

2016

REPORT ON THE HEALTH OF COLORADO'S FORESTS

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FIRE AND WATER



Director's Message

January 2017



Michael B. Lester, State Forester and Director. Photo: Society of American Foresters

Fire and water. The words themselves evoke contrasting forces of nature – fire, often viewed as an all-consuming inferno of destruction; water, a quenching and life-sustaining means of rejuvenation. But such generalizations are not always accurate, especially in Colorado. Fire is necessary to the ecology of healthy forests, and can be a useful wildland firefighting tool for containment and fuels reduction, while life-giving streams and rivers may turn into raging torrents that cause heavy erosion and loss of property and life.

So important are these two natural elements that we've chosen them for the focus of this year's forest health report, to give you a better understanding of their impacts on Colorado's forested lands. Fire and water are integrally linked as necessary components in shaping a healthy, natural forest environment; in return, both are heavily influenced by forests themselves.

The role of wildfire in Colorado's forests has a long history. Human

intervention to manage forests for reduced wildfire risk has evolved as we seek to coexist within forested environments. Fire Adapted Communities® initiatives, supported through such programs as Firewise Communities/USA® and Community Wildfire Protection Plans, are facilitated by the Colorado State Forest Service and other organizations to provide fire mitigation assistance to Colorado landowners.

In this report, we are pleased to share a related success story about residents of Jackson County who have worked to better protect their community from wildfire. A fire they faced in 2016 was the Beaver Creek Fire – a 38,000-acre wildfire northwest of Walden, much of which occurred in areas dominated by beetle-kill lodgepole pine – that burned from mid-summer until well after snow began to fall. The fire could serve as a case study to offer insights regarding future forest management actions and associated impacts on fire behavior in areas containing large amounts of dead timber, to proactively develop strategies to protect property and save lives.

Fire has significant impacts on people and forests; less obvious are the effects it has on the quality and quantity of water available for human and agricultural consumption. The demand for water, of particular concern in rapidly developing sections of our state, underscores the need to work across organizational boundaries to develop effective solutions. Interagency efforts highlight the importance of forest management to safeguard water supplies from post-fire erosion so water providers can maintain

their ability to provide safe, clean water to Colorado residents in a cost-effective, consistent manner. In this report, we take the opportunity to highlight collaborative partnerships and projects with Denver Water, Northern Water, the City of Ouray and professionals implementing Colorado's Water Plan.

I invite you to absorb this information, and its implications, so you can weigh in on the all-important discussions facing our legislators and citizens in directing the management of our forests.

Michael B. Lester
State Forester and Director
Colorado State Forest Service

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Front cover photo: 2012 High Park Fire near Horsetooth Reservoir, Larimer County. Photo: Ryan DeBerardinis, Shutterstock.com

The Role of the Colorado State Forest Service



CSFS Community Forestry Program Manager Keith Wood teaches an urban and community forestry workshop, with Boyd Lebeda, CSFS Fort Collins District forester. Photo: Grace Mirzeler, Council of Western State Foresters



Assistant District Forester Kathryn Hardgrave, CSFS Salida District, on a site visit to a landowner's property. Photo: Grace Mirzeler, Council of Western State Foresters

For more than 60 years, the Colorado State Forest Service (CSFS) has been living out its mission: To achieve stewardship of Colorado's diverse forest environments for the benefit of present and future generations. This is made possible not only by actions within the forestlands of Colorado, but also by initiating face-to-face conversations with surrounding community members, landowners and other agencies.

Areas in which the CSFS offers leadership and guidance include forest management; wildfire mitigation and community planning; wood utilization and marketing; outreach and education; and insect and disease detection, surveys and response. The agency offers technical assistance in urban and community forestry, including tree care and management plans, and is Colorado's primary provider of seedling trees for conservation purposes such as creating living snow fences and windbreaks, reforestation areas after wildfire and enhancing wildlife habitat.

The CSFS works through 19 district and field offices statewide, with a headquarters located in Fort Collins. The agency operates within the Warner College of Natural Resources at Colorado State University and fulfills the responsibilities of the Division of Forestry within the Colorado Department of Natural Resources.

Executive Summary

Annual reports on the health of Colorado's forests provide information to the Colorado General Assembly, stakeholders and citizens by summarizing the current health and condition of forests across the state. This year's report offers a special focus on how forests impact and are conversely affected by wildland fire and water flowing through forested watersheds. Between broader sections on fire and water, the report offers a detailed review of 2016 insect and disease activity in Colorado forests.

Colorado's 24.4 million acres of forestland provide immeasurable social, economic and ecological benefits to its citizens and visitors. Forests offer a sustainable wood products industry, diverse wildlife, fresh water and ample recreation opportunities. But they face numerous threats, and can present risks to citizens and visitors. These risks, ranging from increasingly large, severe wildfires and insect infestations to long-term droughts, are likely to be amplified in the future, as climate model projections predict statewide warming between 2.5°F and 6.5°F by 2050.

In the face of changing climatic conditions, a long history of fire suppression already has altered historic fire cycles and led to the dangerous build-up of fuels in some areas. Population growth into the wildland-urban interface (WUI) – the area where structures and other human developments meet or intermingle with wildland fuels – presents further challenges. More than 2 million people live in Colorado's WUI, and this number is expected to increase significantly. Compounding this challenge is that wildland fuel conditions are changing in the state's forests, in part due to the accumulation of bark beetle-killed trees. Forest management, including thinning trees to improve forest resiliency and reduce or alter fuel loads available for wildfire, is imperative to effectively address threats to forest health and public safety.



Ice forming on the creek near Willis Gulch Trail, Chaffee County. Photo: Joy Jackson

Fire Adapted Communities®, or those taking personal responsibility and implementing actions to reduce wildfire risk, provide another way to deal with WUI challenges. Actions residents take not only reduce their wildfire risk, but also increase forest health through sound forest management practices. The Colorado State Forest Service (CSFS) offers or assists with many programs and resources for landowners and communities working to become fire-adapted, including Community Wildfire Protection Plans (CWPPs), Firewise Communities/USA® and the online Colorado Wildfire Risk Assessment Portal. As testament to the importance of these and similar programs, the Jackson County CWPP played a significant role in helping wildland firefighters prepare for and manage Colorado's 38,000-acre Beaver Creek Fire in 2016.

To help increase funding opportunities to mitigate wildfire risk in the WUI before a fire starts, the Colorado General Assembly created the

Wildfire Risk Reduction Grant (WRRG) Program in 2013 to assist with funding community-level and statewide actions throughout Colorado. To date, the WRRG Program has awarded nearly \$12 million in grants to reduce risk of damage to property, infrastructure and water supplies on non-federal lands.

A key source of information for these reports is the annual aerial forest health survey, a cooperative project between the CSFS and the Rocky Mountain Region of the USDA Forest Service. Other data sources include information derived from CSFS field inspections and contacts with forest landowners, and the Colorado Forest Inventory and Analysis Program. In addition, the CSFS cooperates with other agencies including the Colorado Department of Agriculture and USDA Animal and Plant Health Inspection Service in conducting special surveys to ensure early detection of exotic insect species that threaten both urban and native forests.

Colorado's most destructive forest pests in 2016 continued to be several

species of bark beetles that attack and kill conifers. Spruce beetle was Colorado's most damaging insect pest for the fifth successive year, impacting 350,000 acres of high-elevation Engelmann spruce forest. Other bark beetles that affected Colorado forests in 2016 included Douglas-fir beetle, western balsam bark beetle and associated root disease, and fir engraver beetle. Mountain pine beetle, a major pest of Colorado's forests for two decades, continued to decline statewide and caused only localized damage.

Western spruce budworm was Colorado's most widespread insect defoliator in 2016, causing damage on 226,000 acres of Douglas-fir, white fir and spruce in central and southern Colorado. Douglas-fir tussock moth, another defoliating insect, saw its populations collapse, likely from a viral disease. But the non-native emerald ash borer (EAB) continued to expand, and was detected for the first time in Colorado outside the City of Boulder, in both Longmont and the community of Gunbarrel.

The same Colorado forests impacted by insects, disease and wildfire provide sustainable water supplies – one of the most critical resources throughout the West. Nineteen states and Mexico derive water from Colorado's high-country watersheds, utilized by entities ranging from municipalities, industries and agriculture to fish and wildlife. But here and in other Western states, unhealthy and overly dense forests set the stage for exceptionally large, devastating wildfires that significantly increase risks for dangerous flooding, extreme erosion, degraded water quality and reduced water storage capacity.

CSFS foresters work with land managers and private landowners to accomplish effective forestry practices and reduce the risk of severe wildfire and post-fire flooding. Every year, the CSFS helps treat more than 17,000 acres of forestland to help improve forest health and reduce risks to watersheds. The

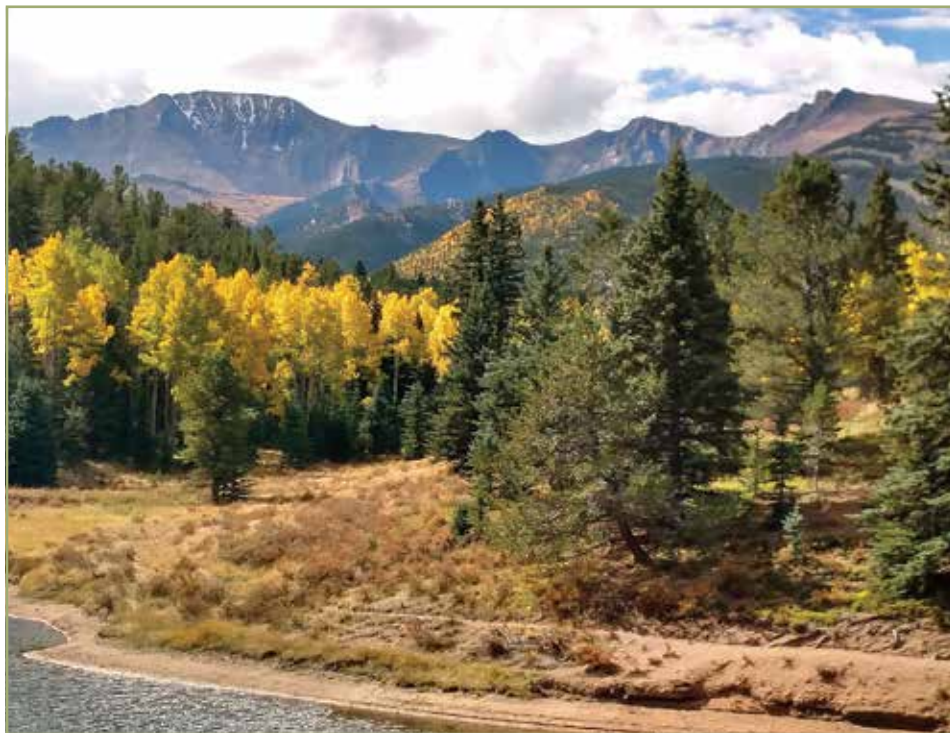
CSFS Nursery also grows more than 500,000 seedling trees and shrubs each year for conservation purposes including reforestation of burned areas, enhancing wildlife habitat and reducing soil erosion. The agency additionally helps address the risk of nonpoint source pollution to water supplies by providing Forestry Best Management Practices for Colorado, which help forest landowners, land management agencies and the timber industry to protect water supplies and avoid inadvertently polluting them.

Partnerships are key to long-term forest and watershed health. As Colorado's primary resource for technical forestry assistance, education and outreach, the CSFS administers programs and participates in collaborative efforts focused on actions that: reduce the impacts of forest insects and diseases; improve forest health; strengthen the wood products industry; and mitigate wildfire risk to help protect life, property and watersheds. Key

partnerships described in this report include those with Denver Water, the City of Ouray, Colorado Springs Utilities and the Colorado-Big Thompson Partnership.

In 2017 the CSFS and its partners will have an augmented capacity to address forest watershed concerns, following the Colorado General Assembly passing new legislation in 2016 that will allow for enhanced management of Colorado watersheds. House Bill 16-1255 will address forest management in three ways: through funding cross-boundary projects under a new Master Good Neighbor Agreement in Colorado; by conducting a statewide watershed analysis; and via the reinstatement of a CSFS-led Forest Health Advisory Council.

The CSFS will continue to work with private forest landowners, cooperators and stakeholders to best manage Colorado forestlands. To learn more about the information within this report, please contact the nearest CSFS office.



View of Pikes Peak from the South Catamount Reservoir, where 90 percent of the area is under active forest management. Photo: Andy Schlosberg, CSFS

Wildfire in Colorado: A Rising Challenge

Colorado's 24.4 million acres of forestland provide immeasurable social, economic and ecological benefits to its citizens and visitors. These forests offer a sustainable wood products industry, diverse wildlife species, fresh water and abundant recreation and tourism opportunities. But Colorado forests face numerous threats, and can present risks to citizens and visitors.

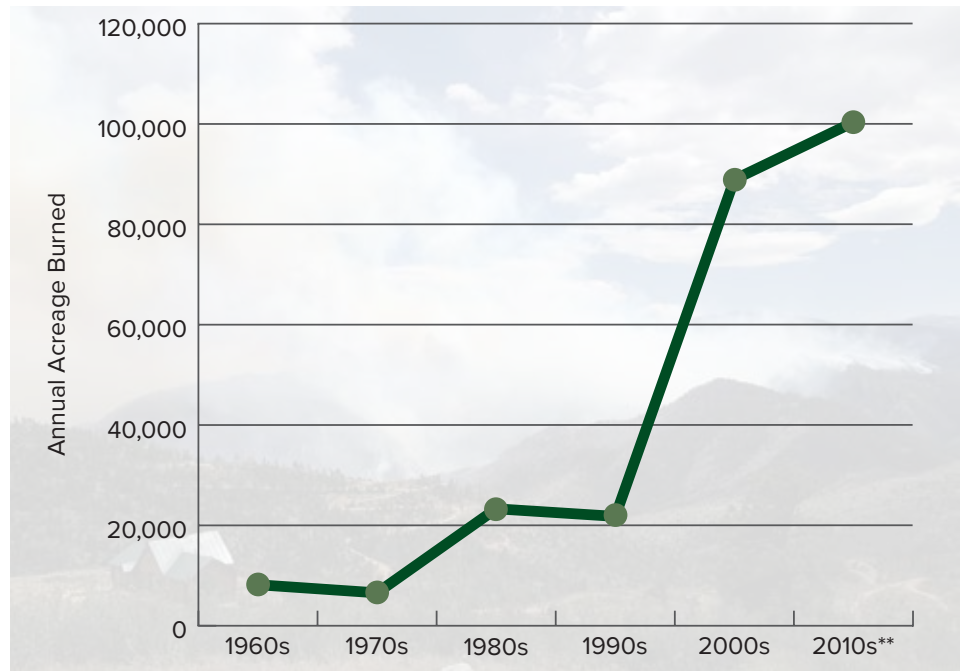
Wildland fire is a prime example. Fire plays a critical role in maintaining the health of forest, shrubland and grassland ecosystems in Colorado. Lower-elevation forests rely on frequent, low-intensity fires to control regeneration and reduce understory vegetation, while some high-elevation forest types, such as lodgepole pine, rely on high-intensity fire to regenerate the forest. But a long history of fire suppression has altered historic fire cycles and led to the dangerous build-up of fuels in some areas.

