Direct Effects of Wildland Fire on Cultural Resources

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Impacts to cultural resources from fire can be conveniently divided into two categories: direct and indirect. Direct impacts are those resulting from fire and its byproducts such as smoke. For the purposes of this overview, "fire impacts" to cultural resources caused by wildland fires are distinguished from, post-fire conditions, and the "fire effects" of those same processes. Both are measureable or perceptible changes to the physical, social, biological and ecological environment; fire effects, however, encompass the full range of those changes—good, bad and indifferent—whereas fire impacts are strictly detrimental (e.g., burning of an historic cabin, fire retardant dropped in sensitive stream, weeds invading a fragile plant community). In other words, all fire impacts are fire effects, but not all fire effects are fire impacts.

The descriptions that follow are intended to introduce readers to these topics, rather than provide an in-depth treatment.

Direct Impacts

The potential for direct impacts are strongly influenced by the general characteristics of wildland fires that occur in a given vegetation type or ecosystem. These general characteristics, referred to as a *fire regime*, can be usefully conceived to have three primary attributes: temporal, spatial and magnitude.

Temporal Attributes

Temporal attributes include seasonality—when fires occur during the year—and fire return intervals—how often fires occur over a given temporal interval. Many factors dictate typical fire seasonality in a given ecosystem. Areas characterized by warm spring weather and abundant fine fuels, such as the Mojave, Colorado and Sonoran deserts and other low elevation grasslands, can exhibit long fire seasons (spring through fall). Middle and upper elevation montane systems of the western United States, with heavier fuels and higher fuel moistures, are generally most receptive to fire from summer through early fall and the length of fire season increases from north to south. High elevation alpine and subalpine ecosystems as well as moist vegetation communities characteristic of the coastal and near-coastal Pacific Northwest may have very short, late season windows within which to burn. Coastal chaparral communities of central and southern California customarily support very late season (late summer though late fall), wind-driven fires.

Even prior to the arrival of Euroamericans and modern fire suppression policies, fire return intervals in the ecosystems of the western United States appear to have exhibited significant variability. Areas occupied and intensively utilized by Native Americans such as oak woodlands, grasslands and meadows experienced frequent (<10 years), even annual, burning. Some low to mid-elevation interior montane communities, ponderosa pine and giant sequoia forests as examples, also burned frequently (<25 years), whether ignited by natural causes, human hands or a combination. Shrublands, such as California chaparral and sagebrush steppe of the Great Basin and Columbia Plateau, exhibited an intermediate return interval (25-100 years). This same interval also applies to some higher elevation montane communities like interior fir and lodge pole pine forests. Wet coastal and near coastal communities of the Pacific Northwest and many high elevation subalpine and alpine interior ecosystems tend to burn very infrequently (100-1000 years).

Spatial Attributes

Spatial attributes encompass fire size—the characteristic amount of area burned in given fire within a given ecosystem—and complexity or patchiness, or the variation in fire severity within the fire perimeter.

Fire size is influenced by a number of variables, including fuel continuity, site productivity, topography, weather, and fuel conditions at the time of the fire. Small fire size (<25 acres) is characteristic of areas containing very discontinuous fuels, such as alpine and desert ecosystems. Medium fire size (25 to 2,500 ac.) is dominant in ecosystems with patchy fuel conditions and limited stand size, limited burning periods, or limited fuel continuity. Some interior coniferous forests in the western United States are characteristic of this fire size. Finally, large fire size (>2,500) occurs most commonly in ecosystems with continuous fuels, such as grasslands, shrublands, and some coastal coniferous forests.

Low complexity fires exhibit a high degree of homogeneity, with few unburned islands and a narrow range of fire severity (see definition below) that produces a course-grained vegetation mosaic. Fires in oak woodlands, grasslands and some chaparral communities are characteristic of this spatial type (Figure 1).

Figure 1. Low spatial complexity/high severity burned area in sagebrush steppe and grassland (Lava Beds National Monument, CA).

Moderate spatial complexity is evidenced by burned and unburned areas and severities creating a mosaic of fine- and course-grained vegetation pattern. Highly complex patterns of burned and unburned areas and severities that produce fine-grained vegetation mosaic characterize high spatial complexity. Finally, many ecosystems exhibit multiple spatial complexities. For example, the understories in some interior California fir forests burn with high spatial complexity, whereas burning of the trees themselves creates a mostly uniform burned area .

