Fire and Weather Analyses

Deschutes National Forest
Fremont-Winema National Forest

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Introduction

Weather and fire occurrence records were acquired and analyzed for the Fremont (FRF), Winema (WNF), and Deschutes (DEF) National Forests in central Oregon in support of a Joint Fire Science Program funded project examining changes in vegetation and surface fuels over a 30-year chronosequence of lodgepole pine mortality in central Oregon due to mountain pine beetle. In order to provide a framework for weather parameters to be used in point and spatial fire behavior analyses, it is often helpful to complete an analysis evaluating fire growth and fire behavior in relation to observed weather. Not only it is easy to identify record-setting years for fire occurrence, but it is also possible to examine the weather that occurred during large fire years including weather that coincided with large fire growth.

This analysis couples weather station data and fire occurrence data from multiple sources. Fire occurrence data and daily 1300 weather data were downloaded from the Fire and Weather Data on the FAMWEB website (refer to https://fam.nwcg.gov/fam-web/) for the DEF, FRF, and the WNF as RAW files to be imported into FireFamilyPlus v. 4.1.0. Hourly weather observations were downloaded from the Western Regional Climate Center (WRCC) for each individual weather station and imported into FireFamilyPlus.

Deschutes National Forest

The DEF had an active fire year in 2003 in terms of acres burned (Figure 1).

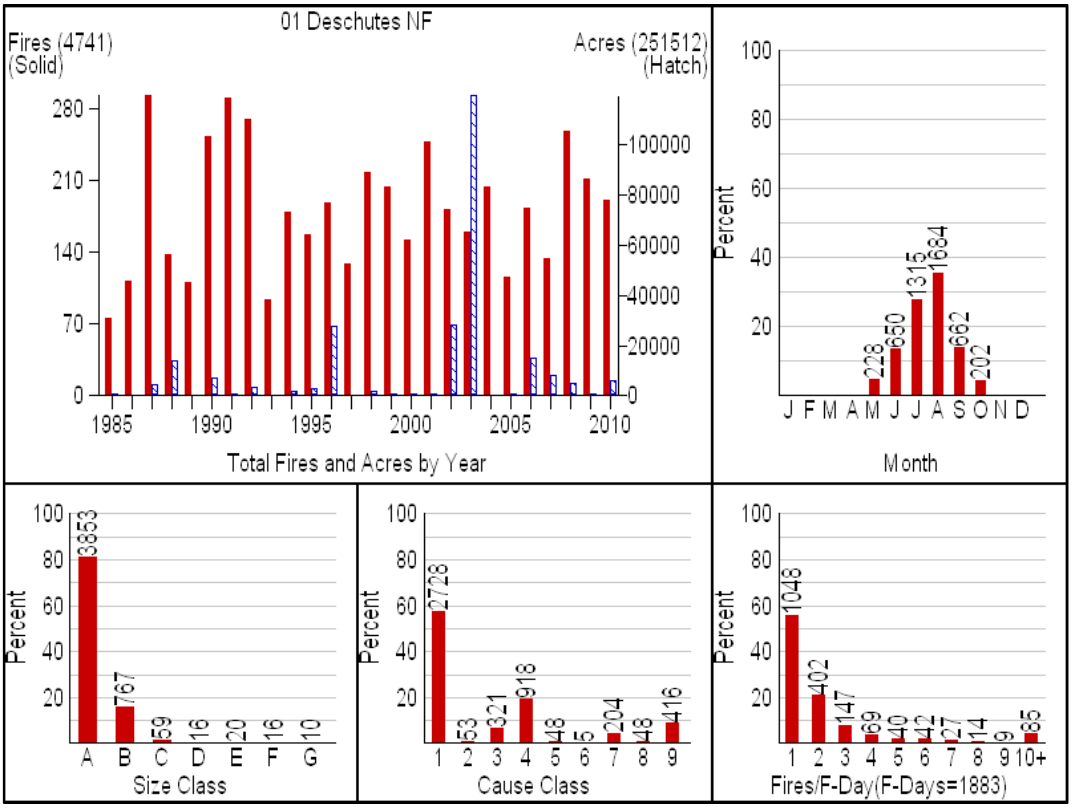


Figure 1. Fire occurrence on the DEF from 1985 to 2011

B & B Complex

The incident status summary reports (ICS-209, refer to http://fam.nwcg.gov/fam-web) were queried for the DEF in 2003. The Booth and Bear Butte Fires both started 8/19/2003 and were managed as a complex (Table 1). Both fires were described as having extreme fire behavior with crown fire runs and maximum spotting distances of 1.5 mi ahead of the fire front. Elevation on the Bear Butte Fire ranged from 3200 to 6200 ft while the Booth Fire ranges in elevation from 2800 to 6100 ft. Vegetation is described as a combination of old growth and conifer regeneration with a component of heavy dead and down and bug kill (fuel model 10).

Table 1. Acres and critical fire behavior and weather as reported in the ICS-209 reports for the B & B Complex

Date and Time	Cumulative Acres	Fire Behavior and Weather Comments
8/20/03 2030	Total – 4,000 ac	88 degrees, 20-25% RH, NE wind 5-10 mph
8/21/03 1700	Total – 10,900 ac Bear Butte – 2,900 ac Booth – 8,000 ac	Plume dominated Long-range spotting 85-95 degrees, 20-25% RH, SW wind 6-10 mph
8/22/03 1700	Total – 24,290 ac Bear Butte – 3,990 ac Booth – 20,300 ac	0.1 in rain Decreased fire behavior 65 degrees, 50% RH, variable wind 2-3 mph
8/23/03 1700	Total – 25,800 ac Bear Butte – 5,000 ac Booth – 20,800 ac	Torching Long-range spotting 77 degrees, 40% RH, NW wind 2-5 mph, gusts to 10 mph
8/24/03 1630	Total – 36,400 ac Bear Butte – 5,450 ac Booth – 30,950 ac	Some group torching Short-range spotting 81 degrees, 28% RH, NW wind 4-7 mph, gusts to 15 mph
8/29/03 1700	Total – 42,572 ac Bear Butte – 7,934 ac Booth – 34,638 ac	Spotting up to 0.25 mi Torching 84 degrees, 18-25% RH, E/NE wind 4-6 mph
8/31/03 1700	Total – 49,130 ac Bear Butte – 10,572 ac Booth – 38,558 ac	Five columns Spotting up to 0.5 mi, torching and crowning runs Majority of new acres in Mt Jefferson Wilderness Area 86 degrees, 15-25% RH, NW wind 6-12 mph
9/2/03 1700	Total – 51,523 ac Bear Butte – 11,035 ac Booth – 40,488 ac	Booth – plume dominated Spotting up to 0.5 mi, torching and crowning runs Significant runs in Mt Jefferson Wilderness Area 85-92 degrees, 12-20% RH, SW wind 6-12 mph
9/3/03 1700	Total – 61,962 ac Bear Butte – 11,250 ac Booth – 50,712 ac	Booth – plume dominated Bear Butte – natural barriers slowed fire spread Spotting up to 0.75 mi, torching and crowning runs Significant runs in Mt Jefferson Wilderness Area 85-92 degrees, 12-20% RH, S wind 6-12 mph
9/4/03 1700	Total – 70,769 ac Bear Butte – 11,250 ac Booth – 59,519 ac Fires merged	Booth – plume dominated Bear Butte – natural barriers slowed fire spread Spotting up to 0.75 mi, torching and crowning runs 84-92 degrees, 14-22% RH, SW wind 3-7 mph
9/5/03 1700	Total – 82,888 ac Bear Butte – 11,664 ac Booth – 71,224 ac	Thunderstorms Inversion lifted late – slowed fire spread 83-90 degrees, 18-25% RH, SW wind 5-8 mph
FINAL	**Bear Butte – 11,035 ac** **Booth – 79,734 ac**	

Davis Fire

This fire started on 6/28/2003 approximately 12 miles west of La Pine, Oregon (Table 2). The elevation range on the Davis Fire was 4400 to 7000 ft. The Davis Fire burned in lodgepole pine (flat ground) and mixed conifer stands (on slopes) with a large component of dead lodgepole.

Table 2. Acres and critical fire behavior as reported in the ICS-209 reports for the Davis Fire

Date and Time	Cumulative Acreage	Comments
6/28/03 2230	1,500 ac	Torching, spotting
6/29/03 1700	3,000 ac	Long range spotting, crown fire runs with south winds
6/30/03 0000	14,000 ac	Torching
7/1/03 1700	16,100 ac	
FINAL	**21,135 ac**	

18 Fire

The 18 Fire (also referred to as the 18 Road Fire) had a reported start date of 7/23 approximately 4 miles south of Bend, Oregon (Table 3). The 18 Fire has elevation ranging from 4200 to 5200 ft. The vegetation composition was described as ponderosa pine with a bitterbrush understory.

Table 3. Acres and critical fire behavior as reported in the ICS-209 reports for the 18 Fire

Date and Time	Cumulative Acreage	Comments
7/23/03 2100	450 ac	
7/24/03 1700	2,500 ac	Inversion most of the day 90 degrees, 25% RH, N/NW wind 0-5 mph
FINAL	**3,800 ac**	

Link Fire

The Link Fire started 7/5/2003 about 12 miles northwest of Sisters, Oregon (Table 4). This fire was directly south of the final perimeter for the Booth Fire (Figure 2) and burned primarily in mixed conifer.

Table 4. Acres and critical fire behavior as reported in the ICS-209 reports for the Link Fire

Date and Time	Cumulative Acreage	Comments
7/6/03 1815	800 ac	Torching, spotting, crown fire runs
7/10/03 2015	2,100 ac	Group torching, 0.75 mi spotting
7/11/03 1815	3,119 ac	Individual tree torching
FINAL	**3,590 ac**	

Weather

Weather data including the daily observation and weather station catalog information was downloaded from FAMWEB as fw9 files to be imported into FireFamilyPlus. Usually representing 1300 weather, these observations are the official record and include manual corrections to fix errors within the data. Additional weather information was downloaded for multiple weather stations from the Western Regional Climate Center (http://www.raws.dri.edu/) for analyses in FireFamilyPlus. The WRCC data includes hourly observations from weather stations that have not been corrected. Cabin Lake, Colgate, Lava Butte, and Round Mountain RAWS are located on the DEF (Figure 3). FireFamilyPlus was used to

Table 5. Acres burned per month from 2001 to 2008

Month	Acres Burned
May	108
June	21,135
July	44,721
August	107,882
September	2,596
October	140
Total	**176,582**

analyze the data to identify anomalous data, determine critical weather thresholds affecting fire growth and fire behavior, and prepare wind and weather files for geospatial fire analyses.

The greatest number of fires occurs in August (Figure 1) and the greatest number of acres has historically burned this month as well (Table 5). The B & B Complex includes two of the largest fires in recent history for the DEF and burned from mid-August to mid-September, therefore representing the height of the fire season. The B & B had numerous days when the fire exhibited large growth and therefore represents weather and fuels conditions suitable for large fire growth to occur.

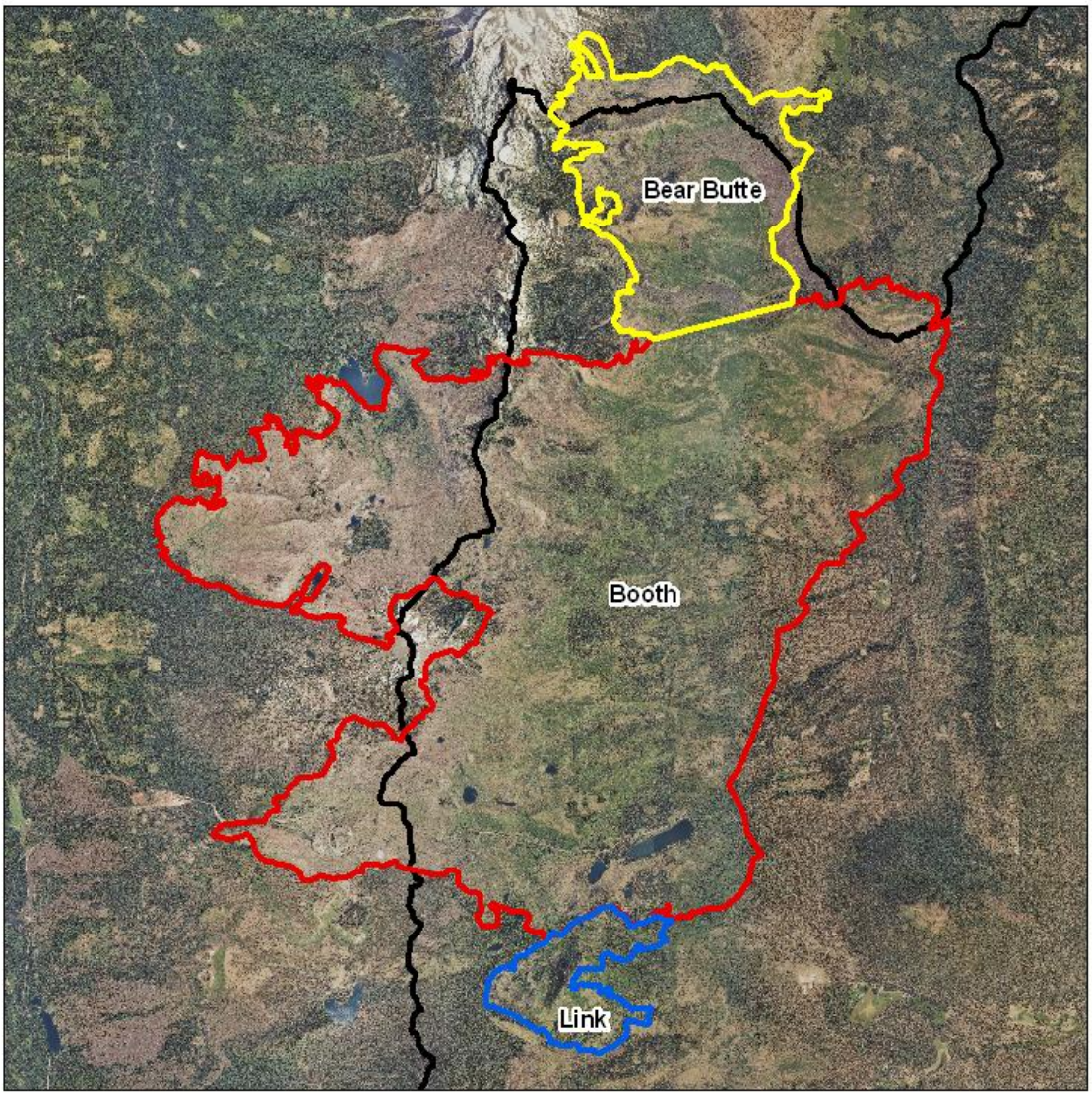


Figure 2. Final perimeters for the B & B Complex (Bear Butte and Booth Fires) and the Link Fire

