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Gaining an Understanding

of the

National Fire Danger Rating System

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Gaining an Understanding of the National Fire Danger Rating System

A publication of the NWCG Fire Danger Working Team

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PREFACE

Gaining an Understanding of the National Fire Danger Rating System is a guide explaining the basic concepts of the National Fire Danger Rating System (NFDRS). This guide is intended for everyone in fire and resource management who needs an elementary understanding of NFDRS, including managers, operations specialists, dispatchers, firefighters, and public information specialists.

This guide was developed by the NWCG Fire Danger Working Team to replace the NFDRS User's Guide (NWCG 1985) and to document basic information that could be used to support NFDRS training.

At the time this document was written, several components of NFDRS were in transition from one method or standard to a new one. These include the NFDRS code, which will change measures of solar radiation from "state of the weather" codes to measured solar radiation; weather station standards, which will include satellite telemetry; and redesigned data distribution, storage and processing systems. Where appropriate, both current and future components of NFDRS are addressed.

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1.01 Purpose

1.01.1 Overview

This document addresses the basic terminology, concepts and applications of the National Fire Danger Rating System (NFDRS).

1.01.2 Target Audience

a. Managers, administrators, specialists, and others whose job duties require them to make or apply decisions that are supported in part by National Fire Danger Rating System outputs.

b. Fire specialists and dispatchers responsible for the day-to-day operation of the National Fire Danger Rating System on their unit.

1.01.3 Purpose of this Document

Upon completion of reading this document individuals should:

a. Be able to describe the basic structure of the National Fire Danger Rating System including the various inputs that drive the system.

b. Be able to describe the outputs of the National Fire Danger Rating System.

c. Understand the general sensitivity of outputs relative to the inputs.

d. Be able to describe the role NFDRS outputs play in principal fire management applications.

1.02 History of Fire Danger Rating Systems

The development of fire danger rating systems in the United States closely parallels the development of fire protection programs. Pioneering efforts in fire danger rating research began about 1922 (National Wildfire Coordinating Group, 1985). The fire events of 1910 demonstrated to managers the need to predict the potential for large fire activity. Much of the early fire danger research was conducted under the leadership of the US Forest Service.

Harry Gisborne developed a fire danger meter in the 1930's that incorporated many of the environmental variables we know today into a system that evaluated fire potential. For the next 25 years numerous other efforts were undertaken to develop fire danger rating systems. By 1958, there were at least eight different systems being used by the Forest Service plus numerous other systems being used by state and private protection organizations. When looking at the characteristics of the various systems that were in use, common threads were evident.

a. All were based on observed conditions.

b. All were based on conditions, circumstances and experience of people.

c. All included some measure of fuel type, weather regime and season of year.

The individuals who developed these early fire danger-rating systems knew there was a relationship between weather influences (temperature, relative humidity, precipitation, and wind) and the way initiating fires grew in size. That relationship was based on their personal experience and local observations, not scientific study.

In 1958, a decision was made to undertake an effort to develop a single fire danger rating system to be used throughout the country. Early efforts focused on a four-part system (risk, ignition, spread, and fuel energy). The spread function was developed first. Developers attempted to incorporate the best features of the various local systems into one system. Their product was the Timber Spread Index and its key component, the Build-up Index, were field evaluated in the mid-1960's by various state and federal agencies across the country. The basis for this system was still local observations of fire spread under various weather and fuel conditions. It had limited success.

In 1968, work began on a fire danger rating system that would be built around science and engineering principles rather than local observations (Bradshaw et al., 1983). It would incorporate the basic laws of physics, which are constant, therefore making the new fire danger rating system applicable anywhere in the country. This is the origin of the National Fire Danger Rating System.

The first version of the National Fire Danger Rating System (NFDRS) was released in 1972. It was a manually operated system consisting of various lookup tables and nomograms (see Burgan et al. 1977 for more details on nomograms). This early version included a provision for evaluating and updating the system within the first five years after release. In 1975, an automated version of the NFDRS was made available on a nationally accessible time-share computer system called AFFIRMS (Administrative and Forest Fire Information Retrieval and Management System). During the initial 5-year evaluation period several modifications and enhancements were made. The current version of NFDRS was released in 1978 and is being used by most state and federal fire protection agencies.

In 1988, in response to concerns raised by users in the southeastern part of the country relative to the accuracy and applicability of NFDRS outputs in their area, a modified version was released that included better recognition of how fuel moistures change during periods of drought and precipitation.

In 1993, the AFFIRMS system was replaced by the Weather Information Management System (WIMS) as the processor of fire danger information and is currently being used by most state and federal agencies. Several private vendors have incorporated the NFDRS computer code in PC based software programs that are being used by some state and federal agencies.

In 2001, an interagency effort began to re-engineer WIMS. Upon completion, the new WIMS is expected to be a state of the art suite of fire danger processor, fire weather database, and source of graphical and tabular displays of value-added assessment products depicting historical, current and projected conditions. Updates to the NFDRS structure were part of the new processor. Products will be available for assessing fire danger at local, regional and national scales.

1.03 Basic Principles of Fire Danger Rating

1.03.1 Defining Fire Danger Rating

Before one can discuss fire danger rating, they must define "fire danger." The most commonly accepted definition of fire danger today is: "The resultant descriptor of the combination of both constant and variable factors which affect the initiation, spread and difficulty of control of wildfires on an area" (from Deeming et al. 1972). The various factors of fuels, weather, topography and risk are combined to assess the daily fire potential on an area. Fire danger is usually expressed in numeric or adjective terms.

Fire danger rating is a system that integrates the effects of existing and expected states of selected fire danger factors into one or more qualitative or numeric indices that reflect an area's protection needs.

The fire danger rating of an area gives the manager a tool to assist in the day-to-day "fire business" decisions. The emphasis is on tool because fire danger rating information is not the answer by itself; it must be considered along with the manager's local knowledge of the area and consequences of the decision when arriving at the best solution to a fire business decision or problem.

Fire danger ratings are typically reflective of the general conditions over an extended area, often tens of thousands of acres, affecting an initiating fire. Ratings can be developed for either current (observed) or future (predicted) situations. They can be used to guide decisions two or three days in advance (subject to the limits of the forecasting system) as well as to compare the severity of one day or season to another.

Since many of the factors (fuels, weather and topography) and terminology (spread and intensity) that are part of fire danger rating are very similar to those that affect fire behavior predictions, fire danger and fire behavior are often confused and misused. The principle difference is that fire danger is a broad scale assessment while fire behavior is site specific. Fire danger ratings describe conditions that reflect the potential, over a large area, for a fire to ignite, spread and require suppression action. Fire behavior on the other hand deals with an existing fire in a given time and space. Fire behavior describes the movement (rate of area increase), intensity (flame length), and indicators of rapid combustion (spotting, crowning, and fire whirls) of that fire. It is expressed as real time or predicted conditions for ongoing fires. As you learn more about fire danger, the differences will become more obvious.

1.03.2 Fire Danger Rating Systems

As one might expect, there are many parts to a fire danger rating system. It is a complex mixture of science, technology and local experience. The five key components of a fire danger rating system are:

a. Models representing the relationships between fuels, weather, and topography and their impact on fire business.

b. A system to gather data necessary to produce the rating numbers.

c. A processing system to convert inputs to outputs and perform data analyses.

d. A communication system to share the fire danger rating information between entities.

e. A data storage system to retain data for historic reference.

1.03.3 The National Fire Danger Rating System

Up until this point in history, fire danger rating had been discussed in general terms. Anyone could apply their own scale or weighting to the various fuels, weather, topography and risk factors and create their own fire danger rating system. That is exactly what happened. As agencies and organizations developed their fire protection capabilities during the first half of the twentieth century, most developed some form of unique fire danger rating system as part of their program.

To develop consistency among protection agencies, the National Fire Danger Rating System (NFDRS) was developed in the early 70's. It was designed around four basic guidelines. The research charter said the National Fire Danger Rating System would be:

a. Scientifically based.

b. Adaptable to the needs of local managers.

c. Applicable anywhere in the country.

d. Reasonably inexpensive to operate.

In 1972, the National Fire Danger Rating System was released for general use by agencies throughout the United States. Modifications to the original system were made in 1978 and 1988.

The current system is based on the physics of combustion and laboratory developed constants and coefficients reflecting the relationships between various fuels, weather, topography and risk conditions. The National Fire Danger Rating System tracks the effect of previous weather events through their effect on live and dead fuels and adjusts them accordingly based on future or predicted weather conditions. These complex relationships and equations can be computed by nomograms and handheld calculators, but are more commonly handled by computers (laptop, desktop, and mainframe). In any case the outputs are expressed in simple terms easily understood by users. The current National Fire Danger Rating System is utilized by all federal and most state agencies to assess fire danger conditions.

1.03.4 Key Assumptions within the National Fire Danger Rating System

There are four fundamental assumptions associated with the National Fire Danger Rating System (NFDRS) that must be understood if the system is to be properly applied and interpreted. They include:

1. NFDRS outputs relate only to the potential of an initiating fire, one that spreads, without crowning or spotting, through continuous fuels on a uniform slope.

2. NFDRS outputs address fire activity from a containment standpoint as opposed to full extinguishment.

3. The ratings are relative, not absolute and they are linearly related. In other words if a component or index doubles the work associated with that element doubles.

4. Ratings represent near worst-case conditions measured at exposed locations at or near the peak of the normal burning period.

In summary, fire danger rating is a numeric scaling of the potential over a large area for fires to ignite, spread, and require fire suppression action. It is derived by applying local observations of current or predicted conditions of fuel, weather, and topographic factors to a set of complex science-based equations. The outputs of a fire danger rating system are numeric measures of fire business that provide a tool to assist the fire manager in making the best fire business decisions.

1.03.5 Foundations to Applications of Fire Danger Rating

Fire Danger Rating Area

When the National Fire Danger Rating System was being developed in the 1970's, it was necessary to create a mechanism to relate fire danger ratings to a specific geographic area for planning and operational purposes. The concept of fire danger rating areas was developed and these areas were described as follows:

> "Fire danger rating areas are necessary for effective and efficient use of NFDRS. The areas represent regions of similar climate, fuels, and topography. The size of these areas must be sufficiently small that similarity of fire danger is preserved and yet they must be large enough that fire control planning can function efficiently. Fire danger rating areas provide geographic regions for fire control planning" (Fosberg and Furman, 1971).

Fire danger rating areas are where the rubber meets the road for fire danger rating. They may be tens of thousands of acres in size. A fire danger rating area can represent either a portion of or an entire administrative unit, but its size and shape is based primarily on influences of fire danger, not political boundaries.

Fire Danger Operating Plan

A fire danger operating plan is a fire danger rating applications guide for agency users at the local level. A fire danger operating plan documents the establishment and management of the local unit fire weather system and incorporates fire danger modeling into local unit fire management decisions. Fire danger operating plans include but are not limited to responsible parties (e.g. station maintenance, data entry); fire danger rating areas (e.g. location, development criteria); NFDRS thresholds and breakpoints (e.g. staffing levels, adjective ratings, preparedness levels, and indexes used for each); operational procedures; and Fire Danger PocketCards.

1.04 National Fire Danger Rating System Terminology

Adjective Rating – A public information description of the relative severity of the current fire danger situation.

Annual Plant – A plant that lives for one growing season, starting from a seed each year.

Brush – Scrub vegetation and stands of tree species that do not produce merchantable timber. (Not a synonym for slash.)

Climatological Breakpoints – Points on the cumulative distribution of one fire weather/fire danger index without regard to associated fire occurrence/business. They are sometimes referred to as exceedence thresholds.

Dead Fuels – Naturally occurring fuels whose moisture content is governed by external factors such as temperature, relative humidity and precipitation.

Duff – The partially decomposed organic material of the forest floor that lies beneath the freshly fallen twigs, needles and leaves. (The F and H layers of the forest soil profile.)

Equilibrium Moisture Content – The moisture content that a fuel particle will attain if exposed for an infinite period in an environment of specified constant temperature and humidity. When a fuel particle has reached its equilibrium moisture content, the net exchange of moisture between it and its environment is zero.

Fire Behavior – The manner in which a fire reacts to the influences of fuel, weather, and topography.

Fire Business Thresholds – Values of one or more fire weather/fire danger indexes that have been statistically related to occurrence of fires (fire business). Generally, the threshold is a value or range of values where historical fire activity has significantly increased or decreased.

Fire Danger – The resultant descriptor of the combination of both constant and variable factors that affect the initiation, spread, and difficulty of control of wildfires on an area.

Fire Danger Continuum – The range of possible values for a fire danger index or component, given a set of NFDRS parameters and weather input.

Fire Danger Rating – A system that integrates the effects of existing and expected states of selected fire danger factors into one or more qualitative or numeric indices that reflect an area's protection needs.

Fire Danger Rating Area – A geographic area relatively homogenous in climate, fuels and topography, tens of thousands of acres in size, within which the fire danger can be assumed to be uniform. Its size and shape is primarily based on influences of fire danger, not political boundaries. It is the basic on-the-ground unit for which unique fire management decisions are made based on fire danger ratings. Weather is represented by one or more NFDRS weather stations.

Fire Weather Forecast Zone – A grouping of fire weather stations that experience the same weather change or trend. Zones are developed by the National Weather Service to assist NWS production of fire weather forecasts or trends for similar stations. Fire weather forecast zones are best thought of as a list of similar-weather stations, rather than an area on a map.

Forb – A non-grass-like herbaceous plant.

Fuel Class – A group of fuels possessing common characteristics. In the NFDRS, dead fuels are grouped according to their timelag (1, 10, 100, and 1000 hr) and live fuels are grouped by whether they are herbaceous (annual or perennial) or woody.

Fuel Model – A simulated fuel complex for which all the fuel descriptors required by the mathematical fire spread model have been supplied.

Fuel Moisture Content – The water content of a fuel particle expressed as a percent of the oven-dry weight of the particle. Can be expressed for either live or dead fuels.

Fuels – Non-decomposed material, living or dead, derived from herbaceous plants.

Green-up – Green-up within the NFDRS model is defined as the beginning of a new cycle of plant growth. Green-up occurs once a year, except in desert areas where rainy periods can produce a flush of new growth more than once a year. Green-up may be signaled at different dates for different fuel models. Green-up should not be started when the first flush of green occurs in the area. Instead, the vegetation that will be the fire problem (represented by the NFDRS fuel model associated with the weather station) when it matures and cures should be identified. Green-up should start when the majority of this vegetation starts to grow.

Herb – A plant that does not develop woody, persistent tissue but is relatively soft or succulent and sprouts from the base (perennials) or develops from seed (annuals) each year. Included are grasses, forbs, and ferns.

Herbaceous Fuel Moisture – This calculated value represents the approximate moisture content of live herbaceous vegetation expressed as a percentage of the oven dry weight of the sample.

Litter – The top layer of the forest floor, typically composed of loose debris such as branches, twigs, and recently fallen leaves or needles; little altered in structure by decomposition. (The L layer of the forest soil profile.)

Live Fuels – Naturally occurring fuels whose moisture content is controlled by the physiological processes within the plant. The National Fire Danger Rating System considers only herbaceous plants and woody material small enough (leaves, needles and twigs) to be consumed in the flaming front of a fire.

Moisture of Extinction – The theoretical dead fuel moisture content above which a fire will not spread.

Perennial Plant – A plant that lives for more than two growing seasons. For fire danger rating purposes, biennial plants are classed with perennials.

Roundwood – Boles, stems, or limbs of woody material; that portion of the dead wildland fuel which is roughly cylindrical in shape.

Shrub – A woody perennial plant differing from a perennial herb by its persistent and woody stem; and from a tree by its low stature and habit of branching from the base.

Slash – Branches, bark, tops, cull logs, uprooted stumps, and broken or uprooted trees left on the ground after logging; also debris resulting from thinning or wind storms.

Slope – The rise or fall in terrain measured in feet per 100 feet of horizontal distance measurement, expressed as a percentage.

Staffing Level – The basis for decision support for daily staffing of initial attack resources and other activities; a level of readiness and an indicator of daily preparedness.

Surface-Area-to-Volume Ratio – The ratio of the surface area of a fuel particle (in square-ft) to its volume (in cubic-ft). The "finer" the fuel particle, the higher the ratio; for example, for grass this ratio ranges above 2,000; while for a ½ inch diameter stick it is 109.

Timelag – The time necessary for a fuel particle to lose approximately 63% of the difference between its initial moisture content and its equilibrium moisture content.

Timelag Fuel Moisture Content – The dead fuel moisture content corresponding to the various timelag fuel classes.

Woody Fuel Moisture – This calculated value represents the approximate moisture content of the live woody vegetation (shrubs, small stems, branches and foliage) expressed as a percentage of the oven dry weight of the sample. Woody fuel moisture is based on 1000-Hr fuel moisture. As a model of woody fuel moisture, it is not intended to be exactly what may be measured at a specific location in the fire danger rating area. Of more significance is the trend in the woody fuel moisture. See also the discussion of Measured Woody Fuel Moisture in section 1.07.1.

