2002 Report on the Health of Colorado's Forests

January 21, 2003

The *2002 Report on the Health of Colorado's Forests* reveals that many of our forested landscapes are under significant stress. Our changing human values and land management policies are partially responsible for this condition. But consecutive years of extreme drought have magnified existing vulnerabilities to insects, disease and wildfire.

From widespread die-off in pinyon pine to record-setting wildfires on both the Front Range and the Western Slope, the events of the past year suggest that Colorado's forests need our attention. We demand and receive a number of benefits from our forested landscapes and watersheds. If we expect them to continue providing these services on a sustainable basis, we must identify those areas most at risk and work together to restore them to a more resilient condition.

Following the publication of last year's report, a number of counties recognized the need to engage land management agencies, local business and opinion leaders, landowners and private citizens in a dialogue regarding the condition of their surrounding forests. Many of these counties are coordinating with the Colorado State Forest Service and other partners to establish a forum for consideration of these issues.

This second annual report builds on the foundation laid in that original document by updating readers on issues of current concern and further highlighting opportunities for action. On behalf of the Colorado Forestry Advisory Board, I encourage you to use this information to promote dialogue within your own community regarding the condition of Colorado's forests, the potential impacts of this condition and the subsequent priorities for action.

Public and private land managers have the knowledge and tools needed to take positive steps toward restoring our forests. Only by working cooperatively will we be able to identify how and where these actions should occur.

Sincerely,

Nancy M. Fishering
Chairperson, Colorado Forestry Advisory Board

2002 Report on the Health of Colorado's Forests

Executive Summary

Colorado's forests will carry the imprint of 2002 for years – even decades – to come. Powerful interactions between insect and disease activity, drought and wildfire caused, or set in motion, landscape-scale changes. The magnitude of these disastrous events continues to grow, both in size and duration, in several areas of the state. According to scientists, these events are largely outside the range of conditions seen historically in Colorado.

During 2002, wildfires burned more than 500,000 acres of forestland in the state. A fast-moving infestation of pinyon ips beetles killed up to 50 percent of the pinyon pines in southwest Colorado. Mountain pine beetle and spruce beetle epidemics continued to expand. And drought's withering influence was seen from high-elevation forests to urban centers and the eastern plains.

Changes in land management policies over the past 150 years have disrupted natural cycles of disturbance and renewal in several of Colorado's forested landscapes. Without these cycles, some forests have become significantly more dense and less diverse than they were in the past. The stress of competing for sunlight, water and other essential resources under these conditions leaves trees extremely vulnerable to insect and disease activity, fire or drought, and sets the stage for much faster and more devastating events to move across the landscape. Record high temperatures and lack of precipitation in 2002 worsened this situation.

Forest condition, or forest health, can be defined by the interactions between three components: a forest's resilience to disturbance; its ability to sustain a natural range of biological diversity; and its ability to meet the current and future needs of people in terms of values, products and services. The trends in forest condition highlighted during the past year suggest that some of Colorado's forests may be increasingly unable to sustain these interactions.

Land management agencies, local governments and individual property owners across the state are using a variety of forest management tools to restore a more natural range of conditions to Colorado's forests. The primary goal of these forest stewards is to increase or maintain the forests' ability to continually provide shelter, food, water, energy and an improved quality of life to both human and non-human communities.

These endeavors often involve prioritizing limited project dollars on activities and locations that offer the greatest opportunity for success, on a meaningful scale, over the long-term. One indicator of success is a diverse local community in support of effective restoration actions. Many scientists and land managers also suggest that projects designed and implemented across ownership boundaries, on a landscape scale, will have the greatest positive impact.

Several counties in Colorado have embarked on public discussion and planning efforts to more clearly identify areas of agreement and treatment priorities for their forests and communities. It is through these locally-based forums that support will be built to improve the sustainability of Colorado's forested landscapes and to protect the state's people and natural resources.

The information contained in this second annual *Report on the Health of Colorado's Forests* builds on the foundation laid in the 2001 report by updating readers on issues of current concern and providing additional details for public dialogue. Coloradans can use these documents to better understand how the interactions between natural and human forces shape our forests and how informed citizens can improve the decisions made regarding future forest management.

Current Issues

Many of Colorado's forests experienced landscape-scale change over the past year due to the powerful interaction between insect and disease activity, drought and wildfire. Hot, dry conditions spurred a fast moving infestation of the tiny pinyon ips beetle that took much of southwest Colorado by surprise; the growing sea of red trees killed by mountain pine beetle continued to expand over the state; and land managers near Steamboat Springs began to see more extensive spruce beetle damage in the areas adjacent to the 1997 Routt Divide blowdown.

Record-setting drought throughout the state placed additional stress on already compromised forests – whether in cities, mountains or across the eastern plains. Parched conditions provided the catalyst for an explosive wildfire season fueled by dense forest vegetation and extreme weather. Additionally, dry reservoirs and streambeds prompted renewed public attention to the connections between forests and water.

Colorado's forests historically exhibited a range of disturbance-driven changes and conditions.[1] A century of aggressive fire suppression and varied management strategies has significantly altered these natural cycles. As a result, the vegetation in some forest types is much more dense and less diverse, in terms of age and size, than at any time in recorded history.

Mountain pine beetle infested pine stand in the Williams Fork drainage near Granby. Courtesy USDA Forest Service.

A General Accounting Office (GAO) Report issued in April 1999 (GAO/RCED-99-65) describes "over accumulation of vegetation" as "the most extensive and serious problem related to the health of national forests in the interior West." The stress of competing for resources under these conditions leaves trees extremely vulnerable to insect and disease activity, fire, drought and other natural or human induced disturbances, and sets the stage for much faster and more devastating events to move across the landscape. The issues of concern described below highlight this trend.

[1] For a more thorough discussion of Colorado's forest types and historic conditions see *The 2001 Report on the Condition of Colorado's Forests,* available on the web at http://forestry.state.co.us/.

1. Insect and Disease Activity

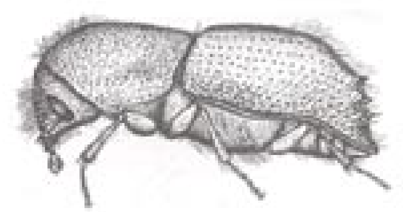
A number of insects and diseases regularly impact the condition of Colorado's forests. Some are exotic or introduced, but many are native. Natural cycles of insect and disease outbreaks are an important component of a functioning forest ecosystem. Changes in the age, size and species diversity of a forest affect carbon and nutrient recycling, wildfire behavior, stream channel morphology, plant reproduction, wildlife habitat and other ecosystem components. While these larger impacts are not detailed in this report, they are nevertheless important components of overall forest condition.

Old infestation from western spruce budworm

The insect and disease activity of greatest concern in 2002 involved native insects operating at outbreak, or near outbreak levels. Severe drought accelerated this activity in many parts of the state. Insect and disease activity generally draw public attention when the resulting damage becomes visible and/or threatens something of public value. The most effective actions to reduce insect and disease damage involve alleviating stress or competition and restoring a forest's resilience prior to attack. Once infestation has begun, management options are limited.

Pinyon Ips Beetle *(Ips confusus)*

Several areas in southwest Colorado and along the southern Front Range are experiencing extensive pinyon pine mortality due to the voracious appetite of the pinyon ips beetle (Leatherman 2002, Grant 2002, Harris 2002, Lebeda 2002), one of eleven pine engraver beetles that naturally occur in Colorado.



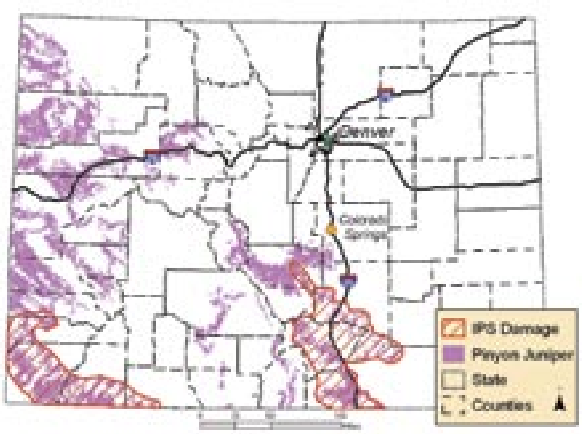
Ips confusus

The pinyon ips beetle is only moderately aggressive unless predisposing factors make conditions ripe for large-scale outbreaks. This year's extreme drought, combined with the overly dense condition of many pinyon-juniper landscapes, appears to have provided those ideal conditions. The tiny insect is currently operating at population levels not seen in Colorado for decades.