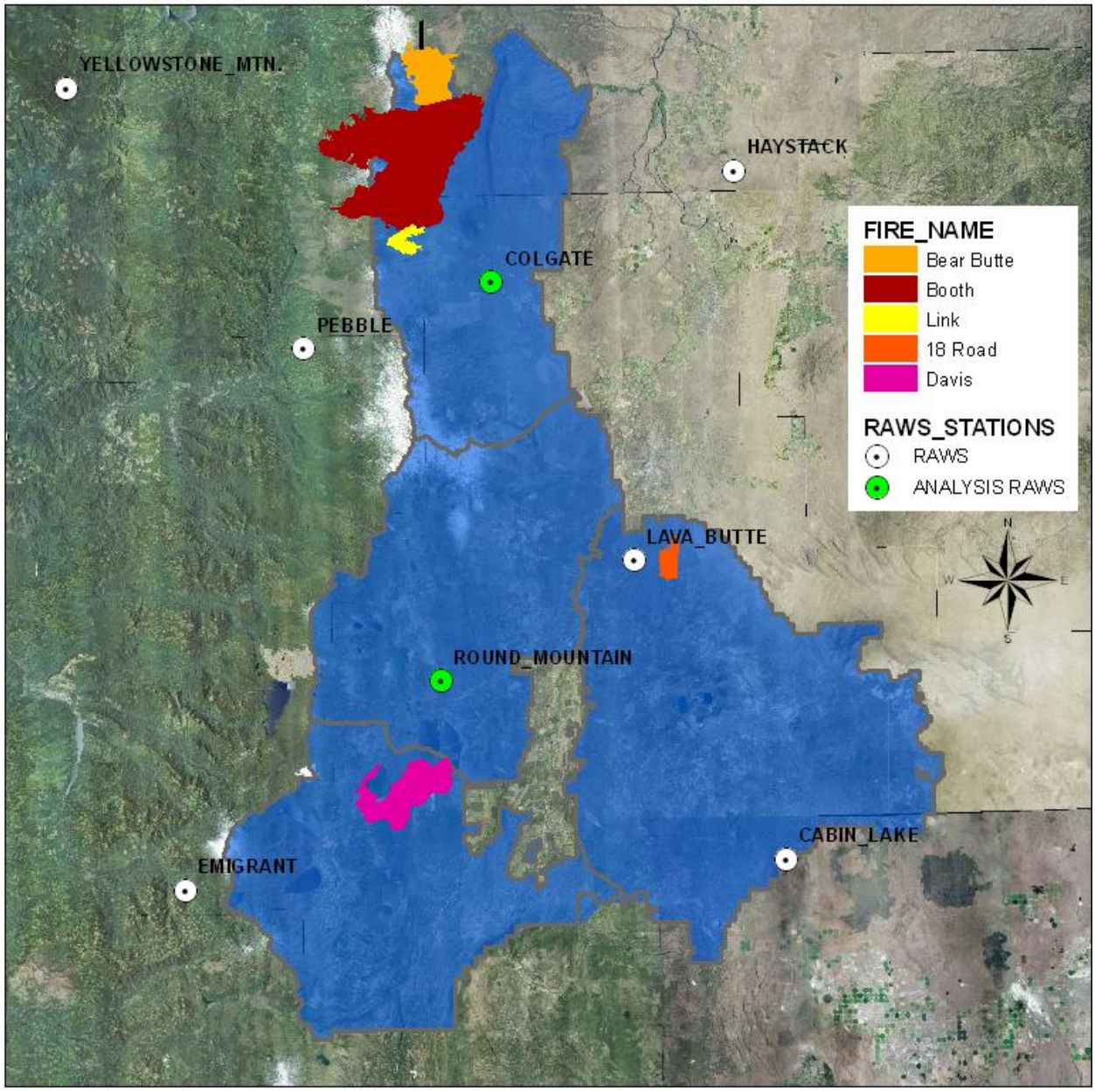
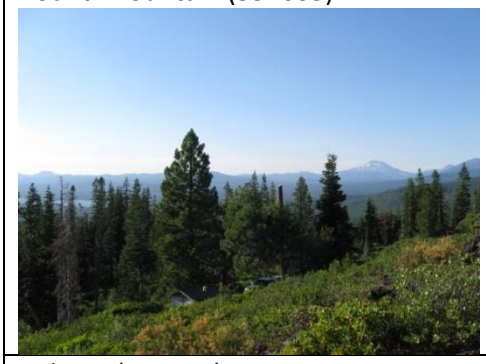


Figure 3. Locations of recent large fires and important weather stations on the Deschutes NF

A number of weather stations were examined in conjunction with the B & B Complex (Figure 2 and 3). After identifying the possible weather station candidates that have hourly weather available for August 1 – September 15, 2003, it was determined that the Round Mountain RAWS has the most representative wind speed and wind direction (Figure 4) whereas the Colgate RAWS best represents temperature (Figure 5) and relative humidity (Figure 6) when compared to the weather documented in the daily ICS-209 reports (Table 6). Colgate is approximately 8 mi southeast of the southern edge of the fire perimeter while Round Mountain is about 45 mi south of the fire perimeter. The Colgate RAWS is closer than Haystack, Yellowstone Mountain, or Lava Butte. The Pebble RAWS does not have hourly data available.

Table 6. Summary of selected weather stations for the Deschutes NF

RAWS Name (WIMS ID)	Elevation	Comments
Round Mountain (352605) 	5900 ft	• Ridgetop • Mixed conifer with mixed tall shrub understory • Rock outcroppings (lava) • 20 in annual precipitation • 1997-2011 data used • Changed fuel model in FireFamilyPlus from C to G
Colgate (352620) 	3280 ft	• Plateau/bench • Ponderosa pine with grass/bitterbrush understory • 15 in annual precipitation • 1991-2011 data used

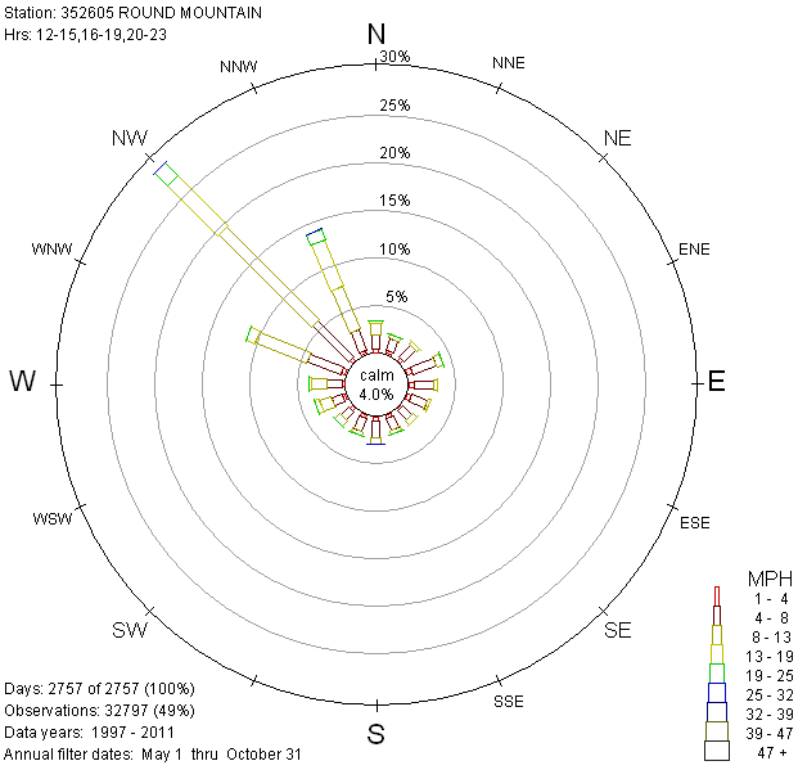


Figure 4. Windrose for the Round Mountain RAWS for 1200 – 2300 for 5/1 through 10/31

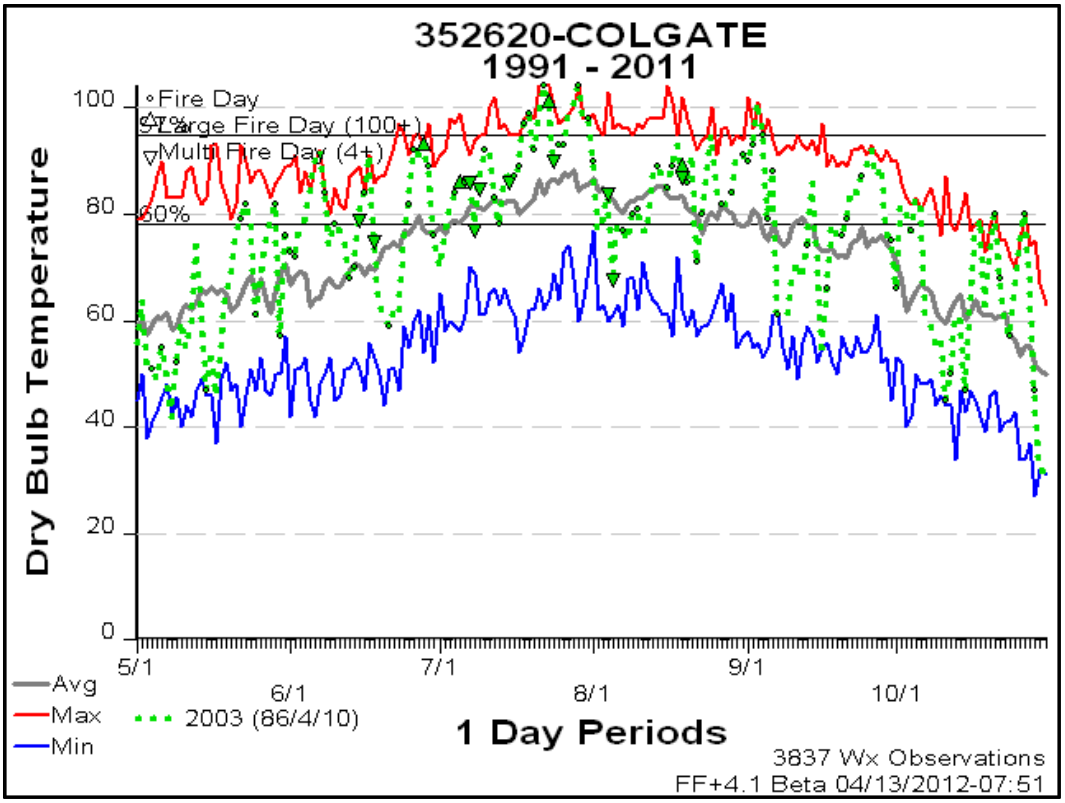


Figure 5. Colgate RAWS record for temperature from May 1 – October 31, 1991 to 2011 with 2003 overlay

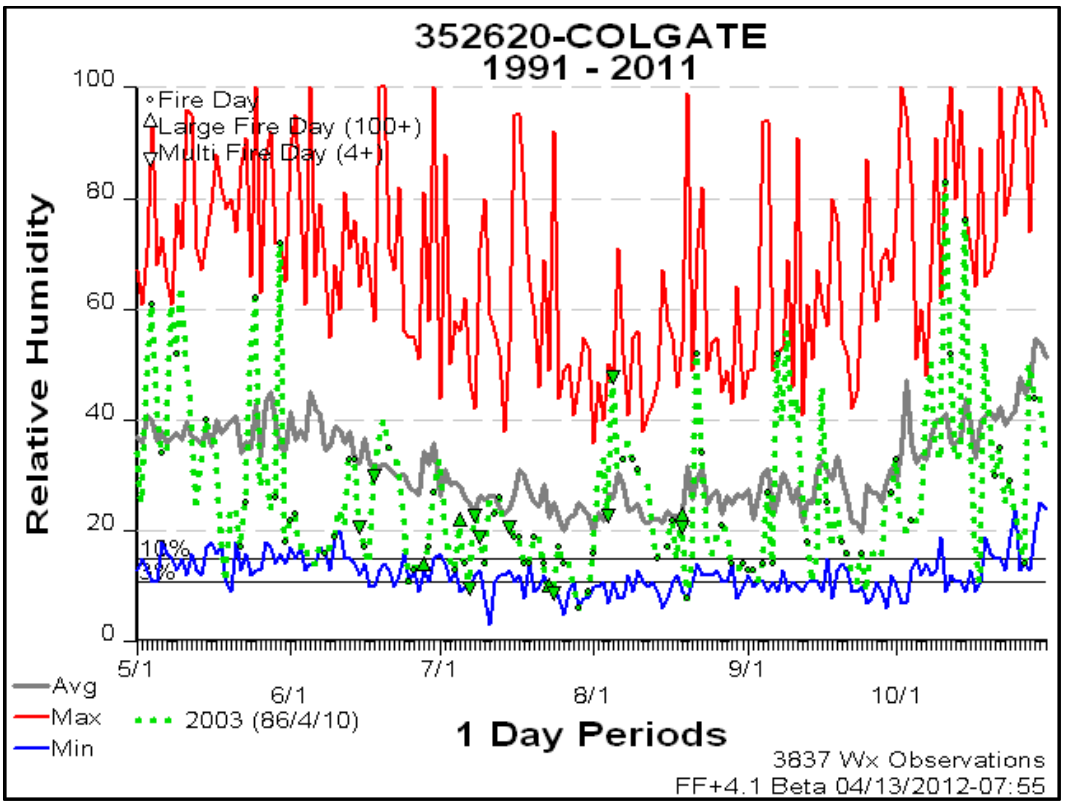


Figure 6. Colgate RAWS record for relative humidity from May 1 – October 31, 1991 to 2011 with 2003 overlay

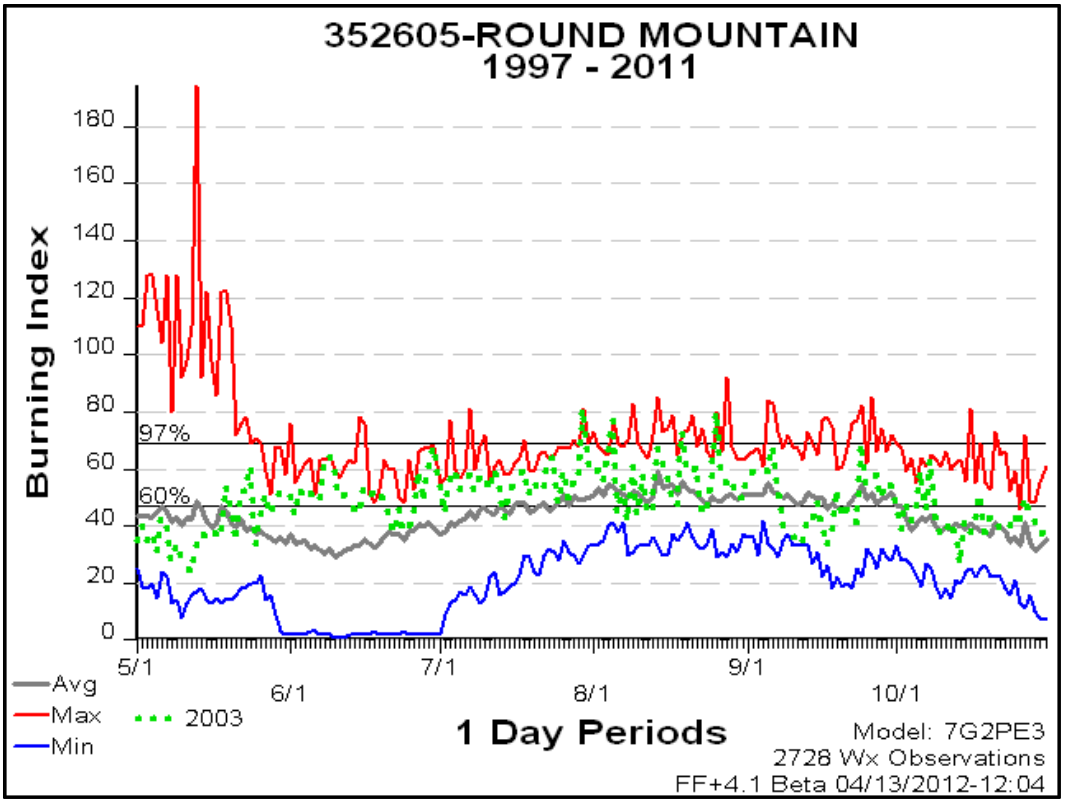


Figure 7. Burning Index for Round Mountain RAWS from May 1 – October 31, 1997 to 2011 with 2003 overlay