1 Hr Timelag Fuels – Dead fuels consisting of herbaceous plants or roundwood less than one-quarter inch in diameter. Also included is the uppermost layer of litter on the forest floor. *

10 Hr Timelag Fuels – Dead fuels consisting of roundwood in the size range of one quarter to one inch in diameter and, very roughly, the layer of litter extending from just below the surface to three-quarters of an inch below the surface. *

100 Hr Timelag Fuels – Dead fuels consisting of roundwood in the size range of 1 to 3 inches in diameter and, very roughly, the forest floor from three quarters of an inch to four inches below the surface. *

1000 Hr Timelag Fuels – Dead fuels consisting of roundwood 3 to 8 inches in diameter or the layer of the forest floor more than about four inches below the surface or both. *

* The NFDRS processor does not include any estimation of subsurface fuel moisture in the calculations of 1-, 10-, 100-, and 1000-Hr timelag fuels.

1.05 Basic Structure of the NFDRS

The structure of the NFDRS is quite simple. There are three major parts: Scientific Basis, User Controlled Site Descriptors, and Data (both weather and non-weather). The next section discusses each of these parts in detail. For a schematic display of the NFDRS structure and how it relates to other systems and activities refer to Figures 1 (page 27) and 2 (page 38).

1.05.1 Scientific Basis

Mathematical models are used to calculate fire danger. These models represent basic principles of combustion physics. Most are laboratory determined values and incorporate such factors as the ignition temperatures of woody material, rates of combustion, the moisture of extinction of various types of plant material, the chemical properties of woody debris, and heat energy potential. Most NFDRS users rarely have need for more than a casual understanding of this part of the system. (See Deeming et al. 1977, Bradshaw et al. 1983, Burgan 1988, References Appendix.)

1.05.2 User Controlled Site Descriptors

This information describes the site or area for which fire danger ratings are calculated. It represents a critical part of the operation of the National Fire Danger Rating System. The best weather data in the world will not produce representative NFDRS values if the site descriptors are not representative of local conditions. The following is a discussion of the various site descriptor assumptions users must make when implementing the National Fire Danger Rating System on their unit. They are generally only input once by the user but can be modified to fine-tune outputs to better fit local conditions.

Fire Danger Rating Area: This is a geographical area of generally homogenous fuels, weather, and topographic features, tens of thousands of acres in size. It can represent either a portion of or an entire administrative unit, but it is primarily based on influences of fire danger, not political boundaries. The guiding principle for developing fire danger rating areas is that each is an area of uniform fire danger where unique fire related decisions are made.

Fuel Models: A fuel model is a set of numbers representing the contribution of the dead and live plant material representative of a fire danger rating area. It reflects the volume, size, weight, type, depth, surface-to-volume ratio and other physical properties of the fuel bed.

The National Fire Danger Rating System groups all fuel beds into six general classes based on the predominant surface fuels: lichens and mosses; marsh grasses and reeds; grasses and forbs; brush, shrubs and tree reproduction; trees; and slash. Several of these are broken into sub-classes thus producing a total of 20 different groupings or fuel models. A fuel model is not intended to be a perfect match to the local fuel bed conditions, only a reasonable representation for fire danger rating purposes.

Appendix I is a dichotomous key that has been developed to aid in the selection of the appropriate fuel models. For communication purposes, National Fire Danger Rating System fuel models are referred to using alpha characters, A to U. (Fuel models in the Fire Behavior Prediction System are identified with numbers 1-13.)

Appendix II contains a narrative description of each fuel model. Different sets of fuel models are involved in the 1978 and 1988 versions of the NFDRS model.

Appendix III displays the physical properties of each fuel model used in the National Fire Danger Rating System. Both appendixes are good references to validate selections from the dichotomous key. Often users get caught in the trap of using the narrative description of the fuel model rather than the physical properties of the model. Open ponderosa pine stands are typically thought of as being Fuel Model C but a closer look may reveal that there is an understory of brush or other tree species which may make it more like Fuel Model T. When selecting representative fuel models for your rating area use all the tools available, the dichotomous key, the narrative descriptions and the table of physical properties.

Slope Class: Slope is the rise or fall in the terrain measured in the number of feet change per 100 feet of horizontal distance. It is expressed as a percentage. The slope class should represent the rating area as a whole. When determining slope class, keep in mind that terrain is usually not uniform and that benches or small flats affect the average slope for an area. The National Fire Danger Rating System groups slope into five classes: 0-25, 26-40, 41-55, 56-75, and greater than 75%. They are labeled numerically, 1 through 5. The effect of slope class is significant on NFDRS outputs in that for every increase in slope class (with no wind), the calculated rate of spread doubles when all other factors are constant.

Grass Type (live fuel type): The National Fire Danger Rating System recognizes that there are seasonal differences in fire danger related to the type of grass vegetation present. Annual vegetation produces a different dynamic situation within the fuel complex than does perennial vegetation. Annuals sprout from a seed each year, grow, reach maturity and die usually all in one season. This process is not affected significantly by seasonal weather factors such as temperature or precipitation. Perennial grasses on the other hand, generally start in a dormant condition, grow, reach maturity, then go back into dormancy. Their cycle is greatly affected by temperature and precipitation. Because of these differences, the mathematical formulas or algorithms associated with the drying of herbaceous vegetation are different for the two types of grasses. The loading of fine fuels associated with annual grasses shifts from live to dead and stays there for the duration of the season. For perennial grasses the shift from live to dead is much slower and may even stop or reverse if the right combinations of temperature and precipitation occur during the season. Where both annual and perennial grasses occur together select the type that predominates the site.

Climate Class: The National Fire Danger Rating System recognizes that vegetation adapts to the general climate of the area and that some of these characteristics affect seasonal fire danger. For example, the herbaceous plants common to a warm maritime climate have a different growing season pattern than those that have evolved in a dry arid environment. Generally the growing period when individual plants are lush and green is longer in the maritime climates than in the arid climates. The NFDRS uses four Climate Classes, numbered 1 through 4. Class 1 represents arid or semi-arid desert or steppe country. Class 2 represents the semi-humid climate where summertime moisture is deficient. Class 3 represents the semi-humid climate where summertime precipitation is adequate to sustain plant growth most of the season (typical of the mountain West and the area east of the Mississippi). Class 4 represents the wet coastal areas where summertime precipitation and fog are common (typical of the Pacific Coast). Appendix IV gives a more detailed description of each climate class as well as a map showing where the various climate classes typically occur across the country.

Associated with each climate class is an assumption as to the length of a typical growing season. In the NFDRS model, herbaceous fuel moistures increase for the number of days associated with each climate class. In Climate Class 1 the modeled fuel moisture increase occurs for seven days. In Climate Class 2 it is 14 days, in Climate Class 3 it is 21 days and in Climate Class 4 it is 28 days. This herbaceous fuel moisture increase occurs in the 1978 version during green-up (Section 1.09.2). The climate class map in Appendix IV is an approximation and should only be used as a guide. Users should examine the characteristics of herbaceous vegetation common in their area to select the climate class that best fits their situation.

Annual Precipitation: This is a critical input for those units using the 1988 version of the NFDRS or those desiring to use the Keetch-Byram Drought Index (KBDI) as an adjunct to the NFDRS. The KBDI is a separate system developed in the southeast part of the United States to address the effects of long term drying, i.e. drought, on the forest soils and duff layer. The relationship between air temperature and the daily KBDI drought adjustment factors varies for different levels of annual precipitation. Therefore, the amount of annual precipitation is needed to select the appropriate lookup table or equation to use when deriving the daily drought factor. Certified NFDRS processors require an entry in this field, regardless of whether you intend to use the KBDI or not. The best source for this information is local climatological data or precipitation maps. Data for average annual precipitation that is accurate to within five inches per year is acceptable for computing the KBDI.

1.05.3 Data

The data used to calculate daily fire danger rating indices and components comes in two forms. The first is the daily weather observations and the second is the parameters that the user sets to control the actual calculations within the NFDRS processor. Each is discussed below.

Weather Inputs: Of the factors that affect the daily changes in fire danger, weather data are the most significant. Data should be reflective of conditions experienced or anticipated to occur within the fire danger rating area. The National Fire Danger Rating System can be operated on either observed data to produce indices and components reflective of today's conditions or on forecasted data to predict tomorrow's conditions. The data needs are the same; where they come from is the only difference. Observed data is obtained from locally operated manual and automatic NFDRS weather stations. Weather forecasters of the National Weather Service develop the predicted data using trends applied to observed conditions within a fire weather forecast zone. (As an example a forecaster might develop a trend forecast for a specific weather zone that tomorrow's temperature will be up three degrees, relative humidity will be down 5%

and there will be no change in wind speed.) Once this information is provided by the forecaster, it is applied automatically within the NFDRS processor to today's observed conditions at all stations within the fire weather forecast zone to calculate the forecasted conditions. NFDRS calculations are usually done on data representative of one p.m. local standard time conditions. See Appendix V, Weather Data Requirements, for additional weather data information.

Quality control is very important, of both the data and the instruments used to collect them. Individuals responsible for the daily input of weather data into NFDRS should be familiar with the normal or expected ranges in environmental conditions (such as temperature, relative humidity, and wind speed) for their local area and take appropriate actions to validate observations that are outside the normal range. Similarly, they should be aware of weather data values that change little from day-to-day. This could be a sign that a sensor or instrument is not working properly. Errors in some data elements, such as relative humidity, have cumulative effects on fire danger rating if allowed to continue over extended periods of time.

A continuous stream of data is just as important as the quality of the data itself. If daily observations are missed two things happen. First, you lose the effects of the day on the drying or wetting of the fuels which may be significant in the early and later parts of the fire season. Secondly, there is no data for the National Weather Service forecasters to use in developing their forecasts or to apply their trends or point forecasts to; thus no forecasted fire danger for the next day.

Other NFDRS Parameters: The mathematical equations that generate the outputs of the NFDRS are simply models of actual circumstances. There are certain conditions and observations that users of the system must input periodically for the outputs to be truly representative of their local conditions, and they are presented here.

> State of Herbaceous Vegetation: As stated earlier, both annual and perennial herbaceous vegetation go through a growing period, a curing period, and a dormant period. Some of these changes can be modeled, some cannot. NFDRS users must be aware of changes occurring in the field and make an appropriate entry to accommodate factors that the model cannot deal with. For example, once herbaceous vegetation is subjected to a killing frost, no subsequent change in temperature will bring it back to life for that season. The actual killing frost temperature is not necessarily 32^{o}F (0^{o}C) for all plant species. Therefore the NFDRS user must enter the occurrence of a killing frost based on local conditions.
>
> Secondly, some refer to the period that plants are actively growing as the period of green-up. In the NFDRS, the climate class you assign to the fire danger rating area controls the modeled length of this time period. The model can estimate when the growing season ends but it cannot determine when to start the growing season. Therefore each year the user must enter a date the growing season begins. Depending on the area, this date may vary by elevation, seasonal weather pattern, etc. Start of green-up can only be determined by observing what is actually happening in the field.

Finally, many areas operate the fire danger rating system before green-up occurs but after the snow has left the fuels. Under these dormant conditions, the herbaceous plant material from the previous growing season is treated as dead fuel in fire danger calculations. For stations operated either on a year-round or on a seasonal basis, the user may adjust the shift from frozen to pre-green herbaceous vegetation condition to reflect this period of the year before green-up starts. (See section 1.09 Operations for operational details on station start-up and green-up.)

Shrub Type Code: One of the modifications made in the 1988 version of the NFDRS was to recognize differences between shrub types. Separate equations were developed for deciduous and evergreen shrub vegetation. Therefore, users of the 1988 fuel models must enter a code indicating whether their local shrub vegetation is deciduous (D) or evergreen (E).

Staffing Index and Display Class Breakpoints: The various processors used to calculate NFDRS indices and components also include the capability of displaying the outputs by group or class. The NFDRS user must first determine which indices or components they want to use to base staffing or other actions on. Generally, this is determined by unit fire managers and may be specific to the local unit or applicable to several units in a larger geographical area.

After the indices or components are selected, the number of breakpoints or classes must be identified. Again this is usually determined by the unit fire manager or in some cases the agency they work for. The number of classes is usually based on the number of different decisions that are to be made using that index or component.

It is also necessary to designate where the individual classes are to be broken. Included in the formulas that execute the NFDRS are equations that automatically determine the breakpoints between classes. All the user has to do is to tell the model where to start. The initiating breakpoint is usually an agency policy decision. For example, the US Forest Service uses the 90^{th} and 97^{th} percentile values for the specific indices as a starting point. The Bureau of Land Management uses 80^{th} and 95^{th} percentile values for their starting point. An analysis of historic indices and component values as well as fire occurrence is necessary to select the appropriate class breakpoints for local applications. See Appendix VI for additional discussion of breakpoints.

Measured Woody Fuel Moisture: The modeled fuel moisture of live woody material does not always track with the measured woody fuel moistures from sampling sites. This is because live fuel moisture values in the NFDRS are modeled values designed for the broad scale of fire danger, rather than site-specific measured values. In these instances, fire managers have a couple of options. Physical measurements of the moisture content of the small branch wood and foliage of live woody plants can be collected monthly. Preferably the user will already be monitoring these measured live fuel moistures in parallel to the outputs of the NFDRS and using experience to include the measured fuel moisture values as another tool in their decision-making toolbox. This allows the NFDRS model to work for the user as it was intended.

Alternatively, the user can regularly enter measured live woody fuel moisture into the NFDRS processor to calibrate the woody fuel moisture model. The calibration based on measured woody fuel moisture is valid for 30 days. If no new measured value is entered within 30 days, the model returns to using only weather data. The woody moisture computed solely from weather data may be quite different from that computed from both weather data and the measured woody moisture. This may result in sudden or unacceptable changes to NFDRS outputs. This approach requires consistent care and feeding of the processor (i.e., a regular live fuel monitoring program) and has been discouraged by some agencies.

Season Codes and Greenness Factors: These are additional data needs resulting from the changes made during the 1988 revision to the NFDRS. They are only required if you are using the 1988 fuel models. The season code corresponds to the season of the year the observations are being taken. The seasonal breakdown represents the various stages of plant development, not necessarily corresponding to calendar days typically represented by each season. Winter is the dormant season when no growth is occurring and the leaves have fallen. Spring is the growing season. Summer is the period when the mature vegetation transitions to dormancy. Fall is the period the leaves are falling and the plants are entering dormancy.

In addition to the season codes, it is necessary, if using the 1988 fuel models, to enter a greenness factor for both the grasses and shrubs. Values are scaled from 0 to 20 with 0 being near dead and 20 representing conditions of maximum greenness or flush. These values must be updated regularly based on field observations as the season progresses.

Refer to Appendix VIII for additional information regarding season codes and greenness factors.

KBDI Initiation: The Keetch-Byram Drought Index (KBDI) is a stand alone drought index that can be used in conjunction with the National Fire Danger Rating System if you are using the 1978 fuel models, but is required if you are using the 1988 fuel models. (KBDI controls the drought fuel load in the 1988 fuel models.) In either event it is important that the KBDI is initialized at the start of each season. Since the index is an estimate of the amount of precipitation (in 100ths of inches) needed to bring the moisture content of the top eight inches of soil back to saturation, a value of 0 is complete saturation of the soil. Since most fire danger stations are not being operated when the soil is in a saturated condition, it is necessary to estimate what the KBDI value is when the user begins daily observations. The technical documentation describing the KBDI includes methodology to estimate the initiating value. Most processors include a default initiation value of 100. (See Burgan, 1993, for more information on initializing KBDI.)

1.06 NFDRS Processors

National Fire Danger Rating System calculations were originally performed by hand using look-up tables and nomograms. These were replaced by handheld programmable calculators and mainframe computers. Sometimes the memory capacity of the calculators or computers being used caused programmers to leave out certain features of the National Fire Danger Rating System. As a consequence different results were often obtained using what appeared to be the same input data.

Today, there are three different types of processors used to produce NFDRS outputs: 1) a central interagency server: the Weather Information Management System (WIMS), 2) private vendor PC software for office use: Fire Weather Plus and Weather Pro, and 3) interagency PC software for office use: FireFamily Plus. These processors are reviewed in the following sections.

In 1997, the National Advisory Group for Fire Danger Rating (NAGFDR) certified one set of NFDRS computer code. The processors in WIMS and FireFamily Plus use the certified NFDRS code. It is up to the user of private vendor software to insure that their NFDRS processor uses the latest version of certified code.

1.06.1 Weather Information Management System - WIMS

WIMS is a comprehensive system that helps users manage weather information. Most federal and state fire and resource management agencies use WIMS to calculate their daily fire danger ratings.

Among the many sub-systems of WIMS is the processing software code for the National Fire Danger Rating System. It runs on a computer at the USDA National Information Technology Center in Kansas City, Missouri (NITC –KC). The system is accessible 24 hours a day from a personal computer via the Internet.

WIMS receives hourly fire weather data from 1) remote automatic weather stations (RAWS) via satellite; 2) non-satellite automatic weather stations (AWS) via a phone modem hub; and 3) manual weather stations via manual entry. This data is stored in WIMS for 18 months. Daily data necessary for NFDRS calculations (e.g. maximum and minimum temperature and relative humidity; 1300 hour observations) are archived in the National Interagency Fire Management Integrated Database (NIFMID) for future reference and analysis. Only weather data is archived. NFDRS outputs associated with archived data have to be re-calculated. All hourly observations from RAWS and AWS are also sent to and archived at the Western Regional Climate Center (WRCC) in Reno, Nevada.

The principal advantage of a centralized processing system like WIMS is that the information can be automatically stored and is available to all users. A user can easily view anyone else's station records, data, and outputs without additional phone calls or connections. For security reasons, only the station owner can modify the information.

