Designation: E3312 – 21

Standard Guide for Mitigation of Wildfire Impact to Source Water Protection Areas and Risk to Water Utilities[1]

This standard is issued under the fixed designation E3312; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *Overview*—Wildfires pose a significant risk to water utilities as they can cause contaminants of concern to be released into surface water and groundwater supplies (**1**).[2] This can endanger human health if systems were not designed to manage these contaminant loads.

1.2 *Purpose*—Mitigation measures of wildfire effects on sediment loads, trace minerals, and contaminants of concern on runoff in a Source Water Protection Area (**2**) is an expanding area of study that does not have a full set of regulations at the federal or state level. This guide provides public-sector and private-sector land managers and water utility operators details on how to assess the potential impacts of wildfires on watersheds and measures that can be employed to minimize or abate those impacts prior to a wildfire occurring or after it occurs.

1.2.1 This guide supplements existing watershed and Source Water Protection Area guidance.

1.2.2 This guide will recommend fuel management prior to a wildfire, suppression strategies during a wildfire, and mitigation opportunities for both forests and water treatment systems after the wildfire. It will also support collaboration between involved stakeholders (see Fig. 1 below).

1.2.3 The purpose of this guide is to provide a series of options that water utilities, landowners, and land managers can implement to limit the chance of a wildfire, specifically in a drinking water watershed, and mitigation opportunities to protect drinking water after a wildfire occurs. This guide encourages consistent management of forests to limit wildfire risks to water resources. The guide presents practices and recommendations based on the best available science to provide institutional and engineering actions to reduce the likelihood of a wildfire and the potentially disastrous consequences. It presents available technologies, institutional controls, and engineering controls that can be implemented by utilities, landowners, and land managers seeking to mitigate the risk of wildfire in a source watershed. With climate change wildfires are an increasing hazard that can affect drinking water supplies. Often water utilities are not prepared for this risk and this guide seeks to support advanced planning.

1.2.4 This guide ties into the ASTM E50 standards series related to environmental risk assessment and management.

1.2.5 The guide does not provide risk assessment, *per se*, but may help set priorities for creating a wildfire resilient watershed.

1.3 *Objectives*—The objectives of this guide are to identify the risks of a source watershed o forest to wildfire and identify actions that can be taken to manage those risks. The guide encourages users to set priorities based upon their associated risk. The guide encourages the us to develop long-term solutions for future wildfire risks.

1.4 *Limitations of this Guide*—Given the different types of organizations that may wish to use this guide, as well as variations in state and local regulations, it is not possible to address all the relevant circumstances that might apply to a particular area. This guide uses generalized language and examples for the user. If it is not clear to the user how to apply standards to their specific circumstances, users should seek assistance from qualified professionals. Risks may vary depending on the entity evaluating the risk. This guide does not take a position on the causes or science of extreme weather, natural disasters, or changing environmental conditions.

1.5 The guide uses references and information from many cited sources on the control, management, and reduction of pre- and post-fire impacts.

1.6 Several national and international agencies served as sources of information on existing and anticipated levels and management of wildfire risks to drinking water supplies including: the Water Services Association of Australia; the U.S. Department of Agriculture; the U.S. Environmental Protection Agency.

1.7 This guide recommends reference to current regulatory information about risks gathered from various state agencies,

[1] This test method is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.05 on Environmental Risk Management.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

