snag is burning. In some cases, stumps from logging operations in the middle of the last century can produce significant quantities of residual smoke. If the burn unit is near a smoke sensitive area, extensive mop-up may be the only solution.

FUEL MOISTURE

Understanding how fuel moisture impacts fire behavior is crucial for prescribed burn managers. Anyone who has attempted to start a campfire using wet wood appreciates the role of fuel moisture in the process of combustion. Prescribed burners are concerned with the moisture content of both dead and live fuels. In either case, fuel moisture is measured by oven-drying the fuels and calculating the percent of total weight occupied by water.

$$\text{Fuel Moisture Percentage} = (\text{Weight of Water/Oven Dry Fuel Weight}) \times 100$$

Dead Fuel Moisture

Dead fuel moisture is regulated by relative humidity and the microclimate where the fuel occurs. Depending upon the microclimate, soil moisture may play a significant role in determining fuel moisture. Factors that can contribute to a change in the dead fuel moisture include:

- 1. Precipitation (amount and duration)**
- 2. Relative Humidity**
- 3. Wind**

Wind can increase or decrease fuel moisture, depending on relative humidity. The fuel itself can regulate the amount of moisture it can absorb or lose. Waxy coatings can inhibit moisture absorption while rotten wood tends to act like a sponge and prevent moisture loss. Dead fuels

gain and lose water from the surrounding air mass in a balancing act to maintain equilibrium. The Equilibrium Moisture Content is reached when fuels are neither gaining nor losing water from the surrounding air mass. Unfortunately, in the real world, air masses are constantly changing. Changes in relative humidity at a given location occur with changes in temperature and with movement and replacement of air masses. For this reason, dead fuels are constantly trying to “catch up” with the changes in the surrounding air mass. Fine fuels, such as dead pine needles and wire grass, have a high surface area to volume ratio and can reach equilibrium rapidly. These fine fuels are called 1 hour timelag fuels. Large logs have a low surface area to volume ratio and reach equilibrium slowly. These large diameter fuels are referred to as 1000 hour fuels. Intermediate size fuels, such as limbs and small trees, are referred to as either 10 or 100 hour fuels based on their diameter or thickness.

Fuel Timelag Categories Based on Diameter

1 Hour	=	Up to ¼ inch in diameter
10 Hour	=	¼ inch to 1 inch in diameter
100 Hour	=	1 to 3 inches in diameter
1000 Hour	=	3 to 8 inches in diameter

Because fine dead fuels are the primary carrier of prescribed fire, measuring their moisture content allows the prescribed burn manager to better predict and understand fire behavior. In Florida, fine dead fuel moistures usually fall within a range of 5-14% under normal daytime burning conditions. Caution should be used when fine dead fuel moisture falls below 7%. Unfortunately, most burners cannot measure fuel moisture on every burn. A fine dead fuel moisture chart, such as the chart found at the end of this chapter, gives the burner a method to estimate moisture under a variety of conditions. It is important to remember this chart only **estimates** fuel moisture.

Live Fuel Moisture

Live fuels also burn in many fires. Because their moisture content may vary considerably, their response to fire also varies. Live fuels with less moisture will burn more readily than live fuels with high moisture. While dead fuels respond quickly to changes in environmental conditions, live fuel moisture is much more dependent upon longer term factors, such as season, growing stage and drought conditions. Other factors, such as relative humidity, wind, flame length, fuel load, residence time and recent precipitation can also influence live fuel ignition probability.

Live fuels are divided into four groups:

- 1. Deciduous leaved trees and shrubs**
- 2. Evergreen broad leaved trees and shrubs**
- 3. Conifers**
- 4. Herbaceous plants (grasses, forbs and grass-like plants)**

Deciduous leaved trees and shrubs tend to have high fuel moisture during their spring flush. With higher fuel moisture, these leaves are less likely to burn, but they are more susceptible to mortality. Many herbaceous plants will maintain relatively high moisture during active growth stages. Stress or adverse conditions can lead to lower moistures and increased susceptibility to fire. In Florida, frost can dramatically increase the fuels available to a fire. Prescribed burn managers should reevaluate proposed burns following any frost or freeze event. In some cases, however, these events allow burners to target specific fuels that will not burn under other circumstances.

The Florida Forest Service has established a network which measures and monitors live fuel moistures across the state. This information is available through the FFS website.