Several enhancements are being made to WIMS. Station data and daily fire danger outputs in WIMS and archived data in NIFMID are now accessible only via the worldwide web at http://famweb.nwcg.gov/. Automatic measures of solar radiation will replace manual estimates of "state of the weather." Further enhancements to the NFDRS model will continue. Products, displays, and applications will be expanded.

WIMS uses a sub-system called the HUB to collect data from non-satellite based automated weather stations. The HUB calls these stations at a pre-determined time (usually twice a day), collects the data, and forwards to WIMS and the National Weather Service. Station owners must request that the HUB collect the data from their stations by contacting the National Systems Support Desk at 1-800-253-5559. The HUB is scheduled to be decommissioned at the close of 2005, as GOES telemetry will then be required for all NFDRS reporting stations.

1.06.2 Fire Weather Plus and Weather Pro

Fire Weather Plus and Weather Pro are privately developed software packages distributed by Forest Technology Systems (http://www.ftsinc.com/) and Remsoft, Inc. (http://www.remsoft.com/) respectively. Both were developed to support fire danger calculations for remote weather data collection platforms that were marketed by the respective companies. Fire Weather Plus and Weather Pro can be operated on a PC usually with telephone or radio modem capability to retrieve data. Data retrieval, communication and graphing features have also been added to these software packages.

The principle advantages of using Fire Weather Plus or Weather Pro software are that all calculations are done on your local PC workstation and that the software also includes graphic display capabilities of the calculated NFDRS outputs.

The disadvantage is that both systems require special actions on the part of the user operating it to make their weather observations available for others to use. Most commonly, this involves uploading the individual observations into WIMS where they can be stored for use by others, such as the National Weather Service for making forecasts. The Hub described in Section 1.06.1 temporarily provides this connection. NFDRS Standard GOES telemetry will provide the automated connectivity in the future.

1.06.3 FireFamily Plus

FireFamily Plus is a PC Windows (95/98/NT) application that operates with a Microsoft Access database. It provides extensive summaries of fire weather/danger climatology and occurrence for one or more weather stations extracted from the NIFMID. The FireFamily Plus database is compatible with fire planning tools and allows pooling of fire occurrence and weather data from adjoining regions covered by different protection agencies, where fire-days, large fire-days, and multiple fire-days are systematically integrated with fire weather. Software and support information are posted at http://www.fs.fed.us/fire/planning/nist/distribu.htm#Software.

The principle advantage of FireFamily Plus is that fire danger as a measure of fire business can be analyzed. FireFamily Plus is a suite of applications including fire danger climatology trends and decision points, fire business thresholds, fire fighter pocketcards with local fire danger information, troubleshooting analysis, and weather, fire danger and fire occurrence summaries.

The value of this software package is its versatility as a troubleshooting, analysis or training tool. Users can play what-if games. Questions such as "what happens if I change fuel models, climate class, etc?" can be answered without affecting the data you are using for your daily fire management decisions. As a training tool, it can allow the user to display the consequences of missing data, erroneous observations, or other data problems simply by entering the poor quality data without corrupting the permanent historic database.

1.07 NFDRS Outputs

The NFDRS calculations result in two types of outputs. These are intermediate outputs that serve as the "building blocks" for the next day's calculations and the indices and components that actually measure the fire danger. An understanding of both is important if the user is to properly manage and utilize the National Fire Danger Rating System.

1.07.1 Intermediate Outputs

These are the calculated fuel moisture values for the various classes of live and dead fuels used to produce the final indices and components. An understanding of these values, including their ranges, seasonal patterns, and associated impacts on indices and components is critical in maintaining the quality of the overall outputs of the system. A trained eye can look at the intermediate outputs and tell what the model thinks is happening on the ground. If they are not representative of what the local fire manager sees happening, they can be adjusted to "fine tune" the system outputs to better fit the local conditions.

Herbaceous Fuel Moisture: This calculated value represents the approximate moisture content of live herbaceous vegetation expressed as a percentage of the oven dry weight of the sample. Both the herbaceous vegetation type (annual or perennial) and the climate class control the rate of drying in the NFDRS processor. Faster drying occurs in annual plants than in perennials. Also, plants native to moist climates respond differently to a given precipitation event than plants native to arid climates would to an event of the same magnitude. For example, modeled fuel moistures respond more drastically to periods of drought in Climate Class 4 than in Climate Class 1. Accurate recording of the herbaceous vegetation type and the climate class is critical if the calculated herbaceous fuel moisture is to be representative of the local area.

Typical herbaceous fuel moisture values start out low (equal to 1-hour fuel moisture), and then increase rapidly as the growing season progresses. They may range from a high of 250, typical of the peak of the growing season, to as low as 3 or 4 when the foliage is dead or has reached maximum dormancy and responds as a dead fuel would to changes in external moisture influences. Fire managers should monitor the trend of herbaceous fuel moisture values as part of their validation of NFDRS outputs.

Woody Fuel Moisture: This calculated value represents the approximate moisture content of the live woody vegetation (shrubs, small stems, branches and foliage) expressed as a percentage of the oven dry weight of the sample. As with the herbaceous fuel moisture, it varies significantly by climate class. Plants native to moist environments tend to have higher woody fuel moisture values than those native to more arid climates. Woody fuel moisture values typically range from a low of 50 or 60 observed just before the plant begins to grow in the spring to a high of approximately 200 reached at the peak of the growing season. The default value used in NFDRS processors to initiate the season varies by the climate class. In Climate Class 1 the default value is 50, Climate Class 2 is 60, Climate class 3 uses 70, and Climate Class 4 uses 80.

Dead Fuel Moisture: This is the moisture content of dead organic fuels, expressed as a percentage of the oven dry weight of the sample, that is controlled entirely by exposure to environmental conditions. The NFDRS processor models these values based on inputs such as precipitation and relative humidity. There is modeled fuel moisture for each of the four-timelag fuel classes recognized by the system. Timelag is the time necessary for a fuel particle of a particular size to lose approximately 63% of the difference between its initial moisture content and its equilibrium moisture content in its current environment.

> 1-Hr Fuel Moisture Content – The 1-hour fuel moisture content represents the modeled fuel moisture of dead fuels from herbaceous plants or roundwood that is less than one-quarter inch in diameter. Also estimated is the uppermost layer of litter on the forest floor. Due to its size, this fuel is very responsive to the current atmospheric moisture content. It varies greatly throughout the calendar day and is principally responsible for diurnal changes in fire danger. Values can range from 1 to 80.
>
> 10-Hr Fuel Moisture Content – This is the moisture content of dead fuels consisting of roundwood in the size range of one quarter to one inch in diameter and very roughly, the layer of litter extending from just below the surface to three-quarters of an inch below the surface. Currently, the NFDRS code models this moisture value based on length of day, cloud cover, temperature and relative humidity. It is planned that by Summer 2002, the NFDRS code will begin modeling this moisture using solar radiation instead of cloud cover for those stations collecting solar radiation measurements. Ten-hour fuel moisture values vary somewhat with diurnal changes but vary more so with day-to-day changes in weather. Values can range from 1 to 60.
>
> 100-Hr Fuel Moisture Content – The 100-hour fuel moisture value represents the modeled moisture content of dead fuels in the 1 to 3 inch diameter class. It can also be used as a very rough estimate of the average moisture content of the forest floor from three-fourths inch to four inches below the surface. The 100-hour timelag fuel moisture is a function of length of day (as influenced by latitude and calendar date), maximum and minimum temperature and relative humidity, and precipitation duration in the previous 24 hours. Values can range from 1 to 50 percent. A default value based on the climate class of the first priority fuel model module in the station catalog will automatically be used if there is a break of 30 days or more in the observations entered.
>
> 1000-Hr Fuel Moisture Content – This value represents the modeled moisture content in the dead fuels in the 3 to 8 inch diameter class and the layer of the forest floor about four inches below the surface. The value is based on a running 7-day average. The 1000-hour timelag fuel moisture is a function of length of day (as influenced by latitude and calendar date), daily temperature and relative humidity extremes (maximum and minimum values) and the 24-hour precipitation duration values for a 7-day period. Values can range from 1 to 40 percent.

X-1000 Hr Fuel Moisture Value – The X-1000 value is not truly a dead fuel moisture value. It is the live fuel moisture recovery value. It is discussed here since it is derived from the 1000-hr fuel moisture value. It is an independent variable used in the calculation of the herbaceous fuel moisture. The X-1000 is a function of the daily change in the 1000-hour timelag fuel moisture, and the average temperature. Its purpose is to better relate the response of the live herbaceous fuel moisture model to the 1000-hour timelag fuel moisture value. The X-1000 value is designed to decrease at the same rate as the 1000-hour timelag fuel moisture, but to have a slower rate of increase than the 1000-hour timelag fuel moisture during periods of precipitation, hence limiting excessive herbaceous fuel moisture recovery.

NFDRS model outputs for 1-, 10-, 100-, and 1000-Hr fuel moistures may be a representation or estimate of the moisture of subsurface organic material as described above; however, the NFDRS processor does not include subsurface parameters in these calculations. Dead fuel moistures are based solely on roundwood fuel moisture parameters.

Weather observations must be started 30 to 45 days prior to the onset of green-up to assure that the 1000-hour timelag fuel moisture and associated X-1000 have stabilized at a reasonable value for the current weather conditions.

1.07.2 Indices and Components

The following paragraphs address each component and index of the National Fire Danger Rating System. They include a definition of each, its numeric value ranges, and the designed function of the component or index. The numbers generated by NFDRS are relative in the sense that as the value of a component or index doubles, the activity measured by that component or index doubles. (An Ignition Component of 60 has twice the ignition probability of an Ignition Component of 30.) This helps the users of the NFDRS interpret the meaning of the numbers produced for their protection area.

Ignition Component – (IC): The Ignition Component is a rating of the probability that a firebrand will cause a fire requiring suppression action. Since it is expressed as a probability, it ranges on a scale of 0 to 100. An IC of 100 means that every firebrand will cause a fire requiring action if it contacts a receptive fuel.

Likewise an IC of 0 would mean that no firebrand would cause a fire requiring suppression action under those conditions. Note the emphasis is on action. The key is whether a fire will result that requires a fire manager to make a decision. The Ignition Component is more than the probability of a fire starting; it has to have the potential to spread. Therefore Spread Component (SC) values are entered into the calculation of IC. If a fire will ignite and spread, some action or decision is needed.

Spread Component – (SC): The Spread Component is a rating of the forward rate of spread of a headfire. Deeming, et al., (1977), states that "the spread component is numerically equal to the theoretical ideal rate of spread expressed in feet-per-minute." This carefully worded statement indicates both guidelines (it's theoretical) and cautions (it's ideal) that must be used when applying the Spread Component. Wind speed, slope and fine fuel moisture are key inputs in the calculation of the spread component, thus accounting for a high variability from day-to-day. The Spread Component is expressed on an open-ended scale; thus it has no upper limit.

Energy Release Component - (ERC): The Energy Release Component is a number related to the available energy (BTU) per unit area (square foot) within the flaming front at the head of a fire. Daily variations in ERC are due to changes in moisture content of the various fuels present, both live and dead. Since this number represents the potential "heat release" per unit area in the flaming zone, it can provide guidance to several important fire activities. It may also be considered a composite fuel moisture value as it reflects the contribution that all live and dead fuels have to potential fire intensity. The ERC is a cumulative or "build-up" type of index. As live fuels cure and dead fuels dry, the ERC values get higher thus providing a good reflection of drought conditions. The scale is open-ended or unlimited and, as with other NFDRS components, is relative. Conditions producing an ERC value of 24 represent a potential heat release twice that of conditions resulting in an ERC value of 12.

As a reflection of its composite fuel moisture nature, the ERC becomes a relatively stable evaluation tool for planning decisions that might need to be made 24 to 72 hours ahead of an expected fire decision or action. Since wind and slope do not enter into the ERC calculation, the daily variation will be relatively small. The 1000-hr timelag fuel moisture (TLFM) is a primary entry into the ERC calculation through its effect on both living and dead fuel moisture inputs. There may be a tendency to use the 1000-hr TLFM as a separate "index" for drought considerations. A word of caution – any use of the 1000-hr TLFM as a separate "index" must be preceded by an analysis of historical fire weather data to identify critical levels of 1000-hr TLFM. A better tool for measurement of drought conditions is the ERC since it considers both dead and live fuel moistures.

Burning Index (BI): The Burning Index is a number related to the contribution of fire behavior to the effort of containing a fire. The BI (difficulty of control) is derived from a combination of Spread Component (how fast it will spread) and Energy Release Component (how much energy will be produced). In this way, it is related to flame length, which, in the Fire Behavior Prediction System, is based on rate of spread and heat per unit area. However, because of differences in the calculations for BI and flame length, they are not the same. The BI is an index that rates fire danger related to potential flame length over a fire danger rating area. The fire behavior prediction system produces flame length predictions for a specific location (Andrews, 1986).

The BI is expressed as a numeric value related to potential flame length in feet multiplied by 10. The scale is open-ended which allows the range of numbers to adequately define fire problems, even during low to moderate fire danger.

A cross-reference for BI to potential flame length, fireline intensity and descriptions of expected prescribed burning and fire suppression conditions is provided in Table 1 (adapted from Deeming et al. 1977). It is important to remember that a computed BI value is an index representing the near upper limit to be expected on the rating area. In other words, if a fire occurs in the worst fuel, weather and topography conditions somewhere in the rating area, these numbers represent the potential fireline intensity and flame length. These conditions are not expected throughout the entire fire danger rating area at any one time or under less severe conditions.

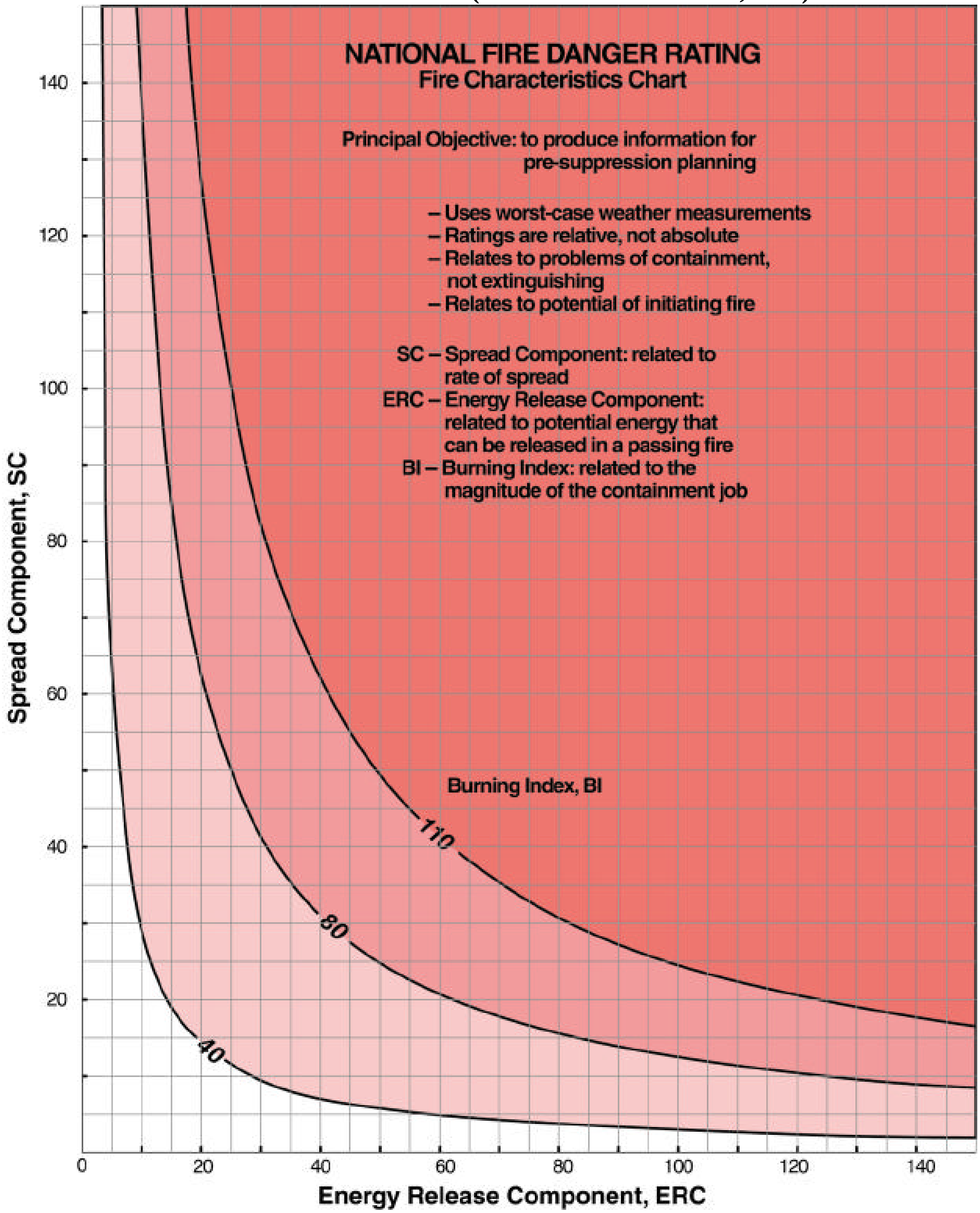
Local relationships of fire danger outputs to fire activity are also portrayed effectively on Fire Danger PocketCards (see section 1.08.9).

The relationship of ERC and SC to BI is shown in the fire characteristics chart in Table 2 (Andrews and Rothermel, 1982).

