UNIT III--TOPOGRAPHY AND FIRE BEHAVIOR

This unit is on topography and fire behavior. Carefully read the instructions on page 1 of your workbook. On page 2, you will find the unit objectives on which you will be tested at the end of this unit. Please study these objectives. Return to this text when you have finished.

Predicting fire behavior is a difficult job because of the many variables in nature. Burning conditions, relating to weather and fuels, are constantly changing as a fire spreads over time and space. Although the terrain usually does not change over time, it can change considerably over space. See figure 1 on page 3. All of the topographic features illustrated here are important in predicting the behavior of fire in mountainous terrain. A common method used to depict these various land features is the topographic map. We will be using topographic maps in the unit exercises. If you are not familiar with these maps and the interpretation of features from contours, you should seek help in map reading.

Generally we can say that topography affects the fire environment by altering the normal heat transfer processes and by modifying general weather patterns, thus producing localized weather conditions that influence the types of vegetation or fuels. These, in turn, result in micro-climates with localized moisture conditions. When we consider all of these ways together, we can state that topography directly or indirectly affects fire intensity and the direction and rate of spread of a fire.

In rare cases of mass ignition or fire storms over which large areas of moderate to heavy fuels are consumed in short periods of time, topography will have the least influence on the fire. The objectives of this unit are in-tended to give you a better understanding of these direct and indirect affects on fire behavior.

We have stated that topography modifies general weather and produces localized weather conditions. Under item A, on page 4, we want you to list the following mechanical effects of topography on weather: Friction layer modifies general winds, induces slope and valley winds, creates thermal belt conditions, produces orographic thunderstorms, and contributes to foehn or chinook winds. We'll discuss each of these briefly in this unit, but they will be covered in more detail in later units on weather.

Figure 2 illustrates how general winds coming in contact with the irregular surface of the terrain are modified and help to produce local surface winds. Under item B, please list the following ways general winds are modified: Channeling and changing wind directions, increasing wind velocities through constricted areas, producing eddies on lee sides of mountains, and mixing with locally induced winds. Although these processes are not thought to occur in flat, level terrain, we find that even certain patterns of vegetative cover and structures can produce the same effects on a smaller scale.

Now please move on to page 5. Slope and valley winds are important local winds that are generated by the terrain and its exposure to the sun. Here's how they occur: See item C. During daytime, the earth receives radiated energy from the sun and therefore warms. This warm air rises during the day resulting in upslope winds. The upslope winds increase in intensity and gradually produce upvalley winds as the day progresses. At night, as soon as the sun goes down, the earth and the air touching it cools at all elevations. The cool, heavier nighttime air at higher elevations slides down the mountain, causing downslope drafts. Downslope drafts form pools of cool air in the bottoms, which eventually develop into downvalley winds as the night progresses. Note that this process is most prominent on cloudless days and nights. Clouds limit, but do not stop, the solar heating and cooling processes.

If you live in a mountainous region, you surely have experienced the effects of a nighttime thermal belt. It's the result of a surface inversion of warmer air over colder air. Nighttime surface inversions occur over flat lands as well as mountainous regions; however, without differences in land elevation, the effects are not as readily realized. Have you ever wondered why orchards are often planted in the low foothills and not in the valley bottoms? Well, the chances of spring frosts are less here in the thermal belt at night than in the valley bottoms. Because nighttime temperature conditions are milder in the thermal belt, fire danger is usually also higher.

Page 6 discusses thermal belts and how they develop. Thermal belts typically have the highest average temperatures, the lowest average relative humidity, and the highest average fire danger. Here's how they occur: During the night, cool, heavy air from higher elevations slides downslope into the valleys below. The warmer air in the valley is replaced and pushed to midslope by the cooler air. The midslope zone has thus cooled less rapidly than other portions of the slope. The midslope is then referred to as the thermal belt.

The development and strength of the surface inversion and thermal belt zone may depend on several influencing weather factors; however, the effects are generally most prominent during clear days and clear nights.

Now let's test your logic regarding daytime burning conditions at various elevations. Please do question 1. Select one of the four choices, then return to the text.

You should have selected number 4, flat bottom lands. A surface temperature inversion that develops at night usually disappears by midmorning, and the air at low elevations best retains the heat from solar and surface radiation. The lower slopes would be next warmest, then midslopes, and so forth.

On page 7, we have illustrated the formation of orographic thunderstorms. Orographic means "of or relating to mountains." Orographic lifting produces thunderstorms when a mass of moist, unstable air is forced aloft by winds as it moves across a prominent mountain range. As the air is lifted, it cools and condenses into clouds. A rapid buildup of cumulus occurs that sometimes reaches the thunderstorm stage. These "thunderheads," as they are called, usually remain stationary; however, they can move after development. There is always the danger that downdraft winds from the thunderhead could cause strong gusty winds on your fire.