Population growth into the wildland-urban interface (WUI) – the area where structures and other human developments meet or intermingle with wildland fuels – presents further challenges. Colorado's WUI population grew from 980,000 people in 2000 to more than 2 million people in 2012, and this number is rising. According to data from Headwaters Economics, only 20 percent of the state's WUI is currently developed.



Wildfire moves through the crowns of trees during the 2016 Beaver Creek Fire, creating a higher-intensity wildfire. Photo: Beaver Creek Incident Management Teams

Colorado Wildfires: Average Annual Acreage Burned, by Decade 1960-2015*



*State and private lands only

**Average for decade through 2015

In addition to the complications of a growing WUI, the wildfire season has lengthened due to a changing climate, resulting in wildfires that start earlier, last longer, cost more to suppress, cause more damage, and threaten more lives than ever before. As Colorado's population increasingly grows in the WUI, human exposure to the side effects of wildfire – including post-fire erosion impacting water sources and reduction in air quality due to smoke – will become a significant public health issue.

Is Beetle-Kill Altering Wildfire Risk?

Beyond the problems of overgrown forests and an increasing WUI population, the state's ongoing forest health concerns are due to a combination of factors, including poor stand

conditions, long-term droughts and warming annual temperatures. The resulting forests are unhealthy and overly dense, and set the stage for current and future insect and disease epidemics.

Colorado's mountain pine beetle (MPB) epidemic from approximately 1996 to 2014 resulted in almost 3.4 million acres impacted, primarily in lodgepole and ponderosa pine forests. Trees that were more recently killed are still standing; those that died from the epidemic more than a decade ago have increasingly fallen to the ground in chaotic fashion. These "jackstrawed" stands are made up of a combination of standing, semi-fallen and downed dead wood, creating a unique arrangement and availability of fuel for future wildfire. The MPB epidemic has thus changed the fuel arrangement within Colorado's forests, which in turn affects fire behavior and wildfire suppression tactics.

Implications for Fire Suppression and Forest Management

Consider how a campfire is properly built: first with kindling, then by adding small branches and larger logs. This is because fires ignite quickly in smaller fuels, while the larger wood ultimately burns longer and puts out more heat. Fuel in the form of kindling and small branches also burns quickly without much smoke; however, the larger logs in a campfire burn and smoke for much longer, even well after the flames die out.

Now, imagine a campfire that encompasses 3.4 million acres, or the area impacted by MPB in Colorado.

During 2016's Beaver Creek Fire, which burned 38,380 acres northwest of Walden, foresters and firefighters were given a glimpse into likely future challenges facing wildfire suppression and forest management efforts. These include longer duration wildfires due to the amount and arrangement of heavy fuels. Observations from fire managers indicated that instead of small branches on live trees, the larger, dead fuels in



The Beaver Creek Fire burned in "jackstraw" lodgepole stands made up of downed trees and those at risk of falling. Photo: Beaver Creek Incident Management Teams



A home still standing after the Beaver Creek Fire. Photo: Beaver Creek Incident Management Teams

jackstraw stands were the primary driver of fire spread.

Long-duration fires have the potential to greatly increase suppression costs, especially when structures are in close proximity to the fire. In dry and windy conditions, jackstraw stands burn as heat-intensive surface fires, with torching of some trees, spotting of embers that create new fires, and heavy smoke. This fuel type also represents a serious hazard of dead trees or "snags" falling, both before and after a wildfire has burned through, and is a significant concern for the safety of air and ground firefighting crews due to the snags and high radiant heat. These conditions have created new challenges for fire managers, as traditional suppression tactics may not be feasible in beetle-kill areas.

"The scale and extent of these conditions pose challenges to fire managers across the state," said Vaughn Jones, Wildland Fire Management Section Chief, Colorado Division of Fire Prevention and Control. "The hazards and fire behavior associated with this fuel type greatly reduce where firefighters

can safely engage in suppression operations."

The Beaver Creek Fire served as an example of how taking advantage of past forest management treatments can pay off in suppression efforts and reduce the amount of negative post-fire effects. Within the wildfire boundary were several areas of natural regeneration from clearcuts made by the USDA Forest Service and Bureau of Land Management in the 1960s. These areas that consisted of younger, more vigorous trees were not attacked by MPB because they were not of favorable size; they also do not carry fire well and produce less smoke. Conversely, areas where there had been no previous forest management were more likely to carry fire and produce more smoke.

The Beaver Creek Fire also emphasized the need for forest management across land ownership boundaries, because Colorado is primed to face similar wildfires down the road if the build-up of beetle-killed fuels is not addressed on a landscape scale.

Wildfire Smoke and Public Health

An increase in the size and intensity of wildfires, paired with increased population density in and near Colorado's wildland-urban interface (WUI), has led to a high potential for wildfire smoke to impact larger populations. Smoke from wildfires is a mixture of gases and fine particles from burning trees and vegetation, which can cause stinging eyes and irritated respiratory systems. Risks are higher for those with chronic heart and lung diseases, and for children and the elderly.

A century of intensive fire suppression has led to a public expectation of a smoke-free environment. However, due to Colorado's current forest conditions, it is a matter of when, and not if, a large wildfire will occur. Wildfire mitigation and forest management focused on reducing the build-up of fuels is essential to help create healthier forests and decrease the risk of smoke impacts to public health resulting from large, catastrophic wildfires. Prescribed fire also is an effective means to reduce hazardous fuels, and to reintroduce fire into naturally dependent ecosystems. The amount of smoke produced from prescribed fires is typically minimal compared to the amount generated during large wildfires, especially long-duration fires like the Beaver Creek Fire.



Smoke from the Beaver Creek Fire. Photo: Beaver Creek Incident Management Teams

Forest Inventory and Analysis Supports Trends

Every year, the Colorado Forest Inventory and Analysis (FIA) program completes an inventory that provides objective and scientifically credible data on the extent, condition, volume, growth, depletion and health of Colorado's forest resources, and measures these changes over time. This information helps researchers, policymakers, private industry, landowners and natural resource professionals better understand current forest conditions and significant changes across the state.

FIA data are showing an increasing trend of forests with vegetative fuel rearrangements that may be more conducive to large fire spread, such as with jackstraw stands due to beetle-killed trees. In 2008, there were an estimated 642 million dead standing trees in Colorado; by 2015, this number had increased to 834 million dead standing

trees – an almost 30 percent increase over seven years. In Colorado's spruce-fir forests, approximately 1.7 million acres have been impacted by the current spruce beetle epidemic. According to FIA data, spruce-fir forests contain two to three times more coarse woody debris – fallen dead trees and large dead branches on the ground – than any other forest type. This has significant implications for fuel loading and fire behavior, as was seen in the 2013 West Fork Fire Complex that burned in the San Juan and Rio Grande National Forests and private lands in southwest Colorado.

The vegetation within the West Fork Fire consisted mainly of dense spruce-fir forests, with large stands of beetle-kill representing up to 80 percent of the trees. Spruce-fir forests contain shade-tolerant trees with abundant branches close to the ground. These branches, even after the dead needles have fallen off, create a dense network of "ladder fuels" that can easily carry fire up into

the forest canopy and are conducive to extreme fire behavior. Similar to the Beaver Creek Fire, the complex terrain and large number of beetle-killed snags within the West Fork Fire created an unsafe working environment for firefighters. Strong winds and low relative humidity led to extreme fire behavior as winds pushed the fire into the crowns of the dead stands of spruce, with smoke plumes visible from over a hundred miles away. The winds also carried embers up to two miles ahead of the fire front, creating spot fires.

Also of concern based on FIA data is that although tree mortality has increased across Colorado, preliminary data suggest that the reduction in competition between new and older trees due to more growing space has not resulted in an increase in forest regeneration. This may be due to lack of seed source, lack of germination, changes in micro-environments or other factors.

Colorado's trees, plants and wildlife have adapted to living with wildfire. Whether through serotinous pine cones triggered by fire to release seeds, thick tree bark resistant to flames or pioneer species that thrive from disturbance, the state's forest types have tools to survive and thrive with wildfire. At the community level, humans also must adapt to the occurrence of wildfire.

Fire Adapted Communities were identified in the 2005 Quadrennial

The CSFS offers multiple programs and resources to assist landowners and communities to become fire-adapted, including guidance in developing Community Wildfire Protection Plans and Firewise Communities/USA®, and



through hosting the Colorado Wildfire Risk Assessment Portal.

The CSFS provides the minimum standards for developing Community Wildfire Protection Plans (CWPPs) in Colorado. CWPPs are authorized and defined by the 2003 Healthy Forests Restoration Act, which placed renewed emphasis on community planning by extending a variety of benefits to communities with a wildfire protection plan in place. Critical among these benefits is the option to establish a localized definition and boundary for the wildland-urban interface (WUI), and the opportunity to help shape fuels treatment priorities for surrounding lands.

Fire and Water 7

CWPP Helps Firefighters Manage Beaver Creek Fire

Detailed information in the Jackson County Community Wildfire Protection Plan (CWPP) played a large role in helping wildland firefighters plan and prepare for the 2016 Beaver Creek Fire. At the onset of the fire, the CWPP and the Jackson County Firefighter Response Guide, created by the CSFS Steamboat Springs District, contained the best available information for incident responders and helped influence the development of further GIS information to utilize throughout the wildfire's duration.

The Firefighter Response Guide was updated as a component of the Jackson County CWPP process, to better inform first responders of access issues, local terrains, potential hazards and possible evacuation routes and plans throughout the county. This information was utilized by the local fire district at the onset of the Beaver Creek Fire to plan its incident response tactics. The county's CWPP itself outlined critical infrastructure, as well as community values requiring protection. This detailed information assisted with prioritizing fuel treatments and implementing structure protection during the fire.



Firefighters at work on the Beaver Creek Fire in 2016. Photo: Beaver Creek Incident Management Teams

Colorado Senate Bill 09-001 also required Colorado counties to identify wildfire hazard areas in unincorporated (non-municipality) areas by Jan. 1, 2011, leading to the development of CWPPs within 180 days of identifying those wildfire hazard areas. As a result, 49 counties in Colorado now have county-wide CWPPs. Including many smaller-scale CWPPs covering fire protection districts and communities at the subdivision or HOA level, Colorado now has a total of 235 CWPPs, all of which can be found at www.csfs.colostate.edu.

CWPPs can quickly become outdated due to changes in community structure, available information and technology, and should be reviewed periodically and updated as needed to refocus and re-energize implementation efforts.

Firewise Communities/USA®

The CSFS is the state liaison for the Firewise Communities/USA national recognition program. The program provides instructional resources to inform people how to adapt to living with wildfire and encourages neighbors to work together and take action to reduce their wildfire risk. Communities are required to follow five steps to become a nationally recognized Firewise Community, which include forming a Firewise board or committee, obtaining a wildfire risk assessment from the CSFS and local fire department that leads to the creation of an action plan, spending \$2 per capita on wildfire risk reduction efforts, and holding a Firewise event each year.

Colorado has 151 Firewise Communities/USA, all of which are listed on the CSFS website and under the state listings on www.firewise.org. Colorado is currently second in the nation in terms of the number of

Firewise Communities/USA, and this number continues to grow.

Colorado Wildfire Risk Assessment Portal

The Colorado Wildfire Risk Assessment Portal (CO-WRAP) is a web-mapping tool provided by the CSFS that offers access to statewide wildfire risk assessment information. In this way, CO-WRAP can help community leaders, professional planners and interested citizens determine wildfire risk and where forest management actions can be best implemented to reduce that risk. CO-WRAP is the primary tool for the CSFS to deploy risk information and create awareness about wildfire issues across the state, with a goal of providing a consistent, comparable set of scientific results to be used as a foundation for wildfire mitigation and prevention planning in Colorado. The site is available at www.ColoradoWildfireRisk.com.

Other Resources to Become Fire-Adapted

The CSFS offers a free Natural Resources Grants and Assistance Database that provides a comprehensive list of grants and funding programs that promote the health and welfare of Colorado's natural resources. These include grant opportunities and programs for Colorado residents to implement fuels mitigation and education efforts with the goal of reducing their wildfire risk. The database, located on the CSFS website, also offers information on CSFS programs and grant assistance opportunities sponsored by federal, state and private organizations.