Magnitude Attributes

Magnitude includes fire type, fireline intensity, and fire severity. Fire type describes the characteristic of the flaming front patterns. These include surface fires, crown fires, and, although lacking a true flaming front, ground fires, and combinations thereof. Surface fires are those that burn through low-stature vegetation and loose debris, such as dead branches, downed logs and litter, on the ground surface. Taller aerial fuels, such as trees, are, at best, minor contributors to sustained fire spread. Grasslands, oak woodlands with grassland understories and ponderosa pine forests are examples of western ecosystems that typically support surface fires (Figure 2).

Figure 2. Surface fire in ponderosa pine (Wind Cave National Park, SD).

Crown fires advance from top to top in trees and shrubs. In some cases, this spread is independent of surface fire, while in others surface fire is necessary to sustain the crown fire. In the case of the former, crown fuel continuity and/or fire behavior is sufficient to carry fire, while no such conditions exist for the latter. Wind-driven fires in California chaparral and pinyon-juniper woodland provide classic examples of the first (Figure 3).

Ground fires burn the organic material, such as duff, roots and punky wood, beneath the surface litter (Figure 4). Burning through a process called glowing combustion, where the solid fuel oxidizes in the absence of active flame or smoke, ground fires typically follow the passage of the flaming front, whether a surface fire, crown fire or combination. Ecosystems with heavy accumulations of ground fuels, such as

Figure 3. Crown fire in southern California chaparral.

many mesic coniferous forests, tend to exhibit the greatest degree of smoldering combustion, but the phenomenon also occurs in areas with sparser fuels.

Fireline intensity refers to the amount of energy—measured in units such as British Thermal Units (BTUs) and kilowatts (kW)—released by the flaming front for a given unit of fireline (e.g., linear meters, square feet). In other words, it is the amount of heat an entity would be exposed to per second if positioned directly in front of a fire.

Flame length, or the average distance from the base of the flame to its highest point, is directly proportional to fireline intensity; the more energy released, the greater the flame length. Low fireline intensity is characterized by flame lengths less than four feet (1.2 m.). Annual grasslands and oak woodlands with annual grass understories are examples of ecosystems that burn with low fireline intensities. Flame lengths of four to eight feet (1.2 to 2.4 m.) are typical of moderate fireline intensities. Many mixed conifer ecosystems exhibit this level of fireline intensity. High fireline intensities are characterized by flame lengths exceeding eight feet (2.4 m.), and occur in, for example, many California chaparral communities. Finally, some western ecosystems burn with a mix of low, moderate and/or high intensities.

Figure 4. Smoldering combustion in mixed coniferous forest. Fuels such as residual logs and duff continue to burn even after the passage of the flaming front (Lassen Volcanic National Park).

Fire severity refers to the magnitude of effect fire has on all ecosystem components, including vegetation, wildlife, soil, watershed, cultural/social values and human life and property. However, this variable is most often expressed as the effect on the plant communities that comprise a given ecosystem. Low fire severity is indicated by slight or no modification to vegetation structure and most mature plants survive. Examples include oak woodlands with grass understories and ponderosa pine forests. Moderate severity, such as occurs in many mixed conifer ecosystems, is characterized by some modification of stand structure, but most mature plants survive. High severity is marked by mortality of aboveground plant parts, but mature plants resprout from surviving parts below-ground. California chaparral is a good example of this severity type (Figure 5). Stand replacing fires, where virtually all mature vegetation suffers mortality, is characteristic of very high fire severity. Pinyon-juniper woodland and lodgepole pine are a good example of this severity type (Figure 6). Finally, other communities such as some interior fir forests, exhibit a combination of low, moderate and high to very high severities.

Other magnitude-related variables also require attention. These include mechanisms of heat transfer, peak temperatures and residence time. Heat is transferred by fire in three principle ways: conduction, convection, and radiation. Conduction occurs when fire comes into direct contact with unburned fuels and heat is transferred to those solids. Convection involves the upward movement of heat in a gas, such as the heat one feels above the flame of a campfire. Radiation is the straight line movement of heat in a gas, as in the heat that is felt when standing next to a campfire.