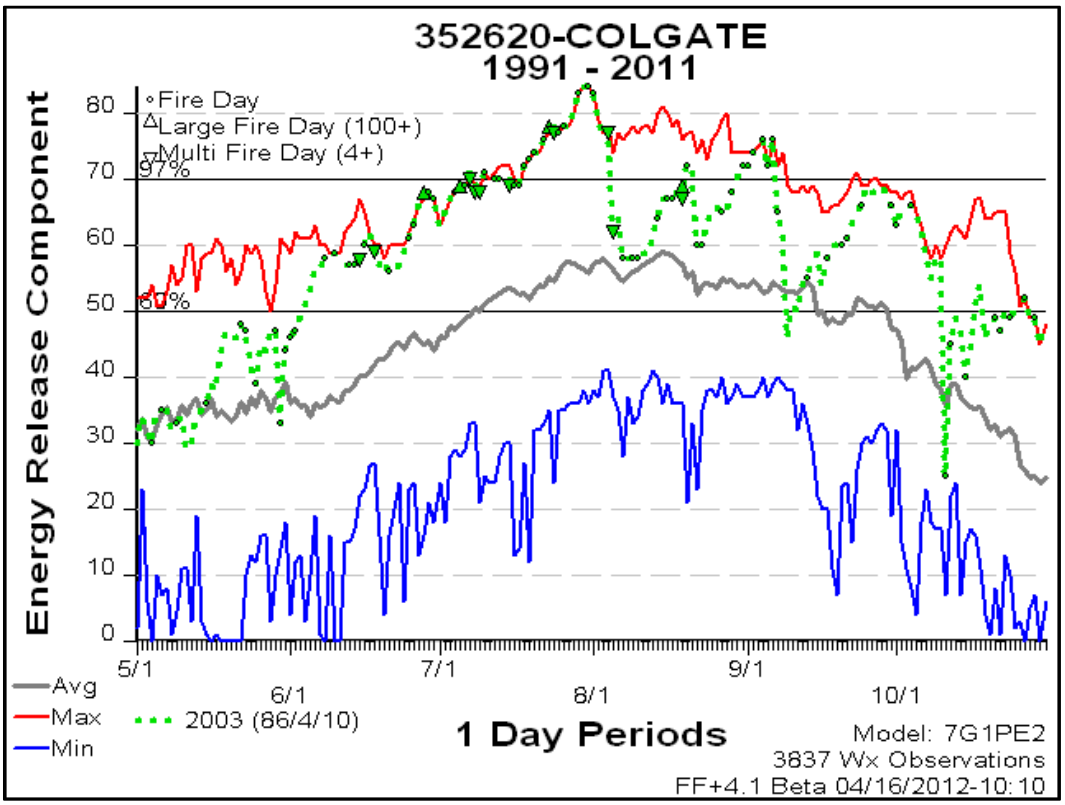


Figure 8. Energy Release Component for Colgate RAWS from May 1 – October 31, 1991 to 2011 with 2003 overlay

Figure 7 displays the Burning Index (BI) statistical graph for the Round Mountain weather station and Figure 8 shows the Energy Release Component (ERC – fuel models G) statistical graph for the Colgate RAWS. The BI estimates the potential difficulty of fire containment as it relates to flame length at the head of a fire. The ERC describes the worst case total energy released per unit area within the flaming zone of a fire. It is a dimensionless number and is a simple estimate of seasonal drought and therefore the availability of fuels to burn. In laymen's terms, the ERC tracks seasonal drought while the BI factors in the influence of wind. Both the BI and ERC were tracking above average in August, 2003.

Weather conditions documented in the ICS-209 reports were compared to weather observations for the Colgate RAWS and wind direction and wind speed at the Round Mountain RAWS. Generally, it appears that the RAWS values track well with values in the ICS-209 (Table 7). It is difficult to know whether the weather listed in the ICS-209 reports comes from actual fire weather observations or a spot weather forecast that may or may not accurately reflect actual weather.

Table 7. Comparison between weather observations in the ICS-209 reports and Colgate RAWS (temperature and relative humidity) and Round Mountain RAWS (wind). The range of values listed for the RAWS are based on a burning period from 1100-1900.

Date	Source	Temp	RH	Wind
8/20/03	ICS-209	88°	20-25%	NE 5-10 mph
	RAWS	69-88°	7-24%	SE→W/SW→NW 3-6 mph
8/21/03	ICS-209	85-95°	20-25%	SW 6-10 mph
	RAWS	78-92°	15-25%	S 5-10 mph
8/22/03	ICS-209	65°	50%	Variable 2-3 mph
	RAWS	61-71°	47-74%	N/NW→NW 2-5, gusts 10-15 mph
8/23/03	ICS-209	77°	40%	NW 2-5 mph, gusts to 10 mph
	RAWS	69-80°	31-45%	S→W→NW 3-8, gusts 10-14 mph
8/24/03	ICS-209	81°	28%	NW 4-7 mph, gusts to 15 mph
	RAWS	80-91°	15-31%	W/NW 3-6 mph, gusts 10-14 mph
8/29/03	ICS-209	84°	18-25%	E/NE 4-6 mph
	RAWS	68-88°	12-23%	E/NE 3-6 mph
8/31/03	ICS-209	86°	15-25%	NW 6-12 mph
	RAWS	75-92°	13-30%	Variable→NW 2-8 mph, gusts 12-18 mph
9/2/03	ICS-209	85-92°	12-20%	SW 6-12 mph
	RAWS	73-96°	11-25%	SE/S/SW 3-6 mph
9/3/03	ICS-209	85-92°	12-20%	S 6-12 mph
	RAWS	81-103°	10-23%	S→NW 5-8 mph, gusts 10-18 mph
9/4/03	ICS-209	84-92°	14-22%	SW 3-7 mph
	RAWS	79-95°	13-23%	S→NW→S 5-11 mph
9/5/03	ICS-209	83-90°	18-25%	SW 5-8 mph
	RAWS	76-89°	18-34%	SE→NW 2-7 mph, gusts 10-12 mph

Anomalies in the WRCC weather data were discovered using the View Observations and Climatology functions in FireFamilyPlus. These records were compared to other data sources such as the Weather Information Management System (WIMS). If the WRCC data were consistent with WIMS records they were retained as this indicated these values were mostly likely accurate but deviate from the average; otherwise the anomalous WRCC records were compared to previous and subsequent day's hourly

records in FireFamilyPlus to ensure the values in question were consistent with the trend. For example, the 8/23/1992 records shown in Table 8 appear anomalous as those values are not outside the range of possibilities, but they are actually errors. Obvious errors in the weather data were discovered using FireFamilyPlus functions previously described in addition to the error logs produced while importing weather station data in FireFamilyPlus. Erroneous records (Table 8) were fixed in the FireFamilyPlus database.

Table 8. Selected records for the Colgate RAWS

Date	Original Value	Amended Value	Comments
8/23/1992	25° F	65° F	Checked hourly weather trend
	73% RH	43% RH	Checked hourly weather trend
8/25/1999	50 in precipitation	0.0 in precipitation	In WIMS, state of the weather at 1300 is 1 (scattered clouds) and precipitation amount listed as 0.0 in
8/26/2001	60 in precipitation	0.0 in precipitation	In WIMS, state of the weather at 1300 is 0 (clear sky) and precipitation amount listed as 0.0 in

The Colgate RAWS had numerous records in the time period between 5/1 to 10/31 with a precipitation amount greater than 2 inches that warranted closer examination; the original values were changed for the following dates: 5/22 – 6/10/1993, 9/14/1995, 10/29/1999, 6/3/2000, and 10/3/2005 based on evaluation of the state of the weather code, temperature, relative humidity, and precipitation tend. The remainder of the values that appeared suspicious yet had no confirming evidence to be wrong were ignored. Specifically looking at 2003, precipitation events occurred 8/5, 9/8-9/9, and 10/11 where the Wet Flag was manually set to Yes; precipitation was recorded by the Colgate RAWS. Setting the Wet Flag has a substantial effect on ERC values and should be used judiciously; the affirmative Wet Flag values as previously specified were overridden. As can be seen on the ERC graph using the edited Wet Flag settings (Figure 8), the ERC values did indeed show a response after the rain events when the ERC temporarily decreased and then recovered.

The Round Mountain weather station dataset included invalid records for current precipitation, wind speed, and temperature. All the invalid records were rejected. Round Mountain also reported questionable gust speeds that were ignored as this data will not be used. As Round Mountain RAWS data will be used for wind speed and wind direction, the remainder of the weather records was not checked for accuracy as they will not be used.

The 18 Fire did not consume near as many acres as the B & B Complex, but it occurred the same year and therefore warrants an evaluation to compare conditions with those during the B & B Complex. The 18 Fire started in late July and therefore better represents weather and fuel conditions during the beginning of the height of the fire season. The Lava Butte RAWS is located just 3 mi west of the fire and station records are reasonably consistent with weather observations recorded on the ICS-209 (Table 3). The Lava Butte RAWS has a problematic record history as numerous years have an official daily observation time of 1200 and 1300. This fire occurred in ponderosa pine with a bitterbrush understory rather than lodgepole pine, the species of interest.

Weather and Fuel Moisture Inputs

In order to perform point fire behavior analyses in a system such as BehavePlus, a variety of inputs including weather parameters and fuel moisture values are needed depending on the requested outputs. Common weather parameters used include temperature and wind. Fuel moisture values represent foliar moisture content, live herbaceous, and live woody; in addition, dead fuel moisture values correspond to diameter classes represented by 1-, 10-, and 100-hr timelag fuels. Fine dead fuel moisture is calculated from temperature and relative humidity as well as aspect and fuel shading. The fine dead fuel moisture calculated value can be used to represent the 1-hr fuel moisture.

To establish a baseline for fire season weather, mean values were calculated based on various ranges (Table 9). Only large fire growth days were included in the mean calculation (Table 1), including: (1) Davis Fire, 6/28 – 6/30; (2) Link Fire, 7/6, 7/10; (3) 18 Fire, 7/23 – 7/24; (4) B & B Complex, 8/19 – 8/22, 8/24, 9/3 – 9/4. As can be seen in Table 9, 2003 was warmer and drier regardless of the analysis filter used. The weather observed during large fire growth days was fairly consistent for all fires with the exception of the 18 Fire which was noticeably warmer and drier. Weather observations as recorded in Table 9 for the B & B Complex will be used for point fire behavior analyses. Consistent weather trends surface by evaluating average fire season weather, weather during the height of the fire season, and weather during large growth days during a busy fire year (Table 9). Temperature was above average, relative humidity was below average, and nighttime humidity recovery (max RH in Table 9) was fairly low.

Table 9. Mean values for 1991 – 2011, 2003, and large fire growth days in 2003

Time Range	Max Temp (°F)	Min Temp (°F)	Min RH (%)	Max RH (%)
5/1 – 10/31, 1991-2011	78	38	22	90
5/1 – 10/31, 2003	82	41	18	77
6/15 – 9/15, 1991-2011	85	41	19	87
6/15 – 9/15, 2003	88	43	15	72
Davis Fire	93	47	14	64
Link Fire	91	44	13	75
18 Fire	103	52	9	64
B & B Complex	94	45	12	67

Daytime wind speeds observed at Round Mountain RAWS average 6 to 7 mph regardless of whether the time range is defined as 5/1 – 10/31 or 6/15 – 9/15. The Round Mountain RAWS had an observed 20-ft wind speed of 12 mph on 8/19/2003, the day the Bear Butte and Booth Fires started. This speed was often observed on the B & B Complex (Table 1) and corresponds to a midflame wind speed ranging from 1 mph (wind adjustment factor of 0.1) to 7.2 mph (wind adjustment factor of 0.6). The Davis Fire and Link Fire had fairly consistent afternoon winds ranging from 10 to 20 mph (6/28 – 7/1) and 10 to 25 mph (7/6 – 7/11), respectively, based on the Round Mountain RAWS. Wind speeds were markedly lower during the 18 Fire based on observations from the Lava Butte RAWS at less than 10 mph during the burning period from 7/23 – 7/25. The 18 Fire would have had extremely aggressive initial attack and subsequent suppression actions due to the proximity to Bend. This fire also mostly burned in ponderosa pine while the B & B and Davis Fires burned in mixed conifer with a component of dead lodgepole.

Although live fuel moisture values are available in FireFamilyPlus, it is suggested to verify the values with other sources as the live fuel moisture calculations are inherently the weakest model in the system. One of the sources that provides valuable information is the National Fuel Moisture Database (refer to http://72.32.186.224/nfmd/public/index.php). Although live fuel moistures are not available in the database prior to 2008, this data can still help inform live fuel moisture values. Antelope bitterbrush collected at the Colgate RAWS ranges from a minimum value of 88% and maximum of 152% for July and August. Greenleaf manzanita ranges from 94 to 181%. Tumalo Ridge, located at 4000 ft, shows fuel moisture for antelope bitterbrush ranging from 81% to 148%, 101 to 174% for ceanothus, and 88 to 167% in greenleaf manzanita in July and August.

Another source of information is the Wildland Fire Assessment System (refer to http://www.wfas.net/). The Keetch-Byram Drought Index (KBDI) is a value quantifying cumulative moisture deficiency in deep duff and upper soil layers. KBDI values for mid-August of 2003 display values ranging mostly between 501 to 600 although there are some pockets identified with KBDI values <500 or >700. At these levels the litter and duff layers are expected to burn actively and spotting is predicted with KBDI >600.

