Long-Term Risk Assessment
Bear Gulch 2 Fire
7 August 2006

Summary

- The season is more severe than indicated by Jefferson RAWS and is expected to continue to be more severe than average.
- 40% chance of an August singularity that would slow the fire, 10% chance it would be large enough to end the fire.
- Otherwise, season end is most likely to occur by first week of October.
- Most likely direction of fire spread is northwest into Olympic National Park and towards the 1985 Beaver Burn. Unlikely that fire will spread far enough east to threaten homes in Mt. Rose subdivision.
- Recommend long-term actions to manage and monitor the fire. This assessment should be revalidated periodically and redone if the season does not follow the expectations laid out in this assessment.

Introduction

The long-term assessment for Bear Gulch 2 Fire consisted of four main components:

1. Seasonal severity analysis and analyses of historical weather,
2. Identification of critical events affecting fire potential,
3. Assessment of the probability that the fire will reach locally-identified points of concern before a season-ending event and
4. Management considerations for long-term management of the fire.

Observed Fire Behavior

The fire area is very steep; average slope on the face of Mt. Rose is 60%, but the slope at the fire's origin is 90 to 100%. Numerous chutes and rocky outcrops combined with areas of dense brush and pockets of heavy fuel loadings combine to provide an especially dangerous environment for firefighters. The aspect is mostly southwesterly. Fuel models present in the burn area include 8 (closed timber litter), and 10 (heavy timber litter), with some 5(intermediate brush). Fuel model 8 dominates the fire area and has been field verified. Daily fire projections and the long term analysis use both fuel model 8 and 10. Fuels are drier than average for late July and early August. The features that have affected the fires growth include:

- The daily up-valley/up-lake diurnal wind (east or southeast at the fire site). On sunny days, this wind influenced the fire at the lower slopes and contributed to spread across the slope (August 2nd & 3rd).
- The primary fire behavior on the east flank was backing across slope (August 4th & 5th).
- A major mechanism of spread was rolling material igniting areas down-slope.
- A pattern of marine cloud layer development occurred most evenings, and results in an inversion in the morning with good humidity recovery (July 30th & 31st).
- Aerial suppression combined with a cooler period with increased humidity checked the spread of the fire (July 28th & 29th).
- The days of most active fire spread were preceded by several days of poor nighttime humidity recovery (July 26th & August 4th).

The Fire Behavior Narrative provides a thorough discussion of fire behavior.

Seasonal Severity

We completed a seasonal severity analysis using both the Jefferson Creek Remote Automated Weather Station (RAWS) (station ID 450911) and Cougar Mountain RAWS (station ID 450117). Jefferson Creek RAWS has reasonably good data for the 1980s and 1990s, but spotty data beginning in 1999. Cougar Mountain RAWS has spotty data for the 1980s and much of the 1990s and reasonably good data since 1996. The two stations are located at similar elevations, but Jefferson lies on the southeast side of the Olympic Peninsula, approximately 7 miles from the fire area, while Cougar lies on the northeast side of the Peninsula, approximately 34 miles from the fire area. Cougar appears to have more direct influence from marine conditions, particularly at night, but its critical energy release component (ERC) values are slightly higher than Jefferson's. Wind speeds recorded at the stations are similar, but wind directions are quite different. Nonetheless, we felt the station records were similar enough that we could use Cougar to supplement temperature, relative humidity, and wind speed information from Jefferson.

This year Jefferson RAWS did not start collecting data until July 19, so we compared the maximum and minimum values for both temperature and relative humidity at Jefferson and Cougar RAWS. While not perfect matches, all values were very similar between the two stations from July 19 through August 1. The main difference was 0.07 inches of precipitation recorded on July 30 at Cougar, which affected minimum relative humidity on July 29 and 30. Given this similarity in values, we believe the ERC trace for Cougar is representative of what likely would have occurred at Jefferson had the station been started in April or May (figure 1). This pattern is also similar to what has been seen at Viewpoint RAWS in connection with the Tinpan Fire and at First Butte RAWS in connection with the Tripod Complex, both on the Okanogan-Wenatchee National Forests. All three stations show a pattern of a warm, dry May; cool, moist June; and warm, dry July.

Before the July 30 precipitation event at Cougar, ERC was running above the 90th percentile. The precipitation event brought ERC back down to seasonal averages, but it has since climbed back above the 90th percentile. Jefferson's ERC would likely have moderated as well, although probably not have dropped back to seasonal values since no precipitation occurred.