Duff Moisture

Most prescribed burns target surface fuels. Ground fuels (peat, duff and muck) are not normally burned as they can produce large volumes of residual smoke due to prolonged smoldering. Fire restoration programs may require duff removal on areas where fire has been excluded for long periods of time. Most successful programs rely on a gradual process where a small percentage of duff is targeted with each prescribed fire. These burns require extra resources for control and mop-up and should be conducted by experienced burners. On intensely monitored sites, the actual moisture content may be measured. The following guidelines have been established for duff consumption:

<u>Duff Moisture</u>	<u>Fire Activity</u>
<30%	Duff layers burn on their own once ignited
30-120%	Duff consumption depends on consumption of related fuels, residence time, relative humidity and post-fire weather
>120%	Duff will not burn under normal conditions

In the absence of intense monitoring, prescribed burn managers utilize a variety of methods to estimate duff moisture. Under high moisture conditions, even the upper layers of duff will have visible moisture. Prior to the burn, examine duff carefully by exposing cross sections at selected locations. Monitor duff moisture under a variety of conditions, not just on the day of the burn. Check water levels in adjacent rivers, lakes or canals. If water levels are below normal, a more intensive assessment may be required.

FUEL MODEL CATEGORIES

Every wildland fire burns differently, but fires with common fuel characteristics will tend to burn in the same manner. Remember the fire environment includes fuels, weather and topography. Describing characteristics in Florida fuels requires the student to identify what fuel or material will be the primary carrier of a particular fire and the general vegetation type in the burn unit.

Wildland fire fuels are classified into 13 fuel models. This list of 13 models are grouped into four basic categories:

- 1. Grass**
- 2. Shrub**
- 3. Timber Litter**
- 4. Logging Slash**

Grass Dominated

Examples of grass dominated fuel models in Florida include Everglades sawgrass, Longleaf pine wiregrass sandhills in north Florida, dry prairie communities in central Florida, and many areas that have been converted to cattle range.

Shrub Dominated

Examples of shrub dominated fuel models in Florida include pine flatwoods with palmetto-gallberry understory, scrub communities around the Ocala National Forest and throughout the Lake Wales Ridge region and ti ti communities in northern Florida.

Timber Litter Dominated

This fuel category is often characterized by a closed or nearly closed canopy. The lack of sunlight inhibits understory growth and the fuels to carry a fire are provided by overstory trees. When hardwoods are dominant, the leaves that are shed annually comprise the primary fuel.

These fuels are sometimes called “blowby leaf” and even light winds may promote fire spread. In Florida, closely planted pines on tree farms fall into this category. Pine needles are the primary fire carrier in this case, but dead and fallen limbs may also be present.

Logging Slash Dominated

Logging slash is generally created as a result of logging or exotic tree control operations, although natural forces can also create this fuel condition. Hurricanes, tornadoes and widespread tree mortality caused by insects or disease can result in logging slash fuels.

More recent fire behavior research has resulted in an additional set of 40 fuel models which are grouped into six categories. These categories include Grass, Grass/Shrub, Shrub, Timber Litter, Timber Litter/Understory and Logging Slash.

RATE OF SPREAD

Rate of spread is determined by wind speed, topography, fuel size and arrangement and fine dead fuel moisture content. A 5 mph wind does not result in a 5 mph rate of spread. Doubling the wind speed can more than double the fire’s rate of spread, but rate of spread will always be less than wind speed on level ground if spotting is ignored. Spotting can obviously result in a fire advancing much faster than its rate of spread. Fires running upslope can also spread faster due to preheating of fuel through convective and radiant heat transfer.

A variety of tools now exist which allow students to predict fire behavior, including but not limited to rate of spread. Some of these tools, such as fire behavior nomograms and tables, do not require the use of modern technology. Other computer based tools, such as Behave Plus, FARSITE and Flam Map are much more technologically advanced. Regardless of the technology, each of these tools uses Rothermel’s Fire Spread Model developed in 1972.