The culprit behind this damage is a dark-colored beetle about the size of an uncooked grain of rice. It tends to attack damaged or stressed trees by tunneling under their bark to mate and lay eggs. The resulting beetle larvae burrow into the tree's cambium and phloem layers between the bark and wood. As the larvae feed, they girdle the tree while spreading a bluestain fungus that disrupts the tree's natural defenses (Grant 2002).

The pinyon ips beetle is thought to produce three to four generations per year, with beetles actively flying from as early as March to as late as November. Following successful attack, the needles of the infested tree quickly fade from green to straw-colored, later turning red and eventually brown. By the time the tree appears to be dying, a new generation of beetles is already maturing beneath the bark.

Damage from pinyon ips attack in Colorado is most extensive in the southwest where mortality has been seen from as far north as Norwood to Montezuma County and parts of neighboring La Plata, Dolores and San Miguel Counties. Visual surveys estimate that about 50 percent of the pinyon resource in that area is already dead. Although the companion junipers have not been affected, this mortality will have a major impact in an area where pinyon-juniper woodlands are a key component of the landscape, an aesthetic resource and critical to habitat and food for wildlife.



2002 pinyon ips damage

Additional mortality has been seen along the southern Front Range from Pueblo to just west of Trinidad and on the eastern plains around Kim (Leatherman 2002). In the San Luis Valley, pinyon ips infestation is considered an emerging forest health issue with mortality occurring around South Fork and in Great Sand Dunes National Park (Lebeda 2002). The true extent of statewide damage will be better known next year when aerial survey data has been analyzed and more of the affected trees' tell-tale red crowns are visible.

Colorado's pinyon ips outbreak is only the "tip of the iceberg" in a regional phenomenon that includes even larger areas in Arizona and New Mexico. Major concerns related to this epidemic include increased risk of wildfire, loss of wildlife habitat and threats to aesthetic or cultural resources.

At the landscape scale, only a return to normal precipitation levels will quiet beetle activity. In unaffected forest or woodland stands, activities such as thinning and reintroduction of fire will help reduce density and restore resiliency. Individual property owners can protect important pinyon trees around homes, businesses, recreation areas and other key locations through preventive spraying with insecticides labeled for "bark beetle prevention." Landowners can purchase and apply preventive insecticides themselves, or hire an arborist or tree care company. Ideally, spraying should be carried out in early April before the first beetles emerge to attack new trees.

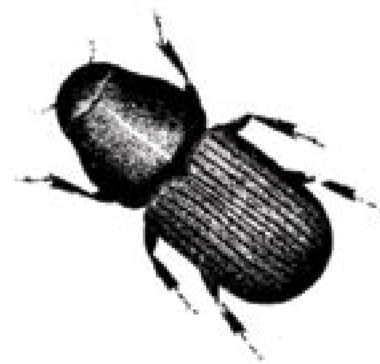
Already infested trees can be treated by removing the tree to a safe site and burning, chipping, debarking and/or burying it. These direct control efforts are most effective when neighboring landowners work cooperatively to locate and treat beetle-infested trees across their respective properties.

Removal of logs, branches, bark and other debris or "slash" from harvesting activities is critical. Ips beetles have a tendency to build up and attack green wood created during fire mitigation operations. It is important to chip, burn or otherwise dispose of this slash in a timely manner or healthy trees identified for retention will face infestation.

Mountain Pine Beetle (*Dendroctonus ponderosae*)

The mountain pine beetle (MPB) is historically the primary agent of mortality in old, slow-growing ponderosa, lodgepole and limber pines in Colorado. It is the most significant damaging insect of the state's low and mid-elevation pine forests and continues to be the insect whose damage attracts the greatest public interest.

The mountain pine beetle attacks and kills trees in a manner similar to the ips beetle, but only produces one generation per year. It is most likely to attack trees that lack vigor due to old age, crowding, poor growing conditions, drought, fire, mechanical damage or root disease (Leatherman 1999). During early stages of an outbreak, attacks are largely limited to trees under stress. As the beetle population increases, attacks often spread to healthy trees in the outbreak area.



Dendroctonus ponderosae

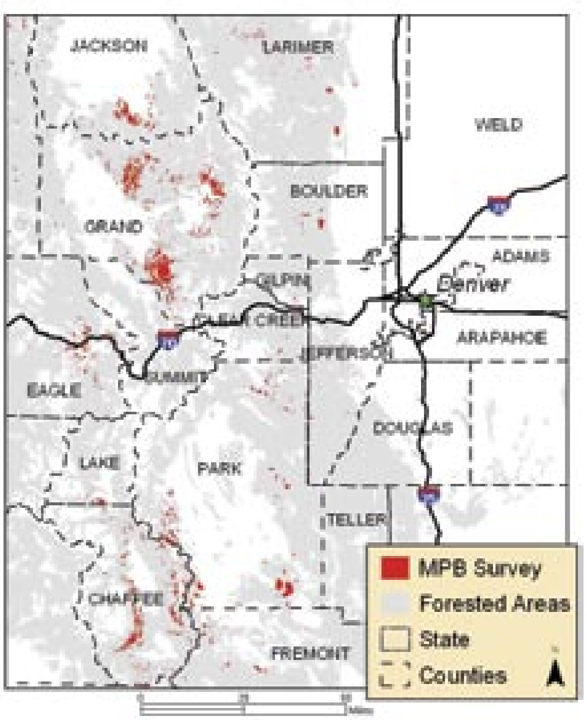
The density and even-aged structure of many of Colorado's ponderosa pine and mixed conifer forests is a major factor in the size and rate of spread of the current outbreak. Scientists estimate that many stands are at least twice as dense as is desirable for natural resistance to bark beetles (Leatherman 2002). MPB populations have nearly doubled each year since the mid 1990s (Johnson 2002, Harris 2002). Aerial survey results showed approximately 450,000 infested trees over 150,000 acres in 2001. Estimates for 2002 indicate an additional 600,000 trees have been impacted (Harris 2002, Leatherman 2002).

Lodgepole pine forests in Grand County continue to see the heaviest MPB mortality with concentrations around Lake Granby, along the William's Fork River near the Henderson Mine, and throughout the Troublesome Creek Watershed. This outbreak is spreading to ponderosa pines of the South Park area in Park County. The Climax Metals Corporation is actively salvaging infested timber on their 10,000 acre Henderson Mill property near Winter Park (Harvey 2002).

Ponderosa pine forests in Chaffee County are experiencing the second largest rate of mortality from MPB, particularly in the upper Arkansas Valley between Salida and Buena Vista. Large portions of the wildland-urban interface are being impacted with mortality of ponderosa pine as high as 80 percent in some stands.

The Vail and Eagle River Valleys in Eagle County continue to experience heavy mortality in even-aged lodgepole forests, where little diversity makes stands susceptible to attack. The outbreak in this area prompted the U.S. Forest Service to initiate Forest Health Environmental Impact Statements (EIS) for the Vail Valley and the Arapaho National Recreation Area. The EIS documents will address MPB damage as well as related issues such as forest age class diversity and fuel build up. The Vail and Beaver Creek ski areas continue to work with the Colorado State Forest Service (CSFS) on detection and removal of infested trees.

Other areas of infestation include upper Poudre Canyon, the US 285 Corridor including Conifer,



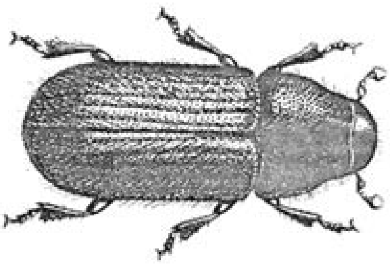
2002 mountain pine beetle damage along the Front Range

Mountain pine beetle damage

Evergreen and Bailey, the Durango area, the northern portion of the Uncompahgre Plateau, and areas of the Sangre de Cristo Mountains, Wet Mountains and Sierra Madre Mountains.

Once MPB successfully infests a tree nothing can be done to save it. Preventive spraying before attack may protect individual high-value trees if done prior to the beetles' normal flight time in mid-July through September. More than 120,000 high-value trees near homes or in recreation areas are currently being treated by this method with assistance from the CSFS (Leatherman 2002). At the landscape scale, thinning that reduces competition, improves tree vigor and lessens fire hazard is a good option for preventive action and can be followed by reintroduction of fire where appropriate.

