In 2012, there were at least 1,300 wildfires in Wyoming that affected more than 600,000 acres of land.

THE SCIENCE BEHIND WILDFIRE EFFECTS ON WATER QUALITY, EROSION

Wildfires are common in western watersheds and are a natural form of disturbance in forests and rangelands. Fire can provide long-term benefits to forest and watershed health; however, high intensity or large wildfires can result in significant increases in runoff and erosion, which can negatively impact water quality in the streams, rivers, and lakes within a watershed.

Large increases in runoff and erosion following wildfires can affect drinking water supplies, water treatment plant operations, irrigation systems, fisheries, and other aquatic life.

Increased runoff and erosion are highest in the areas immediately adjacent to the fire; however, effects can often be seen within a 100-mile radius. Annual runoff volume can increase as much as 30 percent the first year following a fire. In steep terrain, peak runoff may be 10 to 100 times average peak flow rates.

Why Do Runoff and Erosion Increase?

The amount of rainwater or snowmelt absorbed by unburned forest soils is often high (high infiltration rate) compared to the amount that runs off the soil surface. The forest canopy and litter layer protect the soil from the erosive power of high-intensity rainfall and also serve to increase infiltration into the soil by slowing the movement of water from the area and giving it more time to be absorbed.

Photo: U.S. Geological Survey, John A. Moody

- Wildfire can reduce infiltration and increase surface runoff by removing surface litter and vegetation. This decreases the amount of time water is held on the area and exposes the mineral soil surface to raindrop impact and splash that can detach soil particles. Detached clay particles can form a seal (light crust) and keep water from moving into the soil.

The primary factors that affect erosion risk potential are the fire severity, the degree to which the vegetation and soil surface have been disturbed by the fire, and the timing and magnitude of precipitation following the fire.

- Wildfires also reduce the amount of water taken up by plants, further increasing the amount of surface runoff and the subsurface lateral flow (the flow of water below the soil's surface) that occurs in the years following a wildfire.
- Increased runoff may also be caused by a water-repellent (hydrophobic) soil layer that can form following moderate and severe, slow-moving fires. They vary in thickness and duration. To test if the soil is hydrophobic, place a drop of water directly on the soil surface (avoiding burned vegetation.) If the water forms a bead and holds its shape, it is hydrophobic. This drop test should be repeated several times.

High-intensity Fires

Researchers have learned that high-intensity wildfires can cause erosion rates at much higher rates than lower-intensity, prescribed burns due to destruction of the litter layer. The percentage of surface cover from the litter layer and canopy cover are important determinants of erosion risk; less cover, greater the chance of accelerated erosion. The presence of ash can reduce surface runoff, and larger reductions are observed for the thicker ash layers; however, by the second or third rainfall event, the protective effects of the ash are often gone.

A heavy rainstorm following a wildfire could cause excessive runoff and erosion, depending on the local soils and topography, whereas light rains could have minimal impact and increase plant growth.

Soils, topography, and the underlying watershed geology can help determine the types of erosion to expect after a fire. Steep watersheds with shallow soils are more susceptible to large increases in runoff and erosion than gentle slopes with deep soils. Local NRCS, UW Extension educators and conservation district personnel can help landowners identify potential erosion risks.

Impacts of Runoff and Erosion on Water Quality

The streams, rivers, or lakes within a watershed can experience increased sediment loading following a wildfire. Runoff from erosive upland areas can transport sediment to surface waters. Eroding stream banks can also contribute sediment if increased runoff volumes have altered the physical characteristics of a stream channel, such as width, depth, and cross-sectional area, to the point the stream channel becomes unstable.

The loss of vegetation that, prior to the fire, helped hold stream banks together can also lead to bank instability and erosion. Increased sediment loads in surface waters can affect aquatic habitat, food webs, fish spawning grounds, and, in severe cases, can directly cause fish kills.

Wildfire is a natural ecosystem process

While the effects of a severe fire can be devastating, the effects of low- to moderate-intensity fires can be rejuvenating to watershed health. Low- to moderate-intensity wildfires can encourage vegetative succession and promote diverse habitats. Post-fire high flows and floods may be important sources of spawning gravel, and inputs of sediment and nutrients may cause short-term increases in productivity. Short-term impacts to water quality from moderate fires may not always result in long-term degradation of water resources. Prescribed fire can be used as a tool not only for forest health but also for long-term water quality management.

KEY FINDINGS IN RECENT RESEARCH

In the coarse soils studied in the Rocky Mountains, post-fire erosion rates declined to near-normal in five to eight years after fire on most slopes.

The key to reducing post-fire erosion is to maintain or rebuild ground cover. Straw mulch followed by seeding is often more effective than other potential treatments.

Most post-fire erosion occurs during the summer convective thunderstorm season, and little erosion is caused by snowmelt runoff.

There are several post-wildfire runoff and erosion predictive models such as the Revised Universal Soil Loss Equation (RUSLE) and Disturbed Water Erosion Prediction Project (WEPP) that are useful for estimating runoff and "average" sediment yields after wildfires. These tools can be "run" by Burned-Area Emergency Rehabilitation (BAER) teams, land management agencies such as NRCS and USFS, and some universities.

Studies suggest that, for larger watersheds, significant changes in water yield, peak flows, and flow duration following wildfires or other disturbances are not generally detectable until 15 percent or more of the vegetation in the watershed is removed.