Figure 5. Coastal sage scrub resprouting after a high severity fire (Santa Monica Mountains National Recreation Area)

Convection and radiation heating occur almost exclusively during surface and crown fires (Figure 7). Much the heat or energy is dissipated into the atmosphere, as opposed to the surface of the ground, in a phenomenon called "heat pulse up." Exceptions occur under circumstances of high winds and steep slopes where the lower flame angle can also result in significant ground surface heating. Conductive heating, by contrast, is the only significant form of heat transfer that occurs during ground fires. During ground fires most of the heat is dispersed laterally or downward in a process called "heat pulse down." The implications of these differences will be addressed in the chapters on the respective resource types.

Peak temperatures and duration of heating are also important. Generally speaking, heavier fuels tend to promote higher peak temperatures (measured at the ground surface) than lighter ones. For example, surface fire temperatures in annual grasslands will rarely exceed 300-400°C (575-750°F). In many coniferous forests, where surface fires predominate, peak temperatures customarily range from 200°C (390°F) in litter to 700+°C (1,300+°F) beneath logs and other heavy fuel accumulations. In shrublands, such as California chaparral, peak temperatures in low intensity crown fires will be around 500°C (930°F), while 1,000+°C (1,800+°F) is achieved in the same fuels under high intensity fires.

The duration of peak heating is largely a function of the rate at which a fire is spreading. Lighter fuels, such as grasses, and/or dry and windy climatic conditions typically induce surface and crown fires and

Figure 6. Very high burn severity in pinyon-juniper woodland (Mojave National Preserve).

rapid passage of the flaming front. Under such conditions, the duration of peak heating is usually quite short (seconds to minutes). For example, while burning shrublands can exhibit extremely high peak temperatures, the duration of that heating is often only a few minutes (Figure 8). Furthermore, the extent of heating within the duff (if present) that was not consumed during the passage of the flaming front and/or mineral soil (the layer below predominantly organic horizons that contains little combustible material) is generally negligible.

Long-duration heating is typically associated with ground fires following the passage of the flaming front. Residual fuels like logs and duff will, under the right conditions (e.g., low moisture), be fully consumed through smoldering combustion. During this phase, peak temperatures are lower than those achieved during active burning, but the duration of heating can be maintained for hours. Further, as these fuels are consumed, temperatures in underlying mineral soils will also rise and be sustained for a long period. However, the excellent insulation properties of soil typically restricts the depth of significant heating (>100°C) to the upper 20 cm. of the soil profile, and usually much shallower (Figure 9).