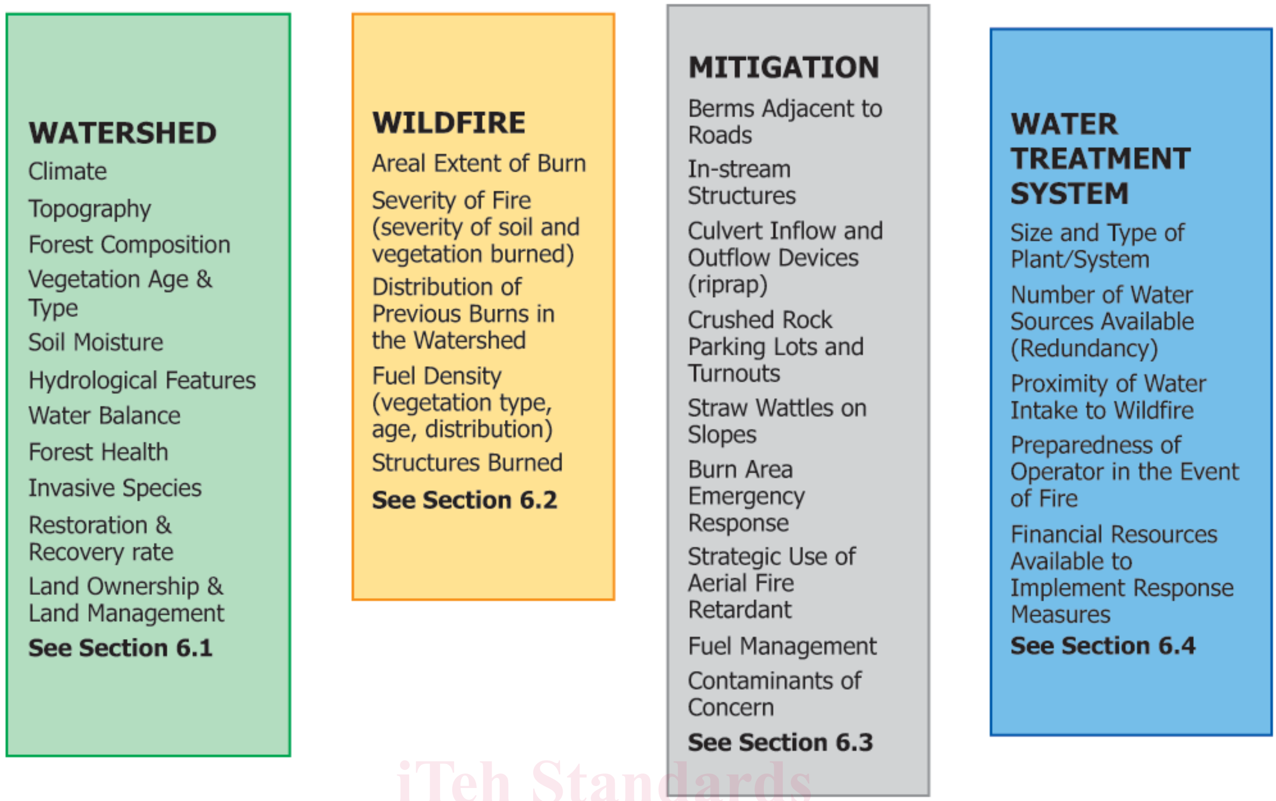

FIG. 1 Place-based characteristics for consideration when assessing threats to water supplies and treatment due to a wildfire (adapted from (3)).

such as departments of environmental protection and water resources boards.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Adaptation and resiliency measures, however, may be consistent with, and complementary to, other safety measures.

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E3032 Guide for Climate Resiliency Planning and Strategy
E3136 Guide for Climate Resiliency in Water Resources
E3241 Guide for Coordination and Cooperation between Facilities, Local Emergency Planning Committees, and Emergency Responders

3. Terminology

3.1 *Definitions:*

3.1.1 *adaptive capacity, n*—the ability of a system, either natural or engineered, to adjust to extreme weather, including climate variability and to moderate potential damages, take advantage of opportunities, or to cope with the consequences.

3.1.2 *climate, n*—the average and range of weather conditions in an area. More rigorously, the statistical description in terms of the mean and variability of relevant weather parameters over a period of time long enough to ensure representative values for a month or season.

3.1.2.1 *Discussion*—These parameters are most often surface variables such as temperature, humidity, air pressure, precipitation, and wind.

3.1.3 *contaminants of concern, n*—any physical, chemical, biological, or radiological substance found in air, water, soil, or biological matter that has a harmful effect on plants or animals; harmful or hazardous matter introduced into the environment.

3.1.4 *extreme weather events, n*—catastrophic storms, high winds, tornadoes, hurricanes, floods, acute water shortages, wildfires, blizzards, heat waves, extreme drought, or any other related instances causing significant injury, loss of life, or property damage.

3.1.4.1 *Discussion*—These phenomena are at the extremes of the historical distribution, including especially severe or unseasonal conditions.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.5 *fire risk, n*—various rating systems to determine the likelihood of a fire, given weather and wind conditions.

3.1.5.1 *Discussion*—The National Fire Protection Association has a rating system (**4**). The USDA developed a Wildfire Risk Assessment Framework for Land and Resources Management (**5**) that stakeholders may find useful.