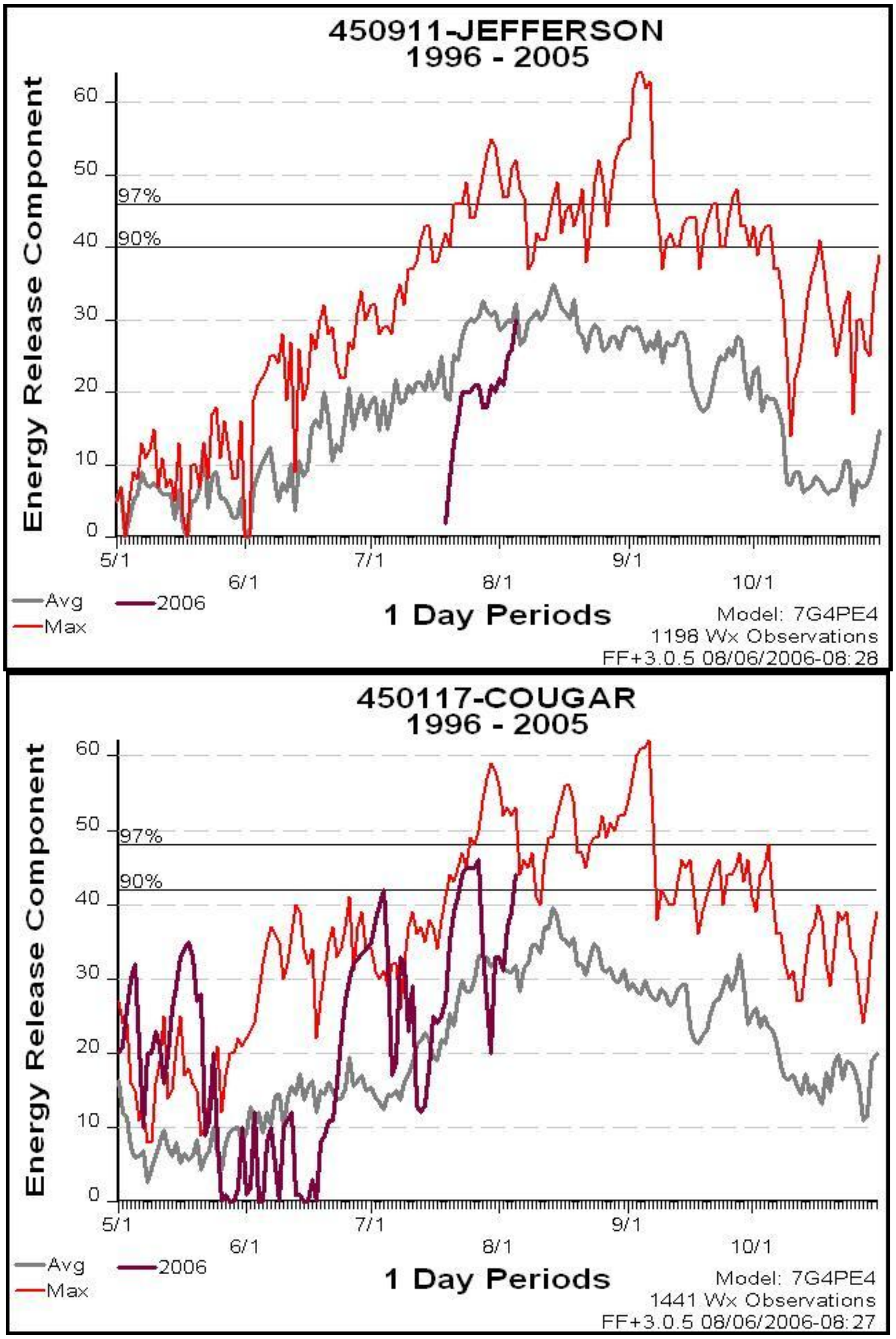


Figure 1. The ERC pattern at Cougar RAWS probably represents what would have happened at Jefferson RAWS had the station been started in April or May.

Other indicators of seasonal severity are the various measures of water year precipitation and drought. This past winter was average to above-average in snowpack and precipitation. The area currently is not in drought and drought is not expected to develop. River levels in the Skokomish River above Lake Cushman were still slightly above seasonal averages as of August 5. However, the long-term Palmer Drought Severity Index indicates the Olympic Peninsula has moderate drought conditions. Fire behavior also suggests that some fuels may be drier than typical for this time of year, although sound logs and duff have not been consuming or only partly consuming.

Long-Term Weather Outlook

The Olympic Peninsula is expected to have below average temperatures and above average precipitation in August but equal chances of above-, below- and average temperatures and precipitation through October. Equal chances means that the various long-term indicators and weather models used by forecasters are providing contradictory outputs or that no strong indicators of a trend are present. Drought conditions are not expected to develop over the next 90 days as well.

Somewhat contradictory to the August forecast are the 6-10 day and 8-14 day forecasts. The 6-10 day forecast (August 11-15) calls for a 40-50% chance of below average temperature and 33-40% chance of below average precipitation (cool and dry). The 8-14 day forecast (August 13-19) calls for a 33-40% chance of above average temperatures and 40-50% chance of below average temperatures (warm and dry). Assuming these forecasts are correct, then the remainder of August would need to be wetter than average to conform to the 30-day forecast. Given that summer weather patterns are usually quite persistent, we do not believe that outcome is likely. Instead, we believe that August will continue to be warmer and drier than average, more in keeping with the two shorter-range forecasts.

Critical Spread Events

The precursor condition for large spread events typically is ERC greater than 75th percentile (28 at Jefferson, 31 at Cougar), with growth most likely when ERC $\geq$ 90th percentile (38 at Jefferson, 40 at Cougar), coupled with a weather trigger. The weather trigger is a combination of high temperature, low relative humidity and wind. The two in combination indicate suitable burning conditions for rapid rates-of-spread, often aided through torching, spotting and short crowning runs and accompanied by flame lengths that restrict or prevent the use of direct attack actions.

Temperature and Relative Humidity

The weather records available do not allow direct analysis of these three weather triggers in combination. Therefore, we analyzed the temperature and relative humidity criteria in combination using Event Locator tool in Fire Family Plus. Then we analyzed characteristic afternoon wind speeds and directions using hourly observations and a wind rose tool available through the Western Regional Climate Center. Hours used as the primary burning period were 1000 through 2000.

The Forest pocket card for Olympic Peninsula East indicated that critical burning conditions occurred under the following conditions:

- 20-foot winds exceed 7 mph,
- Relative humidity drops below 40%,
- Air temperature rises above 72°, and
- 1000-hour fuel moistures were less than 17%.

Frequency analysis in Fire Family Plus showed that a maximum temperature of 72° lay at the 64th percentile for the period between May 1 and October 31 and at the 62nd percentile between August 1 and October 31. A minimum relative humidity of 40% lay at the 33rd percentile for the longer period above and at the 35th for the shorter period. These percentile locations are usually considered low for large growth events and are associated on this forest with escaped slash fires in fall. More typically, the 90th or 97th percentile maximum temperature and 10th or 3rd percentile relative humidity are used for summer fires when conditions are normally warmer and drier.

We used the Event Locator tool in Fire Family Plus to find those days at both Jefferson and Cougar that corresponded to the 90th percentile maximum temperature or higher and the 10th percentile minimum relative humidity or lower (table 1). At Jefferson RAWS, August typically has 3 days that meet both criteria while September has 2-3 days resulting in a 5%

chance on any given August day and 4% chance on any given September day. Cougar RAWS records indicate that August experiences 4 days on average that meet both criteria (for a 10% chance on any given day) and 2-3 events in September (with a 3% chance on each day).

Table 1. Ninetieth percentile maximum temperature and 10th percentile minimum relative humidity at Jefferson and Cougar RAWS.

Station	90th Percentile Max. Temp. (degrees F)	10th percentile Min. RH (%)
Jefferson RAWS (1978-2005)	84	24
Cougar RAWS (1996-2005)	81	29

Wind

High winds can result in large fire spread events at lower temperatures and higher relative humidity. Unfortunately, the 10-minute average wind speeds captured in RAWS data often fail to capture problem wind speeds. In 1966, John Crosby and Craig Chandler, two research foresters, conducted an analysis of the gusts that can 'hide' within a 10-minute average wind speed – the wind speed stored as a part of both daily and hourly observations and in fire weather forecasts. The results of this research were reprinted in the Winter 2004 issue of *Fire Management Today* and partly reprinted in table 2. Wind gusts are usually the element that triggers torching and crowning and can have greater influence on spotting distance than would be predicted by a 10-minute average.

Table 2. Probable average and maximum wind gusts that can be incorporated into 10-minute average windspeeds.

10-minute Average Wind Speed	Probable Maximum 1-minute Wind Speed	Probable Momentary Gust	
		Average	Maximum
5	9	15	18
6	10	16	20
7	11	17	21
8	12	19	23
9	13	20	24
10	14	22	26
11	15	23	27
12	17	25	29
13	18	26	30
14	19	28	32
15	20	29	33

East Winds

East winds is the term used to describe strong dry north to east winds, which may produce extreme fire danger in late summer and early fall. Two synoptic weather types produce this critical fire weather:

1. One is a cold-front passage followed by a bulge of the Pacific high extending inland over the coast. The attendant northeasterly winds blowing downslope produce a

warming and drying foehn effect. This event occurs most commonly in southwest Oregon, although it may occur elsewhere in the Pacific Northwest.

2. The second type follows when higher pressure develops east of the Cascades at the time a trough lies along the coast. The resulting dry easterly winds will cause high fire danger west of the Cascades. East wind events not only keeps the marine air offshore, but also results in adiabatic warming as the air flows from higher elevations down to sea level. This east wind type is more common in western Washington and the Olympic Peninsula.

East wind events can persist for 24 to 48 hours or longer with surface winds reaching 60 mph or more. Generally, wind velocities reach maximum strength during the night and early morning hours.

