Streamline
Watershed Management Bulletin

Volume 7 Number 3 Fall 2003

Wildfires and Watershed Effects in the Southern B.C. Interior

David Scott and Robin Pike

In 2003, over 104 000 ha in the Kamloops Fire Region were burned in one of the worst urban-interface fire seasons on record. In the aftermath, public concerns are focusing on the effects of wildfire and forest fire-fighting activities on soil and water resources. This article outlines the expected short-term hydrologic effects of wildfire. This review does not focus on longer-term issues such as large woody debris recruitment, channel changes, or ecological effects.

All Wildfires Are Not the Same

Wildfires vary in their effects on watersheds, just as fires themselves vary in intensity, duration, and severity. Fire intensity refers to the amount and rate of energy release, and is important for fire control.

Fire severity has to do with the effects on the burned site. A low intensity fire may also exhibit high severity by burning slowly over the ground, consuming all available fuel, and causing extreme soil heating.

Wildfire severity depends on many factors. Wildfires that consume high fuel loads and occur under extremely dry conditions are most likely to exhibit high intensity and severity. Generally, the higher the severity and/or spatial extent of the burn, the greater the hydrologic effects that can be expected. Conversely, fires that burn when the forest soils are moist are unlikely to consume all available fuels or remove most of the ground-covering litter. These fires do not usually generate temperatures that will damage the soil or kill trees. Because foresters often use these low severity conditions in prescribed burning, the effects of prescribed fires are significantly different from those of wildfires.

Characteristics of the 2003 Southern Interior Wildfires

The 2003 southern Interior wildfires were severe for two reasons: (1) large fuel loads, and (2) extremely dry conditions. Under these conditions, the wildfires consumed most of the fuels including many stumps and root systems. These wildfires also consumed the bulk of the organic litter layer and, in many cases, soils themselves were "ashed" when extreme heating combusted the organic matter. All these factors contributed to the high intensity and severity of the wildfires. Yet, a patchwork of "islands" of less severely burned and unburned areas can be seen within the fire boundaries.

Continued on page 2

Inside this issue:

Published by:

FORREX–Forest Research Extension Partnership
Suite 702, 235 1st Avenue
Kamloops, BC V2C 3J4

Project Manager: **Robin Pike**
Tel: 250-387-5887

Distribution / Mailing List: **Janet Jeffery**
Tel: (250) 371-3923

Publication Team: **Robin Pike, Sue Thorne, Julie Schooling**

Technical Review Committee: **Rob Scherer, Dan Moore, Robin Pike**

Technical reviewers this issue: **D. Gayton, S. Hamilton, D. Hogan, R.D. Moore, R. Nordin, J. Parminter, R. Pike, D. Polster, R. Scherer, S. Taylor, P. Tschaplinski, C. Wainwright, A. Wilson, R. Winkler**

Web Site: **Chad Wilkie**

Graphic Layout: **SigZag Design**

Copy Editing: **Ros Penty**

Cover Illustration: **William McAusland**
McAusland Studios, Kamloops, BC

Content and Article Submission Information:
Information in this publication is presented to increase communication and understanding of innovative knowledge and current research results in watershed management. Articles on technical information, research results, perspectives, news releases, conference / workshop highlights, and other relevant submissions are welcomed. All material published reflects the opinions and conclusions of the contributing author(s), not those of FORREX, our editorial staff, or our funding partners. We welcome your feedback on ideas or opinions that have appeared in past issues of Streamline. We reserve the right to edit all submissions for content, style, and relevance to Streamline.

This publication is partially funded by:

B.C. Ministry of Water, Land and Air Protection

Forestry Innovation Investment Ltd.

USDA Forest Service

ISSN 1705-5989

Printed in Canada

Printed on recycled paper

Supporting Sustainable Natural Resource Management Decisions

Continued from page 1

Predicting Wildfire Effects on Soil and Water Resources

While nearly 250 000 ha in British Columbia were burned in 2003, this level is still much less than was thought to burn annually before fire control, and less than the average annual area burned in the early part of the century (S. Taylor, pers. comm., 2003). In many areas, forest soils have developed in the presence of wildfire. The effects of wildfire on a watershed can be more prominent than timber harvesting because wildfire can affect large portions of a watershed in a short time, alter riparian areas (source area generation), expose large areas of mineral soil, and alter the albedo of an area. Yet, these effects will vary. Beschta (1990, p. 220) listed five main factors that influence the hydrologic response to a fire: "the severity of a burn, the proportion of the watershed burned, the relative proximity of the burned area to the stream channel, general slope of the watershed, soil type." These factors influence changes in the water balance (source area generation), soil erosion rates, slope stability, channel stability, and water quality.