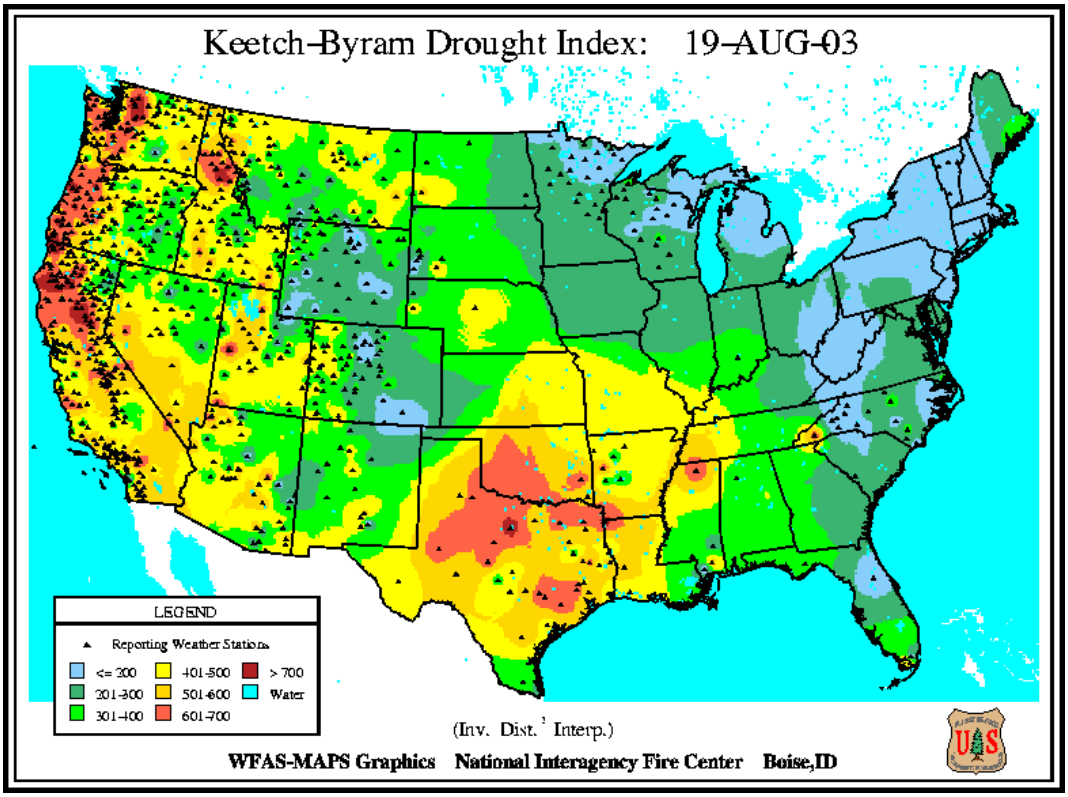


Figure 9. KBDI values in August, 2003

The Palmer Z Index is a metric provided by the NOAA National Climatic Data Center (refer to http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html for information and http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers.php for historical data). The Palmer Z provides a means to evaluate short-term drought based on how the monthly cumulative

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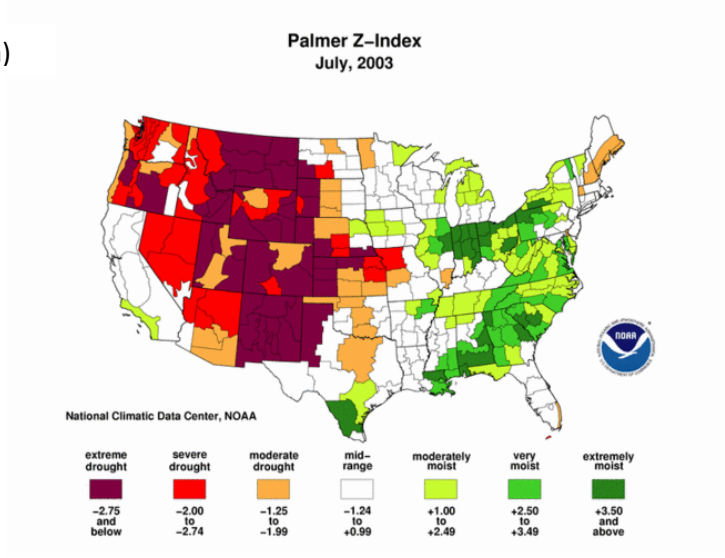

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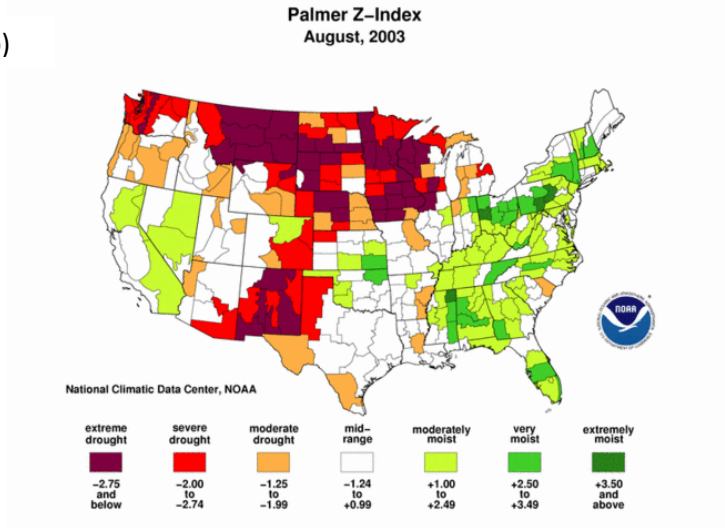

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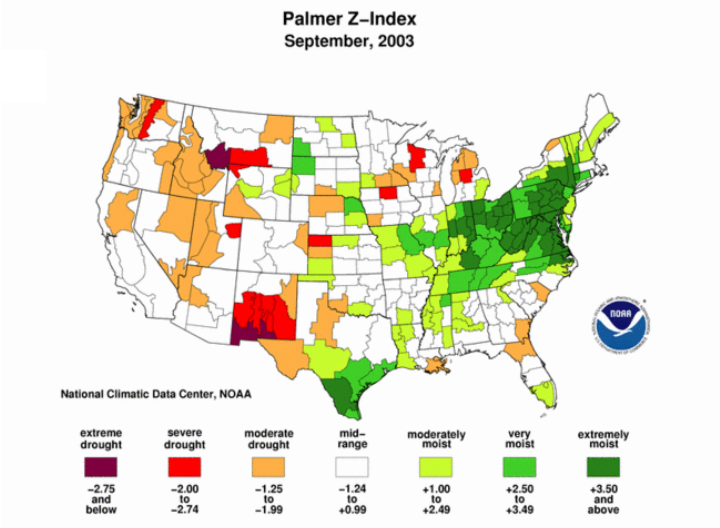
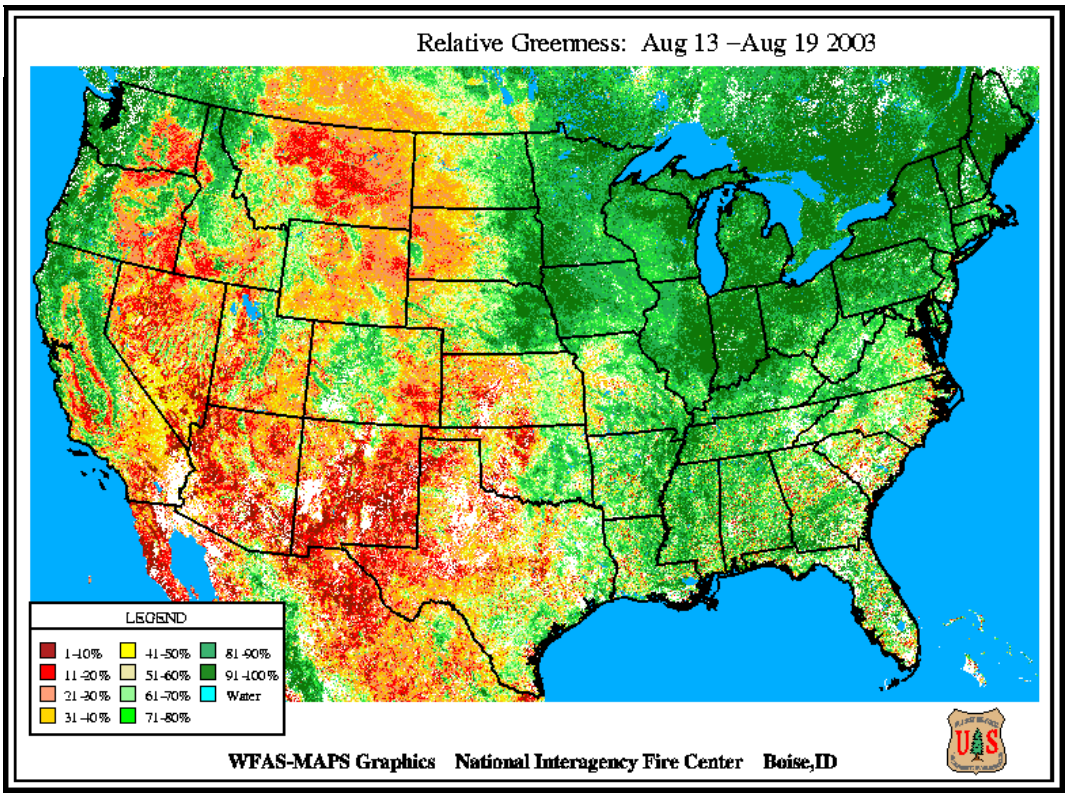


Figure 10. Palmer Z Indices for a) July, 2003, b) August, 2003, and c) September, 2003

a)



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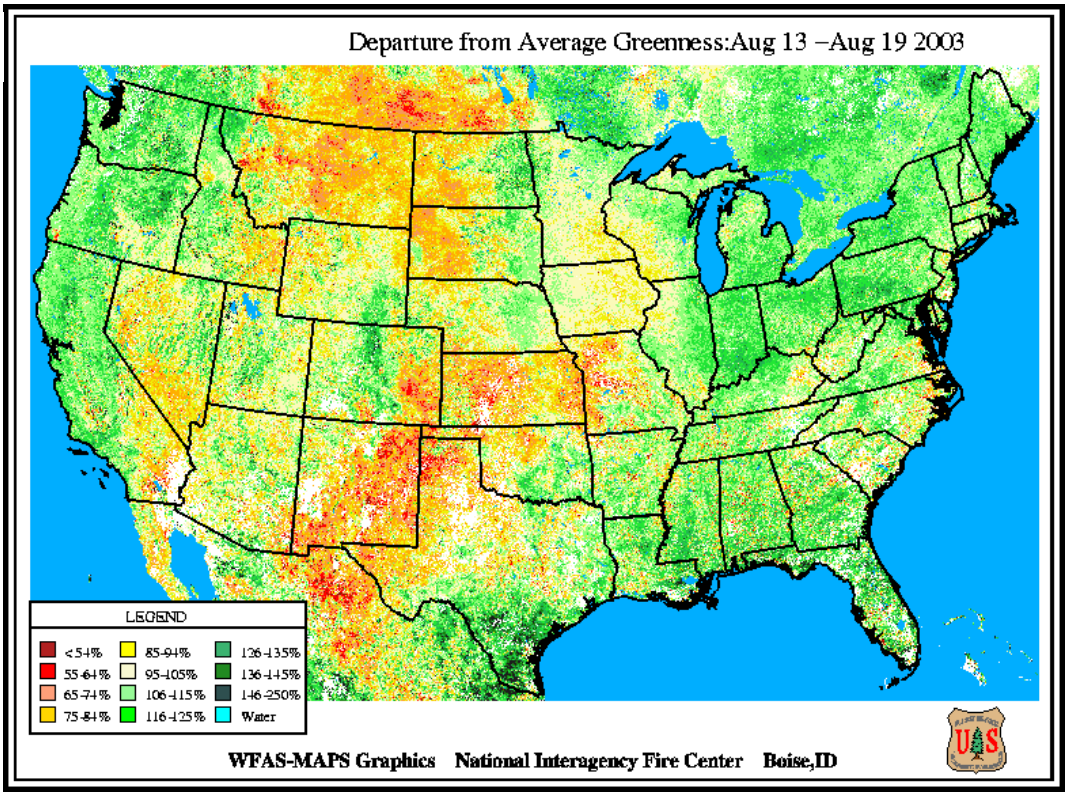


Figure 11. Maps depicting a) relative greenness and b) departure from average greenness

precipitation deviates from normal. While central Oregon was plagued by a significant drought in July of 2003, moisture conditions improved through the summer and were considered neutral by September (Figure 10). However, the short-term drought signals that live moisture values were probably below normal which allowed for substantial fire activity in July and August.

Relative greenness maps compare current to historical greenness conditions. The relative greenness maps for central Oregon in 2003 generally show values >80 percent with some pockets ranging from 70 to 80% (Figure 11a). Departure from average greenness in this area is greater than 100% (Figure 11b). This value compares how green each pixel is compared to its average greenness for that week of the year. Observed 100-hr fuel moisture values range between 6 and 10% (Figure 12).

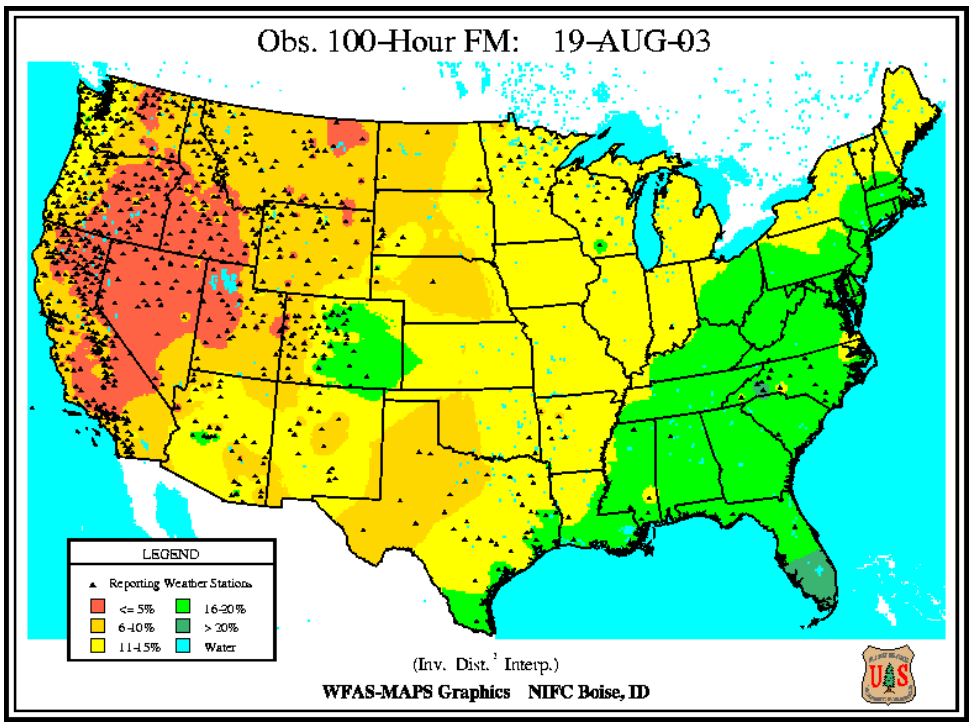


Figure 12. Observed 100-hr fuel moisture values

The values in Table 10, specifically the live herbaceous and live woody fuel moisture values, correspond to mid-August when the Bear Butte and Booth Fires started. Live herbaceous fuel moisture of 50% corresponds to herbaceous fuels that are roughly 75% cured whereas live herbaceous moisture of 70% represents fuels that are about 55-60% cured. Two scenarios are presented, a moderate scenario representing an average fire season in August as defined by temperature, relative humidity, and live and dead fuel moisture values. A dry scenario is also presented that defines more of a worst-case scenario in August in terms of temperature, relative humidity, and live and dead fuel moisture values. Two wind speeds will be used per analysis scenario to be able to evaluate predicted fire behavior based on the influence of weather versus wind.

Table 10. Values and corresponding percentile (based on Colgate weather records from 1991 to 2011 and Round Mountain wind records from 1997 to 2011 for 5/1 – 10/31) for two weather scenarios

Weather Parameter	Dry Scenario		Moderate Scenario	
	Value	Percentile	Value	Percentile
Max Temp	94° F	93	88° F	80
Min RH	12%	11	21%	45
Wind Speed	7 mph	65	7 mph	65
	15 mph	98	15 mph	98
1-hr fuel moisture	2%	3	3%	20
10-hr fuel moisture	3%	2	5%	29
100-hr fuel moisture	7%	2	9%	13
Live herbaceous moisture	50%	-	70%	-
Live woody moisture	80%	-	90%	-

Geospatial fire behavior analyses require wind and weather information. In order to prepare files as required by systems such as FARSITE or FlamMap, hourly wind data and daily weather data can be exported in FireFamilyPlus using the FARSITE Exports function in Weather > Hourly Data Analysis. These files were prepared and named RoundMtnRAWS2003.wnd (wind file) and ColgateRAWS2003.wtr (weather file).