The last mechanical effect of topography on weather that we shall discuss is the foehn wind. See figure 6 on page 8. There are several variations of foehn winds in the Western United States. Instead of dealing with an unstable airmass that produces orographic thunderstorms, here we are concerned with a stable airmass being forced over a mountain range. As this heavy stable air is pushed up on the windward side, it cools, and clouds and precipitation might occur. The air falls on the leeward side and becomes warmer and dryer as it descends. The resulting gravity or foehn winds can be even more pronounced where the air is channeled through saddles or passes. Some localities may experience frequent foehn winds during certain times of year, depending on general weather patterns. Foehn winds take on local names such as the chinooks, which occur in areas east of the continental divide; the Santa Anas of southern California; the Mono and North winds of central- and northern California; and the East winds in the Pacific northwest.

As mentioned before, these weather processes will be covered in more detail in later units. Let's move on to some other effects of topography. In item D, we'll consider how elevation above sea level influences general climate and the effects thereof. Please note the following: The amount of precipitation received, the snow melt dates, the fuel types and loadings, the dates of curing of vegetation, the length of the fire season, and the general fire danger.

The next part, starting on page 9, deals with how topography affects fuels availability. The position on a slope or the relative elevation is also important because this influences the types and loadings of fuels and their availability. Figure 7 provides some fire statistics from the northern Rocky Mountain area. It gives the percents of fires in three slope positions and level areas that reach sizes of 10 acres or more. "Why do fires starting at the base of a slope typically get larger?" There's one very good reason for this. Please make your selection in question number 2.

We'll briefly discuss each of the choices in question 2. Although there may be a higher percent of man-caused fires starting at the base of slopes, this does not necessarily contribute to their size. The daytime fire danger is greater at the base of a slope than higher up, but not necessarily higher than level bottom lands. The statement on fuels being heaviest in this zone is generally not true, depending on overall elevations. The statement in number 3 is the best reason why fires get larger when starting at the base of slopes. A greater fuel area is available for spread of fire before some type of barrier is reached.

In figure 8 on the next page, we have fire occurrence statistics on the percent of fires by aspects. South and southwest facing slopes typically have the greatest numbers of fires. Why? Mark your choice or choices in question 3.

More fires start on south and southwest aspects because of the following: Fuels cure out earlier; average relative humidity is lower; and fuels are smaller-and drier. These aspects also have the longest fire season and have more light, flashy fuels in which to carry fire.

On page 11, figure 9, we see how the size of fires is affected by aspect. The percent of fires reaching sizes of 10 acres or more is greatest on southwest aspects. Why? Study the figure; then answer question 4.

The best answer to question 4 is that on sunny days the southwest aspect would receive the longest heat period before sunset. Burning conditions are usually highest on this aspect, since the active burning period is extended by higher burning conditions.

We've discussed fire danger in general areas or zones. It's important to recognize that fire danger changes substantially due to the micro-climate conditions at all elevations. Item E states that the type and availability of fuels can be affected by micro-climate conditions due to the following: Localized weather patterns, product of accumulative weather, and local soil and terrain factors. General shape of the country and various aspects contribute greatly to the resulting climates of small areas and resulting fuel situations.

Figure 10 on the next page summarizes the effects of aspect on fuels. Take a few moments to look over this figure. Then study figure 11 on the same page. Recall the heat transfer processes involved in fire spread on a slope. When you have finished, return to the text.

On page 13, figure 12 shows examples of how an increase in percent slope affects rate of spread on a fire. As the slope percent increases, the rate of spread increases. The two curves represent two fuel types under the same moisture and wind conditions. As you can see on the chart, chaparral will spread on flat ground at 6 chains/hour; on a 30 percent slope the rate of spread will be 22 chains/hour. Comparing the steepness of the curves shows slope has a greater effect on the chaparral fuel model than it does on the hardwood litter model. Now do question 5.

Let's see how well you did in reading rate of spread from the chart. When the slope increased from 30 percent to 60 percent, the rate of spread in chaparral increased from 22 to 66 chains/hour. The hardwood litter increased from 3 to chains/hour. This should help you realize that slope is important in estimating fire behavior and that the amount of the effect varies, depending on other environmental conditions.

Figure 13 on page 14 illustrates a fire burning on a steep slope. Note the figure, then do question 6.

All four choices would generally be true if fuels and slope were mostly uniform. Frequently, number 4 is not quite true, since fingering can occur, and the head may be split by one or more drainages and varying fuel conditions. We would mark choices 1, 2, and 3 only.

Figure 14 illustrates a fire burning -near the top of a ridge with flames bending back into the fire. Why would this be? Please do question 7 on page 15.

You should have marked choices 1, 3, and 4. Ridgetops are <u>not</u> always a safe location in which to establish control lines for the reasons given in 3 and 4. This will be discussed in more detail in Unit 9.

Figure 15 illustrates a topographic situation that has claimed the lives of several firefighters. See item F. Fires in a box canyon can have an upward draft like a fire in a stove. This dangerous condition occurs in the following circumstances: Unstable air conditions at surface cause a convection current through the canyon; air is drawn in at the base of the canyon to support the convection currents; and fuels are available to support a rapid burnout in the head of the canyon.