These winds are associated with the largest or most difficult fires in western Washington and the Olympic Peninsula. Drought is often a contributing factor for the large fires, such as Ludlow-Quilcene in 1864, Yacolt in 1902, Soleduck in 1907 and Forks in 1951. Strong east winds are most likely in September and October although the main spread event on the Yacolt Burn occurred under an August east wind. The National Weather Service uses Mt. Ellis RAWS on the northwest side of the Peninsula as a primary indicator of east wind events that meet that red flag criterion. Over the period 2001-2005, Mt. Ellis recorded winds in excess of 24 mph 2% of the time in August out of the east and east-southeast and 4.2% of the time in September.

Fire Slowing Events

Fire-slowing events can aid in containing or controlling fires by allowing firefighters to take more direct action or by causing the fire to lose enough energy that another critical spread event is unlikely even when suitable conditions are present. We defined two different fire-slowing events: the first event, 0.10-0.50 inches of precipitation within a 24-hour period, serves to slow fire spread for 1-3 days. The dense canopies characteristic of the Olympic Peninsula require at least 0.5 inches to penetrate the canopy and to begin wetting surface fuels. Smaller events slow fire spread by raising relative humidity and reducing temperatures. The second event, 0.50-1.00 inches of precipitation within a 24-hour period, serves to slow fire spread for 3-6 days. These events penetrate the dense tree canopy and begin to wet surface fuels, which then take several days to dry sufficiently to carry fire readily.

We searched for such events using the Event Locator tool in Fire Family Plus using data from Jefferson RAWS for the months of August and September. Most precipitation events in October are likely to be associated with season end rather than just fire slowing. As might be expected, the larger event is less likely than the smaller event (table 3) and rain events are more likely in September than October.

Table 3. Number of fire-slowing events by type and month.

Event	August	September
Slowing 1-3 days	2	2-3
Slowing 3-6 days	1 every other year	1

Precipitation probability graphs from the Western Regional Climate Center show the likelihood of a certain amount and duration of precipitation based on data from the National Weather Service's cooperative weather network. Figure 2 shows the probability of the smaller fire slowing event over a single day, three-day and five-day period, based on weather records at the Cushman Powerhouse. Tabular records for this same station indicate that August typically sees 6 days with at least 0.01" of rain, September has 8 days and October 14 days.

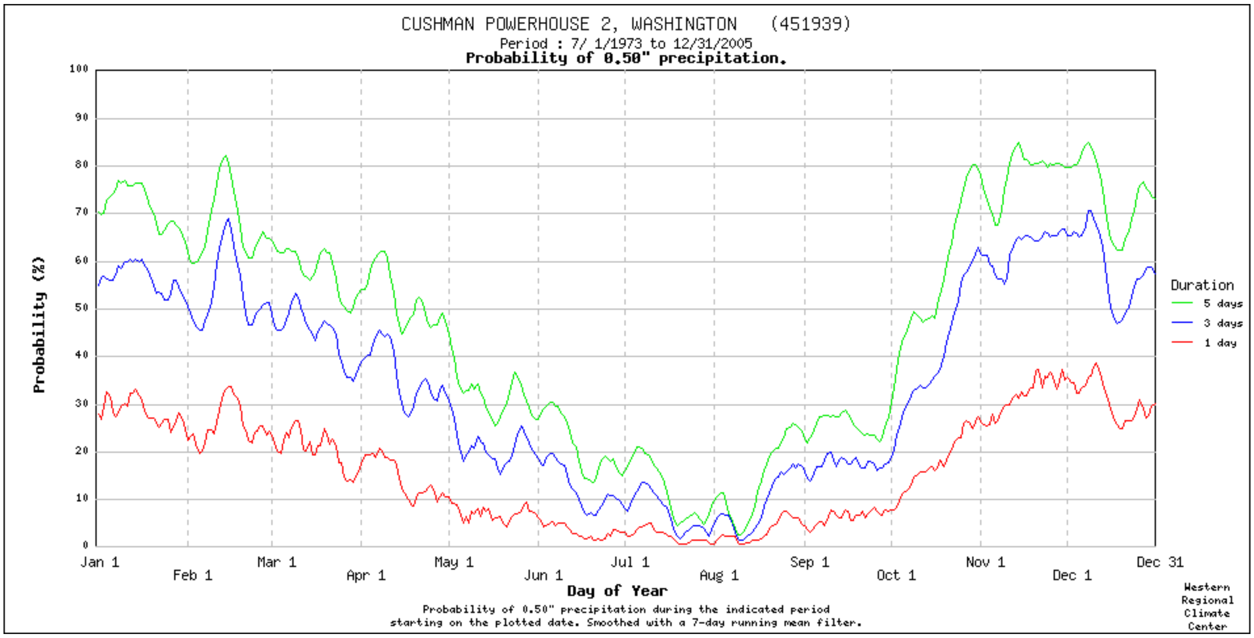


Figure 2. The chance of a ½ inch of precipitation event bottoms out in early August but increases rapidly thereafter with an event indicated in late August.

Season End

With an on-going fire, the season ending date tells managers how long the fire will continue to spread in the absence of successful suppression actions. In turn, it indicates the probable duration of fire and smoke impacts to visitors and residents. The analysis is, of course, based on probabilities, and identification of an appropriate season-ending weather event. The so-called season-ending event does not mean that additional fires cannot start; only that large fires and critical spread events are unlikely. Weather information from a local RAWS site with a long record of information is important. For these analyses, we used the Jefferson Creek RAWS, since it had more years of good records than the Cougar RAWS.

There are several approaches to identifying season end. A common approach is to evaluate the amount and distribution of precipitation. For this analysis, we used the first occurrence of more than one inch of precipitation over a three day period; only occurrences after the 15th of August were used, as earlier occurrences were considered season-delaying or fire-slowing events. Figure 3 displays the probability of one inch of rain over a 3-day period at Cushman Powerhouse.