Fremont-Winema National Forest

The FRF had an active year in 2002 when the Toolbox Complex and Winter Fires occurred (Figure 13).

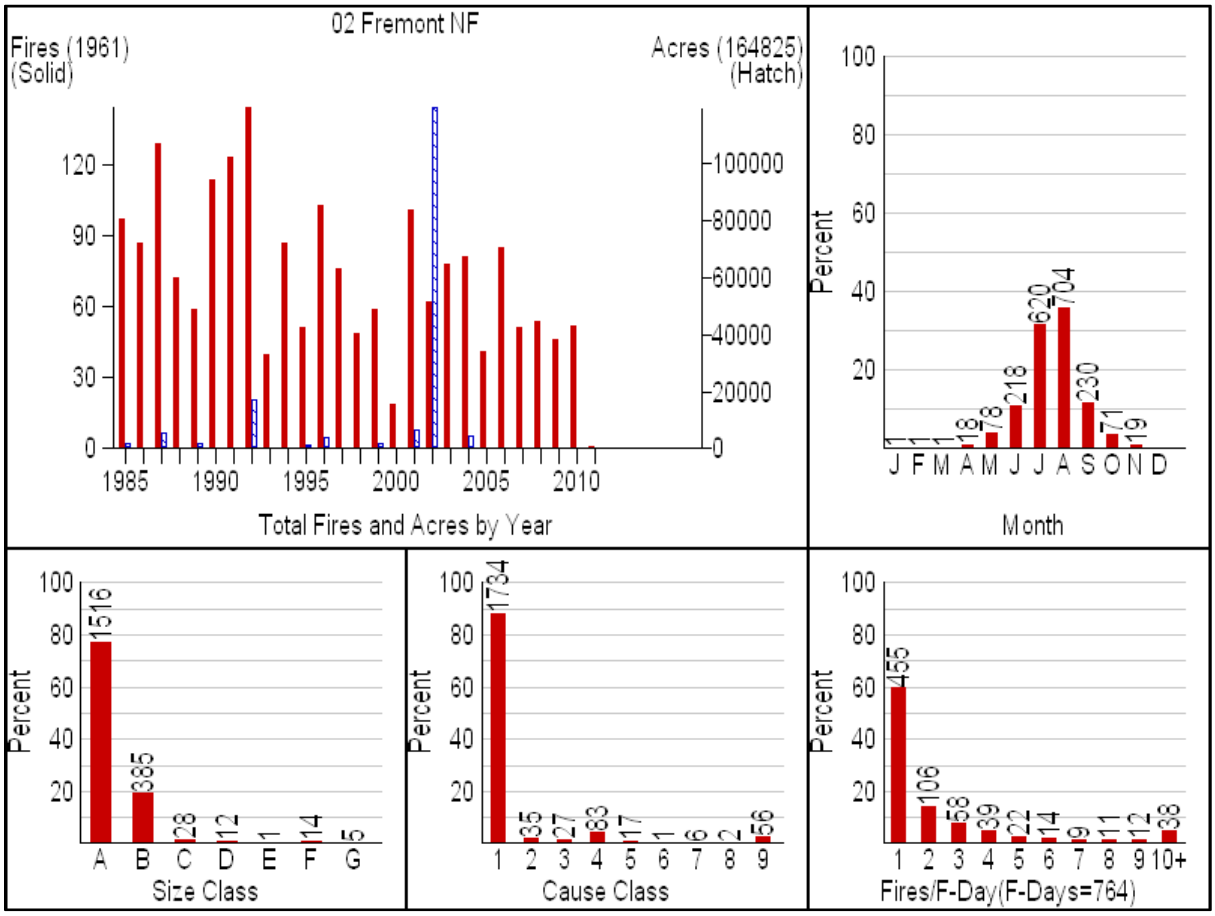


Figure 13. Fire occurrence on the FRF from 1985 to 2011

Winter Fire

The Winter Fire occurred about 10 miles north of Paisley, Oregon and started on 7/12/2002 (Table 11). Elevation on the fire ranged from 4150 to 7100 ft within the main fire area. This fire burned in mixed conifer, ceanothus, and sagebrush.

Table 11. Acres and critical fire behavior as reported in the ICS-209 reports for the Winter Fire

Date and Time	Cumulative Acreage	Comments
7/14/02 2320	1,000 ac	Torching, burning across and down slope 90 degrees, 20% RH, wind 5-15 mph
7/16/02 1700	21,000 ac	Torching, short crown runs 90 degrees, 15% RH, wind 10-15 mph
7/17/02 1700	26,000 ac	Torching and spotting in timber 80 degrees, 19% RH, SW wind 12-16 mph
TOTAL	**35,779 ac**	

Toolbox Complex

The Toolbox Fire and Silver Fire started on 7/12/2002 approximately 12 mi south of Silver Lake, Oregon (Table 12). The Lava Fire started on 7/13/2002 about 15 miles north/northwest of Christmas Valley, Oregon. It was not actively managed until 8/18 but was continually monitored. Elevation ranged from 4350 to 6750 ft on the Toolbox Fire. The Silver Fire ranged in elevation from 4500 to 5700 ft. The Toolbox Complex burned in heavy timber and various other fuel types.

Table 12. Acres and critical fire behavior as reported in the ICS-209 reports for the Toolbox Complex

Date and Time	Cumulative Acreage	Comments
7/15/02 0025	7,355 ac	Burned approximately 1500 ac today 53 degrees, 60% RH, SW/W wind 2-6 mph
7/15/02 0800	9,800 ac	Inversion lifts approximately 1100 63 degrees, 48% RH, W wind 0-3 mph
7/16/02 1025	12,360 ac	Spotting up to 0.5 mi 75 degrees, 60% RH, SW wind 0-2 mph
7/17/02 1700	Total – 24,500 ac	Includes acreage from Toolbox and Silver Fires 87 degrees, 16% RH, S wind 5-15 mph
7/18/02 0900	Total – 31,800 ac	Spotting Gusty winds 54 degrees, 54% RH, S/SW wind 0-2 mph
7/19/02 1700	Total – 52,660 ac Toolbox – 38,400 ac Silver – 14,260 ac	Burning intensities high with high fuel accumulations 83 degrees, 23% RH, W/NW wind 7-10 mph
7/21/02 1700	Total – 59,160 ac Toolbox – 41,547 ac Silver – 15,813 ac Winter – 1,800 ac	Toolbox has merged with Winter Fire Southern portion of Toolbox had active burning 82 degrees, 22% RH, SW wind 1-3 mph
7/23/02 1700	Total – 74,824 ac Toolbox – 52,448 ac Silver – 21,776 ac Lava – 1,600 ac	Toolbox active on N and S Toolbox acres include a portion of the Winter Fire Lava Fire in WSA and is being monitored 64 degrees, 80% RH, S/SW wind 3-5 mph
7/25/02 1700	Total – 81,508 ac Toolbox – 56,400 ac Silver – 23,508 ac Lava – 1,600 ac	Torching and spotting last night 0800 weather: 60 degrees, 45% RH, NE wind 1-4 mph
TOTAL	**Toolbox – 54,800 ac** **Silver – 24,565 ac** **Lava – 2,680 ac**	

The WNF has had fewer acres burn since 1985 than the DEF and FRF (Figure 14). The Lone Pine Fire occurred in 1992 and burned almost 31,000 ac. The Skunk Fire burned about 2,500 ac in 2002; this fire can certainly be defined as a large fire by WNF historical standards.

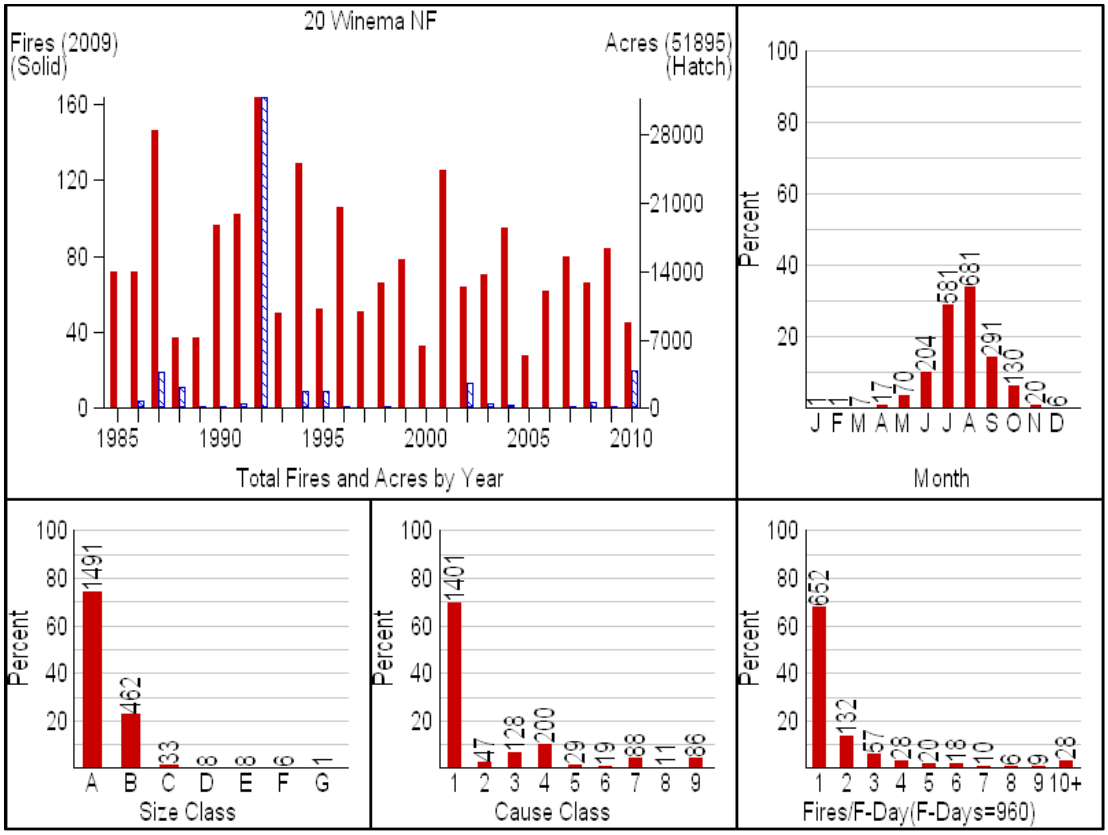


Figure 14. Fire occurrence on the WNF from 1985 to 2011

Weather

Weather data including the daily observation and weather station catalog information was downloaded from FAMWEB as fw9 files to be imported into FireFamilyPlus. Usually representing 1300 weather, these observations are the official record and include manual corrections to fix errors within the data. Additional weather information was downloaded for multiple weather stations from the Western Regional Climate Center (http://www.raws.dri.edu/) for analyses in FireFamilyPlus. The WRCC data includes hourly observations from weather stations that have not been corrected. Hoyt Creek, Calimus, Strawberry, and Chiloquin RAWS are located on or adjacent to the FRF-WNF (Figure 16). FireFamilyPlus was used to analyze the data to identify anomalous data, determine critical weather thresholds affecting fire growth and fire behavior, and prepare wind and weather files for geospatial fire analyses.

Table 13. Acres burned per month from 2001 to 2008

Month	Acres Burned
June	442
July	182,379
August	8,634
October	133
Total	**191,588**

The greatest number of fires occurs in August (Figures 13 and 14) and the greatest number of acres has historically burned in July (Table 13). The Toolbox Complex, Winter Fire, and Skunk Fire are some of the largest fires in recent history on the FRF-WNF and all started in mid-July in 2002. The Toolbox Fire, Winter Fire, and Silver Fire are adjacent to each other and therefore have similarities in vegetation types and fuels conditions (Figure 15); all three fires also had numerous days when the fire exhibited large growth and therefore represents weather and fuels conditions suitable for large fire growth to occur.

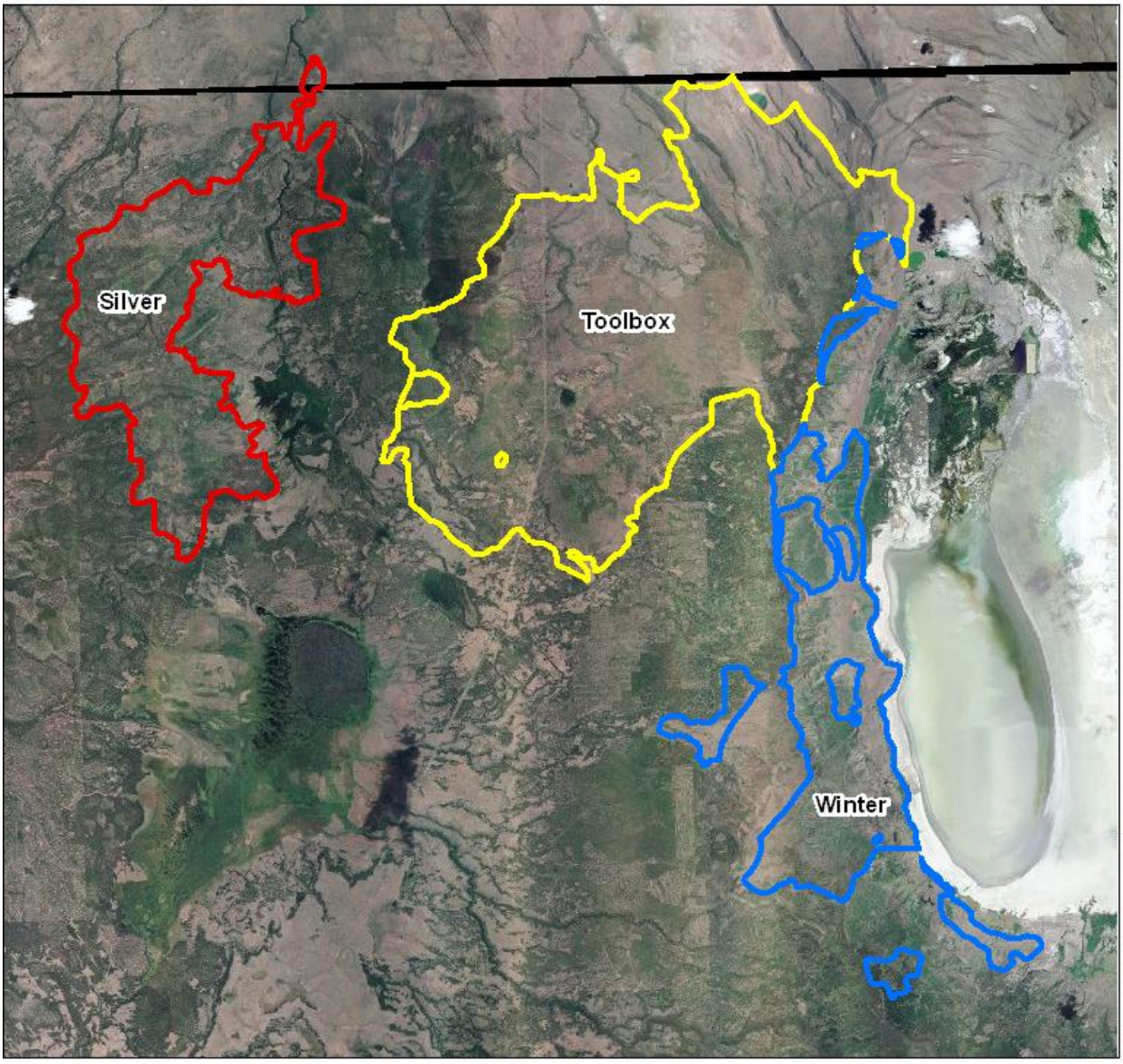


Figure 15. Final perimeters for the Silver Fire, Toolbox Fire, and Winter Fire

A number of weather stations were examined in conjunction with the Toolbox Fire, Winter Fire, and Silver Fire (Figure 15). After identifying the possible weather station candidates that have hourly weather data available for July 1 – September 1, 2002 (Figure 16), it was determined that the Hoyt Creek RAWS has the most representative wind speed, wind direction (Figure 17), temperature (Figure 18), and relative humidity (Figure 19) when compared to the current weather documented in the daily ICS-209 reports. Hoyt Creek is approximately 12 aerial miles from the Silver Fire, 20 miles from the Toolbox Fire, and 30 miles from the Winter Fire (Table 14). While the wind speed values measured at Hoyt Creek are consistently lower than those reported in the ICS-209, it is difficult to know whether the ICS-209 reports are reporting gust or average wind speed. Strawberry is completely devoid of wind speed values for the month of July, 2002 indicating a sensor was most likely malfunctioning. Cabin Lake's predominant wind

direction from 1600 to 1900 and 0800 to 2300 is northwest, which isn't consistent with ICS-209 observations. The winds at the Calimus RAWS from 1600 to 1900 are consistently west and north/northwest but the wind speeds tend to be much higher every afternoon than the Hoyt Creek weather station. Chiloquin was not evaluated due to the distance from the analysis fires.