Through CSFS programs providing technical assistance and education to landowners, Colorado residents also can

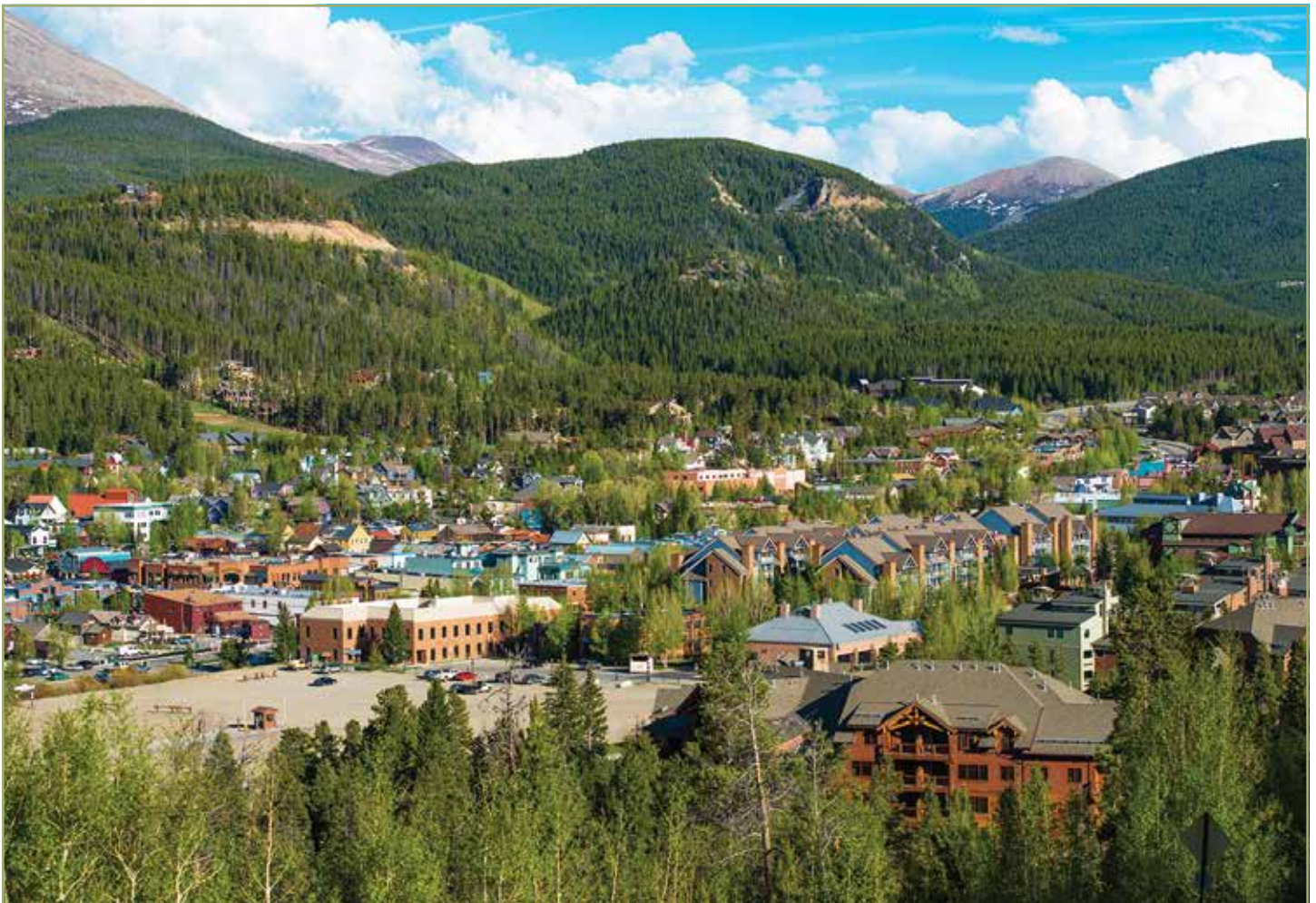
participate in wildfire mitigation efforts to meet the requirements for a state income tax subtraction. Individuals, estates and trusts may subtract up to \$2,500 from their federal taxable income for certain costs incurred while performing mitigation measures. Accepted measures include:

- creating and maintaining defensible space around structures;
- establishing fuelbreaks;
- thinning woody vegetation for the primary purpose of reducing risk to structures from wildland fire; and
- secondary treatment of woody fuels by lopping and scattering, piling, chipping, removing from the site or prescribed burning.

Other tools and resources that communities use to become fire-adapted include implementation of

defensible space; participation in the Ready, Set, Go! program with local fire departments; and using fire-resistant building materials to reduce the structural ignitability of their homes. The CSFS also offers publications about programs, resources and tools that can help homeowners and communities take action to become fire-adapted.

In WUI areas of Colorado, it is not a question of whether a wildfire will occur, but when. Homeowners, policymakers, land-use planners, insurance agents, Realtors, natural resource managers and first responders all have a shared responsibility to collaborate on creating Fire Adapted Communities. Together, Coloradans can plan for the future, prepare for disaster, and quickly recover and thrive when wildfires burn across the landscape.



With a growing wildland-urban interface, Breckenridge now has eight Firewise Communities in and surrounding the community. Photo: Welcomia, Shutterstock

Wildfire Risk Reduction Grants Provide Mitigation Assistance to Residents

During the 2012 fire season in Colorado, six people lost their lives and more than 600 structures were destroyed, with more than \$538 million in losses. To help increase funding opportunities, the following year the Colorado General Assembly created the Wildfire Risk Reduction Grant (WRRG) Program through the Department of Natural Resources to assist with funding community-level and statewide actions specifically in wildland-urban interface areas throughout the state.

Program Overview

The WRRG Program was created through Senate Bill 13-269 to reduce risk of damage to property, infrastructure and water supplies on non-federal lands. The program was initially funded at \$9.8 million with an additional \$1 million added annually in 2015 and 2016. The focus of the program is on community and landscape-scale treatments, which have been shown to be more effective in changing fire behavior than collective treatments on scattered individual properties. Community groups, local governments, public or private utilities, state agencies, and nonprofit groups all are eligible to apply for funds.

Applicants must coordinate with county officials to ensure work is consistent with county-level wildfire risk reduction planning efforts. Applicants also must determine an area's level of risk via the Colorado Wildfire Risk Assessment Portal (CO-WRAP), which provides web-based, statewide wildfire hazard risk/planning information, and include a plan for utilizing woody material generated by the project. The Colorado State Forest Service (CSFS)-administered Colorado Wood Utilization and Marketing Program provides technical assistance for applicants to identify opportunities to utilize this material. Additionally, grant funds must be matched on a 1:1 basis with cash or in-kind funds. Examples of past projects include creating defensible space and fuelbreaks following CSFS guidelines; fuels reduction beyond defensible space designed to protect water supplies and/or reduce fire intensity; and broadcast and slash pile burning. The WRRG Program also has allowed for up to 25 percent of the total funds available to be used for equipment purchases for site-based hazardous fuels reduction treatments (e.g., wood chippers for slash disposal in community chipping programs).

A multidisciplinary advisory committee is responsible for developing scoring criteria, preparing requests for proposals, evaluating and ranking proposals, and awarding grants.

Project Monitoring

A unique aspect of this program is the inclusion of monitoring to examine the effectiveness of various types of treatments and grant resources. The Colorado Forest Restoration Institute (CFRI) at Colorado State University designed a monitoring process to measure changes in fire potential and fuel hazard reduction accomplished with grant funds. This process was designed to be easily replicated, and is being utilized by natural resource professionals for projects outside of the WRRG Program.

Per the monitoring protocol, pre- and post-treatment fuel conditions were measured for a subset of projects representing a variety of forest conditions, vegetation types and management techniques throughout the state. In addition, social and economic factors related to fuels treatments and equipment purchases also are being analyzed to determine the effectiveness of the program. Through 2016, CFRI has established more than 500 monitoring plots at more than 30 sites that received WRRG funding.

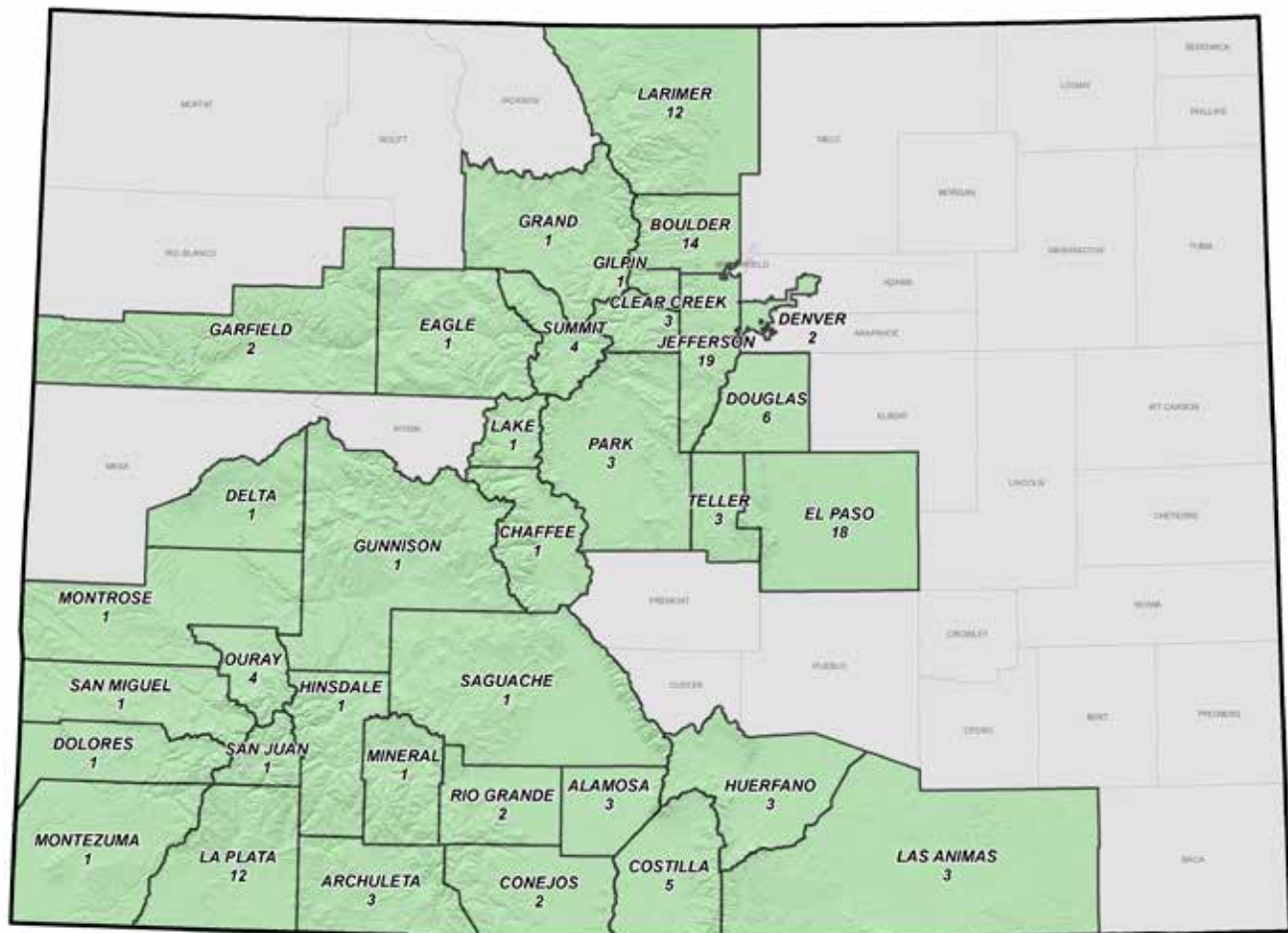
Data indicate that most treatments have been focused on reducing crown fire potential, and initial modeling indicates that many projects have achieved this goal where tree density and ladder fuels are significantly reduced. Reducing crown fire potential helps with fire suppression efforts by keeping fire on the ground, making it easier to suppress and reducing spread and destructive impacts.

Although the monitoring data indicate that crown fire potential has been reduced, they also show that surface fuels are rarely reduced and

Wildfire Risk Reduction Grant Program Summary

WRRG Program				
Year	Grant Funds Requested	Grant Funds Awarded	# of Applicants	# of Awardees
2013	\$4,858,766	\$3,912,872	55	25
2014	\$10,305,407	\$5,439,012	90	64
2015	\$2,339,254	\$1,257,109	36	27
2016	\$2,852,836	\$1,038,161	39	16
Total	\$20,356,263	\$11,647,154	220	132

Wildfire Risk Reduction Grants Per County, 2013-2016



often increase after treatments. Thus management of leftover woody “slash” and surface fuel accumulations remains a challenge in fire mitigation efforts for many WRRG projects. Reducing the accumulation of surface fuels is an important aspect of fire mitigation, but limited wood utilization opportunities and high treatment costs contribute to more surface fuels being left on-site.

Accomplishments

Monitoring has shown the WRRG Program to be a successful one that leverages other state and federal funding sources for wildfire mitigation activities on non-federal lands, while incorporating local science. This provides additional opportunities for communities and local governments to take proactive measures to become fire-adapted and reduce hazardous fuels.

Wildfire Mitigation Assessment Program Raises Awareness

The Colorado State Forest Service (CSFS) Salida District is spearheading a pilot effort to assess the level of wildfire risk to homes in Chaffee and Lake county subdivisions. At the request of a community, foresters perform visual assessments from the road to determine the overall risk rating for individual properties.

Assessment components include:

- access and escape routes
- visibility of address signage
- slope of assessed property
- degree of flammable vegetation near structures
- level of defensible space completed
- exterior construction and roofing, fencing and decking materials

Each of these components is given a score, all of which are then totaled to calculate a property’s overall risk from wildfire. After determining the risk rating for each home within a subdivision, ratings are illustrated on a subdivision map and shared with residents and the local fire protection district. Following conversations among residents, the CSFS often provides a thorough property assessment for interested individuals to determine specific actions to reduce wildfire risk.

Bob Box, a resident in Mount Harvard Estates, says the wildfire risk assessment “adds a great deal to the recipient’s understanding of their property rating, as well as provides guidance for definitive improvements of a property’s risk management.”

To date, the WRRG Program has awarded nearly \$12 million in grants to 132 projects. Successful applicants include counties, cities/towns, non-governmental organizations, metro districts, fire protection districts, homeowners associations, state parks, community organizations, conservation districts, and fire mitigation and watershed coalitions.

Examples of equipment purchases using grant funds include: masticating equipment, wood chippers, air curtain burners, dump trailers, a central boiler wood furnace, a portable sawmill, chainsaws and hand tools.

Addressing Future Fire Risk

Forest management, including thinning trees to improve forest resiliency and reduce fuel loads available for wildfire, is imperative to effectively create Fire Adapted Communities and address threats to forest health and public safety. Prescribed fire is another tool that can effectively reduce fuel loads, and that should be implemented where feasible. Making grant funding available for these actions greatly increases the chances for implementation.

It is also critical that landowners take steps to remove hazardous fuels near their homes, with an emphasis on dead or unhealthy trees. Removing dead trees on a landscape scale in areas with high bark beetle mortality also will help improve suppression opportunities when future wildfires occur. All of these pre-emptive actions cost far less than merely reacting to wildfires after they occur.

WRRG Success Story: Keene Ranch

Dawson Butte Open Space is a 1,028-acre recreation area in Douglas County that adjoins the Keene Ranch subdivision. The subdivision is made up of 247 lots that range in size from 5 to 35 acres, and the primary vegetation type is Gambel oak, which resprouts vigorously after treatments.