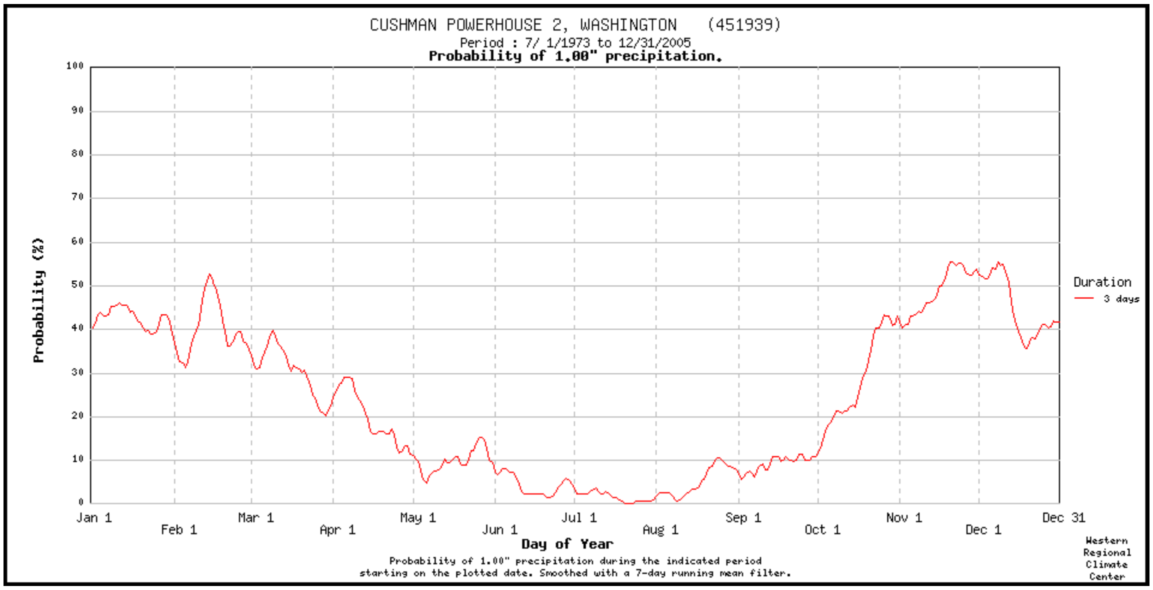


Figure 3. Daily probability of 1 inch of rainfall in a three-day period at Cushman Powerhouse; the chance for a season-ending rain increases greatly in October.

We also used the Event Locator tool in Fire Family Plus to locate similar events after August 15 at Jefferson RAWS (figure 4).

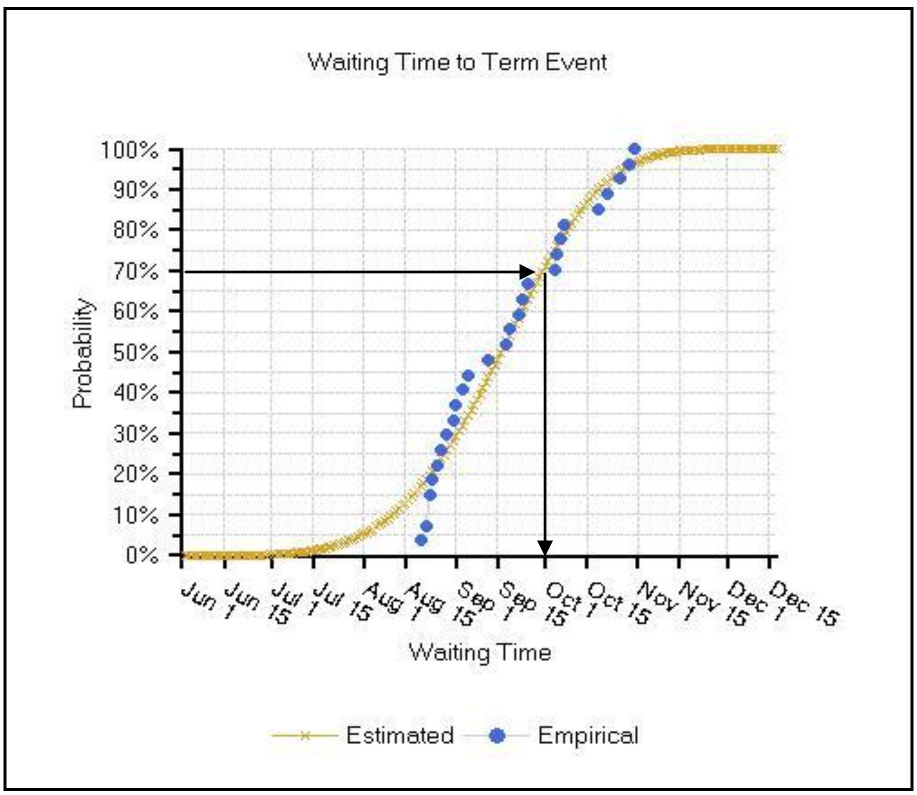


Figure 4. On October 1, 70% of the years in the database had experienced a season-ending event by that date.

Although the season-ending event is frequently described based on precipitation, experience has shown that a single type or amount of precipitation event can be an unreliable indicator. In some seasons, the end often occurs due to a combination of events such as shortening day length, changing sun angles, and less dramatic precipitation events. The Energy Release Component (ERC), an NFDRS variable that evaluates the potential energy in fuels available to support a fire, serves to integrate several factors that affect fire potential, including factors too subtle to analyze or recognize. Although no studies have determined what ERC value or percentile serves as the best indicator, analyses of large fire start dates in conjunction with ERC suggests that once ERC drops below the 75th percentile in the latter part of the year and does not recover, large fires typically do not start (figure 5).

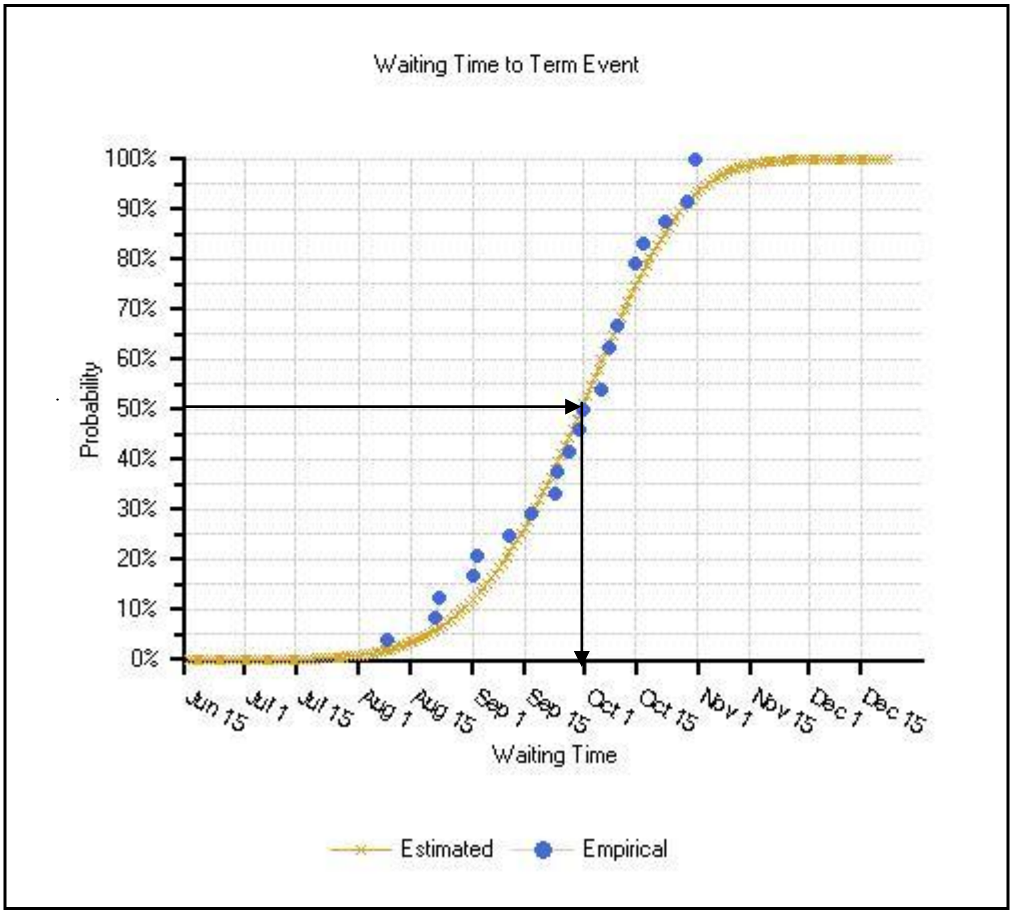


Figure 5: Using the 75th percentile ERC criterion indicates that October 1 marks the season end only 50% of the time.