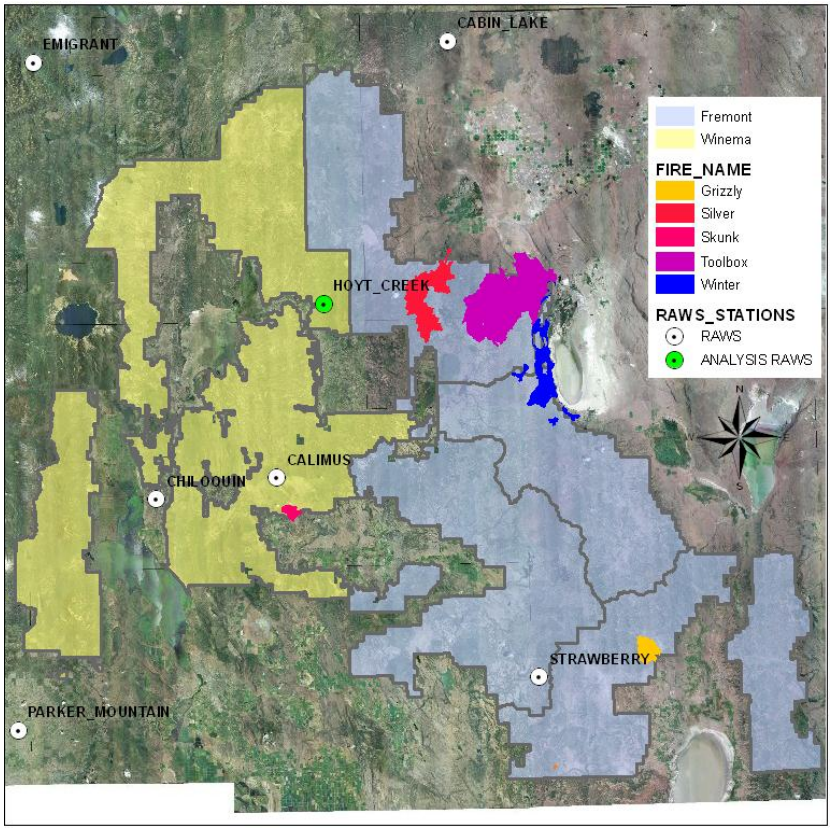


Figure 16. Locations of recent large fires and important weather stations on the Fremont-Winema NF

Table 14. Hoyt Creek location information

RAWS Name (WIMS ID)	Elevation	Location
Hoyt Creek (353343) 	5445 ft	• Plateau/bench • Ponderosa pine with sagebrush/bitterbrush/grass understory • 1990-2011 data used

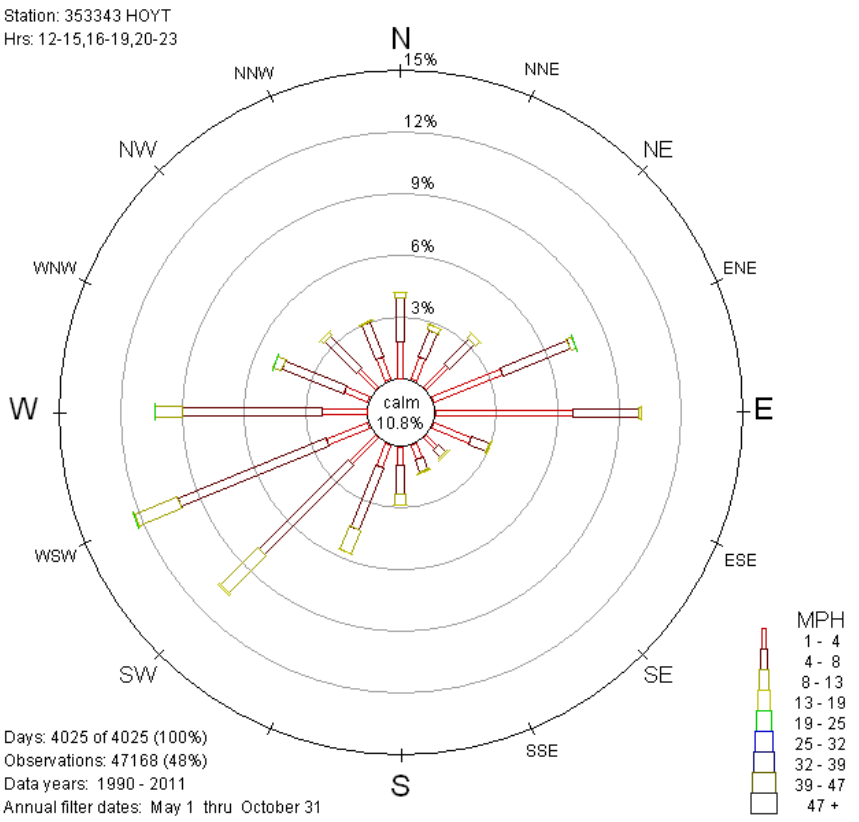


Figure 17. Windrose for the Hoyt Creek RAWS for 1200-2300 for May 1 through October 31

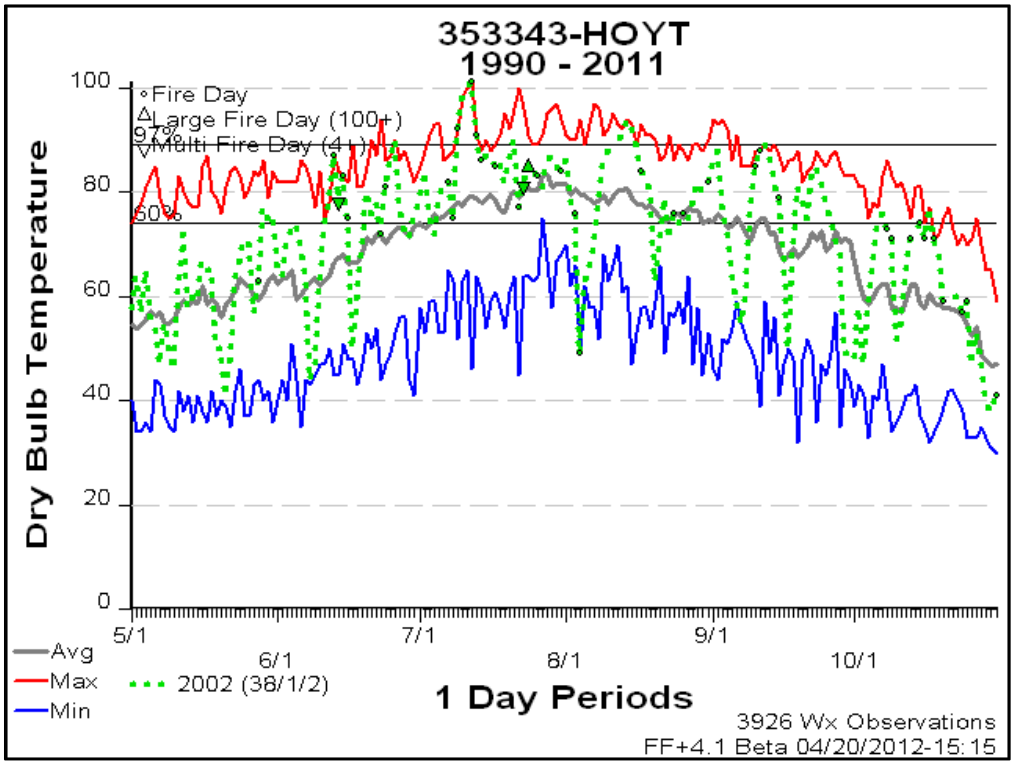


Figure 18. Hoyt Creek RAWS record for temperature from May 1- October 31, 1990 to 2011 with 2002 overlay

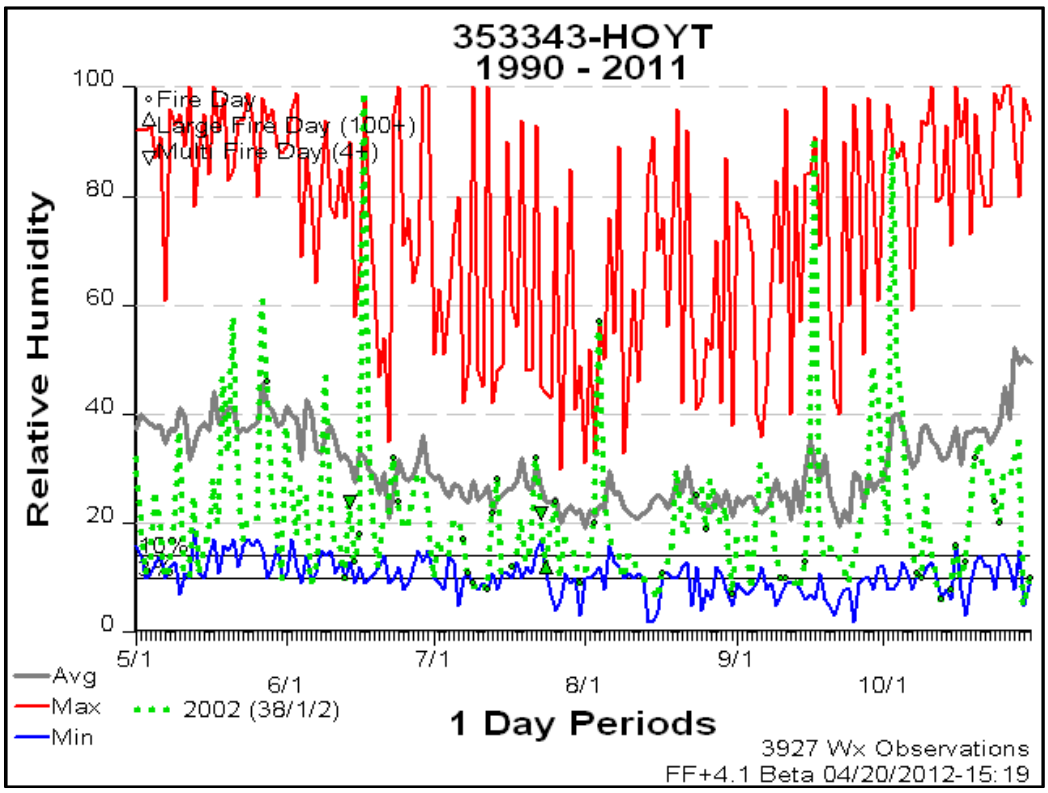


Figure 19. Hoyt Creek RAWS record for relative humidity from May 1- October 31, 1990 to 2011 with 2002 overlay

Figure 20 displays the Burning Index (BI) statistical graph for the Hoyt Creek RAWS and Figure 21 shows the Energy Release Component (ERC – fuel model G) statistical graph for the Hoyt Creek RAWS for fuel model G. The BI estimates the potential difficulty of fire containment as it relates to flame length at the head of a fire. The ERC describes the worst case total energy released per unit area within the flaming zone of a fire. It is a dimensionless number and is a simple estimate of seasonal drought and therefore the availability of fuels to burn. In laymen's terms, the ERC tracks seasonal drought while the BI factors in the influence of wind. Both the BI and ERC indices were above average for much of the 2002 summer, with dips following precipitation events.

Weather conditions documented in the ICS-209 reports were compared to weather recorded at the Hoyt Creek RAWS. Generally, it appears that the RAWS values track reasonably well with values in the ICS-209 (Table 15). It is difficult to know whether the weather listed in the ICS-209 reports depicts actual fire weather observations or a spot weather forecast that may or may not accurately reflect actual weather.