Due to concerns of fire starting on the publicly utilized open space and moving into the community, or vice-versa, Douglas County received funding through the WRRG Program in 2013 to treat 134 acres. The Colorado State Forest Service did the layout and project administration, which included creating firebreaks in Gambel oak within the community boundary and reducing hazardous fuels in adjoining ponderosa pine and Douglas-fir forests. Keene Ranch received another grant in 2014 and treated 327 acres over two years on 74 properties, which included treating the trail system in the open space along the community boundary.

Landowners are currently maintaining these treatments every other year, which is essential to maintain treatment effectiveness. Douglas County also received funding in 2015 for additional work on the Dawson Butte property to improve forest health and reduce fire hazard.



Before (top) and after (bottom) fuels treatments near a residence at Keene Ranch. Photos: Meg Halford, CSFS



Statewide Insect and Disease Update

Forest insects and diseases are necessary to the ecological functioning of forests. Outbreaks of tree-killing bark beetles, for example, often target trees in mature, overly dense forests. They can set the stage for the replacement of old, stagnant forest stands with young, vigorous ones. These outbreaks, on the other hand, also can impact many of the values that humans place on forests, including timber production, wildlife habitat, recreation and watershed protection.

Regular monitoring for damage caused by forest pests is a key component of forest management. In Colorado, the primary source of information on forest pest conditions is the annual aerial forest health survey. This is a cooperative program of the USDA Forest Service – Rocky Mountain Region and the Colorado State Forest Service (CSFS), in which trained aerial observers representing

both agencies fly over the state's forests in small aircraft to map and classify the intensity of current year's damage. Some areas detected during the aerial survey also are ground-checked to verify the agent responsible for the damage, and level of severity.

Another key source of forest pest information is field visits made by CSFS foresters. They identify and assess pest activity while advising private forest landowners, and are also directly responsible for management of many forested state lands. In addition, the CSFS, in cooperation with other agencies such as the Colorado Department of Agriculture and USDA Animal and Plant Health Inspection Service (APHIS), is involved in designing and conducting special surveys to ensure early detection of exotic invasive species that threaten urban or native forests.

Highlights for 2016

Most of the state received near- or above-average precipitation in 2016. The wettest areas were on the Eastern Plains, but precipitation levels in north-central Colorado and the northern Front Range were the lowest on record from May through October. Temperatures statewide also were higher than average for the year, despite wide variability by season and location. These climatic factors helped influence notable forest insect and disease activity in 2016, which included the following:

- For the fifth successive year, Colorado's most widespread and damaging forest insect pest was the spruce beetle. A total of 350,000 acres of active infestations occurred in high-elevation Engelmann spruce forests, with 136,000 new acres impacted.



The Maroon Bells and Pyramid Peak near Aspen, Pitkin County. Photo: Dan West, CSFS



Indigenous Pests of Colorado Forests, 2015-2016

Insect/Disease	Primary Host Tree(s)	Notable Counties Impacted, 2016	2015 Acres Impacted	2016 Acres Impacted	Trend, 2015 to 2016
Spruce beetle	Engelmann spruce	Conejos, Gunnison, Hinsdale, Larimer, Rio Blanco, Rio Grande, Saguache	409,000	350,000	Slight overall decrease; 136,000 previously uninfested acres
Western spruce budworm	Douglas-fir, true firs, spruce	Gunnison, Huerfano, Las Animas, Rio Blanco, Saguache, Teller	312,000	226,000	Slight decrease
Western balsam bark beetle	Subalpine fir	Boulder, Clear Creek, Garfield, Pitkin, Rio Blanco, Routt	122,000	122,000	Unchanged
Douglas-fir beetle	Douglas-fir	Eagle, Garfield, Gunnison, Pitkin, Saguache	12,000	19,000	Increase; 15,000 previously uninfested acres
Aspen defoliator spp.	Aspen	Archuleta, Conejos, Montrose, Rio Blanco, Routt, Saguache	58,000	19,000	Decrease
Fir engraver beetle	White fir	Archuleta, Ouray	19,000	6,300	Decrease
Fungal leaf diseases	Aspen, cottonwood spp.	Gunnison, Rio Blanco	81,000	5,600	Decrease
Mountain pine beetle	Lodgepole pine, ponderosa pine	Saguache, Fremont, Larimer	5,000	940	Endemic levels
Douglas-fir tussock moth	Douglas-fir, true firs, spruce	Douglas	26,000	30	Outbreak collapsed

Note: For information about insect and disease impacts by county, contact the nearest CSFS district office.

- Mature Douglas-fir trees continued to be attacked and killed by Douglas-fir beetle in the central and southern portions of the state.
- White fir continued to be killed by fir engraver beetle in several areas of the state, particularly in Ouray and Archuleta counties.
- Western spruce budworm defoliated 226,000 acres of Douglas-fir, white fir and spruce in central and southern Colorado.
- Populations of Douglas-fir tussock moth, a pest of Douglas-fir and white fir, collapsed.
- Western balsam bark beetle and associated root disease fungi, also known as “subalpine fir decline,” continued to cause tree mortality over 122,000 acres of high-elevation subalpine fir.
- Emerald ash borer, first detected in Colorado in the City of Boulder in 2013, was detected within the City of Longmont and in the community of Gunbarrel in 2016.

Indigenous Pests

Conifer Forests

Spruce Beetle

(Dendroctonus rufipennis)

Spruce beetle was Colorado’s most widespread and damaging forest insect pest for the fifth consecutive year. These native bark beetles infest

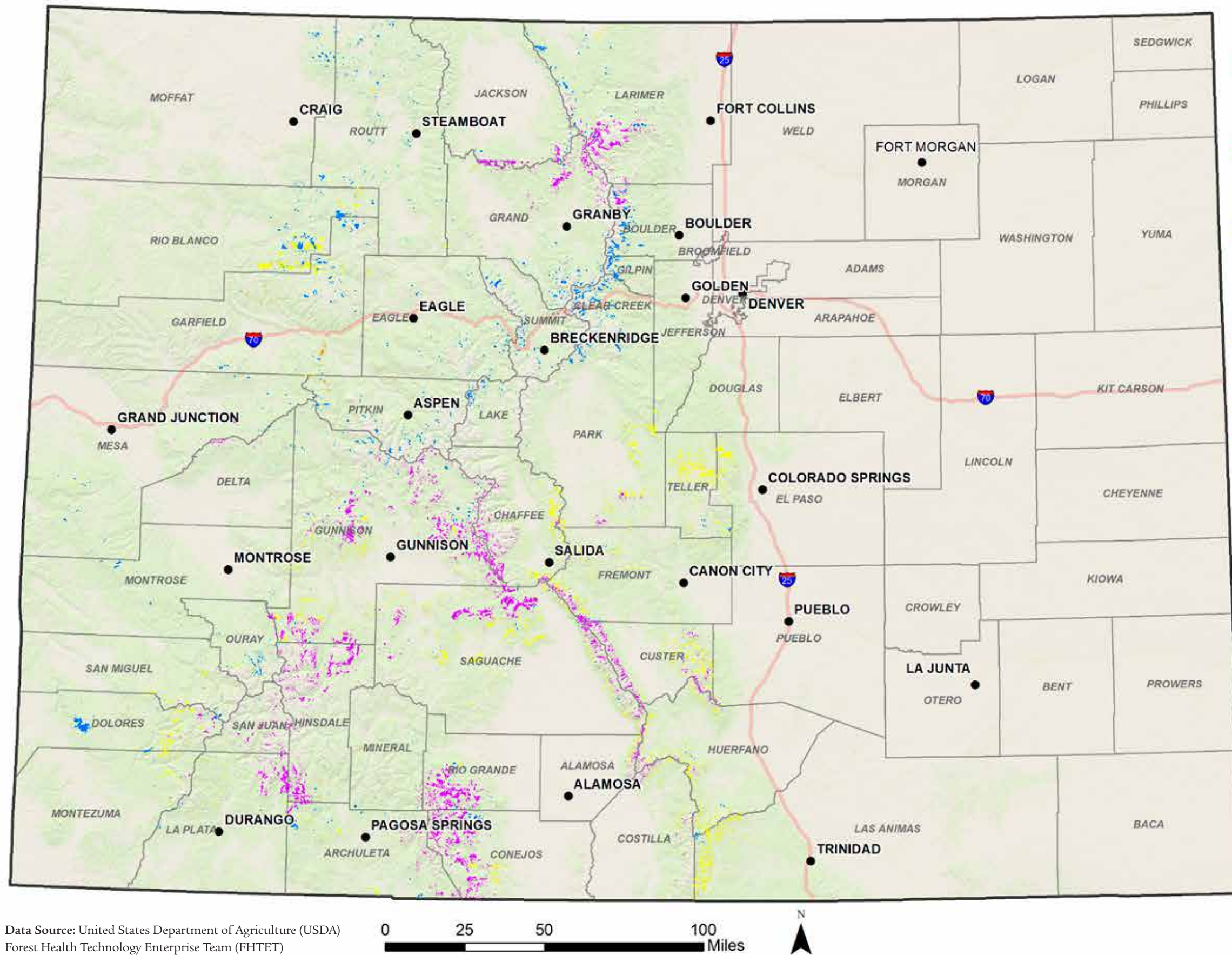
high-elevation Engelmann spruce forests and occasionally impact Colorado blue spruce. Spruce beetles typically produce a new generation in two years, under the bark of spruce trees growing above 9,000 feet elevation. Adults fly to seek new hosts from late May through July, preferring large-diameter trees until they are depleted from the forest.



High-elevation Engelmann spruce mortality caused by spruce beetle near the summit of Marshall Pass, Saguache County. Photo: Dan West, CSFS



2016 Insect and Disease Activity in Colorado Forests



- Forestland**
24.4 million acres
- Spruce Beetle**
350,000 acres
- Western Spruce Budworm**
226,000 acres
- Douglas-fir Beetle**
19,000 acres
- Other Insects and Diseases**
158,000 acres

Aerial Survey Data

Due to the nature of aerial surveys, the data on this map only provide rough estimates of location, intensity and the resulting trend information for agents detectable from the air. Some destructive diseases are not represented on the map because these agents are not detectable from aerial surveys. The data presented on this map should only be used as an indicator of insect and disease activity, and should be validated on the ground for actual location and causal agent. Shaded areas show locations where tree mortality or defoliation were apparent from the air. Intensity of damage is variable, and not all trees in shaded areas are dead or defoliated.

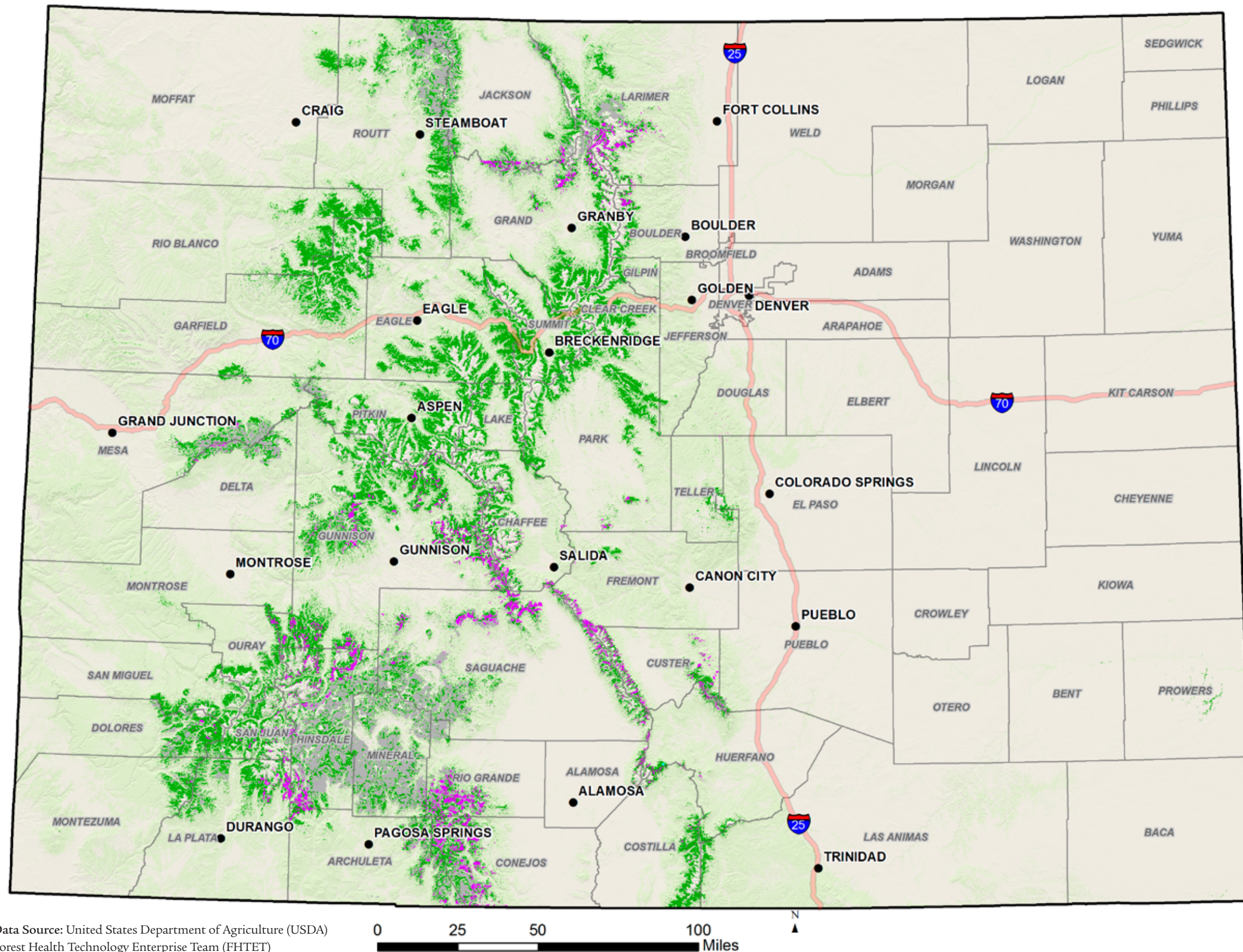
The insect and disease data represented on this map are available digitally from the USDA Forest Service, Region 2 Forest Health Management group. The cooperators reserve the right to correct, update, modify or replace GIS products. Using this map for purposes other than those for which it was intended may yield inaccurate or misleading results.