Spruce Beetle (*Dendroctonus rufipennis*)

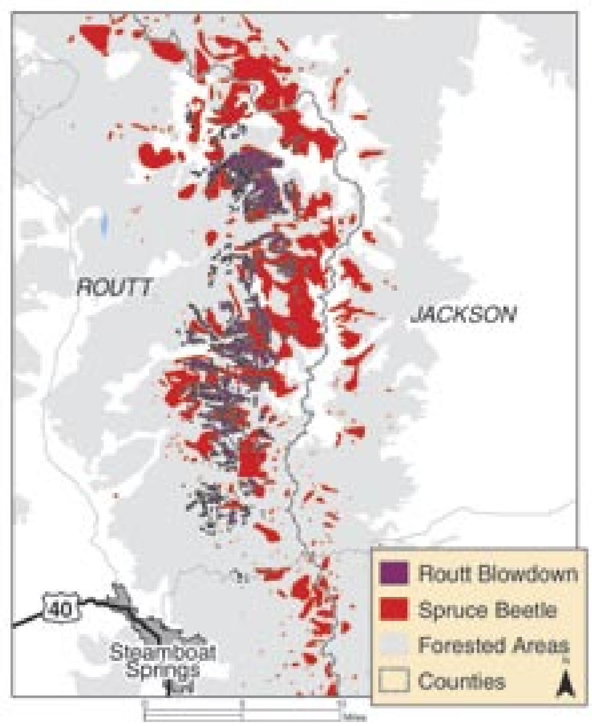


Dendroctonus rufipennis

Landscape-scale outbreaks of spruce beetle infestation generally occur at intervals of a few hundred years and often begin with a wind event that places many large-diameter trees on the ground. Beetles remain endemic in the downed material until populations become large enough, then they spread to nearby susceptible large-diameter standing trees (Holsten 2000).

A blowdown of more than 13,000 acres in the Routt Divide area north of Steamboat Springs created the perfect conditions for a widespread spruce beetle outbreak. In 2000, only 70 trees were reported killed in Routt and Jackson Counties. By 2001, 11,000 affected spruce were identified, in addition to 3,500 trees in the Flat Tops area of Rio Blanco, Garfield, and Moffat Counties.

Many scientists now believe that even these numbers are a gross underestimate of the damage, since trees killed by spruce beetles quickly drop their needles and are difficult to detect through aerial survey. Forest health experts on the Routt National Forest expected up to one million beetle-infested Engelmann spruce to be dead by the close of summer 2002.



Routt blowdown area and associated spruce beetle infestation

Drought conditions worsened the growing epidemic by allowing spruce beetles to reduce their life cycle from two years to one year and by facilitating large-scale wildfire in spruce-fir forests that are usually too moist to carry extreme fire activity. Trees damaged in the recent fires outside of Steamboat Springs will be particularly appealing to beetles and promote continued expansion of insect populations.

Impacts from the beetle build-up in the Routt Divide area now reach as far west as the Elkhead Mountains northeast of Craig and extend north to the Wyoming border and east to the edge of the Mt. Zirkel Wilderness. The epidemic has the potential to spread further east to the Cameron Pass area and south to central Colorado. Other areas of concern due to increasing beetle activity include the Land's End area of Grand Mesa, Eagle's Nest Wilderness Area, the Uncompahgre Plateau, south of Eagle and in the southern San Juan Mountains.

Several high-value sites have been impacted by the insect activity in the Routt area, including popular campgrounds, the Steamboat Ski Area, scenic corridors, critical watersheds, some timber management zones and wildland-urban interface areas. As with other beetles, treatment options are limited once a tree is infested. Protective spraying can be effective on individual trees. Removal and disposal of infested trees can sometimes prevent further spreading. Management activities that increase the diversity of age classes across a spruce-fir landscape could help preclude extensive mortality if implemented prior to attack.

Western Balsam Bark Beetle (*Dryocoetes confuses*) and Subalpine Fir Decline

The western balsam bark beetle (WBBB) has worked in combination with various root disease pathogens such as *Armillaria* spp. and annosum root disease (*Heterobasidion annosum*) to cause the mortality of millions of subalpine fir at higher elevations over the last five years. This poorly understood condition is referred to as Subalpine Fir Decline and constitutes the single greatest forest mortality factor for which land managers have solid figures.

Aerial surveys in 2001 recorded 712,427 trees impacted on 258,751 acres. Results for 2002 are not yet finalized, but are expected to show similar or even greater levels of mortality. Because it generally occurs outside areas of human development and use, subalpine fir decline has attracted little public attention. It is considered a natural response to abnormally mild, low snow pack years and indicates that the impacts of drought extend to Colorado's highest elevations.

Western Spruce Budworm (*Choristoneura occidentalis*)

Although several outbreaks of western spruce budworm have occurred in Colorado, infestation is currently at low levels over most of the state. Aerial surveys in 2001 reported only 35,729 acres affected and similar levels are anticipated for 2002. Current hotspots include the Uncompahgre Plateau from north of Norwood to the Black Canyon of the Gunnison, and northwest of Pagosa Springs in the Weminuche Wilderness. Counties most affected are La Plata, Montrose, Ouray and Conejos.

Favored hosts for this defoliator insect are Douglas-fir, white fir and Engelmann spruce with the most activity occurring in dense stands that have been stressed either by competition or external factors. The last major budworm outbreak in Colorado occurred from 1972-1985.

Current conditions, particularly those brought on by drought, are conducive to an expansion by this insect. It is believed that the widespread late frost of 2001, which killed much of the new growth on which this insect depends, knocked back or delayed its expansion. Resurgence should be anticipated in the near future.

Western spruce budworm

Forest Inventory and Information Resources

This year marked Colorado's entry into a new annualized approach for forest inventory that is being used nationwide to sample forest conditions. In the West, this method is based on taking one-tenth of the samples each year for a ten-year period and then starting all over again. The annual inventory approach will provide Colorado with more current and easily updated information than ever before. But it will be a few years before this initial cycle produces enough data to draw defensible conclusions.

Prior to 2002, Colorado participated in an inventory program that involved periodic visits to each state. All designated plots for this inventory were sampled by federal crews, with the assistance of state personnel, during one to two field seasons. The periodic inventory provided a good "snapshot" of Colorado's forests, but it was expensive and many years passed between cycles. Colorado's last periodic inventory was based on field data collected in 1983.

Inventory crew member takes tree crown measurement

The new annualized sample method, designed and used by the U.S. Forest Service (USFS), is based on a random set of forested locations seen on aerial photos or, increasingly, satellite images. This approach leads to one field sample for approximately every 6,000 acres of forestland. This is not an intensive sampling, since Colorado has 21 million acres of forestland, but crews will still end up measuring and recording conditions on 5,400 plots. Some plots are only partially forested, making the total plot number quite high.

During 2002, funds provided by the USFS enabled Colorado State Forest Service crews to gather information from about 540 plots across the state. Crews recorded their data from each plot on special field computers then transmitted this information to the USFS Forest Inventory Unit in Ogden, Utah. There it will be checked for errors and entered into computers for processing and analysis.

While the initial numbers will be ready by April or May of 2003, we still will not be able to conclude much about the health of our forests. It is a little like being allowed to look at six minutes of a football game, with those minutes scattered randomly throughout the game. We would learn something about what happened, but it would be hard to say who was winning or why.

Crews will soon begin a second year of annualized inventory during which they will collect data from another 540 plots. After five years, enough data will be amassed to reveal important information about the condition and trends of our forests. Some preliminary reports may be available earlier, but significant findings will only begin after year five. After the 10th year, when all of the sample locations have been visited once, crews will start the whole cycle again and each year's new information will be used to update the Colorado forest

2. Drought and Forests

Severe drought conditions throughout the state provided the catalyst for both dramatic and subtle events that impacted forest conditions over the past year. The previous section highlighted the influence of drought on insect and disease cycles in mountain landscapes. But urban and community trees also suffered, as water restrictions limited watering at the same time high temperatures and low precipitation demanded it the most. Cottonwoods and other riparian trees exhibited significant drought stress, as did trees in windbreaks and snow fences across the plains.

As parched days turned into weeks and then months, renewed public interest turned to the connections between healthy, functioning forests and clean, abundant supplies of water. Watershed protection has been an integral goal of forest management since the earliest days of the USDA Forest Service, which was established in the 1897 Organic Act to, in part, secure “favorable conditions of water flows.” Since the majority of Colorado’s water supply comes from forested watersheds, positive impacts on water quality and quantity must continue to be an important component of forest management.