3.1.6 *mitigation, n*—attempts to lower or compensate for risks from weather/climate related events including flood, fire, drought, extreme temperature, sea level rise, and storms.

3.1.7 *source water protection area, n*—watershed area that is safeguarded to preserve and improve water quality for consumers.

3.1.7.1 *Discussion*—U.S. Environmental Protection Agency is the organization that originally defined this term (**6**).

3.2 *Acronyms:*

3.2.1 BAER – Burned Area Emergency Response

3.2.2 DWMAPS – Drinking Water Mapping Application to Protect Source Waters

3.2.3 ENVI – Environment for Visualizing Images

3.2.4 GRASS – Geographical Resources Analysis Support System

3.2.5 gS-SURGO – Gridded Soil Survey Geographic database

3.2.6 HRU – Hydrologic Response Unit

3.2.7 NGO – Non-Governmental Organization

3.2.8 MFI – Mean Fire Interval

3.2.9 NRCS – Natural Resources Conservation Service

3.2.10 SAR – Synthetic Aperture Radar

3.2.11 SBS – Soil Burn Severity

3.2.12 SWAT – Soil and Water Assessment Tool

3.2.13 USDA – U.S. Department of Agriculture

3.2.14 USEPA – U.S. Environmental Protection Agency

3.2.15 USGS – U.S. Geological Survey

4. Significance and Use

4.1 This guide addresses issues related solely to strategies and the development of a plan to address wildfire-related physical and chemical changes to water resources in Source Water Protection Areas. This guide does not include specific advice on risk assessment. Mitigation strategies and planning may consist of a wide variety of actions by individuals, communities, or organizations to prepare for the impacts of wildfires on water quality and quantity in Source Water Protection Areas (see Guide E3136).

4.2 Source water protection activities not only help the utility identify risk, but they are also necessary to educate regulatory agencies, permitting authorities, and the community about the impacts that their actions can have on source water quality or quantity of the drinking water.

4.3 *Example Users:*

4.3.1 Federal, tribal, state, or municipal facility staff and regulators, including departments of health, water, sewer, and fire;

4.3.2 Financial and insurance institutions;

4.3.3 Federal, tribal, state, or local land managers;

4.3.4 Public works staff, including water systems, groundwater supplies, surface water supplies, stormwater systems, wastewater systems, publicly owned treatment works, and agriculture water management agencies;

4.3.5 Consultants, auditors, state, municipal and private inspectors, and compliance assistance personnel;

4.3.6 Educational facilities such as experimental forests and nature preserves;

4.3.7 Non-regulatory government agencies, such as the military;

4.3.8 Wildlife management entities including government, tribal, and non-governmental organizations (NGOs);

4.3.9 Cities, towns, and counties, especially in developing climate vulnerability strategies and plans;

4.3.10 Commercial and residential real estate property developers, including redevelopers;

4.3.11 Non-profits, community groups, and land owners.

4.4 Coordination and cooperation must fit into the process for improving community preparedness.

4.4.1 Preparedness is based first on the community developing a broad awareness and understanding of the risks that are present locally. Next comes a community-wide evaluation of which community members or assets are most vulnerable to risks, the mechanisms or pathways of risks, and the existing capabilities to address those risks should a wildfire occur (see Guide E3241). The capabilities being evaluated include more than the ability of the first responders or wildland firefighters to take actions. It includes the capabilities of all community members to take appropriate actions.

4.4.2 All communities have capability gaps when evaluated against the risks present in the community. Strategic planning aims to fill those capability gaps with prioritization for efforts developed by the community members. Again, improved preparedness is the goal, not simply focusing on response capacity. A wildfire preparedness plan is a good first step.

4.4.3 Filling capability gaps requires the use of all the regulatory and social tools available to the community and its partners. All community members have a stake in accident prevention, consequence reduction, and improved collective ability to communicate and respond. Improvements are made through increased awareness, education, training, cooperative programs, and practice. Addressing the identified capability gaps can include a broad range of options such as accident prevention to creation of expectations for the actions of community members to be able to shelter, evacuate, and provide aid to others. Stakeholder engagement is critical to successfully closing capability gaps. This could include forest management, clearing fuel from around structures, and upgrading water filtration systems.