The ERC method results in a more conservative estimate of the season end dates. It may well be that the precipitation approach works well in years with average to above average precipitation while the ERC method works well in years with below average precipitation. We recommend the Forest and District track season end to validate either or both curves.

Another consideration is how sun angles and day length changes over the course of the fire season. Between August 1 and October 1, the maximum sun angle decreases 3° per day; on September 22, the autumnal equinox, the maximum sun angle is approximately 45.6°, or slightly over halfway from straight up. In addition, day length is decreasing by about 3 minutes per day over this same period, with more time lost in the evening than in the morning. On September 22, the day is approximately 12 hours and 34 minutes long. These factors reduce the length of the burning period, particularly on north and east aspects. The lower 1/3 of north aspects frequently do not dry out again and begin to serve as barriers after a wetting rain in the latter part of September.

Rare Event Risk Assessment Process (RERAP)

Coupled with information about the remaining season length, there are tools we can use to estimate the spread of an established fire over time. By considering this spread in concert with season-ending probabilities, we can evaluate the likely end of season fire size. Again, this is an analysis based on probabilities, since future weather is not predictable with certainty.

We identified three routes of interest to evaluate fire movement – spread to the east (towards private land along Lake Cushman), spread to the north (towards Olympic National Park) and spread up Bear Gulch, to the northeast.

Spread to the East

Of concern to Washington DNR and Mason County is whether the fire may reach areas of their protection responsibilities. We assessed potential fire spread to the east from the current boundary of the fire, as of August 3, to the corner of non-federal land found in the southeast corner of section 11, T23N, R5W, a distance of approximately 49 chains. We used weather data from Jefferson RAWS based on westerly winds (southwest, west and northwest), which occur less than 15% of the time in August, September and October. We ran four primary scenarios:

1. Fuel model 8 with no crowning
2. Fuel model 8 with crowning in September
3. Fuel model 8 with crowning in August and September
4. Fuel model 10 with crowning in August and September (severe scenario)

Fire spread when winds were not westerly was set at 0.1 chains per hour for the same number of hours as set for High spread days. Crowning only occurred under extreme conditions.

The fire is not expected to travel 49 chains in the absence of crowning before season end. In scenario 2, the chance increases to 9%; it doubles to 18% in scenario 3 and scenario 4 estimates a 24% chance. For each scenario, the fire has a 50% chance of reaching the following distances:

1. 30 chains
2. 31 chains
3. 32 chains
4. 38 chains

At present, the fire is spreading slowly to the east, so we also examined how the probability changes in scenarios 3 and 4 if the fire does not begin moving until later in the season (figures 6 and 7). The risks drop rapidly beginning around mid-September. This assessment suggests that the fire has not been moving very quickly to the east. To do so, requires flanking spread (cross wind or cross slope). Fire behavior to date suggests that flanking to the east occurs with very short-range spotting, after which the fire runs uphill and flanks slowly across the slope and against the up-lake winds. This activity has occurred most often in mid- to late afternoon, but results in very slow overall spread to the east.

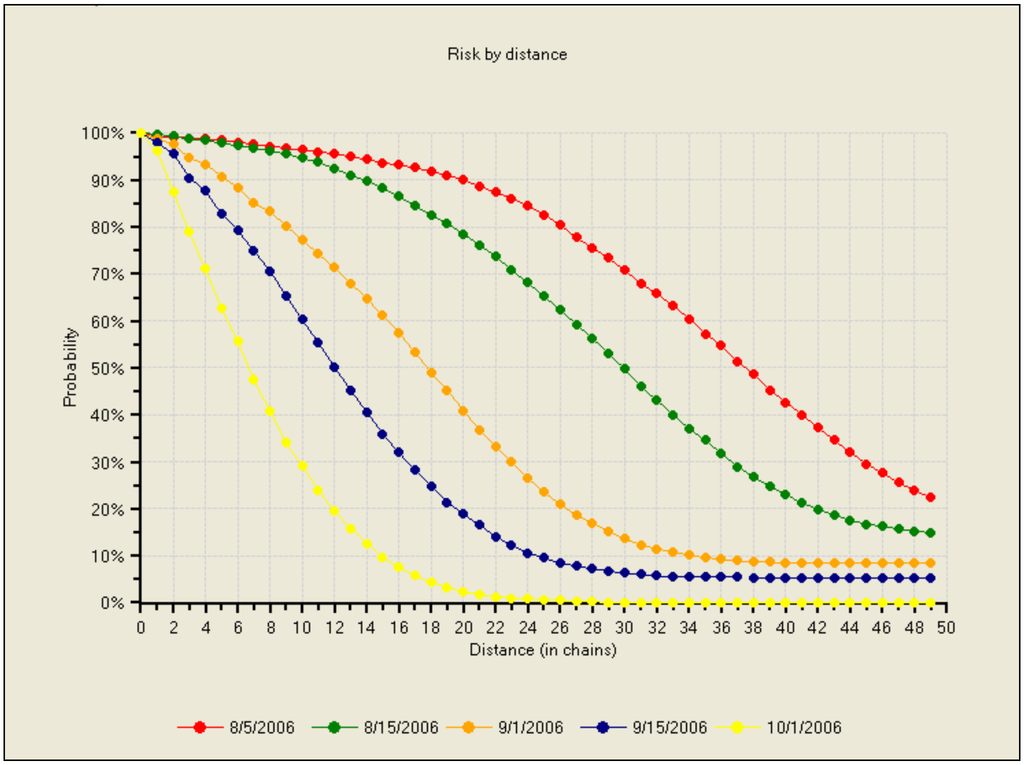


Figure 6. Under scenario 4 the chance of the fire reaching the closest parcel of non-federal land to the east changes dramatically by September.