Map created December 2016
For more information:
www.csfs.colostate.edu
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Spruce Beetle Activity in Colorado Forests, 1996-2016



-  Spruce Beetle 2016
-  Spruce Beetle 1996-2015
-  Spruce-fir Forest

Aerial Survey Data

Due to the nature of aerial surveys, the data on this map only provide rough estimates of location, intensity and the resulting trend information for agents detectable from the air. Some destructive diseases are not represented on the map because these agents are not detectable from aerial surveys. The data presented on this map should only be used as an indicator of insect and disease activity, and should be validated on the ground for actual location and causal agent. Shaded areas show locations where tree mortality or defoliation were apparent from the air. Intensity of damage is variable, and not all trees in shaded areas are dead or defoliated.

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Map created December 2016
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Adult spruce beetle with newly laid eggs, in a gallery under the bark of an Engelmann spruce.
Photo: Dan West, CSFS

In 2016, outbreaks continued in portions of the San Juan/La Garita Mountains, West Elk Mountains, Rio Grande and San Isabel National Forests, Grand Mesa, Sangre de Cristo Range, Wet Mountains, and portions of north-central Colorado in and around Rocky Mountain National Park.

Over the past two decades, a total of 1.7 million acres have been impacted by spruce beetle outbreaks in Colorado. But as the spruce beetle moved through contiguous Engelmann spruce, large-diameter trees were depleted, which resulted in slightly lower impacted acreage in 2016 than in 2015.

- **2016 Acres Impacted:** 350,000
- **New Acres:** 136,000 (previously uninfested)
- **Notable Counties Impacted:** Chaffee, Conejos, Custer, Grand, Gunnison, Hinsdale, Larimer, Rio Grande, Saguache

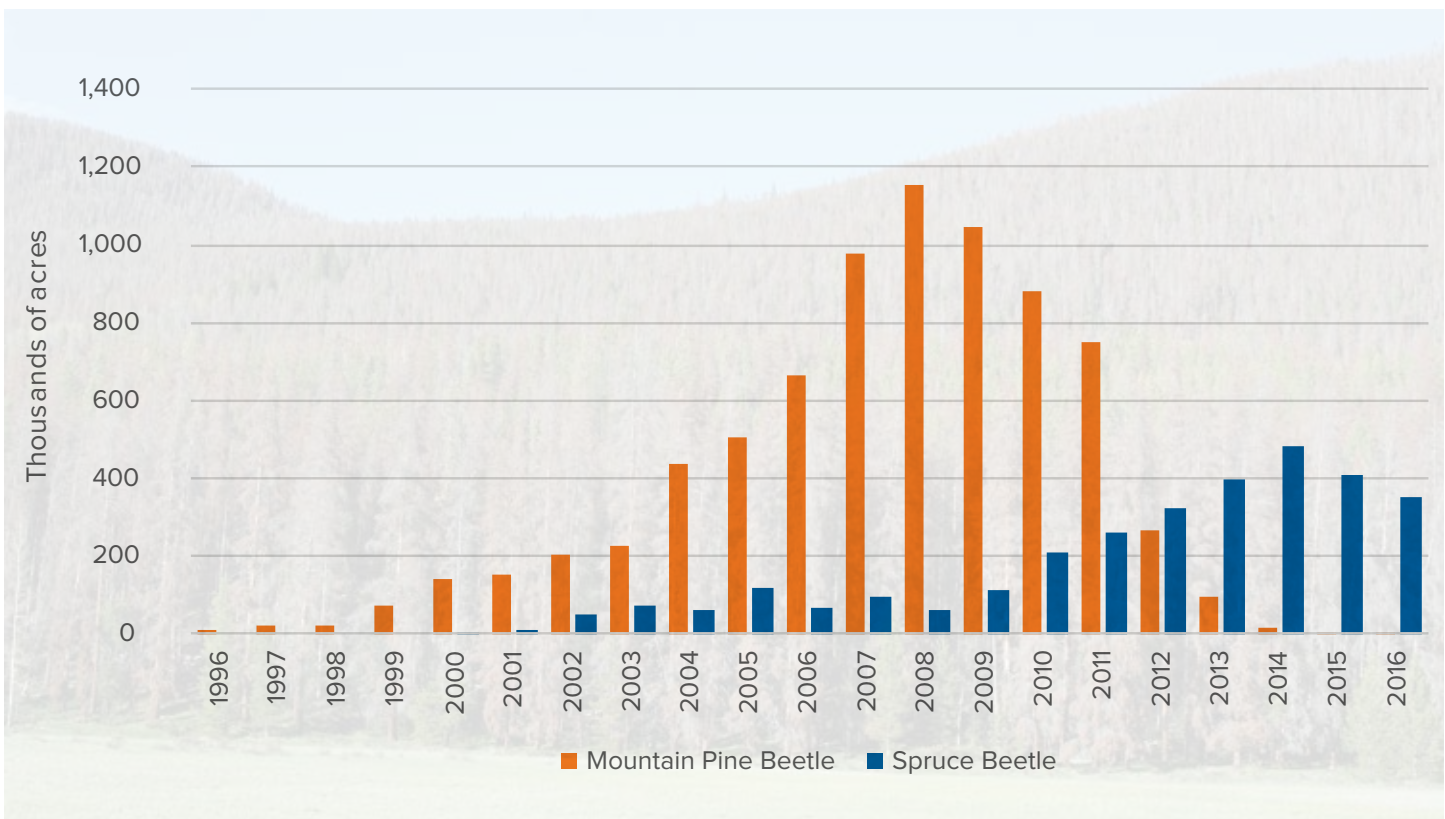
Mountain Pine Beetle (*Dendroctonus ponderosae*)

Mountain pine beetle (MPB) is a native bark beetle that infests all pine species naturally found in Colorado. Populations reproduce once per year, requiring new host trees to complete development. In Colorado, adults typically fly to new trees in June and July. Aside from localized pocket activity, populations remain at endemic or background levels statewide. Infestations in both ponderosa and limber pines continued at low to moderate levels in the northern and central Sangre de Cristo Range. Localized pocket activity also occurred throughout Colorado's Front Range.

Nearly 3.4 million cumulative acres have been impacted by MPB since 1996. However, 2016 saw the lowest acreage impacted by this beetle statewide in two decades.

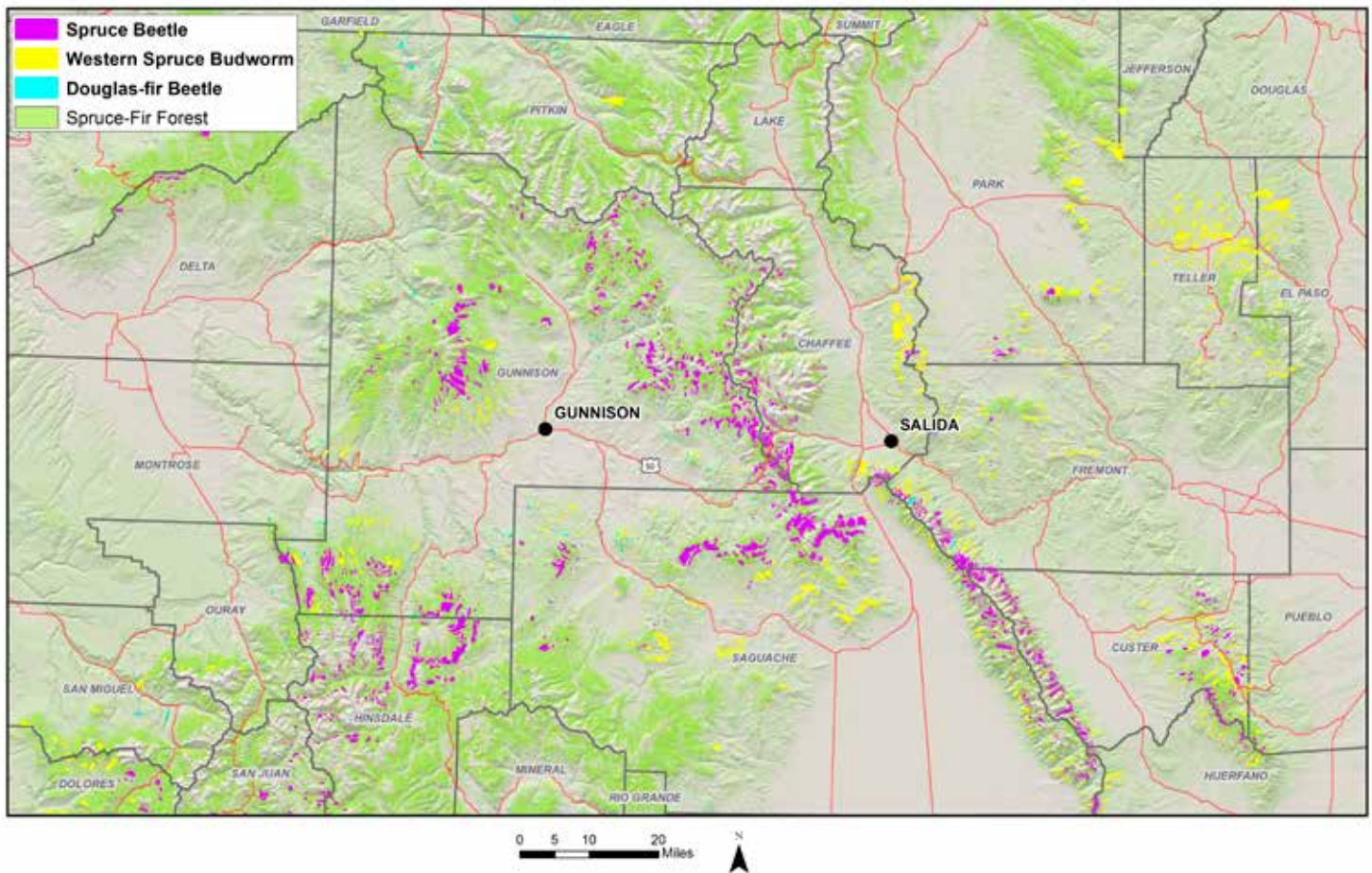
- **2016 Acres Impacted:** 940
- **Notable Counties Impacted:** Fremont, Larimer, Saguache

Acres in Colorado Affected by Spruce Beetle and Mountain Pine Beetle, 1996-2016





Spruce Beetle, Western Spruce Budworm and Douglas-fir Beetle Impacts in the Gunnison/Salida Area



Douglas-fir Beetle

(*Dendroctonus pseudotsugae*)

Douglas-fir beetle, another close relative of spruce beetle and mountain pine beetle, is an important native bark beetle of Douglas-fir forests across most of the West. Outbreaks tend to be associated with mature Douglas-fir forests coupled with periods of below-normal precipitation. Adults typically seek new trees to attack from May through September. Most of the Gunnison Basin, in and around the communities of Ridgway and Ouray, and the southern slopes of the San Juan Mountains all were heavily impacted in 2016. Pocket activity also occurred in portions of the Rampart Range and Sangre de Cristo Mountains.

- **2016 Acres Impacted:** 19,000
- **New Acres:** 15,000
- **Notable Counties Impacted:** Eagle, Garfield, Gunnison, Pitkin, Saguache



Multiple years of Douglas-fir beetle-caused mortality in Douglas-fir trees near the Black Canyon of the Gunnison, Gunnison County. Photo: Dan West, CSFS



Subalpine fir mortality caused by western balsam bark beetle near Monarch Pass. Photo: Dan West, CSFS

Western Balsam Bark Beetle/ Root Disease Complex

Damage caused by western balsam bark beetle (*Dryocoetes confusus*) and several species of fungi that produce root decay remains persistent in high-elevation subalpine fir. Statewide acreage with aerially visible damage from western balsam bark beetle remained unchanged from 2015, although detection has been

complicated by widespread spruce beetle-caused mortality in Engelmann spruce growing with subalpine fir. Several areas of significant damage occurred along the Front Range, Gunnison Basin and Flat Tops Range in 2016.

- **2016 Acres Impacted:** 122,000
- **Notable Counties Impacted:** Boulder, Clear Creek, Garfield, Larimer, Pitkin, Rio Blanco, Routt

Fir Engraver Beetle (*Scolytus ventralis*)

Fir engraver beetle is a native bark beetle that primarily impacts white fir, and occasionally subalpine fir, Douglas-fir and Engelmann spruce. Adult beetles typically fly to seek new trees within which to lay eggs under the bark in summer, with the peak in July and August. Tree mortality occurred in 2016 in southern Colorado where white fir grows in mixed-conifer forests, often near Douglas-fir. Localized areas affected included the Sangre de Cristo Mountains south to the northern portions of the Culebra Range. The eastern slopes of the Wet Mountains continued to experience mortality, ranging from individual tree deaths to pockets of 10 or more trees impacted. Infestations near the mountain town of Ouray continued to impact the few remaining white firs in the area for the fourth straight year, where this beetle is estimated to have killed more than 85 percent of the white fir in the Uncompahgre River Gorge surrounding the town.

- **2016 Acres Impacted:** 6,300
- **Notable Counties Impacted:** Archuleta, Ouray

Western Spruce Budworm (*Choristoneura freemani*)

Larvae of the native western spruce budworm feed in buds and on new shoots of Douglas-fir, true firs (*Abies* spp.) and Engelmann spruce. This feeding on the needles results in a reddish-brown color in the tips and terminal ends of impacted trees. Adult moths are typically active from July through August. This moth has been Colorado's most damaging and widespread forest defoliator for a number of consecutive years. Heavy damage occurred in 2016 in Douglas-fir forests in most southern portions of the state.

- **2016 Acres Impacted:** 226,000
- **Notable Counties Impacted:** Chaffee, Custer, Gunnison, Huerfano, Las Animas, Park, Rio Blanco, Saguache, Teller



White firs killed by fir engraver beetle near Ouray. Photo: Dan West, CSFS



A western spruce budworm larva preparing to pupate within the foliage of a Douglas-fir, Saguache County. Photo: Dan West, CSFS

Douglas-fir Tussock Moth (*Orgyia pseudotsugata*)

Populations of Douglas-fir tussock moth, a defoliator of Douglas-fir, true firs and spruce, typically are cyclical with isolated outbreaks occurring at seven- to 10-year intervals in the state. During outbreaks, larvae can defoliate infested trees and leave them weakened and susceptible to bark beetle attack. Outbreaks generally last from two to five years and then collapse due to a viral disease that spreads throughout each isolated population. Human exposure to the hair-covered larvae and cocoons can cause an itchy skin rash or respiratory issues in some individuals, a condition known as “tussockosis.”