4.4.4 Accomplishing these tasks is a community-level activity. While it might be led by an emergency manager or local emergency planning committee, the key to successful preparedness planning is broad coordination and cooperation involving all community members (see Guide E3241).

5. Risk and Vulnerability Assessment

5.1 This guide establishes a framework of wildfire risk and vulnerability assessment approaches for water resources in North America. It may have value when applied to other areas. The user is advised to review *Handbook for Developing*

Watershed Plans to Restore and Protect our Waters (**7**), and *Developing a Watershed Vulnerability Index* (**8**).

5.2 *Introduction to the Concept of a Risk and Vulnerability Assessment:*

5.2.1 Wildfire may pose both direct and indirect risks or threats to businesses and properties including water utilities and water users. Wildfire may cause economic damages in the form of flood damage, water supply disruptions, critical water supply infrastructure outages, increased insurance rates, decreased property values, and reduction of water quality. This guide addresses wildfire preparedness strategies and plans, taking a measured approach to promote effective risk management strategies for the highest priority vulnerabilities identified by the user.

5.2.2 *Risk Communication and Stakeholder Engagement*—The user should seek the input of the public and conduct outreach activities and community engagement in identifying the most vulnerable Source Water Protection Area in the region of concern. Table 1 identifies potential significant stakeholders. The user should involve all relevant stakeholders based upon the characteristics of land ownership as well as public and private infrastructure within the Source Water Protection Area.

5.3 Communicate vulnerability to the public; ensure stakeholders are aware of actual risk and address risk perception barriers. This includes addressing non-support for key adaptation measures because the risk is perceived as low.

5.3.1 Identify stakeholders and integrate stakeholder needs into wildfire response plans. (See Table 1.)

5.3.2 Plan, prioritize, prepare, implement, and review plan over time. (See Fig. 2 from the U.S. EPA.)

5.3.3 Identify the water resource, its current conditions, beneficial uses, and vulnerabilities. This includes the lifespan of any critical equipment and structures used to manage the resource.

5.3.4 Establish the wildfire-related water utility parameters of concern. Decide on a time frame for the risk and vulnerability assessment.

5.3.5 *Conduct the Risk and Vulnerability Assessment:*

5.3.5.1 Assess the wildfire risk based on the consequence of an impact and the probability and likelihood of occurrence.

5.3.5.2 Understand the level of risk perception and risk tolerance for the source water protection area, the landowner(s), land managers, water utility, with consideration of the contaminants of concern.

5.3.5.3 Contaminants of concern can be sediment that is mobilized after a wildfire or other chemicals or substances that are located in said soil. The contaminants could be a result of heavy industry operating in the area or naturally occurring.

5.3.6 Assess the wildfire vulnerability of the water resource and water utility infrastructure based on 5.3.1 – 5.3.5.3 above.

6. Procedure

6.1 This section follows the four broad categories illustrated in Fig. 1; watershed, wildfire, mitigation, and water treatment system.

6.2 *Steps to Assess Vulnerability in a Source Watershed:*

6.2.1 The land managers and water utility should confirm the boundaries of the watershed and its subbasins in accordance with federal or state regulations. The U.S. EPA's Drinking Water Mapping Application to Protect Source Waters (DWMAPS) is a useful tool and is available at https://geopub.epa.gov/DWWidgetApp. The data sets are current as of March 2021 (**9**).

6.2.1.1 The DWMAPS will show the approximate location of known potential sources of contaminants within the watershed. These potential sources of contamination include, but are not limited to, mines and quarries, serpentine outcrops, and current and abandoned railroad rights-of-way.

TABLE 1 Stakeholder Identification

Users	Potential Stakeholders
Small businesses	Business and neighborhood associations.
Service industries	Customers, industry associations, and consumer groups.
Government facilities and regulators	Federal, military, tribal, state, or municipal employees and citizen concern groups including departments of health, water customers, sewer customers, and fire departments.
Financial institutions	Bank and insurance staff and customers.
Public works managers	Staff and customers of water systems, groundwater supplies, surface water supplies, stormwater systems, wastewater systems, publicly owned treatment works, and agriculture water management agencies.
Consultants	Contractors, auditors, state, municipal, and private inspectors, and compliance assistance personnel.
Non-profit community organizations and groups	Conservation associations, land trusts, community action groups, historic preservation groups.
Non-regulatory government	Military base groups, neighborhood associations, and planning agencies.
Wildlife management	Government and tribal forest and conservation services, park users, and non-governmental conservation organizations.
Local government and the public	Cities, towns, and counties, especially in developing wildfire vulnerability strategies and plans, and associated citizen groups.
Real estate agencies	Commercial forestland, property, real estate professionals and managers.