Table 1. Burning Index/Fire Behavior Cross Reference (Deeming et al. 1977)

BI-1978	Potential Flame Length (ft)	Fireline Intensity (BTUs/sec/ft)	Narrative Comments
0-30	0-3	0-55	Most prescribed burns are conducted in this range.
30-40	3-4	55-110	Generally represent the limit of control for direct attack methods.
40-60	4-6	110-280	Machine methods usually necessary or indirect attack should be used.
60-80	6-8	280-520	The prospects for direct control by any means are poor above this intensity.
80-90	8-9	520-670	The heat load on people within 30 feet of the fire is dangerous.
90-110+	9+	670-1050+	Above this intensity, spotting, fire whirls, and crowning should be expected.

Table 2. Fire Characteristics Chart (Andrews and Rothermel, 1982)



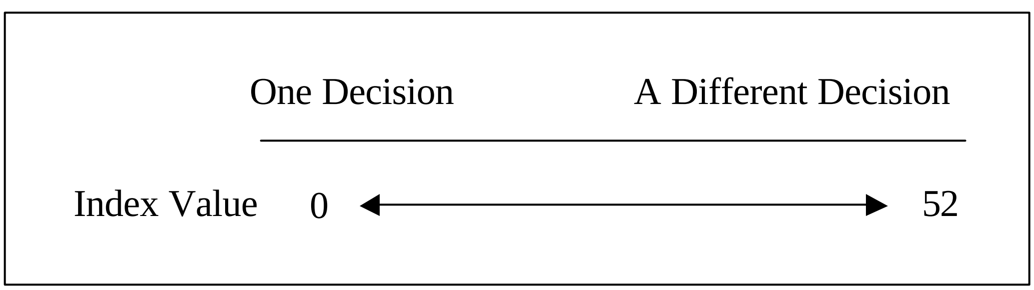
Keetch-Byram Drought Index (KBDI): This index is not an output of the National Fire Danger Rating System itself but is often displayed by the processors used to calculate NFDRS outputs. KBDI is a stand-alone index that can be used to measure the effects of seasonal drought on fire potential. The actual numeric value of the index is an estimate of the amount of precipitation (in 100ths of inches) needed to bring the soil back to saturation (a value of 0 is complete saturation of the soil). Since the index only deals with the top eight inches of the soil profile, the maximum KBDI value is 800 or 8.00 inches of precipitation would be needed to bring the soil back to saturation. The Keetch-Byram Drought Index's relationship to fire danger is that as the index value increases, the vegetation is subjected to increased stress due to moisture deficiency. At higher values, desiccation occurs and live plant material is added to the dead fuel loading on the site. Also, an increasing portion of the duff/litter layer becomes available fuel at higher index values.

If you are using the 1978 version of NFDRS, KBDI values can be used in conjunction with the National Fire Danger Rating System outputs to aid decision-making. If you are using the 1988 version of NFDRS, KBDI values are a required input to calculate daily outputs. Refer to Section 1.05.3 for information on initializing KBDI.

1.07.3 Fire Danger Continuum

The fire danger continuum is the range of possible outputs for a fire danger index or component, given a set of NFDRS parameters and weather input (Figure 1). Each combination of fuel model and index/component has a unique continuum. Different decisions will be made as the value of an index increases along the continuum from its lowest to highest value. Applications of fire danger to support decision-making along this continuum are presented in section 1.09.

Figure 1. A Fire Danger Continuum



1.08 Application of NFDRS Outputs

How fire danger is applied to fire and resource management decision-making depends on the decisions to be made. A brief introduction to nine different applications is presented here.

1.08.1 Staffing Level

Staffing Level can be thought of as a readiness level. The concept behind staffing level is that the fire danger continuum can be divided into classes to which preplanned management actions can be tied. It helps you understand where along the fire danger continuum you are today: Are you at the cool end, the hot end or somewhere in between? For each level or class there should be designated management actions, which address the expected wildland fire workload potential on the unit and the difficulty of the fire suppression effort. Staffing level represents a way of linking fire danger information to fire management decisions.

On most units, the staffing level is based on an analysis of cumulative frequency of occurrence of either Energy Release Component (ERC) or Burning Index (BI). Staffing Levels are expressed as numeric values where 1 represents the low end of the fire danger continuum and 5 the high end. All of the many “readiness” decisions based on fire danger rating should be established in a document such as a Specific Action and Staffing Guide or a Fire Management Plan.

At the protection unit level, the staffing level forms the basis for decisions regarding the “degree of readiness” of initial attack (IA) resources and support resources: Are all resources on base and available for immediate dispatch to a reported wildland fire? Or are some of them in the field doing project work and available with an acceptable degree of delay? Is the fire danger such that evening staffing of IA resources past the normal close of business is warranted?

At the broader scale, the extended staffing of shared resources such as air tankers, helicopters, hotshot crews and other large fire support resources is often linked to the staffing level across an aggregation of protection units. In some locations, the regulation of commercial activities with a potential for starting fires such as logging, construction, and woodcutting are based on the staffing level.

Staffing level is often confused with preparedness levels. Preparedness levels consider many other elements in addition to fire danger (see Section 1.08.6 below).

1.08.2 Preplan Dispatch Actions

Most units preplan their actions in response to reported incidents. Logic says that the higher the fire danger the more personnel and equipment necessary to contain a new fire. The question is which component or index best reflects the local unit’s response needs. Comparison of historic fire size with corresponding spread component, ignition component, ERC or BI can give assistance in making this selection.

Reviewing the definition of each can also give guidance as to the type of resource that might be effective in containing the fire. As an example, a local unit determines that spread component best corresponds to ultimate fire size. From their knowledge of the NFDRS they know that the spread component is forward rate of spread expressed in feet per minute. They also know which resources they usually have available to them, how much fireline each can produce and how long it typically takes for a resource to get to an incident. At some point available hand crews are no longer effective and engines, dozers or air tankers are appropriate. With this information, you can determine how many suppression resources are needed for various spread component value classes. A graduated initial response action can be developed based on local experience using NFDRS outputs. The FireFamily Plus software can help determine the thresholds of NFDRS indexes at which fire business (number and size of fires) occurs.

1.08.3 Determine Daily Adjective Fire Danger Ratings

In 1974, the Forest Service, Bureau of Land Management and state forestry organizations established a standard adjective description for five levels of fire danger for use in public information releases and fire prevention signing. For this purpose only, fire danger is expressed using the adjective levels and color codes described below. In 2000, the NWCG Fire Danger Working Team reviewed and slightly revised these terms and definitions for adjective fire danger.

Fire Danger Rating and Color Code	Description
Low (L) (Green)	Fuels do not ignite readily from small firebrands although a more intense heat source, such as lightning, may start fires in duff or punky wood. Fires in open cured grasslands may burn freely a few hours after rain, but woods fires spread slowly by creeping or smoldering, and burn in irregular fingers. There is little danger of spotting.
Moderate (M) (Blue)	Fires can start from most accidental causes, but with the exception of lightning fires in some areas, the number of starts is generally low. Fires in open cured grasslands will burn briskly and spread rapidly on windy days. Timber fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel, especially draped fuel, may burn hot. Short-distance spotting may occur, but is not persistent. Fires are not likely to become serious and control is relatively easy.
High (H) (Yellow)	All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High-intensity burning may develop on slopes or in concentrations of fine fuels. Fires may become serious and their control difficult unless they are attacked successfully while small.
Very High (VH) (Orange)	Fires start easily from all causes and, immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high intensity characteristics such as long-distance spotting and fire whirlwinds when they burn into heavier fuels.
Extreme (E) (Red)	Fires start quickly, spread furiously, and burn intensely. All fires are potentially serious. Development into high intensity burning will usually be faster and occur from smaller fires than in the very high fire danger class. Direct attack is rarely possible and may be dangerous except immediately after ignition. Fires that develop headway in heavy slash or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions the only effective and safe control action is on the flanks until the weather changes or the fuel supply lessens.

NFDRS processors automatically calculate the adjective class rating. Adjective rating calculations are keyed off the first priority fuel model listed in your station record in the processor. It uses the staffing index (such as ERC or BI) the user associates with the first fuel model/slope/grass type/climate class combination.

The actual determination of the daily adjective rating is based on the current or predicted value for a user selected staffing index and ignition component using the table below.

Staffing Levels	Adjective Fire Danger Rating				
1-, 1, 1+	L	L	L	M	M
2-, 2, 2+	L	M	M	M	H
3-, 3, 3+	M	M	H	H	VH
4-, 4, 4+	M	H	VH	VH	E
5	H	VH	VH	E	E
Ignition Component	0-20	21-45	46-65	66-80	81-100

Given the same weather inputs to the processor, the adjective fire danger can vary for different fuel models.

1.08.4 Guide Restrictions of Industrial Activity

Another daily decision process that NFDRS can support is the regulation of contractors involved in land management activities. This fire prevention decision is an effort to reduce the risk of large damaging fires resulting from timber harvest operations, timber stand improvement projects, ecosystem management and restoration projects, hazardous fuel reduction projects, public works projects, and other industrial activity. These management decisions are handled differently throughout the US.

One example of this application of fire danger rating is the Industrial Fire Precaution Level (IFPL) in the Pacific Northwest. By plotting each industrial-related fire against the Ignition Component (IC) and Energy Release Component (ERC) for the day corresponding to the start of a fire, and by recording the ultimate size class, a relationship was established between the observed NFDRS components and final fire size. The higher the Ignition Component, the more frequent the fire starts; and the higher the Energy Release Component, the larger the fires. These relationships were converted into mathematical equations and are used today to calculate the daily Industrial Fire Precaution Level, a graduated scale of restrictions used by most agencies in the Pacific Northwest to regulate industrial operations. In the 20 years that the IFPL system has been in use, there has been a significant reduction in industrial related fires in all jurisdictions.

The Forest Service in California also utilizes an NFDRS-based decision process to regulate contractor activities on National Forest lands. The approach in Region 5 integrates the Energy Release Component (ERC), Ignition Component (IC), and the thresholds for fires of differing size classes. The Project Activity Level (PAL) considers the relationship between the ERC, IC, and fires less than 10 acres, fires 10 to 99 acres, fires 100 to 999 acres, and fires greater than 1000 acres. The analysis used all equipment fires rather than focusing on only those related to timber harvest. Fuel model 7G was used for all fires. Weather observations from the Region's long established network of "year-round stations" were used to determine the NFDRS components and indices on the fire days between May 1 and November 30. Decision thresholds were established that allowed for a reasonable degree of risk at each of the four levels of regulation.

1.08.5 Guide Public Use Restrictions

A local analysis of conditions associated with human caused fire occurrence is necessary to determine when to initiate public use restrictions. By establishing a relationship between specific types of human caused fire starts such as smoking or campfires, with a NFDRS component or index, and monitoring the current trend of those components or indexes, one can target and time the implementation of specific public use restrictions. The NFDRS Ignition Component can assist in that decision. As an example a unit may find that campfires start becoming a problem when IC values regularly exceed 40. By monitoring the seasonal trend of IC values the manager can easily project when to implement campfire restrictions. The FireFamily Plus program can perform this analysis.

1.08.6 Determine Regional Preparedness Levels

Daily, coordination centers at local, regional, and national levels must assess their readiness. Based on the expected fire activity, their actions may include pre-positioning existing resources to areas with the greatest fire potential; calling back off-duty personnel; or ordering in back-up or contingency resources from outside the area. Each of these decisions can be very costly. Quality fire danger information is critical to aid in the decision process.

Fire managers use various methods to combine fire danger rating areas and their representative weather stations for a regional scale description of fire danger appropriate for regional preparedness planning. This information is combined with the current and projected levels of resource commitment and other factors to determine if resource placement is sufficient to meet anticipated needs or if adjustments in staffing are needed.

1.08.7 Support Severity Requests

Most agencies have a process where local units can request additional funding to supplement their basic funded presuppression organization. Criteria for approval of such requests usually require supporting data to show that their current conditions are more severe than those anticipated during their planning efforts. One technique used is to compare selected current NFDRS components and indices with historic worst case and normal expected values for the corresponding dates. Seasonal patterns can also be shown using the historic data. Since these requests are usually in response to drought conditions, energy release component and 1000-hr timelag fuel moisture values are most frequently used. (FireFamily Plus is a computer program specifically developed to generate and analyze historic trends of NFDRS values.)

1.08.8 Assist in Wildland Fire Use Go/No Go Decisions

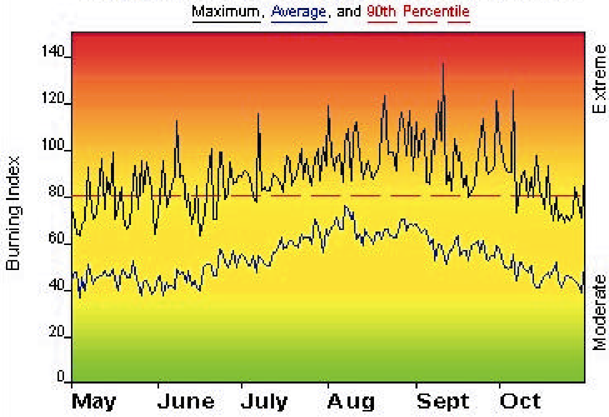
The decision to allow an ignition to burn under prescribed conditions rather than take suppression action is not without serious risk or consequence. Managers need to use all the tools available to aid in this critical decision. Analysis of current NFDRS components and indices and their historic trends and patterns can aid in this decision process. Fire managers can develop a framework to base their decisions on when they 1) examine today's fire danger rating values, 2) compare them to the average and worst-case values historically experienced for the period, and 3) consider the expected seasonal trend. Spread component and ERC are used most frequently. If the selected component is already at historic highs for the year and there is still a significant portion of the drying season to go through, the decision will be much different than if the current values are below seasonal averages and it is near the end of the dry season. Again, NFDRS outputs are just one tool to assist the manager in making the best decision possible.

1.08.9 Facilitate Briefings

One of the failures that have resulted in loss of life on several wildland fires in recent years has been inadequate briefings concerning expected conditions provided to fire fighting personnel unfamiliar with the local area. In 1997, the National Advisory Group for Fire Danger Rating developed the "Fire Danger PocketCard for Firefighter Safety" as a tool to aid in these briefings. The card contains information relative to current conditions, seasonal trends, and comparisons with historic patterns. One of the objectives was to communicate using common terminology. The National Fire Danger Rating System serves that purpose. The terminology used in NFDRS has common meaning throughout the country. NFDRS outputs for the local area are displayed in a combined verbal, numeric and graphic format depicting current and historic values. In addition, the card contains information about NFDRS components and indices associated with recent large fires that occurred in the local area; thresholds of critical fire behavior based on local experience; and local fire danger interpretations. All the information is presented on a single card that can be given to all personnel. The cards can be easily updated and produced locally using a PC-based computer program. Users can download a template for constructing their local cards off the Internet by accessing the following site: http://famweb.nwcg.gov/pocketcards/.

An example of a Fire Danger PocketCard is shown below.

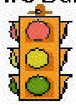
FIRE DANGER -- Central Idaho North Zone



Fire Danger Area:

- Central Idaho
- North Zone
- Skull, Indy, Salmon RAWS

Fire Danger Interpretation:



EXTREME -- Use extreme caution

(Caution) -- Watch for change

Moderate -- Lower Potential, but always be aware

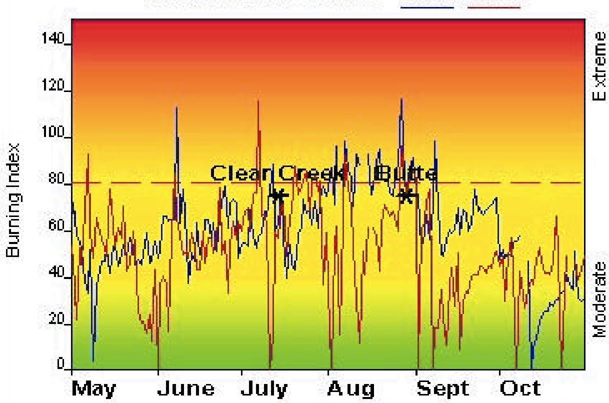
Maximum -- Highest Burning Index by day for 1982 - 2001

Average -- shows peak fire season

90th Percentile -- Only 10% of the days from 1982 - 2001 had an Burning Index above 80

Local Thresholds - Watch out: Combinations of any of these factors can greatly increase fire behavior:
20' Wind Speed over 10 mph, RH less than 15%,
Temperature over 90, 1000-Hour Fuel Moisture less than 10

Years to Remember: 2000 1985



Fuel Model: G - Short-Needle (Heavy Dead)

Remember what Fire Danger tells you:

- ✓ Burning Index gives day-to-day fluctuations calculated from 2 pm temperature, humidity, wind, daily temperature & rh ranges, and precip duration.
- ✓ Wind is part of BI calculation.
- ✓ Watch local conditions and variations across the landscape -- Fuel, Weather, Topography.
- ✓ Listen to weather forecasts -- especially WIND.

Past Experience:

On the afternoon of 7/14/2000 a Type 1 crew had to fall back to their safety zone when the Clear Creek fire made a 23,000 ac run (8 miles). The day's conditions were BI 74, 20 ft winds 40+ SW, RH 10-12 %, temperatures 90-95 degrees, and 1000-Hour 11%.