An outbreak that began in 2014 on the Front Range expanded significantly in 2015, but collapsed in 2016. Some larvae were reported in isolated areas

within the outbreak perimeter, though damage was minimal from larval feeding in 2016. All three previous outbreak populations of this pest within the Front Range are thought to have declined from the build-up and dispersal of the virus.

- **2016 Acres Impacted:** 30
- **Notable Counties Impacted:**
Douglas

Deciduous Forests Defoliating Insects of Aspen

Two insects, western tent caterpillar (*Malacosoma californicum*) and large aspen tortrix (*Choristoneura conflictana*), can build population levels and defoliate Colorado’s aspen forests. Western tent caterpillars live within self-made silken tents, typically in the crowns of affected aspen and cottonwood trees, although mountain mahogany, chokecherry and plums also are occasionally affected.

Adult western tent caterpillars are typically present in spring, though can be seen into September. Large aspen tortrix feed upon the leaves of aspen and roll the leaves around themselves for shelter while they pupate. Adult tortrix are typically present in July and August.

- **2016 Acres Impacted:** 19,000
- **Notable Counties Impacted:** Archuleta, Conejos, Montrose, Rio Blanco, Routt, Saguache

Leaf Diseases of Aspen and Cottonwoods

Thinning and discoloration of the foliage of aspen and cottonwood trees by several species of leaf fungi were common throughout the state last year, particularly along the Front Range corridor. But prolonged damp environmental conditions favorable

to foliar fungal pathogens did not develop over much of the state in 2016, significantly reducing widespread damage. Discoloration of the foliage caused by a combination of Marssonina blight and/or Septoria leaf blight (*Septoria* spp.) caused early leaf drop, followed by thinning of diseased leaves, in isolated areas in the western and southern portions of the state.

- **2016 Acres Impacted:** 5,600
- **Notable Counties Impacted:** Gunnison, Rio Blanco

Other Broadleaf Defoliators

Oak Leaf Roller (*Archips semiferanus*)

Defoliation of Gambel oak by oak leaf roller occurred in several areas surrounding the community of La Veta, in Huerfano County. This pest defoliated

these oak groves for a second consecutive year, though damage was less intense than in 2015.

Thousand Cankers Disease/ Walnut Twig Beetle

Thousand cankers disease is native to the Western United States and is the result of small twig beetles (*Pityophthorus juglandis*) spreading a canker-causing fungi (*Geosmithia morbida*) when feeding primarily on black walnut trees. Black walnut trees have continued to die off along the Front Range and Eastern Plains of Colorado as a result of this disease. It has spread quickly throughout Fort Morgan, with many more symptomatic trees observed in 2015-2016 than in previous years. No new detections occurred elsewhere statewide in 2016.



Discoloration of an aspen stand on the Grand Mesa, caused by a fungal leaf disease. Photo: Dan West, CSFS



Exotic Pests

The introduction and establishment of exotic and potentially invasive insects, fungi, plants and other organisms threatens forests worldwide. Invasive insect species can cause severe damage in their new habitats, because their new host trees may have little or no resistance to the introduced pest, and natural enemies (i.e., predators and parasites) of the pest are not present in the new habitat to help keep populations in check. Once established, invasive tree pests can be spread over long distances via the human transport of firewood, nursery stock and other plant materials. Exotic, invasive insects and diseases pose a threat to both native and urban forests in Colorado.

Emerald Ash Borer

(Agrilus planipennis)

Emerald ash borer (EAB) is an insect native to Asia that was inadvertently introduced into North America sometime during the 1990s. Since its initial discovery in Michigan in 2002, this insect has killed millions of ash (*Fraxinus* spp.) trees throughout the central and northeastern United States and Canada. It is now considered the



Adult emerald ash borer and associated feeding damage, Boulder County. Photo: Dan West, CSFS

A Changing Climate Could Increase Bark Beetle, Wildfire Risks



Reduced water levels at Cheesman Reservoir during extreme drought. Photo: CSFS

Based on statewide meteorological records collected by the National Oceanic and Atmospheric Administration, over the past 30 years Colorado's climate has become 2°F warmer, and this trend is already having impacts. Warmer and drier conditions in the past few decades already have contributed to the largest bark beetle outbreaks in the state's recorded history, as well as the top 10 largest fires all occurring since 2002.

Further warming of between 2.5°F and 6.5°F is expected in Colorado by 2050, according to climate model projections. Earlier springs and hotter summers are anticipated throughout the state, reducing Colorado's spring snowpack levels and causing earlier melting and runoff. Most climate projections indicate that droughts, wildfires and heat waves all will increase in frequency and severity in Colorado by the middle of this century.

One of the best defenses against threats associated with a changing climate is to ensure diverse, resilient forest ecosystems. Forests – including those in Colorado – play a critical role in society's ability to deal with climate change because trees in healthy forests store and absorb carbon that might otherwise end up in the atmosphere. Young and vigorously growing forests absorb the most carbon dioxide, while dead or burned trees conversely release this greenhouse gas back into the atmosphere.

The CSFS helps landowners face the impacts of a changing climate by supporting ongoing forest management to increase forest resiliency and reduce the risk for catastrophic wildfire. As forest conditions change in response to climate shifts, the CSFS can help landowners manage forest composition, stand density and the fuels available for wildfire, while improving resistance to insects and disease.

For more information, go to www.csfs.colostate.edu/colorados-forests-changing-climate.

most destructive tree pest ever to be introduced into North America.

Infestations were first detected in Colorado in the City of Boulder, in September 2013. Approximately 15 percent of the trees in Colorado's urban and community forests are ash, making this insect a major threat to these forests statewide.

EAB was presumed to have infested the entire City of Boulder more than a year ago. Surveys in 2015 and 2016 in communities surrounding Boulder targeted ash trees exhibiting EAB symptoms, such as branch dieback and thinning crowns. A new detection in the City of Longmont was confirmed in 2016, as well as a detection in the community of Gunbarrel.

Approximately 15 percent of the trees in Colorado's urban and community forests are ash, making EAB a major threat to these forests statewide.

A collaborative Colorado EAB Response Team has been organized to coordinate surveys and pest management activities designed to slow the spread and reduce the impacts of this extremely destructive insect. Agencies and organizations represented on this team include: Colorado State Forest Service, Colorado Department of Agriculture, Boulder County, City of Boulder, Colorado State University Extension, Colorado Tree Coalition, Green Industries of Colorado, University of Colorado, USDA Animal and Plant Health Inspection Service (APHIS) and various municipalities. Representatives of this team have been instrumental in evaluating traps designed to attract flying adult beetles for early detection of infestations; the release of four species of parasitic wasps that target EAB; maintenance of an ash/hardwood quarantine zone in Boulder County and nearby areas to restrict movement of plant materials; and providing

up-to-date information on the insect's status and the most effective ways to protect ash trees.

Other Damaging Agents

Pine Needle Scale (*Chionaspis pinifoliae*)

For the second consecutive year, pine needle scale continued to be the most damaging forest insect on private lands in Grand County. Pine needle scale feeds on the needles of most pine species, Douglas-fir and spruce. During outbreaks, insects can settle on every inch of the needles, robbing the tree of nutrients. Heavy infestations can cause premature needle drop, dieback, increased susceptibility to other insects or disease, or even tree death. This insect has been active in many areas throughout the Fraser Valley for the past several years, and lodgepole pines of every size and age are heavily infested. Foresters have observed that where the infestation is heavy enough, and long enough in duration, it can cause tree mortality with no additional insect or disease influence.

Assessments conducted in the fall of 2016 indicated that the infestation is declining slightly in some areas. The communities of Vail, Breckenridge and Frisco also had severe to moderate impacts in both native and transplanted spruce trees.



Parasitic dwarf mistletoe impacting a ponderosa pine in Teller County. Photo: Dan West, CSFS

Dwarf and Leafy Mistletoe

Five species of dwarf mistletoe (*Arceuthobium* spp.) and one leafy mistletoe (*Phoradendron* spp.) occur in Colorado. Dwarf mistletoes are leafless parasitic plants that derive nutrients and water from their host trees, by sinking their roots down into branches and stems. Shoots develop and eventually produce flowers and seeds within six years. All native pines and Douglas-fir



Douglas-fir beetle-caused mortality of Douglas-fir trees in the San Juan Mountains. Photo: Dan West, CSFS



Discolored aspen leaves on the Grand Mesa, caused by a fungal leaf disease. Photo: Dan West, CSFS

trees in the state are susceptible to at least one of these mistletoe species.

Dwarf mistletoes cause branches to swell at the infection site, subsequently forming large “witches’ brooms” of clumped twigs on branches, and eventually cause trees to become stunted and deformed. Shoots of the parasite disperse seeds to surrounding trees by ejecting them, while long-range dispersal occurs via animals and birds. Dwarf mistletoes continue to be a persistent problem for communities and forests statewide. A range of infection severities occurs across the state, from localized pocket and stand occurrence in some areas to severe infections that impact entire drainages and forests.

The only leafy mistletoe, commonly known as the juniper mistletoe (*Phoradendron juniperinum*), occurs in the southwest corner of the state on several juniper varieties. This mistletoe is considered less aggressive than the dwarf mistletoes, though is still impactful in harsh conditions where many junipers occur. Infection rates are currently low in southwest Colorado; however, there is noticeable mistletoe activity in areas around Mancos and Dolores in Montezuma County.

Ponderosa Pine Budworm (*Choristoneura lambertiana*)

Larvae of the ponderosa pine budworm, a close relative to western spruce budworm, feed on the new growth of ponderosa pines, causing severe defoliation in outbreaks. Adult moths fly in mid-summer and females lay eggs upon pine needles. The eggs hatch shortly thereafter and the larvae later overwinter in protective bark crevices and furrows. In April and May, larvae emerge and feed upon newly developed needles, mining through the needle sheath and damaging the needles, and pupation occurs within the foliage. Several years of feeding can cause serious tree damage. For the second year, populations of this moth have impacted the community of Pagosa Springs in Archuleta County. Approximately 1,300 acres of privately owned ponderosa pines were impacted in 2016.

Blowdown

A 600-acre blowdown of Engelmann spruce during a high-wind event occurred near Greenhorn Mountain in the Wet Mountains (Pueblo and Huerfano counties). The affected area was in spruce forest where active spruce beetle populations occurred in 2016.

Winter Drying

Severe tree damage from extreme November 2014 temperature fluctuations was again reported on the Eastern Plains. English elms, Siberian elms, willows, cottonwoods, ornamental thin-barked flowering trees (crabapple, pear, etc.), stone-fruit trees and evergreens were heavily impacted. Substantial sloughing of bark was evident throughout 2016 on ornamental pears, hawthorns, goldenrain trees, crabapples and willows, and to a lesser extent on black walnuts.

Lodgepole Pine Needle Cast

Lodgepole pine forests in the Taylor River Basin northeast of Gunnison were discolored by a needle-cast disease in 2015 caused by two species of fungi of the genus *Lophodermella*, due to an unusually wet spring. Environmental conditions in 2016 were less favorable to the fungi, allowing many trees to recover and flush new leaves. Impacts were greatly reduced by late 2016 throughout the basin and Taylor Park. However, lodgepole stands east of Gunnison, over Monarch Pass near Monarch Park, were impacted in 2016.



Feeding damage on a Douglas-fir in Saguache County, caused by western spruce budworm larvae. Photo: Dan West, CSFS

Water Supplies and Forests: An Interdependent Relationship

Sustainable water supplies are one of the most critical resources throughout the West. Much of the region, along with the central U.S., relies on Colorado for water yields, with 19 states and Mexico deriving at least some of their supply from the state's high-country watersheds. Colorado water is utilized by everyone and everything – from municipalities to farmers and ranchers, and from fisheries to wildlife – with river water typically recycled and reused many times before it ever leaves the state. Colorado's semi-arid climate, recurring droughts and competing demands for an ever more limited resource make these water supplies even more critical and in need of sound management.

According to the Colorado Foundation for Water Education, Colorado agriculture – a \$40 billion industry – remains the primary consumer of the state's water, and irrigated agriculture accounts for approximately 86 percent of total water diversions. The state's farmers and ranchers work to supply food to Colorado's rapidly growing population, but because of this rise in immigration they also increasingly compete with non-agricultural users who have their own essential needs for the state's water. This increasing demand for water is not going away. From 2000 to 2014, the state's population grew by 25 percent – from 4.3 million to 5.4 million people – and

the Colorado State Demography Office expects this trend to continue, with approximately 9 million total residents possible by 2050.

As stated in Colorado's Water Plan, "approximately 80 percent of Colorado's population relies on forested watersheds to deliver municipal water supplies." But here and in other Western states, many forests have become unhealthy and overly dense, setting the stage for large, devastating wildfires. These fires significantly increase risks for dangerous post-fire flooding, erosion and heavy sediment loads that endanger life, damage property, degrade water quality and reduce water storage capacity. They also can alter seasonal



An angler on the Colorado River. Photo: William M. Ciesla

State Forest Water Quality Monitoring Program Longest Running in State

The State Forest Water Quality Monitoring Program began in 1995 as a collective effort of the State Land Board, the Owl Mountain Partnership and the Colorado State Forest Service (CSFS), with a goal to continually survey water supplies derived from the Colorado State Forest east of Walden. The program was initiated through a grant from the Environmental Protection Agency's Section 319 Nonpoint Source Management Program and currently consists of 11 monitoring sites along the watersheds of the Canadian and Michigan rivers. Four of these monitoring sites are located on private land, making cooperation with surrounding landowners essential to success.

The overall goal of the program is to monitor river segments within the State Forest for water quality and to use that information to help determine if best management practices – measures taken to minimize nonpoint source water pollution, such as from road development for timber harvesting efforts – have been effective.

Water quality monitoring is a valuable tool for resource managers and has served to inform forest management through heightened awareness of water quality issues and the implementation of best management practices. Monitoring focuses on factors such as stream flow, sediment loads, pH and water temperature. Photographs also are used to track changes to both the structure and vegetation of stream banks over time.