FIG. 2 Source Water Protection Flow Chart from US EPA Source Water Protection (6).

6.2.2 The land managers and water utility and other stakeholders should also consider applying U.S. Department of Agriculture's Soil and Water Assessment Tool (SWAT) (**10**). The Soil & Water Assessment Tool is a small watershed to river basin scale model used to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control, and regional management in watersheds.

6.2.2.1 Developed in the 1990s by the United States Department of Agriculture (USDA), the public domain SWAT has been widely accepted as a useful modeling tool for watershed analysis and management (**11**). Primary reasons for development of SWAT were to predict the long-term effects of land management practices in large, complex watersheds (**10**). SWAT is a physically-based model that uses topography, climate, soil, land cover, land use, and management data to calculate a wide range of hydrologic outputs through physical equations and laws (**10**). This is different from empirically based models that utilize regression equations to calculate output variables. SWAT operates at the basin scale, making it a semi-distributed model. Sub-basins are defined by topography and a user-specified stream definition threshold. Users can find the latest models and online training from the Texas A&M University at https://swat.tamu.edu/ (**12**).

6.2.2.2 Each sub-basin contains a reach of the stream that will transfer its loadings at its outlet to the inlet of the next downstream sub-basin, therefore creating a stream network. Within each sub-basin, hydrologic response units (HRUs) define unique combinations of land use, soil, and slope categories. These HRUs are not spatially connected but rather represent a percentage of each sub-basin (**11**). HRUs and their unique combination of parameters are used to calculate sub-basin outlet loadings (**11**). SWAT is also a continuous time model allowing for investigation of long-term implications of changes in land management practices, land use, or climate. Further advantages of SWAT include the readily available land use, soil, and climate input data and its ability to model very large watersheds (**10**).

6.2.3 Earth observation remote sensing tools such as Landsat 8 Operational Land Imager and Finland's ICEYE synthetic aperture radar can be used to identify the vegetation species and density of each sub-basin (**13**).

NOTE 1—ICEYE operates small SAR satellites that can provide data on wildfire location and intensity in real time.

6.2.3.1 The Landsat Operational Land Imager data, coupled with Environment for Visualizing Images (ENVI) and the Geographic Resources Analysis Support System (GRASS) software can be used to process satellite images to estimate the level of forest fire danger of the source water area by vegetation types (**13**).

6.2.3.2 The European Space Agency's Sentinel-1 satellite mission provides a spatially and temporally complete global SAR dataset. Operational usage of optical earth observation datasets available at multiple times each day can produce fire hotspot detection point data (and in some instances, fire-affected area products). These datasets have enhanced fire management activities, with information available on web interfaces hosted by state and federal government (**14**).

6.2.4 The National Aeronautics and Space Administration (NASA) has additional remote sensing platforms and datasets available such as soil moisture data, evapotranspiration data, water balance data, elevation, and terrain data. See https://earthdata.nasa.gov/learn/pathfinders/wildfire-data-pathfinder (**15**).

6.2.5 The stakeholders should apply local resources to augment knowledge of potential sources of contamination. For example, local agencies may have information on previous land uses, and they may have generated predictions of increased turbidity, sediment, and water quality impairment that would be expected following precipitation in the watershed and sub- basins that have been burned by wildfire.

6.2.6 Invasive insects, such as western bark beetle, Asian Long-horned beetle, and Emerald ash borer damage and weaken trees, increasing the fuel load in the watershed. Feral swine damage tree bark and root systems. In addition, feral swine damage the A1 and A2 soil horizons, which can lead to increased erosion (**16**).

6.2.7 Remote sensing data from earth orbiting satellites can be used to quantify restoration and recovery rates for specific subbasins (**17**). Fuel treatment options (see 6.3) significantly affect vegetation restoration and recovery rates following fires (**18**). The user should collaborate with landowners and land managers within the source water area to determine basin-specific restoration and recovery rates. The user should consider the effects of drought on watershed growth.