Drought Trends and 2002 in Perspective

Colorado is a semi-arid state that averages only 17 inches of annual precipitation, with several areas receiving much less. Drought occurs frequently but rarely affects the entire state at once. Precipitation and stream flow records, combined with tree ring data, show that severe, multi-year and widespread drought, like that of 2002, occurs only a few times per century (McKee 2000).[2] Climate researchers now believe the 2002 drought actually started with a dry fall and early winter in 1999 and was compounded by very warm temperatures in 2000. By the end of the 2001 water year, soils were dry and reservoirs low statewide.

Exposed bank reveals the effects of severe drought on Cheesman Reservoir.

Colorado gets all of its water supply from precipitation since no major rivers flow *into* the state. The majority of the state’s surface water is stored in winter snow-pack and released during spring runoff from April to July. As of April 1, 2002, Colorado’s statewide snow-pack was at 53 percent of average, the lowest measurement since the state record of 46 percent in 1977. By June, much of this snow-pack had already melted – two months ahead of time.

Impacts of the record drought manifested themselves in the form of severe wildfires, extremely low streamflows, rapidly depleting reservoirs, critical agricultural damage and widespread urban watering restrictions. By late July, weather monitors located Colorado near the epicenter of an extensive regional drought, and reviews of tree ring records revealed 2002 as the driest year since 1703 along the northern Front Range and since 1579 in the Colorado River Basin. Conditions continued in a similar vein until the arrival of significant precipitation in September.

---

2 These and other details regarding the 2002 drought can be found on the Colorado Climate Center’s website at http://climate.atmos.colostate.edu or through the Colorado Water Resources Research Institute at http://cwrri.colostate.edu.

Impacts on Urban Forests

Urban trees provide an important connection between people and nature.

Urban and community forestry programs were doubly hit in 2002 when widespread budget cuts limited tree care resources at the same time extreme drought made watering and mulching of trees more critical than ever (Campbell 2002). Cities and towns all along the Front Range are reporting significant signs of drought stress and injury in their urban trees. Wilted, yellowing or curling leaves, dark brown leaf scorch and yellow, red or brown evergreen needles are just a few of the visible indicators.

Foresters in Denver, Fort Collins, Greeley and Colorado Springs have noticed a particularly troubling epidemic of drought-induced beetle infestations in large, well-established Colorado blue spruce (Campbell 2002, Leatherman 2002). The blue spruce ips beetle (*Ips hunteri*) is found throughout much of the native and planted range of its host in Colorado. It is not considered a problem in native forests, but is becoming an issue throughout urban habitats.

Forty-five large, infested blue spruce had to be condemned by the City of Fort Collins and dozens of very valuable blue spruce succumbed to beetle attack in the Broadmoor Hotel neighborhood of Colorado Springs. The Denver Forestry Department has identified 250 infested trees on private property and 45 trees in city parks and is recommending removal of these and all other infested trees to prevent further insect spread (Brovsky 2002).

Properly placed and maintained trees add value to urban properties and quality of life and contribute significantly to the health of urban ecosystems through reduced levels of carbon dioxide and pollutants in the atmosphere, as well as increased habitat for urban wildlife, energy savings in both summer and winter, and protection of water quality from potentially polluting urban runoff (Wood 2002).

Tree care experts fear that the full-extent of drought-induced damage to this valuable resource will not be fully revealed until next year. They recommend caring for existing trees through watering and the use of organic mulch.[3] Urban residents should also consider replacing water-loving plant materials with more drought tolerant native species.

Forests and Water Yield

Clean, abundant and available water is critical to the sustainability of much that is unique and treasured about Colorado. As the state's population continues to expand, demands on its water supply have increased and diversified. Along with water for drinking, irrigation and hydroelectric power, Colorado residents want supplies for fish and wildlife habitat, rafting, kayaking

High-elevation forests store precipitation in the form of snow-pack.

[3] See www.watersaver.org for instructions on watering and mulching.

and other water sports, snowmaking, light industrial use and a variety of scenic values.

The majority of Colorado's water flows from high-elevation forests such as spruce-fir and lodgepole pine. The condition of these forests and their influence on available precipitation plays a critical role in determining the quantity and quality of water available to supply the state's needs.

The exclusion of fire from nearly all of Colorado's forest types has resulted in some forested landscapes that are several times more dense and/or even-aged than they were historically (Allen 2002, Brown 1999). This increased density is particularly acute in lower to mid-elevation ponderosa pine and mixed conifer forests. A dense, closed forest canopy intercepts more snow in its tree crowns and reduces the amount of precipitation that reaches the soil and, eventually, streams and reservoirs (Covington 1994).

Research at the U.S. Fraser Experimental Forest, located near Winter Park, has shown that openings created through various types of forest management can incrementally increase water yield by increasing the amount of snow able to accumulate on the ground (MacDonald 2002, Troendle 2002, MacDonald and Stednick 2000). Studies also propose that increases in water yield from forested sites are directly proportional to the percent of the canopy that is removed, rather than the pattern of the harvest. This means that even the removal of single trees scattered throughout a stand can increase the amount of snow stored and water released from that site.

Recreation and scenic beauty are among the reasons Coloradans value clean and abundant water.

A number of factors complicate the feasibility of increasing water flows through forest management, including forest type and location, land ownership, opportunities for management, timing of water release and impacts of forest regrowth. While water yield is not the primary goal of forestry activities in Colorado, current research suggests that increased water flow is among the many benefits that can be realized through the restoration of a more natural range of forest conditions (Gosnell 2002).

Forests and Water Quality

Of greater concern to water managers and users than water yield is the threat to water quality posed by excessive runoff and sedimentation in the wake of catastrophic wildfire. Current conditions in many Colorado forests leave them particularly vulnerable to large, destructive crown fires that burn at a much higher intensity and cause more severe ecosystem damage than would have occurred historically. The negative impacts of moderate and high-severity fires on water flows can be much greater than the effects of forest harvest, particularly in lower elevation areas.

Fire severity is a term used to measure the effect of fire on ecosystem components, particularly soil and hydrologic systems. In a forested watershed, surface vegetation lessens the intensity of heavy rainstorms, holds the soil in place and slows runoff, giving the water time to soak into the ground (Rietveld 2002). High severity fires impact soils by removing the protective layer of leaves, twigs, branches and needles, exposing mineral soil and, sometimes, facilitating the formation of a waxy, water-repellent layer that keeps water from penetrating the soil and dramatically amplifies the rate of runoff.

If significant precipitation occurs following a high severity fire, resulting impacts on water systems can include rapid surface runoff and peak flows; flash floods that mobilize large amounts of suspended sediments, ash and debris; formation of soil pedestals, rills and gullies; increased transport of materi-

Post-fire flooding and siltation poses a significant threat to water quality and critical fish habitat.

als such as organic carbon, manganese and iron that can adversely affect water quality for human use; and serious alteration or destruction of aquatic habitat (Scott 2001, Graham 2002, Rietveld 2002).

The 1996 Buffalo Creek Fire was followed by a high intensity thunderstorm that resulted in substantial flooding and erosion and severely impacted Strontia Springs Reservoir, a major storage and distribution facility for Denver's water supply. In the three months following the fire, flooding transported hundreds of thousands of tons of sediment into the reservoir and caused significant degradation in water quality and reservoir operation. The Denver Water Board anticipates spending $15-20 million on continued dredging and clean-up efforts following the Buffalo Creek Fire.

During the 2002 fire season, 26 municipal water storage facilities were shut down due to fire and post-fire impacts. Following the Hayman Fire, field personnel with the Natural Resources Conservation Service (NRCS) estimated that the sediment and debris from one catastrophic rainstorm could cause 1.3 million people to lose their water supply. NRCS assessments after the Missionary Ridge Fire predicted potential post-fire damage to the water supplies for Durango, Bayfield and Ignacio.

Post-fire rehabilitation efforts often begin before the fire is even out. Suppression rehabilitation is the first step and consists of repairing impacts on the land created by fighting the fire. The second step is called "burned area emergency rehabilitation" (BAER) and focuses on urgent actions necessary to minimize threats to human lives and property and to prevent unacceptable resource damage (Rietveld 2002).

On federal lands, formal BAER teams come in immediately after the fire to assess the damage and outline treatments needed to protect communities and watersheds from short-term impacts such as flooding and erosion. On private land, this assessment is conducted by the NRCS and partially funded through the Emergency Watershed Protection Program (EWP). For 2002, the total cost of treating private burned-over lands to prevent post-fire damage to life and property, in the short term, will be $13.6 million. The federal EWP will provide more than $10 million of this total and private, state and local sources must contribute the rest.