Anomalies in the WRCC weather data were discovered using the View Observations and Climatology functions in FireFamilyPlus. These records were compared to other data sources such as the Weather Information Management System (WIMS). If the WRCC data were consistent with WIMS records they were retained as this indicated these values were mostly likely accurate but deviate from the average; otherwise the anomalous WRCC records were compared to previous and subsequent day's hourly

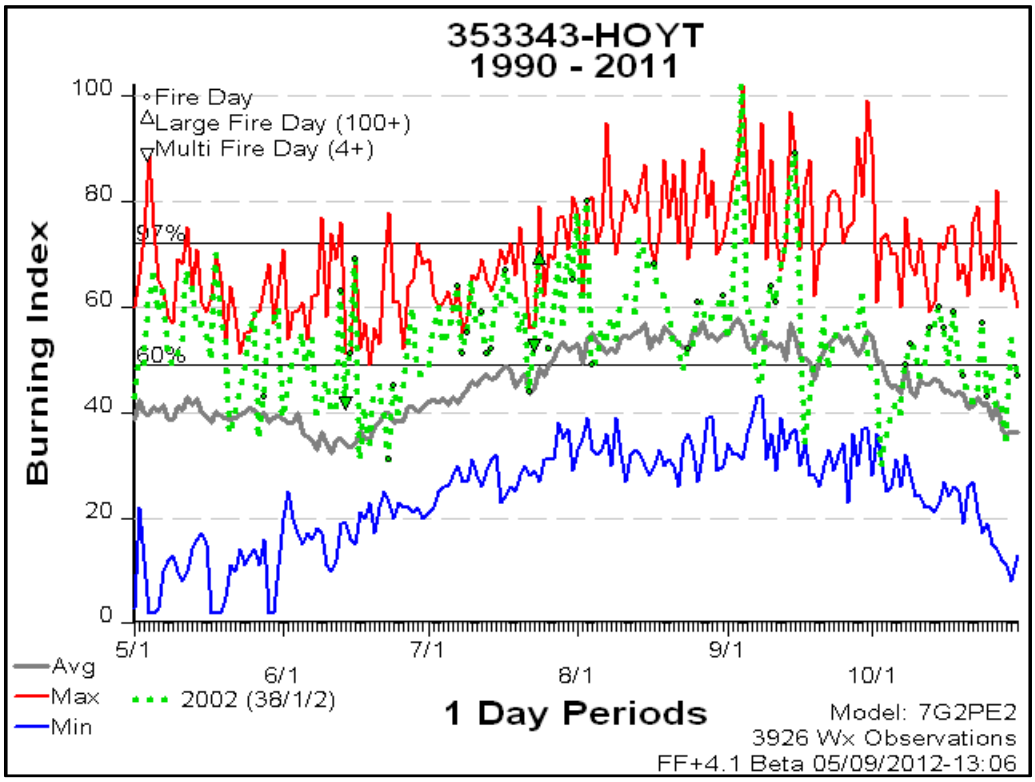


Figure 20. Burning Index for Hoyt Creek RAWS May 1 – October 31, 1990 to 2011 with 2002 overlay

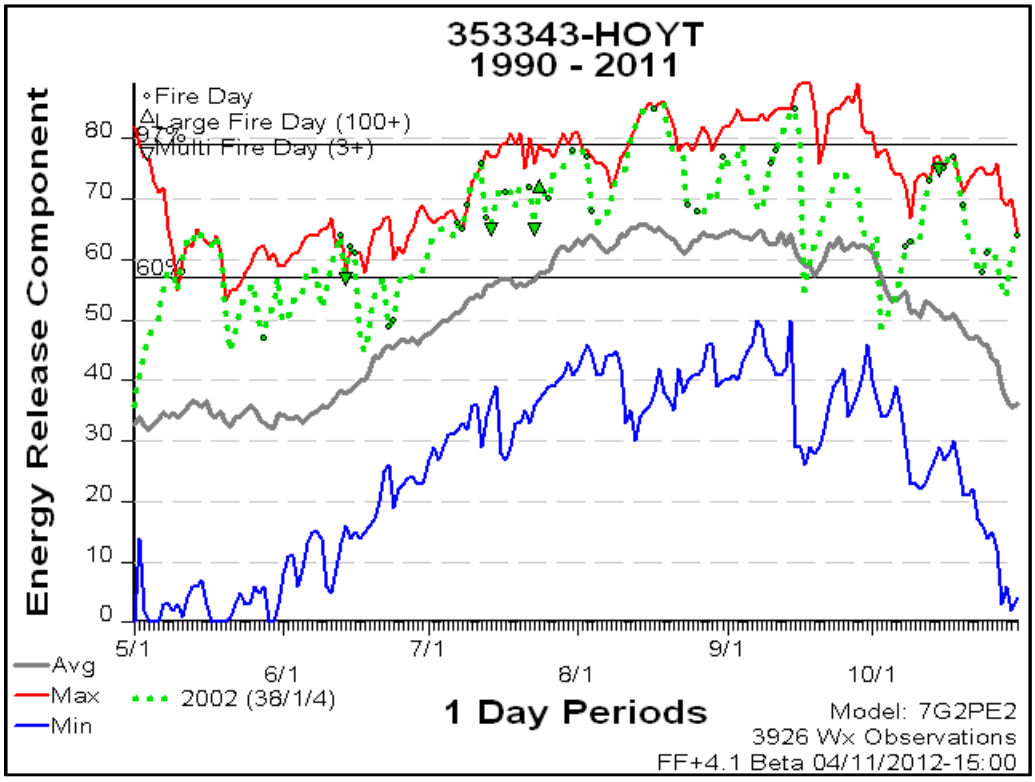


Figure 21. Energy Release Component for Hoyt Creek RAWS May 1 – October 31, 1990 to 2011 with 2002 overlay

records in FireFamilyPlus to ensure the values in question were consistent with the trend. Obvious errors in the weather data were discovered using FireFamilyPlus functions previously described in addition to the error logs produced while importing weather station data in FireFamilyPlus. Erroneous records were fixed in the FireFamilyPlus database. The Hoyt Creek error log lists numerous invalid temperature, current precipitation, fuel moisture, and gust speed records. All the invalid records were rejected; the suspicious gust speeds were ignored as this data will not be used.

Table 15. Comparison between weather observations recorded in the ICS-209 reports and RAWS station selected for analysis, based on a burning period from 1100-1800

Date	Source	Temp	RH	Wind
7/14/02	ICS-209	90°	20%	5-15 mph
	RAWS	82-87°	22-32%	SW 4-8 mph
7/15/02	ICS-209	63° (0800)	48% (0800)	W 0-3 mph
	RAWS	69° (0800) 82-88°	51% (0800) 11-17%	W 0-1 mph (0800) S→SW 4-7 mph
7/16/02	ICS-209	90°	15%	10-15 mph
	RAWS	78-88°	11-27%	SW/W 3-7 mph
7/17/02	ICS-209	80-87°	16-19%	S/SW 5-16 mph
	RAWS	79-87°	6-20%	SW 4-9 mph
7/18/02	ICS-209	54° (0900)	54% (0900)	S/SW 0-2 mph
	RAWS	74° (0900) 77-88°	39% (0900) 9-22%	SW 3 mph SW 5-6 mph
7/19/02	ICS-209	83°	23%	W/NW 7-10 mph
	RAWS	78-86°	11-29%	W/SW 4-6 mph
7/21/02	ICS-209	82°	22%	SW 1-3 mph
	RAWS	85-92°	13-18%	W/SW 4-7 mph
7/23/02	ICS-209	64°	80%	S/SW 3-5 mph
	RAWS	76-87°	11-39%	SW 2-7 mph
7/25/02	ICS-209	60° (0800)	45% (0800)	NE 1-4 mph
	RAWS	68° (0800) 75-86°	36% (0800) 19-27%	SW 0-3 mph (0800) SW/W 2-8 mph

Weather and Fuel Moisture Inputs

In order to perform point fire behavior analyses in a system such as BehavePlus, a variety of inputs including weather parameters and fuel moisture values are needed depending on the requested outputs. Common weather parameters used include temperature and wind. Fuel moisture values represent foliar moisture content, live herbaceous, and live woody; in addition, dead fuel moisture values correspond to diameter classes represented by 1-, 10-, and 100-hr timelag fuels. Fine dead fuel moisture is calculated from temperature and relative humidity as well as aspect and fuel shading. The fine dead fuel moisture calculated value can be used to represent the 1-hr fuel moisture.

To establish a baseline for fire season weather, mean values were calculated based on various ranges (Table 16). Only large fire growth days were included in the mean calculation (Tables 11 and 12), including: (1) Winter Fire, 7/12 – 7/17 and (2) Toolbox Complex 7/12 – 7/25. As can be seen in Table 16, 2002 was warmer and drier regardless of the analysis filter used. Weather observations as recorded in

Table 16 for the Winter Fire and Toolbox Complex will be used for point fire behavior analyses; although a maximum temperature of 90° will be used as referenced in the ICS-209 Winter Fire weather data. Consistent weather trends surface by evaluating average fire season weather, weather during the height of the fire season, and weather during large growth days during a busy fire year (Table 16). Temperature was above average and relative humidity was below average.

Table 16. Mean values for 1990 – 2011, 2002, and large fire growth days in 2002 from RAWS data

Time Range	Max Temp (°F)	Min Temp (°F)	Min RH (%)	Max RH (%)
5/1 – 10/31, 1990-2011	75	40	20	82
5/1 – 10/31, 2002	77	39	14	71
6/15 – 9/15, 1990-2011	81	44	18	77
6/15 – 9/15, 2002	85	44	12	66
Winter Fire	88	51	11	81
Toolbox Complex	88	49	11	78

Daytime wind speeds observed at Hoyt Creek RAWS average 4 to 6 mph regardless of whether the time range is defined as 5/1 – 10/31 or 6/15 – 9/15. The Hoyt Creek RAWS had an observed 20-ft wind speed ranging between 2 to 11 mph on 7/12/2002, the day the Winter Fire, Silver Fire, and Toolbox Fire started. While wind direction was consistently W/SW (Tables 11 and 12) during both the Winter Fire and Toolbox Complex with the exception of a few days, wind speed as documented in the ICS-209 database varies from day to day.

Although live fuel moisture values are available in FireFamilyPlus, it is suggested to verify the values with other sources as the live fuel moisture calculations are inherently the weakest model in the system. One of the sources that provides valuable information is the National Fuel Moisture Database (refer to http://72.32.186.224/nfmd/public/index.php). There are no sampled sites for the FRF-WNF in the database, but northern California sites may be substituted to help formulate fuel moisture values. Greenleaf manzanita averages 120 to 160% in July with low values ranging from 80 to 150%. One site, Greenhorn Yreka, offers a fuel moisture history originating in 2002 when values in mid to late-July dropped from 125 to 77% in greenleaf manzanita.

Another source of information is the Wildland Fire Assessment System (refer to http://www.wfas.net/). The Keetch-Byram Drought Index (KBDI) is a value quantifying cumulative moisture deficiency in deep duff and upper soil layers. KBDI values for mid-July of 2002 displays values ranging from 301 to 400 although there are some isolated pockets identified with KBDI values between 401 and 500 (Figure 22). These values are fairly low and indicate that the litter and duff layers are just beginning to dry enough to contribute to fire intensity. However, by the beginning of August the duff and litter layers across the region were consistently higher and contributing more to fire intensity (Figure 23).

The Palmer Z Index is a metric provided by the NOAA National Climatic Data Center (refer to http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html for information and http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers.php for historical data). The Palmer Z provides a means to evaluate short-term drought based on how the monthly cumulative

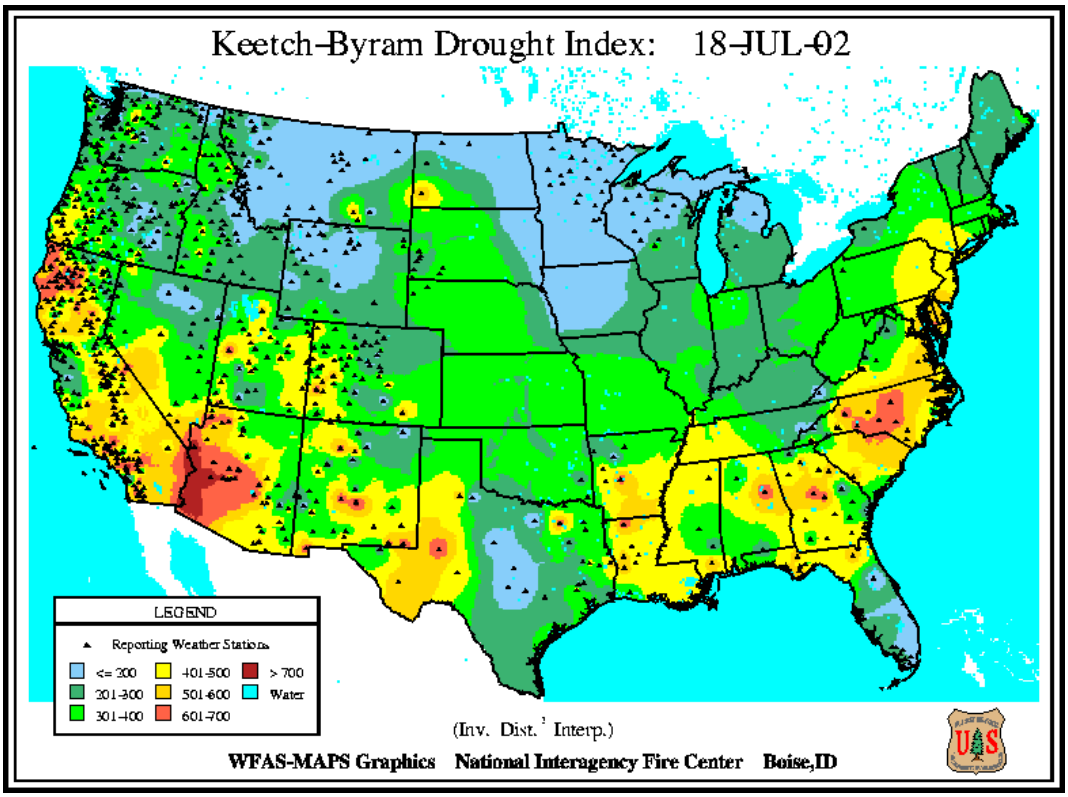


Figure 22. KBDI values in July, 2002

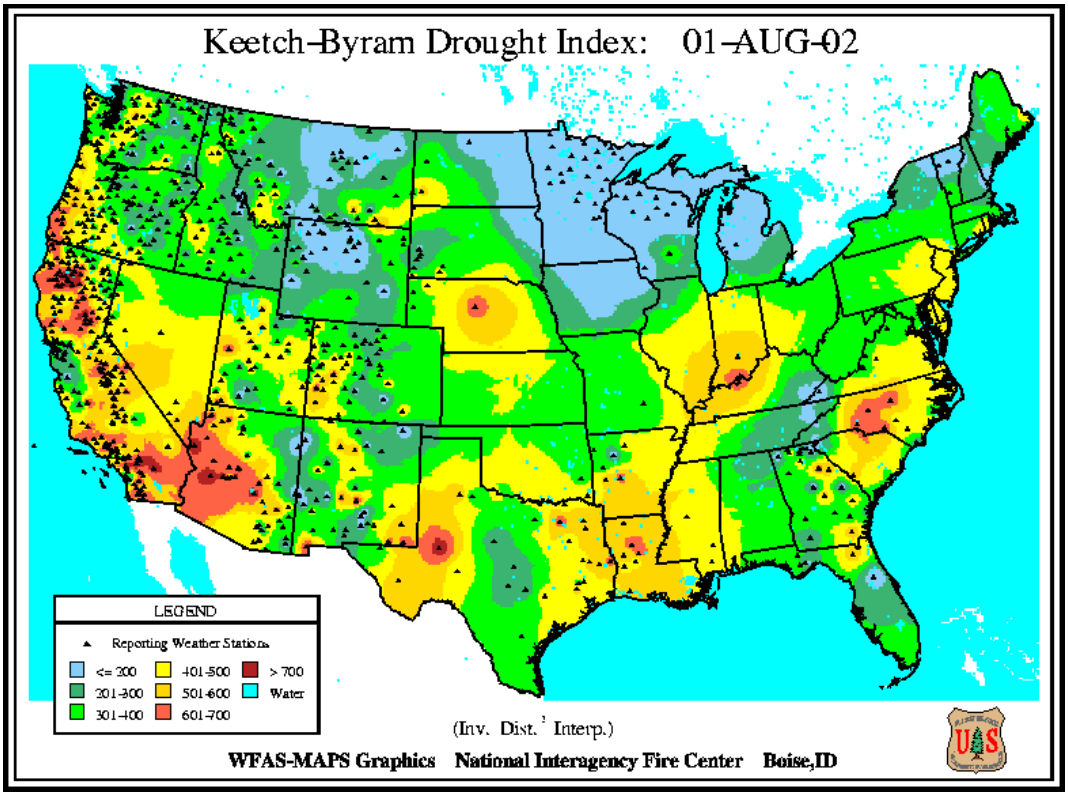
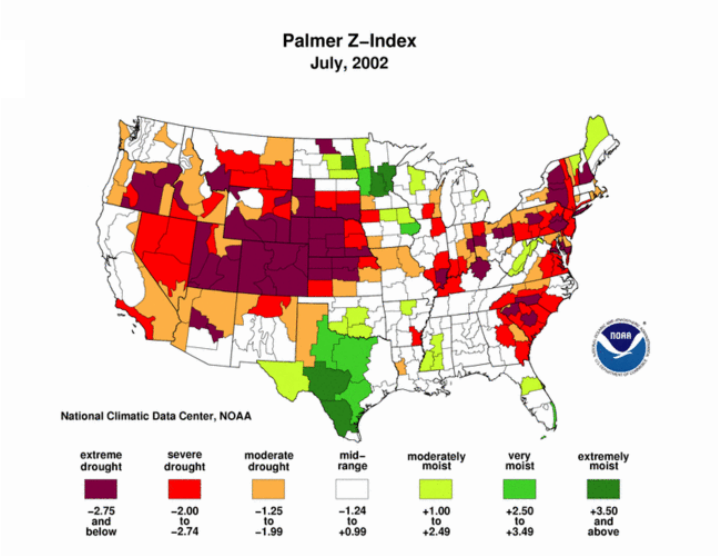
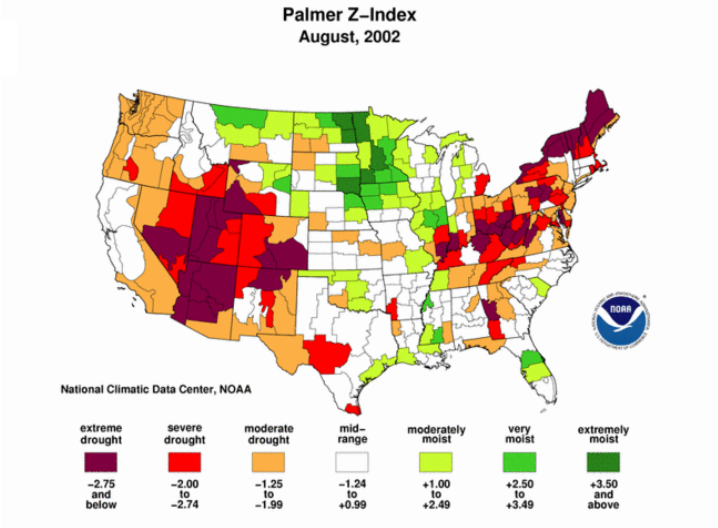


