Wildfire

In the last several decades, both the incidence of large wildfires and the duration of the wildfire season across much of the United States have increased (Westerling and others, 2006, American Water Works Assn, 2008; Finco and others, 2012). Future projections, based on forecasted climate scenarios generated by global general circulation models (GCM's), and down-scaled regional climate models (RCM's) indicate both an increase in the expected severity of wildfires, and an expansion of wildfire season (Liu and others, 2010; Liu and others, 2012) over much of the northern hemisphere, particularly for western North America. Approximately 80 percent of the U.S's freshwater resource originates on forested land, and more than 3,400 public drinking-water systems are located in watersheds containing national forest lands (USDA, 2006). Thus, potential impacts from current and forecast wildfire occurrence on the quantity and quality of runoff used for sourcewater and to support fisheries and aquatic habitats are considerable.

Sourcewater

Wildfire affects many factors within the sourcewater delivery system, ranging from immediate effects during a fire to long-term alteration of watersheds.

- During a fire, interruption of electrical power to water-treatment plants and ambient water-quality monitoring equipment and loss of access to stream diversion and monitoring locations are common. Because existing water-quality cannot be adequately determined, source water suppliers are often forced to shift to secondary source water supplies (Walton, 2012). Secondary (replacement) sources of water may have different, lower quality water-chemistry, which may necessitate increased pre-treatment actions and processes (pre-filtration, coagulation, introduction of chlorine, ozone, or hydrogen peroxide) at considerable additional cost.
- Runoff from burned areas and soils typically exhibits higher and shorter-duration peak flows and is controlled by the interaction of precipitation and the generated ash layer. Altered soil hydraulic properties (Ebel and others, 2012) and ash chemistry have significant effects on the chemistry of receiving waters such as lakes, wetlands, reservoirs, rivers and streams which often constitute primary source water resources for many large populations (Meixner, 2004; Cottingham, 2006).
- With decreased canopy cover, more solar radiation reaches the ground, warming soils and producing earlier spring runoff. Often, there are short-term increases in baseflow as a result of the reduction of evapo-transpiration by large trees. (Neary and others, 2003). Summer or autumn low flows may exhibit warmer temperatures.
- Proportional extent of a basin burned at high severity is closely related to post-fire stream water nitrate and turbidity levels, which have remained elevated for 5 years or more (Rhoades and others, 2011).
- Relatively common thunderstorms have increased turbidity, dissolved organic carbon, nitrate, and some metals by 1 to 4 orders of magnitude after wildfire in Colorado Front Range streams (Writer and Murphy, 2012).
- Microbiological pathogens often are introduced into receiving sourcewaters via increased movement of sediment and debris. Water-quality monitoring instrument performance can be degraded by the influx of sediment and debris, or, in some cases, the instrumentation is either inaccessible or lost. During a fire, or post-fire event, monitoring agencies may be unable to verify water chemistries or pathogen populations in sourcewaters and thus lack critical information for any treatment/pre-treatment processes required.
- Long term, or extensive, landscape alteration may contribute to a complete change in vegetation community

structure, ecosystem processes, and/or the introduction of invasive species. Subsequent changes in runoff dynamics and resultant water-chemistries may preclude use of source water resources.

- Reservoir intakes may become unusable due to increased sediment influx to the bottom of the reservoir and reservoir capacity may be reduced. Costly clean-out and dredging activities may be needed to regain operability.

Fisheries

Although many native species evolve within a specific wildfire regime and are able to tolerate varying degrees of fire disturbance (Gresswell, 1999; Dunham and others, 2003; 2007), the severity and extent of recent fires, and the forecasted potential for increased occurrence of large and intense burns, may exceed the capacity of many species to adequately recover from actual wildfires (Chandler, 2010). Sustained effects from wildfire on watershed conditions result from the loss of aboveground structure and subsequent alteration in soil, chemistry, and hydrologic processes (Rhoades and others, 2011). Severe fire typically causes widespread change to forest structure, extent, and soil condition that dramatically alters chemical, biological, hydrologic and hydraulic processes within the watershed and may result in the permanent loss of native populations and foster the presence and extent of non-native vegetation and biota.

Wildfire influences on native fisheries and other biota are also dependent on pre-fire condition of the watershed and fisheries. Road networks, which segment habitats and increase sediment loading into receiving aquatic habitats, and location and percentage of urbanization represent significant factors for both the severity and extent of actual wildfire, and also the type and extent of watershed post-fire recovery processes.

Wildfire effects upon fisheries range from immediate conditions experienced during the fire event through decades-long changes in habitat condition and character. Specific effects may include:

- Increases in stream temperature during a fire, resulting in fish, aquatic insect, and amphibian mortality (Dunham and others, 2003; Minshall and others, 2003).
- Fire retardant influx directly into stream as a result of fire suppression activities. This may lead to mortality of fish and amphibians due to high levels of ammonia (Little and Calfee, 2005).
- Increased exposure to solar radiation often warms exposed soils, altering associated hydrologic and chemical pathways and processes including runoff timing. The increased temperature and altered chemistries of stream tributaries may significantly alter conditions for fish, amphibian, and insect life-stages (Minshall and others, 1997; Minshall, 2003; Isaak and others, 2010).
- Change in stream pH and chemical water quality. Influx of ash directly into stream may cause increases in pH (alkaline conditions) and clogging of fish gills. Fish and amphibian mortality may result.
- Fractionation of riparian habitat by downed woody vegetation, soil slumping, immediate movement of sediment can occur via hillslope failure and direct effects of fire suppression activities. The geomorphic reworking of in-stream and riparian environments may fractionate already stressed habitats or isolate biological populations entirely, reducing access to fish spawning or rearing sites, or loss of sites completely. These conditions may cause immediate mortality in addition to longer-term temporal effects involving fragmented populations and the potential for losses of threatened or endangered species may be significant.
- Increased influx of nutrients, sediment, and organic and inorganic carbon. Initiation of algal blooms in receiving aquatic habitats due to increased nutrient availability and temperature increases are common. Subsequent dissolved oxygen depletion can be a major factor in fish and amphibian

mortality as well as interference with life-stages of target species.

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