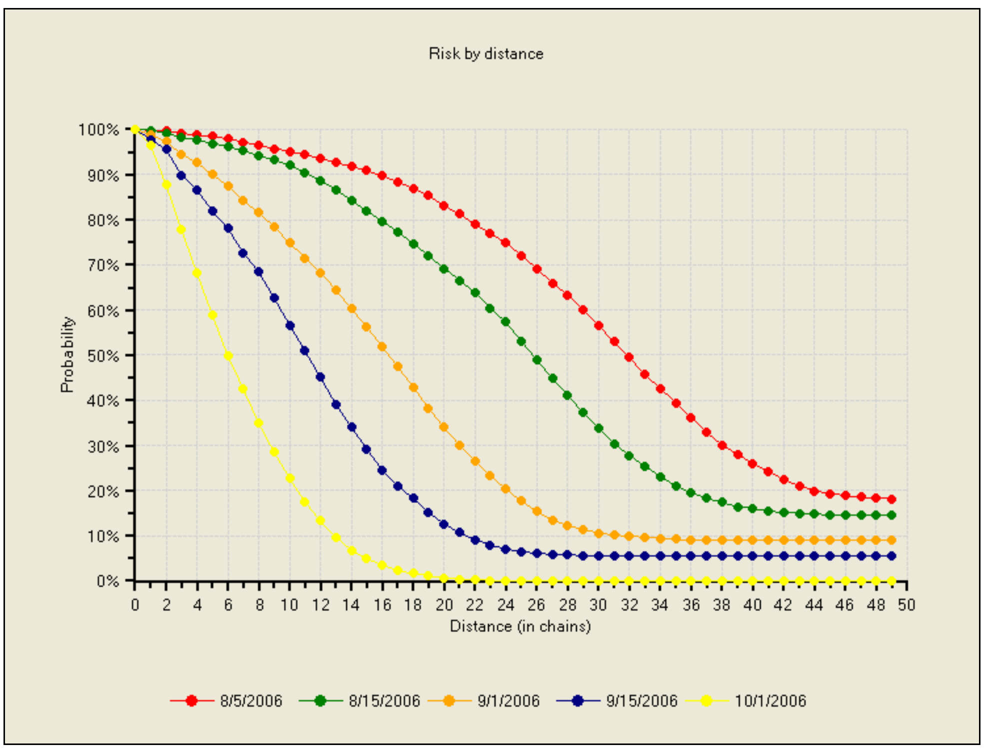


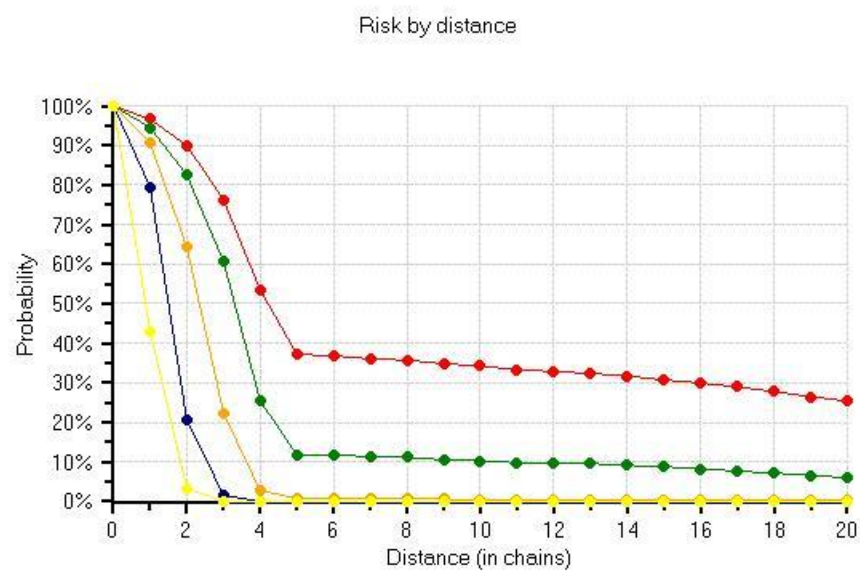
Figure 7. Under scenario 3 the risk is both lower and falls off even more quickly than with fuel model 10.

Spread to the Northwest

The fire is currently burning on National Forest land, but lies within ¼ mile of the Olympic National Park boundary at the head of Lake Cushman. The question we wanted to answer was the likelihood that the fire would reach the National Park by end of season. Again, we used weather data from Jefferson RAWS, and allowed all winds. The area between the fire and the park boundary was classified as FM8; the first segment was a backing fire down to the bottom of Bear Gulch, and the next three segments were straight upslope to the park boundary.

Once the simulated fire crossed Bear Gulch, spread to the park boundary was nearly inevitable; up a steep slope, with less than ¼ mile to cover in FM8, took less than two burn periods using just ground spread. The only uncertainty was whether or not the fire would cross Bear Gulch before the end of the season; the model projects that there is about a 40% chance the fire crosses Bear Gulch from its' location as of August 3 (about 5 chains) (figure 8). This emphasized the importance of holding the fire to the east of Bear Gulch if the goal is to prevent spread onto the National Park.

This is the direction of current fire spread, and in fact the fire is already at the bottom of Bear Gulch in places (as of August 6). This is a wet drainage, and the fire will need to move across the drainage via a falling snag or a drifting ember landing in a receptive fuel bed.



8/4/2006	25%
8/15/2006	6%
8/30/2006	<1%
9/15/2006	<1%
9/30/2006	<1%

Figure 8. If the fire can cross Bear Gulch, it will reach the Park boundary.

Spread to the Northeast

Assuming that the suppression operation is successful at holding the fire east of Bear Gulch, there is a path that a fire could follow, continuing up the drainage and eventually crossing the head of Bear Gulch. To evaluate this possibility, we projected a fire movement path 10,200 feet up the drainage (ENE and NE), through a FM8 near the bottom of the draw. This is a fire moving up drainage but cross slope, with an updrainage wind, and we assumed no crowning and fire movement through spotting.

RERAP analysis showed virtually no chance that the fire will cross Bear Gulch via this path – the amount of time it will require for the fire to cover this distance, cross slope under a sheltering canopy, is longer than the time remaining before the season-ending event (figures 9 and 10). It is much more likely that the fire crosses Bear Gulch through spotting, falling snags, or debris in the bottom of the draw.

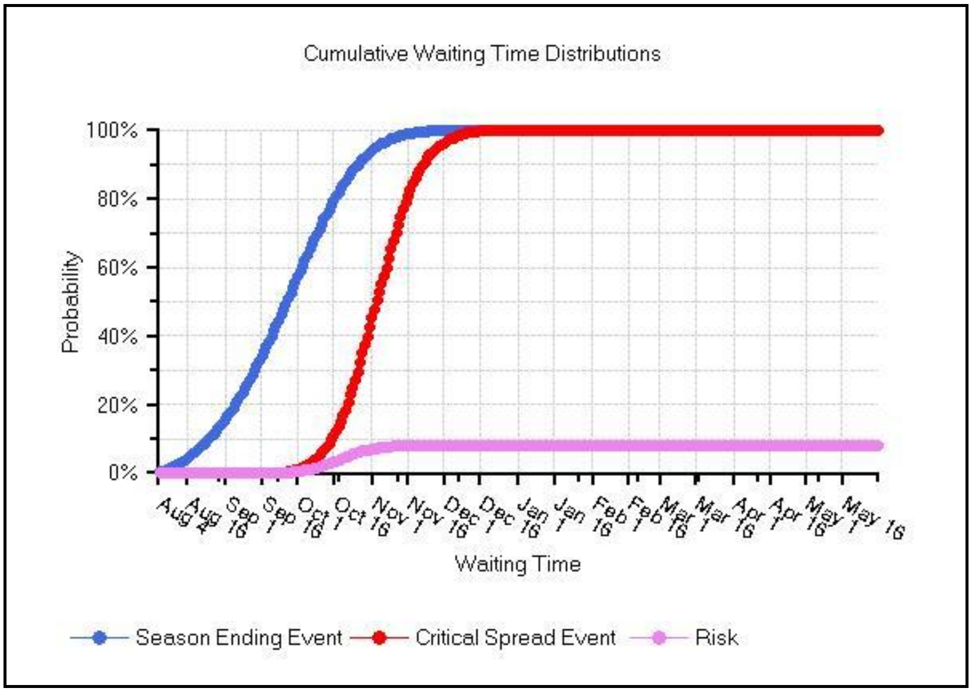
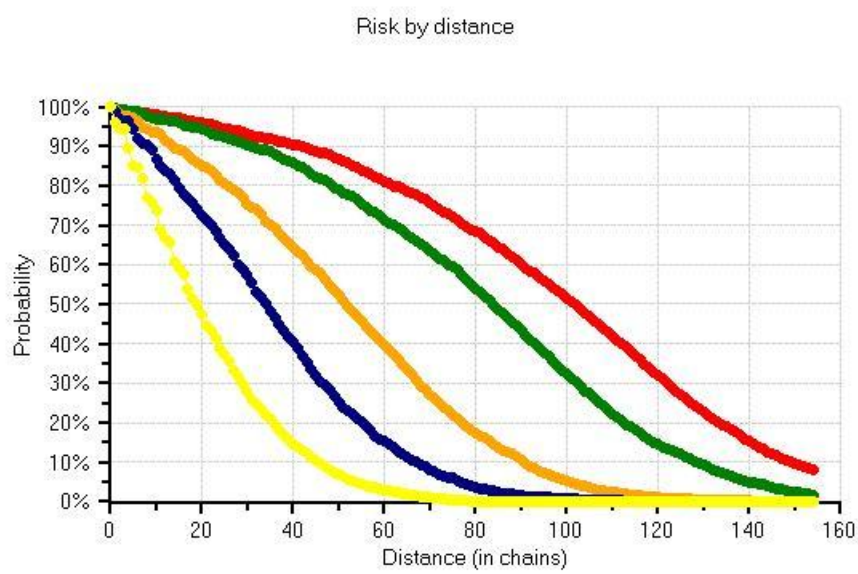