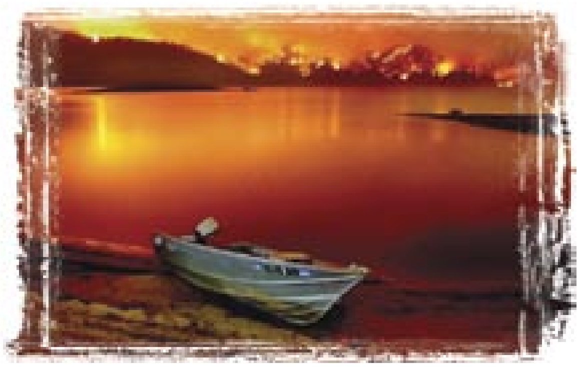
Hillsides burned by the Coal Seam Fire outside of Glenwood Springs show post-fire erosion.

Post-fire rehabilitation activities help to protect soils, reduce run-off and restore vital watershed functions through treatments such as aerial seeding, log erosion barriers, straw mulch, installation of early warning systems for flooding, stream diversion and culvert repair. But in the case of high severity damage, true landscape restoration may take several decades and require tremendous public expense. The federal government has incurred at least $50 million in emergency rehabilitation expenses for their lands damaged by the 2002 fires and will likely require much more to implement longer-term restoration of ecosystem integrity and function.

3. Wildfire

2002 Fire Season Statistics

The 2002 wildfire season vividly displayed the destructive power that can build from components of the fire triangle: weather, topography and vegetative fuels. Extraordinarily dry and dense vegetation, steep terrain and high winds created the ideal conditions for extreme fire behavior throughout the state's lower and middle elevations. Even higher-elevation spruce-fir forests experienced fire activity that generally occurs only once a century or less.



Flames from the Missionary Ridge fire are reflected in the Vallecito Reservoir.

More than 2000 fires burned 502,000 acres during the 2002 season. The ten-year average for these numbers is 3,119 fires, but only 70,000 acres. Suppression costs for 2002 exceeded $152 million. The state's cost for suppressing the Hayman Fire, alone, totaled $5.1 million. Sixteen-thousand five-hundred firefighters fought Colorado's flames. Tragically, nine firefighters were killed.

The evacuation of more than 81,000 Coloradans from their homes and communities highlighted the increasing exposure of wildland-urban interface (WUI) areas to loss of life and property from wildfire. This exposure prompted the Federal Emergency Management Agency (FEMA) to issue emergency declarations on seventeen Colorado fires. The previous record for FEMA declarations was three and occurred during the 2000 season.

Faced with simultaneous threats to municipal water supplies, critical fish and wildlife habitat, important recreation and scenic areas and other natural and cultural resources, land managers and elected officials must make difficult decisions regarding how to prioritize available funds for forest restoration and fuels reduction.

Common Denominators

Throughout the 2002 season, the state's largest and most damaging fires revealed a pattern of extreme fire behavior kindled by record low fuel moisture and carried across the landscape by dense forest conditions. By early spring, the entire West Slope and much of the Front Range were predisposed to extreme fire behavior by the unusually severe drought. Fuel moisture in lower elevation ponderosa pine forests was the driest seen in at least thirty years (Finney 2002).

Dense ponderosa pine forests allow fire to climb rapidly from surface fuels to tree crowns.

Low levels of moisture in both live and dead fuels significantly sped up the initiation and spread of crown fires and promoted extreme fire behaviors such as torching and spotting that can drive fire fronts

Dead and down logs and other fuels fed many fires during the 2002 season.

across natural barriers such as roads, ridges, rivers and rock outcroppings. High temperatures, strong winds and an unstable atmosphere provided additional conditions favorable to crown fire and rapid rates of fire spread (Carlton 2000).

Another catalyst for the unprecedented size and damage of the 2002 season was the thick, continuous layers of vegetative fuel present in many forest types throughout the state. This is particularly true in ponderosa pine, mixed conifer and pinyon-juniper forests where frequent, low to moderate-intensity fires once reduced surface fuel accumulation, increased spacing between trees and promoted greater diversity and vigor.

Although the impacts of fire exclusion have been less in higher-elevation spruce, fir and lodgepole pine forests, scientists believe that even lodgepole stands once had more of a mosaic of different tree sizes and densities as a result of natural fire regimes (Covington 1994).

Examples from 2002 Fire Season

The large fires of 2002, exemplified by the incidents described here, began in heavy, dry layers of needles, leaves, grass, and dead and down branches and logs, then spread to shrubs, low brush and small trees, and then climbed, in ladder fashion, to the low hanging branches of larger conifers and shot to the trees' crowns where flames spread hot and fast across the landscape. The lack of openings or other significant disruption in the continuity of fuel, combined with extreme weather conditions, provided limited opportunity for natural slowing of fire growth or direct suppression tactics.

Although the majority of Colorado's fire activity occurred in lower to middle elevation forests, drought conditions allowed wildfires to burn in nearly every forest type across the state. Wind driven fire spreads of several thousand acres were common, as was torching, spotting up to one mile, flame lengths from 100-150 feet, and plume-dominated fire behavior. While landscapes with a component of higher-moisture aspen experienced less extreme fire behavior, fire reports showed that winds, steep terrain and continuous days of little precipitation promoted extreme activity even in lower hazard areas.

The ongoing success story of the season was the 98 percent of fire starts that were contained through effective initial attack by local and volunteer fire departments.

Snaking Fire (4/23/02)[4]

The Snaking Fire kicked off the 2002 season when an ignition on April 23, 2002 started a fast-moving blaze in the mountains southwest of Denver. The fire began in a layer of dry grasses and brush that included much of the dead fuel from the previous year and showed little evidence of green-up despite the spring season. The fire grew to 800 acres in approximately 11 hours and to 2300 acres by the following day.

---

[4] Information on individual fire incidents was obtained primarily from close-out reports produced by Interagency Incident Management Teams assigned to the fires.

Rapid rates of spread and extreme fire behavior occurred as the flames encountered moderately dense ponderosa pine, where pockets of dense trees – many with significant mountain pine beetle mortality – initiated crown fires. Similar conditions characterized much of the surrounding landscape, which included the sites of the 2000 Hi Meadow Fire and the 1996 Buffalo Creek Fire.

Higher elevation lodgepole and spruce-fir stands experienced less dramatic rates of fire spread, and areas throughout the fire with more open canopy experienced underburn conditions with little mortality.

The Snaking Fire burned a total of 2,590 acres, forced the evacuation of more than 1,000 homes and business, and incurred suppression costs of $2.7 million. No structures were lost.

Black Mountain Fire (5/5/02)

The Black Mountain Fire was ignited seven miles northwest of Conifer on May 5, 2002 and eventually burned 345 acres on federal lands managed by the Pike-San Isabel and Arapaho-Roosevelt National Forests. The fire's primary fuel consisted of dense lodgepole pine with Engelmann spruce and quaking aspen also present. A thick layer of pine needles and occasional pockets of large dead and down fuels carried the fire across the forest's surface. Gusty winds from the southwest, moderately steep slopes and very low relative humidity and fuel moistures drove fire behavior and perimeter expansion. The Black Mountain Fire forced the evacuation of 2400 people in three counties despite its relatively small size and confinement to federal lands. Suppression costs totaled $1.1 million.

Drought and heavy fuels caused many fires to exhibit extreme behavior such as long flame lengths, torching and spotting.

Iron Mountain Fire (6/2/02)

The Iron Mountain Fire started southwest of Canon City on June 2, 2002 and ran quickly through six miles of grass and oak brush, pinyon-juniper woodlands and ponderosa pine stands intermixed with subdivisions and individual residences. Most of the previous season's cured fine fuels remained standing as a result of light winter precipitation. Weather and fuel conditions indicated a 90-100 percent probability of ignition on the day the fire started. High rates of spread occurred as the fire ran and spotted through stands of gambel oak and crowns of dense pinyon-juniper. Ninety-five percent of the 4,439 acres burned was private property adjacent to Bureau of Land Management (BLM) ownership. The fire destroyed 100 cabins, A-frames, doublewide and fifth-wheel trailers and campers along with an additional 100 outbuildings. Suppression costs totaled $7.5 million.

Coal Seam Fire (6/8/02)

Residents in and around Glenwood Springs found their community filled with smoke and surrounded by flames when the Coal Seam fire started on June 8, 2002 and spread quickly over 7,000 acres by the morning of June 9. The fire exhibited extreme behavior with rapid rates of spread, high winds and record low fuel moistures in gambel oak and pinyon-juniper. Steep slopes and subalpine fir stands with heavy dead and down fuels facilitated long-range spotting by falling embers.