On the afternoon of 8/29/1985 the Butte Fire made significant runs that forced fire fighters to retreat to their safety zones, 70 fire shelters were deployed. The day's conditions were BI 75, 20 ft winds 6-10 SW, RH 7%, temperature 86 degrees, and 1000-Hour 8%.

June 2002

Developed by NAGFDR--National Advisory Group for Fire Danger Rating

1.09 Operations

1.09.1 Seasonal Start Up

Automatic weather stations report hourly observations every day of the year unless shut down for environmental reasons (e.g., snow, unfavorable freezing conditions). At a minimum hourly observations should be collected for NFDRS calculations and archived in NIFMID at least 30 days prior to the start of vegetative growth, or green-up, described below. The equations that predict 1000-hr and live fuel moisture contents require at least four weeks to stabilize and predict accurate fuel moisture content values.

1.09.2 Green-up

Green-up is defined as the beginning of a new cycle of plant growth. Green-up usually occurs once a year, except in desert areas where rainy periods can produce a flush of new growth more than once a year. Green-up may be signaled at different dates for different fuel models. For any particular model, green-up should be declared when the annual and perennial herbaceous vegetation starts to grow or the leaves of deciduous shrubs begin to appear within the area represented by the fuel model. Green-up should not be started when the first flush of green occurs in the area. Instead, the vegetation that will be the fire problem (represented by the NFDRS fuel model associated with the weather station) when it matures and cures should be identified. Green-up should start when the majority of this vegetation starts to grow.

If using 1978 NFDRS fuel models, the NFDRS processor assumes a length of this green-up period according to climate class.

Climate Class	Days in Green-up Period
1	7
2	14
3	21
4	28

For example, if green-up is declared May 5 for a fuel model at a weather station in Climate Class 3, it is assumed a large portion of the new growth will have occurred by May 26. At completion of green-up, fire danger should be significantly reduced for fuel models with a high proportion of live woody and/or herbaceous fuel loads.

After the green-up period, fuel moistures begin to drop depending on environmental conditions and other model parameters. The processor triggers transition and cured states automatically when herbaceous fuel moistures reach 120% and 30%, respectively, as shown in the following timetable.

1.09.3 A Suggested Timetable for 1978 Herbaceous Stage

Situation or Plant Growth Phase	Changes You Make	Changes the Model Makes For You
Approximately 30 days prior to Green-up	Pregreen	
New season's growth occurs	Green-up	
Herbaceous fuel moisture down to 120%		Transition
Herbaceous fuel moisture down to 30%		Cured
Freeze or Dormancy	Frozen	
Approximately 30 days prior to Green-up	Pregreen	
And so on		

1.09.4 A Suggested Timetable for 1988 Season Codes and Greenness Factors

Situation or Plant Growth Phase	Season Codes	Greenness Factors
Herbaceous fuels cured; shrubs fully dormant	Winter = 1	Herb: 0 Woody: 0
New season's growth occurs	Spring = 2	Increase each separately according to their growth, to a maximum of 20
Herbaceous growth flush is complete	Summer = 3	Change each separately according to their growth
Shrubs enter dormancy	Fall = 4	Reduce each separately according to their growth, down to 0
And so on		

For more details on season codes and greenness factors see Appendix VIII.

1.09.5 Data Continuity

Continuity refers to two characteristics of data:

1. A record of continuous hourly and daily observations at a site to include the entire year if possible or at least the normal fire suppression and fire use seasons.

2. Many years of data from one observation site. A minimum of ten years is needed. A standard climatological average is based on 30 years of data.

Every effort must be made to provide for continuity in the weather database.

NFDRS applications that produce daily assessments of burning conditions require daily continuity because several of the NFDRS calculations are dependant on values calculated the previous day.

Climatological applications that produce probabilistic information require continuity of the records (e.g., long term risk assessment, *FARSITE*, FireFamily Plus, climate forecasts, NFMAS, fire potential assessments) if they are to have any statistical validity.

1.09.6 Quality Control

Fire danger ratings are no better than the data used to derive them. If fire danger ratings are to be used with confidence, uniform standards and procedures must be correctly followed. The NWCG NFDRS Weather Station Standards establish national weather data measurement standards (See Appendix V). Fire danger operating plans establish local procedures, responsibilities, and actions related to fire danger rating. Other uses of the climatological database also require that data are accurate.

Quality control is recognized as an integral part of the fire danger rating system application.

Figure 2. National Fire Danger Rating System Structure

This representation of the structure of the NFDRS model is adapted from Deeming et al. 1977, and Burgan 1988. Arrows indicate which inputs contribute to each output. Arrows that are dashed or denoted as (88) apply only to the 1988 version of the NFDRS model. Carryover fuel moistures (100- and 1000-hour) are from the previous day's calculations. In decreasing proportion, calculated 1-, 10-, and 100-hour dead fuel moistures contribute to Spread Component. In increasing proportion, calculated 1-, 10-, 100-, and 1000-hour dead fuel moistures contribute to Energy Release Component.

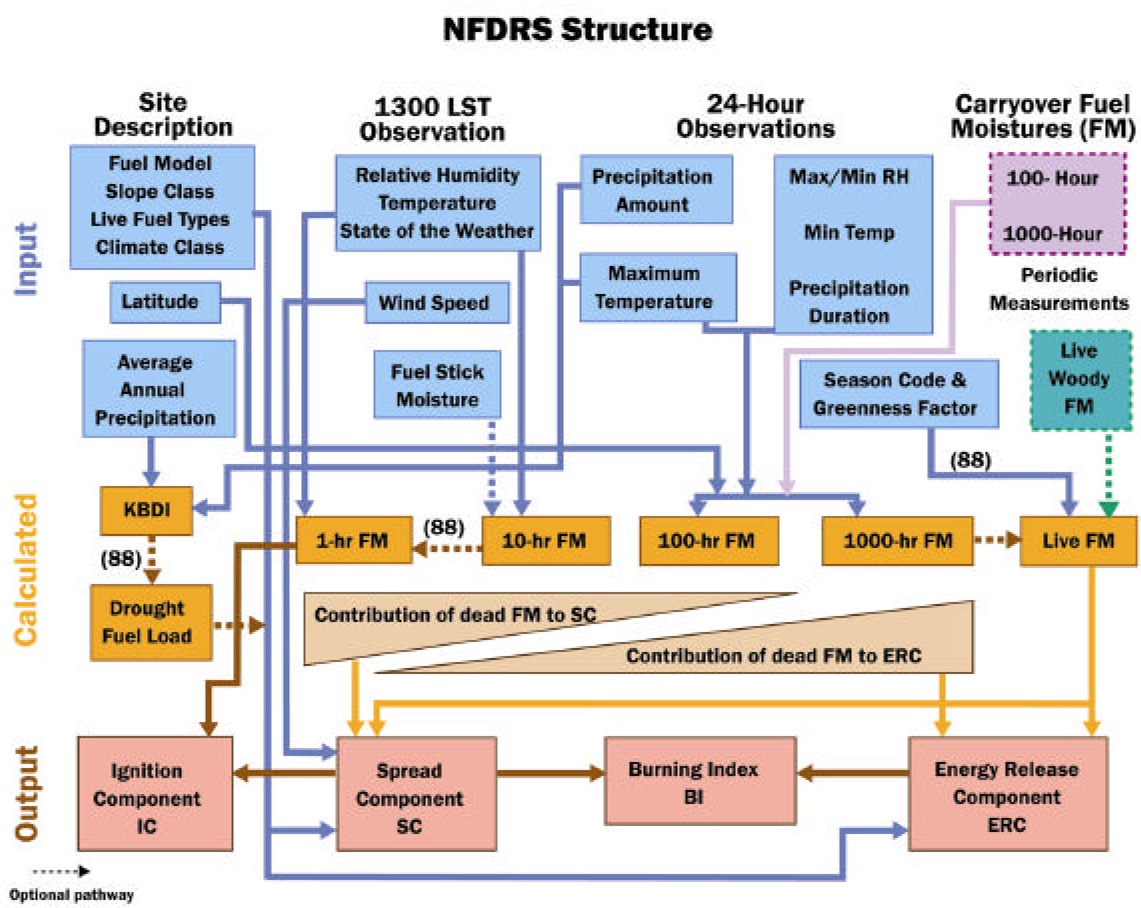


Figure 3A and 3B. Data Delivery, Processing, Storage, and Access

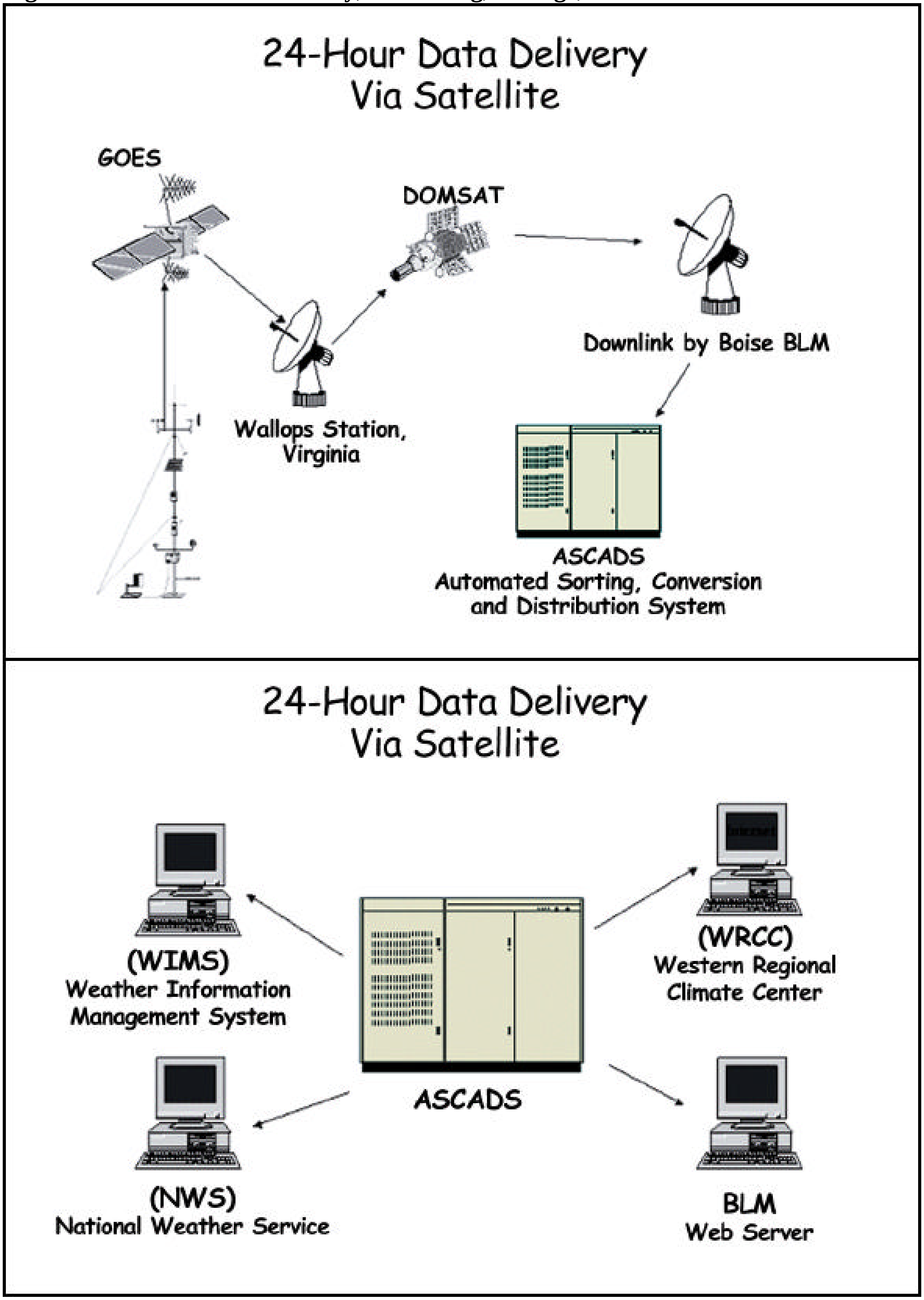
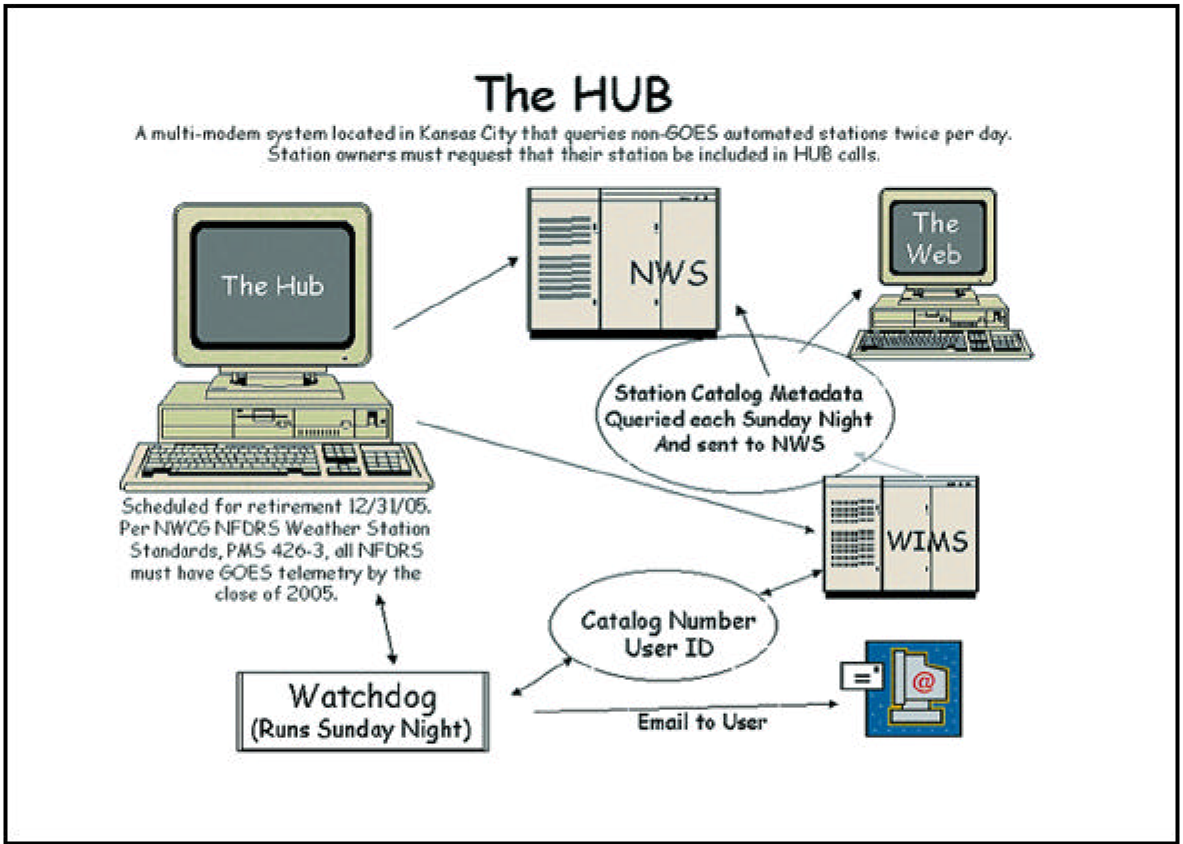