Figure 9. The season-ending event (blue line) is more likely to occur before the critical spread event (red line).



8/4/2006	8%
8/15/2006	2%
8/30/2006	<1%
9/15/2006	<1%
9/30/2006	<1%

Figure 10. The chances that the fire can burn to the head of Bear Gulch and around it are low and diminish rapidly as the season progresses.

Management Considerations

Management Considerations and Recommendations

> To anticipate fire growth days, monitor ERC, nighttime humidity recovery, daytime relative humidity, and forecasts for east winds.
>
> Watch for reliable season ending events – 70% likelihood that season will be over by October 1 (based on rain) or 50% chance (based on ERC)

Weather

Mid-August is the heart of fire season across the western United States, and this season on the Olympic Peninsula is no exception. An analysis of temperature and humidity profiles at the Jefferson Creek RAWS shows that the day of the fire start (and rapid growth) followed a several day period of unusually hot, dry weather (figure 11). Of particular note was poor nighttime humidity recovery during this period; instead of nighttime humidity in the 90-95% range, maximum humidity was in the 50-60% range. Following this, there was a 9 day period of more normal temperatures and humidities. Starting about August 5, another hot and dry period appeared, with low humidity recovery, and the fire became more active once again.

This is not an unusual pattern, with a fire making most of its growth on a few days, but not growing appreciably on most days. The fire managers should be watching fire weather forecasts to identify those growth days, and anticipate greater smoke impacts, public calls, and fire movement. Watch nighttime humidity recovery, as poor recovery means lower humidity during the subsequent burn period, and a longer burn period.

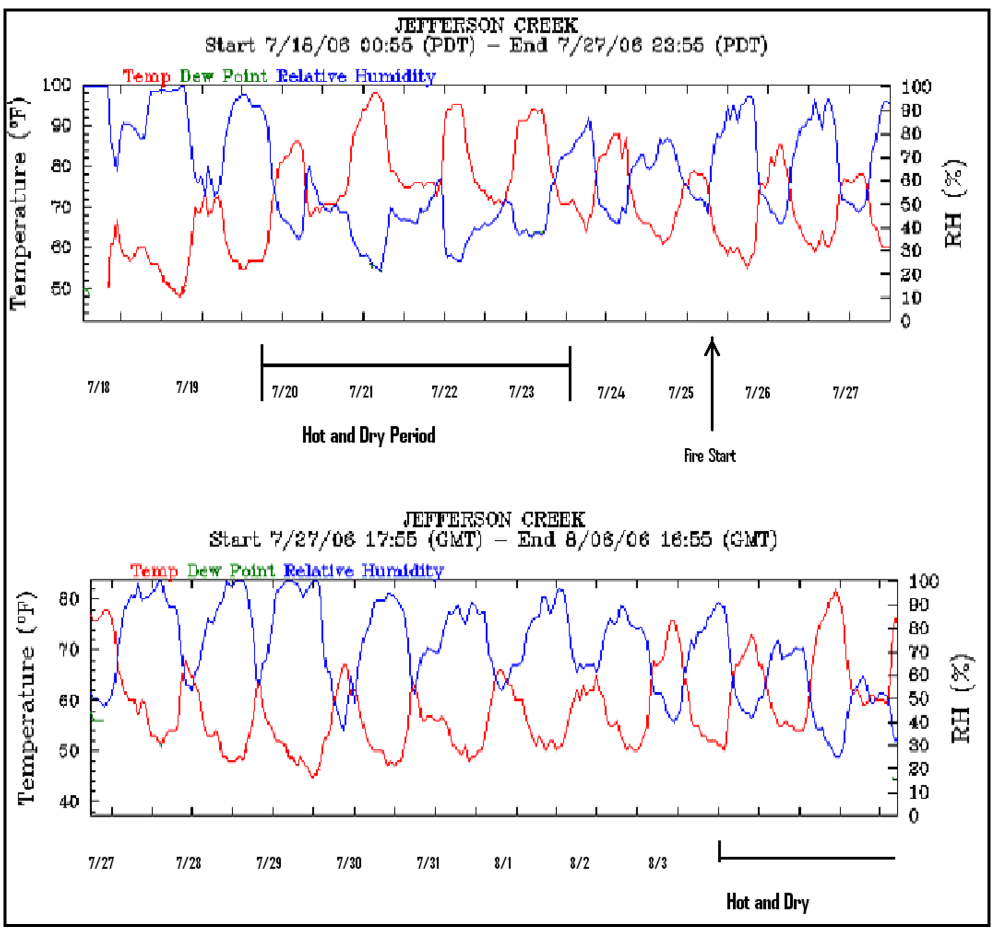


Figure 11: Temperature and relative humidity trace from Jefferson RAWS, July 18-August 06

Fuels and Fire Behavior

Given the weather information and analyses above, we identified several fuels and fire behavior considerations to keep in mind over the life of this fire:

- Poor nighttime humidity recovery increases the rate of fuel drying. Several consecutive nights of poor humidity recovery will likely lead to increased fire activity.
- Anticipate a gradual decrease in live fuel moisture and increase in fire activity. At some point the moist (unavailable fuel) will dry and become available fuel. The burn pattern and perimeter of Bear Gulch 2 as of August 4 show that certain fuels were not available during the late July period. As these fuels dry through August, expect them to begin to burn.
- Changes in aspect will affect fuel moistures and fire behavior. The aspect changes may be subtle. As of August 4, the fire is moving from a drier west aspect to a slightly moister west-northwest aspect in the upper portions of Division B. The aspect across Bear Gulch to the north is S and SW similar to the origin of the fire, which will provide drier fuel.
- Torching trees change the whole fire spread equation. From July 28 to August 4 the fire has spread via creeping through the surface fuel. However, single tree torching began to occur on August 5. Torching trees will indicate that some environmental, fuel, or weather parameters have changed and that the fire can "jump ahead" when embers land in receptive fuel.