The fire crossed I-70 and the Colorado River on June 9, developed an intense terrain-driven run up Mitchell Creek to the northeast and created a fast-moving fire front in dense oakbrush at the base of Red Mountain heading toward the City of Glenwood Springs. Aspen stands near the ridge ending at Windy Point eventually halted the fire spread due to high fuel moistures in the understory vegetation.

Wildfire forced the repeated evacuation of area residents and eventually destroyed 31 homes and more than 30 other buildings and improvements such as bridges. In many areas, fire behavior combined with limited access, lack of safety zones and volatile fuels made structure protection too dangerous for firefighters. The Coal Seam fire burned 12,209 acres of private, USFS, BLM and City of Glenwood Springs land and cost $5.4 million to suppress.

Missionary Ridge Fire (6/9/02)

Extremely hot, dry temperatures and critically dry fuels launched the Missionary Ridge Fire northeast of Durango just one day after the Coal Seam and Hayman fires already had firefighters scrambling for resources. Understory fuels characterized by oak brush, Douglas-fir and budworm-damaged white fir provided ample ladder fuels to carry flames into the continuous, closed-canopy ponderosa pine that comprised the overstory across much of the landscape. Once initiated, crown fires ran quickly and long, encouraged by continued low fuel moisture, high temperatures, steep slopes and dense vegetation that had not been touched by fire for at least 100 years.

Deer and elk may frequent burned areas in hopes of finding fresh sprouts such as aspen or oak brush.

The fire posed a frightening threat to residents of surrounding subdivisions, particularly in the areas of Vallecito and Lemon Reservoirs. At the height of the fire, up to 2,500 people a day had to flee their homes. On June 25, a new start named the Valley Fire ignited on the west side of Missionary Ridge and burned 400 acres and several structures before being contained by local firefighters. Nearly a month after the Missionary Ridge Fire started, a veteran firefighter was killed when he was struck from behind by a fire-damaged aspen. By the time crews finally contained its spread, the Missionary Ridge Fire had destroyed 56 residences and 27 outbuildings and burned 70,485 acres. Suppression costs totaled $40.4 million making this incident the most costly in Colorado's history.

Hayman Fire (6/8/02)

The Hayman Fire's devastating statistics set a new standard for the damaging potential of wildfire in Colorado. The fire perimeter eventually encompassed nearly 138,000 acres in the already scarred South Platte watershed and incurred $39 million in suppression costs to federal, state and local firefighting agencies. Prior to 2002, the state's largest fire was the 14,000 acre Black Ridge fire in La Plata County.

As it spread toward and around Cheesman Reservoir, the Hayman Fire forced 38,000 residents in four counties to flee their homes. One hundred thirty-four residences were lost along with 466 additional structures and outbuildings. Previous records for loss of structures were held by the 1989 Black Tiger Fire, which destroyed 44 homes in Boulder County, and the 2000 Hi Meadow Fire, which consumed 51 homes in Jefferson and Park Counties.

Despite the magnitude of the Hayman event, many scientists and land managers continue to say that Colorado has been lucky – the damage could have been much worse. Not a single human life was lost on the fire line during the weeks and months that Hayman burned, despite the large number of firefighters present and the thousands of people evacuated from homes and recreation areas, often with little time to spare.

Hayman is the fifth large wildfire in six years to burn in the South Platte drainage. While prolonged drought and red flag weather events drove the fire's rapid spread, fuels like those that fed its flames can be found throughout the surrounding area. Overly dense, even-aged stands of ponderosa pine and mixed conifer forests, with a thick understory of ladder fuels, blanket the landscape.

Continuous horizontal and vertical fuels rendered the Hayman area susceptible to torching, crown fire and spotting by burning embers, even under moderate weather conditions. Firefighters reported flame lengths of 100-200 feet, spotting of a mile or more and frequent episodes of torching and other extreme fire behavior. On June 9, the fire ran for 19 miles along the South Platte drainage, burning 60,000 acres in a single day.

The Hayman Fire did encounter a handful of areas where fuels treatment had occurred, but in most cases the treatments were either too small to alter such extreme fire behavior or were old and had not been maintained. Only the recent, large-scale Polhemus prescribed burn and Schoonover Fire appeared to significantly alter or slow the fire's path.

Scientists are still sorting out the implications of the Hayman Fire for landscape-scale restoration and watershed protection efforts. But the message for communities in the wildland-urban interface is clear: act now to increase the defensibility of your home and property and know your evacuation routes, because the potential for more fires like Hayman remains in forests throughout the state.

Million Fire (6/21/02)

The Million Fire began south of the town of South Fork on June 21, 2002 and spread to 6,000 acres in the first day under extreme fire conditions. Fuel moistures in grasses, shrubs and small to medium sized trees were well below the minimum ever measured in the area. The primary fire spread occurred in the mixed-conifer forest type where bug-killed Engelmann spruce, lodgepole pine and Douglas fir facilitated crown fires and accompanying fire runs. When the fire reached pockets of aspen, it generally spread along the surface and helped stop crown runs from conifer stands. Aspen did not prevent spread in cases of extreme wind and fire intensity. The Million Fire threatened four subdivisions and damaged or destroyed 18 residences and two outbuildings. Acres burned totaled 9,346 and resulted in suppression costs of $9.4 million.

Burn Canyon (7/9/02)

Down drafts from thunder cell activity and high winds drove the Burn Canyon Fire near Telluride from less than an acre to 1000 acres between July 9-11. Burning in extremely dry ponderosa pine, gambel oak and pinyon-juniper on the Uncompahgre National Forest, the fire continued to double and even triple in size with each passing day. A regional weather pattern called the "Ring of Fire" facilitated the cyclic formation and collapse of smoke columns over the fire, driving flames rapidly forward and at least 150 feet into the air. A major run on July 13 increased the fire's size to nearly 15,000 acres and forced the evacuation of residents in communities around Norwood and Redvale. Continued low humidity, high temperatures and erratic weather frustrated firefighters' efforts at containment until significant precipitation finally doused the fire's flames on July 21. The Burn Canyon Fire burned 31,300 acres at a cost of $5.75 million.

Local communities found many ways to express their appreciation to firefighters.

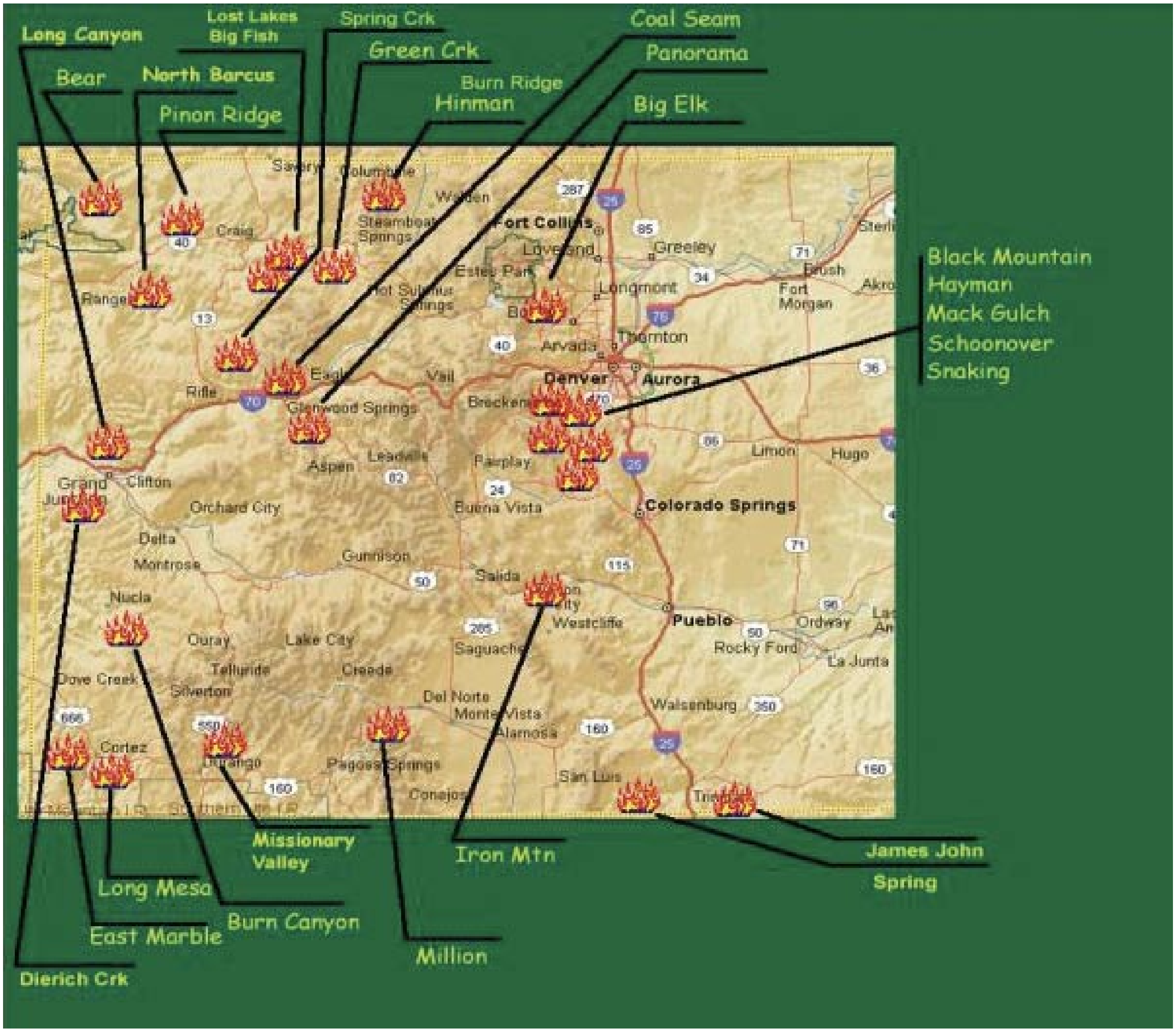
Mt. Zirkel Complex (7/12/02) and Lost Lake and Big Fish Fires (7/14 & 7/19)