Figure 3C and 3D. The Hub



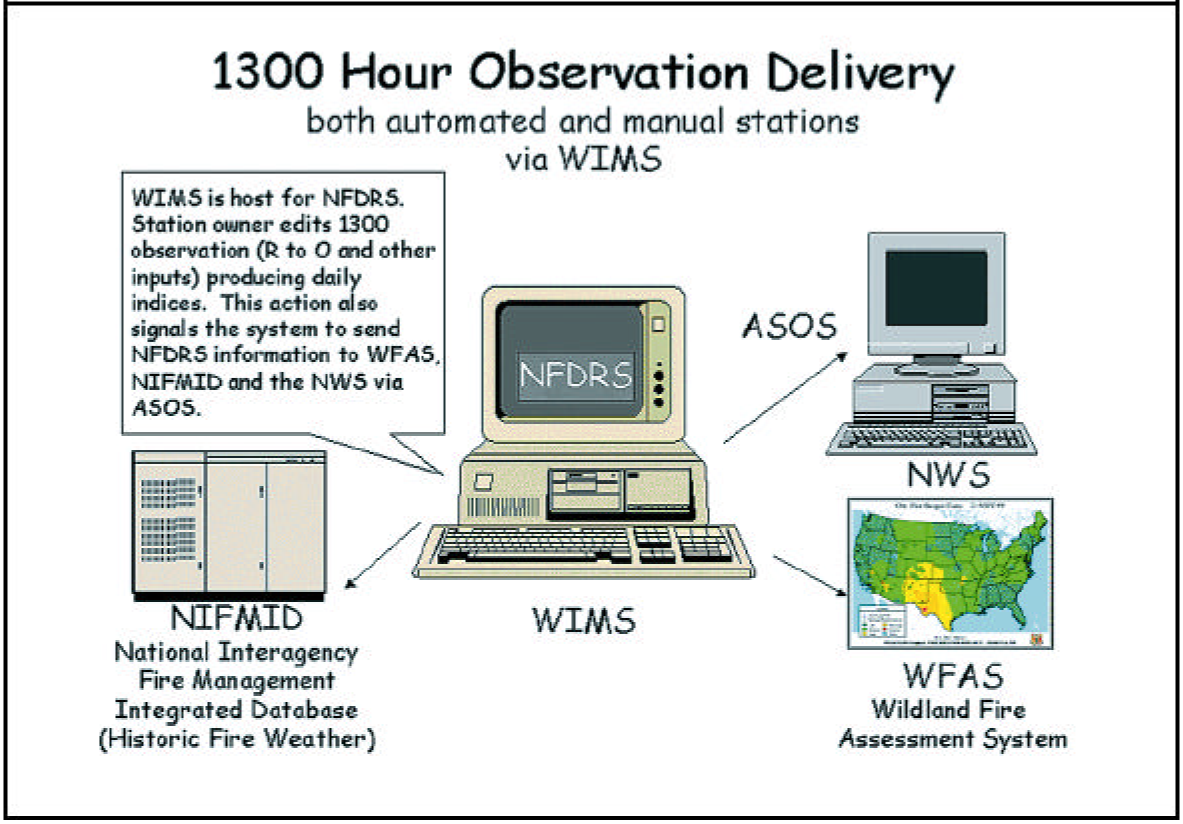
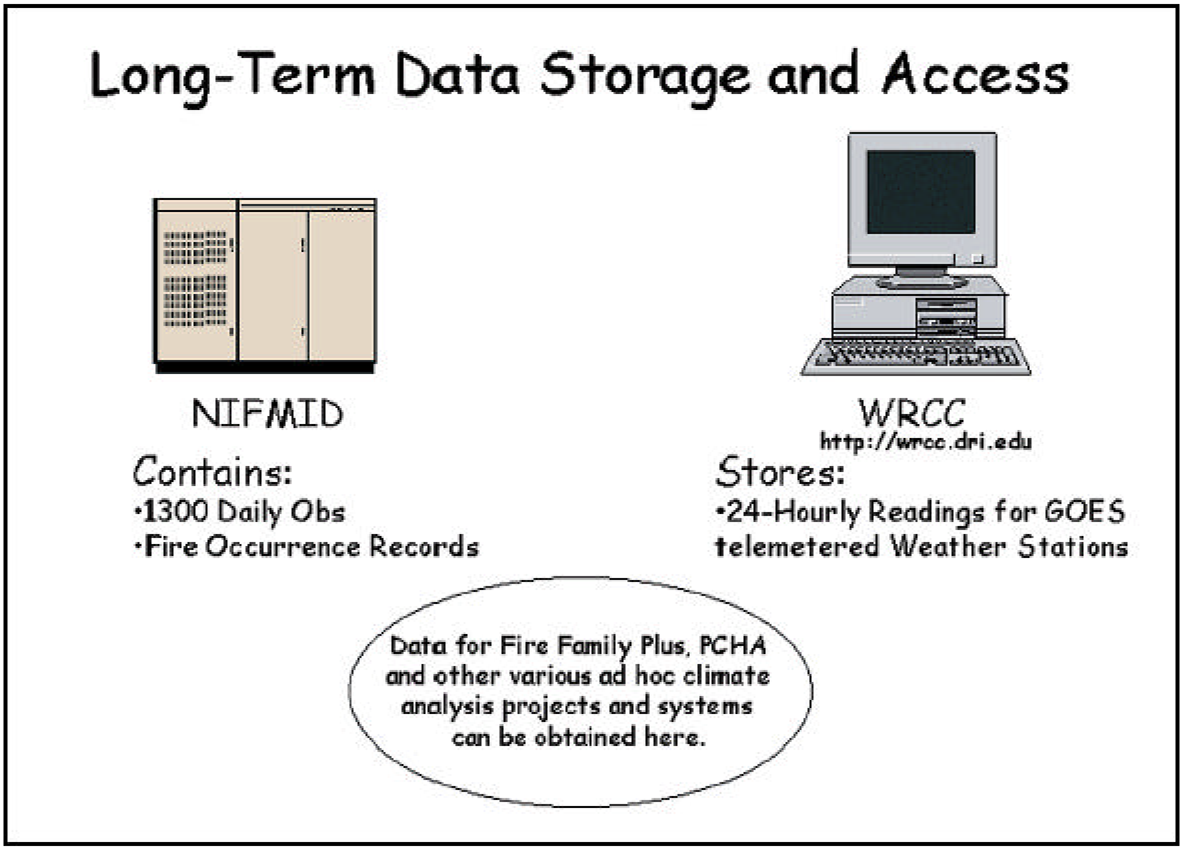


Figure 3E. Long-term Data Storage and Access



APPENDICES

Appendix I – Fuel Model Selection Key

I. Mosses, lichens, and low shrubs predominate ground fuels.

- A. An overstory of conifers occupies more than one-third of site. — Model Q
- B. There is no overstory or it occupies less than one-third of site. — Model S

II. Marsh grasses and/or reeds predominate. — Model N

III. Grasses and/or forbs predominate.

- A. There is an open overstory of conifer and/or hardwoods. — Model C
- B. There is no overstory.
  - 1. Woody shrubs occupy more than one-third, but less than two-thirds of the site. — Model T
  - 2. Woody shrubs occupy less than two-thirds of the site.
    - a. The grasses and forbs are primarily annuals. — Model A
    - b. The grasses and forbs are primarily perennials. — Model L

IV. Brush, shrubs, tree reproduction or dwarf tree species predominate.

- A. The average height of woody plants is six feet or greater.
  - 1. Woody plants occupy two-thirds or more of the site.
    - a. One-fourth or more of the woody foliage is dead.
      - 1) Mixed California chaparral — Model B
      - 2) Other types of brush — Model F
    - b. Up to one-fourth of the woody foliage is dead. — Model Q
    - c. Little dead foliage — Model O
  - 2. Woody plants occupy less than two-thirds of the site. — Model F

B. Average height of woody plants is less than six feet.

1. Woody plants occupy two-thirds or more of the site.

a. Western United States — Model F

b. Eastern United States — Model O

2. Woody plants occupy less than two-thirds but greater than one-third of the site.

a. Western United States — Model T

b. Eastern United States — Model D

3. Woody plants occupy less than one-third of the site.

a. The grasses and forbs are primarily annuals. — Model A

b. The grasses and forbs are primarily perennials. — Model L

V. Trees predominate.

A. Deciduous broadleaf species predominate.

1. The area has been thinned or partially cut leaving slash as the major fuel component. — Model K

2. The area has not been thinned or partially cut.

a. The overstory is dormant; leaves have fallen. — Model E

b. The overstory is in full leaf. — Model R

B. Conifer species predominate.

1. Lichens, mosses, and low shrubs dominate as understory fuels. — Model Q

2. Grasses and forbs are the primary ground fuel. — Model C

3. Woody shrubs and/or reproduction dominate as understory fuels.

a. The understory burns readily.

1) Western United States — Model T

2) Eastern United States

a) The understory is more than 6 feet tall. — Model O

b) The understory is less than 6 feet tall. — Model D

b. The understory seldom burns. — Model H

4. Duff and litter, branch wood and tree boles are the primary ground fuel.

a. The overstory is over mature and decadent; there is a heavy accumulation of dead debris. — Model G

b. The overstory is not decadent; there is only a nominal accumulation of debris.

1) Needles are 2 inches or more in length (most pines).

a) Eastern United States — Model P

b) Western United States — Model U

2) The needles are less than 2 inches long. — Model H

VI. Slash is the predominant fuel type.

A. The foliage is still attached; there has been little settling.

1. The loading is 25 tons/acre (t/ac) or greater. — Model I
2. The loading is less than 25 t/ac but greater than 15 t/ac. — Model J
3. The loading is less than 15 t/ac. — Model K

B. Settling is evident; the foliage is falling off; grasses, forbs and shrubs are invading.

1. The loading is 25 t/ac or greater. — Model J
2. The loading is less than 25 t/ac. — Model K

Appendix II – Narrative Fuel Model Descriptions

The following descriptions of the various NFDRS fuel models are taken from Deeming et al. (1977).

Fuel Model A – This fuel model represents western grasslands vegetated by annual grasses and forbs. Brush or trees may be present but are very sparse, occupying less than one-third of the area. Examples of types where Fuel Model A should be used are cheatgrass and medusahead. Open pinyon-juniper, sagebrush-grass, and desert shrub associations may appropriately be assigned this fuel model if the woody plants meet the density criteria. The quantity and continuity of the ground fuels vary greatly with rainfall from year to year.

Fuel Model B – Mature, dense fields of brush six feet or more in height is represented by this fuel model. One-fourth or more of the aerial fuel in such stands is dead. Foliage burns readily. Model B fuels are potentially very dangerous, fostering intense, fast-spreading fires. This model is for California mixed chaparral, generally 30 years or older. The F model is more appropriate for pure chamise stands. The B model may also be used for the New Jersey pine barrens.

Fuel Model C – Open pine stands typify Model C fuels. Perennial grasses and forbs are the primary ground fuel but there is enough needle litter and branchwood present to contribute significantly to the fuel loading. Some brush and shrubs may be present but they are of little consequence. Types covered by Fuel Model C are open, longleaf, slash, ponderosa, Jeffery, and sugar pine stands. Some pinyon-juniper stands may qualify.

Fuel Model D – This fuel model is specifically for the palmetto-gallberry understory-pine association of the southeast coastal plains. It can also be used for the so-called "low pocosins" where Fuel Model O might be too severe. This model should only be used in the Southeast because of the high moisture of extinction associated with it.

Fuel Model E – Use this model after fall leaf fall for hardwood and mixed hardwood-conifer types where the hardwoods dominate. The fuel is primarily hardwood leaf litter. Fuel Model E best represents the oak-hickory types and is an acceptable choice for northern hardwoods and mixed forests of the Southeast. In high winds, the fire danger may be underrated because rolling and blowing leaves are not accounted for. In the summer after the trees have leafed out, Fuel Model R should replace Fuel Model E.

Fuel Model F – Fuel Model F represents mature closed chamise stands and oak brush fields of Arizona, Utah, and Colorado. It also applies to young, closed stands and mature, open stands of California mixed chaparral. Open stands of pinyon-juniper are represented; however, fire activity will be overrated at low wind speeds and where ground fuels are sparse.

Fuel Model G – Fuel Model G is used for dense conifer stands where there is a heavy accumulation of litter and down woody material. Such stands are typically over mature and may also be suffering insect, disease, and wind or ice damage—natural events that create a very heavy buildup of dead material on the forest floor. The duff and litter are deep and much of the woody material is more than three inches in diameter. The undergrowth is variable, but shrubs are usually restricted to openings. Types to be represented by Fuel Model G are hemlock-Sitka spruce, coastal Douglas fir, and wind thrown or bug-killed stands of lodgepole pine and spruce.

Fuel Model H – The short-needled conifers (white pines, spruces, larches, and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels. Fires in the H fuels are typically slow spreading and are dangerous only in scattered areas where the downed woody material is concentrated.

Fuel Model I – Fuel Model I was designed for clear-cut conifer slash where the total loading of materials less than six inches in diameter exceeds 25 tons/acre. After settling and the fines (needles and twigs) fall from the branches, Fuel Model I will overrate the fire potential. For lighter loadings of clear-cut conifer slash use Fuel Model J, and for light thinnings and partial cuts where the slash is scattered under a residual overstory, use Fuel Model K.

Fuel Model J – This model complements Fuel Model I. It is for clear-cuts and heavily thinned conifer stands where the total loading of material less than six inches in diameter is less than 25 tons per acre. Again as the slash ages, the fire potential will be overrated.

Model K – Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clear-cuts where loading of all fuels is less than 15 tons/acre.

Fuel Model L – This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels. Otherwise the situations are very similar; shrubs and trees occupy less than one-third of the area. The quantity of fuels in these areas is more stable from year to year. In sagebrush areas Fuel Model T may be more appropriate.

There is no Fuel Model M.

Fuel Model N – This fuel model was constructed specifically for the sawgrass prairies of south Florida. It may be useful in other marsh situations where the fuel is coarse and reed like. This model assumes that one-third of the aerial portion of the plants is dead. Fast-spreading, intense fires can occur over standing water.

Fuel Model O – The O fuel model applies to dense, brush like fuels of the Southeast. In contrast to B fuels, O fuels are almost entirely living except for a deep litter layer. The foliage burns readily except during the active growing season. The plants are typically over six feet tall and are often found under open stands of pine. The high pocosins of the Virginia, North and South Carolina coasts are the ideal of Fuel Model O. If the plants do not meet the 6-foot criteria in those areas, Fuel Model D should be used.

Fuel Model P – Closed, thrifty stands of long-needled southern pines are characteristic of P fuels. A 2 to 4 inch layer of lightly compacted needle litter is the primary fuel. Some small diameter branchwood is present but the density of the canopy precludes more than a scattering of shrubs and grass. Model P has the high moisture of extinction characteristic of the Southeast. The corresponding model for other long-needled pines is H.

Fuel Model Q – Upland Alaska black spruce is represented by Fuel Model Q. The stands are dense but have frequent openings filled with usually flammable shrub species. The forest floor is a deep layer of moss and lichens, but there is some needle litter and small diameter branchwood. The branches are persistent on the trees, and ground fires easily reach into the crowns. This fuel model may be useful for jack pine stands in the Lake States. Ground fires are typically slow spreading, but a dangerous crowning potential exists. Users should be alert to such events and note those levels of SC and BI when crowning occurs.

Fuel Model R – This fuel model represents hardwood areas after the canopies leaf out in the spring. It is provided as the off-season substitute for Fuel Model E. It should be used during the summer in all hardwood and mixed conifer-hardwood stands where more than half of the overstory is deciduous.

Fuel Model S – Alaskan and alpine tundra on relatively well-drained sites fit this fuel model. Grass and low shrubs are often present, but the principal fuel is a deep layer of lichens and moss. Fires in these fuels are not fast spreading or intense, but are difficult to extinguish.

Fuel Model T – The sagebrush-grass types of the Great Basin and the Intermountain West are characteristic of T fuels. The shrubs burn easily and are not dense enough to shade out grass and other herbaceous plants. The shrubs must occupy at least one-third of the site or the A or L fuel models should be used. Fuel Model T might be used for immature scrub oak and desert shrub associations in the West and the scrub oak-wire grass type of the Southeast.

Fuel Model U – This fuel model represents the closed stands of western long-needled pines. The ground fuels are primarily litter and small branchwood. Grass and shrubs are precluded by the dense canopy but may occur in the occasional natural opening. Fuel Model U should be used for ponderosa, Jeffery, sugar pine stands of the West and red pine stands of the Lake States. Fuel Model P is the corresponding model for southern pine plantations.

NOTES

Appendix III – Fuel Model Property Tables

Figure 1 – Grass Fuel Models (1978)

1978 NFDRS FUEL MODEL PROPERTIES						
Grass Fuel Models						
Parameter	A	C	L	N	S	T
Fuel Loading (tons/acre)						
0 to ¼ inch	0.2	0.4	0.25	1.5	0.5	1.0
¼ to 1 inch		1.0		1.5	0.5	0.5
1 to 3 inch					0.5	
3 to 8 inch					0.5	
Live Woody		0.5		2.0	0.5	2.5
Herbaceous	0.3	0.8	0.5		0.5	0.5
Fuel Bed Depth (ft)	0.8	0.75	1.0	3.0	0.4	1.25
Moisture of Extinction (%)						
Dead	15	20	15	25	25	15
Surface Area to Volume Ratio (sq.ft/cu.ft)						
0 to ¼ inch	3,000	2,000	2,000	1,600	1,500	2,500
¼ to 1 inch		109		109	109	109
1 to 3 inch					30	
3 to 8 inch					8	
Live Woody		1,500		1,500	1,200	1,500
Herbaceous	3,000	2,500	2,000		1,500	2,000
Heat Content (all fuels)						
BTUs/lb	8,000	8,000	8,000	8,700	8,000	8,000
Wind Adjustment Factor	0.6	0.4	0.6	0.6	0.6	0.6
SCmax	301	32	178	167	17	96
Constant fuel particle values used for all fuel models:						
	Particle Density			32 lb./cu.ft.		
	Total Mineral Content:			5.55%		
	Effective Mineral Content:			1%		

Figure 2 – Grass Fuel Models (1988)

1988 NFDRS FUEL MODEL PROPERTIES						
Grass Fuel Models						
Parameter	A	C	L	N	S	T
Fuel Loading (tons/acre)						
0 to ¼ inch	0.2	0.4	0.25	1.5	0.5	1.0
¼ to 1 inch		1.0		1.5	0.5	0.5
1 to 3 inch					0.5	
3 to 8 inch					0.5	
Live Woody		**0.8**		2.0	0.5	2.5
Herbaceous	0.3	0.8	0.5		0.5	0.5
Fuel Bed Depth (ft)	0.8	0.75	1.0	3.0	0.4	1.25
Drought Fuels	**0.2**	**1.8**	**0.25**	**2.0**	**1.5**	**1.0**
Moisture of Extinction (%)						
Dead	15	20	15	**40**	25	15
Surface Area to Volume Ratio (sq.ft/cu.ft)						
0 to ¼ inch	3,000	2,000	2,000	1,600	1,500	2,500
¼ to 1 inch		109		109	109	109
1 to 3 inch					30	
3 to 8 inch					8	
Live Woody		1,500		1,500	1,200	1,500
Herbaceous	3,000	2,500	2,000		1,500	2,000
Heat Content (all fuels)						
BTUs/lb	8,000	8,000	8,000	8,700	8,000	8,000
Wind Adjustment Factor						
Minimum	**0.6**	**0.3**	**0.5**	**0.5**	**0.6**	**0.6**
Maximum	**0.6**	**0.5**	**0.5**	**0.5**	**0.6**	**0.6**
SCmax	301	32	178	167	17	96
Constant fuel particle values used for all fuel models:						
	Particle Density			32 lb./cu.ft.		
	Total Mineral Content:			5.55%		
	Effective Mineral Content:			1%		