6.2.8 *Soils:*

6.2.8.1 The Natural Resources Conservation Service (NRCS) provides a Gridded Soil Survey Geographic (gSSURGO) database on soil type distribution that includes certain parameters used by the SWAT model (**19**). Soil types are grouped into map units based on their productivity, parameters, and interpretations by NRCS surveyors. These map units and soil parameters are also contained in the "SWAT_US_soils" database where soil type information is accessed and used in calculating model output data.

6.3 *Wildfire:*

6.3.1 *Fire Types:*

6.3.1.1 *Ground fire*—A fire that burns in surface organic materials such as peat or deep duff layers. Ground fires typically undergo a large amount of smoldering combustion and less active flaming than other types of fires. They may kill roots of overstory species because of prolonged high temperatures in the rooting zone.

6.3.1.2 *Surface fire*—Fires that burn only the lowest vegetation layer, which may be composed of grasses, herbs, low shrubs, mosses, or lichens.

NOTE 2—In forests, woodlands, or savannas. surface fires are generally low to moderate severity and do not cause extensive mortality to the overstory vegetation.

6.3.1.3 *Understory or sub-canopy fire*—A fire that burns trees or tall shrubs under the main canopy. Depending on structure, this may also be called a surface fire.

6.3.1.4 *Crown fire*—A fire that burns through the upper tree or shrub canopy.

NOTE 3—In most cases the understory vegetation is also burned. Depending on species, a crown fire may or may not be lethal to all dominant vegetation. An example of this would be many shrub and broadleaf tree species that sprout from roots, root crowns, or stem bases after their tops are killed. A crown fire may be continuous or may occur in patches within a lower severity burn.

6.3.1.5 *Stand replacement fire*—A fire that is lethal to most of the dominant above ground vegetation and substantially changes the vegetation structure.

NOTE 4—Stand replacement fires may occur in forests, woodlands, and savannas, annual grasslands, and shrublands. They may be crown fires or high-severity surface fires or ground fires.

6.3.1.6 *Mixed-severity fire*—The severity of fires varies between nonlethal understory and lethal stand replacement fire with the variation occurring in space or time.

NOTE 5—In some vegetation types the stage of succession, the understory vegetation structure, the fuel condition or the weather, or a combination thereof, may determine whether a low- or high-severity (or surface or crown) fire occurs. In this case individual fires vary over time between low-intensity surface fires and longer-interval stand replacement fires. In others, the severity may vary spatially as a function of landscape complexity or vegetation pattern. The result may be a mosaic of young, older, and multiple-aged vegetation patches.

6.3.1.7 *Fire Intensity*—The amount of energy or heat release per unit time or area during the consumption of organic matter (**20**). The term has also been defined as "the rate of energy or heat release per unit time, per unit length of fire front, regardless of its depth." Other measures of fire intensity include fire line intensity, reaction intensity, and total fire flux, all of which refer to the actual burning event. Fire intensity is a real-time burning measurement and does not directly indicate the effects of the fire on the vegetation or soil or the subsequent ecosystem response (**21**). For example, a high intensity fire that exhibits extreme fire behavior (such as high flame length, rapid rate of spread, or overstory crown consumption) might result in low- or moderate- degree effects on the soil (soil burn severity) due to short heat residence time. Typical examples are crown fires in forests or shrub or grassland fires. Conversely, a low intensity fire (smoldering log) can produce intense heat and can be long duration, resulting in high soil burn severity in the area under the log, tree root channels, or woody debris concentration. The U.S. Forest Service's Field Guide for Mapping Post-Fire Soil Burn Severity (**21**) describes methods for assessing burn severity.

NOTE 6—Fire intensity is correlated to soil hydrophobicity (soil repels water). Water repellent soils tend to have higher erosion potentials.

6.3.1.8 *Fire frequency*—The number of times that fires occur within a defined area and time period.

6.3.1.9 *Fire return interval (or fire interval)*—The time between fires in a defined area, usually at the scale of a point, stand, or relatively small landscape area. This is called Mean Fire Interval (MFI) in the LANDFIRE system, where it refers to the average number of years between fires in representative stands.

6.3.1.10 *Fire rotation (interval)*—is the time required to burn an area equal to a defined area of the landscape (**22**). The entire area may not burn during this period; some sites may burn several times and others not at all.