Extreme drought conditions in the high-elevation spruce-fir forests around Steamboat Springs allowed the usually-moist stands to carry large-scale wildfire of the kind that usually occurs once per century or less. The fires began with the Hinman Fire which started on July 12 just north of Steamboat Springs. Although primarily on the Routt National Forest, this fire threatened several guest ranches and summer homes and led to the closure of key transportation corridors.

The Burn Ridge Fire started in the same area exactly one month later. It was combined with the Hinman Fire into a single management unit called the Mt. Zirkel Complex due to the proximity of the Mt. Zirkel Wilderness Area. Both fires exhibited extreme fire behavior including torching, crowning and spotting in blowndown and beetle-killed spruce. Dry fuels, heavy fuel loading and gusty winds made containment difficult. The two fires eventually burned 31,016 acres at a cost of $13.3 million.

A second set of fires began on July 8 with the Lost Lakes Fire which started on July 8, 40 miles southwest of Steamboat in the Flat Tops Wilderness Area. An interagency team managed the fire to achieve ecosystem benefit according to an existing plan for the wilderness area. Active fire behavior occurred as flames moved through bug-killed spruce and fir, but was significantly curtailed when it reached small islands of less-combustible aspen. The Lost Lakes Fire eventually burned 5,538 acres.

The Big Fish Fire began July 19, 34 miles southwest of Steamboat. It burned 17,056 acres, primarily in the Flat Tops Wilderness, and destroyed the historic Trapper's Lake Lodge, 7 cabins and a barn. Like the Lost Lakes Fire, Big Fish was managed primarily for ecosystem benefit with containment strategies in place to keep the fire from moving off of federal land and threatening homes or other structures. Suppression costs for the Big Fish Fire totaled $1.9 million.



Wildland-Urban Interface and Lessons Learned on Fuels Treatment

The increase in widespread and destructive wildfires in Colorado is cause for particular alarm in the wildland-urban interface (WUI), where increasing numbers of homes, businesses and other components of community infrastructure are intermingled with high-risk forest fuels. Threats to municipal water supplies, critical fish and wildlife habitat, treasured scenic resources and important cultural areas have strengthened the public call for action to reduce the threat and restore fire to a more natural role in the landscape. The question is where and how to go about it.

Wildfires in the interface may leave homes unburned but destroy the homeowner's reason for being there. Courtesy USDA Forest Service.

The fires of 2002 forced more than 81,000 people to flee their homes, sometimes more than once, and resulted in the destruction of 384 primary residences and 624 other structures. Much of the season's $152 million suppression cost was driven by the need to use all available resources to protect life and property in the WUI, often at the expense of unpopulated areas in the fire's path. The Black Mountain Fire, alone, cost $1.1 million to suppress and caused the evacuation of 2,400 homes despite the fact that it burned only 345 acres.

FireWise (www.firewise.org) and similar homeowner education programs provide detailed guidelines for improving the defensibility of individual homes and surrounding properties. But these actions may not provide adequate protection if homeowners do not work together to create defensible space on a more landscape scale or if weather patterns and surrounding forest conditions are conducive to fast-moving, high-intensity wildfire.

Forest researchers have long promoted a variety of fuels treatments, including thinning and prescribed burning, to restore Colorado's forested landscapes to a more natural range of conditions. Particular attention has been focused on restoration of ponderosa pine forests, which scientists believe have been most affected by the exclusion of regular fire cycles (Allen 2002, Covington 1994). The scale of change has been less dramatic in lodgepole pine and spruce-fir forests, but the age and condition of many of these landscapes is also cause for concern, particularly in WUI areas.

Firebreaks established in Mesa Verde National Park protected critical buildings during the Long Mesa Fire. Courtesy National Park Service.

Fuel treatment and forest restoration projects have been implemented on a limited basis in Colorado and across the West with varying degrees of success. Recent, strategically placed fuel breaks protected critical buildings and residences in Mesa Verde National Park from the flames of July's Long Mesa Fire. And on the Hayman Fire, the Polhemus prescribed burn site, the early season Schoonover Fire and thinning on the Manitou Experimental Forest seemed to alter the path and lower the intensity of the oncoming blaze.

Several smaller, older treatments were not up to Hayman's challenge and failed to deter or alter the fire's path (Finney 2002, Romme 2002). Examples such as these suggest that fuels treatment projects achieve maximum effectiveness when they are implemented on a landscape scale, across ownership boundaries, and are maintained over the long-term so that forest regrowth does not eliminate treatment benefits.

Flames from the Big Fish Fire threatened historic cabins near Steamboat Springs.

The National Fire Plan has provided direction and funding to accelerate fire-related treatments being planned and implemented on federal lands. The Plan has also increased the ability of non-federal landowners to improve the condition of their forests through federal cost-share programs administered by the CSFS. In 2001, Colorado awarded $1.8 million in grant funds for community and landowner assistance projects, hazardous fuels reduction treatments and information and education activities. Those efforts leveraged an additional $2.1 million in matching funds and in-kind services.

Despite this increased level of activity, and general public agreement that some action needs to be taken to protect lives and communities, there remains disagreement about what techniques to use and which areas to prioritize for action and allocation of limited funds. Within this ongoing dialogue, some areas of commonality have emerged (Allen 2002, Brown 1999, Covington 1994):

- Restoration projects should aim to reset ecosystem trends toward a more historically natural range of forest conditions and processes;
- Initial treatments should reduce the threat of crown fire and disrupt continuity of hazardous fuels in the vicinity of human developments and important watersheds;
- Treatments should be appropriate to site-specific conditions and forest types;
- A full range of forest management tools should be considered and available; and
- Sensitive species habitat, high-value aesthetic and cultural areas and trees of significant size or age merit particular consideration in treatment design.

Governor Bill Owens joined Colorado Cares Day volunteers in rehabilitating sites burned by the Hayman Fire. Courtesy Colorado Department of Natural Resources.

Some counties in Colorado have embarked on public discussion and planning efforts to more clearly identify areas of agreement and treatment priorities for their communities (Hodges 2002). It is through these locally-based forums, where land managers, local government, stakeholder organizations and private individuals can gather, that the foundation of local support will be formed for timely action to protect Colorado's people, communities and natural resources from the damaging impacts of wildfire.

Conclusion

The trends in forest condition revealed during 2002 tell the story of forests under stress. The underlying message is one of imminent large-scale change that promises to be dramatic and, often, damaging to much of what Coloradans value about their forests.

Changes in land management policies over the past 150 years disrupted natural cycles of disturbance and renewal in several forested landscapes. Without these cycles, forests become more homogenous and lack the diversity in age, size and species distribution that allows them to be resilient in the face of change. They become too dense and experience fierce competition for sunlight, water and other essential resources. Ultimately, they become vulnerable to stand-replacing events such as insect and disease epidemics or catastrophic wildfire.