Figure 3 – Brush Fuel Models (1978)

1978 NFDRS FUEL MODEL PROPERTIES					
Brush Fuel Models					
Parameter	B	D	F	O	Q
0 to ¼ inch	3.5	2.0	2.5	2.0	2.0
¼ to 1 inch	4.0	1.0	2.0	3.0	2.5
1 to 3 inch	0.5		1.5	3.0	2.0
3 to 8 inch				2.0	1.0
Live Woody	11.5	3.0	9.0	7.0	4.0
Herbaceous		.75			0.5
Fuel Bed Depth (ft)	4.5	2.0	4.5	4.0	3.0
Moisture of Extinction (%)					
Dead	15	30	15	30	25
Surface Area to Volume Ratio (sq.ft/cu.ft)					
0 to ¼ inch	700	1,250	700	1,500	1,500
¼ to 1 inch	109	109	109	109	109
1 to 3 inch	30		30	30	30
3 to 8 inch				8	8
Live Woody	1,250	1,500	1,250	1,500	1,200
Herbaceous		1,500			1,500
Heat Content (all fuels)					
BTUs/lb	9,500	9,000	9,500	9,000	8,000
Wind Adjustment Factor	0.5	0.4	0.5	0.5	0.4
SCmax	58	68	24	99	59
Constant fuel particle values for all fuels:					
	Particle Density			32 lb./cu.ft.	
	Total Mineral Content:			5.55%	
	Effective Mineral Content:			1%	

Figure 4 – Brush Fuel Models (1988)

1988 NFDRS FUEL MODEL PROPERTIES					
Brush Fuel Models					
Parameter	B	D	F	O	Q
0 to ¼ inch	3.5	2.0	2.5	2.0	2.0
¼ to 1 inch	4.0	1.0	2.0	3.0	2.5
1 to 3 inch	0.5		1.5	3.0	2.0
3 to 8 inch				2.0	1.0
Live Woody	11.5	3.0	9.0	7.0	4.0
Herbaceous		.75			0.5
Drought Fuels	**3.5**	**1.5**	**2.5**	**3.5**	**3.5**
Fuel Bed Depth (ft)	4.5	2.0	4.5	4.0	3.0
Moisture of Extinction (%)					
Dead	15	30	15	30	25
Surface Area to Volume Ratio (sq.ft/cu.ft)					
0 to ¼ inch	700	1,250	700	1,500	1,500
¼ to 1 inch	109	109	109	109	109
1 to 3 inch	30		30	30	30
3 to 8 inch				8	8
Live Woody	1,250	1,500	1,250	1,500	1,200
Herbaceous		1,500			1,500
Heat Content (all fuels)					
BTUs/lb	9,500	9,000	9,500	9,000	8,000
Wind Adjustment Factor					
Minimum	**0.5**	**0.4**	**0.5**	**0.5**	**0.2**
Maximum	**0.5**	**0.4**	**0.5**	**0.5**	**0.3**
SCmax	58	68	24	99	59
Constant fuel particle values for all fuels:					
	Particle Density			32 lb./cu.ft.	
	Total Mineral Content:			5.55%	
	Effective Mineral Content:			1%	

Figure 5 – Timber Fuel Models (1978)

1978 NFDRS FUEL MODEL PROPERTIES						
Timber Fuel Models						
Parameter	E	G	H	P	R.	U
0 to ¼ inch	1.5	2.5	1.5	1.0	0.5	1.5
¼ to 1 inch	0.5	2.0	1.0	1.0	0.5	1.5
1 to 3 inch	0.25	5.0	2.0	0.5	0.5	1.0
3 to 8 inch		12.0	2.0			
Live Woody	0.5	0.5	0.5	0.5	0.5	0.5
Herbaceous	0.5	0.5	0.5	0.5	0.5	0.5
Fuel Bed Depth (ft)	4.0	1.0	0.3	0.4	0.25	0.5
Moisture of Extinction (%)						
Dead	25	25	20	30	25	20
Surface Area to Volume Ratio (sq.ft/cu.ft)						
0 to ¼ inch	2,000	2,000	2,000	1,750	1,500	1,750
¼ to 1 inch	109	109	109	109	109	109
1 to 3 inch	30	30	30	30	30	30
3 to 8 inch		8	8			
Live Woody	1,500	1,500	1,500	1,500	1,500	1,500
Herbaceous	2,000	2,000	2,000	2,000	2,000	2,000
Heat Content (all fuels)						
BTUs/lb	8,000	8,000	8,000	8,000	8,000	8,000
Wind Adjustment Factor	0.5	0.4	0.4	0.4	0.4	0.4
SCmax	25	30	8	14	6	16
Constant fuel particle values for all fuels:						
	Particle Density			32 lb./cu.ft.		
	Total Mineral Content:			5.55%		
	Effective Mineral Content:			1%		

Figure 6 – Timber Fuel Models (1988)

1988 NFDRS FUEL MODEL PROPERTIES						
Timber Fuel Models						
Parameter	E	G	H	P	R.	U
0 to ¼ inch	**1.0**	2.5	1.5	1.0	0.5	1.5
¼ to 1 inch	0.5	2.0	1.0	1.0	0.5	1.5
1 to 3 inch	0.25	5.0	2.0	0.5	0.5	1.0
3 to 8 inch		12.0	2.0			
Live Woody	**1.0**	0.5	0.5	0.5	0.5	0.5
Herbaceous	0.5	0.5	0.5	0.5	0.5	0.5
Drought Fuels	**1.5**	**5.0**	**2.0**	**1.0**	**0.5**	**2.0**
Fuel Bed Depth (ft)	4.0	1.0	0.3	0.4	0.25	0.5
Moisture of Extinction (%)						
Dead	25	25	20	30	25	20
Surface Area to Volume Ratio (sq.ft/cu.ft)						
0 to ¼ inch	2,000	2,000	2,000	1,750	1,500	1,750
¼ to 1 inch	109	109	109	109	109	109
1 to 3 inch	30	30	30	30	30	30
3 to 8 inch		8	8			
Live Woody	1,500	1,500	1,500	1,500	1,500	1,500
Herbaceous	2,000	2,000	2,000	2,000	2,000	2,000
Heat Content (all fuels)						
BTUs/lb	8,000	8,000	8,000	8,000	8,000	8,000
Wind Adjustment Factor						
Minimum	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Maximum	**0.5**	**0.3**	**0.3**	**0.3**	**0.5**	**0.3**
SCmax	25	30	8	14	6	16
Constant fuel particle values for all fuels:						
	Particle Density			32 lb./cu.ft.		
	Total Mineral Content:			5.55%		
	Effective Mineral Content:			1%		

Figure 7 – Slash Fuel Models (1978)

1978 FUEL MODEL PROPERTIES			
Slash Fuel Models			
Parameter	I	J	K
Fuel Loading (tons/acre)			
0 to ¼ inch	12.0	7.0	2.5
¼ to 1 inch	12.0	7.0	2.5
1 to 3 inch	10.0	6.0	2.0
3 to 8 inch	12.0	5.5	2.5
Live Woody			
Herbaceous			
Fuel Bed Depth (ft)	2.0	1.3	0.6
Moisture of Extinction (%)			
Dead	25	25	25
Surface Area to Volume Ratio (sq.ft/cu.ft)			
0 to ¼ inch	1,500	1,500	1,500
¼ to 1 inch	109	109	109
1 to 3 inch	30	30	30
3 to 8 inch	8	8	8
Live Woody			
Herbaceous			
Heat Content (all fuels)			
BTUs/lb	8,000	8,000	8,000
Wind Adjustment Factor	0.5	0.5	0.5
SCmax	65	44	23
Constant fuel particle values for all fuels			
Particle Density		32 lbs/cu.ft	
Total Mineral Content		5.55%	
Effective Mineral Content		1%	

Figure 8 – Slash Fuel Models (1988)

1988 FUEL MODEL PROPERTIES			
Slash Fuel Models			
Parameter	I	J	K
Fuel Loading (tons/acre)			
0 to ¼ inch	12.0	7.0	2.5
¼ to 1 inch	12.0	7.0	2.5
1 to 3 inch	10.0	6.0	2.0
3 to 8 inch	12.0	5.5	2.5
Live Woody			
Herbaceous			
Drought Fuels	**12.0**	**7.0**	**2.5**
Fuel Bed Depth (ft)	2.0	1.3	0.6
Moisture of Extinction (%)			
Dead	25	25	25
Surface Area to Volume Ratio (sq.ft/cu.ft)			
0 to ¼ inch	1,500	1,500	1,500
¼ to 1 inch	109	109	109
1 to 3 inch	30	30	30
3 to 8 inch	8	8	8
Live Woody			
Herbaceous			
Heat Content (all fuels)			
BTUs/lb	8,000	8,000	8,000
Wind Adjustment Factor			
Minimum	**0.5**	**0.5**	**0.5**
Maximum	**0.5**	**0.5**	**0.5**
SCmax	65	44	23
Constant fuel particle values for all fuels			
Particle Density		32 lbs/cu.ft	
Total Mineral Content		5.55%	
Effective Mineral Content		1%	

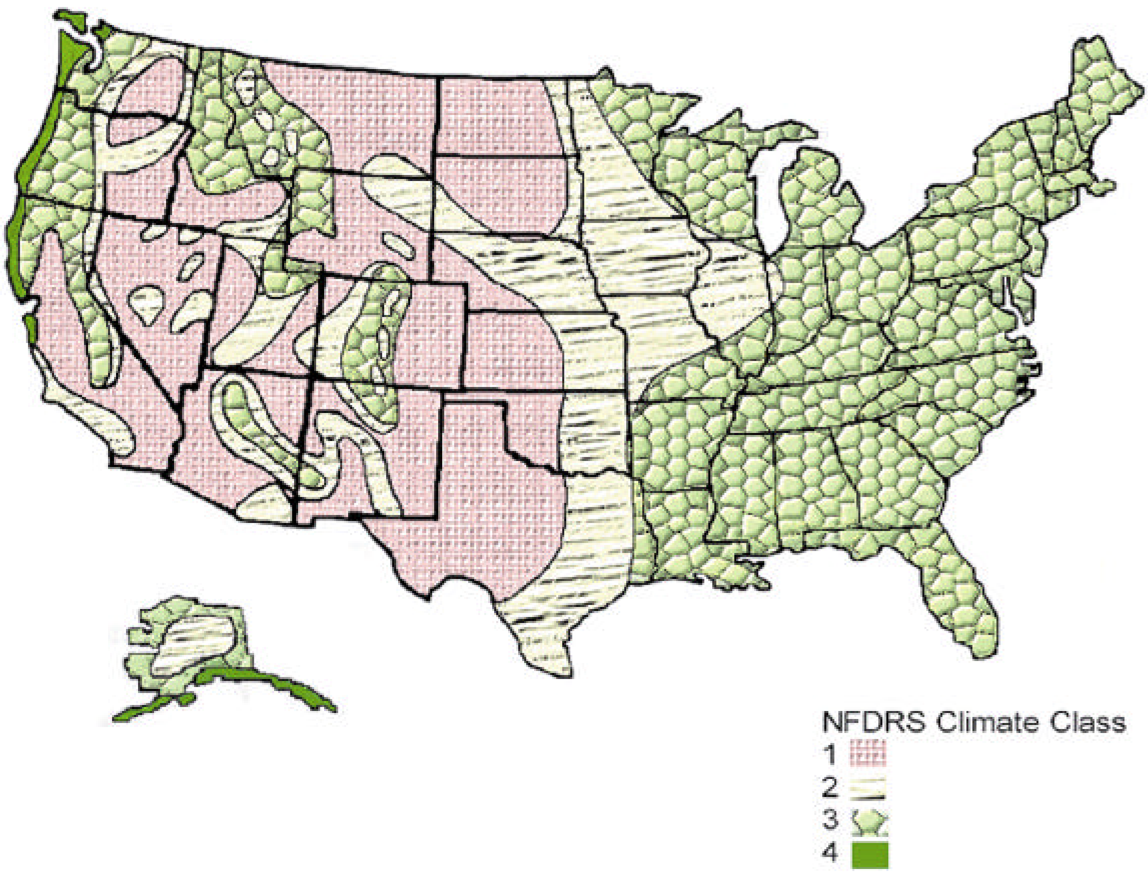
Appendix IV — Climate Class Determination

Figure 1 – Climate Class Selection Guide

NFDRS Climate Class	Thornthwaite Humidity Province	Characteristic Vegetation	Regions
1	Arid	Desert (sparse grass and scattered shrubs)	Sonoran deserts of west Texas, New Mexico, southwest Arizona, southern Nevada, and western Utah; and the Mojave Desert of California.
1	Semiarid	Steppe (short grass and shrubs)	The short grass prairies of the Great Plains; the sagebrush steppes and pinyon/juniper woodlands of Wyoming, Montana, Idaho, Colorado, Utah, Arizona, Washington, and Oregon; and the grass steppes of the central valley of California.
2	Sub-humid (rainfall deficient in summer)	Savanna (grasslands, dense brush and open conifer forests)	The Alaskan interior; the chaparral of Colorado, Arizona, New Mexico, the Sierra Nevada foothills, and southern California; oak woodlands of California; ponderosa pine woodlands of the West; the mountain valleys (or parks) of the Northern and Central Rockies.
3	Sub-humid (rainfall adequate in all seasons)	Savanna (grasslands and open hardwood forests)	Blue stem prairies and blue stem-oak hickory savannas of Iowa, Missouri and Illinois.
3	Humid	Forests	Almost the entire eastern United States; and those higher elevations in the West that support dense forests.
4	Wet	Rain Forests (redwoods and spruce-cedar-hemlock)	Coast of northern California, Oregon, Washington, and southeast Alaska.

Figure 2 – Climate Class Map

This map is adapted from Deeming et al. (1977).



Appendix V — Weather Data Requirements

The reliability and accuracy of the outputs of the National Fire Danger Rating System are dependent on consistent, high quality daily weather observations. This includes using standard equipment that is regularly maintained. In general, NFDRS outputs that are not representative of a unit's local conditions can be traced back to the weather observations.

From the 1920's until 1978, manual fire weather stations were the traditional source for NFDRS inputs. Remote Automated Weather Stations (RAWS) were introduced in 1978 and have gradually replaced many manual stations. By 2005, a national network of automated stations will meet the 2000 NFDRS station standards.

All observations are taken at or near 1300 hr local standard time (or 1400 hr local daylight savings time). The 2000 NFDRS station standards (National Wildfire Coordinating Group, 2000) provide details on weather data collection standards, including observation and transmit times for automated weather stations. Finklin and Fischer (1990) are recommended for more information about maintaining quality weather observations.

The following is a listing of the various weather parameters used by the National Fire Danger Rating System.

Dry Bulb Temperature (DBT) – The temperature of the air measured in the shade 4 ½ feet above the ground.

Relative Humidity (RH) – The ratio of the actual amount of water vapor in the air to the amount necessary to saturate the air at that temperature and pressure. It is expressed as a percentage. Automated weather stations measure this parameter directly. Manual stations derive the value from wet and dry bulb temperature measurements taken with a psychrometer and applied to National Weather Service psychrometric tables applicable to the elevation where the observations were taken.

Dew Point – The temperature at which a parcel of cooling air reaches saturation (100% relative humidity). For manual weather stations, dew point can be an alternate entry to relative humidity and is derived in the same manner as RH using psychrometric tables. Automated weather stations measure relative humidity rather than dew point.

Wind Speed (WS) – Wind, in miles per hour, measured at 20 feet above the ground or the average height of the vegetative cover and averaged over at least ten minutes. Refer to the Weather Station Handbook for procedures to adjust measurement height to account for surrounding vegetation.

Wind Direction – The direction from which the wind is blowing. It is entered as either an alphabetic value (N for north, SE for southeast, etc.) or a numeric value representing the compass direction (90 for east, 315 for winds coming out of the northwest). Calm, associated with a zero wind speed, is entered as a 0 for wind direction. Wind direction does not enter into any NFDRS calculations but is used by the fire weather forecasters in positioning weather systems on their charts and estimating effects of topography.

State of Weather and Solar Radiation – The NFDRS code is in transition between two methods of measuring the contribution of sunlight to fuel moisture. The existing method is a visual estimation of the "state of the weather." The new method is to record an instrumental measure of solar radiation.

For State of Weather, one must record the highest applicable code associated with the weather at the basic observation time. This is a very critical input to the NFDRS as many of the calculated outputs may be overridden based on the current observed state of weather. Automated weather stations do not do a very good job at estimating state of weather. As a result, the individual monitoring daily weather observations from such sites must validate the information being provided by the automated site.

The following coding applies to the observed state of weather:

Code	Associated State of Weather
0	Clear (less than 1/10 of the sky cloud covered.)
1	Scattered clouds (1/10 to 5/10 of sky cloud covered).
2	Broken clouds (6/10 to 9/10 of sky cloud covered).
3	Overcast (more that 9/10 of sky cloud covered).
4	Foggy
5	Drizzling (precipitation of numerous fine droplets, misting).
6	Raining
7	Snowing or sleeting
8	Showering (in sight of or occurring at station).
9	Thunderstorms in progress (lightning seen or thunder heard within 30 miles of observation site).