6.3.2 *Areal extent of burn:*

6.3.2.1 Local, regional, state, and interagency entities provide maps showing the areal extent of wildfires. Additional tools available to determine the areal extent of the wildfire include aerial photography, the LANDSAT Burned Area (BA) datasets available through https://earthexplorer.usgs.gov/, and the datasets available from landfire.gov (**22**).

6.3.2.2 *Monitoring Trends in Burn Severity (MTBS)*—is an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present (**23**). This includes all fires 1000 acres or greater in the western United States and 500 acres or greater in the eastern Unites States. The extent of coverage includes the continental United States, Alaska, Hawaii and Puerto Rico.

6.3.2.3 The area extent of each wildfire should be documented and reviewed to determine if the fire exposed known or suspected sources of contamination.

(1) Sources of inorganic contaminants include, but are not limited to mines, quarries, local serpentine outcrops.

(2) The use of aerial-applied fire retardants should also be mapped to determine the direction of flow of these materials through the watershed during periods of precipitation. However, there is minimal risk of contamination from fire retardants due to designated buffer zones (routinely 300 ft) adjacent to creeks, streams, rivers, and lakes.

(3) Fire breaks and temporary access roads that were constructed as part of the fire response represent additional sources of sediment and total suspended solids.

6.3.2.4 The areal extent of the wildfire can be mapped into the Soil and Water Assessment Tool to help land managers, land owners, and the water utility predict erosion rates and sediment loads within each subbasin.

6.3.3 *Severity of fire:*

6.3.3.1 Land managers and water utilities should use locally generated fire maps coupled with remotely sensed data and information from Burned Area Emergency Response (BAER) teams to quantify the severity of the fire.

(1) Sources of remotely sensed date include the United States government's Burn Severity Portal https://burnseverity.cr.usgs.gov (**24**).

6.3.4 *Soil Burn Severity:*

6.3.4.1 Wildfire burn severity is often thought of in terms of the visual impacts to above- ground vegetation, but the post-fire landscape response (erosion, flooding, and mass movement) is generally more strongly correlated to soil burn severity. When characterizing soil burn severity, examining the vegetation is a good starting place to understand the conditions on the ground. Armed with that information, the BAER team's watershed specialists (soil scientists, hydrologists, and geologists) field verify different vegetation burn intensities to extract patterns of how fire affected and changed the properties of the soil. Pre-fire ground cover, forest type, fire behavior, slope, aspect, and other factors all influence soil burn severity. After field observations are collected, specialists adjust the vegetation severity map to create the soil burn severity (SBS) map. The SBS is broken into four different classes: unburned (dark green), low severity (light green), moderate severity (yellow), and high severity (red).

6.3.4.2 Low severity areas generally have intact and recognizable litter layers (organic material on the forest floor, such as pine needles and twigs). These litter layers may be charred but are not consumed. Underlying topsoil is intact, and near-surface fine roots are unburned. These soils have enough cover to protect them from erosion during rain events because their natural porosity and structure allow rain to soak into the soil instead of running off, while fine roots provide stability. In low severity areas, burns may have been patchy islands of green vegetation and intact canopies may be present.

6.3.4.3 Moderate severity areas generally have up to 80% more their pre-fire surface litter layers consumed by fire. Black or gray ash may be present on the soil surface. Fine roots near the surface may be scorched or killed. Topsoil layers are generally intact with minimal impacts to the soil's ability to absorb moisture. Soils with moderate severity are more susceptible to erosion in post-fire rain events because they have lost protective surface cover and may have less surface stability because of root mortality.

6.3.4.4 High severity areas generally have had all their pre-fire surface litter layers consumed by fire. White or gray ash may be present on the soil surface. Fine roots are often fully burned/consumed within several inches of the soil surface, and even large tree roots may have burned deep into the soil. Soil may be powdery or grainy and loose, unable to bind together and retain water. These soils are very susceptible to erosion and often have high surface run-off during rainstorms.

6.3.4.5 SAR data from earth observation satellites and aerial platforms are advantageous when fires are still active nearby, as it is able to detect changes on the ground through smoke and ash that may inhibit other sensors. Due to the penetration of the SAR signal through vegetation, there is also scope to measure the burning of understory vegetation not visible to optical sensors. These data complement other earth observation data types such as LANDSAT and MODIS, for longer-term fire management objectives, including estimates of fuel load and annual burned area mapping to evaluate fuel age and the efficiency of controlled burns (**14**).