CSFS Steamboat Springs District Forester John Twitchell (right) and State Forest Manager Russ Gross test the water quality on the Colorado State Forest.
Photo: Rich Edwards, CSFS

Water quality in the Colorado State Forest can impact a wide range of organisms downstream, from fish and wildlife to those living in communities along and near the rivers. But for more than 20 years, water quality monitoring carried out by the CSFS in the spring and fall has consistently shown excellent water quality. Having such long-term, continuous water quality data offers the potential to inform ecological research, land management decisions and forestry practices beyond the boundaries of the State Forest, and to assist in better implementation of best management practices.

flow regimes, leading to unfavorably timed spring/summer runoff, while post-fire rainstorms can introduce ash, sediment and other matter into streams, degrading water quality.

Quantifying the Impacts

Research has shown that in mid-elevation forests on Colorado's Front Range, hillslope sediment production rates after recent, high-severity wildfire

can be up to 200 times greater than for areas burned at moderate to low severity. Erosion rates increase to such a degree in areas burned at high severity due to the loss of protective ground cover, the formation of water repellent soils and increases in runoff. These types of sediment yields can impact reservoir storage capacity. For example, downstream sedimentation due to heavy rains following the 1996 Buffalo Creek Fire and 2002 Hayman Fire, which burned southwest of Denver, resulted in more than 1 million cubic yards of sediment in Strontia Springs Reservoir. Following these fires, Denver Water also has spent more than \$27.7 million for restoration and repairs to its collection system.

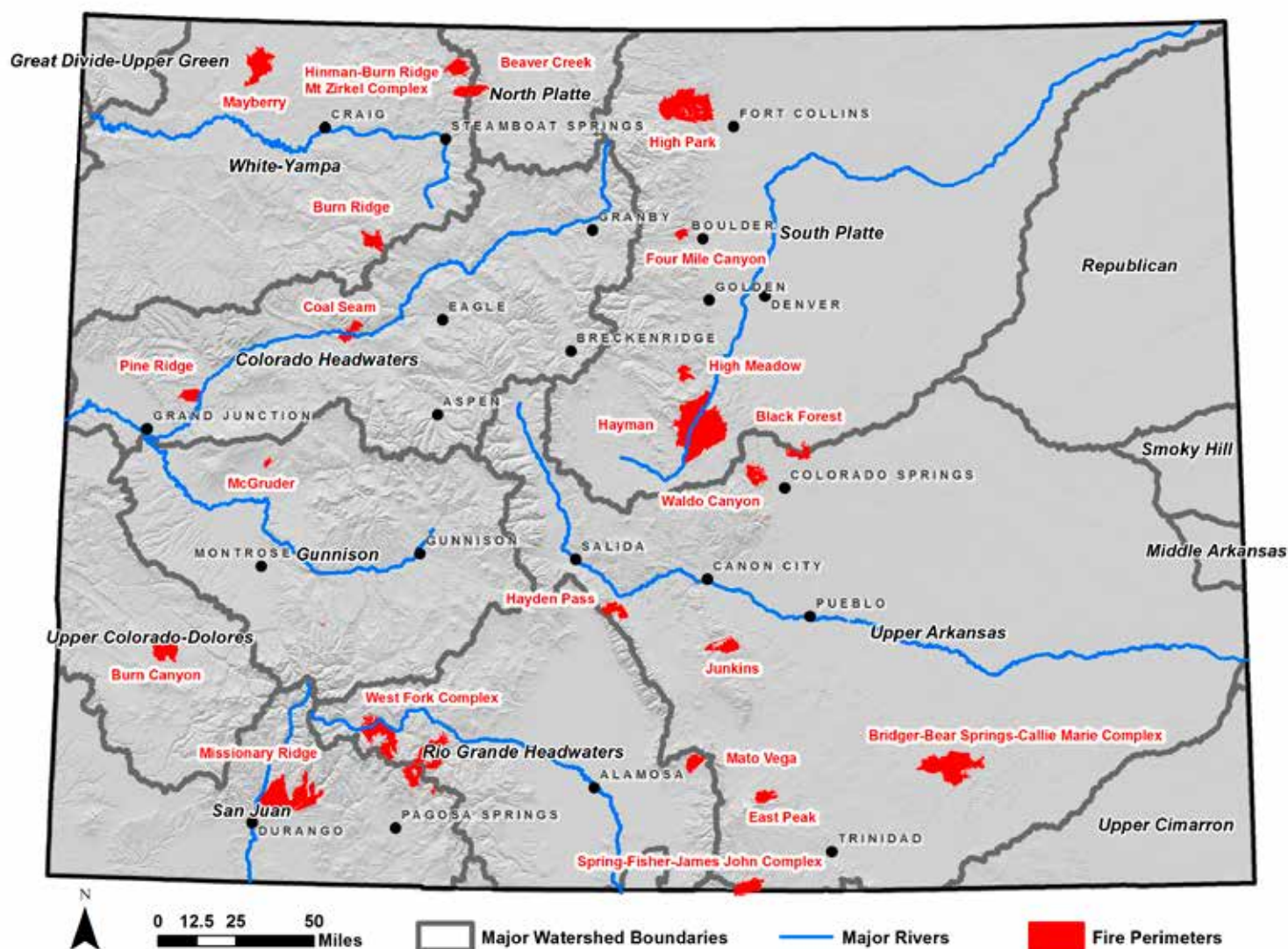
Flows after high-severity wildfires also impact water quality. A 2011 study involved monthly monitoring of stream chemistry and sediment in South Platte River tributaries before and after fire, and showed that basins that burned at high severity on more than 45 percent of their area had streams containing four times the amount of suspended sediments as basins burned less severely. This effect also remained for at least five years post-fire.

Managing Forests to Protect Watersheds

High-severity wildfires responsible for negative outcomes are more common in unmanaged forests with heavy fuel loads than in forests that have experienced naturally recurrent, low-intensity wildfires or prior forest treatments, such as thinning. It is far easier to keep water in a basin clean, from the source headwaters and through each usage by recipients downstream, than to try and restore water quality once it is degraded.

Foresters with the Colorado State Forest Service (CSFS) work with state and federal land managers, water providers, local governments and private landowners to accomplish effective forestry practices and reduce the risk of severe wildfire. Every year, the CSFS helps treat more than 17,000 targeted acres

Prominent Wildfires Within Colorado's Watershed Boundaries



of forestland and assists approximately 2,000 landowners and hundreds of communities, to help improve forest health and reduce risks to watersheds. Management efforts are designed to thin forests, change vegetative fuel structures and remove fuels from the landscape. This is critical, because in the West, almost 40 percent of important watersheds at high risk to wildfire are private or family-owned, with 636,000 of these watershed acres in Colorado.

Because high-severity wildfires eliminate trees and other vegetation that intercepts falling rain, and also cause soils to become water-repellent, anything

that enhances vegetation coverage or otherwise minimizes the area of exposed soil after a fire reduces sediment flows downstream and improves water quality. Thus applying cover onto the ground via chipping/masticating wood or applying wood or straw mulch and/or grass seed is an important first step to immediate post-wildfire recovery. Planting trees on severely burned landscapes after a fire also provides an effective means to hasten forest regeneration.

The CSFS grows seedling trees and shrubs in its nursery, distributing more than 500,000 each year for conservation goals including reforesting burned

areas, enhancing wildlife habitat and reducing soil erosion after flooding. The agency works closely with wildland restoration groups to get these seedlings planted on lands impacted by wildfires, floods and other disasters. More than 291,000 CSFS seedling trees have been planted to help restore the 2002 Hayman Fire burn area, and more than 30,000 seedlings have gone into efforts to restore forests impacted by destructive 2012-2013 Colorado wildfires (e.g., High Park, Waldo Canyon, Black Forest) and areas impacted by the 2013 Colorado floods.

Partnerships Key to Long-Term Forest, Watershed Health

As Colorado's primary resource for technical forestry assistance, education and outreach, the Colorado State Forest Service (CSFS) administers several programs and collaborative efforts focused on actions that help protect watersheds; reduce the impacts of forest insects and diseases and the intensity of future outbreaks; improve forest health; strengthen the wood products industry; and mitigate wildfire risk to help protect human lives and property. Highlighted here are several key CSFS partnerships.

Protecting Denver's Water Supply

A watershed health-oriented partnership between the CSFS and Denver Water began more than 30 years ago. As a direct result of a mountain pine beetle outbreak that began in the late 1970s,

Denver Water enlisted the CSFS to assist in managing its high-country reservoir watersheds in Grand County. In 1985, the first formal forest management plan between the groups was developed on the CSFS Granby District to address many of the emerging forest health issues, which later evolved into a multi-year Forest and Land Management Service Agreement (FLMSA) still in use.

The 1996 Buffalo Creek Fire occurred 10 miles north of Cheesman Reservoir and burned 11,900 acres. At the time it was considered the most damaging and costly fire in Colorado history, and runoff from subsequent rainfall events carried silt, ash and debris into Strontia Springs Reservoir, threatening Denver's water supply and costing approximately \$27.7 million to remediate (to date). As a result, the first wildfire watershed

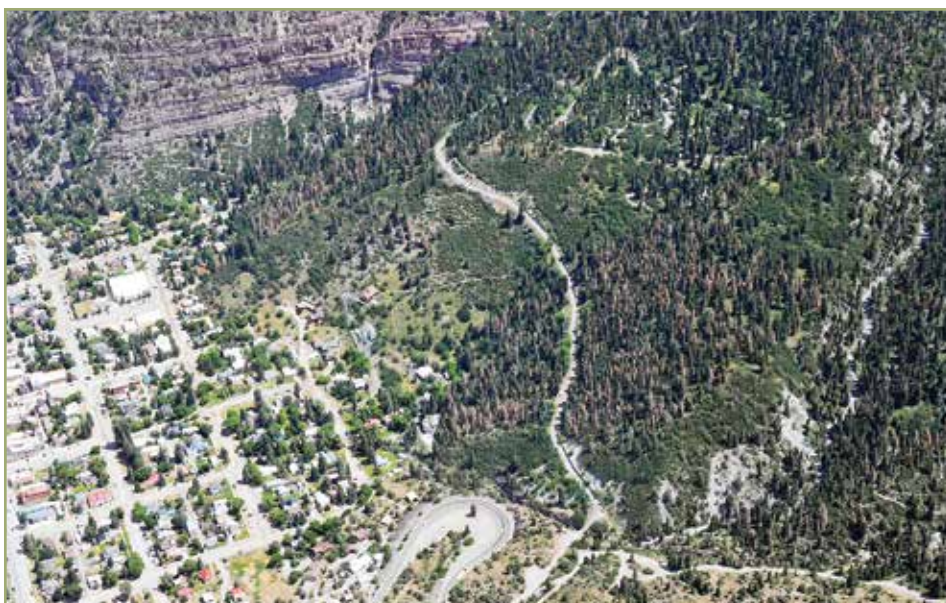
assessment was cooperatively completed in the Upper South Platte Watershed by the CSFS, Denver Water, the U.S. Environmental Protection Agency and the USDA Forest Service (USFS).

Six years later, the 138,000-acre Hayman Fire eclipsed any previous wildfires in Colorado in terms of size and damage, and resulted in the Upper South Platte Watershed Restoration Project, which has now treated more than 40,000 acres on Denver Water, USFS and private land. More recent efforts in the Upper South Platte Watershed include the USFS Forests to Faucets Project and the Upper South Platte Partnership.

Today's CSFS/Denver Water FLMSA focuses on forest management across more than 50,000 acres, eight counties and five CSFS Districts. Annual work



Post-fire erosion near Cheesman Reservoir following the 2002 Hayman Fire. Photo: Kristin Garrison, CSFS



Fir engraver beetle-killed trees near Ouray interspersed with forest management treatments completed to protect the community. Photo: William M. Ciesla

planning between the CSFS and Denver Water addresses activities such as: creating and maintaining defensible space around utility infrastructure; forest management planning; noxious weed management; creating shaded fuelbreaks (where forest stands are thinned) along firefighter and resident ingress/egress routes and infrastructure; and timber stand improvement.

Forest Management in Ouray Creates a Safer Community

The CSFS Montrose District has been assisting the mountain community of Ouray in planning and implementing fuels mitigation projects to increase public safety. Ouray is backed with steep canyon walls that are hallmarks of the iconic Colorado mountain town; however, a wildfire could consume stabilizing vegetation and cause landslides and rock slides within those canyon walls, endangering the people and infrastructure in town. In addition, Ouray has experienced a multi-year epidemic of fir engraver beetle, a native bark beetle that attacks and kills true firs. Beetle-killed trees are a falling hazard, and should a wildfire occur would pose a risk to firefighters and influence wildfire suppression tactics.

Funded by House Bill 09-1199, CSFS foresters and the community of Ouray treated 26 acres on city and county land located along critical roads and near homes and infrastructure. These treated forest acres complemented those completed on adjacent National Forest lands. To offset management costs, the CSFS implemented a 10-acre timber sale that provided material to the local sawmill to turn into marketable products such as boards and wood beams. Ouray County Commissioner Ben Tisdale was involved in the project, and even helped mark trees with CSFS District Forester Jodi Rist.

“Through projects that HB-1199 made possible, the City of Ouray and Ouray County have been able to make headway on preserving economic vitality and public safety,” Tisdale said. “CSFS staff time has been a critical component to helping elected officials understand and deal with our complex forest health issues. The HB-1199 funding for CSFS staffing has made this possible.”

Pikes Peak Watershed Partnership Thriving

In 1987, the CSFS completed the Pikes Peak Watershed Management Plan and since then has been under contract with Colorado Springs Utilities to

implement the plan and provide forest management services. The goals of forest management on the watershed include: to protect water quality and improve water yields; identify and reduce wildfire risk; improve forest health and wildlife habitat; maintain aesthetic qualities and recreational values; and work cooperatively with adjacent federal, local and private landowners.

The Pikes Peak Watershed, owned and operated by Colorado Springs Utilities, consists of 13,000 acres in four management units known as North Slope, South Slope, Longs Ranch and Rosemont. The North Slope management unit encompasses 2,267 acres surrounding North Catamount, South Catamount and Crystal reservoirs. This area serves as an important water collection and storage facility for the City of Colorado Springs and other municipal customers of Colorado Springs Utilities. The North Slope unit is also a public recreation area managed by El Paso County Parks.