In forest types such as lodgepole pine and spruce-fir, this scale of change is within the natural range of conditions under which the forest evolved. But for lower elevation forests like ponderosa pine and mixed conifer, the impacts of stand-replacing change can be devastating. Add people, homes, municipal water supplies, essential wildlife habitat, unique cultural areas and other human values to the mix and the situation becomes critical.

Colorful islands of aspen give Colorado its traditional fall glow. Courtesy USDA Forest Service.

Fortunately, public and private land managers possess the knowledge and tools needed to take positive action toward restoring our forests. Informed public dialogue, particularly at the local level, is key to selecting where and how these actions should occur. Choosing to act and supporting strategic treatments in priority areas can improve the sustainability of Colorado's forests and protect the many values for which they are treasured.

References

Allen, C.A. and others. 2002. Ecological Restoration of Southwestern Ponderosa Pine Ecosystems: A Broad Perspective. Ecological Applications. 12(5):1418-1433.

Brovsky, C. 2002. Spruce Done in by Bugs, Drought. Denver Post, 28 November.

Brown, J.K.; R.D. Oberheu and C.M. Johnston. 1982. Handbook for Inventorying Surface Fuels and Biomass in the Interior West. USDA Forest Service Gen. Tech. Rep. INT-129. Ogden, UT. 48 p.

Brown, P.M., M.R. Kaufmann and W.D. Shepperd. 1999. Long-term Landscape Patterns of Past Fire Events in a Montane Ponderosa Pine Forest of Central Colorado. Landscape Ecology. 14:513-532.

Brown, T.C. and B.L. Harding. 1987. A Preliminary Economic Assessment of Timber and Water Production in Subalpine Forests. Management of Subalpine Forests: Building on 50 Years of Research. USDA Forest Service Gen. Tech. Rep. RM-149: 126-137.

Brown, T.C., B.L. Harding and E.A. Payton. 1990. Marginal Economic Value of Streamflow: A Case Study for the Colorado River Basin. Water Resources Research. 26(12): 2845-2859.

Campbell, R. 2002. Personal Communication. Fort Collins, CO.

Carlton, D. 2002. Crowning and Extreme Fire Behavior Beyond Rothermel. Technical Fire Management – Fuels Management. 10 p.

Colorado's Water: Climate, Supply and Drought. Colorado Water Resources Research Institute. Fort Collins, CO. 16 p.

Covington, W.W. and others. 1994. Historical and Anticipated Changes in Forest Ecosystems of the Inland West of the United States. Journal of Sustainable Forestry. 2(1/2): 13-63.

Finney, M.A. and others. 2002. Report on Fire Behavior, Fuel Treatments and Fire Suppression. Interim Hayman Fire Case Study Analysis. 129 p.

Francis, C., W.R. Jacobi and W.S. Cranshaw. 2002. Pinyon Pine Diseases and Insects. Colorado State University Cooperative Extension Fact Sheet. No. 2.948. Fort Collins, CO. 8 p.

Gosnell, R. 2002. Forestry with Increased Water Yield and Protected Water Quality. Unpublished. Fort Collins, CO.

Graham, R.T., ed. 2002. Interim Hayman Fire Case Study Analysis: Executive Summary. USDA Forest Service Rocky Mtn. Research Station. 1-19.

Grant, K. 2002. Pinyon Pine Mortality in Southwest Colorado. Colorado State Forest Service, Durango District Fact Sheet. Durango, CO.

Grieve, J. 2002. Personal Communication. Canon City, CO.

Harris, J.L., R. Mask and J. Witcosky. 2002. Forest Insect and Disease Conditions in the Rocky Mountain Region 2000-2001. USDA Forest Service, Rocky Mountain Region, Forest Health Management. Lakewood, CO. 42 p.

Harvey, M. 2002. Personal Communication. Granby, CO.

Hodges, G. 2002. Personal Communication. Fort Collins, CO.

Holsten, E.H. and others. 2000. The Spruce Beetle. USDA Forest Service Forest Insect and Disease Leaflet 127. 9 p.

Johnson, E. 2002. 2001 Aerial Detection Survey of the Rocky Mountain Region. USDA Forest Service, Rocky Mountain Region, Forest Health Management. 3410 Report – R2-02-09. Lakewood, CO. 20 p.

Kaufmann, M.R. and W. Shepperd. 2002. Ponderosa Pine Restoration. Unpublished. Fort Collins, CO. 3p.

Knight, Heather. 2002. Personal Communication. Livermore, CO.

Leatherman, D.A. 1999. Mountain Pine Beetle. Colorado State University Cooperative Extension Fact Sheet. No. 5.528. Fort Collins, CO. 6 p.

Leatherman, D.A. 2002. Review of Insect and Disease Activity in Colorado. Unpublished. Fort Collins, CO.

Lebeda, B. 2002. Alamosa District Insect and Disease Update. Unpublished. Alamosa, CO. 3 p.

Lynch, D.L. and K. Mackes. 2002. Evaluating Costs Associated with Forest Restoration Fuel Hazard Reduction Projects in Colorado. In Publication in: Proceedings from Conference on Fire, Fuel Treatments and Ecological Restoration. USDA Forest Service Gen. Tech. Rep. ___. In publication.

MacDonald, L.H. 2002. Effects of Changes in Colorado's Forests on Water Yields and Water Quality. Colorado Water. Vol. 18, No. 5:6-8.

MacDonald, L.H. and J. Stednick. 2000. Forest Management, Water Yield and Water Quality: A State of the Art Assessment. USGS Grant Proposal Narrative. 4 p. [Online: water.usgs.gov/wrri/00grants/COforest.html].

McKee, T.B. and others. 2000. A History of Drought in Colorado: Lessons Learned and What Lies Ahead. Water in the Balance, No. 9. Colorado Water Resources Research Institute. Fort Collins, CO. 20 p.

Omi, P.N. and E.J. Martinson. 2002. Final Report: Effect of Fuels Treatment on Wildfire Severity. Joint Fire Science Program Project Report. Colorado State University, Fort Collins, CO. 36 p.

Rietveld, W. 2002. Missionary Ridge Fire: The Aftermath. Missionary Ridge Complex BAER Team Report. Durango, CO. 10 p.

Romme, W. H. and others. 2002. Ecological Effects. Interim Hayman Fire Case Study. 57 p.

Scott, D. 2001. Walker Ranch Fire: Water Quality Concerns. Boulder County Online Drought, Fire & Flood Seminar. Boulder, CO. [Online: bcn.boulder.co.us/basin/forum/walkerWQ.html].

Troendle, C. A. 1983. The Potential for Water Yield Augmentation from Forest Management in the Rocky Mountain Region. Am Water Resource Bulletin. 19(3): 359-373.

Troendle, C.A. and J.M. Nankervis. 2002. Estimating Additional Water Yield from Changes in Management of National Forests in the North Platte Basin. Fort Collins, CO. 51 p.

Virtue, J. 2002. Potential Fire Behavior Created by Trees Impacted by Insects, Disease, Drought and Other Influences. Unpublished. Denver, CO. 6 p.

Virtue, J. 2002. Differences in Fire Intensity between a Surface Fire and a Crown Fire. Unpublished. Denver, CO. 7 p.

Wilderness Society. 2002. Summary of the Hayman Fire, Colorado. Denver, CO. 6 p.

Wood, K. 2002. Maintaining Urban Trees during Drought Periods. City of Westminster Website. Westminster, CO. [Online: www.ci.westminster.co.us/res/env/water/trees.htm].

Acknowledgements

The *2002 Report on the Health of Colorado's Forests* was prepared by the Colorado Division of Forestry in conjunction with Colorado State University Publications and Printing. Primary authors are Paige Lewis, Tom Wardle, Dave Leatherman and Joe Duda.

Valuable information and assistance was also provided by Ralph Campbell, Jennifer Chase, Skip Edel, John Grieve, Jeri Lyn Harris, Mike Harvey, Rich Homann, Paul Langowski, Boyd Lebeda, John Marshall, Dan Ochocki, Dave Steinke, and others.

Images courtesy of the Colorado State Forest Service unless otherwise noted.

Front cover photos courtesy of the USDA Forest Service and Colorado Division of Water Resources.

Back cover photo courtesy of the USDA Forest Service.

Colorado Department of
Natural Resources
Division of Forestry

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

Colorado State Forest Service

Colorado Department of Natural Resources

printed on recycled paper