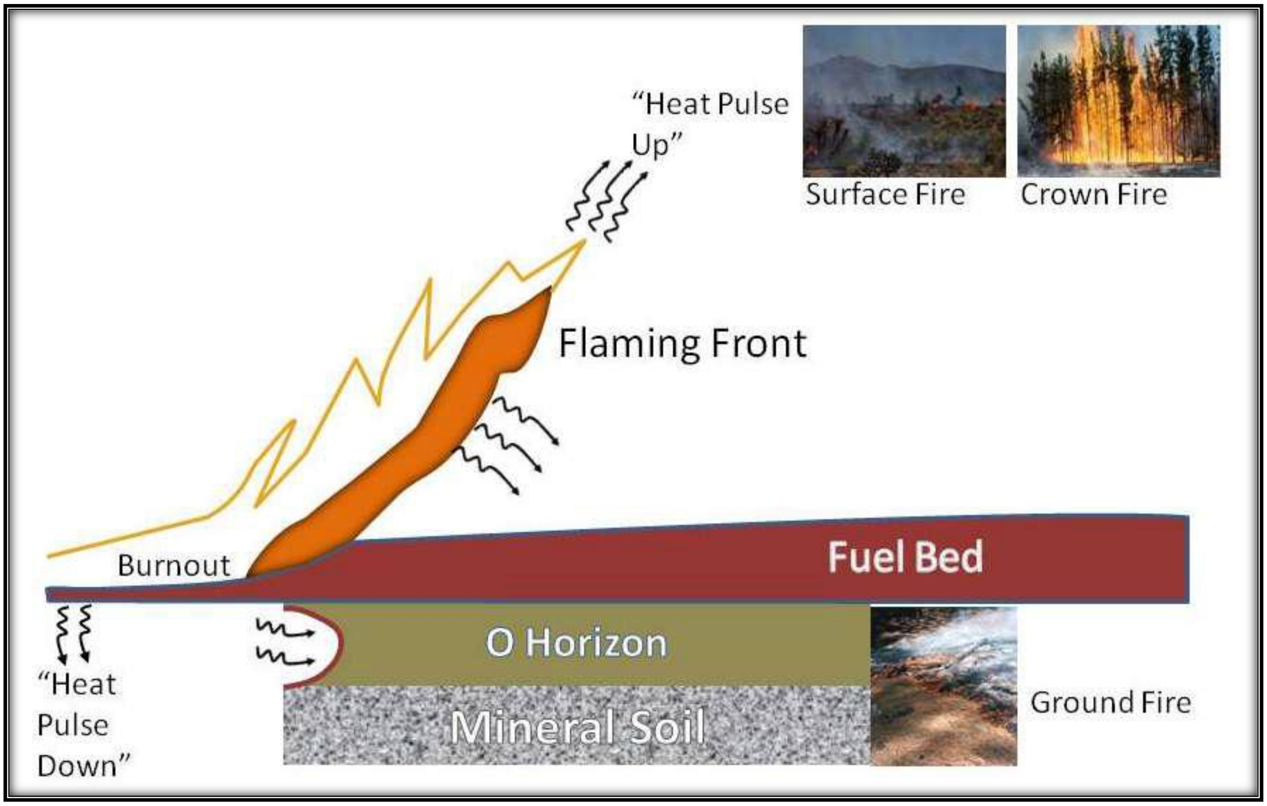

Figure 7. Three types of heating caused by wildland fires: convection, radiation and conduction.