Following the 2002 Hayman Fire, the city put an even higher value on protecting its forested resources and funding was increased significantly, increasing the pace of work. Since that time, the partnership has been able to accomplish 200 to 300 acres of forest management each year over the four units. By late 2016, approximately 90 percent of the North Slope unit has come under active management and the partnership currently is in the process of contracting to have another 200 acres of work completed in 2017. In addition, the USDA Forest Service is now completing a large project known as the Catamount Project along the southern and eastern boundaries of the North Slope. Collaboration remains key to treating acres and protecting vital resources in the Pikes Peak Watershed.

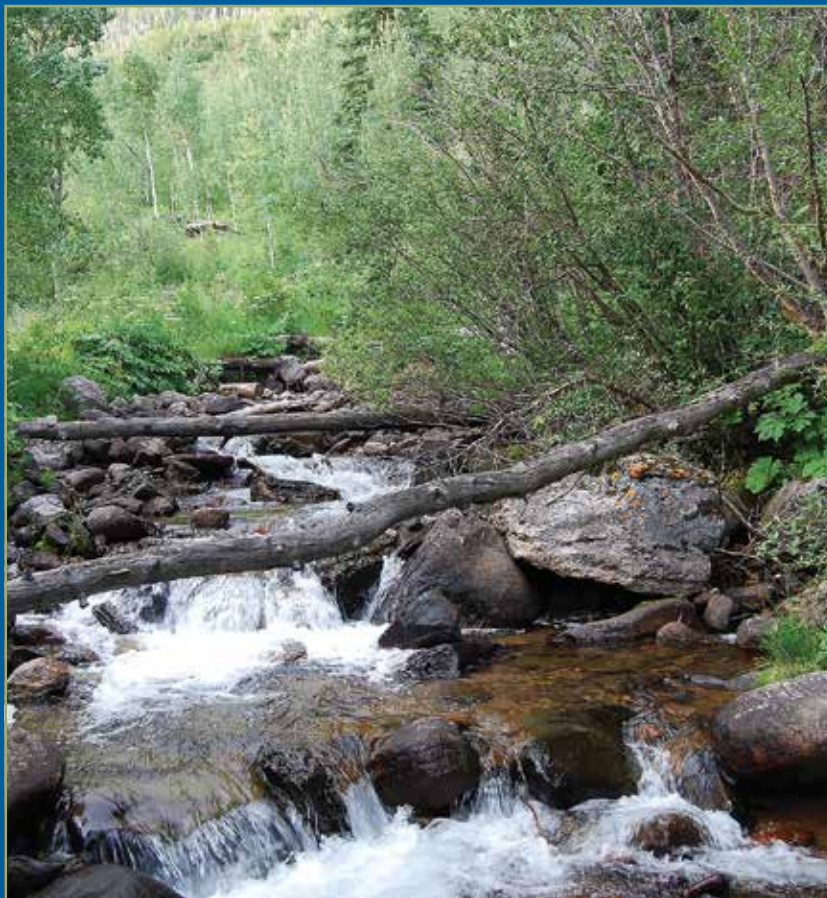
Colorado-Big Thompson Partnership Spans Divide

Northeastern Colorado’s drinking and irrigation water supply comes from watersheds located west of Fort Collins – even as far west as across the Continental Divide. Multiple areas

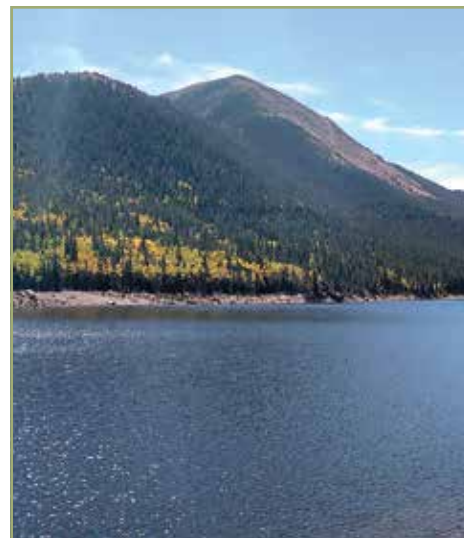
Best Management Practices Help Protect Water Supplies

The Colorado State Forest Service (CSFS) helps address the risk of nonpoint source pollution to water supplies by providing Forestry Best Management Practices (BMPs) for Colorado. These are guidelines that help forest landowners, land management agencies and the timber industry to protect water supplies and avoid inadvertently polluting them. Federal land management agencies subscribe to these practices, but they are voluntary on private lands in Colorado.

Biennially since 2008, the CSFS, in cooperation with researchers and other state and federal agencies, has monitored the application and effectiveness of forestry BMPs through audits and field monitoring. Audit results foster adaptive changes to BMP guidelines published by the CSFS, and help identify landowner, logger and forester training needs.



A stream near Vail. Photo: CSFS



A recently completed forest and fuels management project on the Pikes Peak Watershed, visible from Lake Moraine, El Paso County. Photo: Andy Schlosberg, CSFS

in these watersheds, some previously burned by wildfire, are susceptible to increased rates of post-fire runoff and erosion. And when heavy precipitation and resulting runoff bring post-fire sediment, ash or debris into streams or treatment facilities, drinking water treatment becomes difficult, if not impossible. Due to a variety of factors – including tree mortality caused by the mountain pine beetle epidemic, years of drought and the build-up of fuels in the forested landscape – watersheds on the West and East slopes are becoming more susceptible to high-intensity wildfires that could create poor water quality conditions.

The active 2012 fire season served as a wake-up call to water suppliers in northern Colorado, emphasizing that watershed health is paramount to delivering clean, reliable water to customers. This, along with other Colorado water suppliers' experiences responding to wildfire and forest health planning, led to the formation of the Colorado-Big Thompson (C-BT) Headwaters Partnership between the Northern Water Conservancy District, U.S. Bureau of Reclamation, CSFS and USDA Forest Service. The entities signed a memorandum of

understanding in 2012, with a goal of proactively restoring forest and watershed health, and preplanning post-wildfire response to protect C-BT infrastructure and water supplies. Covered watersheds include those on the Western Slope in the headwaters of the Colorado River, and those to the east in the headwaters of the Big Thompson River.

Implementation projects focus on fuels reduction and forest restoration. The work includes the removal of dead, dying and disease-infected trees; forest thinning; creating patch cuts in unnaturally dense stands; and creating fuelbreaks. Two Wildfire Risk Reduction Grants (see story on p. 10) also have been awarded to the Northern Water Conservancy District in partnership with the Larimer County Department

of Natural Resources and private landowners to implement fuels-reduction projects.

Water quality in the areas downstream have gained even more attention since 2012 specifically because of the High Park Fire. The City of Fort Collins, City of Greeley and the Soldier Canyon Filter Plant – which together serve drinking water to more than 300,000 people in northern Colorado – are now relying more heavily on Horsetooth Reservoir because of occasionally untreatable Poudre River supplies.



Debris flow after a rainstorm following the 2012 High Park Fire. Photo: Tony Simons, Larimer County Emergency Services

2016 House Bill to Enhance Watershed Management

In 2016, the Colorado General Assembly passed new legislation that will allow enhanced management of Colorado watershed conditions. House Bill 16-1255 will address management in three ways: through funding pilot Good Neighbor projects under a new Master Good Neighbor Agreement in Colorado; a statewide watershed analysis; and via the reinstatement of a Colorado State Forest Service (CSFS)-led Forest Health Advisory Council.

The Good Neighbor Authority addressed in this bill promotes greater efficiencies using state personnel and contracting authorities, in combination with project development and expertise from the USDA Forest Service, to address forest management work on federal lands. This allows more work to be done, more quickly and for less money. The first two projects from this bill are currently being implemented in Colorado: an 86-acre timber salvage harvest operation in the CSFS Montrose District to help address spruce beetle mortality on the Uncompahgre National Forest, and public permit-oriented wood removal projects in the CSFS Alamosa District to address beetle-kill in the Rio

Grande National Forest. Both projects will supply forest products to businesses and for local use.

The bill's watershed analysis requires the CSFS, in conjunction with the Colorado Water Conservation Board, to compile and summarize existing information to quantify and document the relationship between Colorado's Water Plan and the importance of forest management in protecting and managing the state's water resources. The compilation will include a summary of the potential costs to and effects on watersheds, communities, water users and infrastructure, if appropriate forest management does not occur in a forested area prior to wildfire.

The revival of a Forest Health

Advisory Council for Colorado will enable the State Forester to receive direct feedback from a broad base of key stakeholders – including nonprofits, water and utilities providers, fire protection professionals and timber industry representatives – to best identify the leading forestry concerns across the state.



State Forester and CSFS Director Mike Lester works with partners at an insect and disease workshop. Photo: Grace Mirzeler, Council of Western State Foresters



Winter in Grand County. Photo: Ron Cousineau, CSFS

Forests, Fire and Water: Adapting to Change

Colorado's forests are dynamic, and have changed throughout history. We know they will continue to change, through processes including climate variability, wildfire, watershed impacts and insect and disease infestation. We must be prepared to change with these forests, and adapt our management efforts accordingly.

Our forests face constant challenges, from increasingly large and destructive wildfires to increasing populations in the wildland-urban interface (WUI) to negative impacts on water quality from reduced watershed health. Destructive bark beetles that attack and kill conifers also continue to be significant in shaping Colorado's forests. These infestations have implications for wildfire behavior and related suppression efforts, and for potential post-fire water supply concerns.

Ongoing management that is responsive to environmental and societal changes will remain essential to ensuring that the state's forests continue to provide fundamental benefits, while minimizing risks within them. Active management of Colorado's diverse forest environments provides clean air and water, enhances wildlife habitat, improves resiliency, reduces wildfire risk and supplies forest products. Forest management also decreases the percentage of forest products Colorado imports from other states and countries – a figure that currently exceeds 90 percent.

As the lead state forestry agency, it is the role of the Colorado State Forest Service (CSFS) to provide state and private landowners the tools they need to address forest and watershed health, and

to address wildfire risk to communities and the forests that surround them. However, the CSFS cannot do this alone. We need everyone's help educating forest landowners and the more than 2 million people who live in the WUI to ensure resilient communities. The ongoing support and assistance of our partners and policymakers is essential for us to remain effective.

Due in part to the already-present millions of acres of beetle-kill at higher elevations and within our critical watersheds across the state, Colorado is likely to experience more large-scale wildfires like the Beaver Creek and West Fork fires in the future. But adaptive forest management actions we take now, and as conditions continue to change, will allow us to achieve stewardship of our state's diverse forest environments for the benefit of present and future generations.

References

- Agnew W., R.E. Labn and M.V. Harding. 1997. Buffalo Creek, Colorado, fire and flood of 1996. *Land and Water*, 41: 27-29.
- American Forest Foundation. 2015. Western Water Threatened by Wildfire: It's Not Just a Public Lands Issue. AFF special report, 28 pp.
- Benavides-Solorio J. and L.H. MacDonald. 2005. Measurement and prediction of post-fire erosion at the hillslope scale, Colorado Front Range. *International Journal of Wildland Fire*, 14: 457-474.
- Centers for Disease Control and Prevention. Protect Yourself from Wildfire Smoke. Accessed Oct. 26, 2016 from: <http://www.cdc.gov/features/wildfires>
- Colorado's Water Plan. 2015. Report prepared by the State of Colorado, 567 pp.
- Edwards R.M. and G. Sundstrom. 2013. Colorado Forestry Best Management Practices: Forest Stewardship Guidelines for Water Quality Protection (2012 Field Audit Report). Colorado State Forest Service, 21 pp.
- Headwaters Economics. 2014. Reducing Wildfire Risks to Communities: Solutions for Controlling the Pace, Scale, and Pattern of Future Development in the Wildland-Urban Interface (white paper), 21 pp.
- Lukas J., J. Barsugli, N. Doesken, I. Rangwala and K. Wolter. 2014. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A report for the Colorado Water Conservation Board, 108 pp.
- Meyer J.P. 2006. Hayman Fire still mucking up water. *The Denver Post*, Nov. 24, 2006.
- Rhoades C.C., D. Entwistle and D. Butler. 2011. The influence of wildfire extent and severity on streamwater chemistry, sediment and temperature following the Hayman Fire, Colorado. *International Journal of Wildland Fire*, 20: 430-442.
- Schweizer D.W. and R. Cisneros. 2016. Forest fire policy: change conventional thinking of smoke management to prioritize long-term air quality and public health. *Air Quality, Atmosphere & Health* (online). 22 April 2016, 4 pp.
- USDA Forest Service. 2014. West Fork Fire Complex Fire Programmatic/Cost Fire Review, San Juan and Rio Grande National Forest, U.S. Forest Service, 20 pp.
- Zaffos J. 2015. Managing Agriculture and Water Scarcity in Colorado (and Beyond). Report prepared jointly by Colorado Foundation for Water Education and CoBank, 17 pp.

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- Pete Barry, GIS Technician, CSFS
- Rich Edwards, Assistant Staff Forester, Forest Management Division, CSFS
- Dave Farmer, Area Forester, State Office, CSFS

- Kristin Garrison, Assistant Division Supervisor-Fire/Fuels Management, Forest Management Division, CSFS
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- Wilfred Previant, Forest Inventory and Analysis Program Manager, Forest Management Division, CSFS
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- Justin Backsen, Aerial Surveyor, USDA Forest Service, Lakewood, Colo.
- Brian Howell, Aerial Survey Program Manager, USDA Forest Service, Lakewood, Colo.
- Roy Mask, Assistant Director, Forest Health Protection, USDA Forest Service, Lakewood, Colo.
- Benjamin Pfohl, Assistant District Forester, Boulder District, CSFS
- Rebecca Powell, Entomologist, USDA Forest Service, Lakewood, Colo.
- Sky Stephens, Entomologist, USDA Forest Service, Lakewood, Colo.
- Jennifer Ross, Geographic Information Systems Specialist, USDA Forest Service, Monument, Colo.
- Michael Till, Assistant District Forester, Woodland Park District, CSFS



.....
Colorado State University
5060 Campus Delivery
Fort Collins, CO 80523-5060
(970) 491-6303
www.csfs.colostate.edu



COLORADO
Department of Natural Resources

.....
Division of Forestry
1313 Sherman Street, Room 718
Denver, Colorado 80203
(303) 866-3311
www.dnr.state.co.us



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OF NATURAL RESOURCES**
COLORADO STATE UNIVERSITY

.....
Colorado State University
1401 Campus Delivery
Fort Collins, CO 80523-1401
(970) 491-4994
www.warnercnr.colostate.edu