Like any model, these are dependent upon accurate input data and the validity of some basic assumptions:

- 1. Fire burns at a steady rate**
- 2. Surface fuels are homogeneous**
- 3. Slope and Aspect are uniform**
- 4. Wind speed and direction are constant**
- 5. Fire behavior outputs are limited to the flaming front**
- 6. Fire behavior is not influenced by ignition patterns or suppression action**

Changes in weather conditions and deviations from these basic assumptions can lead to erroneous predictions. In many cases, only minor deviations occur and fire intensity can be accurately predicted. In addition, there are many fire characteristics which are not predicted by these models. Some of these are fuel burnout time, duration of smoldering and glowing, total heat pulse, and soil heating. All of these factors contribute to burn severity.

SEVERITY vs. INTENSITY

Successful prescribed burns require proper management of both the intensity and severity of the fire. These similar terms have very different meanings.

Intensity is a measure of the rate of heat released during combustion, generally over both time and space (review the section on heat transfer). It is important to remember that both fireline intensity and heat per unit area measure the heat released only during the passing of the flaming front. Neither measure total heat release during all phases of combustion.

While intensity can be described in absolute terms by measuring actual rates and amounts of heat released, in reality intensity is often described in relative terms (e.g. high, medium and low). When these terms are used, they often describe relative intensity within a given fuel type.

Severity measures the impact of the fire on the environment. It includes not only the impact on plants and animals, but also any impacts to the physical environment including soils and water.

Severity is a subjective term. Media reports often state that thousands of acres have been “destroyed” by a particular wildfire. In some cases, valuable timber resources are destroyed, severe economic losses are sustained or other environmental impacts result from wildfire events. In other cases, there may be little resource damage and, in fact, benefits may outweigh losses.

While intensity of a particular fire will influence the severity of that fire, there is not a direct correlation between intensity and severity. Therefore it is possible to have any combination of these two variables including:

1. High Intensity – Low Severity: e.g. a properly planned and executed prescribed fire to improve scrub jay habitat may often fall into this category.
2. Low Intensity – High Severity: e.g. a backing fire in a longleaf pine community that burns into the duff and kills 100 year old trees

3. Low Intensity – Low Severity: e.g. a head fire in a two year rough longleaf pine wiregrass community
4. High Intensity – High Severity: e.g. intense wildfires in the wildland urban interface that destroy homes, timber, habitat and significantly impact travel on major highways

FIRE BEHAVIOR SPECIFICS FOR PRESCRIBED FIRE

To achieve desired fire effects, fire behavior is regulated through the careful selection of weather and fuel conditions, firing technique and ignition pattern. As the weather changes during a burn, firing technique and ignition pattern should be assessed and changed as necessary to best achieve objectives.

Always set a test fire just prior to igniting a burn. Observe fire and smoke behavior on the test burn and incorporate this information into fire behavior predictions. If anticipated fire and smoke behavior are within acceptable limits, continue with ignition.

Measure fire behavior during the burn to develop a numerical record of what transpired. Periodic measurements allow the prescribed burner to evaluate observed fire behavior and fire effects with changing weather conditions, firing techniques and adjustments as the burn progresses. Measurements should include flame length, rate of spread, flame zone depth and residence time. Record whether the fire is backing, flanking or heading during measurements.

Flame Length

Flame length is at least equal to flame height. Flame length is measured from the tip of the flame to its base, midway between the leading and trailing edge (review Figure 7.3). In the absence of wind, flame length and flame height (the vertical distance from the tip of the flame to the ground) are equal. As two lines of fire merge, flame lengths will increase, thereby increasing the probability of crown scorch.

Rate of Spread

Rate of spread can be estimated by recording the length of time it takes for the fire move a known distance. Use a mark in the fireline, a ribbon on a tree or some other method to determine a starting point. Measure the distance travelled in no less than 15 minutes to determine the rate of spread in feet per minute.

Flame Zone Depth

Used to calculate residence time, the flame zone depth is simply a measurement of the distance from the leading edge to the trailing edge of the flaming front.

Erratic Fire Behavior

In young conifer stands, think about ladder fuels. Needle drape is a major concern when conducting the initial burn in dense southern pine stands, particularly if a woody understory is present because of the threat of severe crown scorch. Copious needle drape or flammable understory plants such as palmetto, gallberry and waxmyrtle may result in fire torching out an occasional pine, but the threat of crown fire is low under good prescribed burning weather.

It is also important to recognize the conditions contributing to and indicators of potentially erratic fire behavior.