A great deal of information is available concerning impacts from the 1988 Yellowstone fires, which burned more than one million acres in the Greater Yellowstone Ecosystem. These fires provided researchers an opportunity to understand the impacts of fire and compare severely burned watersheds to watersheds with minimal burned area. Overall, researchers have concluded that the 1988 fires did not cause long-term degeneration of aquatic ecosystems. Most water quality impacts were seen in low-order streams (i.e., smaller tributaries) with steep gradients.

Downstream, higher sediment loads can fill reservoirs used for drinking water and can increase processing requirements for water treatment plants.

The sediment that ends up in streams often carries other pollutants, most notably phosphorus, which readily binds to sediment. Phosphorous is an important nutrient; however, elevated levels in waterbodies can overstimulate growth of aquatic vegetation leading to depletion of oxygen levels in water that can kill fish.

The deposition of ash into waterbodies can also affect fish by limiting visibility or clogging gills.

Nitrogen released from plant tissues during and after a fire can leach as nitrate from burned areas and be carried to nearby lakes, rivers, and streams. High nitrate levels in waterbodies used for drinking water can be a concern for human health.

Fire retardants are usually ammonia, nitrogen, and phosphorus-based and therefore can be an additional source of nutrient pollution into aquatic systems if the retardant is released into or near surface waters. Retardants that are released or flushed into waterbodies can cause short-term increases in nutrient levels and eutrophication.

Through direct heating, wildfires can increase the temperature of surface waters for a short time during the fire, and long-term increases in water temperature can occur due to removal of riparian plants that previously shaded the streams or due to streams becoming wider and shallower if channel morphology is altered.

Temperature increases can be a factor in reduced or depleted oxygen levels, which are detrimental to fish populations.

Photo: USFS Baer

THESE PRACTICES CAN HELP SLOW RUNOFF AFTER WILDFIRES

Once you have established how intense the wildfire was and how susceptible the property is to erosion, you can determine if you will need to take action to reduce erosion.

Some Runoff and Soil Erosion Control Measures

The most critical period for recovery is the first two years following a fire; however, the sooner steps are taken to reduce runoff and the potential for erosion, the better. A number of measures can lower the soil erosion hazard and protect the land's productivity and water quality. A combination of measures is often recommended when appropriate or feasible. BAER (Burned-Area Emergency Rehabilitation) treatments that provide immediate ground cover are the most effective in reducing post-fire runoff and erosion rates.

1. **Reseeding** *(For more information, see article page 36)*
   Many plants can recover after even a severe fire; it is recommended to leave existing vegetation when possible. For areas without plant cover, the soil can be covered with a mulch and/or planted or seeded vegetation, which is usually a grass that sprouts quickly and has a dense, fibrous root system to bind the soil.
2. **Mulch** can be effective ground cover immediately after wildfire; it is a common choice for post-fire hillslope stabilization. It protects the soil surface and is often used with seeding to provide ground cover in critical areas. The improved moisture retention it provides may increase the success of a seeding. Due to the cost and logistics of mulching, it is usually applied where there are items downstream at high risk for damage such as above municipal water intakes, heavily used roads, and stream reaches that are critical habitat for protected species.
3. **Channel treatments**, such as straw bales and check dams, can decrease streamflow rates in channels and streams and store sediment. They should be viewed as secondary treatments, and their use should be evaluated carefully, especially in areas where the adjacent hill slopes are

unstable. When not used correctly, check dams can cause more harm than good and may cause channel bank instability and increased erosion.

4. **Contour log** terraces can provide a barrier to runoff from heavy rain. Properly placed, they can force the water to meander back and forth across the slope between the logs, slowing the water and allowing it more time to soak in. Trees (with limbs removed) or logs 6 to 8 inches in diameter are placed on the contour perpendicular to the direction of water flow or slope. Logs should be placed in an alternating pattern so water cannot flow directly down the slope. Embed logs into the soil their entire length and backfill with soil to prevent water from running underneath. Stabilize the logs by driving in stakes on the downhill side of the logs.
5. **Straw wattles** can be used in a similar fashion. Straw wattles are flexible enough to follow the contour of the slope. Wattles are tubes of plastic netting packed with straw or similar packing material. The wattle tubes can be purchased from an erosion control material supplier (such as www.strawwattles.com). As with contour logs, the wattles should be fully embedded in the soil and secured with stakes.
6. **Silt fences** can be used where runoff is more dispersed, such as broad, flat areas. Silt fences can trap and remove sediment from runoff water. Silt fences are constructed out of woven wire fence with a fabric filter cloth. Soil is filtered out as the water and sediments pass through the cloth. Silt fences may need to be periodically maintained to remain effective.

Additional Information

Firewise: The national Firewise Communities Program is a multi-agency effort designed to reach beyond the fire service by involving homeowners, community leaders, planners, developers, and others in the effort to protect people, property, and natural resources from the risk of wildland fire – before a fire starts. Information can be found on line at www.firewise.org/.

More specific information on how to install soil erosion control practices and other methods to lessen the effects of wildfire can be found by accessing links in these U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) and WY NRCS Wildfire Recovery websites:

http://www.wy.nrcs.usda.gov/technical/ewpfactsheets/firebmp.html
http://plant-materials.nrcs.usda.gov/technical/publications/wildfirepubs.html

As mentioned previously, determining the severity of the fire and your land's erosion potential as soon as possible after a fire will help determine if any of the above measures are needed or appropriate. On federal lands, BAER teams will often develop a "post-wildfire" risk assessment. However, on private lands there are several resources that can help a landowner 1) assess the potential runoff and erosion risks that exist and 2) identify the potential practices to address those risks.

These resources include local NRCS, Wyoming State Forestry Division, conservation districts, and local extension offices.

Wattles (Photo: US Forest Service)

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