To reduce the chances of being surprised by fire behavior, we recommend assigning someone at the District or PSICC to track daily outputs from RAWS for maximum temperature, minimum relative humidity, wind speed and gusts, 1000-hour fuel moisture, ERC and Burning Index (BI). The outputs should then be relayed to operations personnel for inclusion in morning operational briefings. Pay attention to the thresholds for increases in active fire behavior and base actions on the predicted fire behavior. Operations personnel should collect representative weather observations several times per shift and report these observations to District Fire Management personnel or PSICC as part of daily submission of spot weather forecast to support the next day's operational planning and implementation. Periodically confirm the fire behavior forecast by calculating fire behavior based on the both the observations and the forecast. For example, a return to very hot conditions would warrant new fire behavior calculations.

Smoke

Since this fire is likely to be a long-duration event, smoke becomes more of an issue and concern both for visibility needed to assess and manage the fire and for social and political concerns. As fire activity increases and suppression effort remains low to minimal, smoke will become more visible. The east edge of the fire is very visible to residents and visitors on Lake Cushman. With these fuel types, a relatively small acreage burned often results a large amount of smoke that gives the appearance the fire is moving more quickly and is more dangerous than it may well be. In addition, as more acres are producing smoke, the overall volume will increase and a well defined smoke column is likely during the day that may well be visible from the Seattle area. Residents and visitors to the local area need to be kept informed on what the smoke on a given day or period really means.

Day Time Smoke. The lake-effect winds tend to send smoke on the lower part of the fire to the northwest, up-lake and up-river during the day. Higher on the slopes and away from Lake Cushman, general smoke movement should be up-valley and up-canyon, principally to the west and north. On warmer, drier days when fire activity is higher, expect a smoke column to develop and rise above the general terrain. Once smoke rises above Mt. Rose, the general transport winds then steer it. Since transport winds are more often from the west and southwest, smoke will tend to disperse towards the northern part of Hood Canal and Puget Sound.

There also appears to be additional influence from both Mount Olympus and the Puget Sound that results in a somewhat U-shaped track as smoke first moves northeasterly and then is turned southeasterly. This effect is more noticeable toward evening when winds are shifting from generally up-valley to down-valley.

Night time Smoke. At night, as the air cools, local winds tend to shift to down-valley, down-canyon and down-lake. These winds are usually lighter than day time winds so smoke tends to pool in low spots. Smoke pooling will likely occur near the mouth of Bear Gulch and further up the Skokomish River, potentially affecting Staircase Ranger Station in the Park. Depending on where the fire is located, smoke may also flow through saddles and over lower ridges into drainages where there is no fire, giving the false impression that the fire has moved further in the night than it really has.

Smoke pooling on Lake Cushman is not expected to be a problem in the short-term due to the current small size of the fire, the size of the lake and air flow down-lake and out of the immediate area. As fire activity increases, residents and visitors on the lake may smell smoke in the morning. As both fire size and fire activity increases, smoke pooling due to inversions may become more problematic on Lake Cushman and Hood Canal. Such problems are more likely to develop in September as the lake is drawn down, reducing night time ventilation, and as weather patterns begin shifting from summer to winter norms, increasing the risk of stronger night time inversions. Night and early morning mixing heights are typical very near the surface. Night time smoke may well become more noticeable over a larger area along Hood Canal.

Other Smoke Events. In addition to normal day and night time smoke concerns other weather features can affect smoke production and dispersal. Rain will temporarily reduce smoke production, but also temporarily increase production as wetted fuels dry enough to burn, but with smoldering combustion more than flaming combustion. Rain can also temporarily increase night time pooling, but also tends to restrict the extent of that pooling. It also removes particulates from the air further away from the fire, reducing the smell of smoke in areas along Hood Canal and part of Lake Cushman.

Marine push events tend to produce relatively weak winds on the Olympic Peninsula, but may be strong enough to reverse the usual up-valley and up-lake winds and push day time smoke down-lake. Marine pushes also tend to bring cooler, moister conditions that reduce fire spread and growth. We are not certain how it may actually affect smoke production since we are unsure which factor will become more important in smoke production – reduced overall burning and spread potential but increased smoldering. Cold fronts can also result in down-lake smoke during the day, although it is more likely that the instability that accompanies a cold front will lift smoke higher, increasing its visibility to residents, visitors and the Seattle area and leaving Lake Cushman and the Hood Canal area relatively smoke-free.

East wind events will present more smoke problems for Olympic National Park, a mandatory Class 1 area, than for the Lake Cushman and Hood Canal area. These winds may drive smoke deep into the Park, primarily up the Skokomish River drainage. Depending on the actual strength of the winds and size and location of the fire at the time, smoke may or may not be very visible to the Seattle area. Higher winds will tend to keep the smoke lower relative to the ridgetops, but large columns can develop.

Lastly, periods of stable conditions may occur in August, keeping smoke close to the surface. Smoke then becomes more of a concern for those in the Lake Cushman and Hood Canal area, reducing visibility and increasing overall pollution levels. It can reduce general visibility to the west for the Seattle area. Stable layers can develop higher in the atmosphere such that smoke rises out of the fire area, but spreads over a larger area once it encounters the stable layer. This situation is likely to be visible to both local residents and visitors and to the Seattle area. Should the fire activity allow the column to punch through the stable layer, it can then contribute to fire spread by increasing instability over the fire area and potential result in cloud formation if the column reaches the condensation layer. This situation is less likely to develop on the Olympic Peninsula than east of the Cascades, but remains a possibility.

Monitoring the smoke production and smoke column can help answer questions and concerns from members of the general public. Local residents and visitors will likely have more questions than those in the Seattle area, so keeping locals informed should probably be the priority. Several tools are available for both the District and Park personnel as well as the public, depending on how Internet-savvy an individual is:

1. The simplest method is to track smoke plume rise and trajectory using weather observers.
2. Visible satellite imagery at 1 km resolution, available through the Seattle NWS website (http://www.wrh.noaa.gov/satellite/?wfo=sew) is useful for large fires producing large columns or large volumes of smoke. At present (August 7), the Bear Gulch 2 fire is too small to be easily detected in this imagery.
3. Use BlueSky animated images to track smoke trajectory in general (http://www.blueskyrains.org/animation.html). The GIF images work with all browsers and the 4 km images are focused on the Pacific Northwest. These images do not provide much detail, however.
4. Use BlueSkyRAINs maps to track forecast smoke trajectories (http://www.blueskyrains.org/mapper.php). These maps require more understanding of ArcIMS web-based mapping. The default setting is for a smoke forecast such that a user need only to click on item 4 (Click here to view Forecast Maps) to get a map. The user can then use the various tools at the bottom and left-hand side to zoom into the area of interest, view additional features such as county lines and major roads, and obtain a forecast trajectory for different times of the day. These forecasts have proven very useful and accurate, but do require more knowledge and skill. Computer problems at the source can result in no trajectory forecast as well.

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