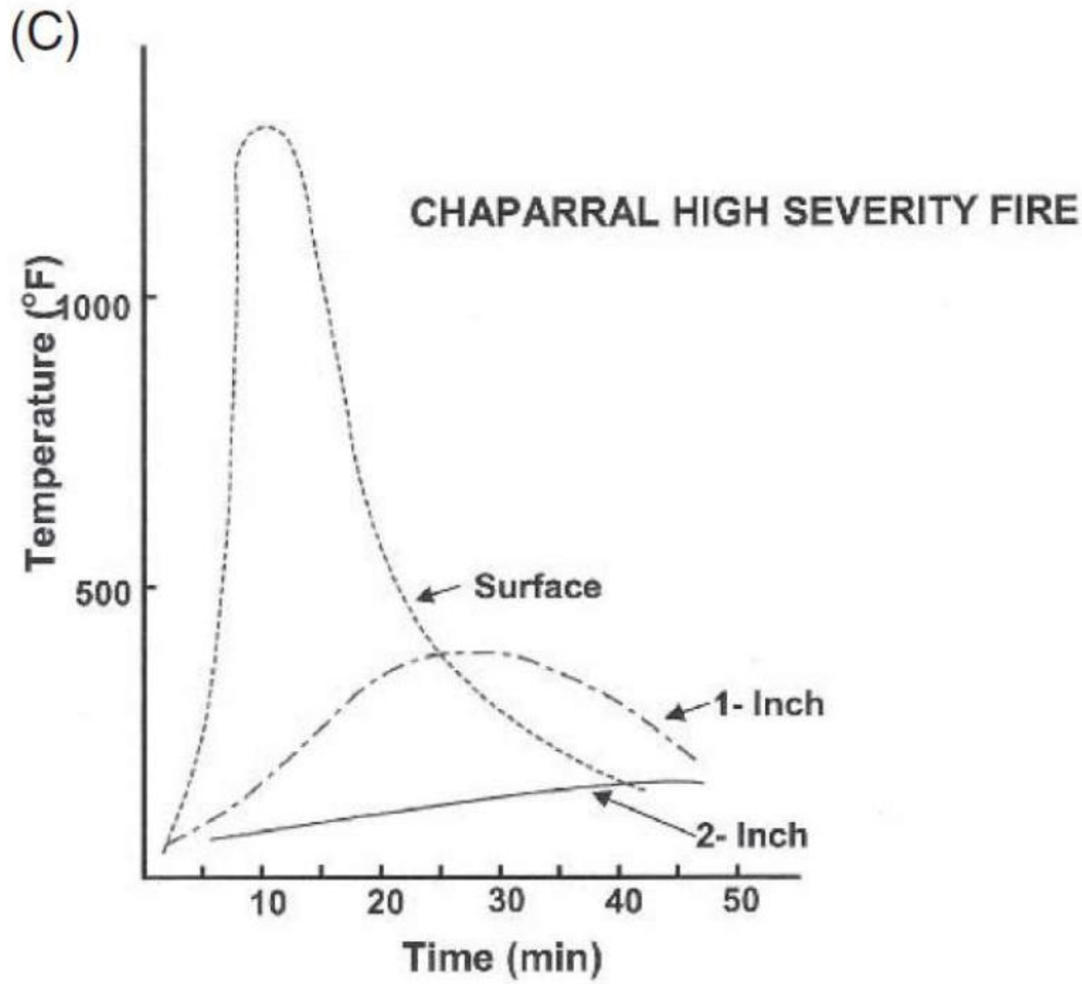

Figure 8. Surface and near-surface temperatures in a high intensity chapparal fire. Note that the duraftion of heating is measured in minutes (adapted from DeBano et al. 2005).

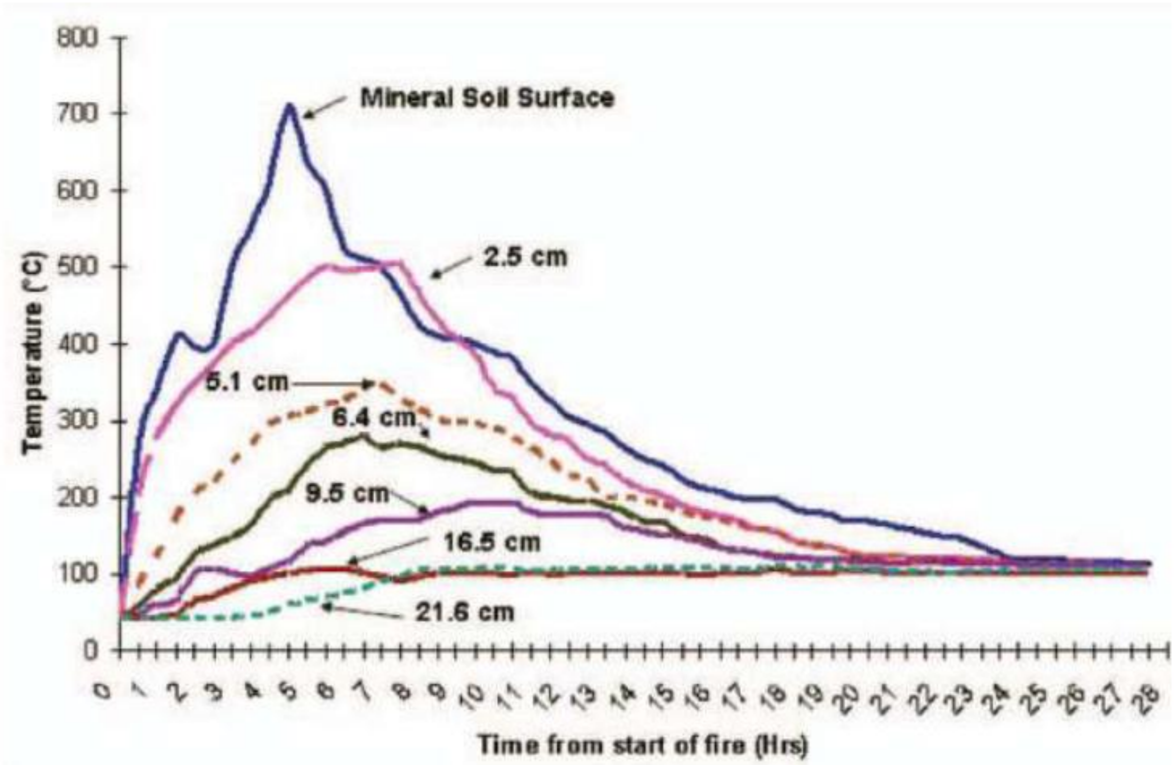

Figure 9. Surface and near-surface temperatures beneath windrowed logs. Note that duration of heating is measured in hours (adapted from DeBano et al. 2005).