Figure 16 on page 16 illustrates more canyon bottom problems for firefighters. Fuels on the opposite slope from a fire in a narrow canyon are subjected to intense heat and flying embers. This fire situation is especially dangerous to firefighters when the fire is burning under an inversion or stable air conditions, and the smoldering fire is slowly drying out aerial fuels. When the inversion breaks, winds will increase into the canyon

Increased fire activity often produces crowning and spotting, and fire crosses to the opposite slope by radiation and convection. This change can happen in a matter of a few minutes, giving little warning to firefighters working in the canyon. Obviously, firefighters need to recognize when these situations can occur, and later units of this course will describe methods of monitoring weather and predicting fire behavior in mountainous terrain.

Figure 17 on the next page illustrates a fire at the forks of two drainages. Which way will the fire spread? Where drainages intersect, fire might follow one or both drainages, depending on the following: The direction of canyon winds as determined by aspect and time of day; the dominant winds in the canyon; wind eddies at the forks of the canyon; and the availability of fuels in the forks area. This complexity of factors often makes predictions on fire spread very difficult at this point.

We can describe combinations of terrain features as the shape of the country. Looking back through materials presented in this unit, we can conclude that the shape of the country affects the arrangement or continuity of fuel beds, influences the rate and direction of fire spread, and modifies weather, thus influencing fuel availability.

Turn to page 18. Another important terrain feature to discuss is barriers, whether natural or artificial. See item G. Barriers that either retard or stop the spread of fire are the following: Rocks or bare soil conditions; lakes, streams, and moist soil situations; roads, trails, and other improvements; and change in fuel type and fuel moisture conditions. A change in fuel conditions may offer only a partial barrier by slowing the spread of fire. The important point to be made here is that barriers can help to limit the direction of fire spread and provide opportunities for easier control.

A combination of topographic factors is usually present to influence fuels availability and the manner in which fire spreads through those fuels. See figure 19 on page 19. Slope percent, aspect and position on the slope are all important factors here. What will happen to this fire once it has reached the top of the hill? Please do question 8.

The best answer to question 8 is choice number 3: "It will continue to burn, and will spread down the other side of the hill at a slower rate of speed."

Obviously there are more factors involved here *than* just topographic factors. This course will try to discuss all of the various environmental factors that will help you make better estimations of fire behavior.

Now it's time to see how much you've learned about topographic features and what they mean to initial attack forces. On page 20, see exercise 1. Do the exercise; then return to the text.

You should have checked your answers with those on page 31. If you have any problems reading the topographic map, please find someone to help you.

Earlier in the unit we learned that the slope percent has a direct effect on rate of spread. The steeper the slope, the faster the rate of spread. We generally measure slope in slope percent. Slope percent is considerably different from degrees of slope, and the two should not be confused. Figure 20 on page 22 gives an example of a 50-percent slope. This means 50 feet of rise in 100 feet of horizontal distance. We're going to discuss some ways in which you can determine the slope percent in order to perform rate-of-spread calculations. There are several ways of taking necessary measurements in the field to determine slope percents. In item H, list the following: Direct readings from an abney; elevation readings with an altimeter; distance measurements from a map; mileage readings from vehicles; and sightings on power poles, trees, and axe handles. The first method is preferred if an abney hand level is available. Items 2 through 4 provide measurements for inputs into a formula which will give you slope percent. The last method gives a perpendicular from which to quickly estimate slope degrees or percent. There is a slope percent/degrees conversion table presented as figure 25 on page 30 that could aid you in your estimations.

A means for determining slope percent, without actually being in the field, is the use of a standard topographic map with contour lines. The most common are the USGS quadrangle maps. Page 23 gives several ways that you can use to determine slope percents from topographic maps. The first is the use of the slope indicator, which matches contour lines to those on the map. The slope indicator given in figure 21 on page 27 is for a USGS 7 1/2-minute quadrangle; however, with proper conversions, it can be used on other map scales.

A second aid available is the contour table. Two examples of this table are given on pages 28 and 29, each for a different scale map. These tables are mostly self-explanatory, and we will not spend any more time on them.

We do want you to learn to use the two formulas on calculating slope per-cent. The first can be used with data taken in the field or from a topographic map. It simply states that slope percent equals the rise in elevation between two points, divided by the horizontal distance between those points times 100.

Formula 2 is for use with contour maps only. It states that the slope per-cent is equal to the contour interval in feet, times the number of contours from point to point, divided by the horizontal distance between those points in feet, times 100.

Now let's try working with these formulas. On page 23, we briefly take you through the steps to using formula 1. Read through these steps; then do exercise 2. Study the map on page 25 very carefully as you complete the steps to calculating slope percent. When you have finished, return to the text.

You should have checked your answers with those on page 31. Now move on to exercise 3 on page 26. This time you will be using formula 2. If you have any problems in calculating slope percent, discuss them with your supervisor or call your designated instructor. This concludes the unit on topography. The last requirement for completing the unit is to take the Unit 3 test. You should go back and review all the materials presented in this workbook in preparation for the test.