State of weather codes 5, 6 and 7 automatically force the Ignition Component (IC), Spread Component (SC), and Burning Index (BI) to zero. Energy Release Component (ERC) is not set to zero but may be computed to zero based on fuel model and moisture conditions. If fuel moisture sticks are not used, state of the weather codes 5, 6, and 7 also set the 1-hour and 10-hour fuel moistures to 35%. Care must be taken to make sure that state of the weather codes are accurate entries.

Solar radiation sensors measure the amount of sunlight received by the sensor, and therefore, by fuels in the area of the weather station. Use of measured solar radiation for dead fuel moisture calculations is planned to replace manual estimates of State of Weather.

Maximum and Minimum Dry Bulb Temperature and Relative Humidity – These are the highest and lowest values for each element measured at the observation site during the preceding 24-hour period. The values are used to adjust the standard drying function of the NFDRS algorithms to more nearly reflect actual conditions. WIMS automatically computes this information from hourly RAWS data. Manual weather stations should be equipped with maximum/minimum recording thermometers and a hygrothermograph to record this information. In the absence of maximum-minimum data, NFDRS processors can calculate the approximate values for both temperature and relative humidity; though experience has shown that these observations are not as accurate as actual observations and over time can have an effect on the outputs.

Precipitation Amount – This is the total amount of precipitation that occurred within the preceding 24-hour period measured in inches or centimeters. (NFDRS processors convert metric to English units.) Amounts less than 0.005 inch should be recorded as a trace (T). Snow and hail should be melted before being measured.

Precipitation Duration – This is a critical input into the calculation of NFDRS indices and components. Report the actual number of hours that precipitation fell in the 24-hour period immediately preceding the observation time. If several periods of precipitation occurred, the value entered must be the cumulative total of the duration of all periods of precipitation during the 24-hour period rounded to the next highest hour. If precipitation is occurring at the time of observation, record only the duration up until the time of observation, the remainder of the precipitation event will be reported the following day. Remote Automated Weather Stations automatically record precipitation duration. For manual stations obtaining accurate precipitation duration values is often difficult since seldom is the observer at the site for the full 24-hour period. The observer's best estimation is all that can be expected. Precipitation duration should, as best as possible, represent the total time that the fuels were exposed to liquid water, i.e., rain, snow, or sleet, during the 24-hour recording period.

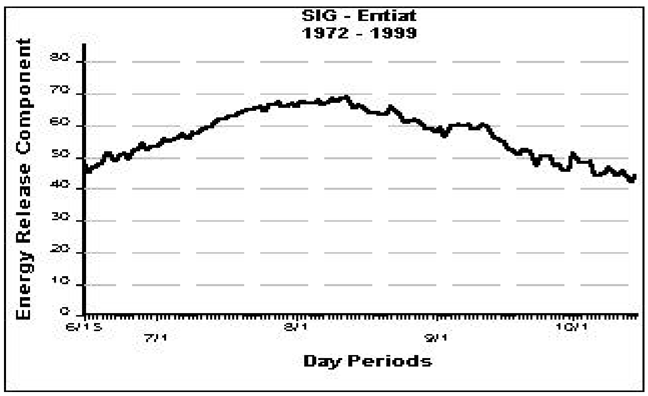
Fuels Wet Flag –When rain is in progress or has recently ended at the time of observation, the fine fuels are often covered with water and may be saturated. NFDRS calculations require the observer to note whether this condition is present using the Fuels Wet Flag. A Y is entered for yes and an N is entered for no. NFDRS processors automatically assign a Fuels Wet Flag of Y to state of weather codes 5, 6, and 7. Persons reviewing data input must insure that this assignment is appropriate for current local conditions.

The Wet Flag should also be set to yes when fuels are covered with snow even though no precipitation occurred on the day the observations are being recorded. This feature controls a melting algorithm that is keyed to air temperature.

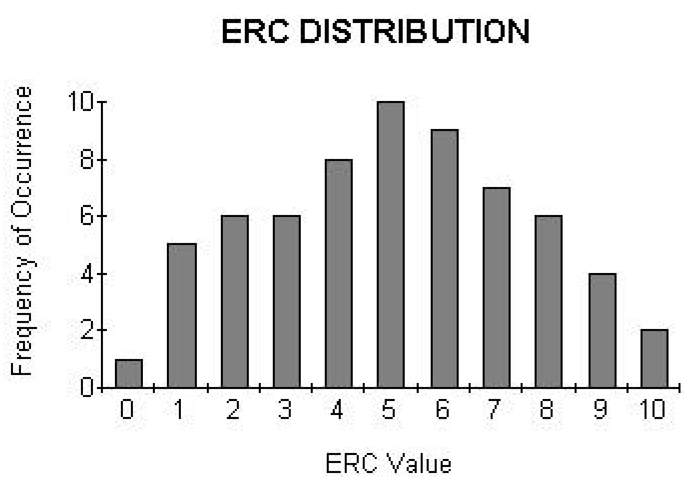
Appendix VI — Concept of Climatic Breakpoints Described

The concept of breakpoints can be confusing. The following is a simplified description of the concept as it is used in determining climatological breakpoints for inclusion in your NFDRS station record.

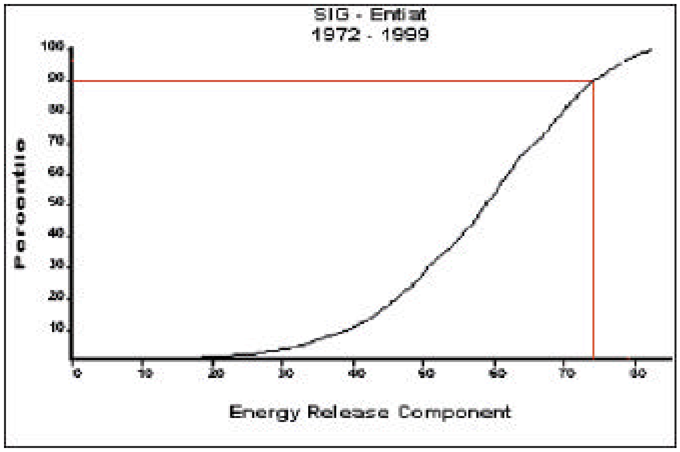
There are three basic types of statistical distributions. The simplest is a Seasonal Distribution. This is a plot of a weather parameter or NFDRS output value against the day that it occurred. The value can be for a single year or an average of several years. A graph might something look like the display below.



The second type of statistical distribution is a Standard Frequency Distribution. It is constructed by displaying a plot of the number of times a particular value occurs within the data set. A Standard Freque ncy Distribution looks like the example below.



The final example of a statistical distribution is the Cumulative Frequency Distribution. It is constructed by plotting on the Y (vertical) axis the number of times (frequency) a value occurs in the data set that is equal to or less than the value being plotted on the X (horizontal) axis. When the Y-axis value is expressed as a percent of the total data set the distribution is referred to as a Percentile Frequency Distribution as displayed in the graph below.



The Staffing Level Breakpoint is the value on the X-axis that corresponds to the percentage of the total observations you want to group in staffing levels 1, 2 and 3. For example, if your data set has 1200 observations and your agency recommends using the 90^{th} percentile as a breakpoint for ERC between class 3 and 4, your breakpoint value would be the point on the graph that 90% of the values occurred at or below. In the example above it would be 74 or the point on the ERC continuum where the 1080^{th} observation occurred (90% of 1200). If your agency uses the 80^{th} percentile as the breakpoint, the ERC value would be 70 or the point on the ERC continuum that the 960^{th} observation occurred (80% of 1200).

In the examples above we considered Energy Release Component, but any of the NFDRS outputs or weather parameters could be plotted. The general shape of the curves would be the same. The magnitudes (Y-axis) may be different because each NFDRS index or component has a unique range of possible values or continuum for a given set of weather records (refer to section 1.07.3). The resultant breakpoints, when using NFDRS outputs or weather data, are referred to as Climatological Breakpoints.

If you plot cumulative fire occurrence instead of weather or NFDRS outputs, the same principles apply. The resultant breakpoints are referred to as the Fire Business Thresholds.

Appendix VII — Subjects Related to the National Fire Danger Rating System

Haines Index

This is a fire weather index based on the stability and moisture content of the lower atmosphere that measures the potential for existing fires to become large fires. (It is not a predictor of fire starts.) It uses a numeric scale ranging from 2 to 6 with six being the highest potential for large fires. It is named after its developer, Donald Haines, a Forest Service research meteorologist, who did the initial work and published the scale in 1988.

For years, meteorologists and fire researchers have known that atmospheric stability contributes significantly to the intensity and spread of fires. Haines compared twenty years of fire occurrence data with atmospheric stability data and found a strong relationship between large fire occurrence and the temperature lapse rate (change in temperature crossing through the atmosphere vertically) and moisture content of the lower layers of the atmosphere. Haines assigned scaling factors to each of the atmospheric variables that when added together, formed an index that measured the potential for large fires.

The following table displays the Haines Index and associated large fire potential:

Haines Index Value	Potential for large fires
2 or 3	very low
4	low
5	moderate
6	high

Additional information about the Haines Index can be found in Werth and Ochoa (1993) and Werth and Werth (1997).

Normalized Difference Vegetation Index

Four vegetation greenness maps are derived weekly from Normalized Difference Vegetation Index (NDVI) data collected by US Geological Survey Earth Resources Observation System (EROS) satellites. These maps have a spatial resolution of 1-kilometer (.6 miles). They can be downloaded from the Wildland Fire Assessment System at http://www.fs.fed.us/land/wfas/. These maps are used to assess the state of live vegetation.

Visual Greenness Maps – These maps portray vegetation greenness compared to a very green reference, such as an alfalfa field or golf course. The resulting image is similar to what you would expect to see from a high altitude. Normally dry regions will never show as green as normally wetter areas.

Relative Greenness Maps – These maps portray how green the vegetation is compared to how green it has been historically (since 1989). Because each pixel is normalized to its own historical range, all areas (dry to wet) can appear fully green at some time during the growing season.

Departures from Average Greenness Maps – These maps portray how green each pixel currently is compared to its historic average greenness for the corresponding week of the year.

Live Moisture Maps – These maps portray experimentally derived live vegetation moisture with values ranging from 50 to 250 percent of dry weight.

As would be expected with any satellite-sensed data, there will be instances when cloud or snow cover prevents accurate coverage. To minimize this occurrence, the actual maps are a composite of several satellite passes over an area, thus the reason for weekly updates rather than daily.

Additional information on the Normalized Departure Vegetation Index and associated greenness maps can be found in Burgan and Hartford (1993) and Burgan et al. (1996).

Lightning Activity Level

Lightning Activity Level (LAL) is a measurement of the cloud-to-ground lightning activity observed (or forecasted to occur) within a 30 mile radius of the observation site. Two inputs for LAL are necessary in the Weather Information Management System (WIMS) during daily NFDRS data entry. The first covers the period from when the previous day's observation was taken until midnight (commonly referred to as Yesterday's Lightning) and the second covers the period from midnight until today's observation time (commonly referred to as Morning Lightning). The Fire Weather Forecasters of the National Weather Service use the same scale when forecasting lightning activity levels.

Lightning Activity Level is rated on a scale of 1 to 6 as described below:

1 No thunderstorms or building cumulus clouds observed.

2 A single or a few building cumulus clouds with only an occasional cloud reaching thunderstorm intensity are observed. Thunderstorms or lightning need not be observed for this activity level to be assigned; however at least one large cumulus cloud must be present.

3 Occasional lightning (an average of 1 to 2 cloud-to-ground strikes per minute) is observed. Building cumulus is common; thunderstorms are widely scattered.

4 Frequent lightning (an average of 2 to 3 cloud-to-ground strikes per minute) is observed. Thunderstorms are common and cover 10 to 30 percent of the sky. Lightning is primarily of the cloud-to-cloud type but cloud-to-ground lightning may be observed.

5 Frequent and intense lightning (cloud-to-ground strikes greater than three per minute) are observed. Thunderstorms are common, occasionally obscuring the sky. Moderate to heavy rain may occur with the thunderstorms and light to moderate rains usually precede and follow the lightning activity. Lightning of all kinds (cloud-to-cloud, in-cloud and cloud-to-ground) is characteristically persistent during the storm period.

6 A dry lightning situation. Low lightning flash rate observed (less than one to three cloud-to-ground strikes per 5-minute period per storm cell passage). Scattered towering clouds with a few thunderstorms. Bases of the clouds are high. Virga is the predominant form of precipitation.

Lightning Detection System

In 1976, the U.S. Department of the Interior Bureau of Land Management (BLM) entered into a development contract with the University of Arizona, Institute of Atmospheric Physics, to develop a lightning detection system. In 1977, the first experimental networks were installed in Alaska and the Great Basin. The BLM contracted with a company called Lightning Location and Protection (LLP) to provide the first “operational” Automatic Lightning Detection System (ALDS) ever fielded. By 1979, the BLM had operational networks in Alaska and the Western U.S. From the Bureau’s experience and demonstrated capabilities of ALDS, other smaller networks began to appear during the early 1980’s.

Now, the BLM, Forest Service, National Weather Service and several states have contracts with a commercial vendor to provide real time lightning detection information. Refer to the website (http://www.lightningstorm.com) for more information.

In 1999, the Forest Service implemented a development process that addressed the use of lightning location data in conjunction with local fine scale spatial data to produce a customized display of real time lightning detection information. The result of this development process is the Automated Lightning Mapping System (ALMS). ALMS is a client based ESRI ArcView extension that allows the download and display of lightning information on systems that have the ArcView software and Internet connection. The information is transferred to the client via the BLM Lightning website (http://www.nifc.blm.gov/index.html), which requires a valid username password logon.

Archived lightning data is available from the vendor and, for the historic BLM network, from the Western Regional Climate Center (http://www.wrcc.dri.edu/).

Appendix VIII — Season Codes and Greenness Factors

Use of Seasons Codes and Greenness Factors with the 1988 Revisions to NFDRS

In 1988, a revised set of fuel models and calculation formulas was released for use as an alternative to the previously released 1978 version of the National Fire Danger Rating System. The primary purpose of the 1988 revisions was to improve drought response in humid environments and to provide more flexibility in the greening and curing of live fuels.

Greenness Factors and Season Codes

Instead of allowing the model to calculate the herbaceous and woody fuel moisture as the greening process occurs, the 1988 revisions allow the user to control the calculation process by entering season and greenness factor values periodically throughout the season. The 1988 NFDRS revisions recognize four season-like conditions (Winter, Spring, Summer, and Fall). It also uses greenness factors that range from 0-20 where 0 represents a fully cured condition and 20 represents as green as the herbaceous and shrub vegetation ever gets in the area. As the season progresses, the user must manually adjust the season and greenness factors to reflect the current conditions in their area. There is no hard and fast rule to use as to when to switch season codes and how frequently to change greenness factors. Users need to watch the development of the live vegetation in their area and adjust the codes only when physical conditions change.

The season codes represent stages in the life cycle of the live herbaceous and shrub vegetation and are not tied directly to calendar dates. Similarly greenness factors represent a scaling of plant development progression through their life cycle from cured to green and back to cured again.

The following describes what happens within the NFDRS model with changes in the season code.

Winter—(Code 1) Live herbaceous and woody moistures are set to their minimums. The greenness factor value is always 0. The live herbaceous moisture content is equal to the fine dead fuel moisture content and the live woody fuel moisture is equal to the default dormant season woody fuel moisture as determined by climate class. (This is the season of plant dormancy and is similar to the way 1978 version handles pre-green or frozen conditions.)

Spring—(Code 2) Live woody and herbaceous fuel moistures are increasing rapidly. This is generally the green-up period. Greenness factors increase from 1 to 20 during this period. The herbaceous and woody fuel moistures are calculated for the 1988 fuel models using the same formulas as are used in the 1978 models but with an adjustment applied. The adjustment factor is the assigned greenness factor divided by 20.

Summer—(Code 3) Live woody and herbaceous moistures fluctuate in response to drying and wetting cycles. Greenness factor values fluctuate up and down within the 20 and 1 range during this period. Annual herbaceous vegetation most likely will cure sometime during this period. In the NFDRS model, the live fuel moisture is initially calculated using the same formulas as are used after the completion of greening in the 1978 models, but is adjusted by a factor equal to the greenness factor divided by 20. The woody fuel moisture is calculated using the same formulas as are used in the 1978 models, and it too is adjusted by the greenness factor.

Fall—(Code 4) Live herbaceous and woody fuel moistures are decreasing. Vegetation is entering dormancy. Greenness factors drop during this period approaching 0. The live herbaceous and woody fuel moistures are calculated the same as for the transition period in the 1978 models, though are adjusted for greenness by a factor equal to the assigned greenness factor divided by 20.

The Season Codes and Greenness factors work independently of KBDI. The table on page 16 of Burgan (1988) is only a suggested relationship between KBDI and Greenness Factors to be used when starting a station mid-season.

The Herbaceous and Shrub Greenness factors can be different, depending on local plant species and how they respond during the growing season.

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Suggested Websites

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http://www.fs.fed.us/fire/planning/nist - Fire Applications Support

http://www.fs.fed.us/land/wfas - Wildland Fire Assessment System

http://famweb.nwcg.gov/pocketcards/default.htm - Firefighter's PocketCard Homepage