Figure 23. KBDI values in August, 2002

a)



b)



c)

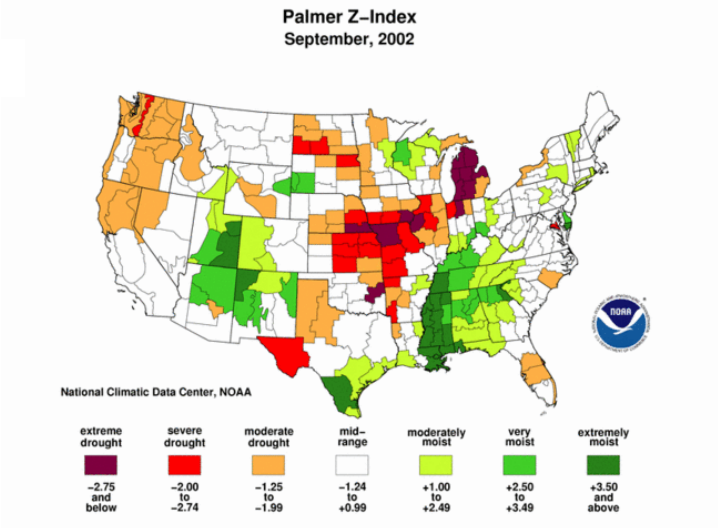


Figure 24. Palmer Z Indices for a) July, 2002, b) August, 2002, and c) September, 2002

precipitation deviates from normal. While central Oregon was plagued by a significant drought in July of 2002, moisture conditions improved through the summer and conditions were classified as a moderate drought by September (Figure 24). However, the short-term drought signals that live moisture values were probably below normal which allowed for substantial fire activity in July and August.

Relative greenness maps compare current to historical greenness conditions. The relative greenness maps for central Oregon in 2002 generally show values <40 percent with some pockets along the Cascade Range ranging from 50 to 80 percent (Figure 25). Departure from average greenness in this area is <85 percent (Figure 26). This value compares how green each pixel is compared to its average greenness for that week of the year. Observed 100-hr fuel moisture values are <10 percent (Figure 27).

Based on the Palmer Z, relative greenness, and departure from average greenness for 2002 (Figures 25, 26, and 27) and 2003 (Figures 10 and 11), the short-term drought and associated effects to vegetation was more pronounced in 2002 than 2003. While this may not affect weather inputs for fire behavior analyses, the potential ramifications to fuel moisture should be evaluated.

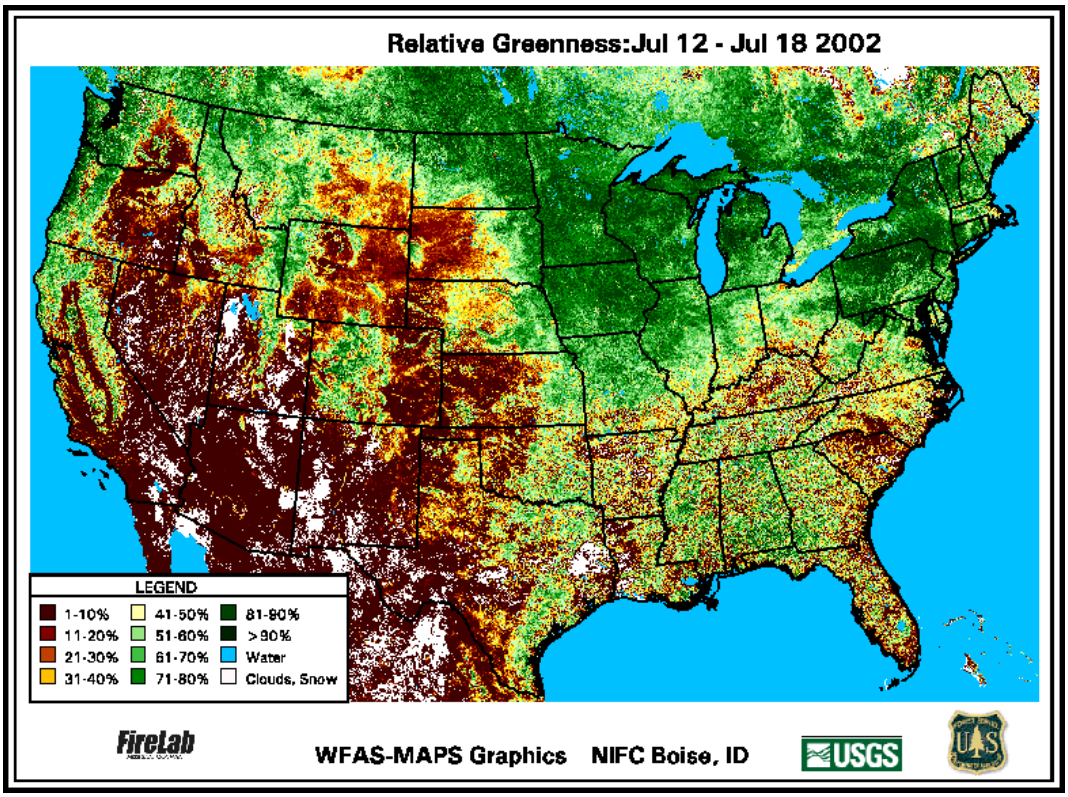


Figure 25. Map depicting relative greenness in 2002

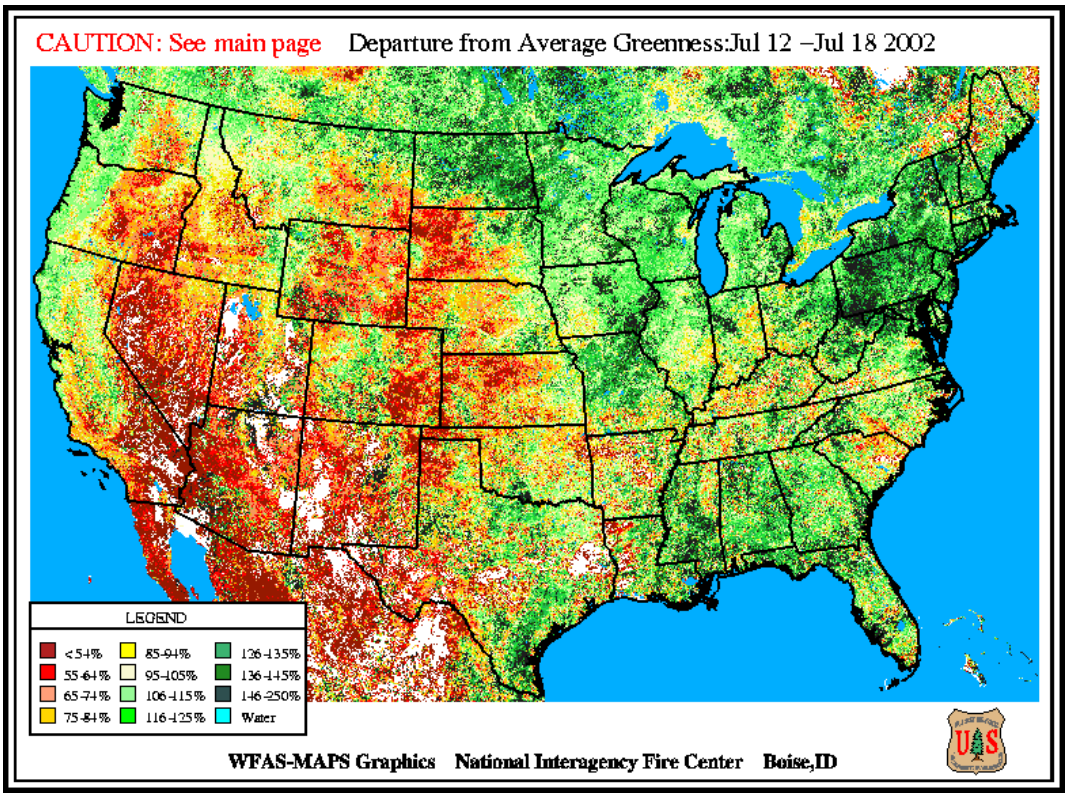


Figure 26. Map depicting departure from average greenness in 2002

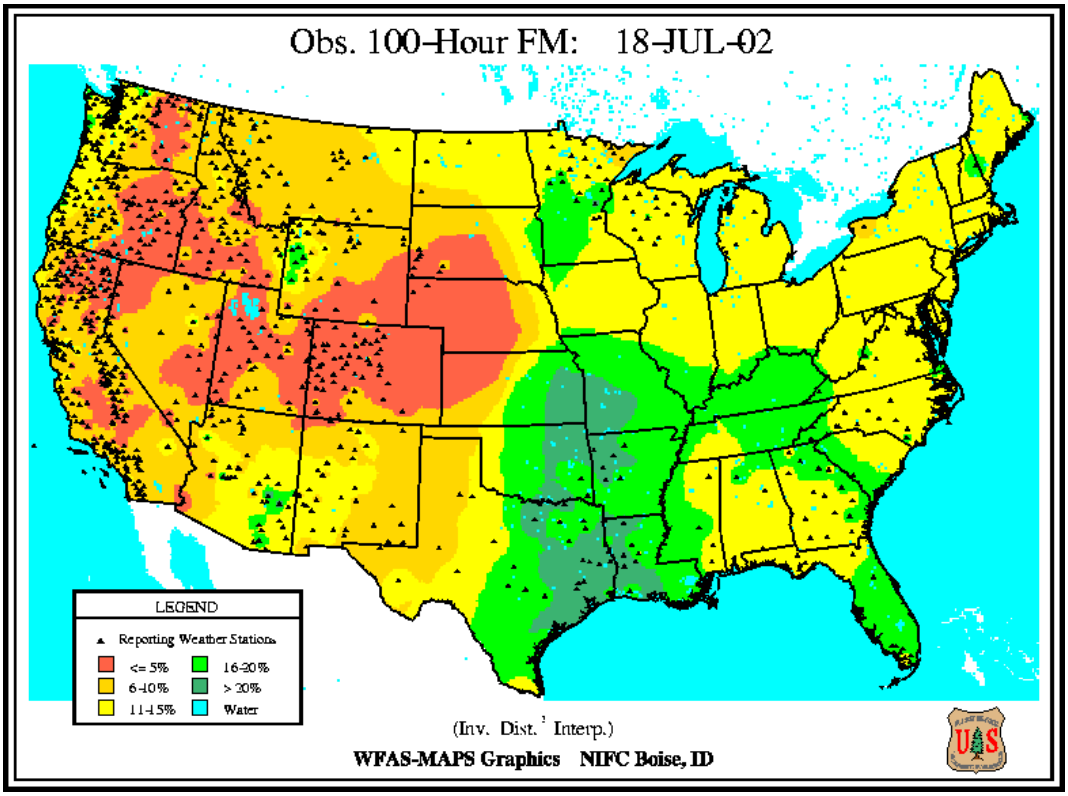


Figure 27. Observed 100-hr fuel moisture values

Table 17. Values and corresponding percentile (based on Hoyt Creek weather and wind records from 1990 to 2011) for two weather scenarios

Weather Parameter	Dry Scenario		Moderate Scenario	
	Value	Percentile	Value	Percentile
Max Temp	90° F	95	84° F	80
Min RH	11%	10	20%	13
Wind Speed	7 mph	75	7 mph	75
	15 mph	99	15 mph	99
1-hr fuel moisture	2%	5	4%	50
10-hr fuel moisture	3%	5	5%	43
100-hr fuel moisture	6%	3	9%	32
Live herbaceous moisture	60%	-	80%	-
Live woody moisture	80%	-	100%	-

The values in Table 17, specifically the live herbaceous and live woody fuel moisture values, correspond to mid to late July when the Silver, Winter, and Toolbox Fires started. Live herbaceous fuel moisture of 60% corresponds to herbaceous fuels that are roughly 66% cured whereas live herbaceous moisture of 80% represents fuels that are about 55% cured. Two scenarios are presented, a moderate scenario representing an average fire season in July as defined by temperature, relative humidity, and live and dead fuel moisture values. A dry scenario is also presented that defines more of a worst-case scenario in July in terms of temperature, relative humidity, and live and dead fuel moisture values. Two wind speeds will be used per analysis scenario to be able to evaluate predicted fire behavior based on the influence of weather versus wind.

Geospatial fire behavior analyses require wind and weather information. In order to prepare files as required by systems such as FARSITE or FlamMap, hourly wind data and daily weather data can be exported in FireFamilyPlus using the FARSITE Exports function in Weather > Hourly Data Analysis. These files were prepared and named HoytRAWS2002.wnd (wind file) and HoytRAWS2002.wtr (weather file).

Glossary

Burning period – corresponds to the length of time each day when a fire is actively spreading.

Coarse woody debris – dead wood greater than 3 inches in diameter or 1000-hr timelag fuels.

Live fuel moisture – herbaceous and live woody fuels; 100% refers to mature foliage with new growth complete.

Timelag fuels – the length of time needed under consistent conditions for a fuel particle to lose about 63 percent of the difference between its initial moisture content and its equilibrium moisture content. For dead roundwood fuel:

1-hr = <0.25 inch diameter
10-hr = 0.26 – 0.99 inch diameter
100-hr = 1-3 inches diameter
1000-hr = 3-8 inches diameter

Wind adjustment factor – adjusts the 20-ft windspeed to midflame windspeed depending on the sheltering of fuels from the wind.

0.1 - fully sheltered, dense stands
0.2 - fully sheltered, open stands
0.3 - partially sheltered
>0.4 - unsheltered