Evapotranspiration/ Interception

Wildfire directly affects the evapotranspiration/interception regime of an area by reducing or eliminating vegetation surfaces from which these processes occur. The result is decreased losses of precipitation to evapotranspiration, and proportionately more water available to flow through a watershed. Also, a reduction in duff depth (i.e., organic forest floor layer) by wildfire will lower the duff's ability to delay and store precipitation before entering the soil matrix. Overall, dry season baseflow (low flows) can be expected to increase due to less precipitation being "lost" to evapotranspiration. These effects should be most prominent where fire has affected riparian areas.

Dave Scott

Road drainage over hydrophobic soil.

Dave Scott

Water drop beading on hydrophobic soil (near coin).

Snowpack Accumulation and Melt

In general, wildfires that reduce the vegetation cover can result in deeper snowpacks that melt faster than normal (Skidmore *et al.* 1994; Pyne *et al.* 1996). Deeper snow accumulations result from redistribution of snow, reduced interception losses and alteration of wind velocity and turbulence patterns via forest canopy friction changes, and forest edge creation by wildfire. For example, after a wildfire in north-central Washington, Helvey (1980) observed deeper snowpacks and streamflow rates three times greater than the maximum values observed during the calibration period. While we found few studies that documented the process effects of wildfire on snowmelt rates, it is likely that snowpacks in areas affected by wildfire will behave similarly to snowpacks in clearcut areas and melt earlier in the year.

Infiltration, Soil Properties

Wildfire modifies the infiltration and percolation (movement of water through soil) characteristics of a watershed by removing the organic litter layer (duff) and creating water-repellent layers. Reduction in duff depth is also important as buffering of incoming precipitation will be reduced and the erosive potential of precipitation and throughfall increased. When fire severity is high, all protective litter on the soil surface may be consumed, which exposes the soil to greater heating and more erosion. If soil temperatures are high enough, organic matter in the soil matrix may actually burn, leaving it in an ashed condition. Organic matter aggregates soil particles, so an "ashed" soil has lost its natural cohesiveness and has the consistency of powder. The result is a highly erodible soil (i.e., soil is vulnerable to high winds or overland flow).

Wildfire may create or enhance water-repellent soil conditions. Naturally, many forest soils exhibit water-repellent characteristics when dry, but this effect diminishes once soil moisture is increased. Wildfire can create a more severe and thicker water-repellent layer by partially volatilizing soil organic compounds, which subsequently condense onto cooler soil particles deeper in the profile (McNabb and Swanson 1990; Wondzell and King 2003). Such water-repellent conditions may slow the movement of water through the soil and, hence, alter subsurface water recharge, quicken streamflow delivery, and increase the potential for surface erosion especially during storms on a dry watershed. Generally, water repellency will weaken with the first few rainfalls following the wildfire and will not persist longer than 6 years after a wildfire (Dyrness 1976; Debano 1981). In Colorado, Huffman *et al.* (2001) observed a weakening of hydrophobic conditions under ponderosa pine/lodgepole pine stands after 3 months, but water repellency persisted for at least 22 months after the fire.

Streamflow

To date, relatively few B.C. studies have quantified changes in water yield as a result of forest fires. This is partially due to the difficulty in studying the subject (i.e., lack of pre-disturbance data, lack of control). In 1980, Cheng reported on the effects of a severe wildfire that burned several watersheds near Salmon Arm, B.C. Using data from a burned watershed (60%) and an unburned control, Cheng determined that the wildfire resulted in "higher and earlier annual peak flows, the advancement in time of the major snowmelt runoff volume, increases in total April-August runoff volume and in monthly water yields during the August-November period" (Cheng 1980, p. 251). Four years after the wildfire, Cheng (1980) observed an average seasonal water yield increase of 24% and attributed peak flow increases to increased snowmelt rates and reduced evapotranspiration losses. Overall, his study supports the conclusion that reduced evapotranspiration, altered snow accumulation and melt processes, and changed infiltration rates will generally result in higher water yields, higher and earlier peak flows, and increased base flow after a wildfire. Such changes in water yields and timing are likely to have consequences for stream channels, but discussion of these effects is beyond the scope of this article.

Water Quality and Erosion

The potential for wildfire to increase erosion depends on "fire severity, soil erodibility, steepness of slope and intensity or amount of precipitation" (McNabb and Swanson 1990). Whether such accelerated erosion occurs will depend largely on the magnitude of the first few storms after the fire and in subsequent dry seasons. Similar to water quantity, few relevant studies are available to quantify the anticipated effects of wildfire on water quality in the southern Interior. Residents of community watersheds are concerned about potential increases in sediment, turbidity, nutrients, and stream temperature of their drinking water. For aquatic habitat, removal of streamside vegetation and the subsequent increase in exposure to solar radiation can increase stream temperature. This may have an effect on temperature-sensitive streams until revegetation (re-establishment of shade) occurs. A good review of the effects of wildfire on water quality can be found in Beschta (1990).