- 1. Keetch Byrum Drought Index above 500**
- 2. Fine dead fuel moisture content below 7%**
- 3. Relative humidity below 30%**
- 4. Cold front approaching with probability of rain less than 30%**
- 5. Gusty winds**
- 6. Dust devils / fire whirls**
- 7. Adverse wind profile (stronger winds closer to the ground)**
- 8. Sea breeze front**
- 9. Tall, well-defined convection column**
- 10. Thunderstorms**
- 11. Spotting in several directions**
- 12. Dispersion index approaching 70**

Residence Time

Residence time may be a better indicator of stem-kill than fireline intensity. Residence time is the time it takes the flaming front to pass a given point. The longer the residence time, the more heat energy is released. Residence time can be calculated as follows:

$$\text{Residence Time (in minutes)} = \text{Flame Zone Depth (in feet)} / \text{Rate of Spread (feet/minute)}$$

The wide flame zone and rapid rate of spread of a low intensity headfire may result in the same residence time as the narrow flame zone and slower rate of spread of a backing fire. It is important to remember that residence time does not consider the entire period of combustion.

Large diameter fuels may continue to burn long after the passage of the flaming front. Glowing and smoldering can be prolonged when duff or organic soils burn with little or no flaming. All of these factors can have profound impacts on plants, soils and micro organisms.

SUMMARY

Understanding fire behavior is essential for every successful prescribed fire manager. A successful burn is achieved by careful regulation of the duration and intensity of the fire. Unlike wildfires which often are the result of a single ignition, the prescribed burner must develop an ignition plan which involves several steps and multiple ignitions designed to achieve predetermined measurable objectives.

Because more than one ignition is used, the convergence of two or more flaming fronts is a common occurrence on prescribed fires. When and how that convergence occurs often determines success or failure. The prescribed fire manager who understands fire behavior and how fuels, weather and topography interact on a given fire can utilize this knowledge to manage convergence and achieve desired results.

FINE DEAD FUEL MOISTURE ESTIMATION IN FLORIDA

STEP ONE – Determine Reference Fuel Moisture:

Daytime (08:00 – 19:59)

% Relative Humidity	Dry Bulb Temperature (Degrees F)			
	30-49	50-69	70-89	90-109
15-19	3	3	2	2
20-24	4	4	3	3
25-29	5	5	4	4
30-34	5	5	5	4
35-39	6	6	5	5
40-44	7	6	6	6
45-49	7	7	7	7
50-54	7	7	7	7
55-59	8	8	8	8
60-64	9	8	8	8
65-69	9	9	8	8
70-74	10	9	9	9
75-79	10	10	10	10
80-84	11	11	10	10
85-89	12	12	11	11
90-94	13	12	12	12
95-99	13	12	12	12
100	13	13	13	13

Nighttime (20:00 – 07:59)

% Relative Humidity	Dry Bulb Temperature (Degrees F)			
	30-49	50-69	70-89	90-109
15-19	4	4	4	3
20-24	5	5	4	4
25-29	6	6	5	5
30-34	7	6	6	6
35-39	8	8	7	7
40-44	9	8	8	8
45-49	9	9	9	9
50-54	11	10	10	9
55-59	11	11	10	10
60-64	12	11	11	10
65-69	13	12	12	11
70-74	14	14	13	13
75-79	16	16	15	14
80-84	18	17	17	16
85-89	21	20	20	19
90-94	24	23	23	22
95-99	25	25	25	25
100	25	25	25	25

STEP TWO – Add Fuel Moisture Correction:

November, December, January

Time	Shading <50%	Shading >50%
08:00 - 09:59	5	5
10:00 - 11:59	4	5
12:00 - 13:59	3	5
14:00 - 15:59	2	5
16:00 - 17:59	4	5
18:00 - 19:59	5	5

February, March, April and
August, September, October

Time	Shading <50%	Shading >50%
08:00 - 09:59	4	5
10:00 - 11:59	2	4
12:00 - 13:59	1	4
14:00 - 15:59	1	4
16:00 - 17:59	2	4
18:00 - 19:59	4	5

May, June, July

Time	Shading <50%	Shading >50%
08:00 - 09:59	3	4
10:00 - 11:59	1	4
12:00 - 13:59	0	3
14:00 - 15:59	0	3
16:00 - 17:59	1	4
18:00 - 19:59	3	5

Do not add a Fuel Moisture Correction for
Nighttime Estimations