Peter Tschaplinski

Channel erosion at Rembler Creek, October 2003.

Continued on page 4

Continued from page 3

In a study in southeastern British Columbia, Gluns and Toews (1989) found that wildfire produced detectable changes in several measured drinking water parameters. While increases in nitrate-nitrogen, pH, total nitrogen, magnesium, calcium, conductivity, total hardness, and total alkalinity were observed, only turbidity (0.6 above standard) and true colour (10 TCU above recommended level) exceeded the Canadian Drinking Water Standards during their study period.


Peter Tschaplinski

Sedimentation from rapid channel erosion, Rembler Creek.

can accelerate the potential for soil erosion by removing the protective litter layer, exposing the soil surface, destroying the soil aggregates, and creating water-repellent conditions. The high erodibility of ash and exposed mineral soil means that the risk of accelerated erosion and sedimentation, especially on steep slopes following wildfires, is great. Fireguards and emergency access roads that are not rehabilitated promptly after the fire may also contribute to increased sediment deposition. The high nutrient content and solubility of the ash is likely to increase the risk of nutrients reaching both surface and groundwater. Stream temperatures may increase where riparian shade is reduced. Many of the observed effects of wildfire will depend on the post-fire rate of revegetation and the intensity of the first storms in the wet season that follows.

Summary of Effects

Wildfire results in reduced evapotranspiration losses, and thus increased water availability for replenishing soil and groundwater stores. Similar to timber harvesting, wildfire can increase streamflow, create earlier and larger peak flows, and result in deeper snowpacks that melt earlier. The proportion of increase in water yield as a result of wildfire, however, will be proportional to the amount of watershed burned, annual precipitation, ecosystem type, and fire severity. Where fire-induced water repellency is widespread, a risk exists that large and high-intensity rainstorms will produce overland flow, and resultant streamflow and peak flows will be much greater than would be normally expected. Severe wildfires

For further information, contact:

Dr. David Scott
Okanagan University College
Kelowna, BC V1V 1V7
Tel: (250) 862-5464 ext 7565
E-mail: dscott@ouc.bc.ca

References

Beschta, R.L. 1990. Effects of fire on water quantity and quality. In Chapter 17, Natural and prescribed fire in Pacific Northwest forests. J.D. Walstad, S.R. Radosevich, and D.V. Sandberg (editors). Oregon State University Press, Corvallis, Oreg., pp. 219–232.

Cheng, J.D. 1980. Hydrologic effects of a severe forest fire. In *Symposium on watershed management-1980. Boise, Idaho, July 21–23, 1980. American Society of Civil Engineers, New York, N.Y., pp. 240–251.*

Debano, L.F. 1981. Water repellant soils: a state-of-the-art. U.S. Department of Agriculture Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif. General Technical Report PSW-46.

Dyrness, C. 1976. Effect of wildfire on soil wettability in the High Cascades of Oregon. U.S. Department of Agriculture Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg. Research Paper PNW-202.

Gluns, D. and D. Toews. 1989. Effect of a major wildfire on water quality in southeastern British Columbia. In *Headwaters hydrology. W. Woessner and D. Potts (editors). American Water Resources Association, Missoula, Mont., pp. 487–499.*

Helvey, J. 1980. Effects of a north-central Washington wildfire on runoff and sediment production. Water Resources Bulletin 16:627–634.

Huffman, E.L., L.H. MacDonald, and J.D. Stednick. 2001. Strength and persistence of fire-induced soil hydrophobicity under ponderosa and lodgepole pine, Colorado Front Range. Hydrological Processes 15:2877–2892.

McNabb, D. and F. Swanson. 1990. Effects of fire on soil erosion. In *Chapter 14, Natural and prescribed fire in Pacific Northwest forests. J.D. Walstad, S.R. Radosevich, and D.V. Sandberg (editors). Oregon State University Press, Corvallis, Oreg., pp. 159–176.*

Pyne, S.J., P.L. Andrews, and R.D. Lavern. 1996. Introduction to wildland fire. Second edition. John Wiley & Sons, Inc., New York, N.Y.

Skidmore, P., K. Hansen, and W. Quimby. 1994. Snow accumulation and ablation under fire-altered lodgepole pine forest canopies. In Proceedings of the Western Snow Conference. Sante Fe, N. Mex., April 18–21, 1994. Colorado State University, Fort Collins, Colo., pp. 43–52.

Wondzell, S.M and J.G. King. 2003. Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions. Forest Ecology and Management 178:75–87.